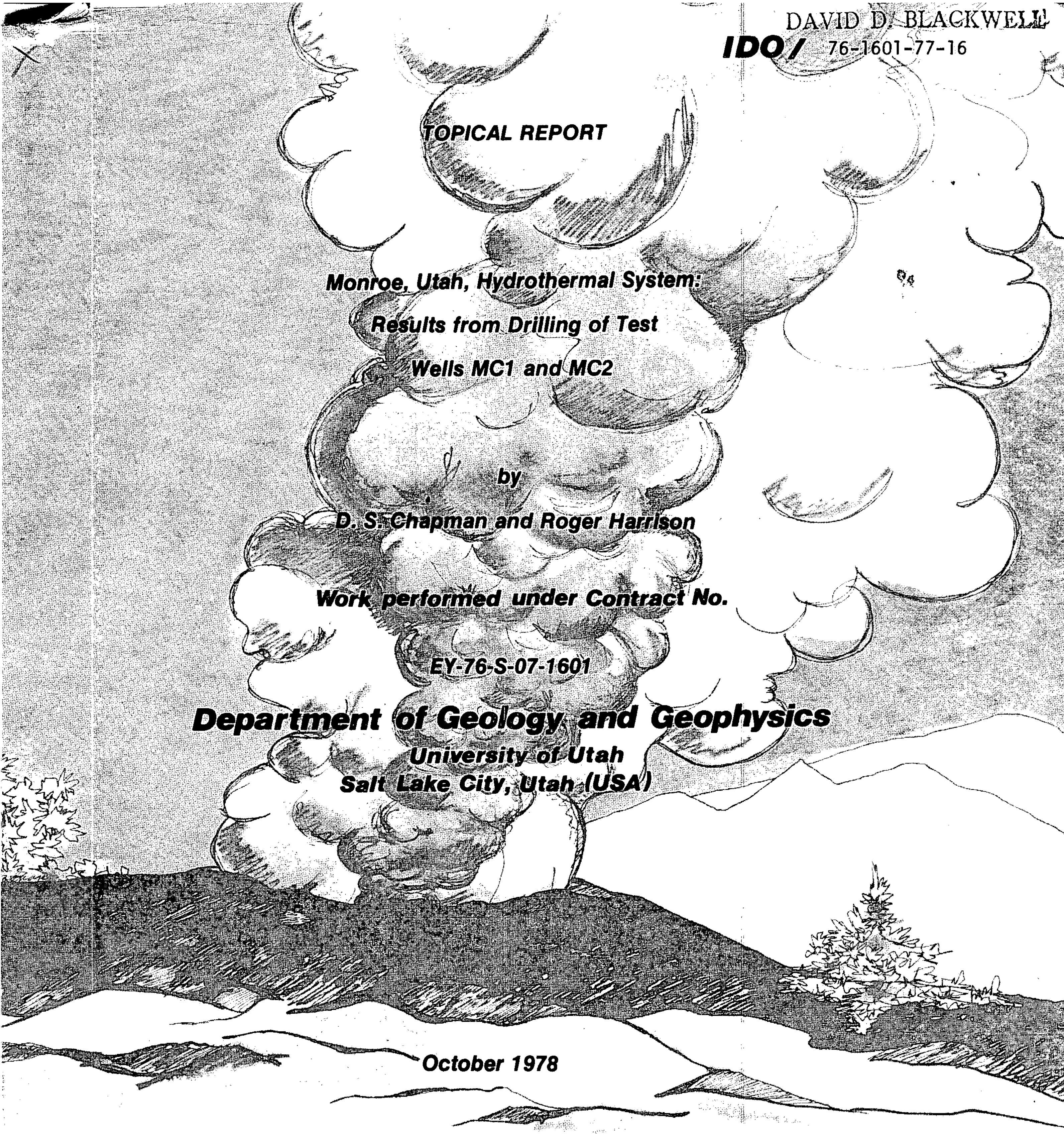
DAVID D. BLACKWELL

IDO/ 76-1601-77-16



TOPICAL REPORT

Monroe, Utah, Hydrothermal System: Results from Drilling of Test Wells MC1 and MC2

by

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Division of Geothermal Energy

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1.0 Introduction

Following detailed geological (Parry et al., 1976; Miller, 1976) and geophysical (Mase, Chapman, and Ward, 1978; Kilty, Mase, and Chapman, 1978) studies of the Monroe, Utah hydrothermal system, a program of drilling two intermediate depth test wells was undertaken. The objectives of the test well drilling were three-fold: (1) to obtain structural information bearing on the poorly known dip of the Sevier Fault, (2) to obtain temperature information below the shallow depths (approximately 300 ft.) sampled in the first phase of exploration, and (3) to provide cased wells which could act as monitor wells during the production phase of the project. The test well drilling was seen to be vital to the selection of a site for a production well. This report describes the results from the drilling of the two test wells, designated MC1 and MC2, and offers interpretation of the hydrothermal system which may be used as a basis for selecting production wells.

2.0 Drilling Program

The test holes designated MC1 and MC2 were drilled by Grimshaw Drilling Inc. of Cedar City using a Franks 4000 Mud Rotory Drill Rig.

MC1: A 6 3/4" hole was drilled to 362 feet, 3" API 9 lb/ft casing with the bottom 30 feet slotted was set to total depth and the casing annulus gravel packed to within 50 feet of the surface. The remaining 50 feet was grouted to the surface. The well was capped with a 3" valve.

Chip samples were collected at 10 foot intervals and a continuous log of mud return temperature and penetration rate was maintained. A temperature log was obtained after the well had stabilized without mud circulation for

12 hours when at a depth of 260 feet. The bottom 110 feet could not be logged due to the presence of drilling mud in the bottom of the hole through which the temperature sonde would not penetrate.

Some lost circulation was experienced at approximately 330 feet and was attributed to a shatter zone at the alluvium-volcanics interface. A small artesian head was noted on removal of the drilling mud pressure during clean-out and development.

MC2: A 12 inch hole was drilled to 100 feet. Five 20 foot welded joint sections of 8" water well casing (wall thickness 0.313 inches) was grouted to the surface.

A 12" 300 lb. gate valve was installed on the casing head for hole containment during drilling. A 6 3/4" hole was drilled to total depth of 825 feet. Chip samples were collected at 10 foot intervals and a continuous log of mud return temperature and penetration rate was maintained. A significant lost circulation zone was encountered at approximately 760 feet and was partially plugged with continued pumping of a heavy mud. A moderate artesian flow was encountered when the hole was cleaned for logging. Rapid silting of the bottom of the hole was noted while running the logs and the combination of the time required to run the logs and an ensuing delay before casing was run resulted in the loss of the bottom 250 feet.

