

Geology
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GEOLOGY

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National Uranium Resource Evaluation

**ENGINEERING REPORT
ON THE DRILLING IN THE
MISSOULA/BITTERROOT BASINS
OF MONTANA**

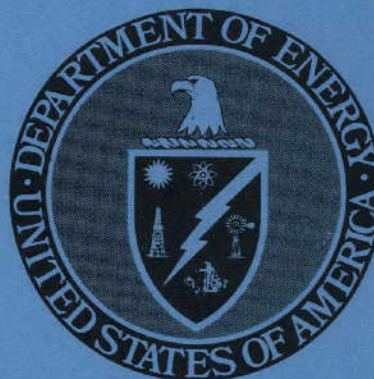
GEOLOGICAL SURVEY OF WYOMING



**Field Engineering
Corporation**

Grand Junction Operations
Grand Junction, CO 81502

August 1979



PREPARED FOR U.S. DEPARTMENT OF ENERGY
Assistant Secretary for Resource Applications
Grand Junction Office, Colorado

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ENGINEERING REPORT
ON THE DRILLING IN THE
MISSOULA/BITTERROOT BASINS
OF
MONTANA

BENDIX FIELD ENGINEERING CORPORATION
Grand Junction Operations
P.O. Box 1569
Grand Junction, Colorado 81502

August 1979

Prepared for the U.S. DEPARTMENT OF ENERGY
Assistant Secretary for Resource Applications
Grand Junction Office, Colorado

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 Geophysical logs (microfiche) In pocket

INTRODUCTION

This report presents engineering details, statistics, individual borehole histories and geophysical logs of the seven holes drilled in the Missoula/Bitterroot Drilling Program. A separate geological report is being prepared and will be available through the GJO Technical Library in the near future.

SUMMARY

The Missoula/Bitterroot Drilling Project was conducted by Bendix Field Engineering Corporation in support of the Department of Energy (DOE) National Uranium Resource Evaluation program (NURE). This project consisted of seven drillholes (Table 1) ranging in depth from 1,030 feet (313.94 m) to 2,907 feet (886.05 m). A total of 14,448 feet (4,406.64 m) were drilled, of which 319 feet (97.30 m) were cored.

The objective of the project was to obtain data which could enable more accurate assessments to be made of the favorability for uranium in the predominantly unexplored subsurface of the Missoula/Bitterroot Tertiary basins. This project started on May 9, 1978, and continued until January 9, 1979, when it was temporarily discontinued due to severe weather conditions and serious mechanical problems with the drilling rig. The remaining hole was completed between March 23, 1979, and April 6, 1979.

LOCATION

This project was conducted in the Missoula Valley, Missoula County, and the Bitterroot Valley, Ravalli County in southwestern Montana. All drill sites were within 25 miles (40.23 km) of the Missoula, Montana and Hamilton, Montana population centers (see Figure 1).

Access to the Bitterroot Valley is provided by U.S. Highway 93 which connects with Highway 90 at Missoula, Montana. Highway 90 passes through the Missoula Valley northwest of the city of Missoula. Other state, county, and Forest Service paved and graveled roads intersecting the major highways provided access to the drill sites.

All drill sites were selected for the best possible access with a minimum of road construction, while still remaining in geologically favorable areas. Surface topography ranges from flat-lying plains to gently sloped foothill areas at elevations between 3,000 feet (914.40 m) and 4,000 feet (1,219.20 m). The project site is bounded by mountains with summits generally below 6,000 feet (1,828.80 m).

PRINCIPAL FIRMS AND AGENCIES

OWNER

U.S. Department of Energy
Grand Junction Office
Grand Junction, Colorado 81502

OPERATOR

Bendix Field Engineering Corp.
Grand Junction Operations
Grand Junction, Colorado 81502

Table 1. Drillhole Summary

HOLE NO.	ROTARY FOOTAGE	CORED FOOTAGE	TOTAL FOOTAGE	ELEVATION	LOCATION						USGS TOPO SHEET
					$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	Sec	Twp	Rng	
MB-2	2,436.5 (742.65 m)	78.5 (23.93 m)	2,515 (766.57 m)	3,429 (1,045.85 m)	SW	SW	SW	17	15N	21W	Alberton, Montana
MB-4	2,827 (861.67 m)	80 (24.38 m)	2,907 (886.05 m)	3,538 (1,079.09 m)	NW	SE	NE	24	14N	20W	NW Missoula, Montana
MB-6	1,687 (514.20 m)	71 (21.64 m)	1,736 (529.13 m)	3,612 (1,101.66 m)	SW	NE	SE	32	10N	20W	St. Mary Peak, Montana
MB-8	2,689.5 (819.76 m)	32.5 (9.91 m)	2,722 (829.67 m)	3,488 (1,063.84 m)	NE	NE	NW	6	9N	19W	Stevensville, Montana
MB-9	1,020 (310.90 m)	10 (3.05 m)	1,030 (313.94 m)	4,016 (1,224.88 m)	NW	NW	NW	26	10N	19W	Cleveland Mt., Montana
MB-11	2,416 (736.40 m)	0	2,416 (736.40 m)	3,505 (1,069.03 m)	SW	NW	NW	18	6N	20W	Hamilton North, Montana
MB-12	1,063 (324.22 m)	47 (14.34 m)	1,110 (338.55 m)	3,792 (1,156.56 m)	NW	NW	NW	14	6N	20W	Corvallis, Montana

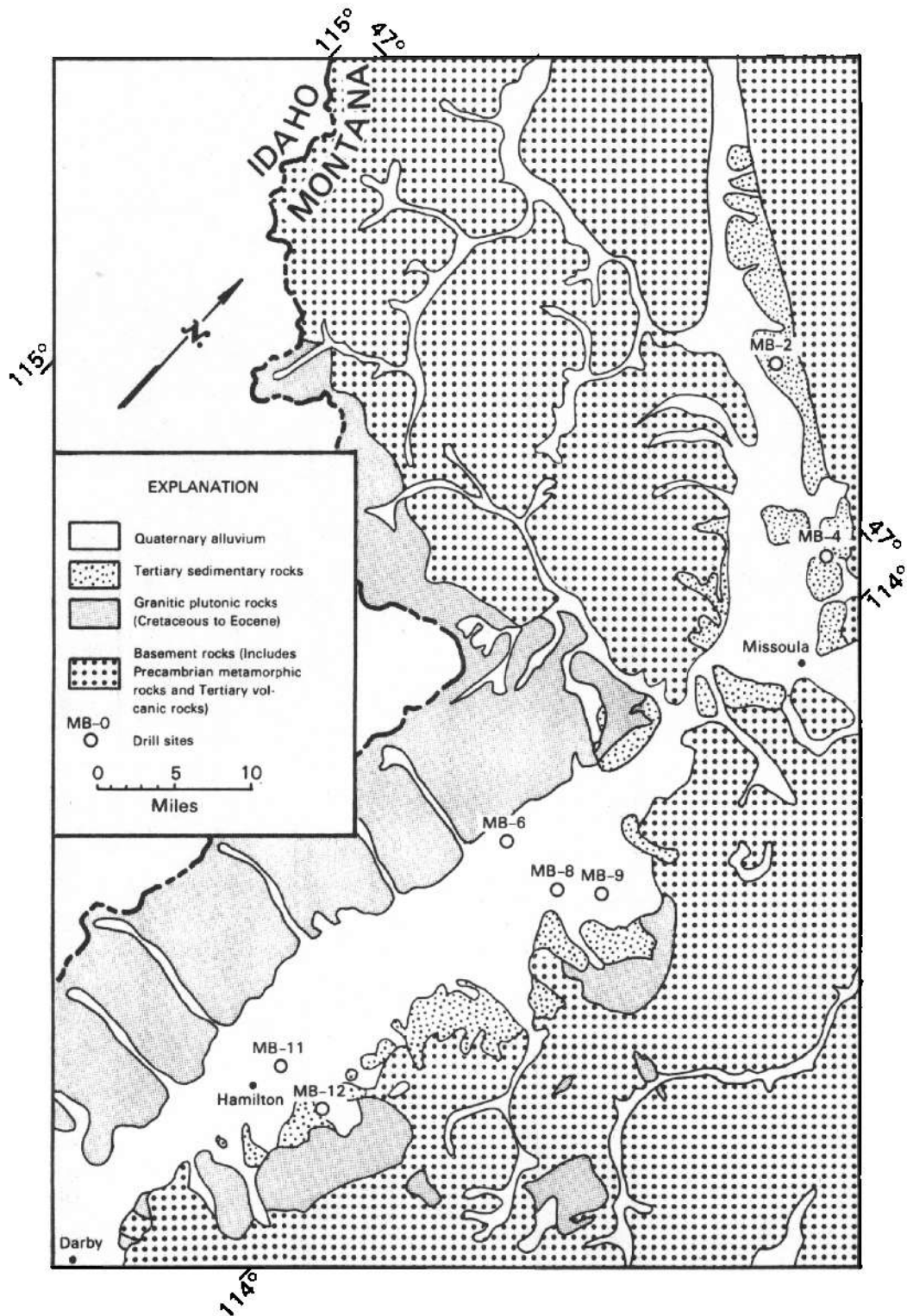


FIGURE 1. *Drillhole location plan for Missoula/Bitterroot drilling project.*

LANDOWNERS

U.S. Forest Service and Private Landowners

SUBCONTRACTORS AND SERVICE FIRMS

DRILLING CONTRACTOR

X-L Drilling Co., Inc.
P.O. Box 2109
Montrose, Colorado 81401

WELL DRILLING CONTRACTORS

Liberty Drilling and Pump Co.
2500 Reserve St.
Missoula, Montana 59806

Bill Preston Well Drilling
Highway 93 North
Hamilton, Montana 59840

DRILLING MUD

Northwestern Mud Co.
Terrace Estate #14
Craig, Colorado 81625

GEOPHYSICAL LOGGING

Goodwell, Inc.
P.O. Box 195
Upton, Wyoming 82730

(Subsidiary: Woodell, Inc.
P.O. Box 968
Mattoon, Illinois 61938)

MUD LOGGING

Monaco Engineering, Inc.
2405 Lincoln Center Bldg.
1660 Lincoln St.
Denver, Colorado 80264

FISHING SERVICES

NL Acme Tool Co.
401 South Bent
Powell, Wyoming

CEMENT

AB Concrete, Inc.
Rt. 2 Box 2126
Hamilton, Montana 59840

Monroc
P.O. Box 5104
Missoula, Montana 59806

GEOLOGIC CONSULTING

Montana Bureau of Mines & Geology
Montana College of Mineral Science and Technology
Butte, Montana 59701

Dr. R. Fields
University of Montana
Missoula, Montana 59806

Special geophysical logging was supplied by Bendix Field Engineering Corporation, GJO.

