GL02428

AMAX EXPLORATION, INC.
A SUBSIDIARY OF AMAX INC.

GEOTHERMAL BRANCH

August 20, 1981

Mr. Joseph N. Fiore
Department of Energy
Nevada Operations Office
P .O. Box 14100
Las Vegas, Nevada 89114

Re: McCoy Area

Geothermal-Reservoir Assessment Case History
Northern Basin and Range DE-AC08-79ET27010
Annual Report

Dear Joe:

Pursuant to the provisions of the AMAX/DOE McCoy contract DE-AC08-79ET27010, I am enclosing as the 1980 annual report, three copies of the following:

1. McCoy Area, Nevada, Geothermal Reservoir Assessment Case History Northern Basin and Range, Annual Report, 1/1/80-12/31/80 dated August 1981 by H. D. Pilkington.

Please acknowledge receipt of the above data by returning a signed copy of this letter.

DOE/ET/27010-2

MC COY AREA, NEVADA

Geothermal Reservoir Assessment Case History

Northern Basin and Range

ANNUAL REPORT

1 January 1980 - 31 December 1980

H. D. PILKINGTON

August 1981

WORK PERFORMED UNDER CONTRACT

DE AC 08-79 ET 27010

AMAX EXPLORATION, INC.
7100 West 44th Ave.
Wheat Ridge, CO 80033

DOE/ET/27010-2
Distribution Category

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PREPARED FOR THE U. S. DEPARTMENT OF ENERGY
DIVISION OF ENERGY TECHNOLOGY

Under Contract DE AC 08-79 ET 27010

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ABSTRACT

The McCoy geothermal prospect is located at the junction of the Augusta Mountains, Clan Alpine Mountains and the New Pass Range. The prospect was discovered in 1977 and in 1978 was made a part of the Geothermal Reservoir Assessment Case Study Program of the Department of Energy under contract DE-AC 08-79 ET 27010.

Geothermal exploration done during 1980 included geological and geochemical studies. Geophysical work included interpretation of gravity data, a tensor MT survey and an EM-60 survey by the Lawrence Berkley Laboratory. Two intermediate depth exploration wells were completed in 1980.

A shallow low-temperature geothermal reservoir was encountered in the Triassic rocks. The analysis of the exploration continued in an attempt to determine the source area for the thermal fluids.

INTRODUCTION

The McCoy geothermal prospect was discovered in 1977 during reconnaissance coverage of Nevada. The prospect was identified by thermal gradient measurements of existing holes and hydrogeochemical analysis of well water from the McCoy Mine water well. The prospect is located approximately 72 kilometers northwest of Austin, Nevada (Figure 1) and can be reached by means of a graded road which leads from U. S. Highway 50.

The McCoy prospect is located at the confluence of the Augusta and Clan Alpine Mountains and the New Pass Range. The prospect straddles the Churchill and Lander County borders.

In 1978 AMAX submitted a proposal in response to the Department of Energy's RFP No. ET-78-R-08-003, Geothermal Reservoir Assessment Case Study, Northern Basin and Range and was awarded a contract providing partial funding for exploration at the property. Detailed results of the work funded through the DOE will be published by the DOE through the University of Utah Research Institute (UURI) under DOE contract DE-AC 08-79 ET 27010.

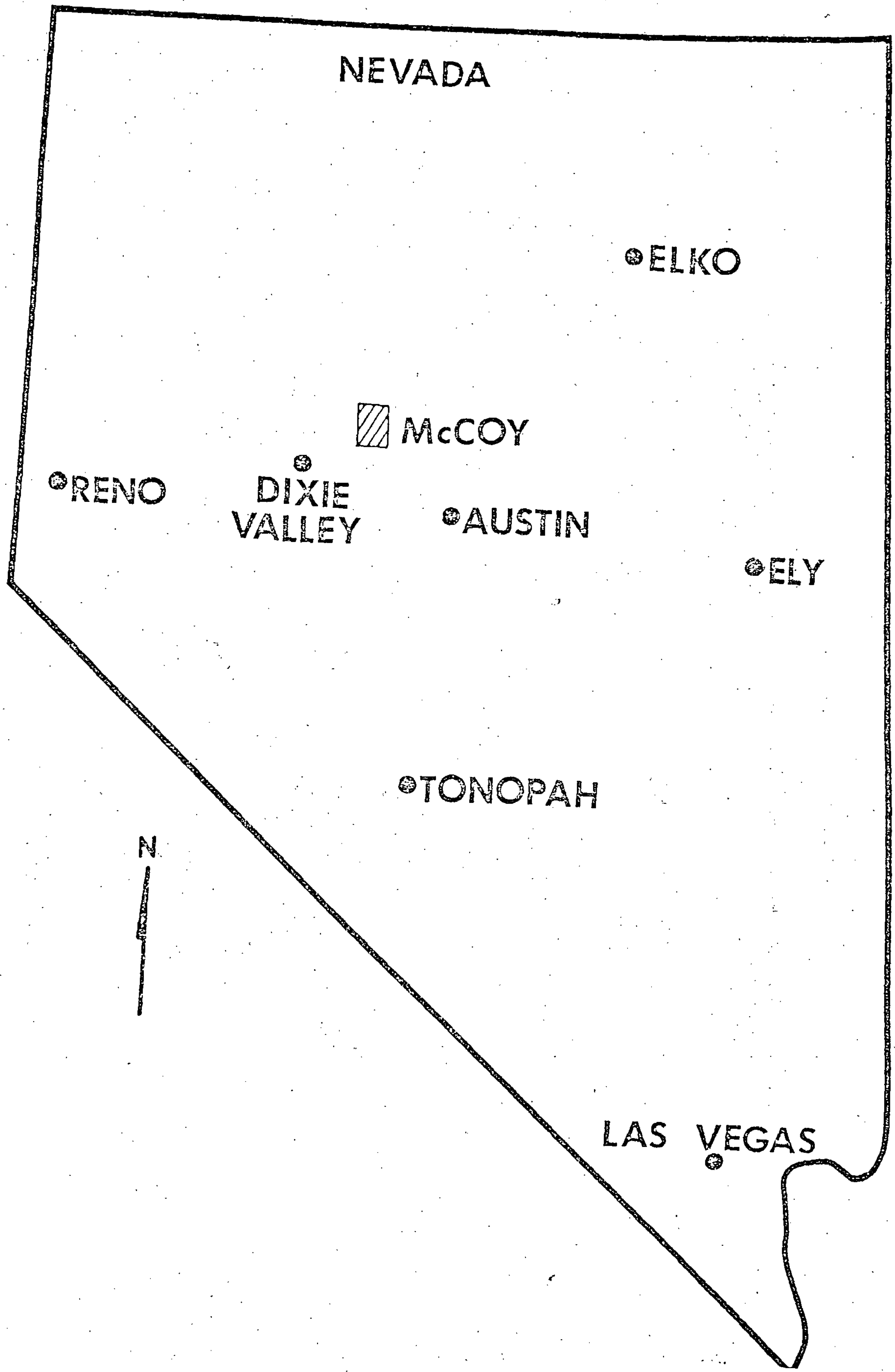


Figure 1. Location map for the McCoy geothermal project.

