TEC-25

DOE/ET/28405-1

GEOTHERMAL RESERVOIR ASSESSMENT

COVE FORT SULPHURDALE UNIT

FINAL REPORT
FOR THE PERIOD
SEPTEMBER 1977 - JULY 1979

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

DECEMBER 1979

WORK PERFORMED UNDER CONTRACT

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GEOTHERMAL DIVISION
UNION OIL CENTER
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ABSTRACT

During 1978 and 1979 Union Oil Company of California drilled three exploratory geothermal wells in the Cove Fort-Sulphurdale geothermal resource area in southwestern Utah 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 an earlier exploratory well at the Cove Fort-Sulphurdale area was also provided.

Two of the wells were abandoned before reaching target depth because of severe lost circulation and hole sloughing problems. The two completed holes reached depths of 5,221 ft. and 7,735 ft., respectively, and a maximum reservoir temperature of 353°F at 7,320 ft. was measured. The deepest well flow tested at the rate of 47,000 lbs./hr with a wellhead temperature of 200°F and pressure of 3 psig. Based upon current economics, the Cove Fort-Sulphurdale geothermal resource is considered to be sub-commercial for the generation of electrical power.

This report is a synopsis of the exploratory drilling activities and results, and it contains summary drilling, testing, geologic and geochemical information from four exploratory geothermal wells. Detailed information for each of the wells is contained in four separate technical reports 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
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INTRODUCTION

The Cove Fort Sulphurdale Unit (CFSU) Final Report has been prepared to compare and summarize results from the four exploratory geothermal wells drilled on the unit. The general location of CFSU is shown in Figure 1. Specific well locations are shown in Figure 2.