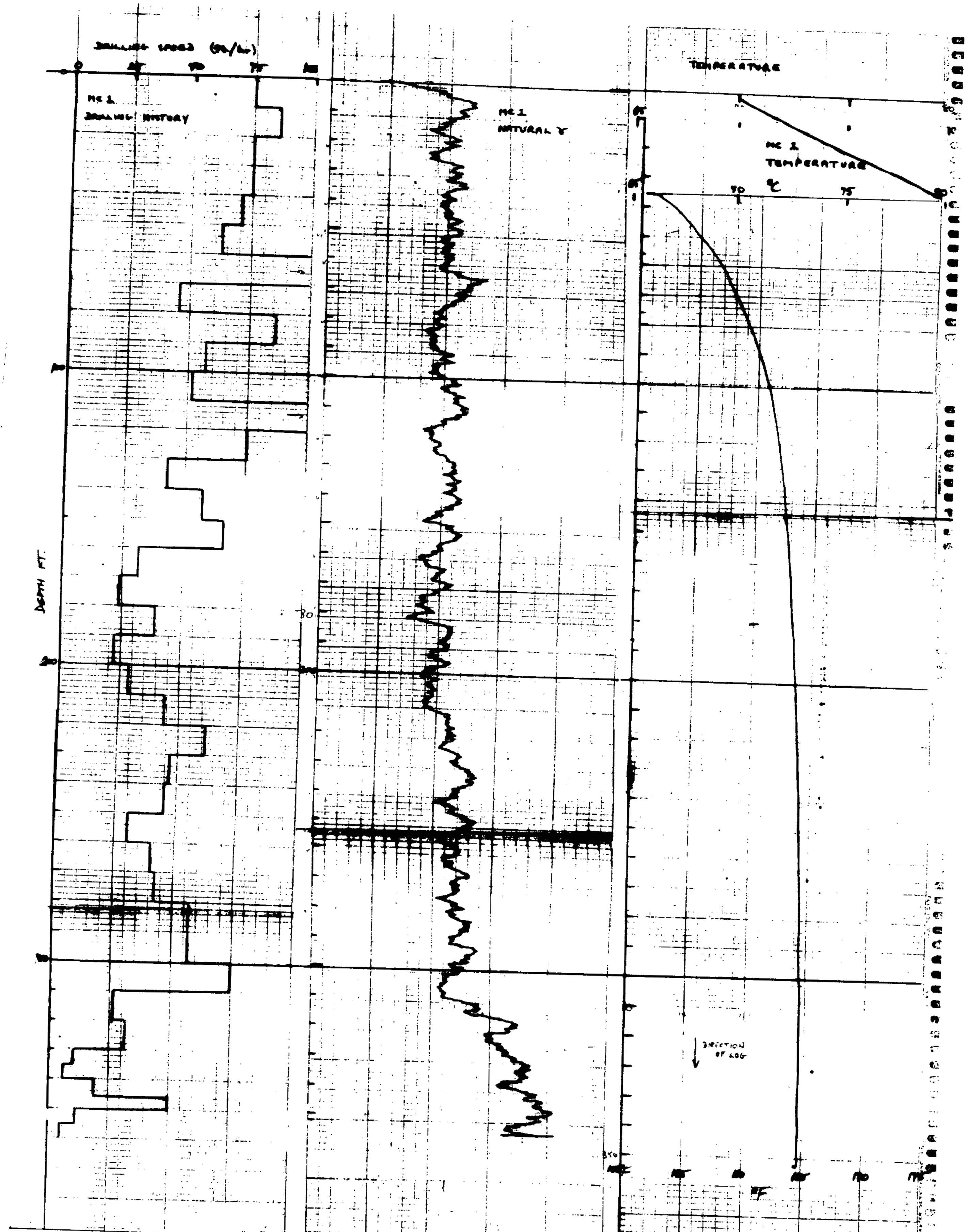
The driller was directed to redrill the bottom of the hole; however, he was unable to penetrate below about 620 feet due to very rapid silting and consequent hole collapse. As a result, 3" API casing with the bottom 60 feet slotted was run to 620 feet. The casing annulus was gravel packed to within 200 feet of the surface. The remaining 200 feet was grouted to the surface. A flange was welded to the casing head and the well capped with a 3" value.

3.0 Results of Test Hole Drilling

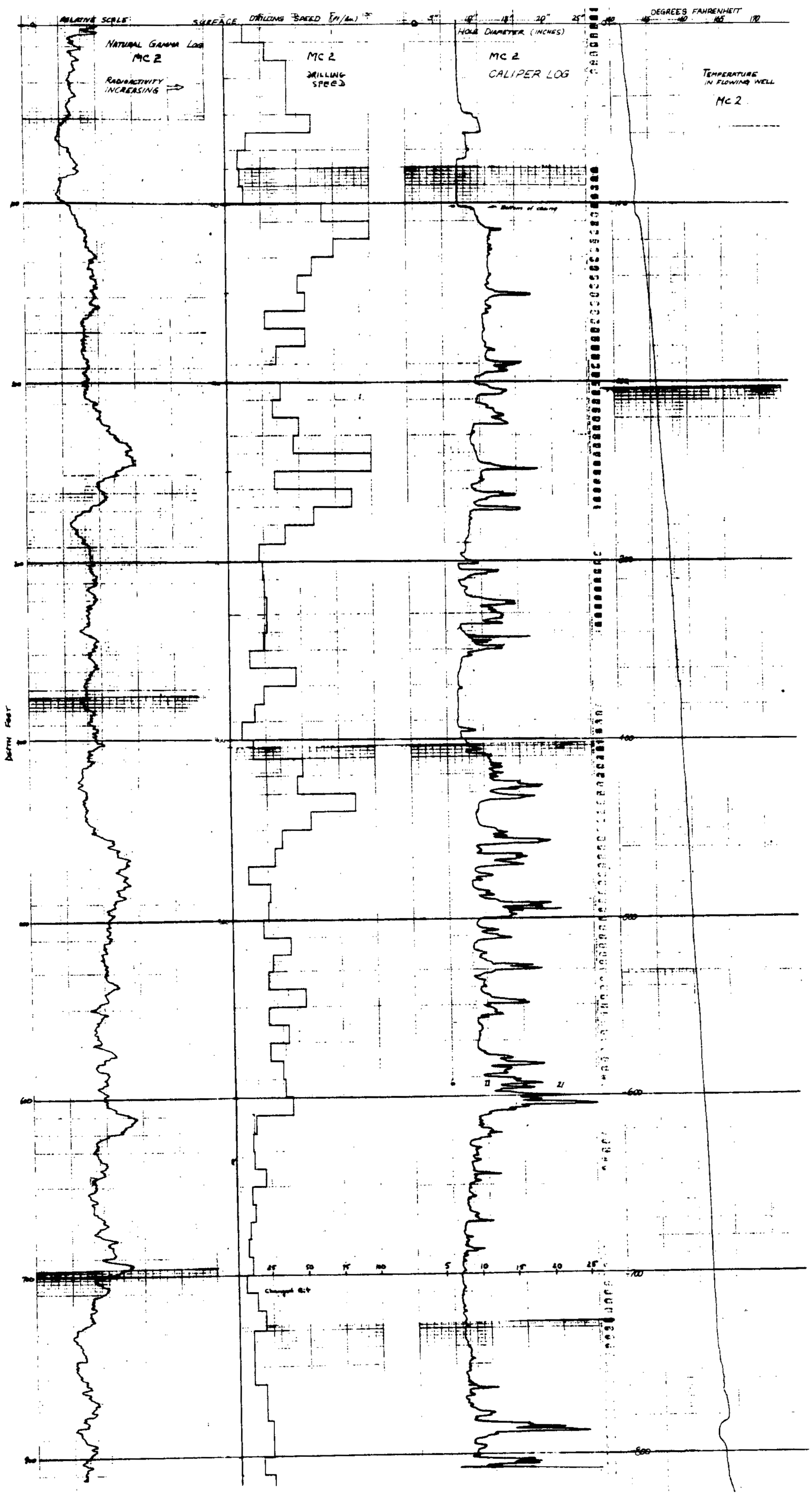
3.1 Drilling Logs

a) Well MC1: Temperature and natural gamma logs were obtained for the completed hole while flowing at a natural artesian rate of approximately 5 gallons/minute. The logs are reproduced below along with the drilling rate log for comparison.

b) Well MC2: MC2 was logged prior to completion. Temperature (flowing), natural gamma, and caliper, logs are reproduced below along with the drilling rate log.



DRILLING SPEED (ft/hr)
MC 1
DRILLING HISTORY
MC 1
NATURAL γ
TEMPERATURE
MC 1
TEMPERATURE °C
DEPTH FT.
DIRECTION OF LOG
°F


RELATIVE SCALE
SURFACE
DRILLING SPEED (Ft/hr)
HOLE DIAMETER (INCHES)
DEGREES FAHRENHEIT
NATURAL GAMMA LOG
Mc 2
RADIOACTIVITY INCREASING
Mc 2
DRILLING SPEED
Mc 2
CALIPER LOG
TEMPERATURE IN FLOWING WELL
Mc 2
DEPTH FEET

3.2 Lithology

a) Lithology of MC1

0 - 2'	Sinter mound
2' - 7'	CLAY - Gray, green
7' - 10'	CLAY with rounded granules of alluvial material predominantly quartz latite.
10' - 20'	CLAY with rounded to subangular granules of quartz latite alluvial material with some crystals of mica and quartz.
20' - 30'	Subrounded to subangular granules of quartz latite alluvial material with crystals of mica and quartz mixed with clay.
30' - 40'	Same as 20' - 30' with the addition of angular flecks of altered quartz latite indicating the presence of cobbles or boulders of the said material.
40' - 50'	Same as 30' - 40' with diminishing amounts of clay.
50' - 60'	Same as 40' - 50' with little clay and a noticeably smaller size fraction of quartz latite grains.
60' - 70'	Predominantly angular granules of quartz latite.
70' - 80'	Same as 60' - 70' with the inclusion of altered quartz latite - hematite stained.

