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MASTER

DRILLING REPORT:

STATE NURSERY TEST WELL

NO. 1

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TEST WELL NO. 1

INTRODUCTION

A geothermal test well was sited and drilled approximately 0.8 miles (1.3 km) east of Broadwater Hot Springs, near Helena, Montana. The site is on the property of the State Nursery, along the north side of Ten Mile Creek. The purpose of the drilling was to test a thermal infrared imagery anomaly and to evaluate whether a source of warm water for space heating of a series of new greenhouses could be developed to replace ones destroyed in the spring 1981 flooding of Ten Mile Creek.

SITING AND LOCATION

The test well was sited in T. 22 N., R. 4 W., section 22 CD. This location is on a small low-intensity thermal anomaly apparent on infrared imagery flown over the Broadwater Hot Springs area in September 1977. It is also near the contact between a late Cretaceous granite body and Belt sediments (Proterozoic) of the Helena Formation. The well was sited at the intersection of the projection of this contact with the long axis of a small colluvium-filled draw, which probably represents a fault or pronounced joint plane cutting through the Precambrian section. The exploration rationale was to investigate the infrared anomaly, assuming that hot water circulation is encouraged along the granite-limestone contact, particularly near an intersecting fault. The infrared anomaly was not the largest or the most intense in the vicinity, but was the only one which was located on State Nursery property.

LOCAL GEOLOGY

The test well site is located near the center of a gently-dipping anticlinal structure across which are exposed lower Belt sediments of the

Precambrian Helena, Empire, and Spokane Formations, as mapped at a scale of 1:48,000 by Knopf (1963) (Figure 1). The anticline is, according to Knopf's map, intruded by a late Cretaceous granite-adamellite stock associated with a late stage of the Boulder Batholith. In the field, a pre-drilling site investigation of the granite-limestone contact approximately 200 feet (65 m) from the test site was made. Chilled margins in the granite and obvious contact metamorphism in the sediments (viz., calc-silicates or argillic alteration products) were not evident at the outcrop. Therefore, it was tentatively interpreted that the contact could be either of fault or intrusive origin.

DRILLING SUMMARY

The test well was spudded with a churn drill operated by the Montana Department of Highways Core Drill Section on 10/19/81. 6" I.D. well casing was driven through poorly-sorted colluvial sand, clay, and cobbles derived from the rock outcrops immediately upslope, dominated by Helena Formation quartzite and limestone. Solid bedrock was encountered in the well at 27 feet (8.2 m) below ground surface, where the casing was set and the cable tool rig moved off the hole. A Failing 1500 air rotary rig was moved onto the hole on 10/21/81 to proceed into bedrock with a tungsten carbide chisel-tooth tricone bit. However, due to insufficient pull-down pressure on the rig, it was unable to penetrate deeper than 33 feet (10.1 m). A water well contractor (Lindsay Drilling of Clancy, MT) was mobilized on the hole on 10/26/81 with an Ingersoll-Rand TH-60 air rotary rig. Drilling proceeded rapidly with an air hammer to a depth of 280' (85.3 m) under open hole conditions.