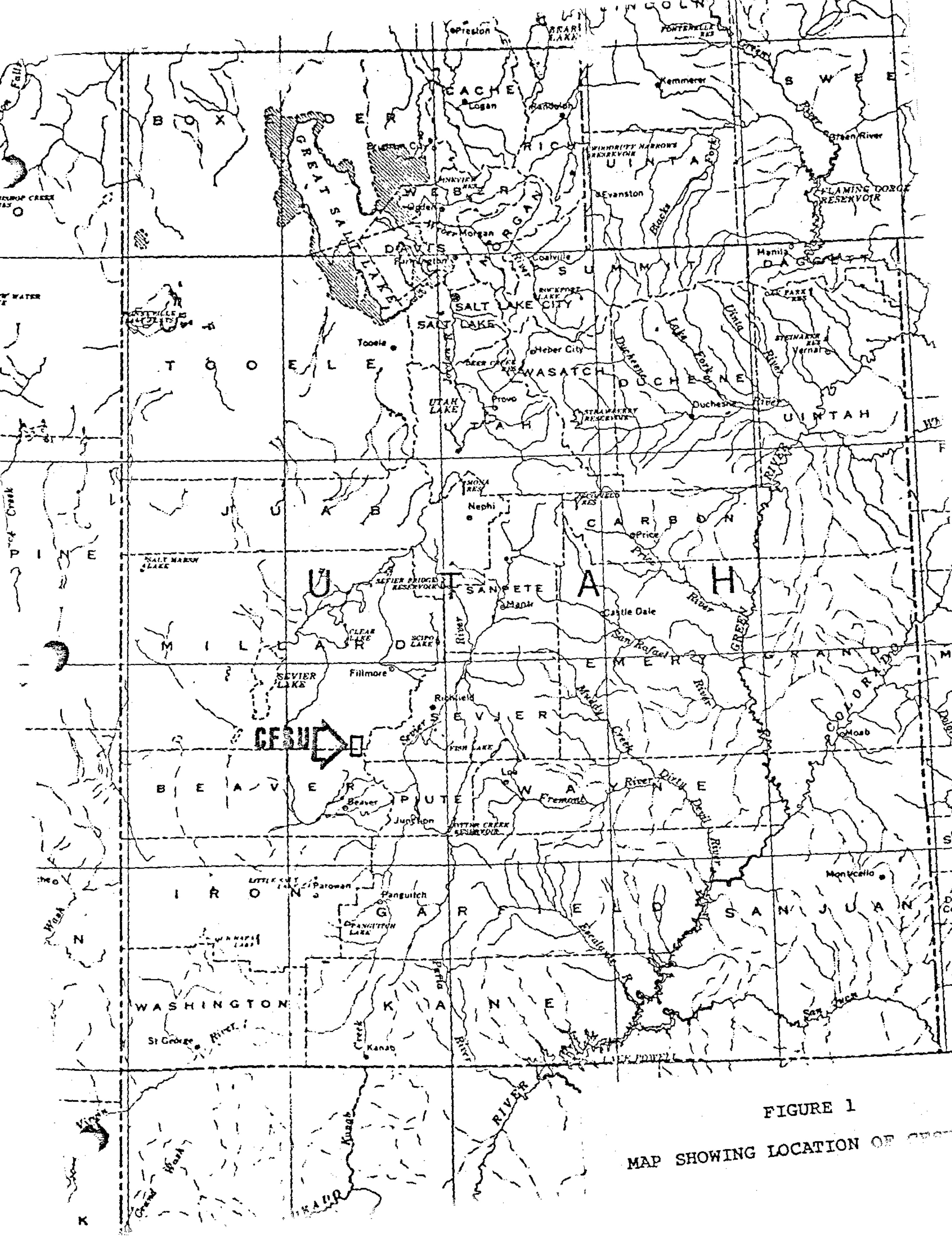


FIGURE 1

MAP SHOWING LOCATION OF

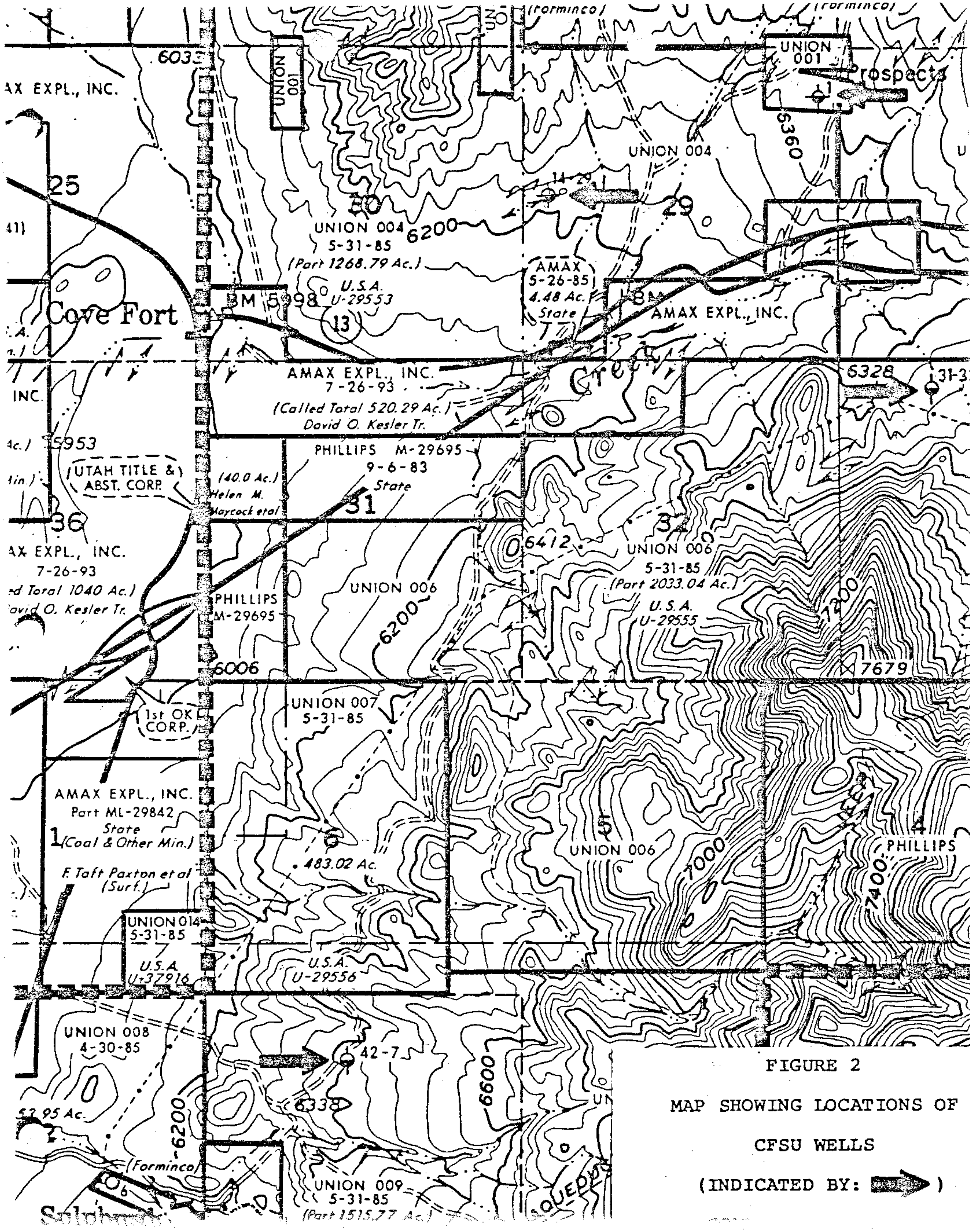


FIGURE 2

MAP SHOWING LOCATIONS OF

CFSU WELLS

(INDICATED BY: ➡)

COVE FORT SULPHURDALE UNIT

DRILLING SUMMARY

The four exploration wells in the Cove Fort Sulphurdale Unit were drilled at the following total depths, days and costs per foot:

1. Forminco #1: 1051'; 34 days; $594/foot;
2. CFSU #42-7: 7735'; 105 days; $266/foot;
3. CFSU #31-33: 5221'; 64 days; $243/foot;
4. CFSU #14-29: 2620'; 45 days; $407/foot.

The two wells with the highest costs per foot, Forminco #1 and CFSU #14-29 were abandoned before reaching target depth because of severe hole cleaning problems. In the case of Forminco #1 a "sanded dolomite" caused the hole cleaning problems, while in CFSU #14-29 a formation of conventional dolomite/dolomitic limestone caused sloughing problems. CFSU #31-33 was plugged back to 2600' to eliminate cross flow below that point, and a 2-7/8" tubing string was hung to facilitate future temperature surveys. CFSU #42-7 was completed with a 7" liner at total depth and a 7" tie-back to surface.

The major problems contributing to the high costs per foot in the CFSU wells were lost circulation and corrosion. Each of the wells encountered severe lost circulation zones. The major corrosion problems were experienced while drilling with aerated water in wells CFSU #42-7 and #31-33. Details of lost circulation and corrosion are discussed in separate sections devoted to these topics.

Fishing jobs were confined to losses of one to two days per well with one exception. While spotting a lost circulation cement plug in Forminco #1, the cement flash set sticking the drill string. A ten day fishing/washing-over operation was required before the well was sidetracked and drilled ahead.

H_2S was encountered in all of the CFSU wells. Only the Forminco #1 well produced high concentrations of H_2S (600 ppm). An extensive H_2S monitoring system was installed on each of the CFSU wells. Personnel were familiarized with H_2S safety equipment and procedures through training and drills. Fortunately no H_2S related injuries were experienced.

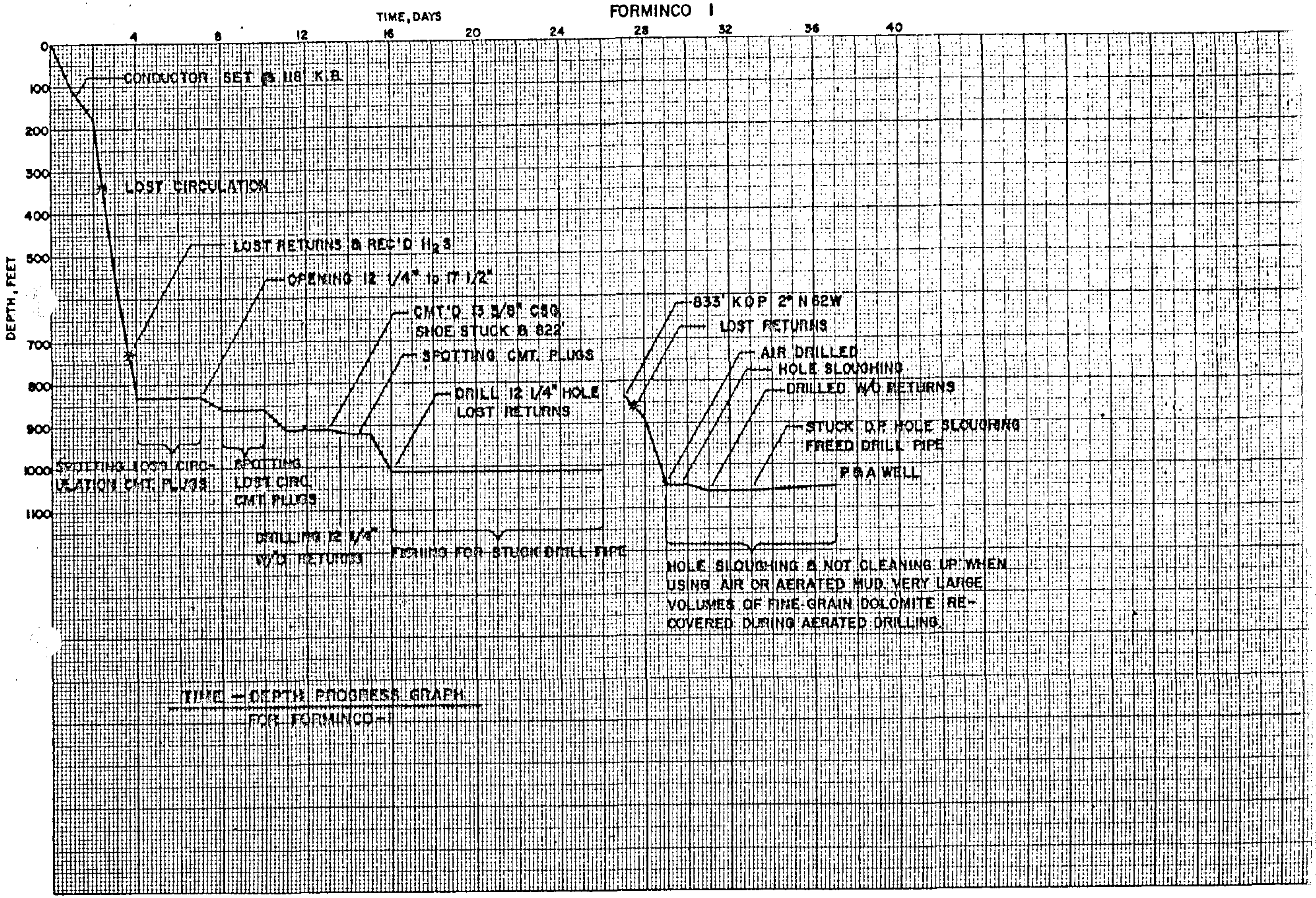
The following CFSU Drilling Data Well Comparison Table and the Time vs. Depth Progress Graphs can be used to compare the four wells drilled.