80' - 90'	Same as 70' - 80' with increased amounts of hematite stained altered quartz latite and increased amounts of clay.
90' - 130'	Same as 80' - 90' with decreasing clay content and larger grain size with increased depth.
130' - 140'	Much decreased grain size and reintrodution of clay.
140' - 150'	Little clay, with continued small size fraction of quartz latite and hematite stained altered material with occasional quartz crystals.
150' - 170'	Same as 140' - 150' with increasing size fraction.
170' - 240'	Larger granules quartz latite and altered quartz latite with blubs of clay. Occasional flecks of rock with indicate drilling into boulders or cobbles.
240' - 300'	Same as 170' - 240' except a noticeable increase in angular flecks of quartz latite indicating boulders; also clay present.
300' - 310'	Small pebbles of rounded quartz latite and considerable clay fraction.
310' - 330'	Granules of angular-subrounded quartz latite with diminishing amounts of clay and increased amounts of rock flecks.
330' - 340'	Small size fraction of quartz latite and introduction of chlorite as altered from feldspars and micas - bed rock 333'.
340' - 362'	Same as 330' - 340' with larger and fresher flecks of bed rock, quartz latite porphyry, with some rounded granules which are probably derived from above.

(b) Lithology Log MC2

0 - 10'	Sand 1-2 mm subrounded to subangular grains of quartz, quartz latite, sinter, oxidized volcanics (green, red).
10' - 20'	As above - higher % oxidized material.

20' - 30'	As for 0 - 10' interval + mica chips.
30' - 40'	As for 0 - 10' interval.
40' - 50'	Same composition as above; 2mm size.
50' - 60'	As for 40' - 50', mainly blue/grey altered quartz latite.
60' - 70'	As above, larger grains (between 2 & 3 mm) blue/grey/ green.
70' - 80'	Coarse alluvial gravels, subrounded 1-5 mm in blue clay matrix. Soft altered volcanics blue/purple.
80' - 90'	As above.
90' - 100'	As above; subrounded to subangular.
100' - 110'	1-10 mm quartz latite chips, angular to subangular. Somewhat altered. Probably in boulder field. Minor amount of clay.
110' - 120'	Predominantly angular quartz latite chips 1 mm in size; fresh, blue/grey.
120' - 130'	Extremely poor sample (mostly vegetation from mud pit); appears to be same as for 110-120 interval.
130' - 140'	Subrounded to angular quartz latite chips, slightly altered, <1-4 mm size. Hematite-stained chips probably washed in from above. In gravels/boulders.
140' - 150'	As above (no hematite).
150' - 160'	As above, higher % larger chips, purple.
160' - 170'	Subrounded quartz latite grains, predominately 1-2 mm size. Looks more like sand. Some clay.
170' - 180'	Subrounded quartz latite in blue clay matrix.
180' - 190'	As above (170-180) + free quartz chips (subrounded).
190' - 200'	Slightly altered quartz latite subrounded to angular, 1-3 mm, very little clay.
200' - 210'	As above; no clay visible.
210' - 220'	As for 200' - 210' interval.
220' - 230'	As for 200' - 210' interval; max size 5 mm.

230' - 240' As above.

240' - 250' Quartz latite chips, subrounded to subangular; <1-3 mm size, slightly altered. Minor amount of quartz chips (subrounded) alone + some buff colored chips (sburounded, hard) - siliceous (?); slow drill rate.

250' - 260' As above. Higher % "buff colored" chips. Appear to be part of the quartz latite - recrystallized? Possibly part of a silicified breccia zone (one chip).

260' - 270' Quartz latite subangular to rounded <1-5 mm. Some chips appear "frothy". Buff colored grains well rounded in general. Quartz latite slightly altered. Minor amount of clay.

270' - 280' Quartz latite - subrounded to subangular, <1-3 mm, slightly altered, in blue/grey clay matrix. Rounded buff colored pebbles present.

280' - 290' Quartz latite chips - altered, <1-4mm. Some hematite stained subrounded to subangular; rounded buff pebbles; angular flat dk chips - soft enough to be scratched by knife - crystalline appearance; brown "talcose" clay (rounded) w/chlorite alteration. General alluvial material.

290' - 300' Quartz latite, subangular to rounded; <1-5 mm. Altered. Some hematite-stained. Minor clay.

300' - 310' Predominantly quartz latite <1-5 mm, altered. Subangular to subrounded. A few subangular chips of agate(?) - white. Minor amounts of lithologies as described in 280' - 290' interval present. Some clay.

310' - 320' Quartz latite, subrounded - angular, 1-5 mm, altered (some chlorite alteration). Some hematite stain. Blue/grey color; no clay apparent.

320' - 330' Predominantly quartz latite, seems to be more highly altered. Subrounded-subangular, 1-5 mm (higher % larger pebbles); red/brown "clay" pebbles, rounded. (May be highly altered volcanic grains.)

330' - 340' Quartz latite sands, 1-4 mm rounded - subangular; altered some red/brown clay present. 1 mm size grains most abundant.

340' - 350' As above, brownish tint due to high % brittle clays (very slow drill rate).

350' - 360' As above - highly altered quartz latite, subrounded-subangular; brown/red clay.

360' - 370' Angular - subrounded altered quartz latite, 1-3 mm. Some clay, but less than previous intervals. Slow drill rate - boulders/gravels.

370' - 380' As above - more subrounded grains. Little or no clay. Some mica flecks present.

380' - 390' Composition as above; more angular chips - more clay.

390' - 400' Altered quartz latite, angular to subrounded; <1-2 mm size.

400' - 410' Subrounded quartz latite sand (1-2 mm) in brown/red clay matrix.

410' - 420' As above; some larger pebbles.

420' - 430' As above.

430' - 440' As above, hematite staining due to oxidation of some mineral (micas?).

440' - 450' As above.

450' - 460' <1-3 mm subrounded quartz latite sands (altered). Water was added to mud pit here so not as much clay in sample.

460' - 470' As above - <1-2 mm, more clay present.

470' - 480' Subangular-subrounded quartz latite chips; <1-5 mm, altered. Much less clay.

480' - 490' Angular-subrounded quartz latite; 1-5 mm. Appears slightly fresher than last sample. More clay.

490' - 500' Quartz latite sands (subrounded) in blue/purple clay matrix. Highly altered.

500' - 510' Predominantly subrounded quartz latite (other lihtologies present) 1-5 mm; in clay.

510' - 520' As above; larger gravels blue/grey clay (alteration of latite itself?).

520' - 530' Subangular - subrounded highly altered quartz latite gravels (1-4 mm) in clay as above.

530' - 560' As above.

560' - 570' As above, mainly subrounded pebbles in clay.

570' - 580' As above, mainly subrounded pebbles in clay.

580' - 590' As for 570' - 580' interval, some pebbles up to 10 mm.

590' - 600' As for 580' - 590' interval.

600' - 610' Subrounded - subangular highly altered quartz latite <1-5 mm; less clay than previous 90'. Most grains are subrounded.

610' - 620' Poor sample - as above, <1-3 mm; no clay.

620' - 630' As above.

630' - 640' As above + some clay.

640' - 650' Angular-subrounded altered quartz latite, 1-2 mm chips. Some mica present; some green alteration product. No clay.

650' - 660' 1 mm angular-subangular quartz latite (blue/purple altered); no clay.

660' - 682' As above.

682' - 700' Larger chips; same composition as above 1-3 mm; angular-subangular. Some mica. Brown/red alteration.

700' - 720' Larger chips; altered quartz latite; 1-3 mm, high % brittle beig/grey colored clay (angular chips).

720' - 740' As above - quartz latite highly altered. Grey + red/brown brittle clay.
(lost circulation zone)

740' - 760' As for 700' - 720' interval; less clay - more subrounded than angular chips. Mica present.
(lost circulation)

760' - 780' As above, very little clay.

