

DOE/ET/27010-2

MC COY AREA, NEVADA
Geothermal Reservoir Assessment Case History
Northern Basin and Range

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WORK PERFORMED 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.

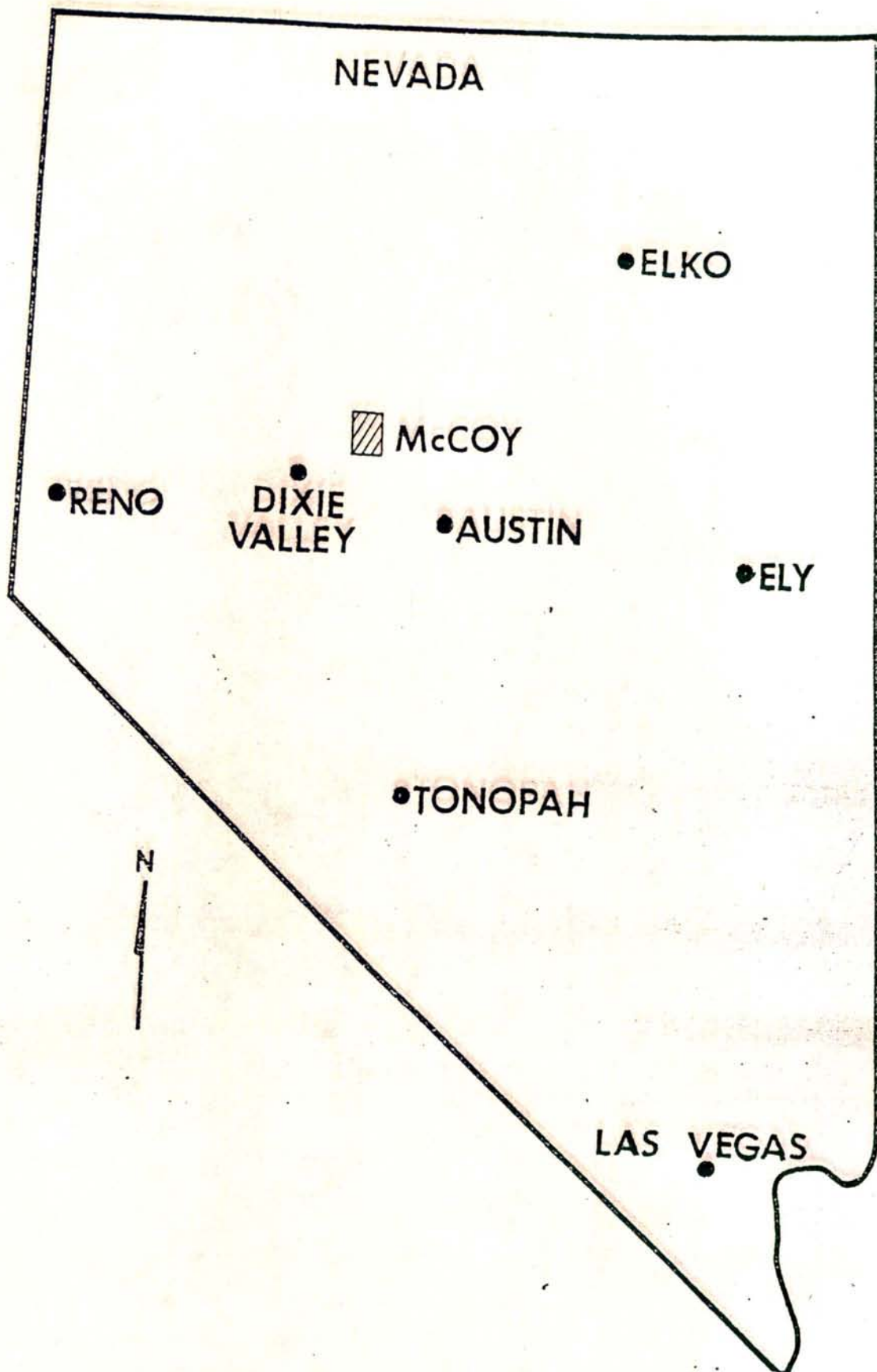


Figure 1. Location map for the McCoy geothermal project.