CFSU DRILLING DATA WELL COMPARISON TABLE

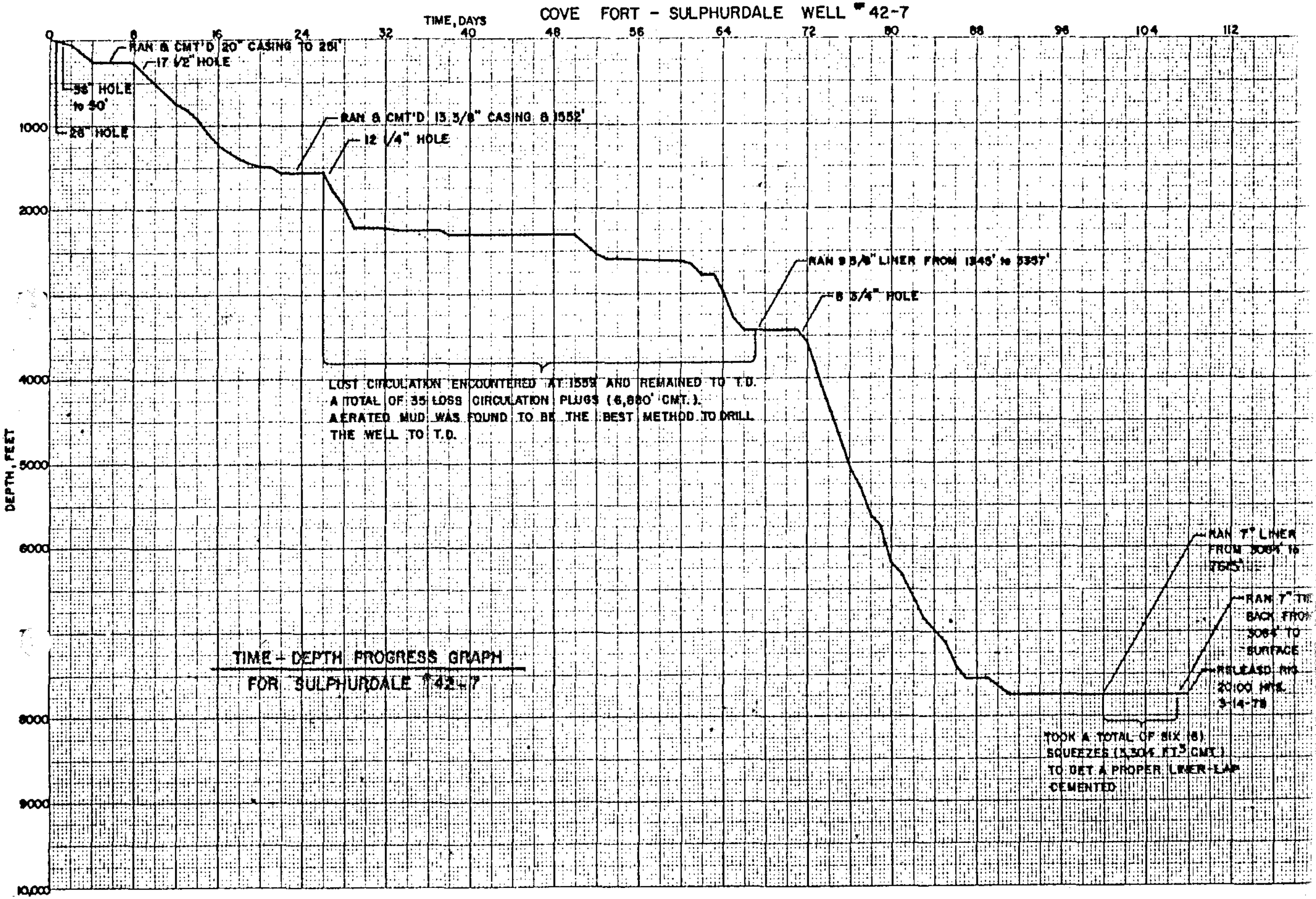
WELL	SPUD DATE	COMPLETION DATE	RIG #	TOTAL DEPTH (FT)	TOTAL DYS	TOTAL COST ($)	TOTAL COST/FT ($/FT)
Forminco #1	7/26/76	8/29/76 (Aban.)	Loffland Rig 35	1051	34	624,000	594
CFSU #42-7 Permit #0045	11/29/77	3/14/78	Loffland Rig #184	7735	105	2,056,000	266
CFSU #31-33 Permit #0049	5/24/78	7/27/78	Loffland Rig #5	5221	64	1,270,000	243
CFSU #14-29 Permit #0072	5/25/79	7/9/79 (Aban.)	Brinkerhoff Signal Rig #3	2620	45	1,065,000	407

WELL	MUD COST	MUD COST/FT ($/FT)	CMT. PLUGS FOR LOST CIRCULATION	H_2S MAX. RECORDED CONCEN. (PPM)	FISHING JOBS	FISHING DAYS	MAX. TEMP. LOGGED
Forminco #1	44,025	42	9	600	1	10	--
CFSU #42-7 Permit #0045	182,889	24	37	<10	2	1	353°F @ 7320'
CFSU #31-33 Permit #0049	72,437	14	27	10	2	2	294°F @ 4700'
CFSU #14-29 Permit #0072	35,616	14	18	50	2	2	196°F @ 2180'

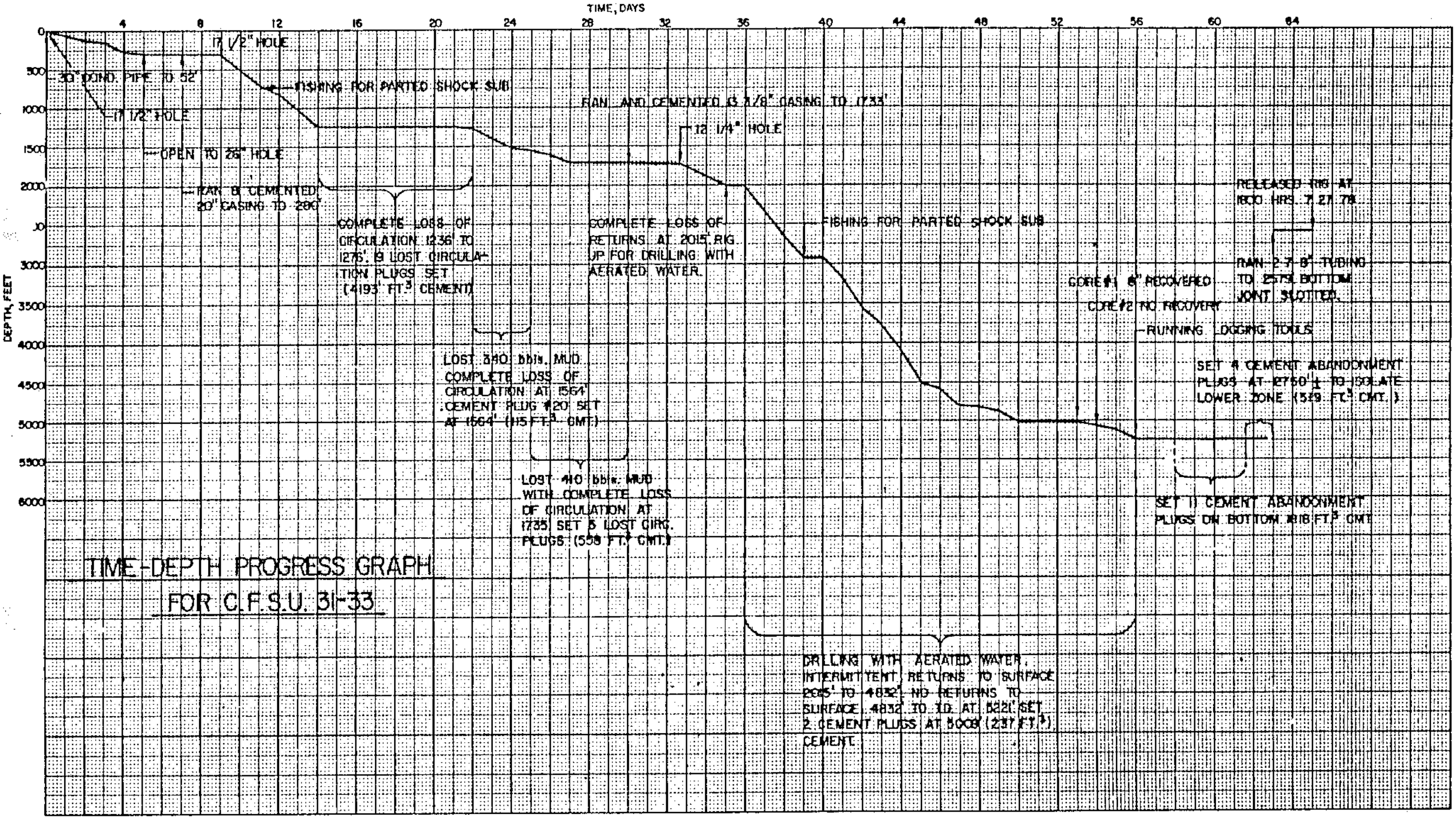
WELL	CASING PROGRAM (ALL DEPTHS RKB)					FINAL CONDITION
	CONDUCTOR CASING	SURFACE CASING	INTER-MEDIATE CASING	OTHER	OTHER	
Forminco #1	20" @ 120'	13-3/8" @ 822'	--	--	--	Abandoned due to inability to clean hole of unconsolidated "sanded dolomite".
CFSU #42-7 Permit #0045	30" @ 50'	20" @ 251'	13-3/8" @ 1552'	Liner 9-5/8": 1345' to 3357'	Liner 7" @ 7615' Tied Back	Suspended with 7" tied back to surface.
CFSU #31-33 Permit #0049	30" @ 52'	20" @ 280'	13-3/8" @ 1733'	Hanging Tubing 2-7/8" @ 2579'	--	Plugged back to 2600' to eliminate cross flow below that point and hung 2-7/8" tubing at 2579' to facilitate future temperature surveys.
CFSU #14-29 Permit #0072	30" @ 38'	20" @ 224'	13-3/8" @ 1240'	Liner 9-5/8": 998' to 2078'	--	Abandoned due to inability to clean hole and eliminate fill.



