AMAX EXPLORATION, INC.
A SUBSIDIARY OF AMAX INC.

GEOTHERMAL BRANCH

SUBJECT: Review of the Geothermal Potential of the McCoy Prospect.

February 4, 1983

TO: H. J. Olson

cc: J. E. Deymonaz
W. M. Dolan

FROM: H. D. Pilkington

The McCoy geothermal prospect was discovered in 1977 during reconnaissance work in Nevada. The prospect was identified by thermal gradient measurements in existing holes, presence of mercury mineralization, and by the hydrogeochemical analysis of water from the McCoy Mine water well. The preliminary thermal gradient drilling (1977 & 1978) outlined a thermal anomaly covering approximately fifty-five (55) square miles. On July 1, 1979 the U. S. Geological Survey approved the McCoy geothermal exploration unit of approximately 30,000 acres which solved our chargeability problems but requires a drill test every six months.

Under the "tight" money situation facing AMAX, we must review our properties to determine where our limited funds should be spent. Pilkington has completed a draft of the final report to the DOE for work done under contract DE-AC08-79ET016 (Pilkington, 1982). The report summarizes all the geothermal exploration done under the DOE contract. The purpose of this memorandum is to review the geothermal potential of the McCoy prospect and to recommend future action on the property.

EXPLORATION HISTORY

The geothermal exploration done on the McCoy prospect has been an integrated approach involving geological, geochemical, and geophysical studies as well as exploration drilling. For the purposes of this memorandum the exploration will be discussed under exploration methods rather than a chronological description.

GEOLOGICAL STUDIES

The prospect is located at the junction of the Augusta Mountains, the Clan Alpine Mountains and the New Pass Range. The McCoy Mercury Mine is located near the eastern side of a circular feature seen on the enhanced landsat imagery (Fig. 1). The circular feature is not a caldera; however, it may be related to a buried intrusive which caused some doming and resultant ring fractures. The area is underlain by Tertiary volcanics and associated sediments, Triassic sediments and Permo-Pennsylvanian eugeosynclinal sediments (Stewart and McKee, 1977 & Welden and Speed, 1974). A considerable thickness of travertine covers an area of over 2Km^2 west of the McCoy Mine. The travertine rests upon eroded Traissic rocks, dips slightly to the west and has been somewhat eroded. Under DOE funding UURI (Adams, et al, 1980) completed a detailed map of the cooling units in the Tertiary Volcanics. The fossil spring deposit in the form of travertine and the hydrothermal alteration and mercury

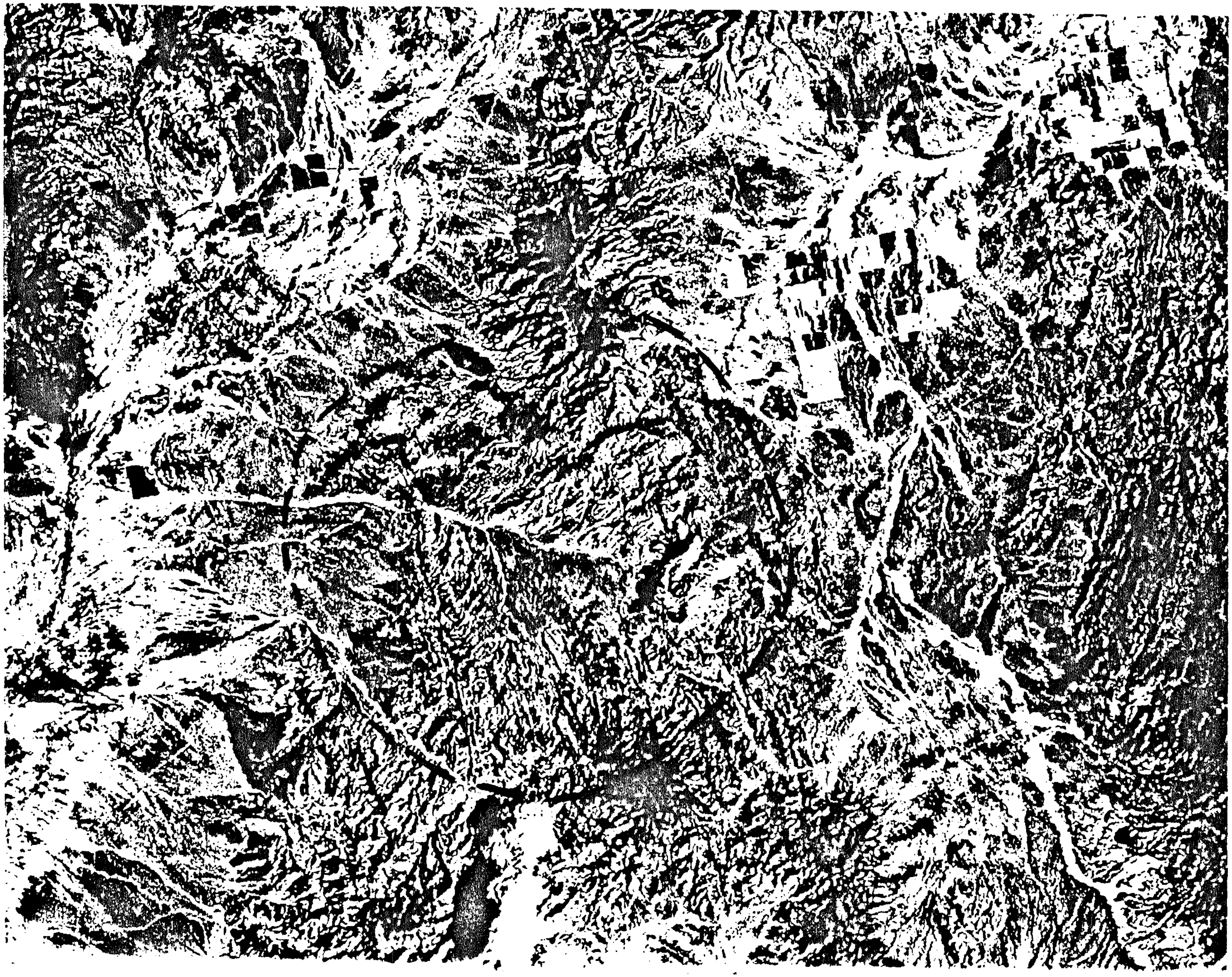


Figure 1. Fotocopy of the landsat image of the McCoy area, Nevada with the circular feature outlined

mineralization at the McCoy Mine and Wildhorse Mine indicate a hydrothermal system has been present in the area. The above may indicate the presence of an active geothermal system in the area, as does the association of mercury deposits and active geothermal systems in other parts of the world.

GEOPHYSICAL STUDIES

The presence of heat, as anomalous bottom hole temperatures measured in existing holes was one of the features which attracted AMAX to the property. The thermal anomaly in the McCoy area has been defined by thermal measurements in fifty-two shallow temperature gradient holes and five existing holes. The heat flow map (Fig. 2) is based upon thermal conductivities from 12 measurements and the values for the remaining holes are estimated. The thermal anomaly consists of a large area outlined by the four HFU contour and three distinct highs which outline convective heat flow above shallow thermal aquifers.

A comprehensive geophysical study has been made of the area. The areomagnetic and gravity surveys provide useful data for the interpretation of geologic structure, but do not help us understand the thermal anomaly or help us "see" a geothermal reservoir.

Microgeophysics Corporation conducted a 31-day passive seismic survey in the area. Thirty-six events were recorded during the survey and sixteen of the microearthquakes fell within the map boundaries including three

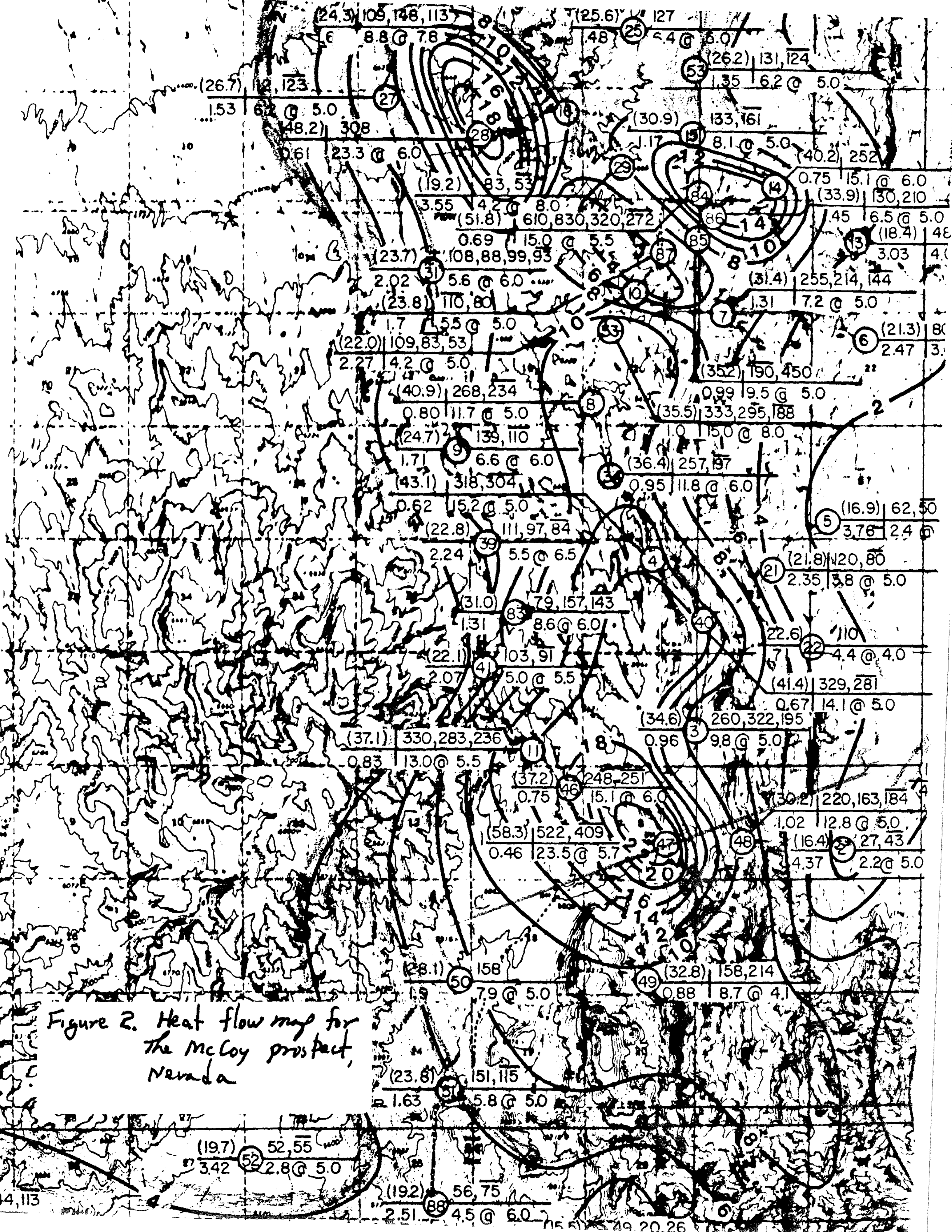


Figure 2. Heat flow map for the McCoy prospect, Nevada

near McCoy Mine, three at the northern end of Edwards Creek Valley and three south of Hole-in-the-Wall (Fig. 3). Lange (1980) concluded the passive seismic survey might see a deep reservoir under the southwestern part of the southern thermal anomaly.