DRILLING GUIDELINES

Due to unstable surface conditions and potential artesian aquifers it was required that 6-5/8 inch (16.38 cm) minimum O.D. surface casing be installed. The annulus was cemented, except in cases where the casing was driven through virgin material rather than installed in a pre-drilled hole.

The top of casing was equipped with either a blowout preventer, a rotating head and valve system or just a valve system that would control artesian water if encountered.

Drilling mud was used as the circulation medium. A low water loss mud system with organic polymers was utilized due to difficult drilling conditions encountered (e.g., swelling clays).

Cuttings were obtained from the flowline at 10 foot (3.048 m) intervals throughout the rotary drilling, either by mud loggers or drillers helpers.

A two-man mud logging unit with a hot wire and chromatograph assembly was utilized for holes MB-2, MB-4, MB-8, and MB-11. The unit was equipped with a binocular microscope and other equipment needed for collecting and classifying samples. A final lithologic log and report was furnished for the four holes.

Inclination surveys were taken periodically by the drillers with a single-shot Eastman Whipstock, Inc., instrument. A maximum of 10° deviation at total depth was allowable; all holes remained within allowable limitations. A geograph was utilized to monitor drilling penetration rates.

Spot coring operations were initiated and terminated at the direction of the Project Manager. A Christensen 3 inch x 4-5/8 inch (7.62 x 11.75 cm) 15 foot (4.57 cm) core barrel with a face discharge diamond bit was utilized.

DRILLING ASSEMBLIES

X-L Drilling of Montrose, Colorado, utilized a local well drilling contractor, Liberty Drilling, to drill and case the first hole (MB-11) on the project. The water well rig, an Ingersoll Rand TH-60 mobilized to the site on May 10, 1978. Mobilization of the X-L drilling rig to the site occurred on May 18, 1978, after the casing was installed. On Hole MB-8, Bill Preston Well Drilling, another local contractor, installed the casing using a Chicago Pneumatic CP-650.

The drilling unit that completed all of the drilling was X-L Drilling Rig No. 7, a Gardner Denver Model 2000 crane carrier mounted, equipped with a GD 5 inch (12.7 cm) x 10 inch (25.4 cm) pump, rated at 210 gpm, and a 58 foot (17.68 m) mast, racking board, etc. Approximately 4,000 feet (1,219.2 m) of 2-7/8 inch (7.30 cm) x 20 foot (6.10 m) IF drill pipe and nine 4-1/2 inch (11.43 cm) x 20 foot (6.10 m) drill collars made up the initial drill string for this rig. A 3,000 gallon (11,355 l) water truck and flatbed pipe truck served as support for this rig.

WEATHER AND ROAD CONDITIONS

The weather in May and June was cool and wet; late July, August and early September proved to be hot and dry. Cooler temperatures prevailed in late September, October and November. The first snow appeared in late November from which time bitter cold and snow prevailed through December and January. Road conditions during the summer were ideal, but in the winter, roads were slippery and hazardous.

WORK SCHEDULE

The rig was operated on a 24 hour per day basis (i.e., two 12 hour shifts). Work was conducted on a flexible schedule of 10 to 20 days on and 4 to 8 days off, depending on progress at each hole or to allow personnel days off for intervening holidays.

Except for use of the local water well rigs to install the surface casing, all of the drilling was completed by the Gardner Denver Model 2000.

The project was divided into two major phases, a basic program and an option program. The four basic holes were drilled between May 10, 1978, and October 27, 1978. The option program originally consisted of six holes of which only three were drilled. Two were drilled between October 27, 1978, and December 18, 1978, immediately following completion of the basic program. The last hole was drilled between March 23, 1978, and April 6, 1978.

LOGISTICS

All drill sites were in close proximity to populated areas of either Missoula or Hamilton, Montana. Primary land use in the area is agricultural and recreational. Fuel, room and board facilities were readily available. Drilling water was easily available from streams and ponds adjacent to drill sites and never had to be hauled more than two miles.

Due to the remote location of the project from any exploration activity, material supply proved to be a problem. Mud and additives were shipped from Craig, Colorado, or occasionally from Dillon, Montana. Rig and drilling equipment parts and supplies were almost impossible to obtain in the area and had to be shipped from exploration centers in Colorado and Wyoming.

ACKNOWLEDGEMENTS

The Project Manager and Project Geologist was I. N. Abramiuk, BFEC. The Project Assistant Manager was P. Weiser, BFEC. The Montana Bureau of Mines under the direction of Dr. Sid Groff arranged for all the pre-drilling landwork, permits and consulting during the project. Dr. R. Fields of the University of Montana provided the geologic consulting support. Pete Norbeck acted as the Project Manager for the Montana Bureau of Mines.

DRILLING SUMMARY

MB-2

Location: SW1/4SW1/4SW1/4 sec. 17, T. 15 N., R. 21 W.
Total depth: 2,515 feet (765.77 m)
Spud date: September 1, 1978
Completion date: October 27, 1978
Rig: Gardner Denver Model 2000, X-L Drilling Rig No. 7
Drill pipe: 2-7/8 inch (7.30 cm) I.F. x 20 feet (6.10 m)
Drill collars: Seven 4-1/2 inch (11.43 cm) x 1-1/2 inch (3.81 cm) x 20 feet (6.10 m). Switched to three 4-1/2 inch (11.43 cm) x 1-1/2 inch (3.81 cm) x 20 feet (6.10 m) plus five 3-1/2 inch (8.89 cm) x 1-1/2 inch (3.81 cm) x 20 feet (6.10 m).
Sample interval: 10 feet (3.05 m)
Coring interval: 811 feet to 821 feet (247.19 m to 250.24 m), 965 feet to 975 feet (294.13 m to 297.18 m), 980 feet to 990 feet (298.70 m to 301.75 m), 1,074 feet to 1,084 feet (327.36 m to 330.40 m), 1,232 feet to 1,243 feet (375.51 m to 378.87 m), 1,748 feet to 1,758 feet (532.79 m to 535.84 m), 1,937 feet to 1,945.5 feet (590.40 m to 592.99 m), 2,237 feet to 2,246 feet (681.84 m to 684.58 m).
Total core recovered: 51.1 feet (15.58 m)
Core barrel: 4-5/8 inch (11.75 cm) x 3 inch (7.62 cm) x 15 feet (4.57 m).

Borehole history: Hole MB-2 was rotary drilled to a depth of 83 feet (25.30 m) with a 12-1/4 inch (31.12 cm) bit and casing set and cemented. Blow out prevention equipment was mounted on the casing head and the hole was continued with a 6 inch (15.24 cm) bit to terminal depth with spot cores run at the noted intermediate depths.

Penetration rates were very slow and the bit wear was very high due to the abrasive nature of the quartzite conglomerate encountered. Three of the 4-1/2 inch (11.43 cm) collars were replaced with five 3-1/2 inch (8.89 cm) collars due to pinbreaks. A total of 280 feet (85.34 m) of pipe and all collars twisted off at 2,172 feet (662.03 m). A total of nine days were spent fishing, retrieving most of the fish on September 30, 1978. The remaining collars, bit and subs were finally retrieved by NL Acme Tool Corp. on October 8, 1978. The major difficulty was a boulder that fell in on top of the remaining fish, so the overshot could not get over the lost tools. The washover barrel was used to core and retrieve the boulder obstruction, facilitating re-entry and retrieval with the overshot tool. Drilling continued to 2,515 feet (766.57 m) where a mismatch on the elevators caused a loss of 240 feet (73.15 m) of tools in the hole on October 24, 1978.

Tools were fished out on October 26, 1978, but the cones lost from the bit during the fishing operations could not be retrieved so the hole was abandoned.

The circulation system consisted of earthen pits having approximately 15,000 gallons (56,775 l) total capacity. Drilling fluid was primarily a gel base with organic polymers and other additives. Viscosity averaged 39 sec/qt and weight averaged 8.7 pounds per gallon.

The hole was logged by Goodwell, Inc., on three occasions; twice before the break periods on September 11, 1978, and October 10, 1978, and again at completion. The Bendix unit logged the hole before the second break period. Hole responsibility was transferred to the Montana Bureau of Mines at completion. The Bureau installed 4 inch (10.6 cm) casing to a depth of 2,400.8 feet (731.76 m) for purposes of future hydrologic testing and observation.