FORMINCO I
TIME, DAYS
DEPTH, FEET
CONDUCTOR SET @ 118 K.B.
LOST CIRCULATION
LOST RETURNS & REC'D H_2S
OPENING 12 1/4" to 17 1/2"
CMT'D 13 3/8" CSG
SHOE STUCK @ 822'
SPOTTING CMT. PLUGS
DRILL 12 1/4" HOLE
LOST RETURNS
SPOTTING LOST CIRCULATION CMT. PLUGS
SPOTTING LOST CIRC. CMT PLUGS
DRILLING 12 1/4" W/O RETURNS
FISHING FOR STUCK DRILL PIPE
833' K O P 2° N 62W
LOST RETURNS
AIR DRILLED
HOLE SLOUGHING
DRILLED W/O RETURNS
STUCK D.P. HOLE SLOUGHING
FREED DRILL PIPE
P & A WELL
HOLE SLOUGHING & NOT CLEANING UP WHEN USING AIR OR AERATED MUD. VERY LARGE VOLUMES OF FINE GRAIN DOLOMITE RE- COVERED DURING AERATED DRILLING.
TIME - DEPTH PROGRESS GRAPH
FOR FORMINCO-I

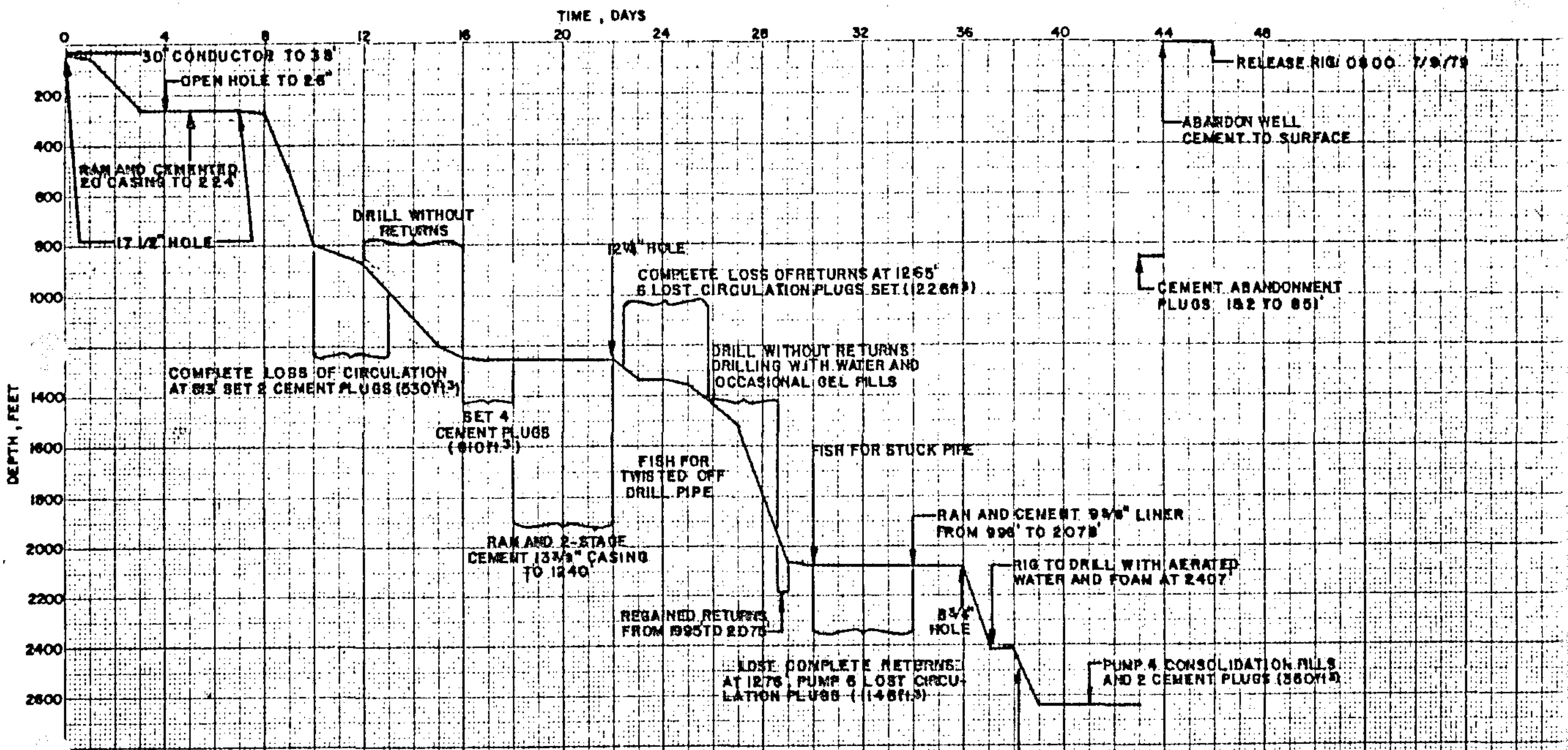


COVE FORT - SULPHURDALE WELL # 42-7
TIME, DAYS
0
8
16
24
32
40
48
56
64
72
80
88
96
104
112
DEPTH, FEET
1000
2000
4000
5000
6000
8000
9000
10,000
RAN & CMT'D 20" CASING TO 261'
17 1/2" HOLE
36" HOLE to 50'
26" HOLE
RAN & CMT'D 13 3/8" CASING @ 1552'
12 1/4" HOLE
RAN 9 5/8" LINER FROM 1345' to 3357'
8 3/4" HOLE
LOST CIRCULATION ENCOUNTERED AT 1559 AND REMAINED TO T.D.
A TOTAL OF 35 LOSS CIRCULATION PLUGS (6,880' CMT.).
AERATED MUD WAS FOUND TO BE THE BEST METHOD TO DRILL
THE WELL TO T.D.
RAN 7" LINER FROM 3064' to 7615'
RAN 7" TIE BACK FROM 3064' TO SURFACE
RELEASD RIG 20:00 HRS. 3-14-78
TOOK A TOTAL OF SIX (6)
SQUEEZES (3,304 FT.³ CMT.)
TO GET A PROPER LINER-LAP
CEMENTED
TIME - DEPTH PROGRESS GRAPH
FOR SULPHURDALE # 42-7



TIME-DEPTH PROGRESS GRAPH

FOR C.F.S.U. 31-33



TIME-DEPTH PROGRESS GRAPH FOR C.F.S.U. 14-29

COVE FORT SULPHURDALE UNIT

LOST CIRCULATION SUMMARY

All of the CFSU wells encountered severe lost circulation zones. A wide range of lost circulation materials, including fiber, cellophane, cotton seed hulls, mica, walnut hulls, sodium silicate-calcium chloride, and diatomaceous earth, were attempted with virtually no success. Cement plugs consisting of a variety of slurry types met with very limited, often short term, success in regaining circulation. In some cases it became necessary to drill without returns providing the thief zone accepted drill cuttings and the hole was kept clean. Drilling with aerated water was often effective in competent formations but greatly increased corrosion rates and sometimes resulted in the production of large quantities of formation water causing disposal problems.