The electrical geophysical methods have been touted, by many, as techniques which permit geothermal reservoir identification. The electrical resistivity of thermal waters is significantly different than that of most host rocks with the exception of clays. The measured resistivity depends upon the physical properties of the host rock, the porosity of the rock mass, and the extent to which the voids are filled with thermal waters. Examination of the resistivity values determined over the southern thermal anomaly by magnetotelluric methods (Fig. 4) and by the dipole-dipole survey (Fig. 5, line C) suggest that at a depth of 0.5 Km in well 66-8 (NWSE8 T22N R40E) the resistivities should be on the order of 20 ohm-meters and that at a depth of 1.0Km the resistivities would be in the 8 ohm-meter range. Similarly, the values on well 28-18 (SWSW18 T22N R40E) would be about 8 ohm-meters at a depth of 0.5 Km and drop to 8 ohm-meters at a depth of 0.5 Km and drop to 4 ohm-meters at a depth of 1.0 Km. According to Lange (1980) the conductivity continues to increase to about 1 ohm-meter at a depth of 5 Km.

When we compare the geologic section through well 66-8 (Fig. 4) with the MT section we note major discrepencies between the measured resistivities and those one would assign based upon rock type; i.e. the measured values are one to two orders of magnitude lower than the rock resitivities expected. The electric well log for 66-8 gives a value of 60 ohm-meters

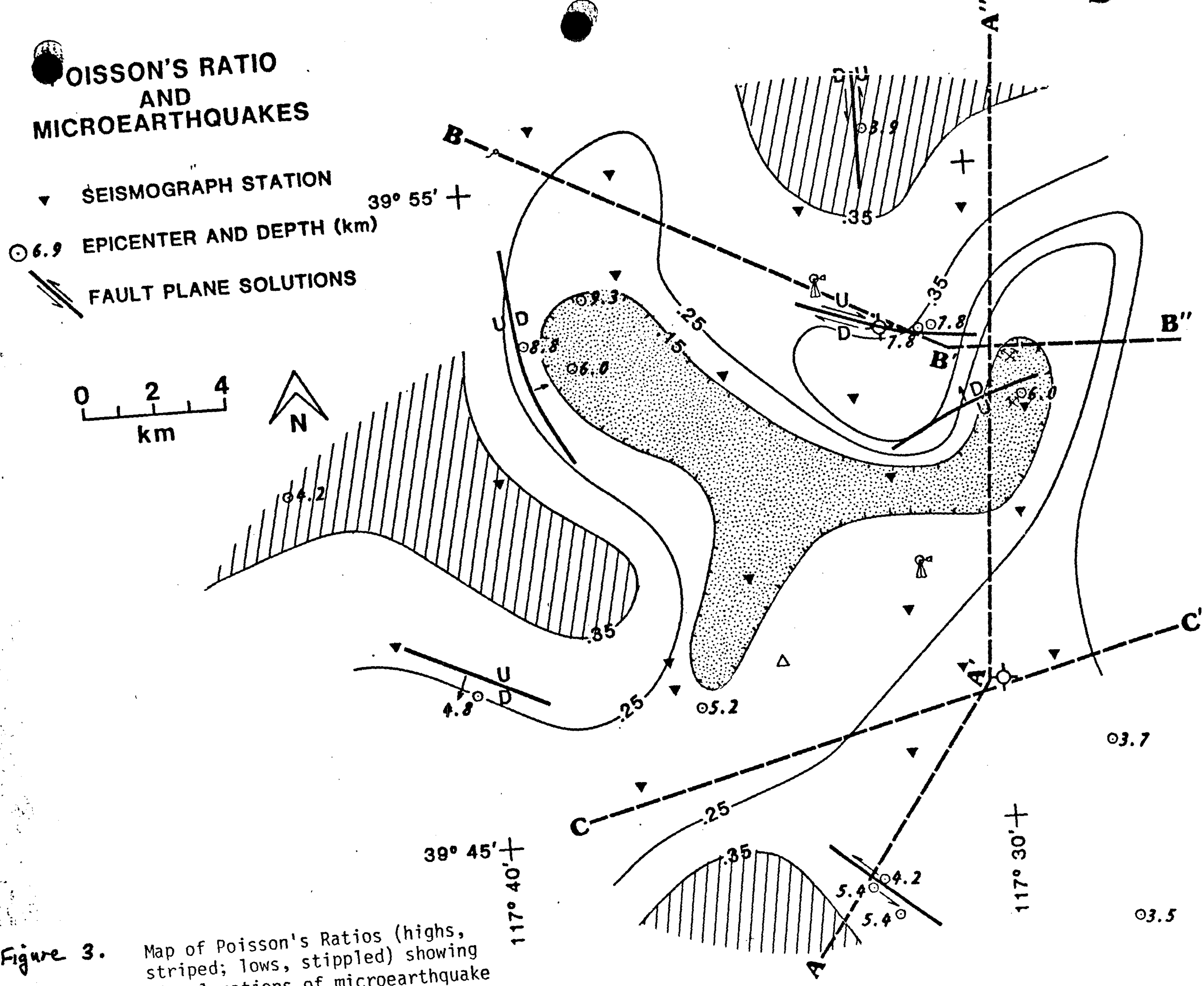
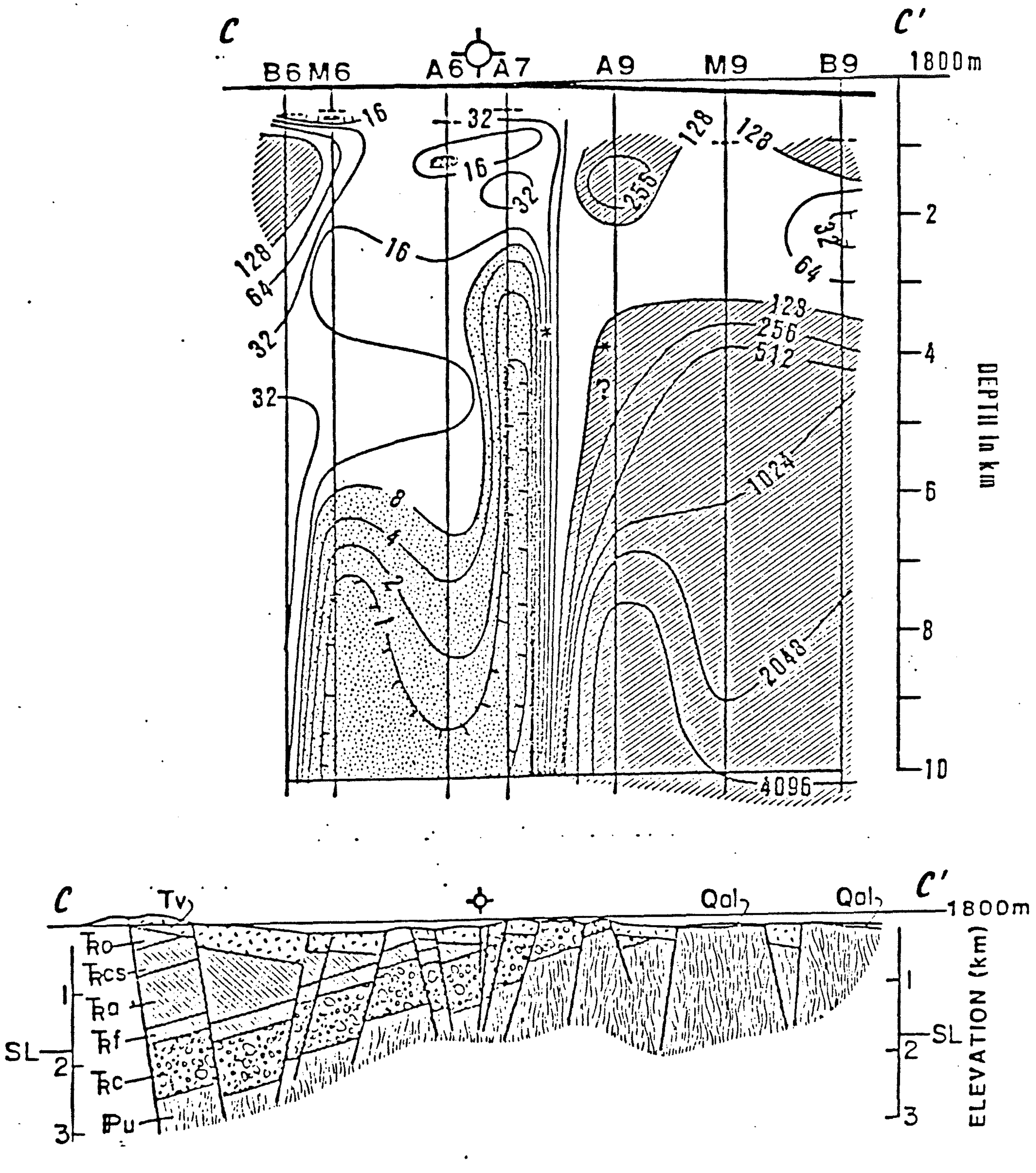


Figure 3. Map of Poisson's Ratios (highs, striped; lows, stippled) showing also locations of microearthquake foci and fault-plane solutions



C–C'

MAGNETOTELLURIC 1-D INVERSION WITH GEOLOGIC PROFILE

Figure 4. MT section (T_e mode, 1D inversion) along Line C, compared with geologic section (Lange, 1980).