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 2T* Hot Springs deposits -
Travertine/some silica
- 832 Ts2 Tuffaceous sediments
- 854 Tad2 Andesite and dacite flows
and intrusives
- 846 Tdm

| |
|----|
| 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 Twt5

| |
|----|
| 4c |
| 4b |
| 4a |

 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 Tc Osabb Formation - sandstone,
conglomerate, shale, minor
ls.
- 888 Tcs Cane Spring Formation - massive
limestone and dolomite;
minor shale and conglomerates.
- 868 Tad Augusta Mountain Formation - massive
limestone with minor dolomite,
shale and conglomerate.
- 858 Tf

| |
|----|
| Tu |
|----|

 Favaret Formation - thin bedded
ls/calcareous shale and
siltstone dark grey to black.
- 878 Tc

| |
|----|
| Tu |
|----|

 Conglomerate with purple siltstone
and tuffs in lower part.
- 878 Fr

Tsi 862

Sandstone,
conglomerates
and tuffaceous
sediments.

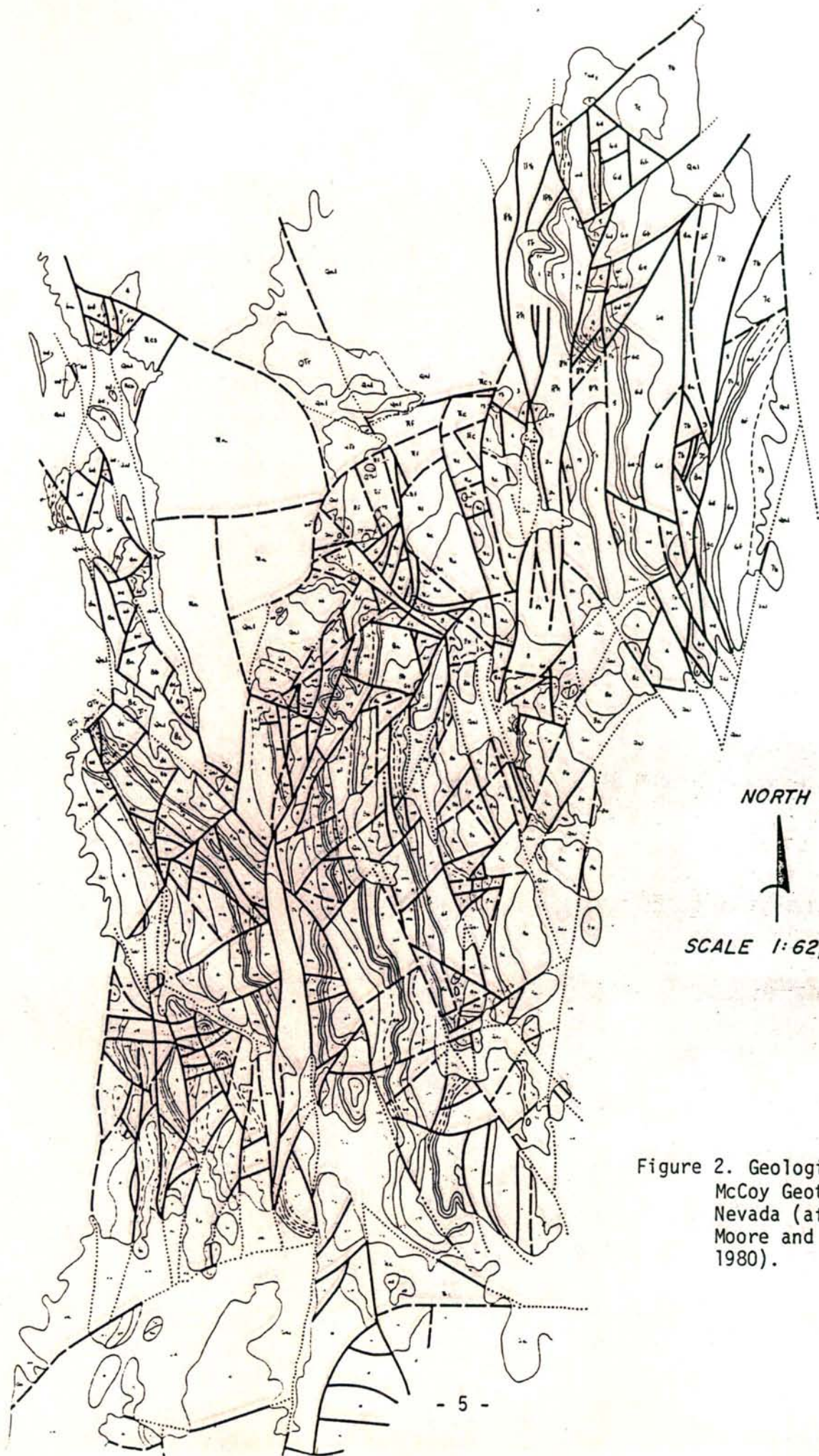
Tr 866

Undifferentiated rhyolitic
rocks. 22-30 m.y.