780' - 790' Angular-subrounded highly altered quartz latite; 1-4 mm. Some dark brown brittle clay chips (angular); mica present.

790' - 800' As above - green alteration (1-2 mm chips). No mica visible.

800' - 820' Angular-subrounded quartz latite (highly altered) - most chips subangular, <1-2 mm. No clays.

820'-825.5' As above.

4.0 Analysis of results

4.1 Comparison of temperature-depth profiles

Temperature profiles obtained in MC1 at several time intervals during and after drilling are shown in Fig. 4.1. One temperature profile was obtained after a weekend lapse in drilling with the well effectively "shut in" by the weight of drilling mud. The other profiles were obtained after completion of the well.

The most important feature of Fig. 4.1 is the striking similarity between the Monroe mound MC1 and the Red Hills RH4 (Fig. 4.2b) which are in approximately the same position relative to the Sevier Fault and the tufa mound. We deduce from this that the Monroe and Red Hill mounds have similar thermal structure.

4.2 Compilation of cross sections across the Monroe mound

A compilation of sections across the Monroe mound is shown in the following figures: Fig. 4.2(a) Temperature-depth curves and temperature cross-section at Monroe hot springs; Fig. 4.2(b) Temperature-depth curves and temperature cross-section of Red Hill hot spring; Fig. 4.2(c) Heat flow cross section; Fig. 4.2(d) Dipole-dipole resistivity pseudo-section and interpretation of Monroe hot springs; Fig. 4.2(e) Gravity interpretation; Fig. 4.2(f) Magnetics interpretation.