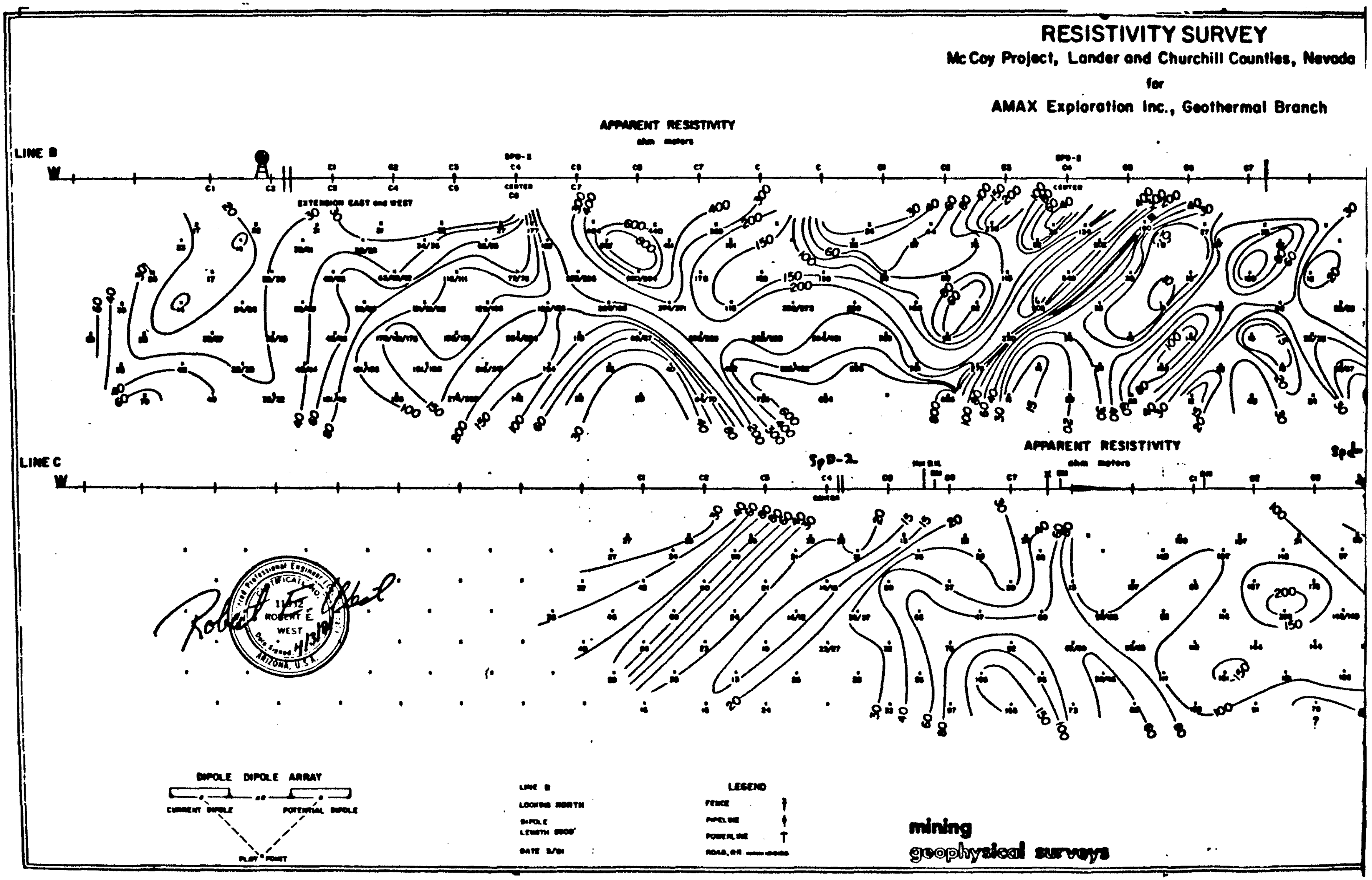


Figure 5. Resistivity survey McCoy Project, Nevada Line B and C

for the Triassic conglomerates at a depth of 0.5 Km. The temperature log for well 66-8 was basically isothermal below a depth of 0.5 Km which suggests a low temperature geothermal reservoir is present below 0.5 Km. The electrical conductivity of the waters encountered in wells 66-8, 25-9 suggests that the resistivity values determined from the MT are dominated by the geothermal fluids and thus, the electrical methods did in fact see the low temperature geothermal reservoir. However, it is extremely doubtful if the electrical methods really see through the shallow geothermal reservoirs.

EXPLORATION DRILLING

The exploration drilling done at the McCoy prospect includes fifty-two shallow thermal gradient holes, three intermediate depth thermal gradient wells, and two intermediate depth exploration wells. Drilling has confirmed the presence of two shallow low temperature geothermal reservoirs. In the northern anomaly well 38-9 north of McCoy Mine encountered 45°C fluids at 550 feet (25 gpm/air lift), by 1200 feet we 115 gpm/air lift and at 1430 feet about 300 gpm/air lift. The well remained isothermal after sand packing suggests a continuous geothermal reservoir in the Havallah Formation (Permo-Penn) from 550 feet to TD at 2036 feet. The primary porosity and permeability of the siliceous sillstone and cherts would be very low; however, the thermal log and the resistivity log suggests a reservoir condition with the thermal waters dominating the rock properties. Well 14-7 was drilled in the western "bullseye" of the northern thermal anomaly approximately two miles west of McCoy Mine. A warm water entry (55°-60°C) occurred at about 570 feet with a flow of about 100 gpm with air lift. Lost circulation problems and consequent lack of sample returns prevented an accurate stratigraphic determination; however, I believe the hole bottomed in the Augusta Formation (Triassic limestones). The thermal log goes isothermal at 570 feet and remains so to final TD which suggests a continuous low temperature geothermal reservoir exists in the Augusta Formation.

In the southern part of the thermal anomaly, Well 66-8 encountered boiling water 96-101°C at a depth of 1630 feet with a flow of about 25 gpm/air lift. Several water entries were recorded between 1630 and 2050 feet where the flow rate had increased to about 75 gpm with air lift. The final water entry was noted at a depth of 2410 feet when the flow increased to 100 gpm /air lift. The final TD was 2510'. The thermal log was originally interpreted as downhole water flow from the upper hot water entry and out through deeper lost circulation zones. Certainly water movement did occur; however, the temperature and resistivity logs both indicate that all movement was within the same geothermal reservoir.

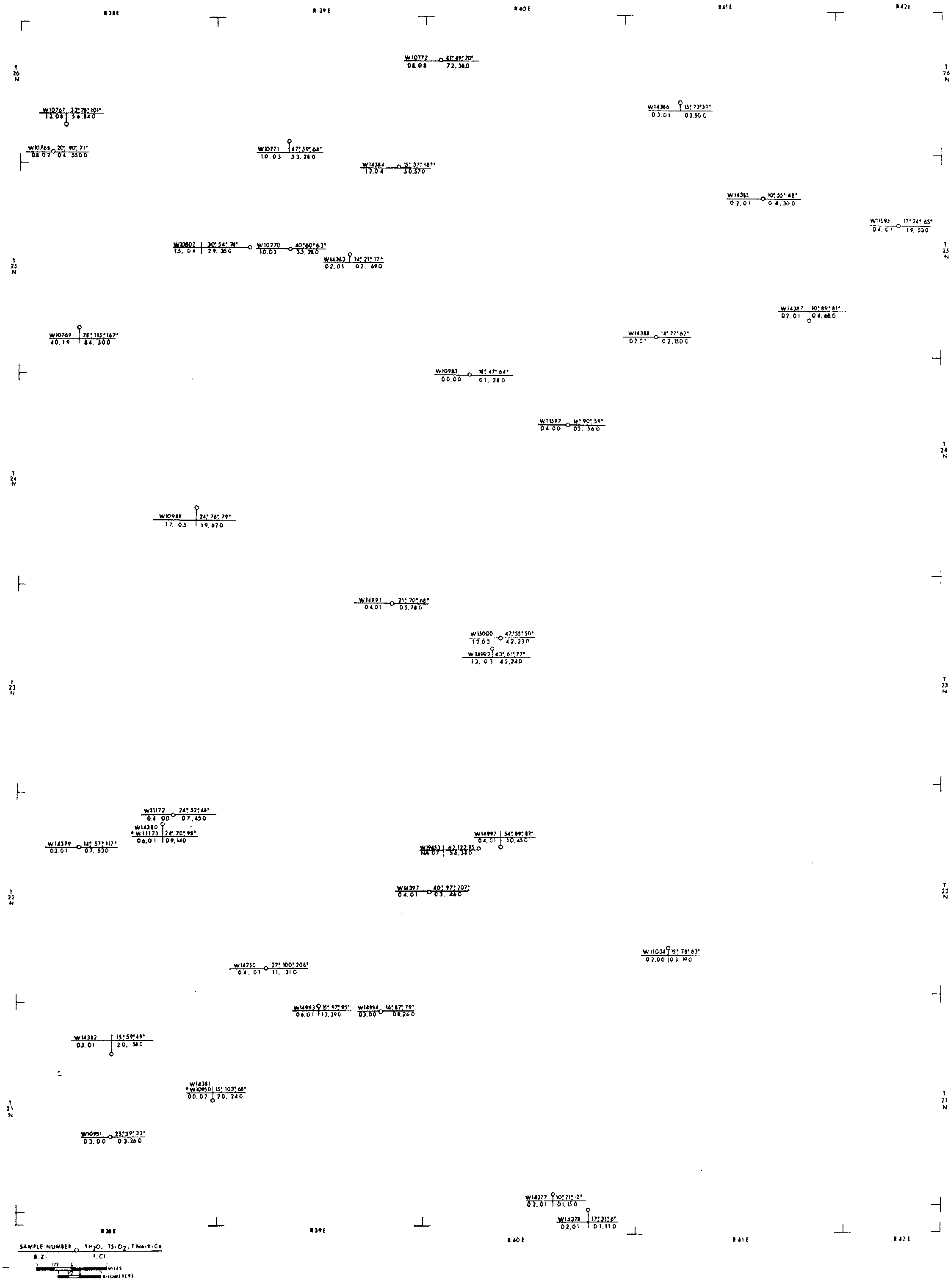
Well 25-9 (NWSW9 T22N R40E) was drilled to test the geothermal model proposed by Lange (1980). Lange concluded that the geophysical anomalies could best be explained by an upwelling of thermal waters along the faults bounding a horst block (Fig. 4). Warm water entries were noted at 1640 feet, 1840 feet and 2000 foot TD. The flow line temperatures 44, 48 and 54°C respectively at 25-30 gpm with air lift. The thermal aquifer was penetrated between 1440 and 1570 feet in the base of the Triassic conglomerates. The temperature of the aquifer is about 71°C which negated the concept of upwelling thermal waters as proposed by Lange.

Well 28-18 (SWSW18 T22N R40E) was planned as 3500 feet thermal observation well to test the electrical anomaly to the southwest of Well 66-8. The well was stopped at a depth of 1948 feet because of lost circulation problems and budgetary reasons. Warm water was encountered at 600 feet, 960 feet (33°C @ 40 gpm/air lift) and at 1083 feet (60 gpm/air lift. The Paleozoic section consisting of dark carbonaceous shales, probably Favret Formation of Triassic age, were encountered below 1341 feet and may be the cuase electrical anomaly.

GEOCHEMICAL STUDIES

The hydrogeochemical analysis of a water sample from the McCoy Mine water well was one of the manifestations which attracted AMAX to the area. A total of forty-four (44) water samples have been collected to date around the McCoy prospect (Fig. 6). Table I compares the chemical analyses for the area. The chemical geothermometers given include silica with maximum steam loss (Tq SiO_2) and chalcedony (Tc SiO_2) and the alkali geothermometer (T Na-K-Ca) without magnesium corrections.

Chemically the waters fall into three distinct groups when plotted on a potassium versus sodium diagram (Fig. 7). The majority of non-thermal waters (Type I, Fig. 7) are mixed cation-anion waters of low salinity and low silica content. The termal waters in the McCoy area fall into two groups (Type II & III, Fig. 7). The thermal waters in the McCoy Mine



McCOY, NEVADA

HYDROGEOCHEMISTRY MAP

Figure 6. Hydrogeochemical sample map for the McCoy prospect, Nevada.