EXPLORATION HISTORY

The geothermal exploration partially funded under DOE contract DE AC08-79 ET 27010 was an integrated approach including geological, geochemical and geophysical studies as well as exploration drilling. For the purpose of this report the exploration will be discussed under exploration methods rather than a chronological description.

GEOLOGICAL STUDIES

The McCoy geothermal prospect is located at the junction of the Augusta Mountains, the Clan Alpine Mountains and the New Pass range. The area is underlain by Tertiary volcanics and associated sediments, Triassic sediments and Permo-Pennsylvanian eugeosynclinal sediments as shown on the county maps (Stewart, J. H. and McKee, E. H., 1977 and Wilden, R. and Speed, R. L., 1974). The county geologic maps are at a scale of 1:250,000 and, therefore, do not show much detail.

In the late fall of 1979 Joe Moore of the University of Utah Research Institute began a geologic mapping program under DOE contract DE-AC 07 - 80 ID 12079. Joe Moore and Eric Struhsacker established the mapping units in the Tertiary volcanics and then Mike Adams of UURI did most of the field mapping in 1980. A detailed geologic map at a scale of 1:24,000 has been completed (Figure 2).

The oldest rocks mapped in the McCoy area are the cherts, volcanics, siltstones, sandstones and minor limestones of the Havallah sequence of Permo-Pennsylvanian age. The rocks were deformed, uplifted and deeply eroded prior to the deposition of the basal Triassic sediments which

817	Qal	Alluvium
867	QTt	Hot Springs deposits- Travertine/some silica
832	Ts_2	Tuffaceous sediments
854	Tad_2	Andesite and dacite flows and intrusives
846	Tbm (8c, 8b, 8a)	Bates Mountain Tuffs-crystal poor rhyolite tuff with 3 cooling units. 23-24 m.y.
864	Tmm (7c, 7b, 7a)	McCoy Mine Tuffs-usually has three cooling units. 26 m.y.
813	Tec (6g, 6f, 6e, 6d, 6c, 6b, 6a)	Edwards Creek Tuff-ash flow tuff with up to 7 cooling units. Sometimes contains sediments (Tsi) between cooling units. 27 m.y.
853	Twt_5, Twt_4 (4c, 4b, 4a), Twt_3, Twt_2, Twt_1	Welded Tuffs-ash flow tuffs with five recognizable map units. Unit 4 may contain 3 cooling units. Often has sediments (Tsi) in place of a particular unit, and may sediment separating Twt from Tec. 29-30 m.y.
893	Tvo	Older volcanics
883	Tf	Fanglomerate
845	Kg	Granodiorite to quartz monzonite. 69-104 m.y.
844	Ja	Gabbro of the Humbolt lopolith. 150-165 m.y.
848	TRo	Osabb Formation-sandstone, conglomerate, shale, minor ls.
888	TRcs	Cane Spring Formation-massive limestone and dolomite; minor shale and conglomerates.
868	TRa	Augusta Mountain Formation-massive limestone with minor dolomite, shale and conglomerate.
858	TRf (TRu, 895)	Faveret Formation-thin bedded ls/calcareous shale and siltstone dark grey to black.
879	TRc (TRu, 895)	Conglomerate with purple siltstone and tuffs in lower part.
805	Ph	

TRu- undivided

Bracketed with Tec, Twt and Tvo:

862	Ts_1	Sandstone, conglomerates and tuffaceous sediments.

Bracketed with Tbm through Kg:

866	Tr	Undifferentiated rhyolitic rocks. 22-30 m.y.
844	Tad	Older andesite and basalts.

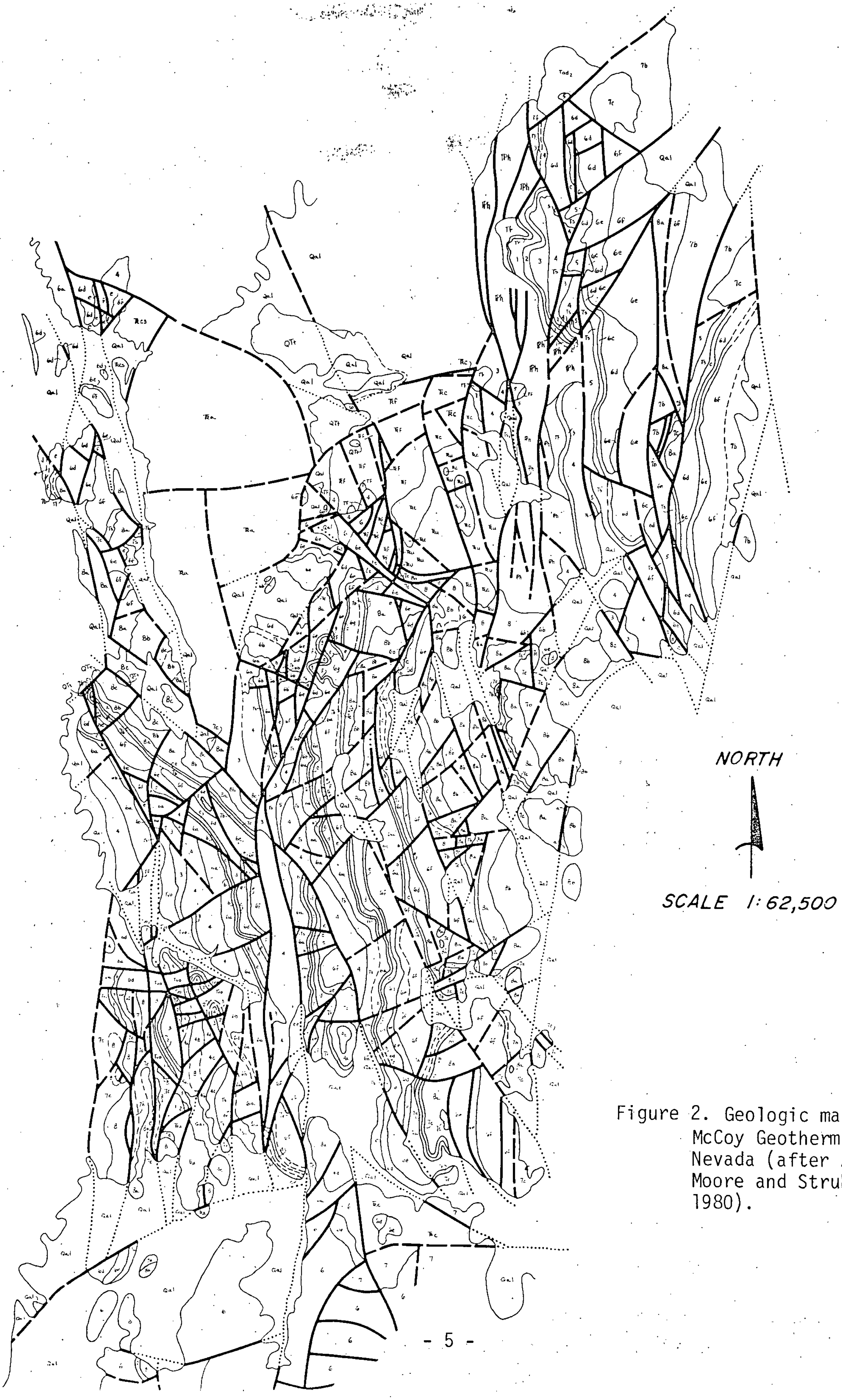


Figure 2. Geologic map of the McCoy Geothermal Prospect Nevada (after Adams, Moore and Struhsaker, 1980).