Since it is ultimately important to cement casing strings completely from shoe to surface, lost circulation problems were faced as they occurred. When efforts to regain circulation were abandoned and the decision was made to drill ahead, lost circulation problems were only postponed until the next casing point was reached. A total of 91 cement plugs were utilized to combat lost circulation while drilling the four CFSU wells. The following tables compare slurry compositions for each of the lost circulation cement plugs. Success of the cement plugs was very limited. There was no single slurry composition that proved conclusively to be the most effective.

Most of the lost circulation problems occurred in carbonate formations. In some cases extensive caverns were encountered as evidenced by the drill string abruptly falling 30'. A satisfactory solution to the more severe lost circulation problems in the CFSU remains to be found.

C.F.S.U. WELL FORMINCO #1 LOST CIRCULATION CEMENT PLUG COMPARISON

PLUG NO.	TOTAL DEPTH (FT)	OEDP DEPTH (FT)	FORMATION TYPE	SLURRY COMPOSITION							
				VOLUME (FT^3)	PERLITE RATIO	SILICA FLOUR (%)	GEL (%)	$CaCl_2$ (%)	CFR-2 (%)	LCM #/SK	OTHER
1	796	787	Sanded Dolomite	1000	2:1		4	3		½	
2	796	772	Sanded Dolomite	435	2:1		4	3		½	
3	829	776	Sanded Dolomite	408	2:1		4		3/4		Caustic Water Flush
4	860	819	Sanded Dolomite	500	2:1		4	2		½	Caustic Water Flush
5	860	713	Sanded Dolomite	250	1:1		2	3		½	Caustic Water Flush
6	860	855	Sanded Dolomite	250				3	½		
6	860	855	Sanded Dolomite	500	1:1		2			½	
7	910	786	Sanded Dolomite	500	1:1		2		½	½	
8	913	882	Sanded Dolomite	694							Thix-Set Cement
9	1004	976	Sanded Dolomite	500	1:1		2	2	½		

C.F.S.U. WELL #42-7 LOST CIRCULATION CEMENT PLUG COMPARISON

PLUG NO.	TOTAL DEPTH (FT)	OEDP DEPTH (FT)	FORMATION TYPE	SLURRY COMPOSITION							
				VOLUME (FT^3)	PERLITE RATIO	SILICA FLOUR (%)	GEL (%)	$CaCl_2$ (%)	CFR-2 (%)	LCM #/SK	OTHER
1	1494	1457	Andesite	198	1:1	40	3				0.3% Retarder
2	1494	1353	Andesite	200	1:1	40	3				0.3% Retarder
3	2244	2202	Sandstone	250	1:1	40	3				
4	2244	2046	Sandstone	120	1:1	40	3				
5	2244	2046	Sandstone	250	1:1	40	3				
6	2244	2060	Sandstone	150	1:1	40	3				
7	2244	2172	Sandstone	396	2:1	40	3				
8	2250	2205	Sandstone	142						½	Thix-Set and Gilsonite
9	2250	1829	Sandstone	142						½	Thix-Set and Gilsonite
10	2250	1860	Sandstone	240	1:1	40	3				
11	2250	2209	Sandstone	120	1:1		3				
12	2250	2169	Sandstone	193	2:1	40	3				
13	2250	2170	Sandstone	180	1:1	40	3				
14	2250	1946	Sandstone	100						½	Thix-Set and Gilsonite
15	2342	2108	Sandstone	223						1½	Thix-Set and Gilsonite
16	2342	2232	Sandstone	59				2		1½	Frac Gel Flush
17	2342	2232	Sandstone	118				2		1½	Frac Gel Flush
18	2342	2201	Sandstone	210				2		½	Frac Gel Flush
19	2342	2232	Sandstone	136				2		½	Frac Gel Flush
20	2342	2239	Sandstone	136				2		½	Frac Gel Flush
21	2342	2201	Sandstone	98				2		½	6% Gilsonite
22	2342	2232	Sandstone	88				2		½	12% Gilsonite
23	2342	2233	Sandstone	88				2		½	8#/sk Gilsonite
24	2342	2232	Sandstone	161	2:1	40	3				Frac Gel Flush
24	2342	2232	Sandstone	98				2		½	8#/sk Gilsonite
25	2342	2201	Sandstone	161	2:1	40	3	3			NaSi-$CaCl_2$ Flush
26	2342	2201	Sandstone	352	1:1	40	3	3			Frac Gel Flush
27	2606	2575	Sandstone	174				2			Thix-Set and Gilsonite
28	2606	2448	Sandstone	175				2			Thix-Set and Gilsonite
29	2606	2418	Sandstone	247	2:1		5	2			
30	2606	2248	Sandstone	367	2:1		5	2			
31	2606	2139	Sandstone	215	1:1		4	2			
32	2606	2046	Sandstone	250	1:1	40	3				
33	2606	1860	Sandstone	250	1:1	40	3				
34	2606	1675	Sandstone	250	1:1	40	3	2			
35	2606	1490	Sandstone	250	1:1	40	3				
36	2804	2765	Dolomite	312	1:1	40	3		½		
37	2804	2731	Dolomite	312	1:1	40	3				

C.F.S.U. #31-33 LOST CIRCULATION CEMENT PLUG COMPARISON

PLUG NO.	TOTAL DEPTH (FT)	OEDP DEPTH (FT)	FORMATION TYPE	SLURRY COMPOSITION							
				VOLUME (FT^3)	PERLITE RATIO	SILICA FLOUR (%)	GEL (%)	$CaCl_2$ (%)	CFR-2 (%)	LCM (%)	OTHER
1	1241	1230	Dolomitic Limestone/ Dolomite	375	1:1	40	3		½		
2	1241	1230	Dolomitic Limestone/ Dolomite	350	1:1	40	3		½		
3	1241	1230	Dolomitic Limestone/ Dolomite	240	1:1	40	3		½		Gel Mud-LCM Flush
4	1241	1230	Dolomitic Limestone/ Dolomite	125	1:1	40	3		½	15	
5	1241	1230	Dolomitic Limestone/ Dolomite	225	1:1	40	3		½	15	
6	1241	1230	Dolomitic Limestone/ Dolomite	305	2:1	40	3				Gel Mud-LCM Flush
7	1241	1230	Dolomitic Limestone/ Dolomite	305	2:1	40	3				
8	1241	1230	Dolomitic Limestone/ Dolomite	230	1:1	40	3			15	
9	1241	1230	Dolomitic Limestone/ Dolomite	230	1:1	40	3			25	
10	1241	1230	Dolomitic Limestone/ Dolomite	210	1:1	40	3	2		20	
11	1241	1230	Dolomitic Limestone/ Dolomite	210	1:1	40	3	2		20	
12	1241	1230	Dolomitic Limestone/ Dolomite	210	1:1	40	3	2		20	
13	1241	1230	Dolomitic Limestone/ Dolomite	166				2		1#/ sk	Thix-Set and Gilsonite
14	1257	1230	Dolomitic Limestone/ Dolomite	166				2		1#/ sk	25#/sk Gilsonite
15	1257	1230	Dolomitic Limestone/ Dolomite	210	1:1	40	3		½		
16	1257	1230	Dolomitic Limestone/ Dolomite	86	1:1	40	3	3			
17	1257	1230	Dolomitic Limestone/ Dolomite	200	1:1	40	3	3			
18	1257	1230	Dolomitic Limestone/ Dolomite	235							Gel-Gilsonite Flush
19	1276	1260	Dolomitic Limestone/ Dolomite	115	1 Perlite: 1 Sand: 1 Cement						Pal-Mix Flush
20	1564	1535	Dolomitic Limestone/ Dolomite	115							Pal-Mix Flush
21	1735	1649	Dolomitic Limestone/ Dolomite	104				2		1#/ sk	25#/sk Gilsonite