No significant amount of water was obtained in the overburden

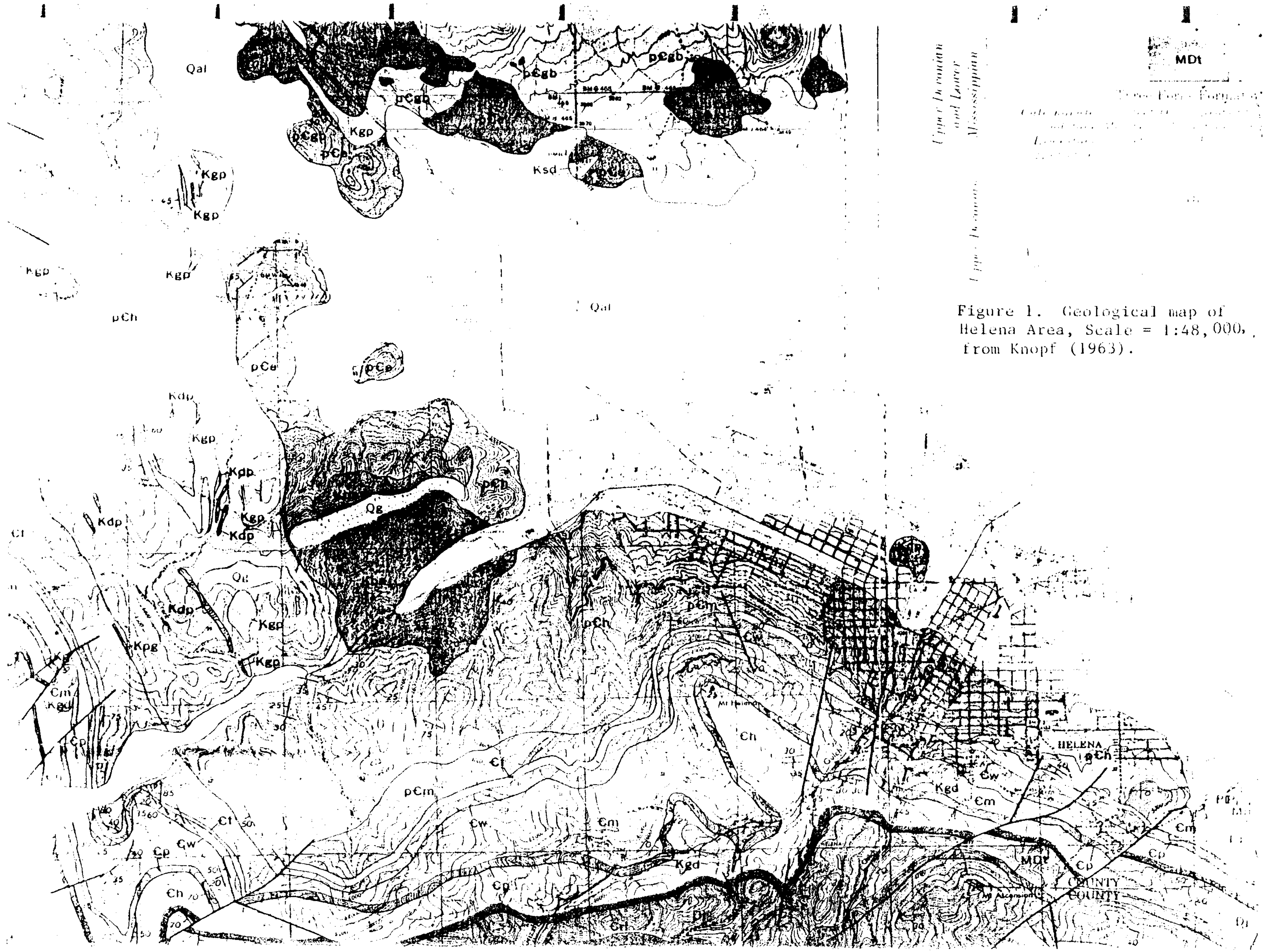

Figure 1. Geological map of Helena Area, Scale = 1:48,000, from Knopf (1963).

Kp

...est Pass Leucomonzonite
...ple pattern, leucosyenite border facies

Ksd

Syenodiorite, d = 2.70-2.78

...townite gabbro, d = 3.02-3.18

Shonkinite, d = 2.86
West of Austin

Kgp

Granodiorite porphyry and related porphyries

Kgd

Granodiorite, undivided

Kgr

Graphophyre, d = 2.67-2.70

Kog

...e-orthoclase gabbro and gabbro, undivided

...ite porphyry, includes some that is synbathylithic

Gabbro, d = 2.97-3.06

Td

Dacite

Kal

Alaskite and aplite, d = 2.57-2.61

Muscovite-biotite granite, d = 2.61

Biotite adamellite, d = 2.65

Kpg

Porphyritic granodiorite, d = 2.65-2.71

Nonporphyritic granodiorite equigranular equivalent of the porphyritic granodiorite

Kc

Clancy Granodiorite, d = 2.67-2.75

Ku

Unionville Granodiorite (d = 2.78) including its basic facies granogabbro (d = 2.85)

Andesite, basalt, and rhyodacite
Granodiorite undivided

TERTIARY OR ...