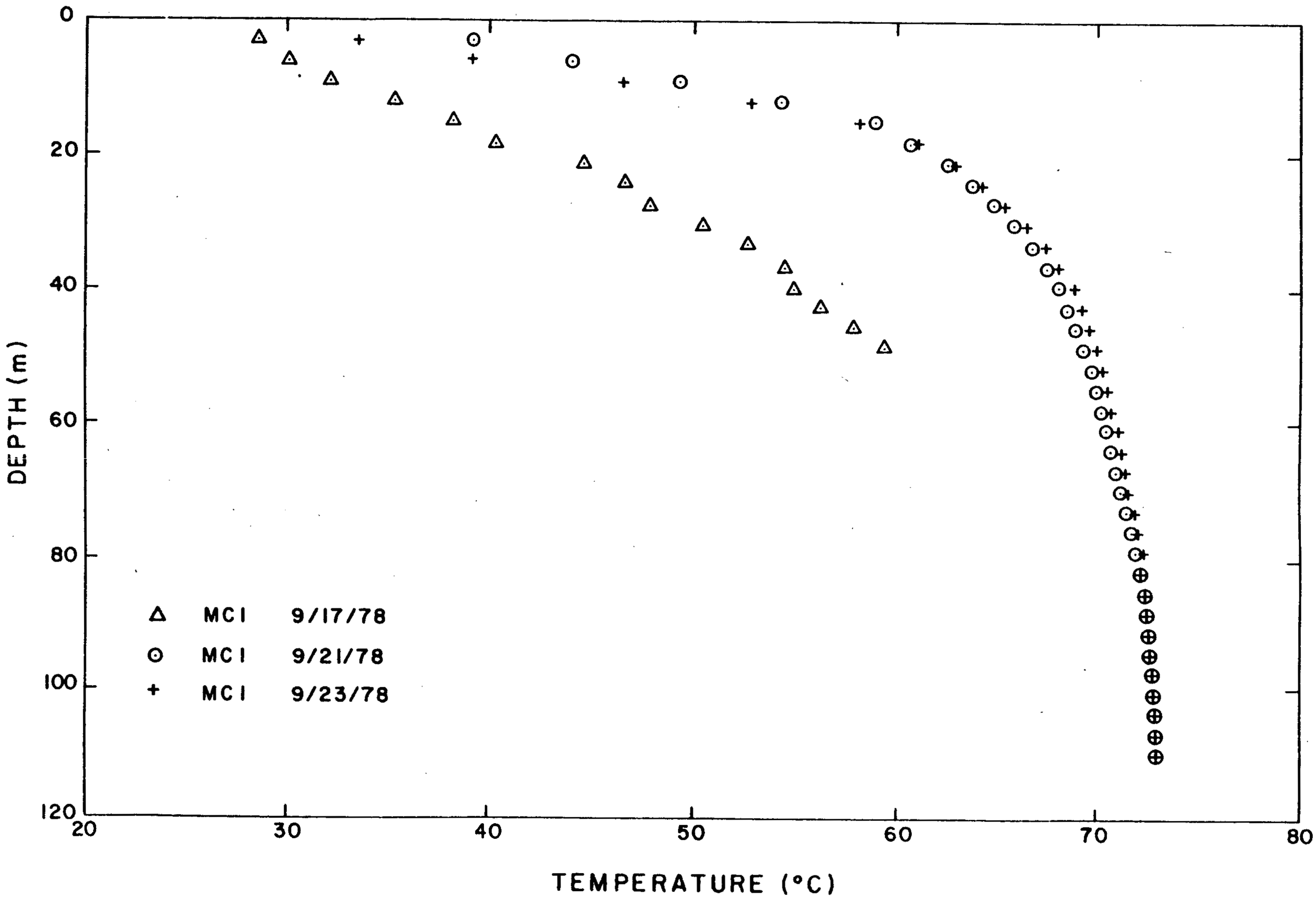

DEPTH (m)
0
20
40
60
80
100
120
20
30
40
50
60
70
80
TEMPERATURE (°C)
MCI 9/17/78
MCI 9/21/78
MCI 9/23/78

Figure 4.1

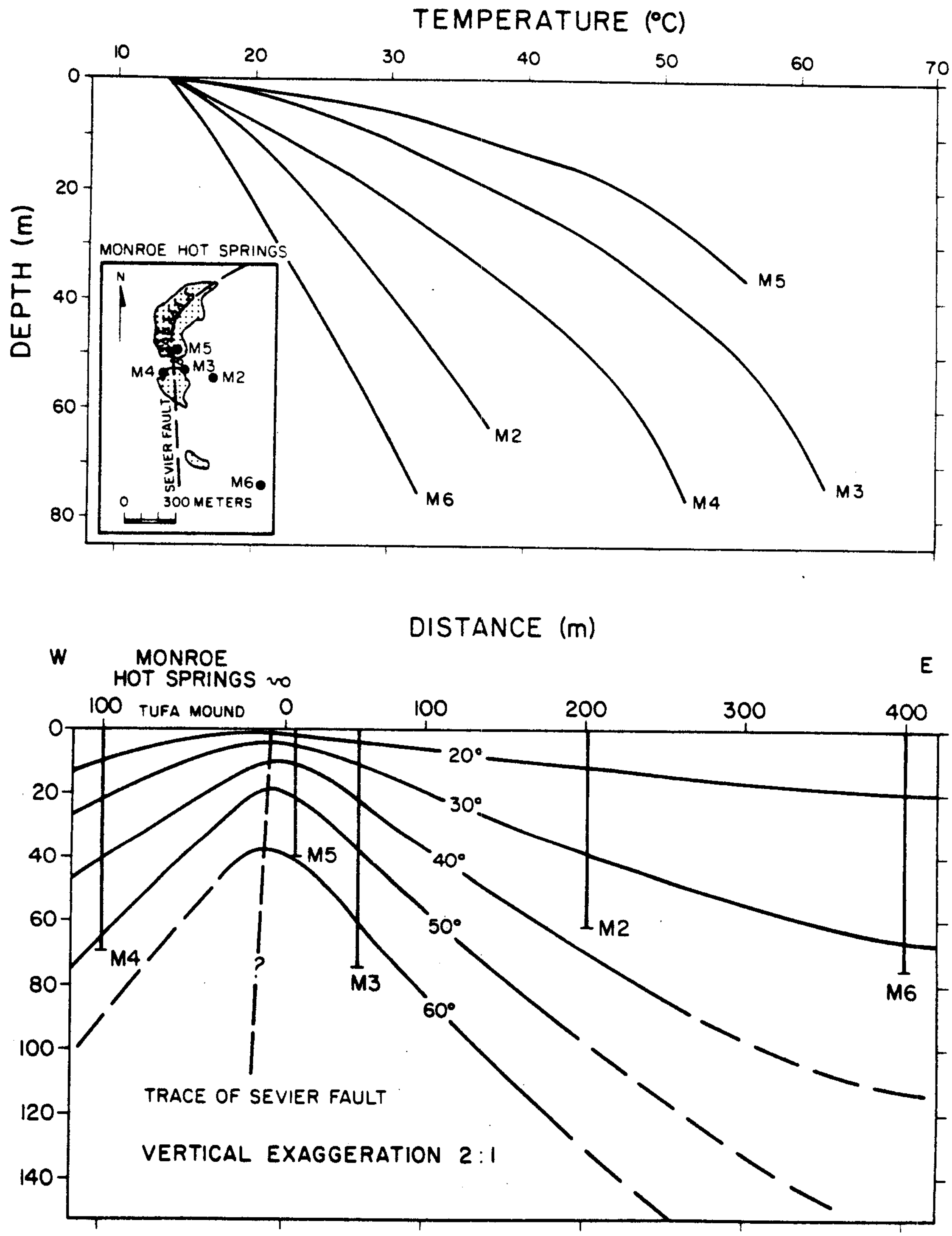

TEMPERATURE (°C)
DEPTH (m)
MONROE HOT SPRINGS
N
M5
M4
M3
M2
M6
SEVIER FAULT
0 300 METERS
DISTANCE (m)
W
E
MONROE HOT SPRINGS
TUFA MOUND
20°
30°
40°
50°
60°
TRACE OF SEVIER FAULT
VERTICAL EXAGGERATION 2:1

Figure 4.2(a)

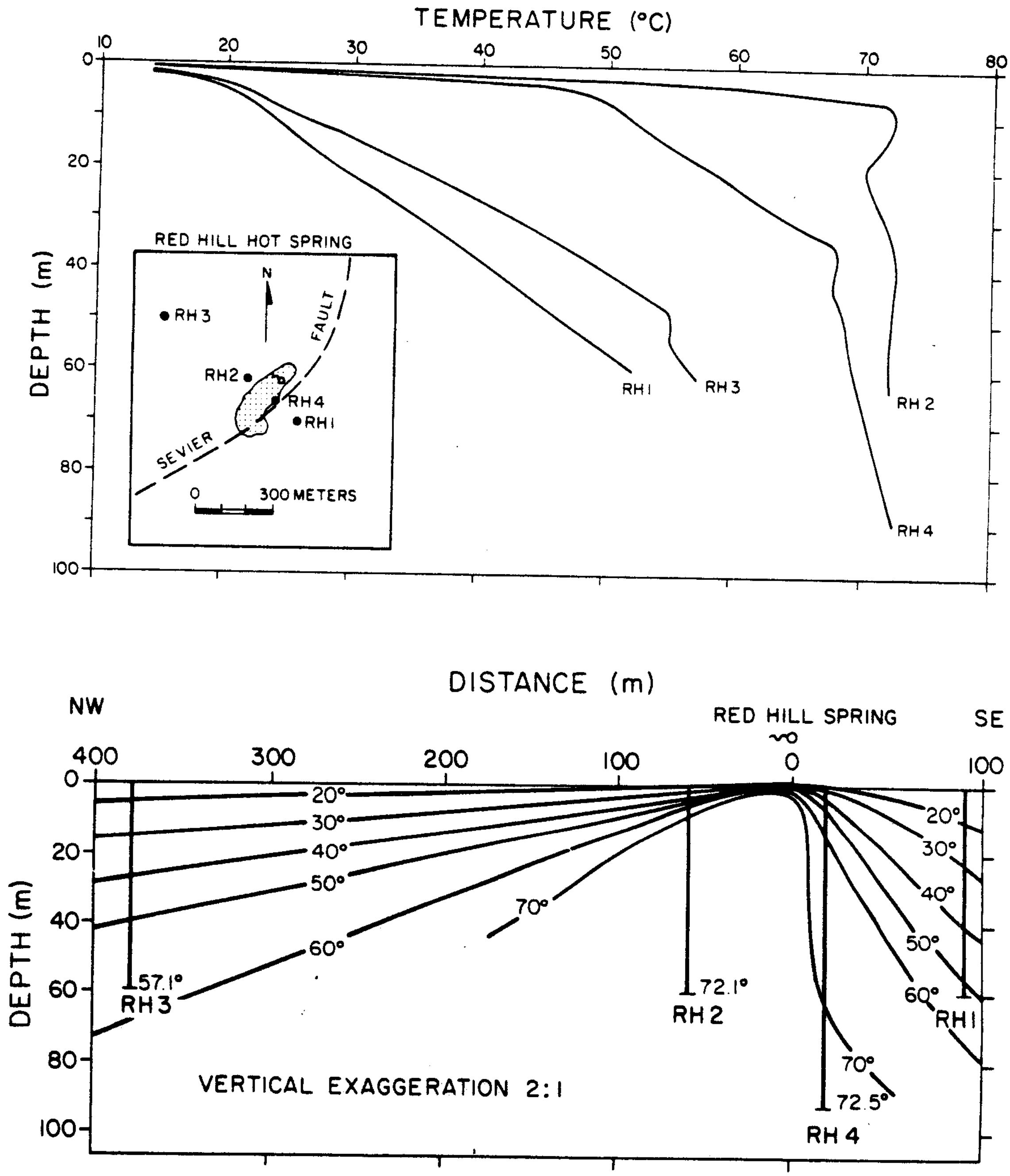

TEMPERATURE (°C)
10
20
30
40
50
60
70
80
0
20
40
60
80
100
DEPTH (m)
RED HILL HOT SPRING
N
RH 3
FAULT
RH2
RH4
RH1
SEVIER
0
300 METERS
RH1
RH 3
RH 2
RH 4
DISTANCE (m)
NW
RED HILL SPRING
SE
400
300
200
100
0
100
DEPTH (m)
20°
30°
40°
50°
60°
70°
57.1°
RH3
72.1°
RH2
70°
72.5°
RH 4
RH1
VERTICAL EXAGGERATION 2:1

Figure 4.2(b)