Bit Record MB-2

No.	Make	Type	Size		In		Out		Footage	
			in.	cm	ft	m	ft	m	ft	m
1	HTC	OSC	12-1/4	31.12	0	0	83	25.30	83	25.30
2	GW	GR-4	6	15.24	83	25.30	455	138.68	372	113.39
3	GW	GR-4	6	15.24	455	138.68	811	247.19	356	108.51
4	GW	GR-4	6	15.24	811	247.19	965	294.13	154	46.94
5	GW	GR-1H	6	15.24	965	294.13	980	298.70	15	4.57
5A	GW	GR-1H	6	15.24	980	298.70	1,072	326.75	92	28.05
6	GW	GR-1H	6	15.24	1,072	326.75	1,232	375.51	160	48.77
7	GW	GR-1H	6	15.24	1,232	375.51	1,353	412.39	121	36.88
8	GW	GR-1H	6	15.24	1,353	412.39	1,430	435.86	77	23.47
9	GW	GR-1H	6	15.24	1,430	435.86	1,538	468.78	103	31.39
10	GW	GR-1H	6	15.24	1,538	468.78	1,652	503.53	114	34.75
11	GW	GR-1H	6	15.24	1,652	503.53	1,748	532.79	96	29.26
12	GW	GR-1H	6	15.24	1,748	532.79	1,766	538.28	18	5.49
13	GW	GR-1H	6	15.24	1,766	538.28	1,825	556.26	59	17.98
14	GW	GR-1H	6	15.24	1,825	556.26	1,889	575.77	64	19.51
15	GW	GR-1H	6	15.24	1,889	575.77	1,937	590.40	48	14.63
16	GW	GR-1H	6	15.24	1,937	590.40	1,987	605.64	50	15.24
17	GW	GR-1H	6	15.24	1,987	605.64	2,021	616.00	34	10.36
18	GW	GR-1H	6	15.24	2,021	616.00	2,056	626.67	35	10.67
19	GW	GR-1H	6	15.24	2,056	626.67	2,116	644.96	60	18.29
20	GW	GR-1H	6	15.24	2,116	644.96	2,172	662.03	56	17.07
21	GW	GR-1H	6	15.24	2,172	662.03	2,216	675.44	44	13.41
22	GW	GR-1H	6	15.24	2,216	675.44	2,237	681.84	21	6.40
23	GW	GR-1H	6	15.24	2,237	681.84	2,277	694.03	40	12.19
24	GW	GR-55	6	15.24	2,277	694.03	2,365	720.85	58	26.82
(rerun No. 12)										
25	GW	GR-1H	6	15.24	2,365	720.85	2,423	738.53	58	17.68
26	GW	GR-55	6	15.24	2,423	738.53	2,515	766.57	92	28.04

Note: GW--Gruner Williams

Mud Record MB-2

<u>Material</u>	<u>Quantity</u>
Gel	378 sks (100 lbs/45.36 kg ea)
Cypan	39 sks (50 lbs/22.68 kg ea)
Cedar Fiber	8 sks (40 lbs/18.14 kg ea)
Lime	1/2 sks (50 lbs/22.68 kg ea)
Kwik Seal	2 sks (40 lbs/18.14 kg ea)
Surfdril	38 cans (5 gal/22.73 l ea)

Deviation Tests MB-2

<u>Depth</u>	<u>Deviation</u>
83 feet (25.30 m)	1/2°
1,353 feet (412.39 m)	6°
2,021 feet (616.00 m)	9-3/4°

Geophysical Logs MB-2

Gamma	Resistivity
Density	Caliper
Neutron	KUT
Spontaneous Potential	

MB-4

Location: NW1/4SE1/4NE1/4 sec. 24, T. 14 N., R. 20 W.
Total depth: 2,907 feet (886.05 m)
Spud date: July 20, 1978
Completion date: August 28, 1978
Rig: Gardner Denver Model 2000, X-L Drilling Rig No. 7
Drill pipe: 2-7/8 inch (7.30 cm) x 1-1/2 inch (3.81 cm) x 20 feet (6.10 m)
Drill collars: Seven 4-1/2 inch (11.43 cm) x 1-1/2 inch (3.81 cm) x 20 feet (6.10 m)
Sample interval: 10 feet (3.05 m)
Coring interval: 695 feet to 710 feet (211.84 m to 216.41 m), 710 feet to 718 feet (216.41 m to 218.85 m), 826 feet to 841 feet (251.76 m to 256.34 m), 1,489 feet to 1,504 feet (453.85 m to 458.42 m), 2,395 feet to 2,410 feet (730.00 m to 734.57 m), 2,895 feet to 2,907 feet (882.40 m to 886.05 m).
Total core recovered: 46.3 feet (14.11 m)
Core barrel: 4-5/8 inch (11.75 cm) x 3 inch (7.62 cm) x 15 feet (4.57 m)

Borehole history: Hole MB-4 was spudded with a 12-1/4 inch (31.12 cm) bit and drilled to a depth of 115 feet (35.05 m). 6-5/8 inch (16.83 cm) casing was installed, butt welded in approximately 30 foot (9.14 m) lengths and cemented to 115 feet (35.05 m). Blow out prevention equipment was mounted to the casing head. A 6 inch (15.24 cm) diameter hole was drilled to 2,895 feet (882.40 m) with spot cores run at the noted intermediate depths and a bottom hole core run from 2,895 feet (882.40 m) to terminal depth. Penetration rates were generally slow and bit wear was high due to the abrasive nature of the quartzite conglomerate encountered. Cones sheared off the bit at 1,300 feet (396.24 m) but were milled out to complete the hole successfully. The circulation systems used consisted of earthen pits having approximately 15,000 gallons (56,775 l) total capacity. Drilling fluid was primarily a gel base with organic polymers and other additives. Viscosity averaged 39.9 sec/qt and the weight averaged 9.35 pounds per gallon on August 12, 1978.

The hole was logged by Goodwell, Inc. prior to the break period and again at the completion of the hole on August 27, 1978. Responsibility for the hole was transferred to the Montana Bureau of Mines who installed 4 inch (10.16 cm) casing to a depth of 2,863.1 feet (872.67 m) for hydrologic testing and observation purposes.

Bit Record MB-4

No.	Make	Type	Size		In		Out		Footage	
			in.	cm	ft	m	ft	m	ft	m
1	HTC	OSC	12-1/4	31.12	0	0	115	35.05	115	35.05
2	GW	GR-4	6	15.24	115	35.05	475	144.78	360	109.73
3	GW	GR-4	6	15.24	475	144.78	695	211.84	220	67.06
4	Varel	H-2	6	15.24	695	211.84	826	251.76	131	39.93
5	GW	GR-4	6	15.24	826	251.76	975	297.18	149	45.42
5A	GW	GR-4	6	15.24	975	297.18	1,030	313.94	55	16.76
6	Varel	H-2	6	15.24	1,030	313.94	1,095	333.76	65	19.81
7	GW	GR-1H	6	15.24	1,095	333.76	1,195	364.24	100	30.48
8	GW	GR-4	6	15.24	1,195	364.24	1,295	394.72	100	30.48
9	GW	GR-1H	6	15.24	1,295	394.72	1,355	413.00	60	18.29
10	GW	GR-1H	6	15.24	1,355	413.00	1,489	453.85	134	40.84
11	GW	GR-1H	6	15.24	1,489	453.85	1,695	516.64	206	62.79
12	GW	GR-4	6	15.24	1,695	516.64	1,885	574.55	190	57.91
13	GW	GR-4	6	15.24	1,885	574.55	2,155	656.84	279	82.30
14	GW	GR-4	6	15.24	2,155	656.84	2,395	730.00	240	73.15
15	GW	GR-4	6	15.24	2,395	730.00	2,603	793.39	208	63.39
16	GW	GR-4	6	15.24	2,603	793.39	2,755	839.72	152	46.33
17	GW	GR-4	6	15.24	2,755	839.72	2,895	882.40	140	42.67