CRETACEOUS

PRECAMBRIAN

Ch

Hasmark Dolomite
Upper part, light-colored dolomite. Lower part thick-bedded dark dolomite mottled in bizarre patterns. Density 2.81 to 2.86. Commonly is metamorphosed to white marble

Park Argillite
Dk... compact rock (d = 2.72 to 2.80), locally fossiliferous. Thickness, 200 feet

Cm

Meagher Limestone
Upper part, massive pure limestone, 280 feet thick. Lower part, thin-bedded impure limestone, 160 feet thick

Wolsey Formation
Micaceous siltstone, largely detrital quartz, muscovite, and biotite, and possibly glauconite; phyllitic appearance on bedding surfaces; 200 feet thick

Cf

Flathead Quartzite
White, vitreous; almost 100 percent quartz; 90 to 170 feet thick

CAMBRIAN

pCg

Greenhorn Mountain Quartzite
Feldspathic quartzite with about 15 percent of clear limpid microcline. Upper third is well stratified in beds averaging 1 to 2 inches. Lower part massively bedded, 1,500 feet thick. Density 2.58 to 2.62

Marsh Formation
Argillites, commonly deep-red, maroon, purple, and violet, with interbedded quartzite in belts as much as 500 feet thick, cross-bedded siltstones, and laminites containing casts of salt crystals; 3,000 feet thick

Helena Dolomite
Siliceous dolomite, buff-weathering, and subordinate limestone; 4,000 feet thick. Collenia ***bioherms are common. Density of dolomite 2.76 to 2.82***

...mpire and Spokane Formations
... deep-red argillites (brick-red, maroon, ...), and clear-green fine-grained feld... quartzite. 1,000 feet thick

PRECAMBRIAN

Figure 1 (cont.). Map legend from Knopf (1963).

material. A good flow of water was obtained from permeable zones in the limestone from 90-120 feet (27-37 m) and from fractures associated with the granite-limestone contact and within the granite itself, from 120-150 feet (36-46 m). Yield by air lift was estimated by the driller at 100-150 gallons per minute, although this is by no means a precise value. The specific capacity of each producing zone is not known.

The water-producing zones were subject to caving and sloughing at several levels between 110-150 feet (34-46 m). For this reason the driller did not remove the drill string from the hole after water was encountered; to continue much deeper than 280 feet (85.3 m) a steel liner would have had to have been set to prevent the sloughing from endangering the drill string.

A temperature log (Figure 2) was run while the rig was still on the hole, running the thermistor down the inside of the drill steel to penetrate the sloughed zone. The water ranged from 9.8°-12.8°C from top to bottom. The ten foot spacing on the readings was inadequate to delineate water producing zones in detail, but does describe in general the zone from 120-140' (36-43 m) as being an aquifer. Temperature gradients in the bottom 80 feet (25 m) of the hole, which the driller had indicated had produced no additional water, ranged from 3.3°-16.4°C/km, with an average of about 9°C/km, far less than a 'normal' conductive geothermal gradient of 25°C/km. This was interpreted to indicate that (a) no warm water source (>30°C) was located within a few hundred feet of the bottom of the hole, and (b) the depressed gradient at the bottom of the well suggests an extensive cold water reservoir, either below or around the 280 foot (85 m) depth of the test well. For this reason, and due to the additional expense of the liner needed to pursue deepening of the well, the well was drilled no deeper than 280 feet and the rig demobilized on 10/27/81.

Geophysical logs (gamma, SP, and resistivity) were run on the hole after drilling (Figure 2). Water-bearing fractures in both the limestone and the granite can be recognized by a characteristic high SP-low resistivity signature. Unfractured dry granite is characterized by generally higher gamma values and a slightly higher frequency and amplitude of transient noise-like spikes in the gamma curve, probably due to gamma radiation from potassium in clots of biotite.

DRILL CUTTINGS

Both cable tool and rotary cuttings were fine, ranging from 0.1-5 mm in size, with rarely a few larger chips mixed in. Cuttings were sampled in the field and returned to the lab, where they were washed to remove the fine carbonate flour which coated many of them, sieved to obtain the coarser than 100 mesh fraction, and split. One split was saved for storage, while the other was used for microscopic examination and, for intervals for which there was sufficient sample, for carbonate determinations. Carbonates were determined using an acid digestion-pressure bomb technique, using the washed sieved fraction. Cuttings were pulverized in a Buehler puck mill prior to bomb carbonate determination, to assure complete digestion of carbonates.