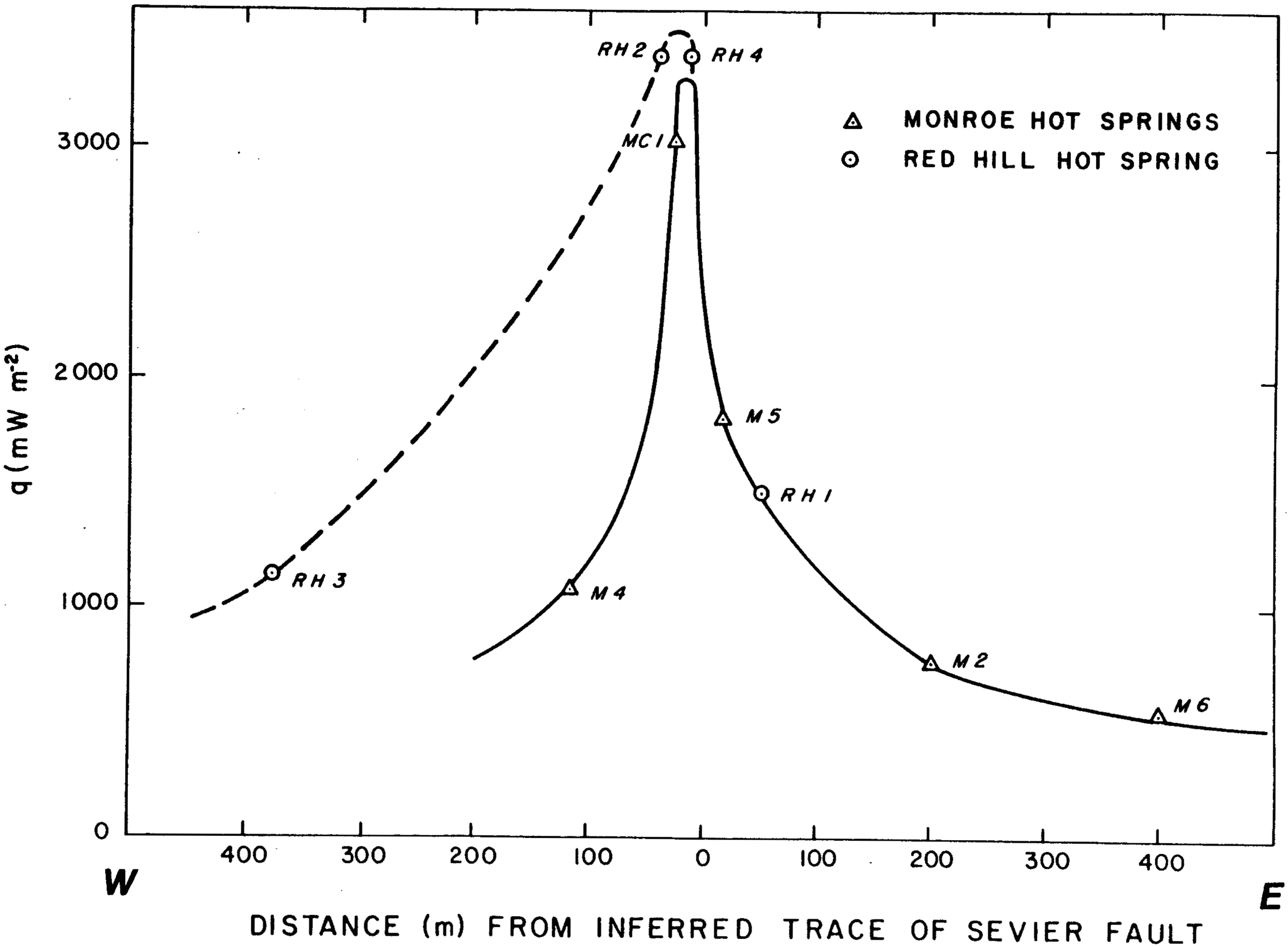

MONROE HOT SPRINGS
RED HILL HOT SPRING
RH2
RH4
MC1
M5
RH1
RH3
M4
M2
M6
3000
2000
1000
0
q (mW m^{-2})
400
300
200
100
0
100
200
300
400
W
E
DISTANCE (m) FROM INFERRED TRACE OF SEVIER FAULT

Figure 4.2(c)

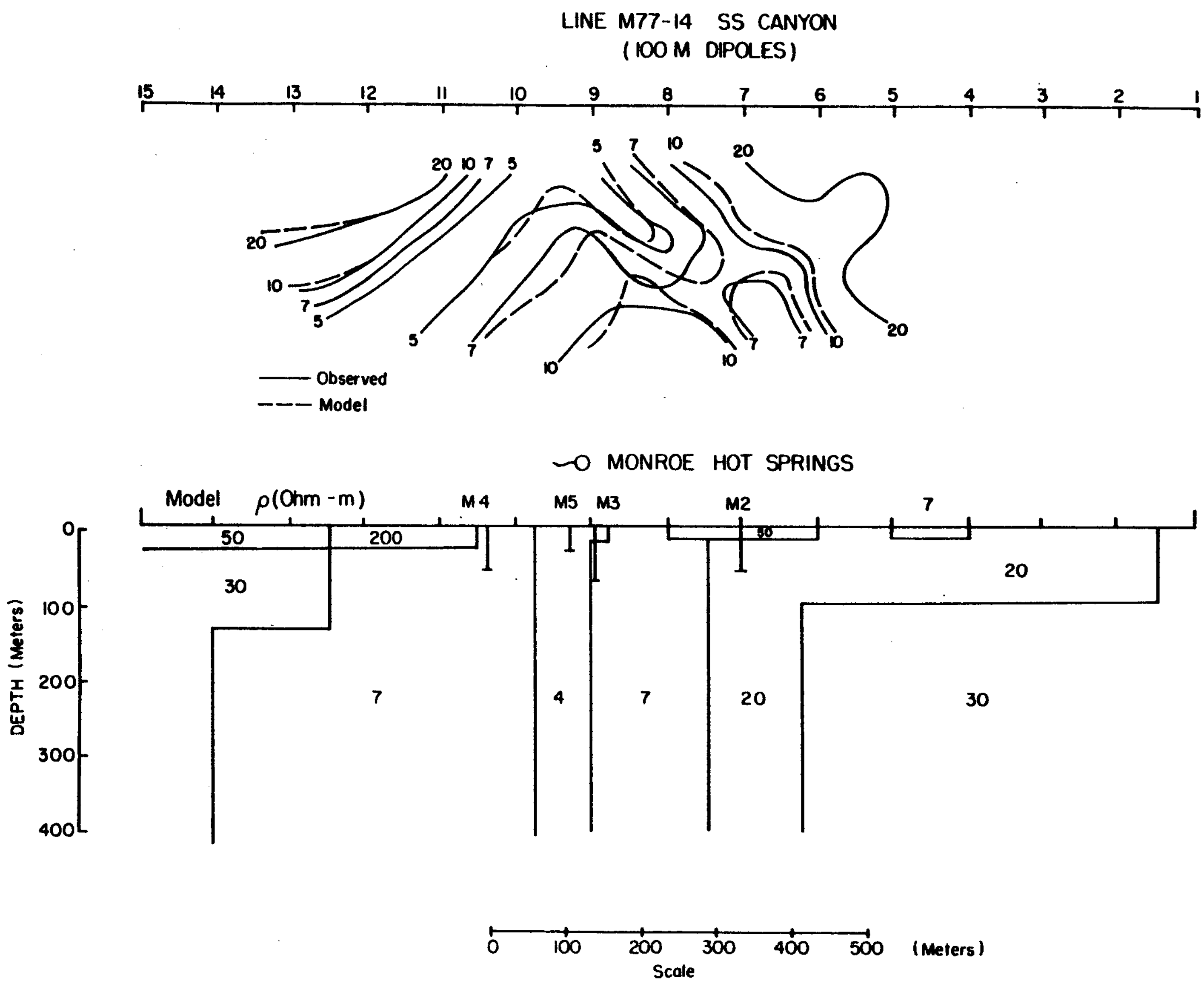

LINE M77-14 SS CANYON
(100 M DIPOLES)
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
Observed
Model
MONROE HOT SPRINGS
Model ρ(Ohm-m)
M4 M5 M3 M2
DEPTH (Meters)
0
100
200
300
400
50
200
30
7
4
7
20
30
20
7
0 100 200 300 400 500 (Meters)
Scale

Figure 4.2(d)