Note: GW--Gruner Williams

Mud Record MB-4

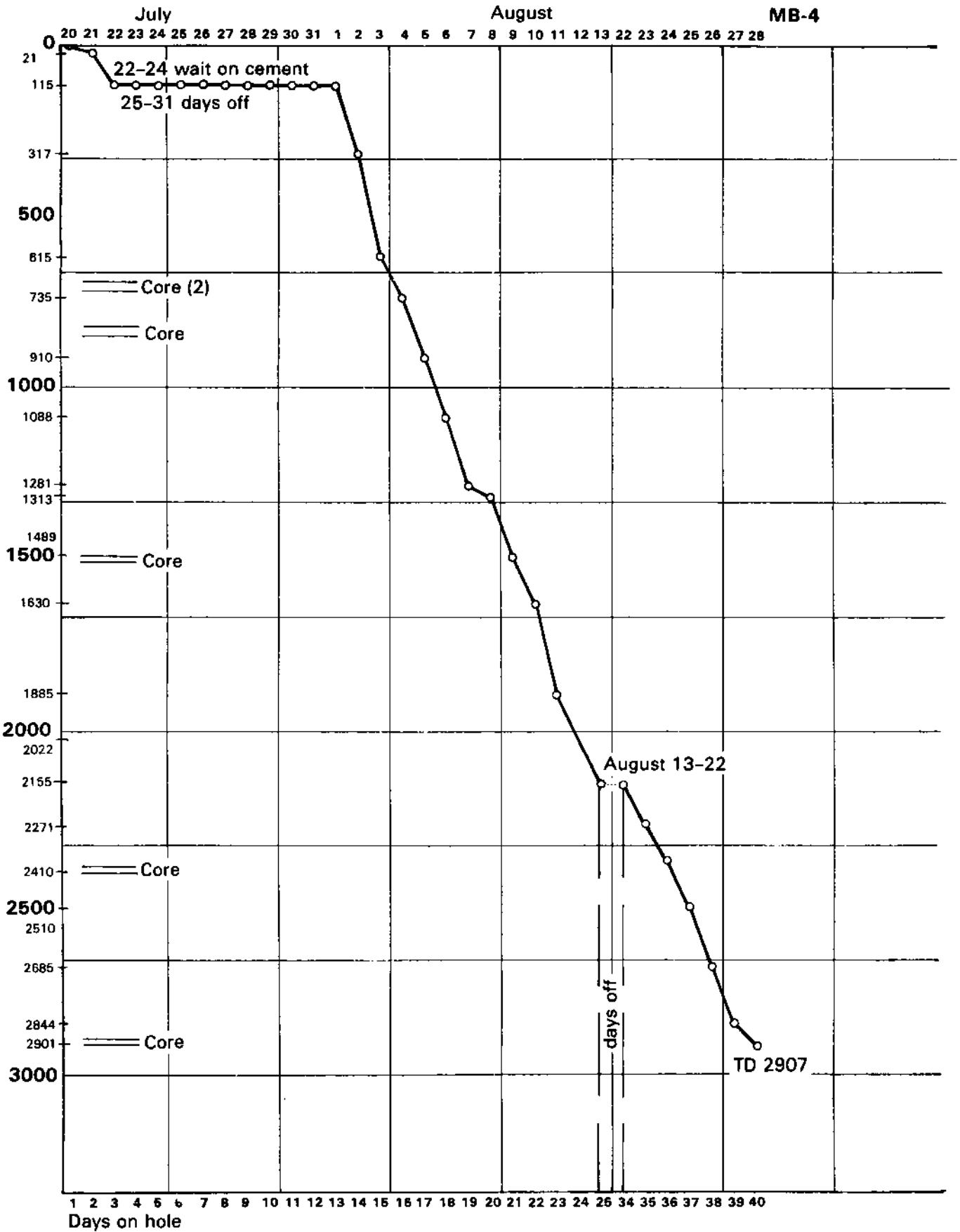
<u>Material</u>	<u>Quantity</u>
Gel	109 sks (100 lbs/45.36 kg ea)
Lime	1 sk (50 lbs/22.68 kg ea)
Driscose	1 sk (50 lbs/22.68 kg ea)
Cedar Fiber	2 sks (50 lbs/22.68 kg ea)
Rayvan	4 sks (50 lbs/22.68 kg ea)
Surfdrill	13 cans (5 gal/22.73 l ea)
Cypan	26 sks (50 lbs/22.68 kg ea)

Deviation Tests MB-4

<u>Depth</u>	<u>Deviation</u>
115 feet (35.05 m)	1/2°
690 feet (210.31 m)	4°
846 feet (257.86 m)	5°
975 feet (297.18 m)	5°
1,095 feet (333.76 m)	4°
1,353 feet (412.39 m)	8°
1,920 feet (585.22 m)	4°

Geophysical Logs MB-4

Gamma	Resistivity
Density	Caliper
Spontaneous Potential	Neutron



MB-6

Location: SW1/4NE1/4SE1/4 sec. 32, T. 10 N., R. 20 W.
 Total depth: 1,736 feet (529.13 m)
 Spud date: October 31, 1978
 Completion date: December 5, 1978
 Rig: Gardner Denver Model 2000, X-L Drilling Rig No. 7
 Drill pipe: 2-7/8 inch (7.30 cm) I.F. x 20 feet (6.10 m)
 Drill collars: Three 4-1/2 inch (11.43 cm) x 1-1/2 inch (3.81 cm) x 20 feet (6.10 m). Five 4-1/2 inch (11.43 cm) x 1-1/2 inch (3.81 cm) x 20 feet (6.10 m)
 Sample interval: 10 feet (3.05 m)
 Coring interval: 470 feet to 480 feet (143.26 m to 146.30 m), 619 feet to 629 feet (188.67 m to 191.72 m), 867 feet to 877 feet (264.26 m to 267.31 m), 1,092 feet to 1,104 feet (332.84 m to 336.50 m), 1,356 feet to 1,367 feet (413.61 m to 416.66 m), 1,558 feet to 1,568 feet (474.88 m to 477.93 m), 1,727 feet to 1,736 feet (526.39 m to 529.13 m).
 Total core recovered: 26.6 feet (8.41 m)
 Core barrel: 4-5/8 inch (11.75 cm) x 3 inch (7.62 cm) x 15 feet (4.57 m).

Borehole history: Hole MB-6 was rotary drilled with a 12-1/4 inch (31.12 cm) bit to a depth of 53 feet (16.15 m) and 6-5/8 inch casing (16.83 cm) was set and cemented. Gate valves were mounted on the top of the casing and the outflow pipe as an artesian blow out prevention measure. A 6 inch (15.24 cm) diameter hole was then drilled to a depth of 1,727 feet (526.39 m) with intermediate spot coring intervals and a final bottom hole core from 1,727 feet (526.39 m) to terminal depth at 1,736 feet (529.13 m). Most of the material encountered was granite wash which proved to be very abrasive on bits.

The circulation system used consisted of earthen pits having approximately 10,000 gallons (37,850 l) total capacity. Drilling fluid was primarily a gel base with organic polymers and other additives. Viscosity averaged 43.4 sec/qt and the weight was generally below 9 pounds per gallon.

The hole was logged by Goodwell, Inc., prior to the break periods on November 6, 1978, and November 22, 1978, and at the completion of drilling. The Bendix Field Engineering Corp. logging unit also logged the hole at completion. The hole responsibility was transferred to the Montana Bureau of Mines who installed 2 inch (5.08 cm) casing to a depth of 1,736 feet (529.13 m) to facilitate heat transfer studies.

Bit Record MB-6

No.	Make	Type	Size		In		Out		Footage	
			in.	cm	ft	m	ft	m	ft	m
1	HTC	OSC	12-1/4	31.12	0	0	53	16.15	53	16.15
2	GW	GR-4	6	15.24	53	16.15	340	103.63	287	87.48
3	GW	GR-4	6	15.24	340	103.63	470	143.26	130	39.62
4	GW	GR-4	6	15.24	470	143.26	619	188.67	147	44.81
5	GW	GR-IH	6	15.24	619	188.67	742	226.16	123	37.49
6	GW	GR-IH	6	15.24	742	226.16	867	264.26	125	38.10
7	GW	GR-IH	6	15.24	867	264.26	1,000	304.80	123	37.49

Bit Record MB-6 Cont.

<u>No.</u>	<u>Make</u>	<u>Type</u>	<u>Size</u>		<u>In</u>		<u>Out</u>		<u>Footage</u>	
			<u>in.</u>	<u>cm</u>	<u>ft</u>	<u>m</u>	<u>ft</u>	<u>m</u>	<u>ft</u>	<u>m</u>
8	GW	GR-IH	6	15.24	1,000	304.80	1,092	332.84	92	28.04
9	GW	GR-IH	6	15.24	1,092	332.84	1,197	364.85	105	32.00
10	GW	GR-IH	6	15.24	1,197	364.85	1,283	391.06	86	26.21
11	GW	GR-IH	6	15.24	1,283	391.06	1,337	407.52	54	16.46
12	GW	GR-IH	6	15.24	1,337	407.52	1,367	416.66	30	9.14
13	GW	GR-IH	6	15.24	1,367	416.66	1,473	448.97	106	32.31
14	GW	GR-IH	6	15.24	1,473	448.97	1,558	474.88	85	25.91
15	GW	GR-IH	6	15.24	1,558	474.88	1,727	526.39	158	48.16

Mud Record MB-6

Material

Quantity

Gel	89 sks (100 lbs/45.36 kg ea)
Cypan (incomplete)	5 sks (50 lbs/22.68 kg ea)