The drill cuttings log (Table 1) indicate that the Helena Formation at this site is generally a weakly calcareous, well-crystallized siliceous limestone or calcareous quartzite, with secondary calcite precipitated along the fracture planes. The granite is of relatively homogenous composition: quartz, biotite, plagioclase, and potassium feldspar, in most cases relatively fresh, although the biotite in some zones has been strongly weathered and oxidized, staining the surrounding rock a bright orange with iron hydroxide weathering products. The biotite is fine-grained and subhedral to euhedral, sometimes occurring in euhedral subsequent hexagonal plates in the cuttings, characteristic of plutonic biotite.

The first trace of granite in the bedrock cuttings occurs at 110' (33.5 m). This sample is composed almost exclusively of granite cuttings (limestone <15%). The next deeper sample (120', 36.6 m) showed about 35% granite cuttings but was dominantly limestone fragments. The next deeper sample (120-140', 36-43 m)) was almost exclusively granite cuttings again (limestone <15%), with an amount of carbonate material that could be accounted for by contamination from the open-hole or sloughing portion of the hole above the drilling depth. It seems likely that about 8 feet (2.4 m) of granite was drilled through at 110-118 feet (33.5-36.0 m) then about 6 feet (1.8 m) of limestone, and finally back into granite from 123 feet (37.5 m) to total depth (see geophysical logs, Figure 2). This makes a fault block hypothesis for the igneous sedimentary contact seem unlikely; the contact is probably of intrusive origin despite the apparent lack of chilled margins in outcrop.

INTERPRETATION AND SUMMARY

The test well site was picked to investigate a thermal imagery anomaly located near a suspected fault. The well was drilled to 280 feet (85 m) total depth, with no success in obtaining hot or even warm water. The thermal anomaly has been confirmed to be spurious with regard to the presence of underlying warm or hot ground water, or to the existence of anomalously high subsurface heat flow. No cold water was encountered at shallow depth (<80 feet) that could have contributed to the anomaly. Abundant cold water (12°C) was encountered at 100-150 feet (30-46 m) depth; this water may be associated with the intrusive contact zone between the late Cretaceous granite and the Helena Formation sediments penetrated by the well. There is no indication from the test well data that this well is connected in any way with the hot water system at Broadwater Hot Springs, or that deeper drilling at this site would tap into this system.

REFERENCE CITED:

Knopf, A., 1963. Geology of the Northern Part of the Boulder Bathylith and Adjacent area, Montana. U.S. Geological Survey Misc. Geologic Investigations, Map I-381 .

Table 1. Sample Lithologic Log: State Nursery Test No. 1

DEPTH	CUTTINGS DESCRIPTION	VISUAL ESTIMATES OF CONSTITUENTS		WEIGHT % CARBONATE
15-20'	Disaggregated quartz, fragments of quartzite and quartzite ls., minor granite fragments	quartz	40%	
		quartzite	25	
		quartzitic limestone	15	---
		granite fragments	10	
		white opalline silica	10	
20-25'	Quartz; quartzitic fragments; granite fragments; white opalline silica; minor ls. fragments	quartz	40%	
		quartzite	25	---
		granite	30	
		limestone	2	
		opalline silica	2	
25-28'	light gray and pink quartzitic ls.; dark gray quartzite; disaggregated quartz	light gray siliceous limestone	50%	
		pink siliceous ls.	10	3.0
		dark gray quartzite	20	
		quartz	20	
28-33'	light gray quartzite ls.; pink and clear quartzite fragments	light gray siliceous limestone	90%	3.0
		quartzite	10	
30-40'	light gray quartzitic ls.; buff quartzitic ls.; pink quartzite	light gray siliceous limestone	30%	2.8
		buff quartzitic ls.	50	
		pink quartzite	20	
40-50'	Fine grained white and light gray recrystallized siliceous limestone	lt. gray siliceous ls.	25%	
		white siliceous ls.	25	
		dark gray finely crystalline argillaceous limestone	20	3.4
		white quartzite	10	
		clear quartz	15	
50-60'	Fine grained white to light gray siliceous limestone and calcareous argillite, carbonate cement in fractures	light gray siliceous limestone	50%	3.1
		white quartzite	5	
		clear quartz	25	
		dark gray crystalline argillaceous ls.	20	
60-70'	Fine grained light gray siliceous limestone, clear quartzite and argillaceous limestone, calcareous cement in fractures	light gray siliceous limestone	60%	2.3
		white quartzite	20	
		dark gray argillaceous limestone	10	
		micaeous siltstone	10	
70-80'	Fine grained light gray siliceous limestone, white quartzite	light gray siliceous limestone	50%	1.5
		white quartzite	40	
		micaceous siltstone	10	