PLUG NO.	TOTAL DEPTH (FT)	OEDP DEPTH (FT)	FORMATION TYPE	SLURRY COMPOSITION VOLUME (FT^3)	PERLITE RATIO	SILICA FLOUR (%)	GEL (%)	$CaCl_2$ (%)	CFR-2 (%)	LCM (%)	OTHER
22	1735	1229	Dolomitic Limestone/ Dolomite	104				2		1#/ sk	25#/sk Gilsonite
23	1735	1610	Dolomitic Limestone/ Dolomite	104	1:1	40	3		½		Pal-Mix Flush
24	1735	1550	Dolomitic Limestone/ Dolomite	101	1:1	40	3		½		Pal-Mix Flush
25	1735	1580	Dolomitic Limestone/ Dolomite	145	1:1	40	3	2			
26	5009	4926	Siltstone/ Sandstone	112	1:1	40	3		½		NaSi-$CaCl_2$ Flush
27	5009	4833	Siltstone/ Sandstone	125	1:1	40	3		½		

C.F.S.U. WELL #14-29 LOST CIRCULATION CEMENT PLUG COMPARISON

PLUG NO.	TOTAL DEPTH (FT)	OEDP DEPTH (FT)	FORMATION TYPE	SLURRY COMPOSITION VOLUME (FT^3)	PERLITE RATIO	SILICA FLOUR (%)	GEL (%)	$CaCl_2$ (%)	CFR-2 (%)	LCM (%)	OTHER
1	833	830	Conglomerate	265	1:1	40	3	2	½	5	
2	866	866	Conglomerate	265	1:1	40	3	2	½	5	
3	1249	935	Limestone/ Dolomite/ Sandstone	203		20		3			22% Kolite, 8% D53
4	1249	893	Limestone/ Dolomite/ Sandstone	203		20		3			22% Kolite, 8% D53
5	1249	872	Limestone/ Dolomite/ Sandstone	203		20		3			22% Kolite, 8% D53
6	1249	861	Limestone/ Dolomite/ Sandstone	201		20		3			22% Kolite, 8% D53
7	1330	1330	Limestone/ Dolomite/ Sandstone	187				2			12% Kolite, 10% RFC
8	1330	1295	Limestone/ Dolomite/ Sandstone	181				2			12% Kolite, 10% RFC
9	1330	1245	Limestone/ Dolomite/ Sandstone	181				2			12% Kolite, 10% RFC
10	1345	1344	Limestone/ Dolomite/ Sandstone	181				2			12% Kolite, 10% RFC
11	1345	1343	Limestone/ Dolomite/ Sandstone	248				2			21% Kolite, 8% RFC
12	1429	1429	Limestone/ Dolomite/ Sandstone	248		20		2			26% Kolite, 8% RFC
13	2080	2070	Limestone/ Dolomite/ Sandstone	191		20		2			25% Kolite, 8.2% RFC
14	2080	1885	Limestone/ Dolomite/ Sandstone	191		20		2			25% Kolite, 8.2% RFC
15	2080	1698	Limestone/ Dolomite/ Sandstone	191		20		2			25% Kolite, 8.2% RFC
16	2080	1490	Limestone/ Dolomite/ Sandstone	191		20		2			25% Kolite, 8.2% RFC
17	2080	1543	Limestone/ Dolomite/ Sandstone	191		20		2			25% Kolite, 8.2% RFC
18	2080	1466	Limestone/ Dolomite/ Sandstone	191		20		2			25% Kolite, 8.2% RFC

COVE FORT SULPHURDALE UNIT

CORROSION SUMMARY

Oxygen corrosion at rates in excess of $40\#/ft^2/yr$ was experienced while drilling with aerated water in CFSU wells 42-7 and 31-33. During normal drilling with mud oxygen corrosion was effectively controlled by maintaining high pH with caustic and adding an oxygen scavenger, sodium sulfite, with cobalt as a catalyst. When severe lost circulation necessitated drilling with aerated water, oxygen corrosion was greatly accelerated.

After experimenting with a variety of inhibition programs in the field and laboratory, a sodium nitrite-caustic program proved to be the most effective. Laboratory tests with a water designed to duplicate drill water used on well CFSU 42-7 indicated that a sodium nitrite concentration of 2.6 #/bbl and a pH of 11.5 should provide an effective program. Corrosion rates were reduced from over $40\#/ft^2/yr$ to $8\#/ft^2/yr$. Although this was a considerable improvement, corrosion rates were still well above the acceptable limit of $2\#/ft^2/yr$.

Lack of success in reducing corrosion rates to acceptable levels using the sodium nitrite program was probably due to the following:

1) High concentrations of dissolved salts in the

drill water accelerated corrosion. (These concentrations varied from well to well.)

2) Upset conditions allowed concentrations of sodium nitrite and pH to fall below critical levels at times.

3) Reaction with drill cuttings, reaction with produced carbon dioxide, and dilution with produced formation water caused a reduction in pH.

Before introducing the sodium nitrite-caustic system, corrosion severely affected both casing and drill pipe. Casing caliper logs indicated casing corrosion. Drill pipe inspection downgraded 54% of the joints inspected in the CFSU well 42-7.

After introducing the sodium nitrite-caustic system on CFSU well 31-33, 14% of the joints inspected were downgraded. Chemical costs of $68,000 using the sodium nitrite-caustic system on this well were at a breakeven point with the estimated savings in drill pipe damage. Potential casing damage and fishing jobs due to drill pipe failures were avoided making the chemical costs economical.

Although the sodium nitrite-caustic program did not reduce the corrosion rate to an acceptable limit, it appears to be the best practical chemical inhibition system available. A variety of other corrosion control methods were considered and rejected during the drilling of the CFSU wells. Union is currently considering using nitrogen in place of air to eliminate the problem of oxygen corrosion. A new type of nitrogen generator may overcome some of the logistical and economic problems that have precluded the use of this method to date.

GEOLOGIC SUMMARY OF THE COVE FORT-SULPHURDALE UNIT

The four geothermal exploration wells drilled by the Geothermal Division of Union Oil within the Cove Fort-Sulphurdale Unit area failed to establish the existence of a geothermal resource of sufficient temperature and productivity needed for electrical power utilization. The wells penetrated an underpressured, highly fractured, moderate to low temperature (178°C to 93°C), highly permeable geothermal reservoir consisting of contact metamorphic and sedimentary carbonate rock in a geologically complex area. The lack of production was due to the low temperature and low pressure which together with problems of toxic H_2S gas, lost circulation and fractured and unstable formations, lead to the abandonment of the project.

Figures 3 through 6 summarizes the geology of the four exploratory wells. Lost circulation and blind drilling has prevented the identification of parts of the geologic column.

Summary of the geochemical analyses which best represents the geothermal waters encountered is presented in the following table. Like the geology, the geochemical data is complex. The wide variety of water, ranging from 1320 ppm TDS to

10,000 ppm TDS was unexpected in the highly permeable reservoir that was thought to be well mixed and geochemically similar throughout the prospect.

The four wells penetrated a variable thickness of surface volcanics of Mid-Tertiary age (200 to over 2000 feet) which lies, with angular unconformity, over highly faulted and folded Lower Mesozoic and Upper Paleozoic sedimentary rocks. Superimposed over a portion of this geologic framework is an aureole of contact metamorphism and mineralization related to a Mid-Tertiary intrusive event.

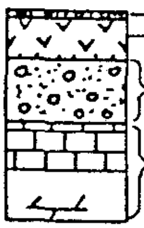
Static fluid levels in the wells are present between 1200 to 1400 feet below the surface. Very high temperature gradients (13 to 16°F/100 ft.) are present from the surface to the static water level of the reservoir. Below the top of the reservoir, the temperature profiles become nearly isothermal in the highly fractured and permeable geothermal reservoir. These isothermal sections are 300° to 310°F in the #42-7 well, 270° to 275°F in the #31-33 well, and 190° to 195°F (not stable) in the #14-29 well. The maximum temperature measured in the prospect was 353.5°F at 7320 feet in the #42-7 well. The area around the #42-7 well appears to be near the source of the geothermal anomaly, as defined by the deep drilling. The rapid termination of the shallow well temperature anomaly east, south and

and west of the #42-7 well leave little room for the presence of higher reservoir temperatures, considering the highly convective nature of the reservoir. Therefore, the geothermal anomaly has been evaluated and the reservoir judged to be inadequate for development.