consist of conglomerates, siltstones, sandstones and minor tuff. The basal member is overlain by several hundred feet of dominantly carbonate sediments of the Favret Formation, the Augusta Mountain Formation and the Cone Springs Formation. The uppermost Triassic unit is the detrital sediments of the Osobb Formation.

The Tertiary volcanic rocks in the McCoy area (Fig. 2) range in age from about 36 m.y. to 15 m.y. (McKee and Stewart, 1971). Sedimentary rocks are found at various horizons within the volcanic units. A considerable thickness of sediments overlie the volcanic rocks to the northwest of the McCoy Mine area. West of the McCoy Mine over $2km^2$ of fossil Quaternary travertine is exposed. The travertine lies unconformably upon the eroded Triassic rocks. The travertine dips gently westward and is only slightly dissected.

Tectonically the area has had a long and complex history. The detailed mapping permitted the construction of detailed geologic cross section (Fig. 3). Reasonable approximations of the fault offsets could be made using the displacement of cooling units on Mike Adams geologic map.

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 McCoy area. During the exploration drilling in 1980 water was encountered in well 66-8. Table I compares the chemical analyses from McCoy Mine well and exploration well 66-8.

GEOLOGIC CROSS-SECTIONS

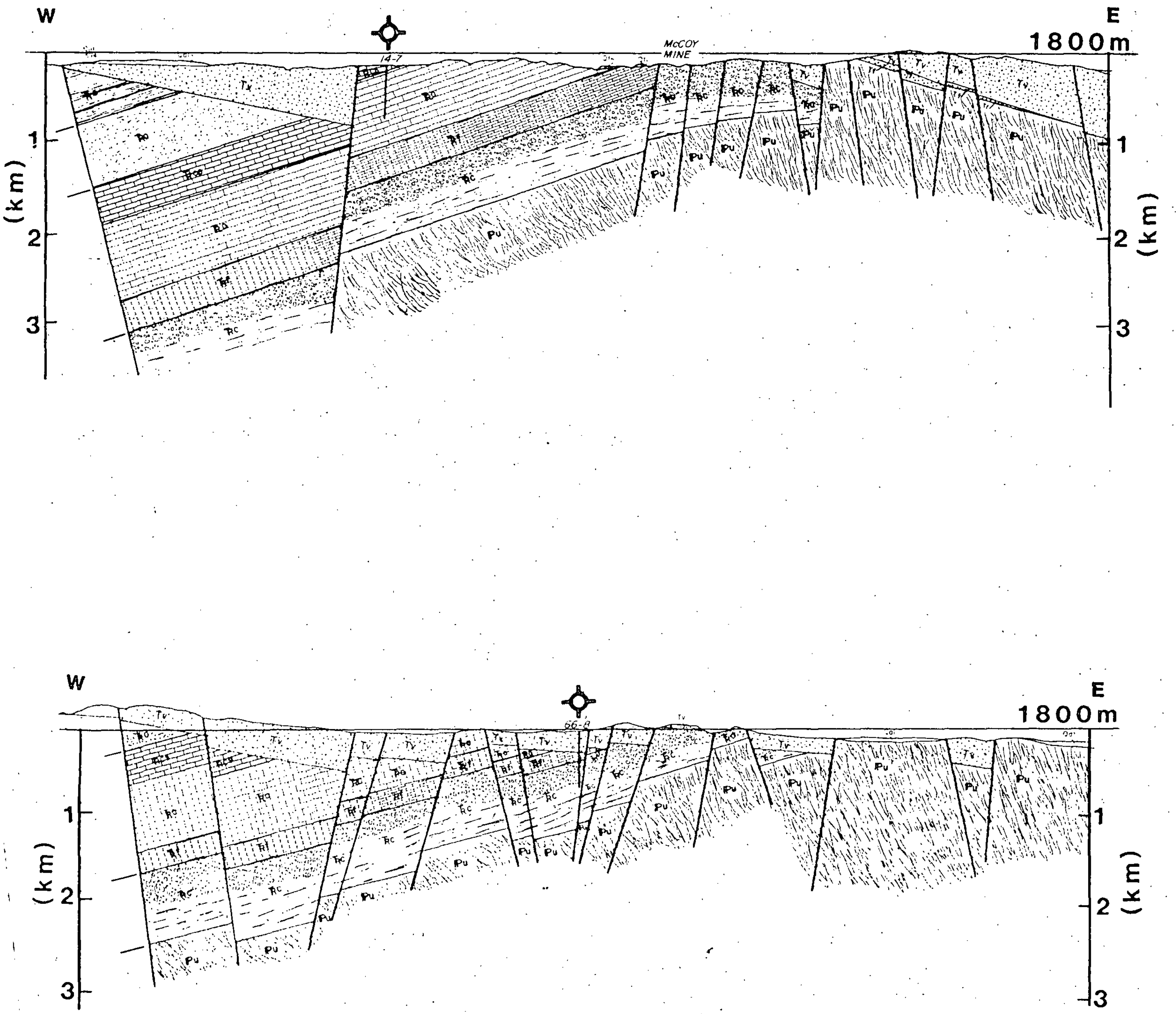
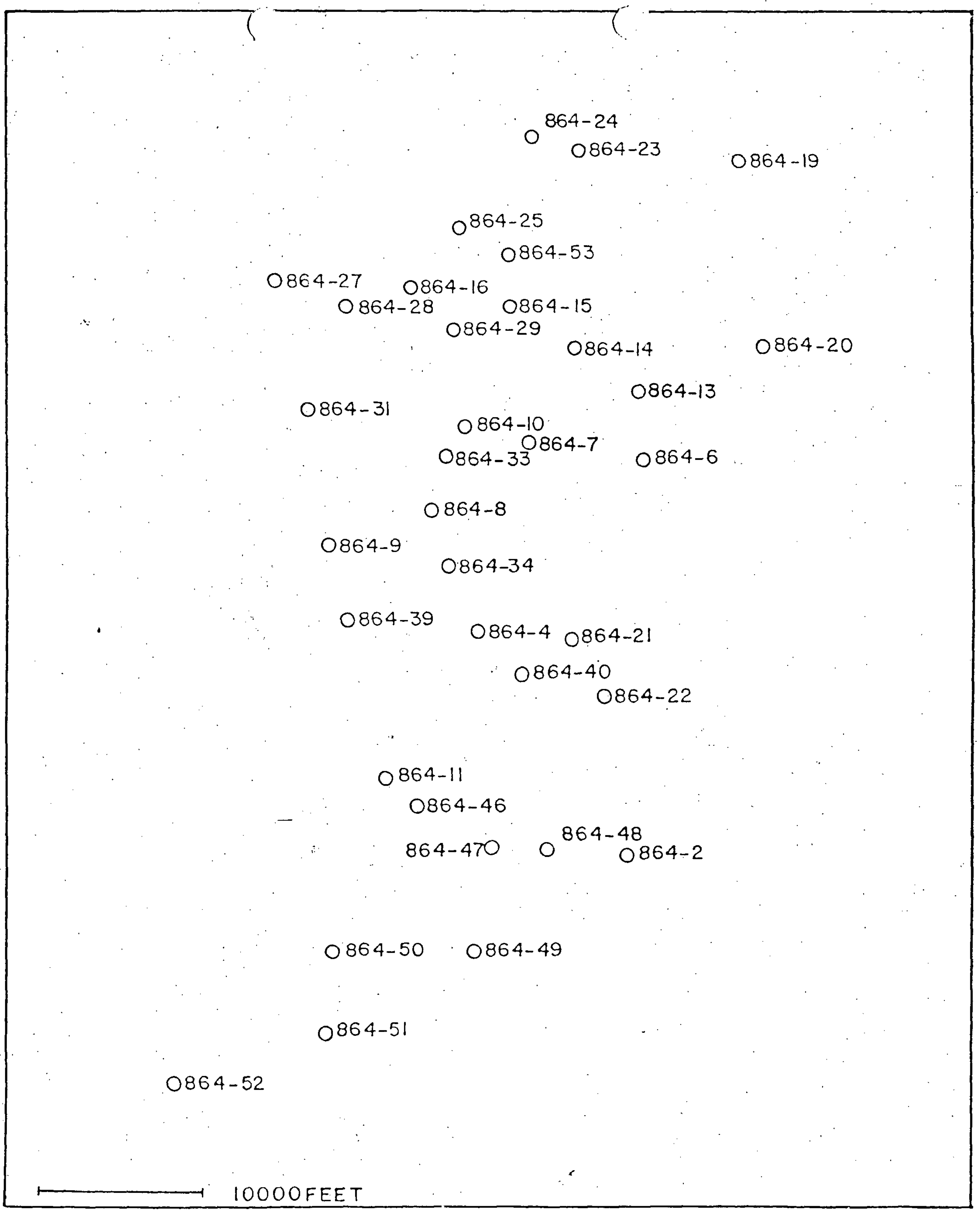