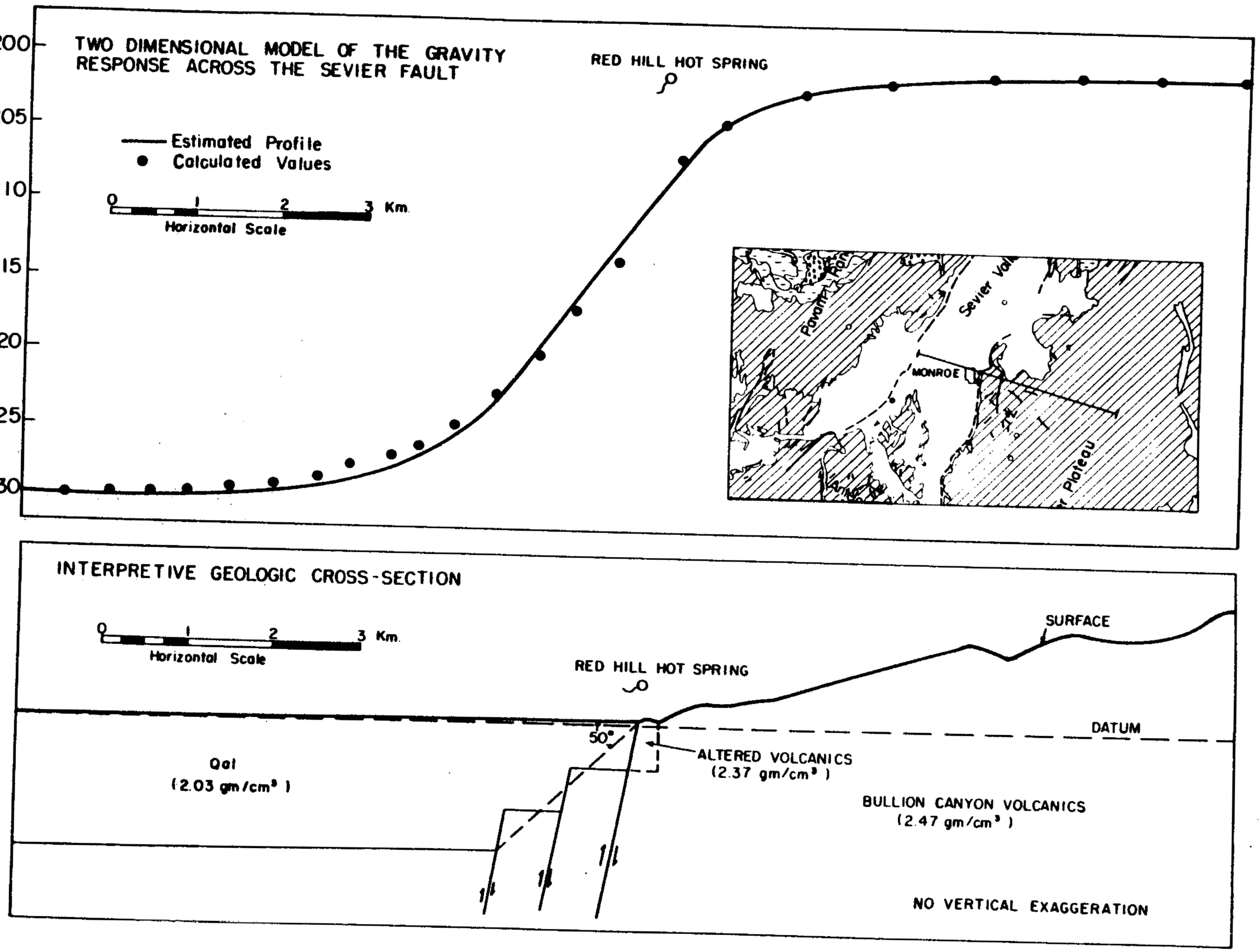

TWO DIMENSIONAL MODEL OF THE GRAVITY RESPONSE ACROSS THE SEVIER FAULT
RED HILL HOT SPRING
Estimated Profile
Calculated Values
0 1 2 3 Km.
Horizontal Scale
COMPLETE BOUGER (mgal)
-200
-205
-210
-215
-220
-225
-230
Sevier Val
MONROE
Plateau
INTERPRETIVE GEOLOGIC CROSS-SECTION
0 1 2 3 Km.
Horizontal Scale
RED HILL HOT SPRING
SURFACE
DATUM
50°
Qal
(2.03 gm/cm³)
ALTERED VOLCANICS
(2.37 gm/cm³)
BULLION CANYON VOLCANICS
(2.47 gm/cm³)
NO VERTICAL EXAGGERATION

Figure 4.2(e)

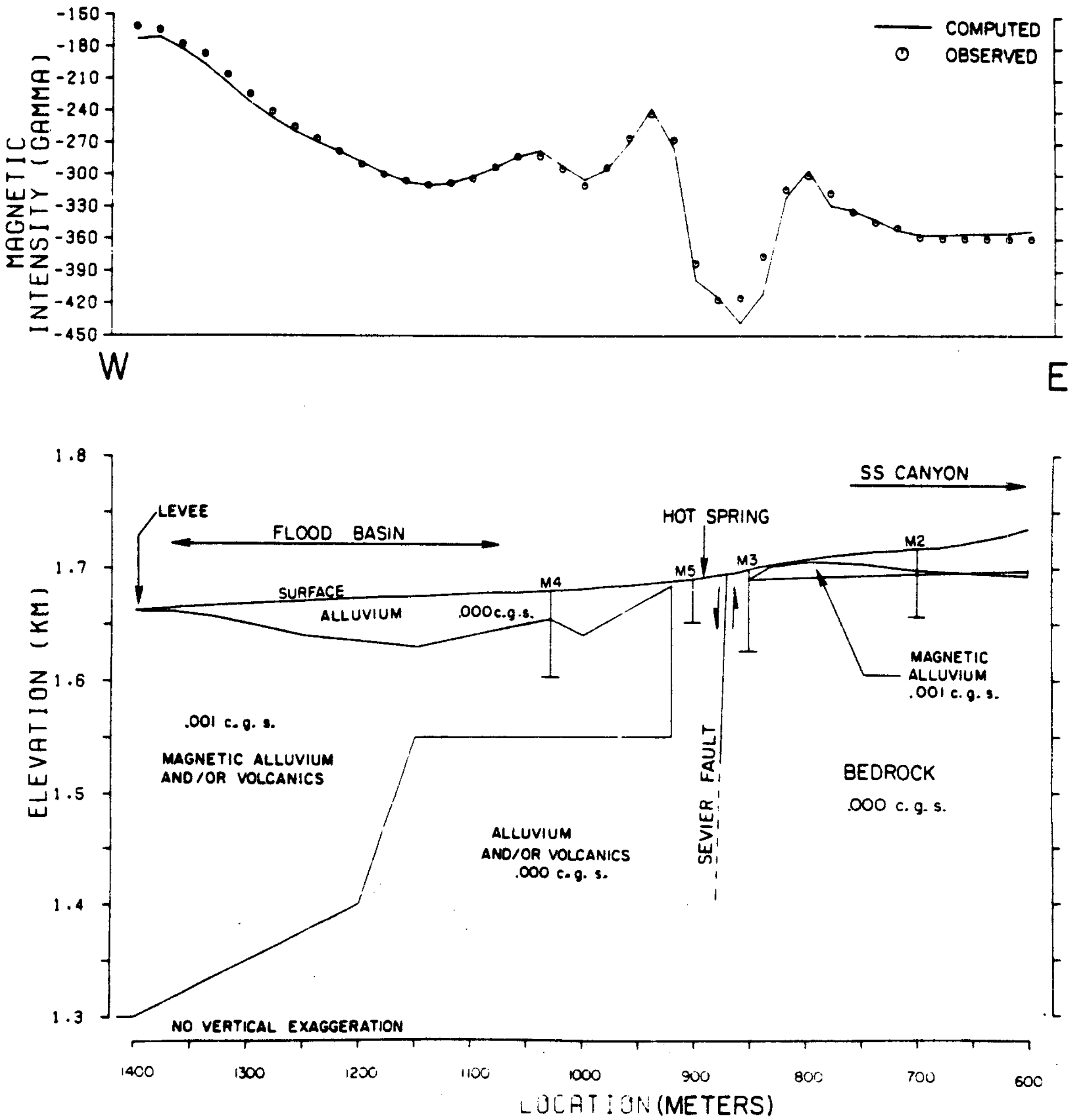

-150
-180
-210
-240
-270
-300
-330
-360
-390
-420
-450
MAGNETIC INTENSITY (GAMMA)
COMPUTED
OBSERVED
W
E
1.8
1.7
1.6
1.5
1.4
1.3
ELEVATION (KM)
SS CANYON
LEVEE
FLOOD BASIN
HOT SPRING
M2
M3
M4
M5
SURFACE
ALLUVIUM
.000c.g.s.
MAGNETIC
ALLUVIUM
.001 c.g.s.
.001 c.g.s.
MAGNETIC ALLUVIUM
AND/OR VOLCANICS
SEVIER FAULT
BEDROCK
.000 c.g.s.
ALLUVIUM
AND/OR VOLCANICS
.000 c.g.s.
NO VERTICAL EXAGGERATION
1400
1300
1200
1100
1000
900
800
700
600
LOCATION (METERS)

Figure 4.2(f)

4.3 Interpretation

The first phase of geological and geophysical investigations (Mase, Chapman, and Ward, 1978) resulted in the following conclusions about the Monroe-Red Hills hydrothermal system: 1) The system is aligned north-south along a prominent range front and is apparently structurally controlled by the Sevier Fault Zone. A dip of 80° ± 10° for the Sevier Fault satisfies several of the data sets; 2) the thermal structure can be effectively modeled by assuming a discharge of hot water from a reservoir at depth up through the Sevier Fault Zone; 3) maximum temperatures of 78°C were observed at Red Hills. Higher temperatures of 118°C for the reservoir were predicted from water geothermometry but the depth at which these higher temperatures are achieved depends on levels of cold water mixing in the system; 4) hot water presently discharges both through surface springs and through leakage in the alluvium. The discharge pattern is revealed by the resistivity surveys and by heat flow measurement; 5) the total conductive plus convective heat loss is 7.8 MW.