Tad 844

Older andesite and
basalts.

Tu - undivided



NORTH



SCALE 1:62,500

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 overlies the volcanic rocks to the northwest of the McCoy Mine area. West of the McCoy Mine over 2km² 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

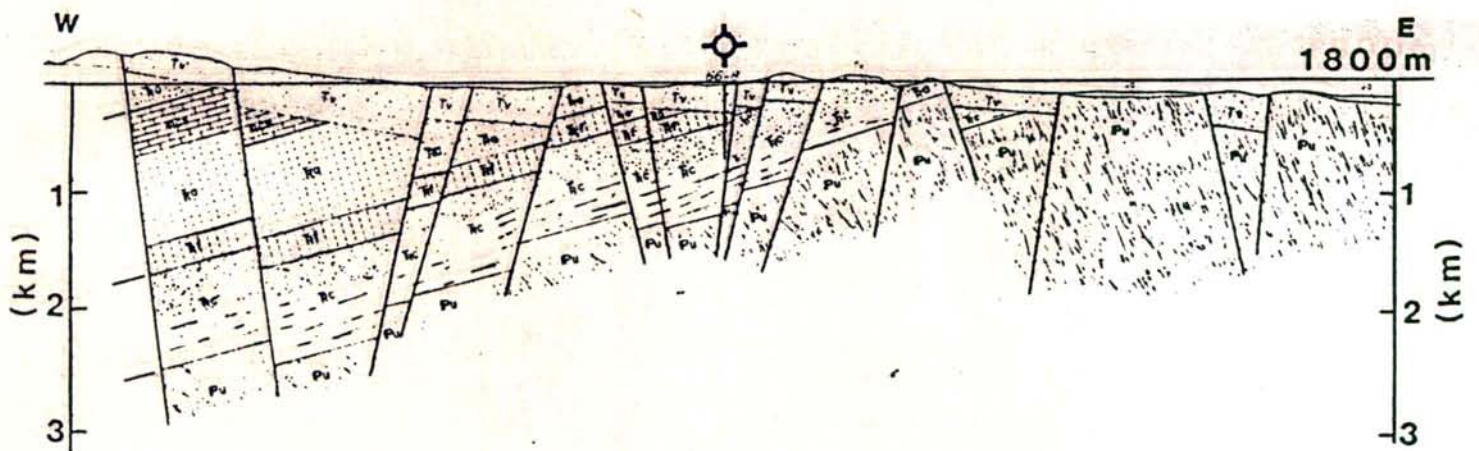
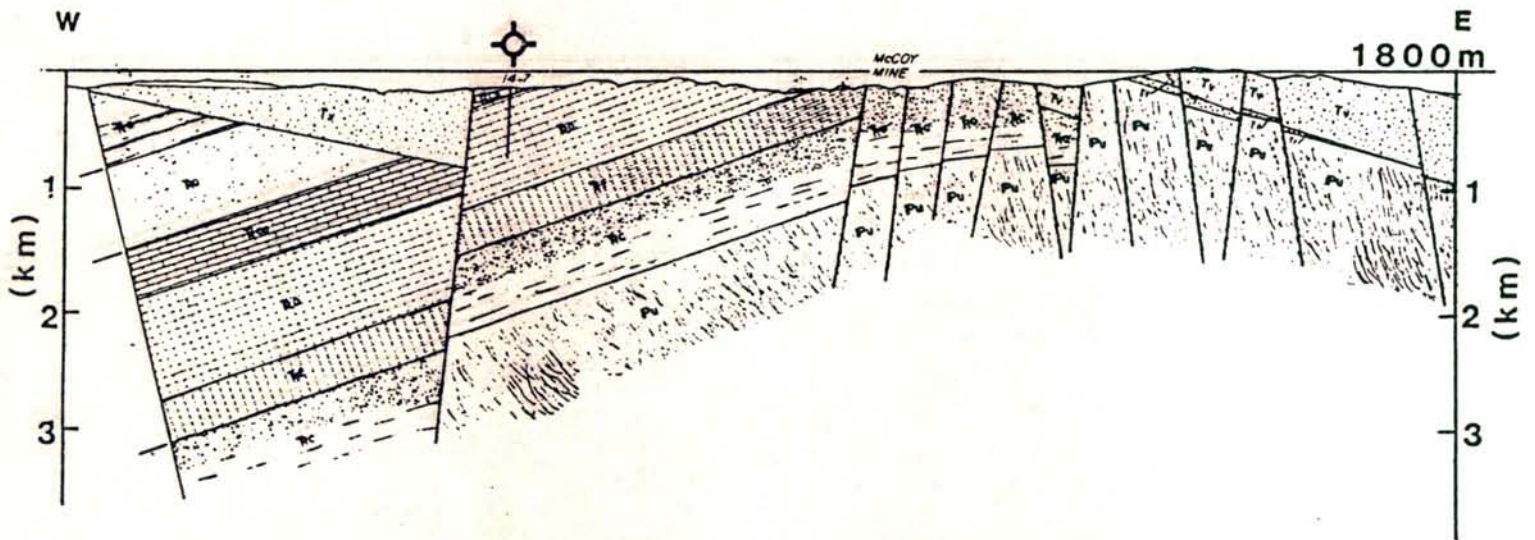
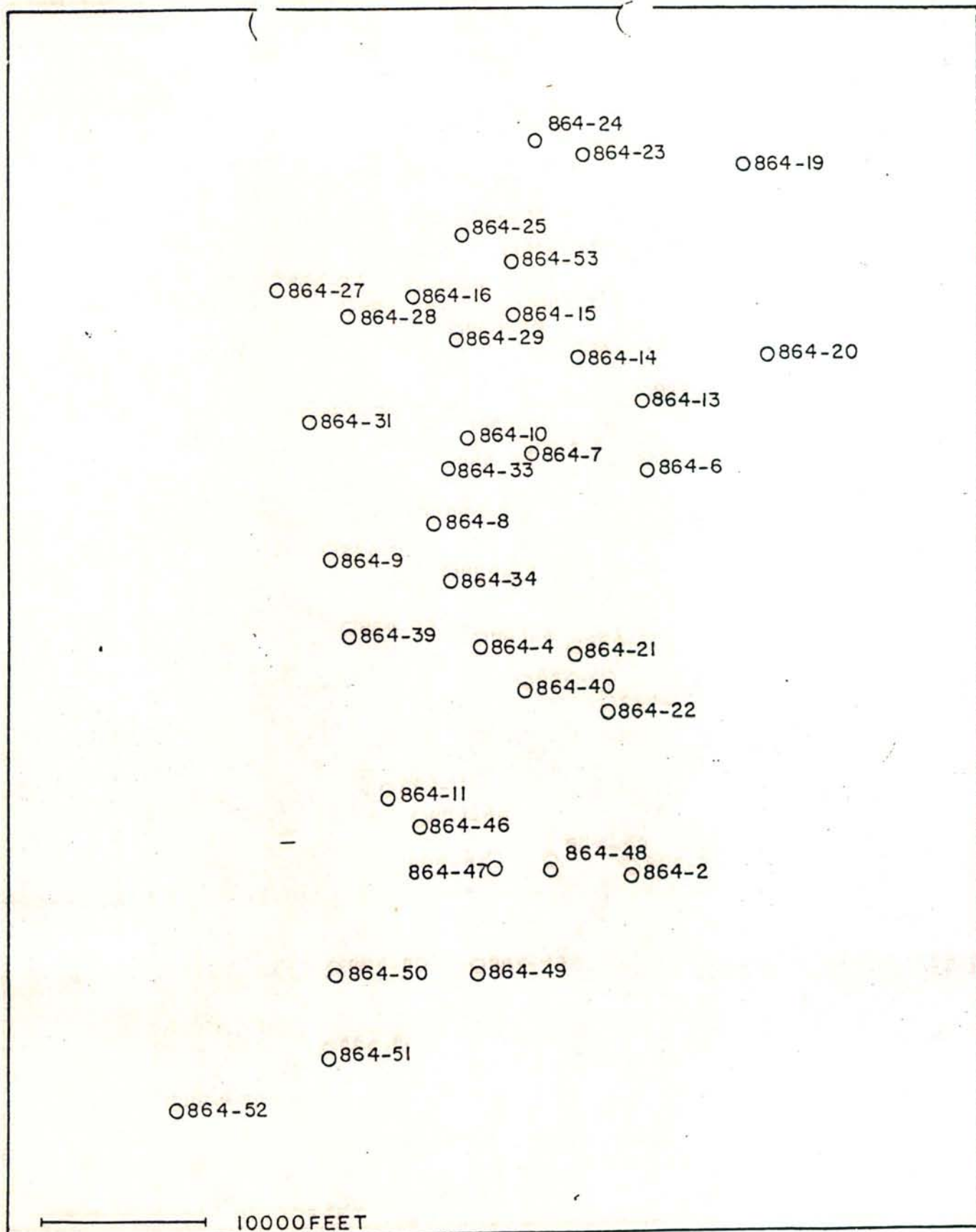


Figure 3. Geologic cross-sections through well 14-7 (Top) and well 66-8 (bottom) after Pilkington, 1980.