Figure 3. Geologic cross-sections through well 14-7 (Top) and well 66-8 (bottom) after Pilkington, 1980.

Table I. Chemical analyses of McCoy Mine Well and Well 66-8

	W 10981 McCoy H. W. Sec.9T20NR40E	W13453 Well 66-8, 1630' NWSE 8,T22NR40E	W13454 Well 66-8, 2050' NWSE 8,T22NR20E	W13456 Well 66-8,2410' NWSE 8, T22NR40E
Temp°C	39	±100	-	-
Flow (gpm)	-	25	-	-
pH	7.05	9.4	9.1	9.0
Cl	22.0	38.0	31.0	31.0
F	4.4	5.6	3.0	4.1
SO_4	54.0	100.0	100.0	80.0
HCO_3	611.6	144.0	142.0	204.0
CO_3	0.0	72.0	24.0	20.0
SiO_2	44.0	120.0	75.0	62.0
Na	260.0	160.0	98.0	110.0
K	15.0	21.0	14.0	14.0
Ca	43.0	6.6	9.6	6.0
Mg	9.0	2.6	16.0	18.0
Li	0.3	0.7	0.4	0.5
B	1.3	-	-	-
NH_3	0.74	-	-	-
TDS	1065.3	670.0	513.0	550.0
Tq SiO_2	98	148	120	112
Te SiO_2	66	122	94	83
T Na-K	174	242	250	239
T Na-K-Ca(1/3)	153	206	197	197
T Na-K-Ca(4/3)	-	-	-	-
T Na-K-Ca/ Mg corr.	75	95	-	-



MCCOY GEOTHERMAL — DRILL HOLE MAP

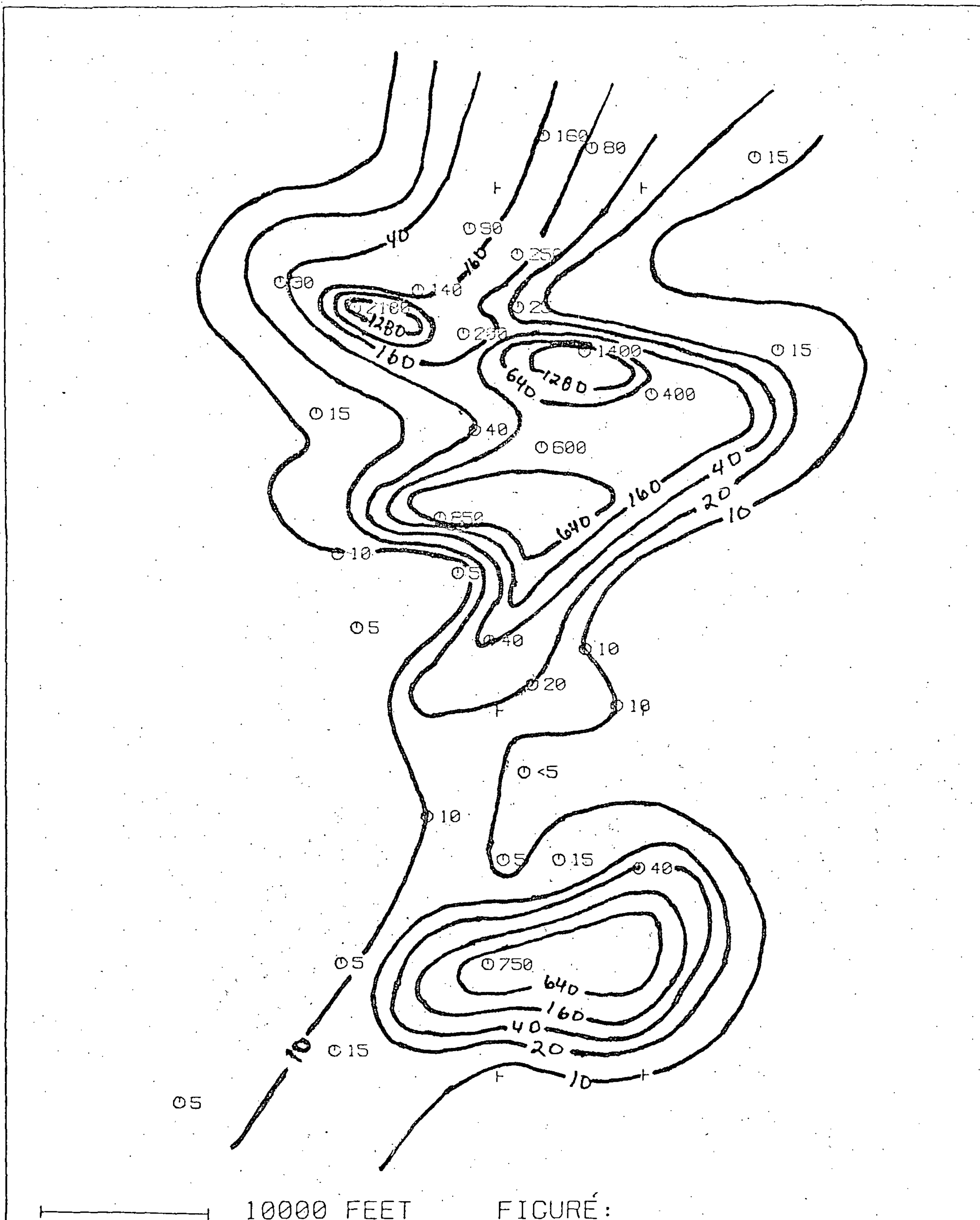
Figure 4. Location map of drill holes used in geochemical study of drill cuttings.