Deviation Tests MB-6

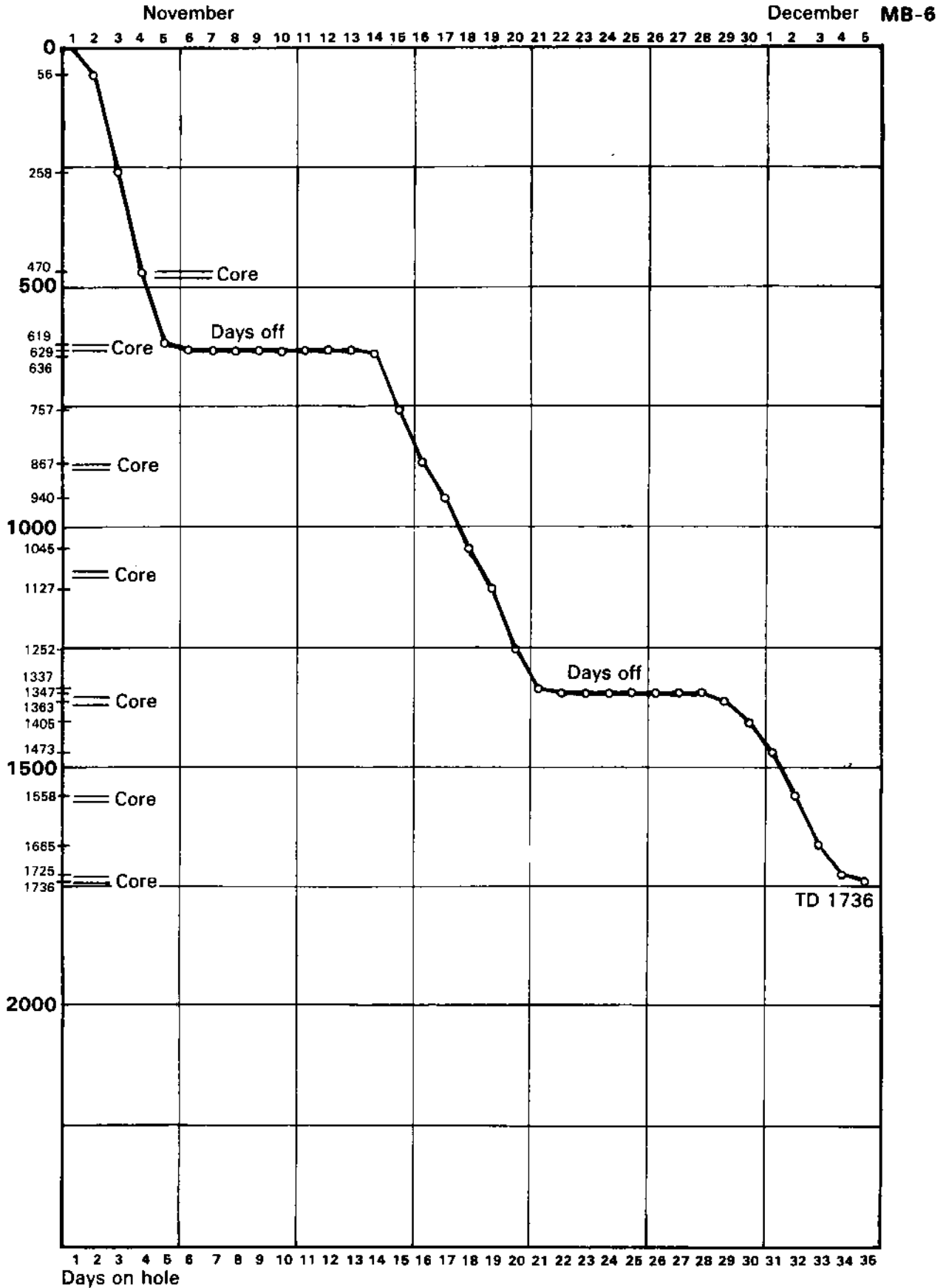
Depth

Deviation

880 feet (268.22 m)	4°
1,000 feet (305 m)	4°

Geophysical Logs MB-6

Gamma	Resistivity
Density	Caliper
Neutron	KUT
Spontaneous Potential	



MB-8

Location: NE1/4NE1/4NW1/4 sec. 6, T. 9 N., R. 19 W.
Total depth: 1,736 feet (529.13 m)
Spud date: June 1, 1978
Completion date: July 17, 1978
Rig No. 1: Chicago Pneumatic--CP650, Bill Preston Well Drilling
Rig No. 2: Gardner Denver Model 2000, X-L Drilling Rig No. 7
Drill pipe: 2-7/8 inch (7.30 cm) IF x 20 feet (6.10 m)
Drill collars: Seven 4-1/2 inch (11.43 cm) x 1-1/2 inch (3.81 cm) x 20 feet (6.10 m)
Sample interval: 10 feet (3.05 m)
Coring interval: 1,815 feet to 1,821 feet (553.21 m to 555.19 m), 2,310 feet to 2,322 feet (704.09 m to 707.75 m), 2,708 feet to 2,722 feet (825.40 m to 829.67 m).
Total core recovered: 32.5 feet (9.91 m)
Core barrel: 4-5/8 inch (11.75 cm) x 3 inch (7.62 cm) x 15 feet (4.57 m)

Borehole history: Hole MB-8 was spudded by Bill Preston Well Drilling using a CP-650 water well rig equipped with a casing hammer. The initial 380 feet (115.82 m) was drilled with an 8-5/8 inch (21.91 m) bit and cased with 8-5/8 inch (21.91 m) casing to a depth of 355 feet (108.20 m). The casing was butt welded in approximately 30 foot (9.14 m) lengths and driven in place. A rotating head was mounted to the wellhead with a gate valve welded to the out-flow pipe to contain any artesian pressure. The casing was set by July 9, 1978, but the Gardner Denver Model 2000 did not occupy hole until June 22, 1978. Drilling resumed with a 6-1/4 inch (15.24 cm) bit to a depth of 598 feet (182.27 m). Complete circulation was lost between 380 feet to 440 feet (115.82 m to 134.11 m) and 490 feet to 510 feet (149.35 m to 155.45 m), resulting in a loss of about 25,000 gallons (94,625 l) of drilling fluid. The use of lost circulation material, mainly Cedar Fiber and Pro Fiber, solved the fluid loss problem. In the process of tripping to 598 feet (182.27 m) a casing separation at 233 feet (71.02 m) was discovered which was verified by caliper log. As a result of this separation a 6-5/8 inch (16.83 cm) liner was set and cemented within the 8-5/8 inch (21.91 cm) casing to a depth of 370 feet (112.78 m). At the same time the hole was cemented to 560 feet (170.69 m) as insurance against further lost circulation problems in that interval.

From a depth of 598 feet (182.27 m) the hole was continued with a 6 inch (15.24 cm) bit, obtaining spot cores at intermediate intervals, to a depth of 2,708 feet (825.40 m). A bottom hole core was obtained from 2,708 feet (825.40 m) to the terminal depth. Drilling problems consisted of considerable amounts of swelling clays (which created bridging effects) interbedded with abrasive quartzose sands. Cones locking up in the claystone zones and skidding on the abrasive quartzose layers were a major problem throughout the drilling.

The hole was logged by Goodwell, Inc. on three different occasions: (1) Prior to installation of the liner on June 23, 1978; (2) prior to the break period on July 3, 1978; (3) at the completion of the hole on July 16, 1978. The Bendix unit logged the hole prior to the break period on July 3, 1978. An

interesting feature of this hole was the presence of gas (methane) in amounts up to 450 units encountered at 2,360 feet (719.33 m) and persisting in varying amounts to terminal depth at 2,723 feet (829.97 m). Hole responsibility was transferred to the Montana Bureau of Mines and Geology who installed a 4 inch (10.16 cm) casing to a depth of 2,627 feet (800.71 m) to facilitate future hydrologic testing and observation.

The circulation system consisted of earthen pits having approximately 15,000 gallons (56,775 l) total capacity. Drilling fluid was primarily a gel base with organic polymers and other additives. Viscosity average 45.7 sec/qt and weight was generally between 9 and 9.5 pounds per gallon.

Bit Record MB-8

No.	Make	Type	Size		In		Out		Footage	
			in.	cm	ft	m	ft	m	ft	m
1	Vareil	H2	6-1/4	15.88	355	108.20	598	182.27	243	74.07
2	Walker	Mac#3	6	15.24	598	182.27	597	291.69	359	109.42
3	Walker	Mac#1	6	15.24	957	291.69	1,197	346.85	240	73.15
4	GW	GR-4	6	15.24	1,197	364.85	1,537	468.48	340	103.63
5	GW	GR-2	6	15.24	1,537	468.48	1,815	553.21	287	87.48
6	GW	GR-2	6	15.24	1,815	553.21	2,062	628.50	247	75.29
7	GW	GR-1	6	15.24	2,062	628.50	2,175	662.94	113	34.44
8	GW	GR-4	6	15.24	2,175	662.94	2,285	696.47	110	33.53
9	GW	GR-4	6	15.24	2,285	696.47	2,310	704.09	25	7.62
10	GW	GR-4	6	15.24	2,310	704.09	2,355	717.80	45	13.72
11	GW	GR-4	6	15.24	2,355	717.90	2,419	737.31	64	19.51
12	GW	GR-4	6	15.24	2,419	737.31	2,575	784.86	156	47.55
13	GW	GR-4	6	15.24	2,575	784.86	2,655	809.24	80	24.38
14	GW	GR-4	6	15.24	2,655	809.24	2,708	825.40	53	16.15