Table I. Chemical analyses of McCoy Area Waters

	W 10767 7 Devils W.S. SWSES29T26NR38E	W10768 7 Devils W.W. NWSWS32T26NR38E	W10769 Hyder H.S. NWSWS28T25NR38E	W10770 Lower Ranch H.S. SWNWS16T25NR39E
Temp°C	33	20	78	40
Flow (gpm)	1	ND	50	20
pH	7.39	7.35	8.59	7.41
Cl	84.0	550.0	50.0	28.0
F	5.6	0.4	8.4	3.3
SO_4	460.0	180.0	125.0	65.0
HCO_3	278.0	180.0	665.0	377.0
CO_3	0.0	0.0	31.0	0.0
SiO_2	56.0	70.0	68.0	39.0
Na	170.0	150.0	350.0	140.0
K	30.0	19.0	22.0	11.0
Ca	130.0	230.0	24.0	43.0
Mg	22.0	62.0	9.5	13.0
Li	0.8	0.2	1.9	0.3
B	1.3	0.8	4.0	1.0
TDS	1237.7	1442.4	1442.4	720.6
Ec(k)	NA	NA	NA	NA
Tq SiO_2	107	117	115	93
Tc SiO_2	78	90	88	60
T Na-K-Ca	101	71	167	89

Table I. Continued

	W10771 McCoy H.S. SWNWS33T26NR39E	W10772 H.S. NWNES19T26NR40E	W10802 W.S. NWNWS19T25NR39E	W10950 C.S. SWSWS18T21NR39E
Temp^{o}C	47	41	30	15
Flow (gpm)	5	1	15	1
pH	7.08	6.75	7.10	7.90
Cl	300.0	38.0	35.0	24.0
F	1.4	7.2	2.9	2.0
SO_4	210.0	100.0	130.0	50.0
HCO_3	280.0	677.0	466.0	117.0
CO_3	0.0	0.0	0.0	0.0
SiO_2	38.0	31.0	34.0	87.0
Na	220.0	240.0	160.0	52.0
K	9.2	22.0	11.0	7.0
Ca	110.0	80.0	90.0	35.0
Mg	37.0	18.0	18.0	1.5
Li	0.2	0.8	0.4	0.2
B	0.8	0.8	1.5	0.0
TDS	1206.6	1214.8	948.8	375.7
Ec(k)	NA	NA	NA	NA
Tq SiO_2	92	84	88	126
Tc SiO_2	59	49	54	103
T Na-K-Ca	68	170	74	68

Table I. Continued

	W10951 W.W. SESES22T21NR38E	W10981 McCoy Mine W.W. Sec 9 T23NR40E	W10983 Cain Spr. SWS5T24NR40E	W10988 Hole-In-Wall W.S. SWSES24T24NR38E
Temp°C	25	39	18	24
Flow (gpm)	ND	ND	25	10
pH	7.90	7.05	7.75	7.53
Cl	26.0	22.0	28.0	62.0
F	0.3	4.4	0.1	1.9
SO_4	90.0	54.0	60.0	500.0
HCO_3	138.0	611.6	184.0	370.0
CO_3	0.0	0.0	0.0	0.0
SiO_2	24.0	44.0	10.0	56.0
Na	51.0	260.0	37.0	260.0
K	2.8	15.0	11.0	16.0
Ca	60.0	43.0	70.0	160.0
Mg	8.3	9.0	18.0	20.0
Li	0.0	0.3	0.0	0.5
B	0.3	1.3	0.0	1.7
TDS	400.7	1065.3	418.1	1448.1
Ec(k)	NA	NA	NA	NA
Tq SiO_2	75	98	47	107
Tc SiO_2	39	66	7	78
T Na-K-Ca	33	153	64	79

Table I. Continued

	W11004 Big Antelope Spr. NWSWS29T22NR41E	W11172 Shoshone Meadows WS NESES2T22NR38E	W11173 Shoshone Meadows WS NESES2T22NR38E	W11596 WW NENWS17T25NR42E
Temp^{o}C	15	24	24	17
Flow (gpm)	10	20	1	ND
pH	7.81	7.78	8.28	7.69
Cl	19.0	45.0	140.0	53.0
F	0.3	0.7	0.9	1.9
SO_4	31.0	75.0	250.0	50.0
HCO_3	120.0	139.0	21.0	176.0
CO_3	0.0	0.0	0.0	0.0
SiO_2	56.0	33.0	48.0	52.0
Na	40.0	130.0	270.0	81.0
K	6.1	0.6	9.0	6.6
Ca	32.0	4.0	30.0	46.0
Mg	7.0	0.0	1.5	9.0
Li	0.0	0.0	0.1	0.1
B	0.2	0.4	0.6	0.4
TDS	311.6	427.7	771.1	476.0
Ec(k)	NA	NA	NA	NA
Tq SiO_2	107	87	101	104
Tc SiO_2	78	52	70	74
T Na-K-Ca	63	48	98	65

Table I. Continued

	W11597 WW SESES10T24NR40E	W13453 Well 66-8, 1630' NWSE S8T22NR40E	W13454 Well 66-8, 2050' NWSES8T22NR40E	W13455 Well 66-8, 2050' NWSES8T22NR40E
Temp°C	16	62	62±	62±
Flow (gpm)	1200	25/air lift	75/air lift	75/air lift
pH	7.88	9.40	9.10	9.00
Cl	56.0	38.0	31.0	32.0
F	0.5	5.6	3.0	4.4
SO_4	60.0	100.0	100.0	87.0
HCO_3	135.0	144.0	142.0	154.0
CO_3	0.0	72.0	24.0	44.0
SiO_2	70.0	120.0	75.0	65.0
Na	42.0	160.0	98.0	110.0
K	6.9	21.0	14.0	14.0
Ca	47.0	6.6	9.6	8.0
Mg	14.0	2.6	16.0	14.0
Li	0.0	0.7	0.4	0.4
B	0.4	1.3	1.0	1.0
TDS	431.8	670.0	513.0	532.8
Ec(k)	NA	NA	NA	NA
Tq SiO_2	117	148	120	115
Tc SiO_2	90	122	94	86
T Na-K-Ca	59	205	197	194

Table I. Continued

	W13456 Well 66-8, 2410' NWSES8T22NR40E	W14377 Gilbert Spring SES34T21NR40E	W14378 WS NES2T20NR40E	W14379 WS NWSWS9T22NR38E
Temp°C	62±	10	17	18
Flow (gpm)	100/air lift	12	25	2
pH	9.0	8.1	8.6	8.9
Cl	31.0	15.0	11.0	53.0
F	4.1	0.1	0.1	0.7
SO_4	80.0	21.0	15.0	78.0
HCO_3	204.0	149.0	124.0	176.0
CO_3	20.0	0.0	12.0	22.0
SiO_2	62.0	15.0	20.0	37.0
Na	110.0	22.0	17.0	170.0
K	14.0	0.6	0.9	3.3
Ca	6.0	43.0	37.0	4.0
Mg	18.0	7.0	7.0	1.0
Li	0.5	<0.1	<0.1	<0.1
B	0.9	<0.2	<0.2	0.3
TDS	550.0	273.0	244.3	545.4
Ec(k)	NA	350.0	300.0	640.0
Tq SiO_2	112	53	63	88
Tc SiO_2	83	21	31	57
T Na-K-Ca	197	-2	6	116

Table I. Continued

	W14380 Shoshone Meadows W.S. NESES2T22NR38E	W14381 CS SWSWS18T21NR39E	W14382 Smooth Canyon Sp. NWS10T21NR38E	W14383 CS SES16T25NR38E
Temp°C	25	14	15	14
Flow (gpm)	1	5	ND	20
pH	8.8	8.5	8.6	8.5
Cl	44.0	27.0	58.0	69.0
F	0.6	2.0	2.0	0.2
SO_4	66.0	54.0	48.0	98.0
HCO_3	117.0	119.0	189.0	144.0
CO_3	13.0	8.0	11.0	6.0
SiO_2	38.0	91.0	38.0	15.0
Na	130.0	52.0	88.0	57.0
K	1.8	8.4	4.5	3.0
Ca	3.0	35.0	62.0	190.0
Mg	<1.0	2.0	12.0	71.0
Li	<0.1	0.2	<0.1	<0.1
B	<0.2	0.2	0.3	<0.2
TDS	417.7	398.8	512.9	653.5
Ec(k)	510.0	450.0	730.0	1300.0
Tq SiO_2	89	132	89	53
Tc SiO_2	59	105	59	21
T Na-K-Ca	87	74	49	17

Table I. Continued

	W14384 CS NWS11T25NR39E	W14385 Thompson WW SENWS10T25NR1E	W14386 Hess Spr. SWNES29T26NR41E	W14387 Red Butte WW SESES26T25NR41E
Temp^{o}C	15	10	15	10
Flow (gpm)	1	500	2	1000
pH	8.5	8.6	8.9	8.7
Cl	57.0	30.0	50.0	68.0
F	5.0	0.4	0.3	0.4
SO_4	68.0	25.0	43.0	41.0
HCO_3	254.0	121.0	0.0	96.0
CO_3	14.0	10.0	11.0	9.0
SiO_2	23.0	35.0	51.0	69.0
Na	170.0	39.0	62.0	59.0
K	24.0	2.6	2.6	9.8
Ca	82.0	19.0	40.0	33.0
Mg	58.0	5.0	7.0	3.0
Li	0.4	<0.1	<0.1	<0.1
B	1.2	<0.2	0.3	<0.2
TDS	756.6	287.3	267.3	388.5
Ec(k)	1400	360.0	510.0	500.0
Tq SiO_2	69	86	103	117
Tc SiO_2	37	55	73	89
T Na-K-Ca	187	48	39	81

Table I. Continued

	W14388 Swanson WW Center 531 T25NR41E	W14397 Well 28-18, 1470' SWSWS28T22NR40E	W14350 Shoshone Pass WW NWS32T22NR39E	W14991 Hole-in-Wall WW SENES2T23NR39E
Temp°C	14	40	27	21
Flow (gpm)	100	50/air lift	65	3
pH	8.3	8.1	7.6	7.5
Cl	150.0	46.0	31.0	78.1
F	0.2	0.3	1.1	0.5
SO_4	68.0	59.0	98.0	87.0
HCO_3	106.0	78.0	206.0	120.0
CO_3	0.0	0.0	0.0	0.0
SiO_2	55.0	80.0	85.0	48.0
Na	52.0	69.0	77.0	78.0
K	11.0	15.0	18.0	7.7
Ca	100.0	22.0	40.0	50.0
Mg	12.0	3.8	10.0	7.8
Li	<0.1	0.1	0.1	0.1
B	0.2	0.4	0.4	0.4
TDS	554.5	351.6	566.6	477.5
Ec(k)	880.0	445.0	689.0	NA
Tq SiO_2	106	123	128	101
Tc SiO_2	77	97	101	70
T Na-K-Ca	61	207	208	68