The second phase of exploration, namely the drilling of two test wells at MC 1 and MC 2 described in the results was designed to determine (a) the dip of the Sevier Fault and (b) the intermediate depth, thermal and hydrologic state of the system, thereby providing a better rationale for siting a production well.

Intersection of more consolidated volcanic bedrock in the drill holes was deduced from the drill logs (drilling rate, caliper, natural gamma; reference section 3.1) and lithologies (reference section 3.2), although changes in the latter were subtle as expected. The dip of the Sevier Fault Zone determined from encountering more consolidated volcanic bedrock at depths of 310 ft. in MC 1 and 610 ft. in MC 2 is 67° ± 3°. This value utilizes the survey results given in Appendix 2 and assumes a fault trend of N 10° W ± 10°. The computed dip of 67° is shallower than the dip deduced from geophysical modeling and may indicate enecheloned faulting.

Temperatures observed in MC 1 after completion of the hole and in MC 2 while the well was flowing indicate the central part of the Monroe system is isothermal at 74° C between depths of 50m (165 ft.) and 250m (820 ft.). Significantly higher temperatures may be expected only below depth where cold water mixing may occur.

Both MC 1 and MC 2 produced artesian flow to the surface after they were cleaned. The major part of the approximately 200 gallons per minute flow from MC 2 is likely produced from the fracture within the volcanic bedrock at depths of 230m and 238m, as the flow was diminished to approximately 40 gallons per minute when the bottom 64m (210 ft.) of the hole silted.

APPENDIX I

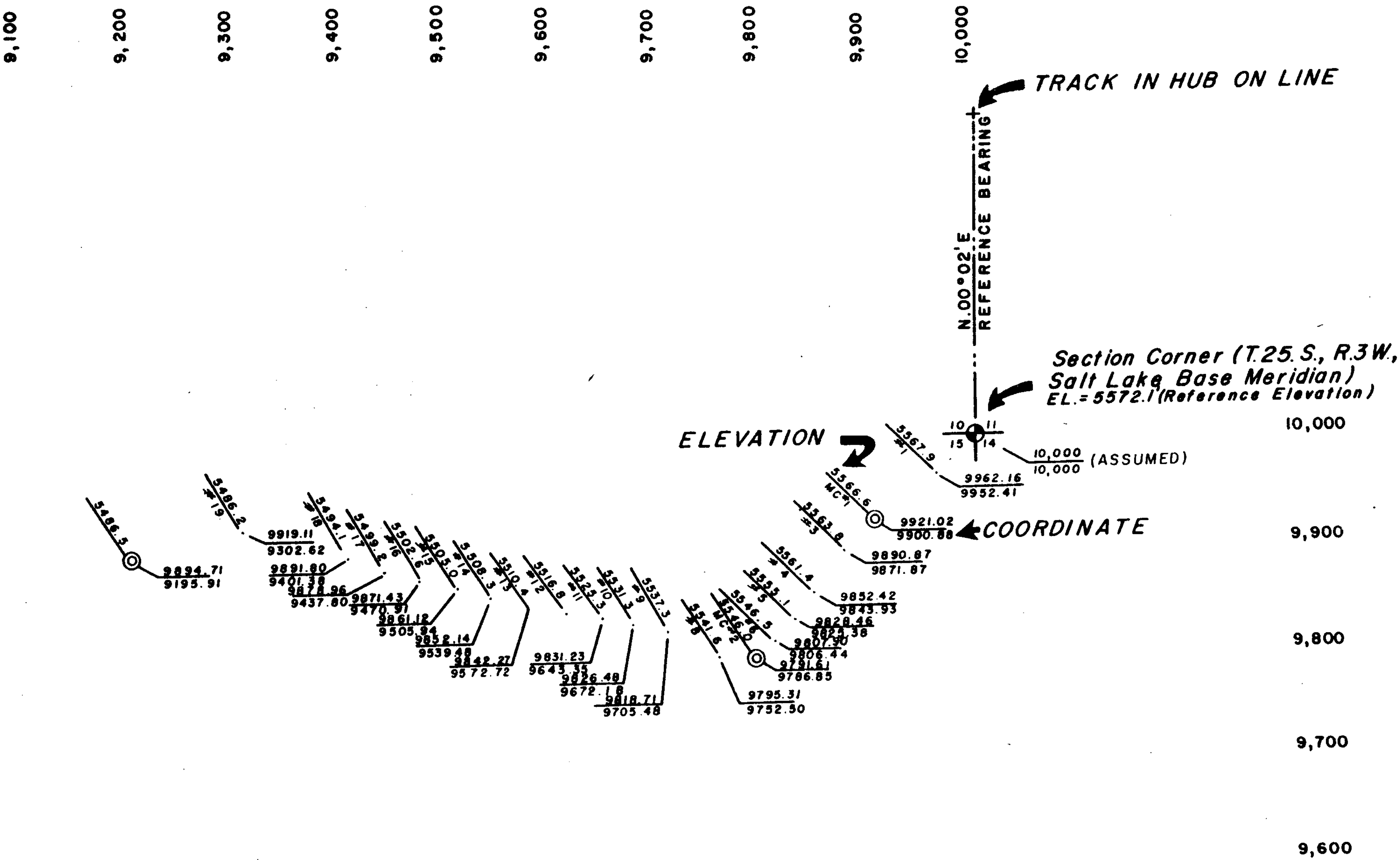
Drilling Costs

		QUANTITY AND UNIT	UNIT PRICE	TOTAL
1.	Mobilization and Demobilization	Lump Sum		$ 1,500.00
2.	Mc.1 - Drill nominal 6¼" hole, run 3" casing, gravel pack annulus from bottom to within 60 ft. of surface, group top 60 ft., install 3" isolating valve.	362 ft.	$12.50/ft.	4,500.00
	Extra footage authorized by David Chapman			
3..	Clean out and develop hole Mc.1	Lump Sum		500.00
4.	Location to Location move	Lump Sum		500.00
5.	MC2 - Drill 12" hole to 100 ft., run and group 8" casing to surface, install 8" containment valve.	100 ft.	25.00/ft.	2,500.00
6.	MC2 - Drill nominal 6¼" hole to 650 ft. run 3" casing, gravel pack from bottom to within 200 ft. of surface, group to 200 ft., install 3" isolating valve.	650 ft.	12.50/ft.	8,125.00
	Extra grouting approved by David Chapman	150 ft.	2.00/ft.	300.00
7,	Clean out and develop hole MC.2	Lump Sum		1,200.00

	QUANTITY AND UNIT	UNIT PRICE	TOTAL
8. Casing Costs:			
8" nominal western water well casing	100 ft.	$ 3.85/ft.	385.00
3" nominal water well casing	1100 ft.	1.80/ft.	1,980.00
slots - 6 row 12 slots/ft. (2"x½")	80 ft.	2.40/ft.	192.00
9. Expendable items:			1,829.78
10. Less cost of Blow out protection included in item 6 but not provided by contractor			(1,000.00)
		TOTAL DUE	$22,511.78

Appendix II

Survey of Well Locations


9,100
9,200
9,300
9,400
9,500
9,600
9,700
9,800
9,900
10,000
TRACK IN HUB ON LINE
N.00°02'E
REFERENCE BEARING
Section Corner (T.25.S., R.3W., Salt Lake Base Meridian)
EL.=5572.1 (Reference Elevation)
ELEVATION
COORDINATE
10,000
10,000 (ASSUMED)
10
11
15
14
10,000
9,900
9,800
9,700
9,600
5567.9
#1
9962.16
9952.41
5566.6
MC#1
9921.02
9900.88
5563.8
#3
9890.87
9871.87
5561.4
#4
9852.42
9843.93
9828.46
9824.38
9807.90
9806.44
9791.61
9786.85
9795.31
9752.50
5486.5
9894.71
9195.91
5486.2
#19
9919.11
9302.62
9891.80
9401.38
9437.80
9871.43
9470.91
9861.12
9505.94
9539.48
9572.72
9831.23
9643.35
9826.48
9672.18
9818.71
9705.48

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