Mud Record MB-8

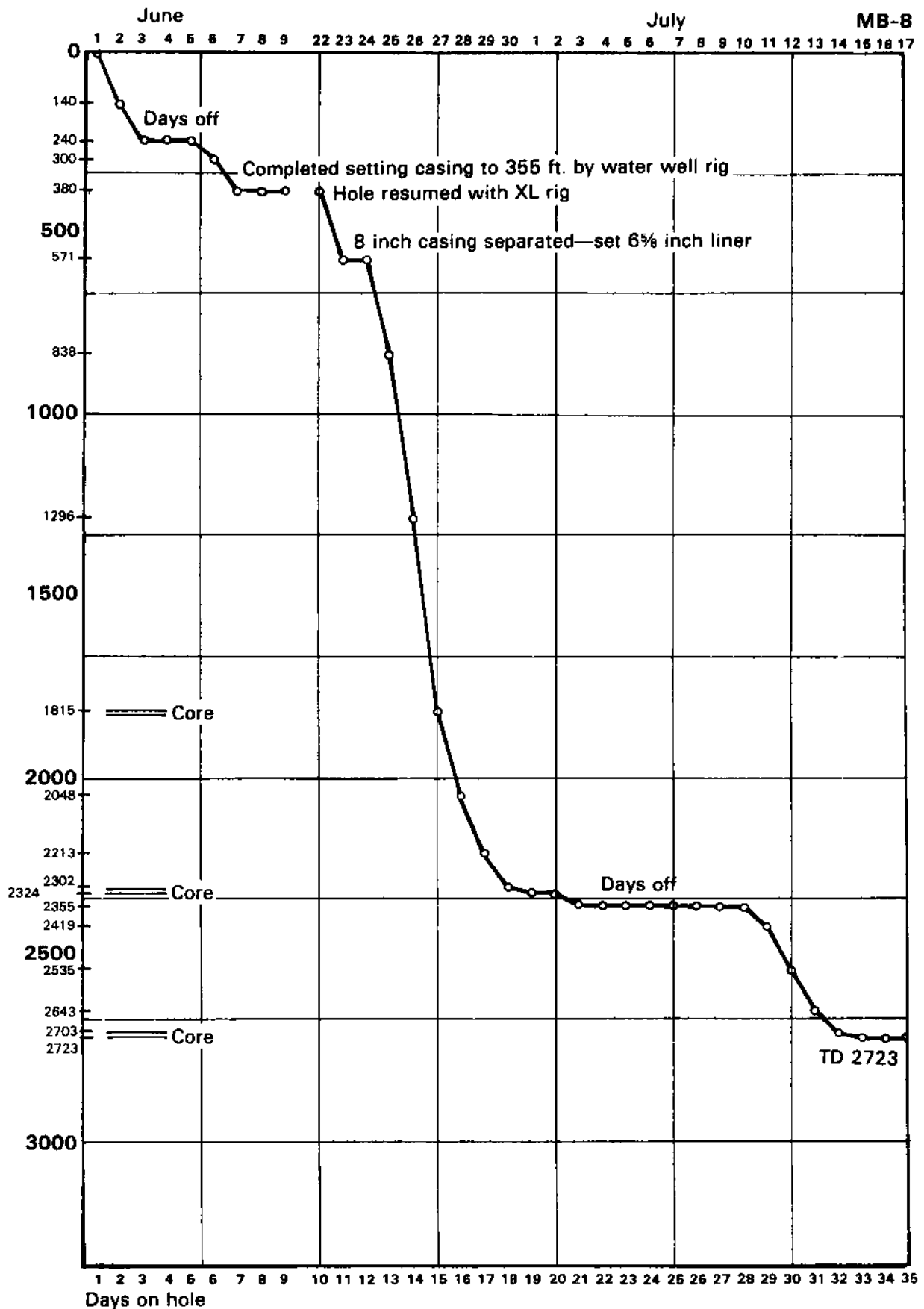
<u>Material</u>	<u>Quantity</u>
Gel	126 sks (100 lbs/45.36 kg ea)
Starlose	19 sks (50 lbs/22.68 kg ea)
Rayvan	17 sks (50 lbs/22.68 kg ea)
Surfdrill	13 cans (5 gal/22.73 l ea)
Cedar Fiber	11 sks (40 lbs/181.4 kg ea)
Soda ash	3 sks (100 lbs/45.36 kg ea)
Pro Fiber	2 sks (40 lbs/18.14 kg ea)
Lignite	2 sks (50 lbs/22.68 kg ea)
Floc	7 sks (50 lbs/22.68 kg ea)
Driscose	4-1/2 sks (50 lbs/22.68 kg ea)
Lime	1-1/2 sks (50 lbs/22.68 kg ea)
Caustic	1 sk (50 lbs/22.68 kg ea)

Deviation Tests MB-8

<u>Depth</u>	<u>Deviation</u>
355 feet (108.20 m)	0°
600 feet (182.88 m)	0°
950 feet (289.56 m)	0°
1,200 feet (365.76 m)	1°
1,580 feet (481.58 m)	2°
1,815 feet (553.21 m)	1°
2,170 feet (661.42 m)	1°

Geophysical Logs MB-8

Gamma	Caliper
Density	KUT
Neutron	



MB-9

Location: NW1/4NW1/4NW1/4 sec. 26, T. 10 N., R. 19 W.
 Total depth: 1,030 feet (313.94 m)
 Spud date: December 8, 1978
 Completion date: December 15, 1978
 Rig: Gardner Denver Model 2000, X-L Drilling Rig No.7
 Drill pipe: 2-7/8 inch (7.30 cm) IF x 20 feet (6.10 m)
 Drill collars: Three 4-1/2 inch (11.43 cm) x 1-1/2 inch (3.81 cm) x 20 feet (6.10 m) and five 4-1/2 inch (11.43 cm) x 1-1/2 inch (3.81 cm) x 20 feet (6.10 m).
 Sample interval: 10 feet (3.05 m)
 Coring interval: 970 feet to 980 feet (295.96 m to 298.70 m)
 Total core recovered: 10 feet (3.05 m)
 Core barrel type and size: 4-5/8 inch (11.75 cm) x 3 inch (7.62 cm) x 15 feet (4.57 m)

Borehole history: Hole MB-9 was rotary drilled with a 12-1/4 inch (31.12 cm) bit to a depth of 64 feet (19.51 m). Casing was then set and cemented and gate valves were mounted on top of the well head and the outflow pipe to contain artesian water if encountered. The hole was continued with a 6 inch (15.24 cm) bit from 64 feet (19.51 m) to completion at 1,030 feet (313.94 m). One core was pulled in the granite basement as indicated above.

The circulation system consisted of earthen pits having approximately 12,000 gallons (45,420 l) total capacity. Drilling fluid was primarily a gel base with organic polymers and other additives. Viscosity averaged 46 sec/qt and weight was generally about 9 pounds per gallon.

Goodwell, Inc., logged the hole at completion. The hole responsibility was transferred to the Montana Bureau of Mines who set 2 inch (5.08 cm) casing to the bottom of hole for future heat transfer flow studies.

Bit Record MB-9

No.	Make	Type	Size		In		Out		Footage	
			in.	cm	ft	m	ft	m	ft	m
1	HTC	OSC (rerun)	12 1/4	31.12	0		64	19.51	64	19.51
2	GW	GR-4	6	15.24	64	19.51	492	149.96	428	130.45
3	GW	GR-4	6	15.24	492	149.96	970	295.66	478	145.69
4	GW	GR-4	6	15.24	970	295.66	1,030	313.94	60	18.29

Mud Record MB-9

<u>Material</u>	<u>Quantity</u>
Gel	56 sks (100 lbs/45.63 kg ea)
Cypan	11 sks (50 lbs/22.68 kg ea)
Cedar Fiber	3 sks (40 lbs/18.14 kg ea)
Kwik Seal	3 sks (40 lbs/18.14 kg ea)

Deviation Tests MB-9

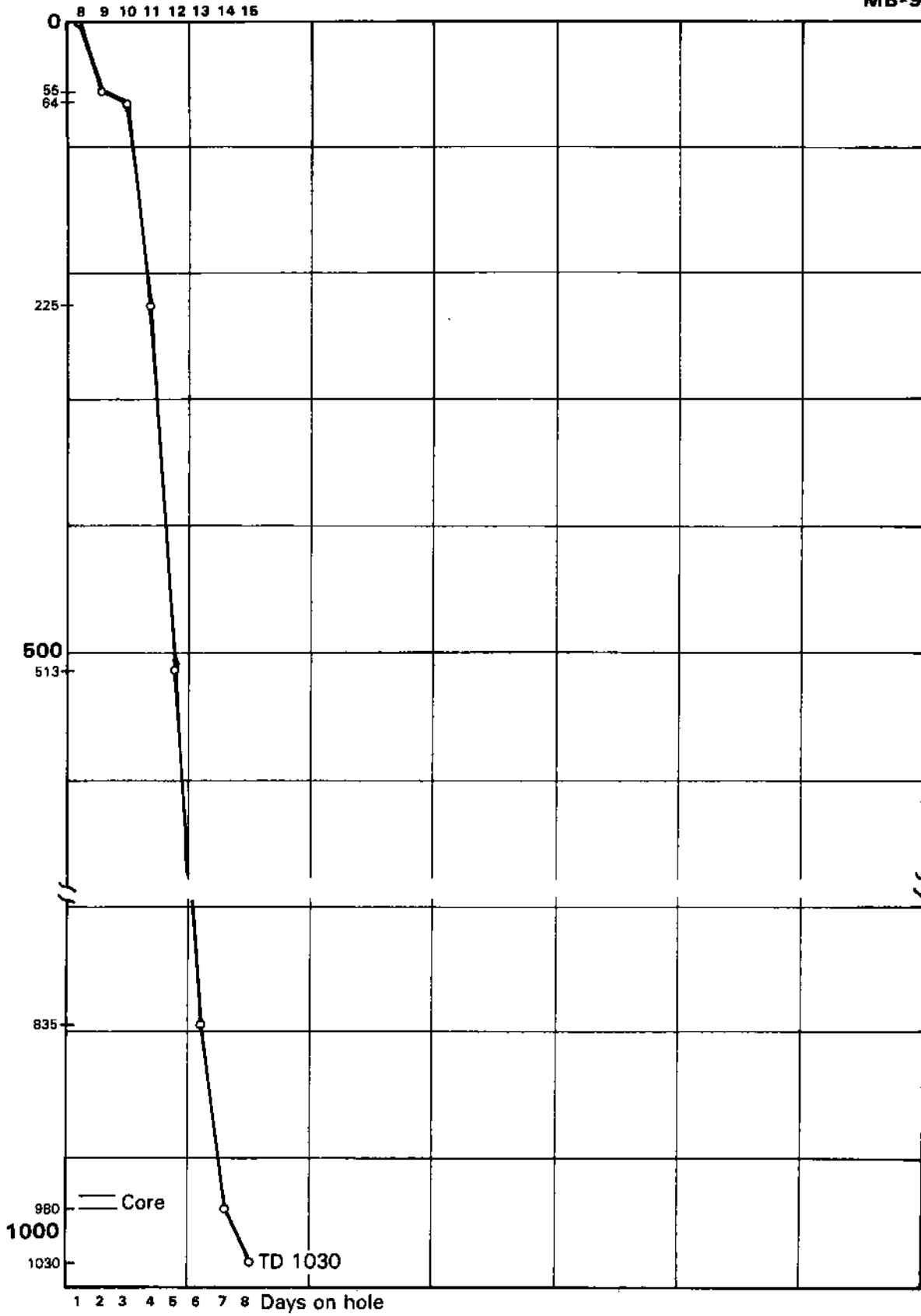
<u>Depth</u>	<u>Deviation</u>
1,000 feet (304.80 m)	4°