Chemically the waters from Well 66-8 and the McCoy Mine well are sodium bicarbonate waters with projected subsurface temperatures of 98-148^{o}C based upon the conductive quartz geothermometer and 153^{o}-206^{o} using the N-K-Ca geothermometer.

In 1979 Joe Moore of the University of Utah Research Institute proposed to undertake a geochemical study of the drill cuttings from McCoy. AMAX agreed to provide Joe with a split of our samples. UURI prepared composite samples for the intervals of 0-40, 40-80, 80-120 and 120-160 feet for each shallow thermal gradient hole (Figure 4). The geochemical study was done under DOE contract DE-AC 07-80 ID 12079. Multielement geochemical analyses using Inductively Coupled Plasma-Atomic Emission Spectroscopy (Moore 1980) were performed on each composite sample. Preliminary analysis of the data from Joe Moore indicates that Zn, As, Pb, F and Hg show some correlation with the thermal anomaly and also with the known areas of hydrothermal alteration and mineralization. Figure 5 shows the contour map for mercury for the interval 120-160 feet. The contour pattern appears to emphasize certain structural directions and the linear trends become more pronounced with depth (Pilkington, 1980).

Geophysical Studies

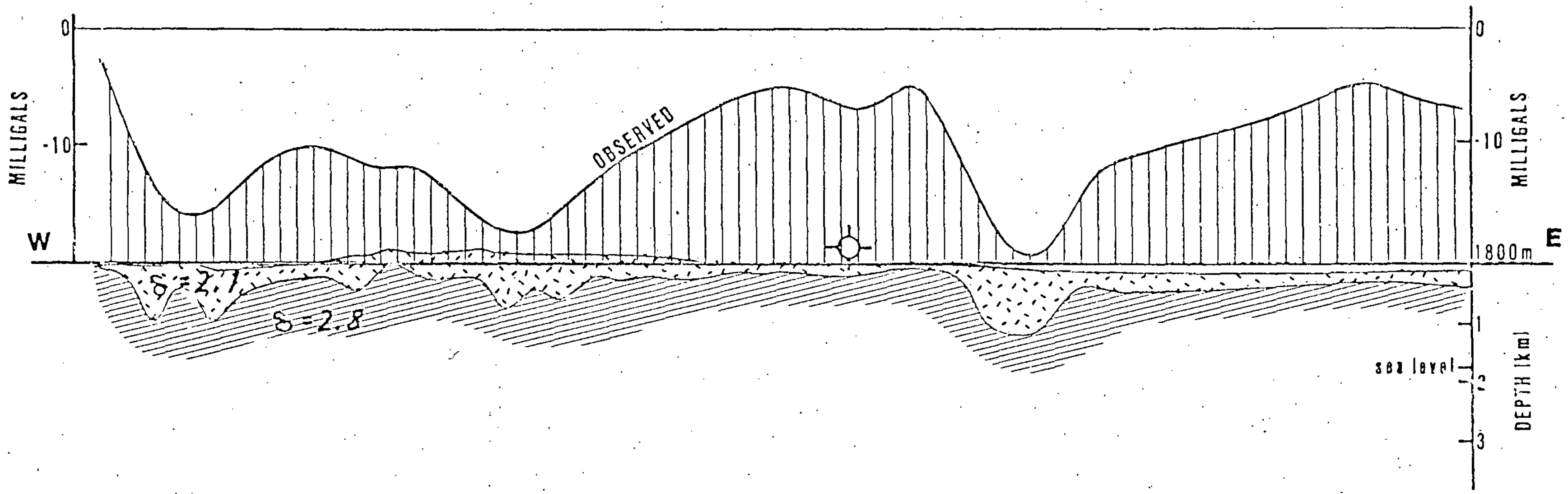
A gravity survey of 340 stations was conducted by AMAX and Microgeophysics in 1979 and Fred Berkman has been involved in the analysis of the data. Berkman prepared a residual gravity profile (Complete Bouguer) and depth analysis along an east-west line through well 66-8 (Figure 6) as reported by Lange, 1980. The gravity interpretation (top) is compared with the geologic cross-section by Pilkington (1980) on the bottom part of Figure 6.



MCCOY GEOTHERMAL AREA (D)
LANDER & CHURCHILL. NV

MERCURY (PPB) 120-160 ft.
SAMPLE TYPE:
ANALYTICAL METHOD: GOLD FILM

Figure 5. Contour map of mercury in drill cuttings from 120-160 ft interval at McCoy (Pilkington, 1980).



RESIDUAL GRAVITY PROFILE (COMPLETE BOUGUER) AND DEPTH ANALYSIS

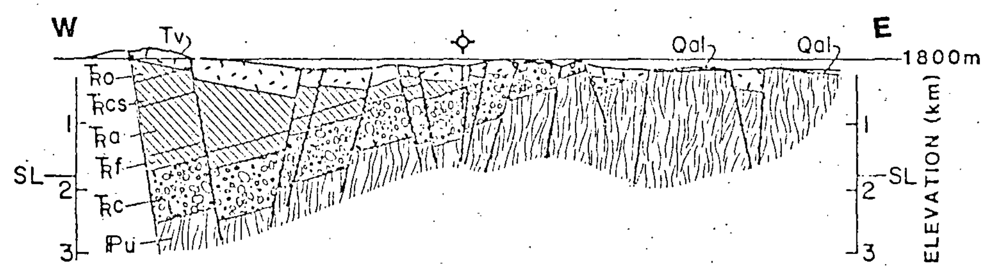


Figure 6. Gravity profile with automatic interpretation for densities (top) compared with geologic cross-section (bottom).