Table I. Continued

	W14992 McCoy Mine WW Sec9T23NR40E	W14993 Edwards Cr. WW NWNWS3T21NR39E	W14994 WW NES2T21NR39E
Temp ^{o}C	43	15	16
Flow gpm	25	5	5
pH	7.2	8.0	7.6
Cl	24.0	39.0	26.0
F	4.2	1.3	0.8
SO_4	47.0	80.0	42.0
HCO_3	580.0	178.0	130.0
CO_3	0.0	0.0	0.0
SiO_2	40.0	80.0	61.0
Na	230.0	110.0	71.0
K	15.0	9.4	4.8
Ca	43.0	23.0	14.0
Mg	8.7	2.1	2.7
Li	0.3	0.1	0.1
B	1.3	0.6	0.3
TDS	993.5	523.5	352.7
Ec(k)	NA	NA	NA
$TqSiO_2$	94	122	111
$TcSiO_2$	61	97	82
TNa-K-Ca	157	95	79

Table I. Continued

	W14995 Well 25-9, 1640' NWSW9T22NR40E	W14996 Well 25-9, 1840' NWSW9T22NR40E	W14997 Well 25-9, 2000' NWSW9T22NR40E
Temp ^{o}C	44	48	54
Flow gpm	25/air lift	30/air lift	30/air lift
pH	8.7	8.2	8.2
Cl	29.0	34.0	45.0
F	2.9	1.7	1.0
SO_4	64.0	75.0	86.0
HCO_3	182.0	158.0	156.0
CO_3	12.0	0.0	0.0
SiO_2	17.0	25.0	35.0
Na	85.0	69.0	58.0
K	14.0	11.0	12.0
Ca	8.4	19.0	34.0
Mg	20.0	16.0	29.0
Li	0.3	0.2	0.1
B	0.8	0.5	0.4
TDS	435.4	409.4	456.5
Ec(k)	624.0	570.0	655.0
$TqSiO_2$	64	77	89
$TcSiO_2$	25	40	55
TNa-K-Ca	69	53	50

Table I. Continued

	W14998 Well 38-9, 550' SESW9T23NR40E	W14999 Well 38-9, 1200' SESW9T23NR40E	W15000 Well 38-9, 1300' SESW9T23NR40E
Temp ^{o}C	34	47	47
Flow gpm	25/air lift	115/air lift	125/air lift
pH	8.4	7.9	7.8
Cl	22.0	23.0	23.0
F	4.2	4.2	4.2
SO_4	58.0	53.0	57.0
HCO_3	472.0	538.0	530.0
CO_3	28.0	0.0	0.0
SiO_2	44.0	35.0	35.0
Na	230.0	230.0	230.0
K	18.0	16.0	16.0
Ca	24.0	33.0	35.0
Mg	13.0	11.0	12.0
Li	0.3	0.3	0.3
B	1.2	1.2	1.2
TDS	914.7	944.7	963.75
Ec(k)	1128.0	1190.0	1201.0
$TqSiO_2$	97	89	89
$TcSiO_2$	66	55	55
TNa-K-Ca	171	163	162

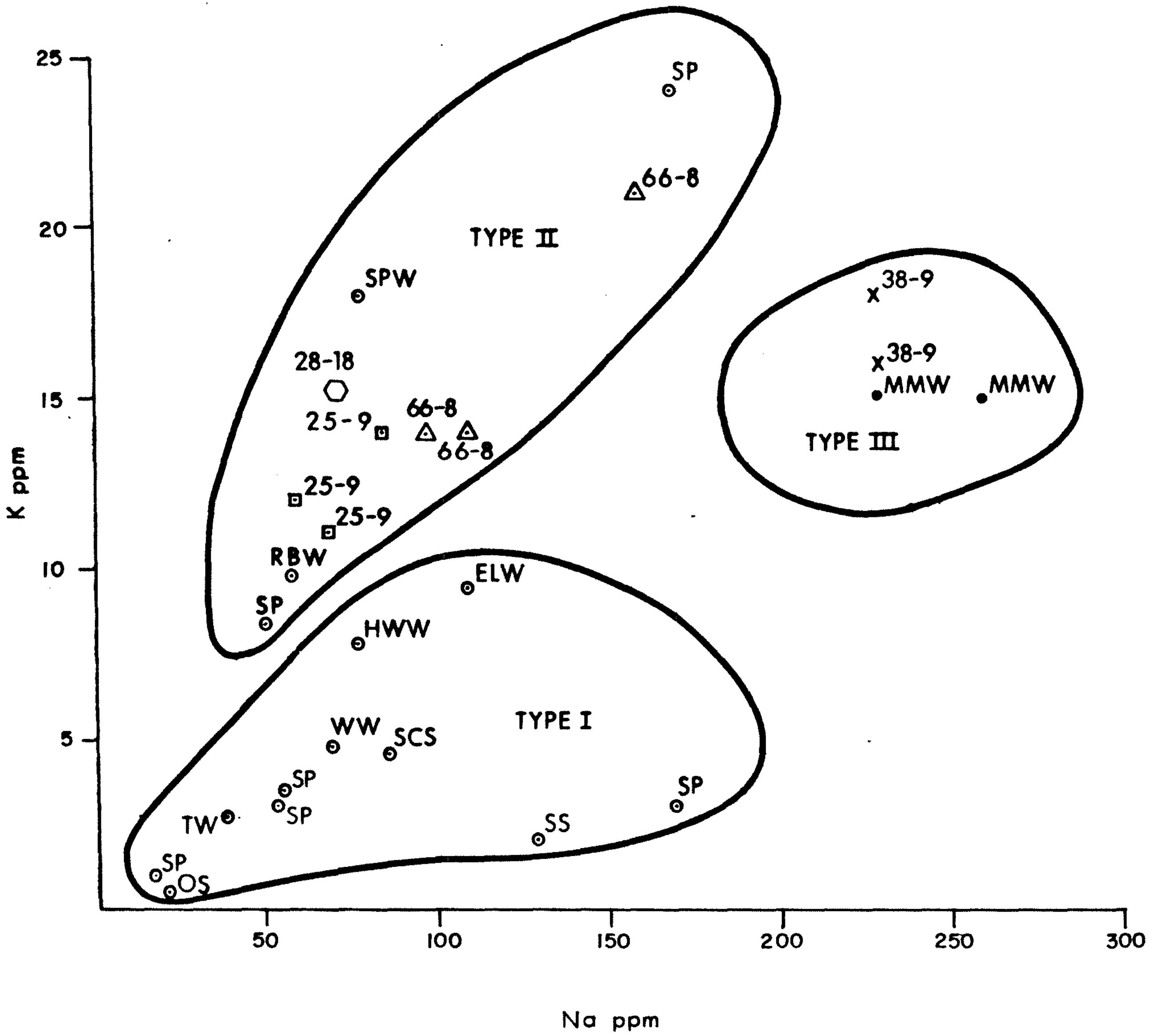


Figure 7. Potassium vs sodium diagram for McCoy waters

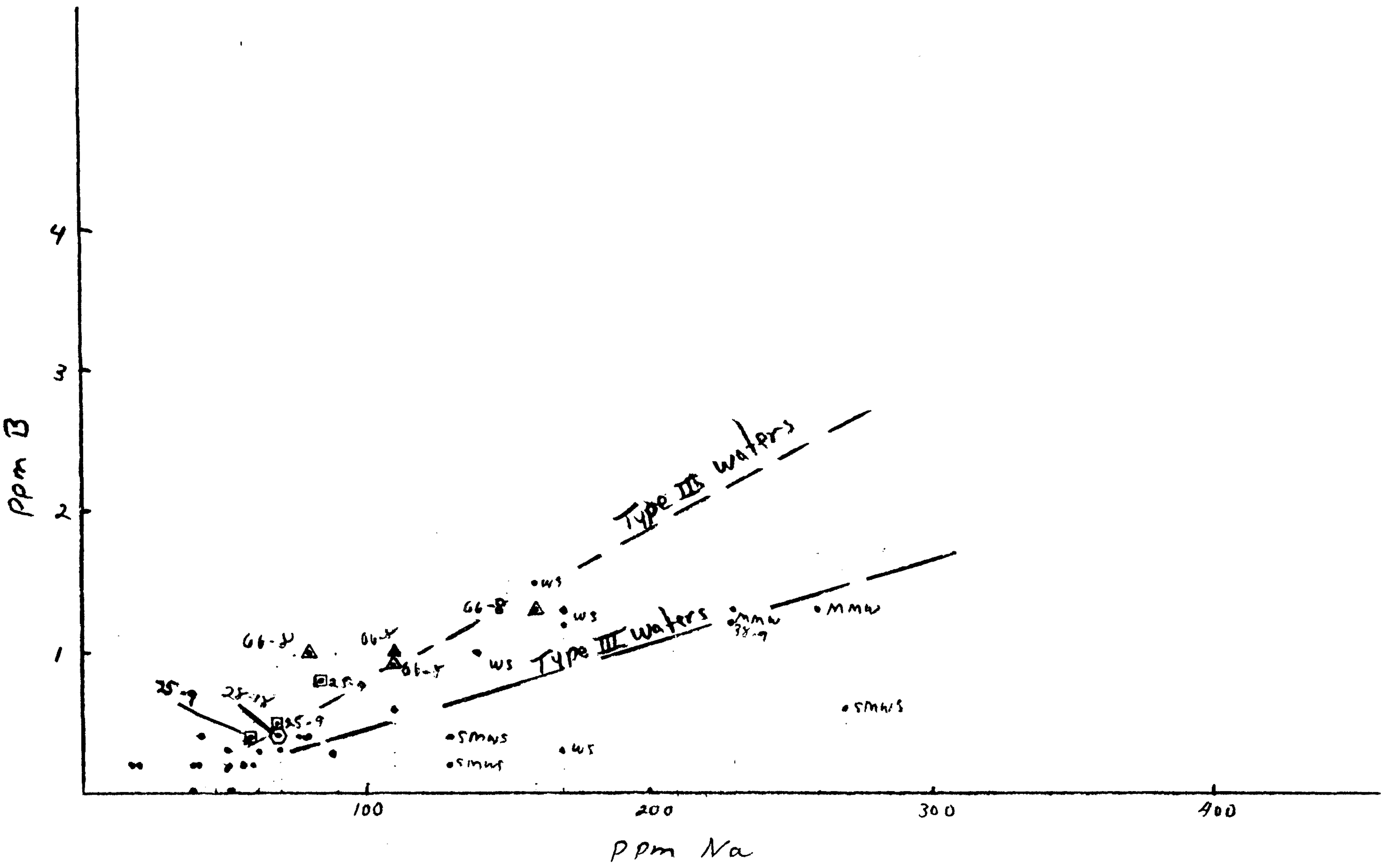


Figure 8. Boron vs sodium diagram for McCoy waters

area (Type III) are characterized by a higher sodium content than the thermal waters from the southern part of the thermal anomaly (Type II). Several spring and water well samples fall within the boundary of the Type II waters which suggests a mixing of thermal and meteoric waters.

A similar two-fold separation of the thermal waters on the McCoy area is seen on the boron versus sodium diagram (Fig. 8). Much of the scatter of points about the two lines is due to water-rock reaction. Some of the warm springs, such as Shoshone Meadows Warm Spring (SMWS) fall to the right of the lines because of the effects of evaporation on small flow springs. The distribution of points along the line for Type II suggests rather complete mixing of thermal fluids and groundwaters.