WELL #	#42-7	#42-7	#31-33	#31-33	#14-29
pH	9.98	9.54	9.79	7.44	7.41
TDS	9405	4775	10,000	1320	4776
Alkalinity as CO_3	2380	470	1440	200	158
Na	3460	1310	4000	355	1220
K	225	585	443	56.2	41.5
Ca	26.4	32.0	14.4	74.4	332
Cl	2450	1820	3900	502	2060
SO_4	1280	560	760	187	900
F	4.7	2.3	3.6	1.03	2.5
SiO_2	180	170	79	64.5	92
Mg	12.0	4.8	3.36	19.2	115.2
Li	- -	- -	13.31	1.16	265
HCO_3	1322	265.9	658.8	244	192.8
CO_3	- -	252	540	0	0
B	0.8	0.30	0.5	0.2	6.4
As	6.08	2.88	5.71	2.99	0.75
Cu	0.324	0.271	0.166	0.914	0.010
Pb	- -	0.022	0.420	0.006	0.005
Ni	0.493	0.007	0.975	- -	0.085
Ag	0.015	0.011	0.037	- -	- -
Zn	0.075	1.811	0.041	0.104	0.350

GEOCHEMISTRY OF FORMATION WATERS ENCOUNTERED IN THE COVE FORT-SULPHURDALE UNIT AREA

Generalized Lithologic Log
Well Forminco #1



Age	Formation
Recent	Alluvium
Oligocene to Miocene (?)	Bullion Canyon volcanics, porphyritic andesite with argillic alteration
Upper Cretaceous to Paleocene (?)	Claron formation, quartzose boulder conglomerate
Paleozoic	Limestone, microcrystalline, with crinoid fragments
	Dolomite, poorly cemented, very fine to finely-crystalline "sanded" dolomite

FIGURE 3

Generalized Lithologic Log
Well ※42-7

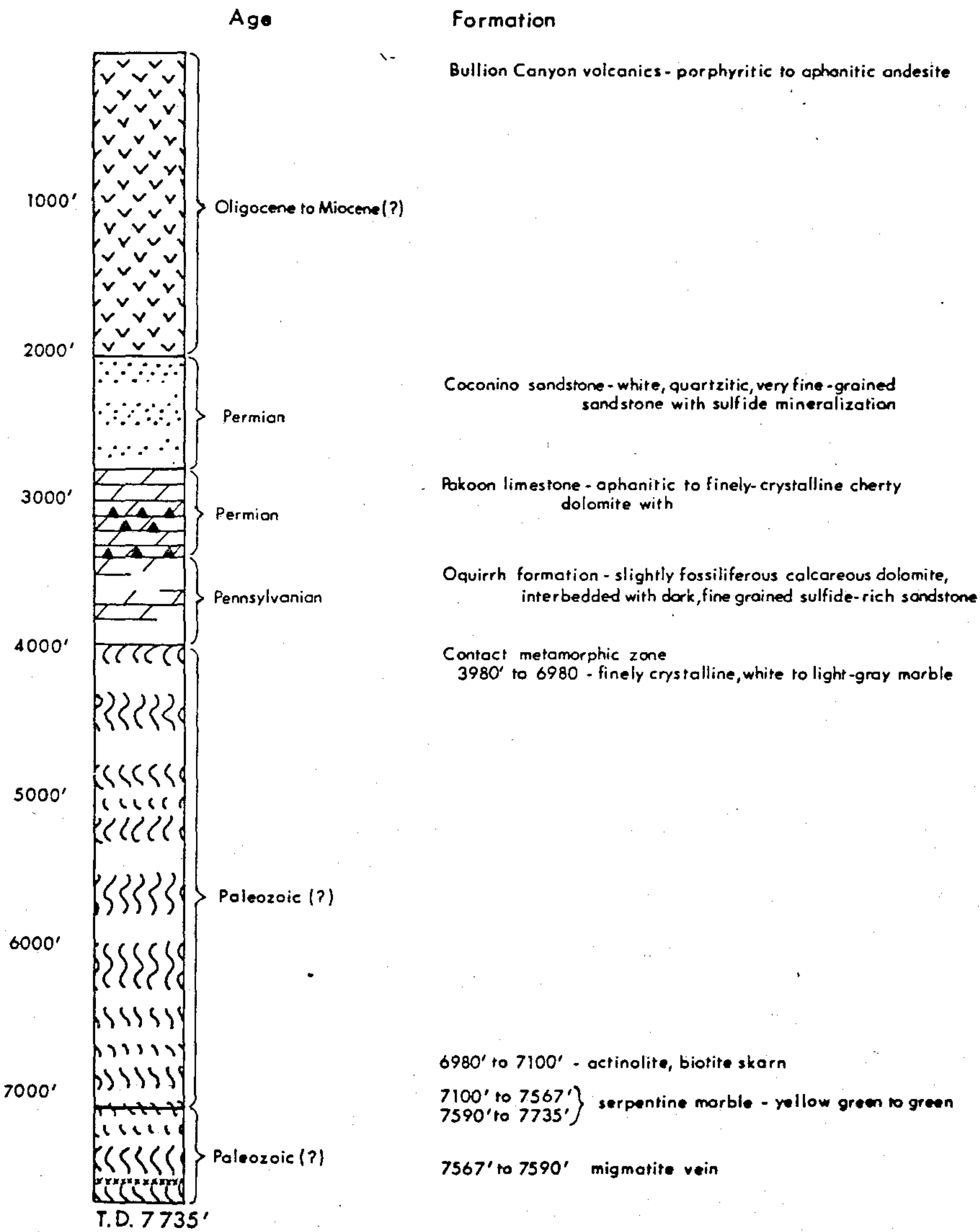
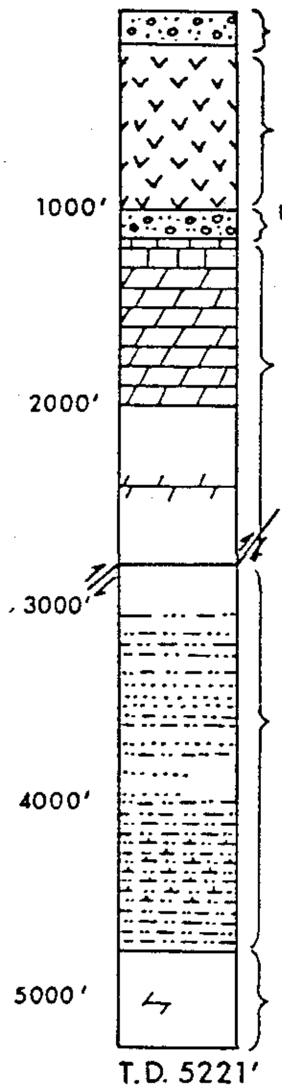


FIGURE 4

Generalized Lithologic Log
Well #31-33



Age	Formation
Recent	Alluvium
Oligocene to Miocene (?)	Bullion Canyon volcanics - porphyritic to aphanitic andesite with Chlorite and argillic alteration and sulfide mineralization
Upper Cretaceous (?) to Paleocene (?)	Claron formation - poorly sorted conglomeratic red siltstone
Upper Paleozoic	Unidentified - 1150' to 1300' medium grained dolomitic limestone with minor sandstone and chert 1300' to 2885' aphanitic, cherty dolomite and medium-grained calcareous dolomite with scattered sulfide mineralization
	Fault at 2886'
Lower Triassic	Moenkopi formation - red, calcareous, micaeous siltstone, and white, fine-grained sandstone
Permian	Kaibab limestone - no returns. Core at 5015' to 5021', recovered 8 inches. Dolomite, dark gray, fractured, brecciated