A tensor MT survey was run by Terraphysics in February 1980 (Lange, 1980) at the McCoy property (Fig. 7). The location of the lines along which the MT survey was done are shown on Figure 7. The resistivity as deduced by Lange (1980) at a depth of 5 km from the ID inversion of the MT (Te mode) is also shown on Figure 7. The MT section along line C-C' (Figure 8) illustrates the correlation with geology. Lange (1980) believes the MT sees a deep reservoir, (three or more kilometers) along line C-C' which is leaking fluids up the faults bounding the horst block east of well 66-8.

As a part of the Department of Energy's program to stimulate the development of geothermal resources Lawrence Berkley Laboratory (LBL) conducted a survey with the EM-60 frequency domain system over the McCoy prospect (Wilt, M. et al, 1980). The stations for the LBL survey are shown in Figure 9. The survey consisted of 19 frequency-domain electromagnetic soundings from three transmitter loops. A comparison between the EM data from LBL and the AMAX MT data is shown in Figure 10. Wilt et al (1980) conclude that the EM results agree well with the data gathered from well 66-8. A conductor was found at the approximate depths that boiling water was found in the well. The EM does give information on the shallow depths where MT does not give reliable results.

Exploration Drilling

Two intermediate depth exploration wells were completed in 1980. Well 66-8 located in the NWSE Sec. 8 T22N R40E had a TD of 765 meters (2510') and well 14-7 located in the SE NW Sec. 7 T23N R40E had a TD of 613m (2010').

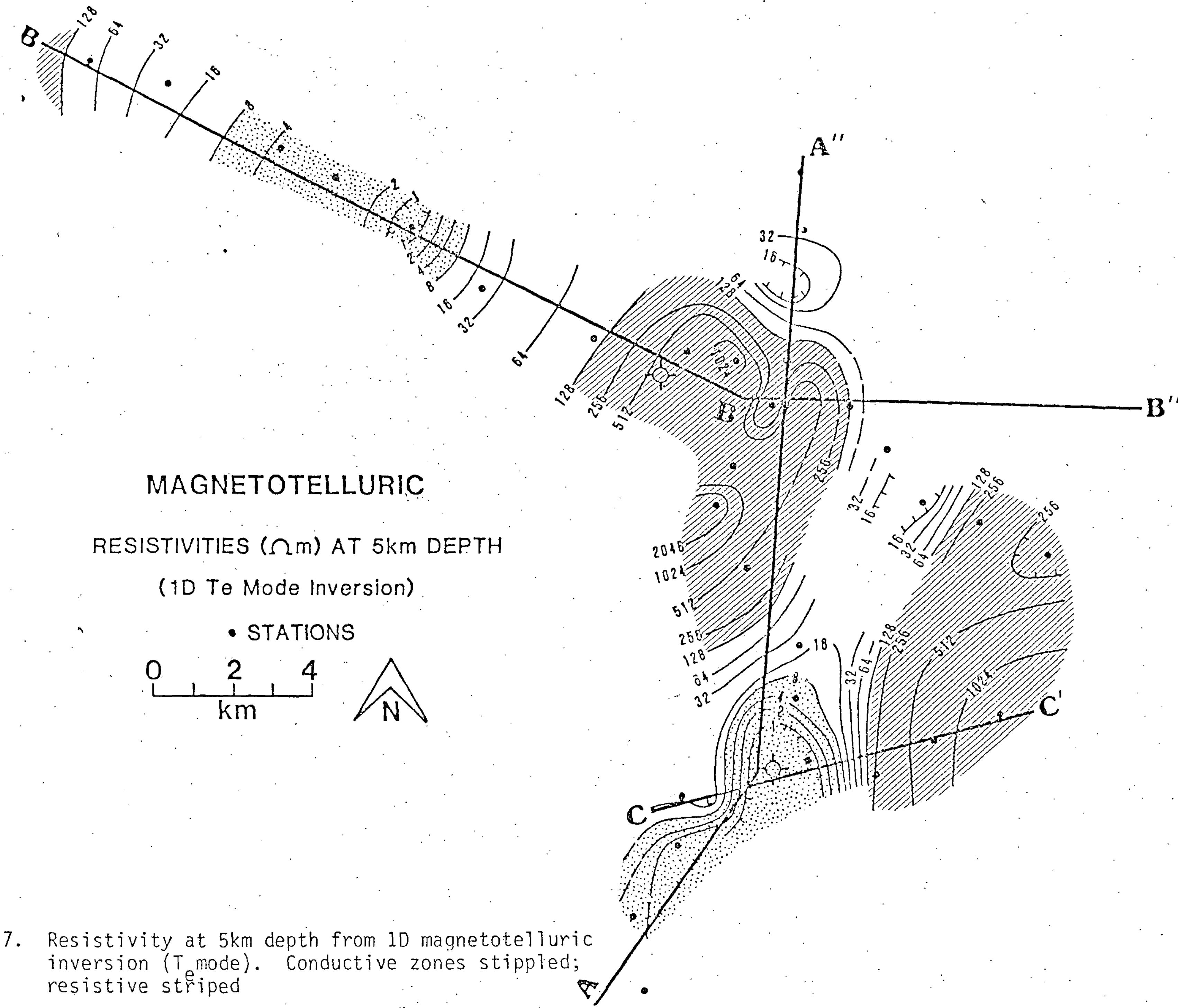
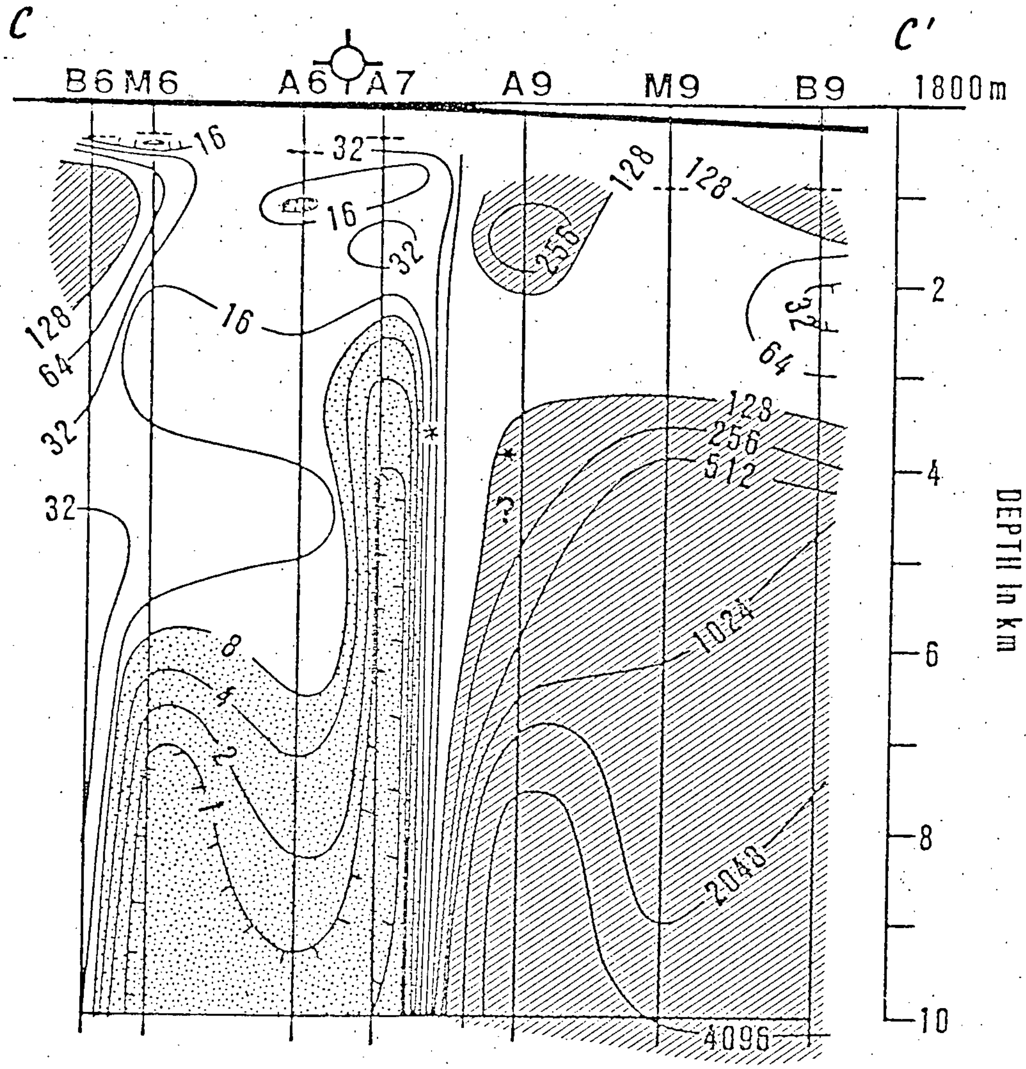
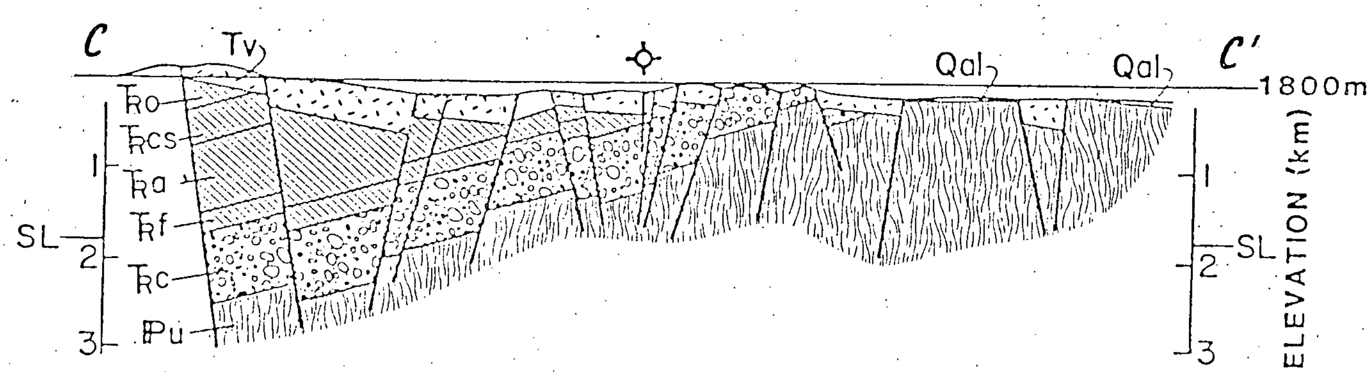