Table 1 (continued)

DEPTH	CUTTINGS DESCRIPTION	VISUAL ESTIMATES OF CONSTITUENTS		WEIGHT % CARBONATE
80-100'	Fine grained lt., gray siliceous limestone, white and clear quartzite	clear quartz	30%	2.1
		white quartzite	30	
		light gray siliceous limestone	40	
110'	small fragments of quartz and biotite, very few small fragments of fine-grained granite; large cuttings of light gray siliceous limestone and clear quartzite	quartz	20%	2.3
		biotite	30	
		granite fragments	5	
		light gray limestone	35	
		clear quartzite	10	
		sparry clear calcite	trace	
120'	rounded granite fragments, small biotite and quartz fragments, large light gray siliceous limestone cuttings Fe-oxide stained granite cuttings	granite fragments	10%	1.4
		biotite	15	
		quartz	20	
		light gray siliceous limestone	45	
		clear quartz	5	
120-160'	angular and rounded granite fragments, disaggregated quartz and biotite, very minor limestone fragments	granite fragments	65%	1.1
		biotite	10	
		quartz	10	
		light gray limestone	10	
160-180'	angular and rounded granite fragments, disaggregated quartz and biotite, very minor limestone fragments	limestone	5%	1.3
		granite fragments	70	
		quartz	15	
		biotite	10	
180-280'	angular and rounded granite fragments, perthitic intergrowths in granite; disaggregated quartz and biotite, very minor limestone fragments	limestone	5%	1.3
		granite fragments	70	
		quartz	10	
		biotite	15	

Form No. 603 R10/79

File No. ____________

WELL LOG REPORT

State law requires that this form be filed by the water well driller within 60 days after completion of the well.

1. WELL OWNER
Name: Montana Bureau of Mines at State Nursery

2. CURRENT MAILING ADDRESS
Montana Tech College
Butte, Mt. 59701

3. WELL LOCATION

___ ¼ ___ ¼ ___ ¼ Section 2C
Township 10 N/S Range 4 E/W
County L&C
Lot ___ Block ___
Subdivision ___
Well Elevation ___
Accuracy: ___ ±10'; ___ ±50'; ___ ±100';

4. DRILLING METHOD ___ cable, ___ bored, ___ forward rotary, ___ reverse rotary, ___ jetted, X other (specify) Air Rotary

5. WELL CONSTRUCTION AND COMPLETION

Size of drilled hole	Size and weight of casing	From (feet)	To (feet)	Perforations and/or Screen: Kind Size	From (feet)	To (feet)
6"	6 5/8 17#	0	27			
6"		27	280			

Was casing left open end? X Yes ___ No
Was a packer or seal used? ___ Yes X No
If so, what material ___
Was the well gravel packed? ___ Yes X No
Was the well grouted? ___ Yes X No
To what depth? ___
Material used in grouting ___
Well head completion: Pitless adapter ___
12 in. above grade ___, other ___
(if other, specify) ___
Pump horsepower ___, pump type ___
Pump intake level ___ feet below land surface
Power (electric, diesel, etc.) ___

6. WATER LEVEL
Static water level 31 feet below land surface
If flowing, closed-in pressure ___ psi
___ gpm flow through ___ inch pipe
Controlled by: ___ valve, ___ reducers, ___ other
(if other, specify) ___

7. WELL TEST DATA ___ pump ___ bailer X other
(if other, specify) Air
Pumping level below land surface:
260 ft. after 1 hrs. pumping 100+ gpm
___ ft. after ___ hrs. pumping ___ gpm

8. WAS WELL PLUGGED OR ABANDONED? ___ Yes X No
If yes, how? ___

9. DATE STARTED 10-26-81
DATE COMPLETED 10-27-81

10. WELL LOG

Depth (ft.) From	To	Formation
0	27	rotten rock
27	110	limestone
110	130	granite
130	160	fault zone
160	280	granite

(use separate sheet if necessary)

11. DRILLER'S CERTIFICATION
This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Date: 10-29-81
Firm Name: Lindsay Drilling
Address: Clancy, Mt
Signature: Terry Lindsay License No. 253

MONTANA DEPARTMENT OF NATURAL RESOURCES & CONSERVATION DNRC
32 SOUTH EWING HELENA, MONTANA 59601 449-3634

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