Geophysical Logs MB-9

Gamma	Resistivity
Density	Caliper
Spontaneous Potential	Neutron

December

MB-9



MB-11

Location: SW1/4NW1/4NW1/4 sec. 18, T. 6 N., R. 20 W.
Total depth: 2,416 feet (736.40 m)
Spud Date: May 10, 1978
Completion date: June 21, 1978
Rig No. 1: Ingersoll Rand TH-60, Liberty Drilling
Rig No. 2: Gardner Denver Model 2000, XL Drilling Rig No. 7
Drill pipe: 2-7/8 inch (7.30 cm) IF x 20 feet (6.10 m)
Drill collars: Nine 4-1/2 inch (11.43 cm) x 1-1/2 inch (3.81 cm) x 20 feet (6.10 m)
Sample interval: 10 feet (3.05 m)

Borehole history: Hole MB-11 was spudded by an Ingersoll Rand TH-60 water well rig equipped with a Tiger Tiara casing hammer. The initial 297 feet (90.53m) was drilled and cased utilizing a simultaneous drilling and driving procedure. For the first 200 feet (60.96 m) the driving usually preceded the drilling by as much as 20 feet (6.10 m), due mainly to running sand conditions. The drive casing utilized was 8-5/8 inch (21.91 cm) O.D. with 1/4 inch (0.64 cm) wall thickness, butt welded in 30 foot (9.14 m) lengths. A 7-7/8 inch (20.0 cm) bit was used inside the casing. Due to coarse sand and boulder alluvium being encountered, the casing veered to a 9° inclination which created significant drilling problems. A rotating head was mounted to the wellhead with a gate valve welded to the outflow pipe to contain artesian pressure if encountered. A 6-1/4 inch (15.86 cm) hole was drilled below the casing to terminal depth.

Artesian waters were encountered at 667 feet (203.30 m). The shut in pressure measured 21 psi (1.48 kg/cm²) with about 100 gpm (378.5 l/min) flow which required heavy mud to control. Barite was used as a weighted agent and mud weights of 10 to 11 pounds per gallon were realized in controlling the artesian flow. Slow drilling and abundant solids in the mud created chronic pump problems. The hole was continued to 1,493 feet (455.07 m) at which point a twistoff occurred; the saver sub pin broke off leaving a full string of pipe in the hole. Lateral pressure on the pin due to the extreme casing deviation was probably responsible for the break. The resulting fishing operation required three days. Drilling was resumed and at 1,624 feet (495.00 m) a broken swivel caused another three day delay for repairs. The hole was continued to 2,416 feet (736.40 m) at which point cones were sheared off. In an attempt to fish for the cones, a magnet and a string of tools keyseated. Most of the string of tools were retrieved even though the fishing operation was compounded by the resumption of the artesian flow. All attempts at recovering the remaining magnet and two collars failed. The hole was plugged with 32 cubic yards (24.47 cubic meters) of cement and cemented at 2,416 feet (736.40 m). Goodwell, Inc., could only log the hole to 393 feet (119.79 m) due to the poor hole conditions.

Bit Record MB-11

No.	Make	Type	Size		In		Out		Footage	
			in.	cm	ft	m	ft	m	ft	m
1	GW	GR-3	7-7/8	20.00	0	0	297	90.53	297	90.53
2	Varel	2	6-1/4	15.87	297	90.53	676	206.04	379	115.52
3	Smith	DTJ	6-1/4	15.87	676	206.04	1,002	305.41	326	99.36
4	Smith	DG	6-1/4	15.87	1,002	305.41	1,253	381.01	251	76.50
5	Smith	DG	6-1/4	15.87	1,253	381.91	1,493	455.07	240	73.15
6	Smith	DTJ	6-1/4	15.87	1,493	455.07	1,624	495.00	131	39.93
7	Walker	Mac#3	6-1/4	15.87	1,624	495.00	1,624	405.00	0	0
(reaming only)										
8	Walker	Mac#3	6-1/4	15.87	1,624	495.00	1,702	518.77	77	23.47
9	Walker	Mac#2	6-1/4	15.87	1,702	518.77	1,944	592.53	243	74.07
10	Walker	Mac#2	6-1/4	15.87	1,944	592.53	2,122	646.79	178	54.25
11	Walker	Mac#2	6-1/4	15.87	2,122	646.79	2,284	696.16	162	49.38
12	Walker	Mac#3	6-1/4	15.87	2,284	696.16	2,416	736.40	132	40.23

Mud Record MB-11

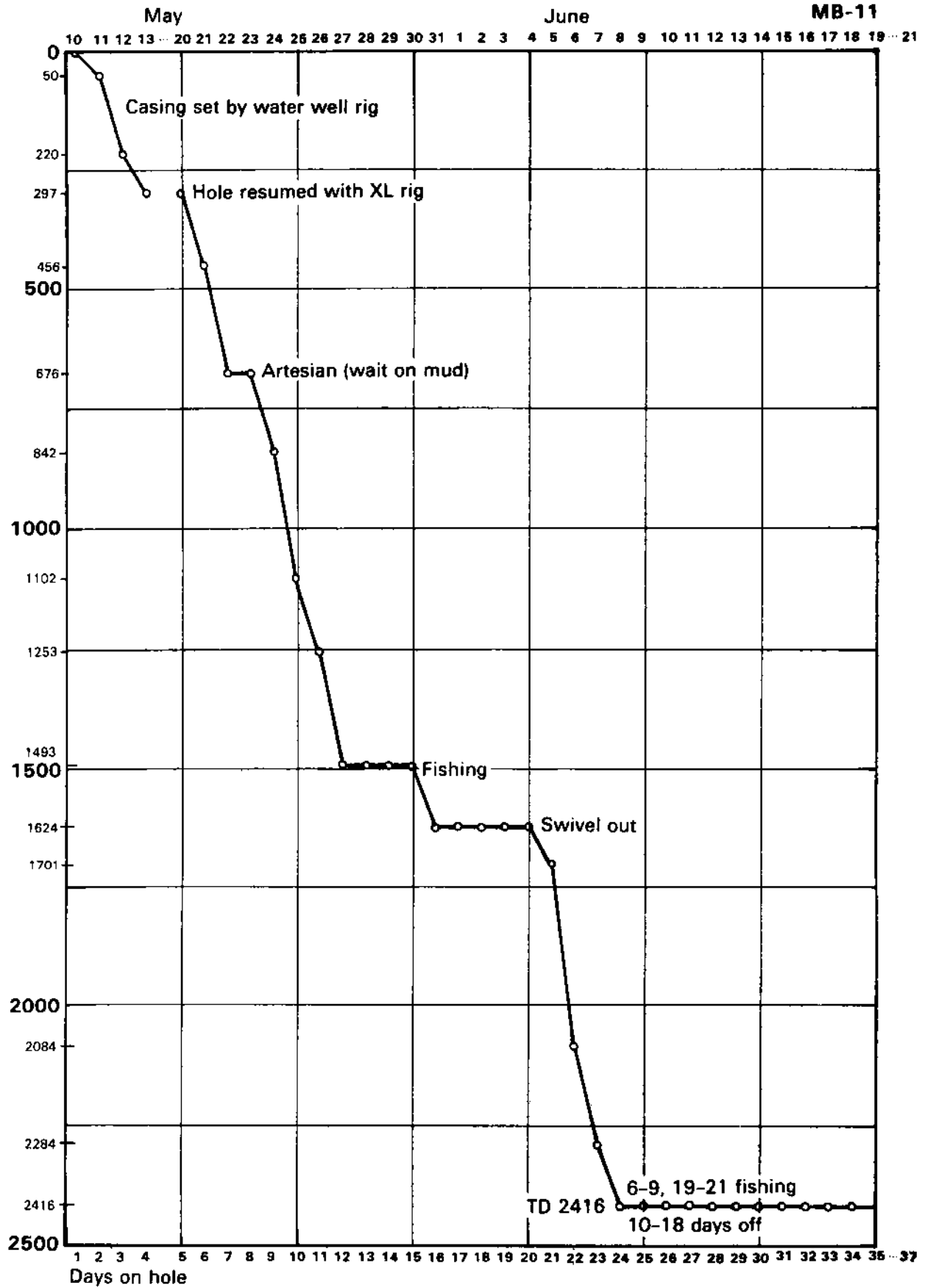
<u>Material</u>	<u>Quantity</u>
Gel	172 sks (100 lbs/45.63 kg ea)
Barite	686 sks (100 lbs/45.63 kg ea)
Lignite	26 sks (50 lbs/22.68 kg ea)
Rayvan	13 sks (50 lbs/22.68 kg ea)
Surfdrill	9 cans (5 gal/22.73 l ea)
Pro Fiber	7 sks (40 lbs/18.14 kg ea)
Driscose	4-1/2 sks (50 lbs/22.68 kg ea)
Fuco Detergent	4 cans (5 gal/22.73 l ea)
Cedar Fiber	3 sks (50 lbs/22.68 kg ea)
CMC	1 sk (50 lbs/22.68 kg ea)