Figure 7. Resistivity at 5km depth from 1D magnetotelluric inversion (T_e mode). Conductive zones stippled; resistive striped





C-C′
MAGNETOTELLURIC 1-D INVERSION WITH GEOLOGIC PROFILE

Figure 8. MT section (T_e mode, 1D inversion) along Line C, compared with geologic section

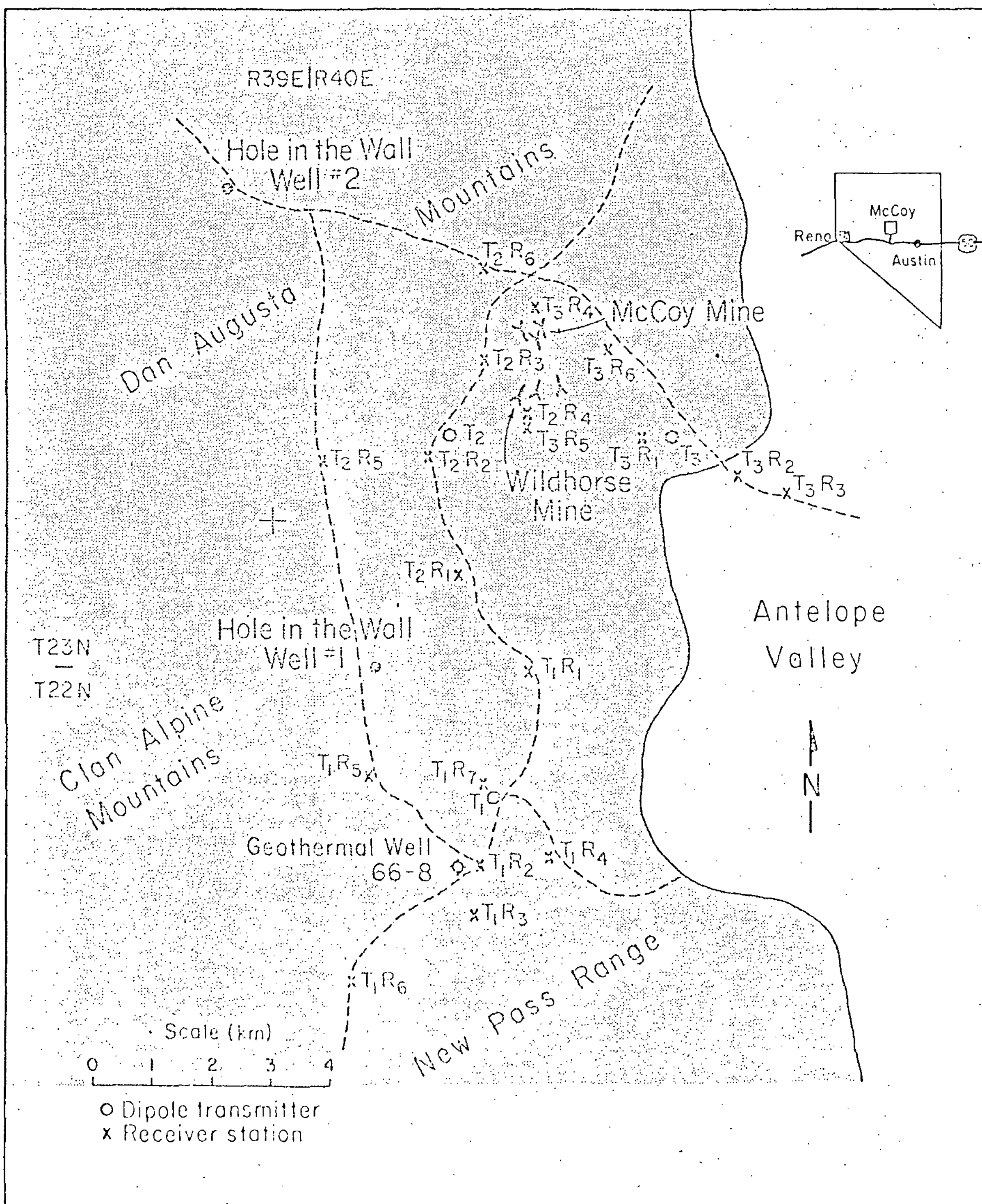


Figure 9. Survey location map of the McCoy prospect. after Wilt et al, 1980.