The nature of mixing can be shown by means of the silica mixing model. Figure 9 is a plot of silica concentration versus temperature using the average ground center valves from Table I and the analyses from the thermal wells. To be perfectly correct the silica solubility should be plotted against enthalpy; however, for temperatures up to 250°C the valves are nearly equal and for convenience temperature will be used. The waters from Well 38-9 north of the McCoy Mercury Mine plot out separately from those in the southern part of the anomaly and the line is extended from the average ground water through the point for Well 38-9 to the quartz solubility curve we obtain a maximum subsurface temperature of 110°C. For the thermal waters in the southern part of the anomaly there are two separate mixing lines. On one line we have the first water sample from Well 66-8 and the sample from well 28-18. Both samples are suspect because very finely ground silica from the drill cuttings and

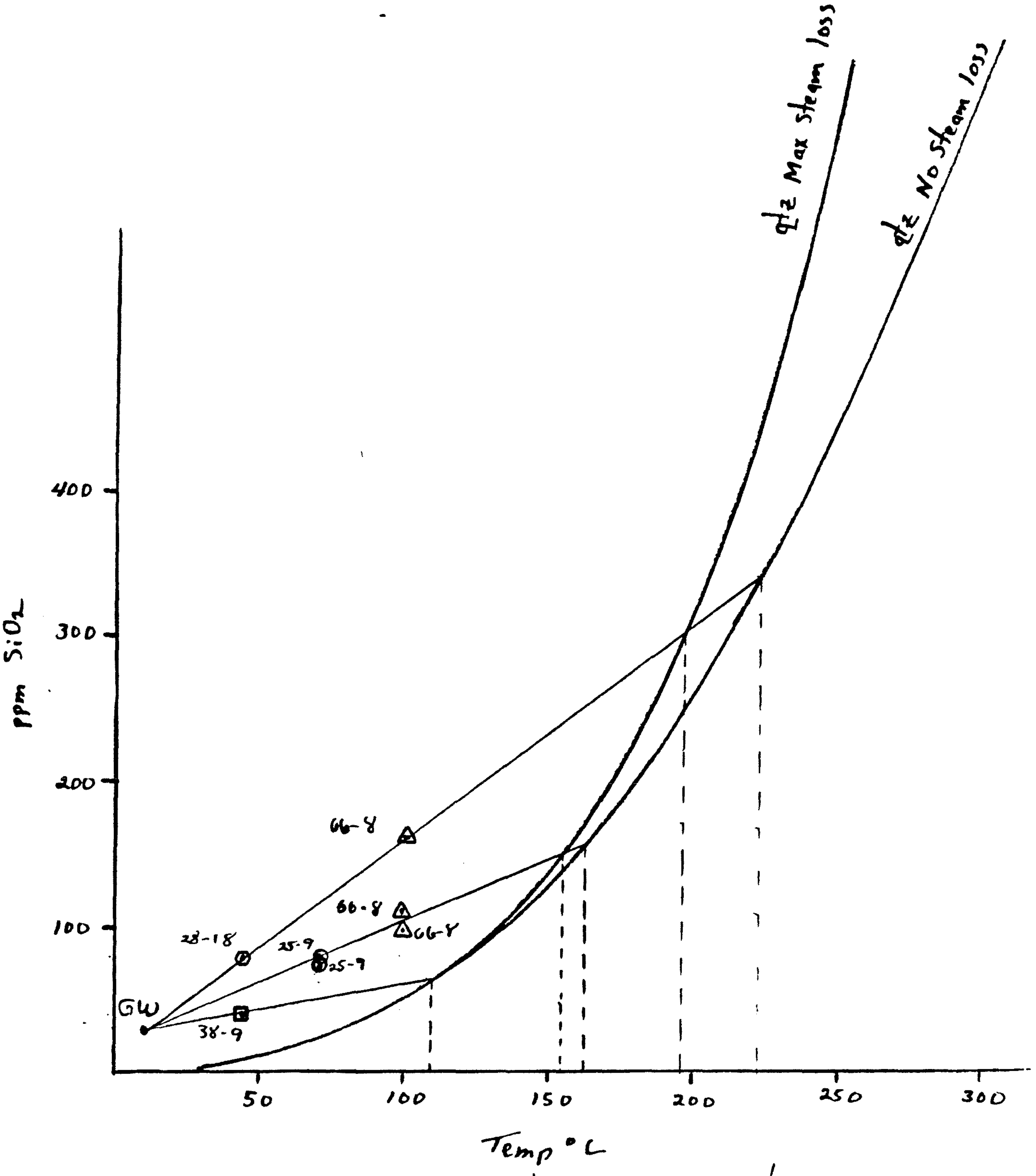


Figure 9. Silica concentration vs temperature diagram for McCoy waters.

both were somewhat soapy. However, if we use those samples we get a maximum subsurface temperature of 195°C if boiling has occurred or 220°C if the fluids have cooled conductively. The bulk of the water samples from the southern thermal anomaly plot out on the intermediate line (Fig. 9) which gives a maximum subsurface temperature of 155°C if boiling has occurred or 163°C if the fuid cooled conductively.

Using the lever principle we can graphically determine the amount of mixing for each of the thermal fluids. The fluids from Well 38-9 contain about 35 percent of a deep component and 65 percent ground water. The fluids along the intermediate mixing line from the southern anomaly contain 41% and 62% deep component respectively.

GEOTHERMAL POTENTIAL

The geothermal exploration at the McCoy prospect has established the presence of two chemically distinct geothermal systems. The purpose of this section of the report is to synthesize what the geological, geochemical and geophysical manifestations tell us about the geothermal reservoir and hence the geothermal potential of the area.

Geological Manifestations

The mercury mineralization and associated hydrothermal alteration at the McCoy Mine and Wildhorse Mine indicate a hydrothermal system has been present in the area, and may indicate the presence of an active geothermal system. North and west of the McCoy Mine is a large travertine deposit which indicates a former hot spring area. The travertine dip westward suggesting some past depostional uplift and erosion has cut through the travertine and into the underlying Mesozoic limestones. Thus the geological indications suggest the presence of a geothermal system in the past and that the reservoir was probably carbonate rocks.

Geophysical Manifestations

The presence of heat must be regarded as the most positive evidence of a possible geothermal resource. The thermal anomaly (Fig. 2) contains three distinct highs which were interpreted as possible hydrothermal convection cells. The question which must be answered for a given thermal anomaly is can the data be projected downward to give the location and depth to either a heat source or to a geothermal reservoir.

Downward Continuation Models

The simplest method of projecting thermal gradient data to depth involves linear extrapolation (Fig. 10). The procedure is valid only in one-dimensional homogeneous half-space; i.e. it assumes no vertical or horizontal changes in thermal conductivity and that the thermal regime is purely conductive. The end result is a approximation which can lead to misinterpretation. For example, the linear extrapolation of shallow

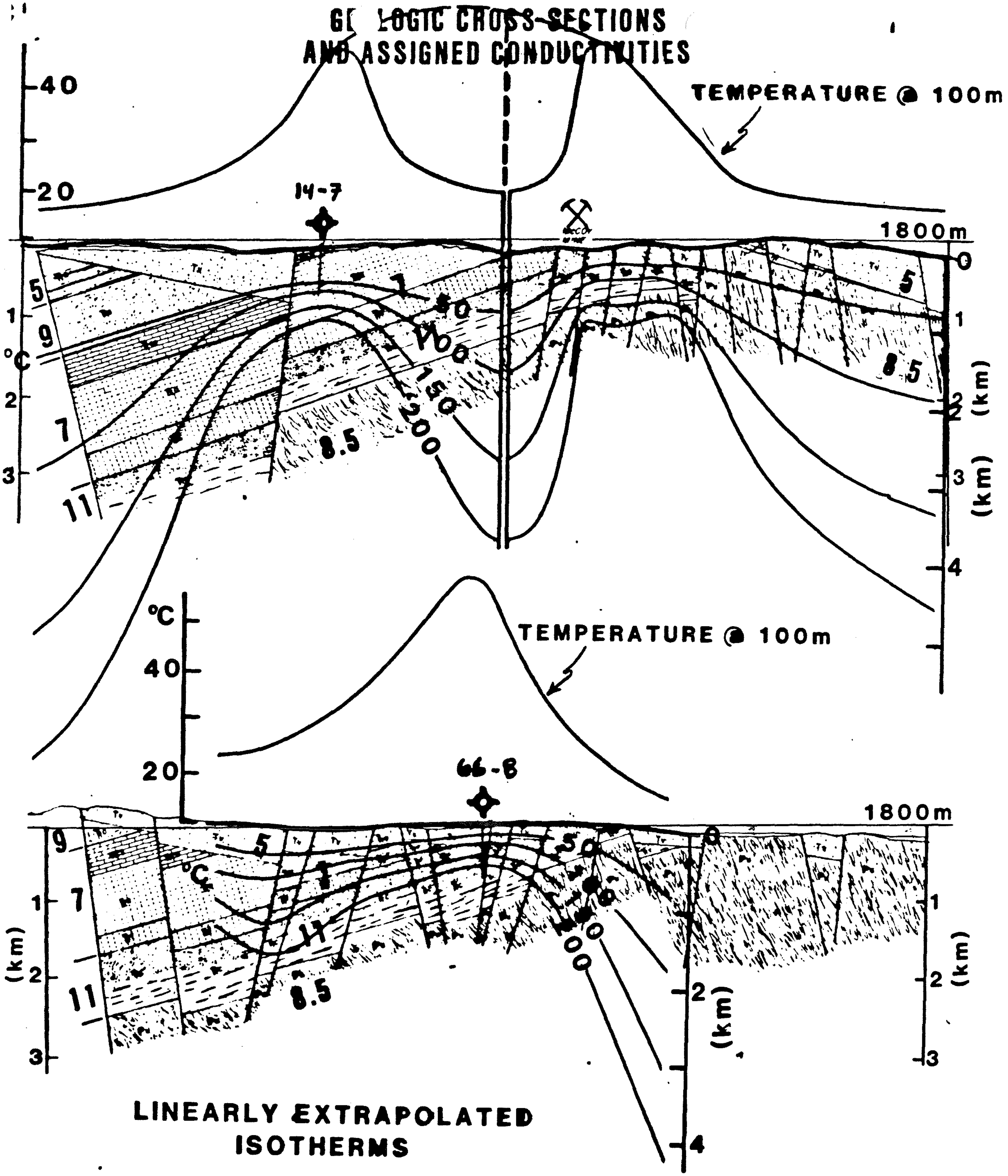
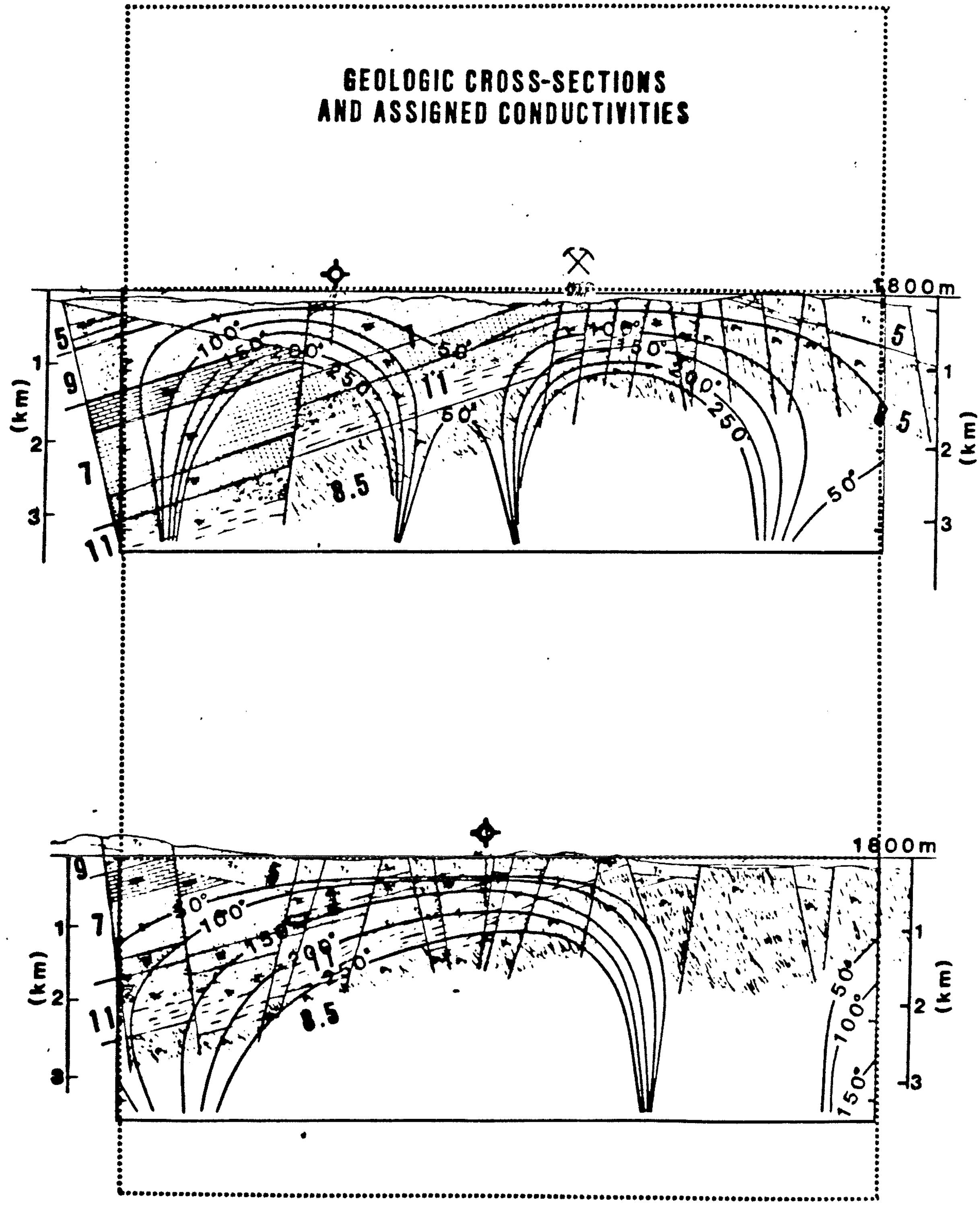