FIGURE 5

Generalized Lithologic Log
Well #14-29

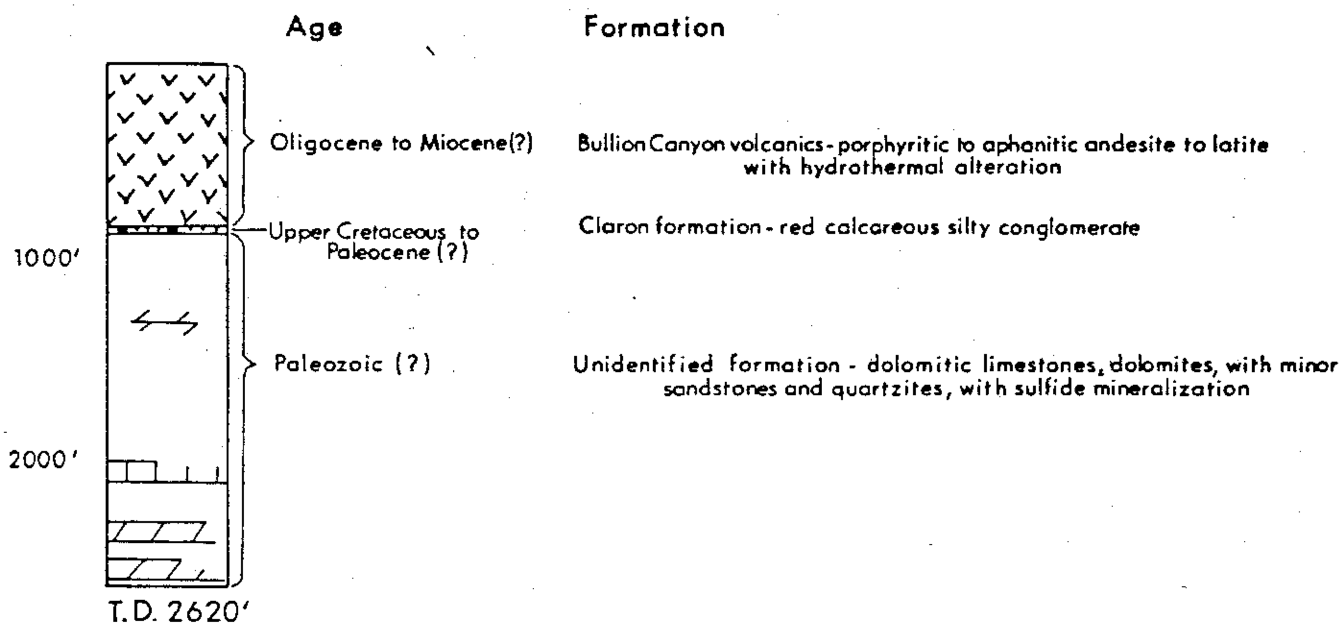


FIGURE 6

DOWNHOLE LOGGING TABLES

The following tables summarize downhole logging runs in the CFSU wells. Logs will be available from:

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

COVE FORT-SULPHURDALE #42-7

SCHLUMBERGER LOGGING DATA

DATE	TYPE OF LOG RUN	LOGGED INTERVAL	TOTAL DEPTH
1 Feb. 78	Dual Induction-Laterolog with linear correlating log; SP	1520' - 3444'	3447'
1 Feb. 78	Compensated Neutron Log: GR	50' - 3428'	3445'
1 Feb. 78	Temperature Log	1320' - 3447'	3447'
4 Feb. 78	Cement Bond Log	162' - 3314'	3323'
4 Feb. 78	Temperature Log	0' - 3058'	3065'
28 Feb. 78	Dual Induction-Laterolog with linear correlation log; SP	3358' - 7692'	7695'
28 Feb. 78	Borehole Compensated Sonic Log; GR	3358' - 7674'	7681'
28 Feb. 78	Compensated Neutron-Formation Density with GR, Caliper	3358' - 7679'	7680'
28 Feb. 78	Temperature Log	300' - 7550'	7680'
1 Mar. 78	Four-arm continuous Dipmeter	3358' - 6003'	6004'

"GO-INTERNATIONAL" LOGGING DATA

DATE	TYPE OF LOG RUN	LOGGED INTERVAL	TOTAL DEPTH
26 Feb. 78	Temperature Log	3450' - 7327'	7332'
26 Feb. 78	Temperature Log	300' - 7327'	7332'
27 Feb. 78	Temperature Log	300' - 7327'	7332'
27 Feb. 78	Temperature Log	1200' - 7320'	7332'

COVE FORT - SULPHURDALE #31-33

LOGGING DATA

DATE	TYPE OF LOG RUN	LOGGED INTERVAL	TOTAL DEPTH
	Schlumberger		
7/18/78	Temperature Log (malfunction suspected) [two maximum reading thermometers run simultaneously]	0' - 4858'	4858'
	Dipmeter and Four Arm Caliper [three maximum reading thermometers run simultaneously]	5207' - 1735'	5207'
7/19/78	Dual Induction - Laterolog [three maximum reading thermometers run simultaneously]	5207' - 1735'	5207'
	Compensated Neutron - Formation Density [three maximum reading thermometers run simultaneously]	5206' - 1735'	5206'
	Temperature Log	0' - 4858'	4858'
	Geotex		
7/19/78	Temperature, Spinner and Water Aquifer Log	0' - 4858'	4858'
	Radioactive Tracer and Spinner Log	0' - 4858'	4858'
	R. F. Smith Corporation		
5/24/78 to 7/24/78	Geothermal Data Log (includes engineering data related to drilling, geological, and other data)	52' - 5221'	5221'

COVE FORT-SULPHURDALE UNIT #14-29

LOGGING DATA

DATE	TYPE OF LOG RUN	TOTAL DEPTH	LOGGED INTERVAL	MAXIMUM READING THERMOMETERS	HOURS SINCE FLUID INJECTION
	SCHLUMBERGER				
/27/79	Dual Induction-Laterolog 8	2080'	2080'-1240'	121°F	2-1/2
	Formation Density-Compensated Neutron	2080'	2080'-1240'	127°F	3-1/2
	Dipmeter and Four Arm Caliper	2080'	2080'-1240'	134°F	5-1/2
/07/79	Temperature Log	2620'	2452'-220'	186°F	4-1/2
	Dual Induction-Laterolog 8	2620'	2462'-2078'	185°F	6-1/2
	Formation Denisty-Compensated Neutron	2620'	2468'-2078'	194°F	7-3/4
	Dipmeter and Four Arm Caliper	2620'	2469'-2078'	198°F	9-1/4
	Temperature Log	2620'	2464'-220'	198°F	2

RESERVOIR ANALYSIS

The reservoir analysis of Cove Fort-Sulphurdale Unit is based on the following tests:

1. Well #42-7: Flow test, injection test, temperature surveys, pressure surveys, and spinner surveys.
2. Well #31-33: Temperature and pressure surveys.

The important reservoir characteristics of the Cove Fort-Sulphurdale reservoir are that it is (1) a low temperature, and (2) a low pressure system. Reservoir permeability-thickness product is about 23,000 md-ft.

The wells will make poor producers because of the low pressure. The pressure at 5,000 ft. datum is about 1540 psi which is less than the hydrostatic head of fresh water. The free water surface in the wells is about 1500 ft. below the wellhead.

Well #42-7 produced at a rate of 47,000 lbs/hr at 3 psig wellhead pressure and 200°F± wellhead temperature.

Low temperature resource also reduces the flow rates of the wells. At high temperatures, a larger fraction of the fluid will vaporize in the well-bore thus reducing the bottomhole flowing pressure and increasing the flow from the reservoir.

Permeability of the reservoir is fairly high. We calculated a kH product of around 23,000 md-ft. from the production/injection tests. High permeability and low pressure make these wells good injectors. The wells are capable of taking 1,000,000 lbs/hr at 0 psig wellhead pressure.

Based on the current economics, the resource discovered in the Cove Fort-Sulphurdale Unit is sub-commercial.