MAGNETOTELLURIC 1-D INVERSION WITH EM PROFILE A-A'-A''

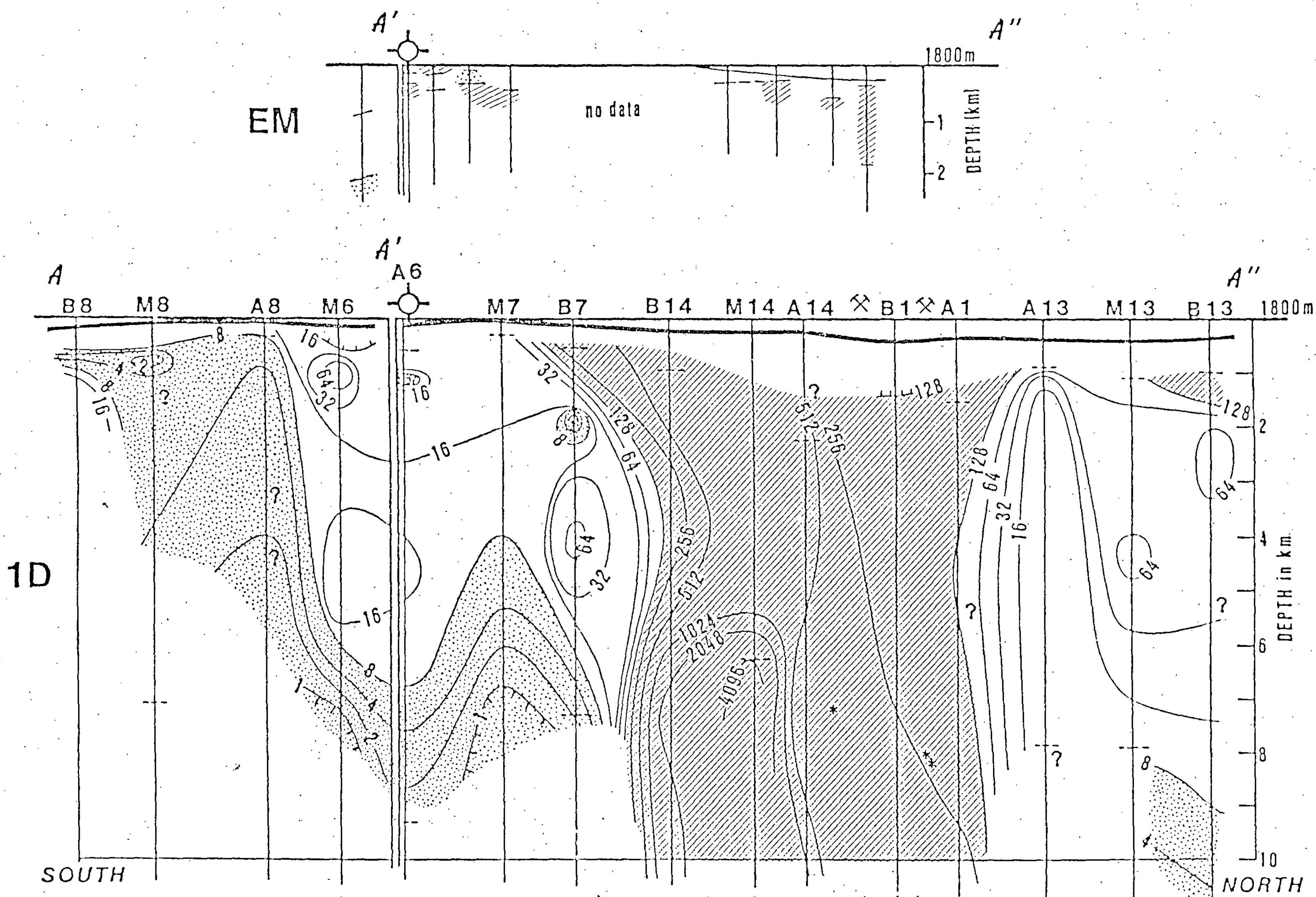


Figure 10. MT section (T_e mode, 1D inversion) along Line A compared with available EM data, after Lange, 1980.

Both wells were drilled as unit wells for the McCoy Federal Geothermal Unit under a Plan of Operation approved by the U.S. Geological Survey. The generalized drilling plan for the holes was:

1. Move on. Rig up.
2. Drill 17-1/2" hole to ±20 ft.
3. Run 20 ft of 13-3/8 conductor pipe, cement.
4. Drill 12-1/4 hole to ±505 ft.
5. Run 500 ft of 8-5/8" casing, cement.
6. Install BOP equipment, test.
7. Drill 6-1/4-6-3/4 hole to TD.
8. Run electric logs.
9. Equip hole for flow test if appropriate
10. Equip hole for temperature observation if no suitable production encountered - 3" Black iron pipe installed capped top & bottom - filled/water.

Well 66-8 encountered a low temperature geothermal reservoir between 1630 feet and TD. Numerous hot water entries were recorded; with first entry at 1630 feet being the hottest at about 100°C, or just slightly above boiling for the elevation. The chemistry of the fluids was discussed in the section on geochemical studies. Lost circulation was encountered at several depths below the upper water zone. After completing the well as a thermal observation well it was discovered that drilling mud left in the hole had flowed out into the formation, and the 100°C water flows into the hole and out one of the lost circulation zones near bottom of hole. Therefore, no valid temperature gradients can be measured. It is proposed to back fill the annulus in 1981 to try and obtain reliable bottom hole temperature data.

Well 14-7 encounterrd lost circulation in the Triassic carbonates at a depth of 409 feet. With considerable difficulty the 8-5/8" casing was set and cemented at a depth of 495 feet. A flow of warm water $\pm 50^{o}C$ was encountered just below the casing. Below 800 feet drill blind with no returns to TD. The well was completed as a temperature observation well, but the $\pm 50^{o}C$ water at 500 feet is going out into formation somewhere near the bottom of hole so that hole is isothermal below 500 feet.

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