Figure 10. Linearly extrapolated isotherms superimposed upon geologic sections through well 14-7 and well 66-8, McCoy prospect, Nevada (after Pilkington 1980 and Lange,1981).

thermal gradients over the southern thermal anomaly predicted temperatures in excess of 200°C at 2000 feet at the location of Well 66-8. However, when the well was dilled measured bottom hole temperature was 86°C. Well 66-8 penetrated a 100°C aquifer at a depth of 1630 feet which means we can not apply the linear extrapolation method.

A three-dimensional heatflow downward-continuation program (Lange, 1981) has been applied to the McCoy data. The system is based upon patented theory and the thermal model is deduced from a three-dimensional thermal conductivity model. The results of downward continuation in a purely conductive model are shown in Figure 11. The model tends to spread the isotherms and tend to displace them downward; however, the predicted temperatures are still higher than the observed temperatures. The program will model the effects of intervening aquifers by the introduction of zones of very high thermal conductivities (Fig. 12). The simulation further depresses the isotherms so that the final result is much closer to the truth than was the pure conductive model. If one were to attempt to model all three quifers encountered in Well 66-8 perhaps the result would be even closer to the observed temperatures. However the downward continuation program will not allow us to unequivocally define a geothermal reservoir.

DOWNWARD CONTINUATION: PURE CONDUCTIVE MODEL



GEOLOGIC CROSS-SECTIONS
AND ASSIGNED CONDUCTIVITIES

Figure 11. Three-dimensional downward continuation, pure conductive model with isotherms superimposed on geologic sections through well 14-7 and well 66-8, after Lange, 1981.

DOWNWARD CONTINUATION: WITH EXTENDED AQUIFERS

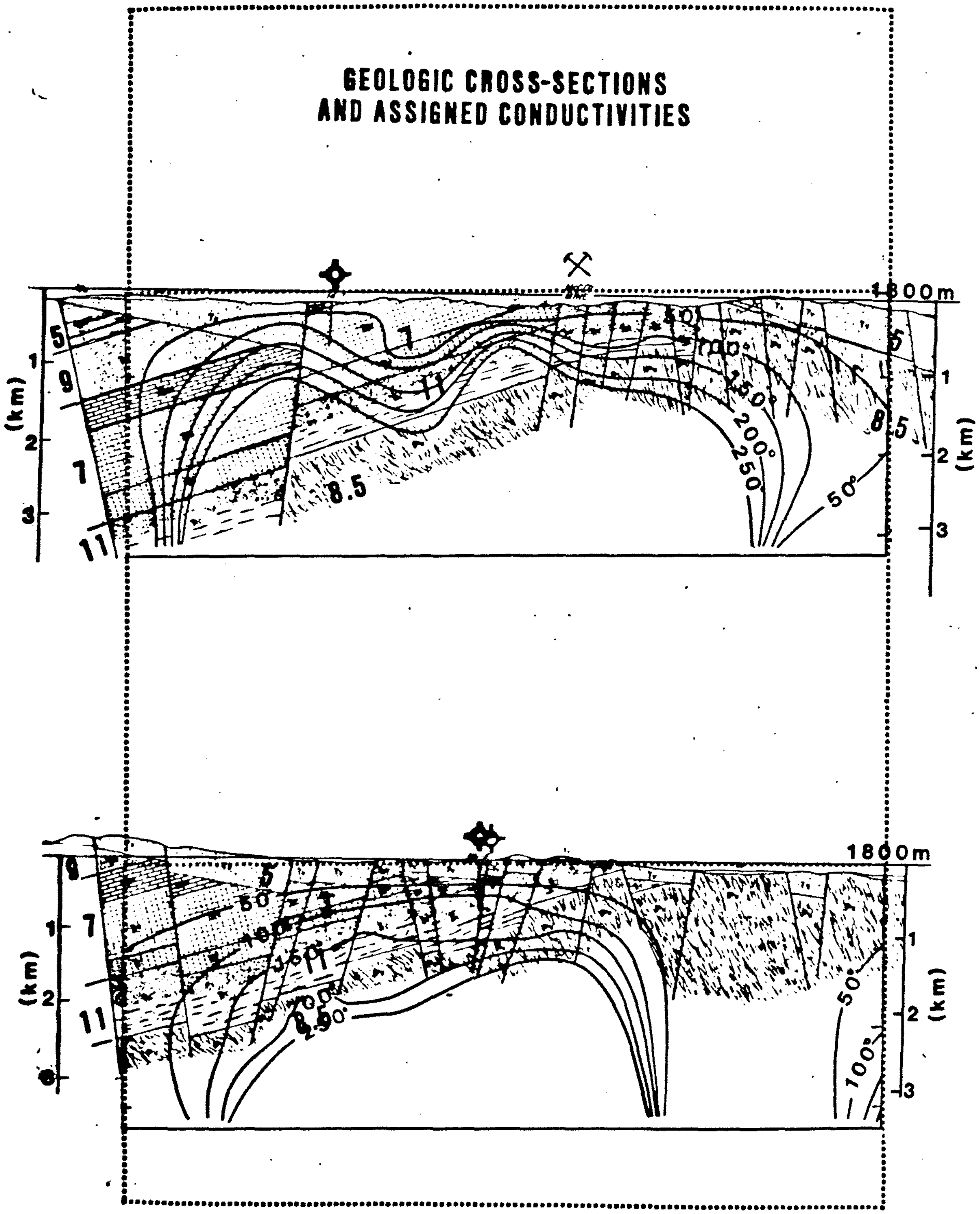


Figure 12. Three-dimensional downward continuation with extended aquifers (Tra limestone at well 14-7 and Trc conglomerate at well 66-8) superimposed on geologic sections, after Lange, 1981.

Wave Number Filtering Models

In May of 1982, Teledyne Geotech proposed a project to develop a method of filtering hot spring noise from shallow temperature gradient data. The consortium did not come into being; however, Teledyne will contract to do the wave filtering technique to shallow thermal well data. As a test of the technique it was decided to apply the Teledyne Geotech two-dimensional wave filtering technique to the shallow thermal gradient data at McCoy. AMAX supplied Teledyne with sixty (60) shallow temperature-depth logs for the study. Thermal gradients were selected from the 30 meter depth interval, and gradients were computed using at least squares fit to the thermal log in the chosen depth interval. The thermal gradient data were then corrected for topography and elevation and all were reduced to a common elevation of 5237 feet. A computer surface thermal gradient map was generated from the corrected thermal data. Four thermal gradient profiles were calculated along lines including the locations of our intermediate depth thermal observation wells. The teledyne two-dimensional wave number filtering technique was then applied to the four profiles and estimates of subsurface temperatures were made for the locations of the five intermediate depth thermal gradient wells.

The northern thermal anomaly appears to contain two thermal aquifers (Fig. 13). The upper isothermal zone, or rollover zone, occurs at a predicted temperature of 74°C from 1500 to 2000 feet depth. Drilling of Well 38-9 has shown one continuous aquifer from 550 to TD at 2000 feet.