Deviation Tests MB-11

<u>Depth</u>	<u>Deviation</u>
300 feet (91.44 m)	9°
675 feet (205.74 m)	7°
1,002 feet (305.41 m)	4°
1,253 feet (381.91 m)	3°
1,493 feet (455.07 m)	2°
1,944 feet (502.53 M)	1°

Geophysical Logs MB-11

Gamma	Resistivity
Density	Caliper
Spontaneous Potential	Neutron



MB-12

Location: NW1/4NW1/4NW1/4 sec. 14, T. 6 N., R. 20 W.
Total depth: 1,110 feet (338.33 m)
Spud date: March 24, 1979
Completion date: April 6, 1979
Rig: Gardner Denver Model 2000, XL Drilling Rig No. 7
Drill pipe: 2-7/8 inch (7.30 cm) IF x 20 feet (6.10 m)
Drill collars: Nine 4-1/2 inch (11.43 cm) x 1-1/2 inch (3.81 cm) x 20 feet (6.10 m)
Sample interval: 10 feet (3.05 m)
Coring Interval: 400 feet to 410 feet (121.92 m to 124.97 m), 410 feet to 415 feet (124.97 m to 126.49 m) 768 feet to 778 feet (234.09 m to 237.13 m), 880 feet to 892 feet (268.22 m to 271.88 m), 1,100 feet to 1,110 feet (335.28 m to 338.33 m).
Total core recovered: 33.3 feet (10.15 m)
Core barrel type and size: 4-5/8 inch (11.75 cm) x 3 inch (7.62 cm) x 15 feet (4.57 m)

Borehole history: The drilling rig was set up on January 4, 1979, but due to subzero temperatures creating major rig breakdowns, work on the project was temporarily discontinued. The rig was removed for overhaul and did not resume drilling until March 23, 1979.

The hole was rotary drilled with a 12-1/4 inch (31.12 cm) bit to a depth of 160 feet (48.77 m). The casing was set and cemented on March 26, 1979. Gate valves were mounted to the well head to control artesian water flow, if encountered. Drilling was continued using a 6 inch (15.24 cm) bit to a total depth of 1,110 feet (338.33 m) with five spot cores being taken at the depths indicated above.

Penetration rates were slow after 550 feet (167.64 m) and got progressively slower, averaging 2 feet per hour at terminal depth, due to the hard and abrasive nature of the granite clast conglomerate.

The circulation system consisted of earthen pits with a holding capacity of 20,000 gallons (75,700 l). The viscosity averaged 43 sec/qt while the mud weight remained stable at 8.7 pounds per gallon (1.04 kg/l).

The hole was logged at completion by the Bendix Field Engineering Corp. unit. Hole responsibility was transferred to the Montana Bureau of Mines who installed 4 inch (10.16 cm) casing to a depth of 1,110 feet (338.33 m) for hydrologic testing and observation purposes.

Bit Record MB-12

<u>No.</u>	<u>Make</u>	<u>Type</u>	<u>Size</u>		<u>In</u>		<u>Out</u>		<u>Footage</u>	
			<u>in.</u>	<u>cm</u>	<u>ft</u>	<u>m</u>	<u>ft</u>	<u>m</u>	<u>ft</u>	<u>m</u>
1	HTC	OSC	12-1/4	31.12	0		160	48.77	160	48.77
2	GW	GR-4	6	15.24	160	48.77	549	167.34	374	113.99
3	GW	GR-1H	6	15.24	549	167.34	768	234.09	219	66.75
4	GW	GR-1H	6	15.24	778	237.13	880	268.22	102	31.09
5	GW	GR-1H	6	15.24	892	271.88	1,010	307.85	118	35.97
6	GW	GR-1H	6	15.24	1,010	307.85	1,054	321.26	44	13.41
7	GW	GR-1H	6	15.24	1,054	321.26	1,100	335.28	46	14.02

Note: GW--Gruner Williams

Mud Record MB-12

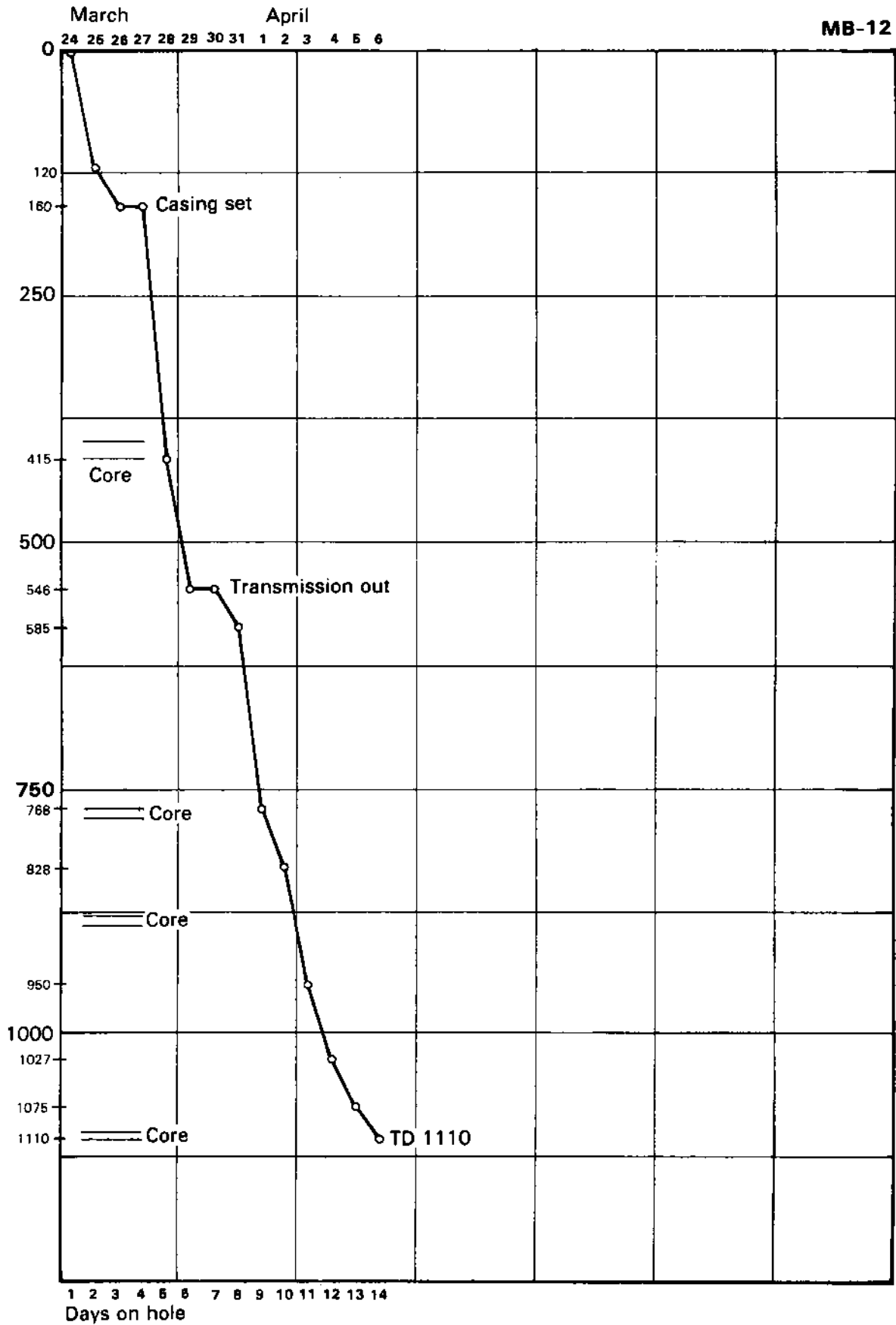
<u>Material</u>	<u>Quantity</u>
Gel	109 sks (100 lbs/45.36 kg ea)
Lime	9 sks (50 lbs/22.68 kg ea)
Flucculant	2 qts
Caustic	4 sks (50 lbs/22.68 kg ea)
Rayvan	1/2 sk (50 lbs/22.68 kg ea)

Deviation Tests MB-12

<u>Depth</u>	<u>Deviation</u>
160 feet (48.77 m)	1-3/4 °
880 feet (268.22 m)	2°
1,010 feet (307.85 m)	3°

Geophysical Logs MB-12

Gamma	Resistivity
Neutron	Caliper
Spontaneous Potential	KUT



APPENDIX A

List of Geophysical Logs

<u>HOLE</u>	<u>OPERATOR</u>	<u>LOGS RUN</u>
MB-2	Goodwell (Woodell) Bendix	Gamma*, Density*, Caliper* Gamma, Resistivity, Spontaneous Potential KUT**
MB-4	Goodwell (Woodell)	2 Gamma, Density, Caliper, Resistivity, Spontaneous Potential, Neutron
MB-6	Goodwell (Woodell) Bendix	2 Gamma, Density, Caliper Resistivity, Spontaneous Potential, Neutron KUT
MB-8	Goodwell (Woodell) Bendix	2 Gamma, Density, Caliper KUT**
MB-9	Goodwell (Woodell)	Gamma, Density, Caliper, Neutron, Spontaneous Potential, Resistivity
MB-11	Goodwell (Woodell)	Gamma, Density, Resistivity, Spontaneous Potential**
MB-12	Bendix	Gamma, Caliper, Resistivity, Spontaneous Potential, Neutron, KUT

* - Logged in two parts on different days

** - Logs incomplete due to hole conditions, etc.