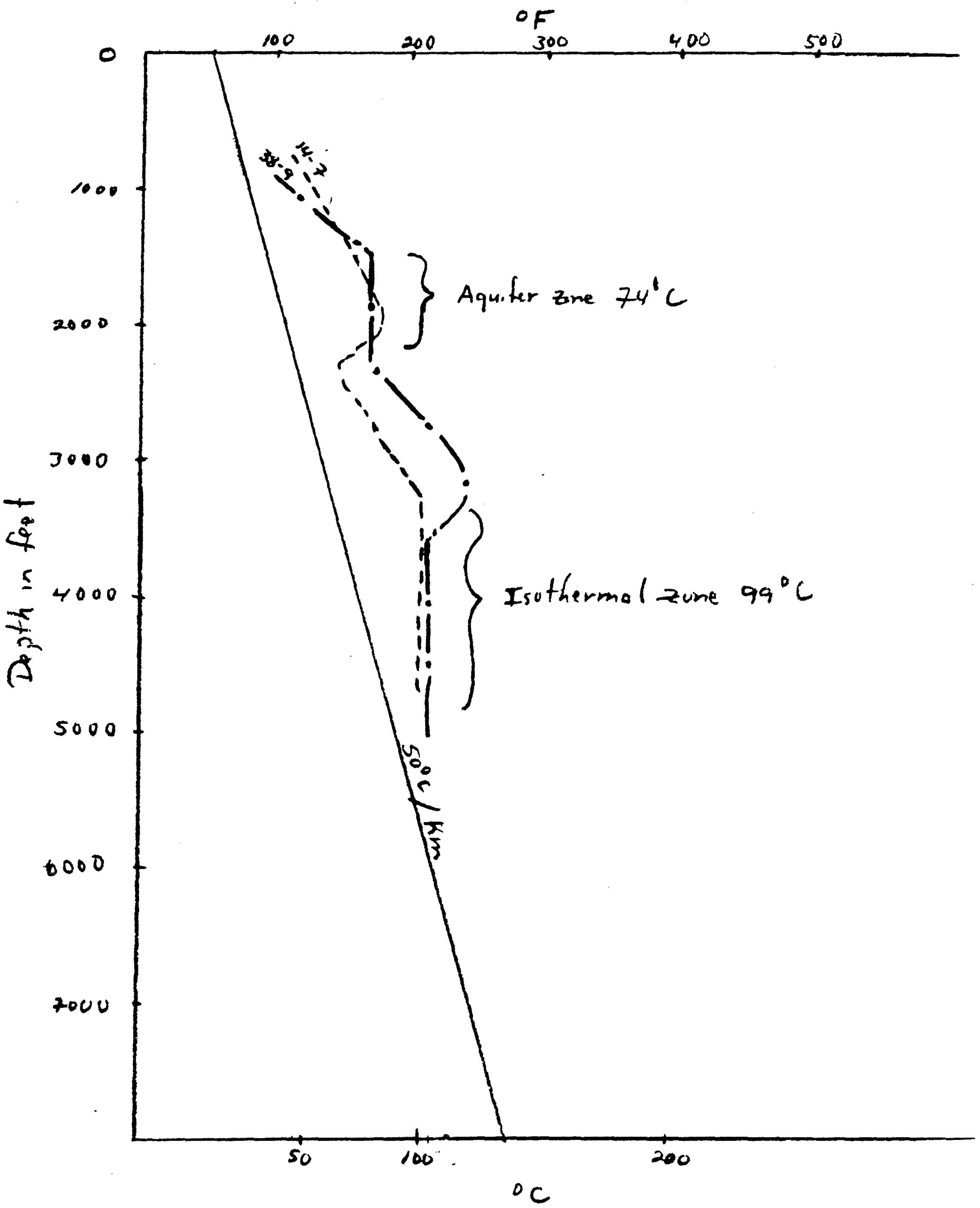


Figure 13. Depth-temperature profiles derived from the Teledyne wave filtering technique, northern thermal anomaly McCoy, Nevada.

The maximum observed temperatures in this zone are 46°C. Well 14-7 was isothermal at 55-60°C from 570 feet to TD. The method predicts a deeper isothermal zone below 3300 feet and continuing to at least 5000 feet (Fig 13) at a temperature of ±100°C..

The southern thermal anomaly may have a deeper, and hotter, source (Fig. 14) as seen on the profiles at the location of Well 66-8 and 25-9. The profile at Well 28-18 (Fig. 14) goes isothermal at 99°C between 2000 and 4000 feet. The profile at Well 66-8 goes isothermal at 113°C from 1300 to 1700 feet, at 135°C from 2000-3300 feet and then gradient shows an increase to at least 5500 feet. Drilling of Well 66-8 established the presence of a geothermal reservoir from 1630 feet TD at 2510 feet at a temperature of 100°C. The profile for the 25-9 location (Fig. 14) has a small isothermal zone at about 150°C between 3000 and 3300 feet. Below the gradient pick up again to about 4000 feet.

GEOCHEMICAL MANIFESTATIONS

Geochemically the thermal waters encountered in the exploration drilling at McCoy fall into two distinct types (Fig. 7 & 8). Table II is a summary of the chemical geothermometers for the thermal waters encountered at McCoy.

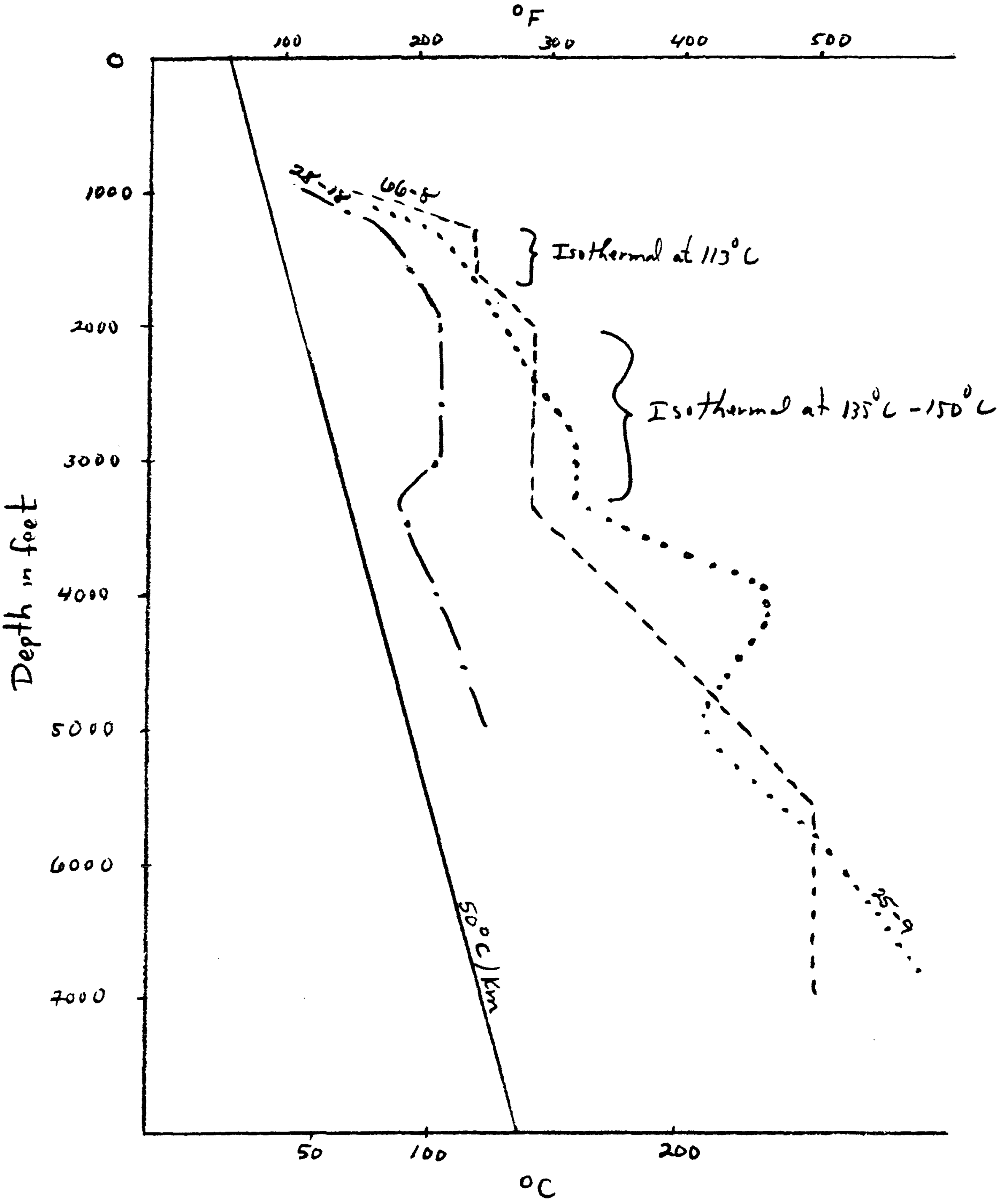


Figure 14. Depth-temperature profiles derived from the Teledyne wave-number filtering technique, southern thermal anomaly, McCoy, Nevada.

Table II Chemical geothermemetry summary, McCoy thermal waters.

Well #	Depth	T°C SiO_2	T°C Na-K-Ca	T°C Na-K-Ca-Mg	T Li	Max Obs. T
66-8	1630'	148*	205	128	142	102
	2050'	120	197	R>50	124	102
	2050'	115	194	R>50	124	102
	2410'	112	197	R>50	131	102
28-18	1470'	123*	207	122	86	62
38-9	550'	97	171	45	116	45
	1200'	89	163	63	116	45
	1300'	89	162	60	116	45
25-9	1640'	64	69	R>50	116	71
	1840'	77	53	51	104	71
	2000'	89	50	R>50	86	71

*High SiO_2 values may be related to contamination by drilling action.

The silica geothermometers for Well 66-8 all indicate subsurface temperatures of 120°C or less except for T_qSiO_2 of 148°C from the first water sample collected. If we throw out the first silica value and the first Li value then the remaining geothermometers agree quite well. The chemical geothermometers applied to average of the other three analyses are: $TSiO_2$ 115°C, TNa-K-Ca 196°C, TNa-K-Ca-Mg 128°C and T_{Li}, 127°C. The Mg correction brings the alkali geothermometer into good agreement with silica for both Well 66-8 and Well 28-18. The general agreement between the silica geothermometer and the alkali or Mg corrected alkali geothermometers in Well 38-9 and 25-9 lend credibility to the values. Thus, for 38-9 the maximum subsurface temperature seen by those waters is 60-62°C and for Well 25-9 it is about 50°C which was equal to temperature of water produced.

The waters of Well 38-9 and Well 25-9 are products of deep circulation along faults and then lateral migration. In Well 25-9 it would appear we are seeing recharge waters.

The waters from Well 28-18 and 66-8 are probably a part of the same hydrological regime and represent waters which migrated downward along faults and fractures to a depth where the rock temperatures were in the 100-128°C range. The waters were heated then moved upward until they reached the appropriate reservoir in the Triassic rocks then moved laterally. Some dilution with cool meteoric water could have occurred.

The silica mixing model (Fig. 9) for Well 66-8 predicts a subsurface temperature of 155-163°C if we throw out the analyses from the first water sample which probably has silica contamination. Thus, the predicted subsurface temperatures based upon the silica mixing model agree well with the temperature predicted by the wave number filtering technique (Fig. 14).

RECOMMENDATIONS

1. The geological, geochemical and geophysical data indicate the northern thermal anomaly is entirely due to near suface low temperature fluids, and therefore has very little geothermal potential. AMAX should be prepared to (a) reduce the size of the unit or (b) drop the unit entirely when the lease payments come due in July, 1983.

2. The data for the southern part of the thermal anomaly suggest some potential. AMAX should retain about 10 sections, 6400 acres, centered on the southern anomaly. The acreage can be retained in a reduced unit or the unit can be dropped entirely. The reduced area will still be available for the SRC portfolio and would also impress potential investors that exploration and evaluation in an ongoing process.

3. If the data from Well 26-8 to be drilled in January 1983 to a depth of 2000 feet is encouraging, we should plan to deepen the well to 4000 feet in July or August, 1983.

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