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 ^{OC} | 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

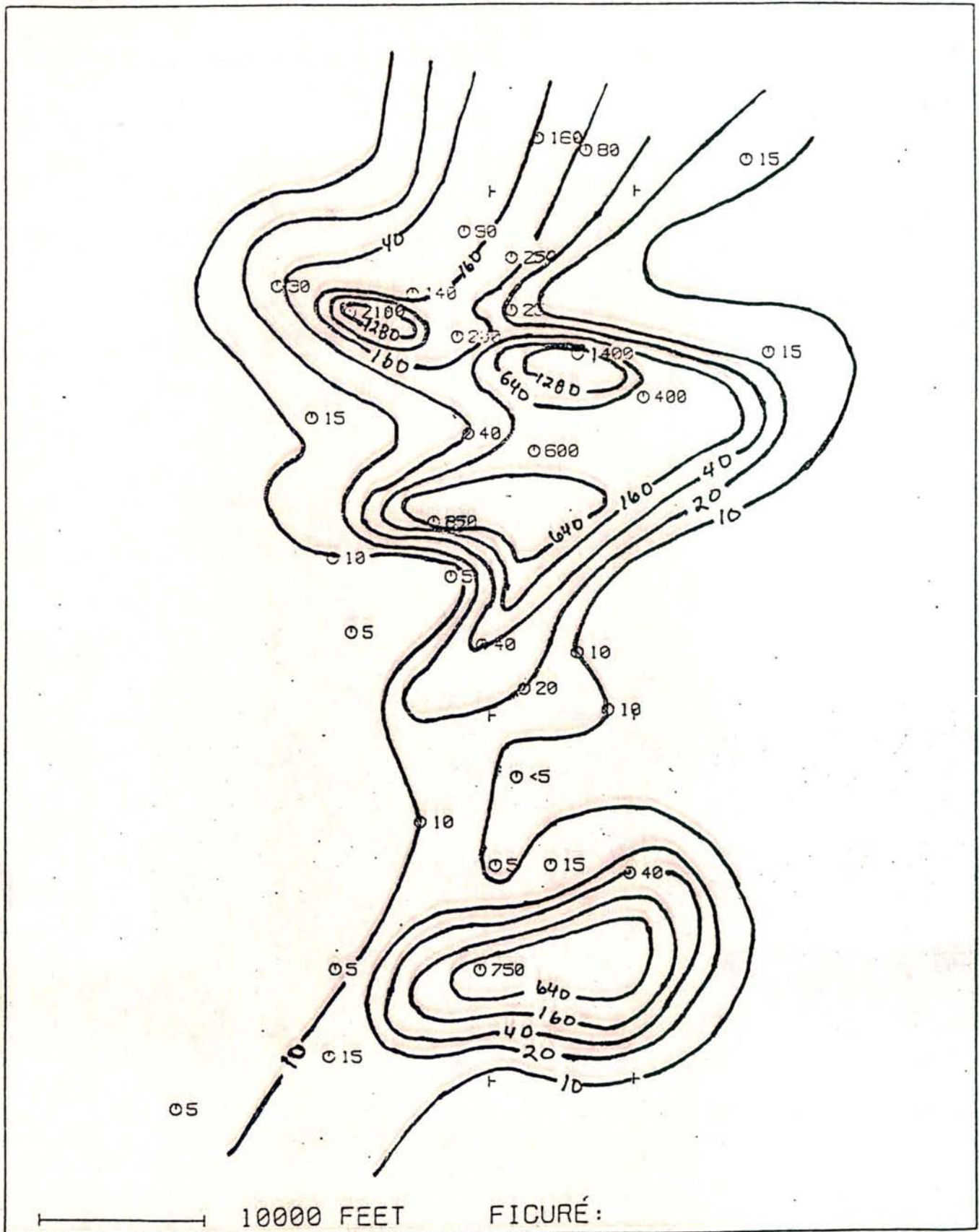
Figure 4. Location map of drill holes used in geochemical study of drill cuttings.

Chemically the waters from Well 66-8 and the McCoy Mine well are sodium bicarbonate waters with projected subsurface temperatures of 98-148⁰C. based upon the conductive quartz geothermometer and 153⁰-206⁰ 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

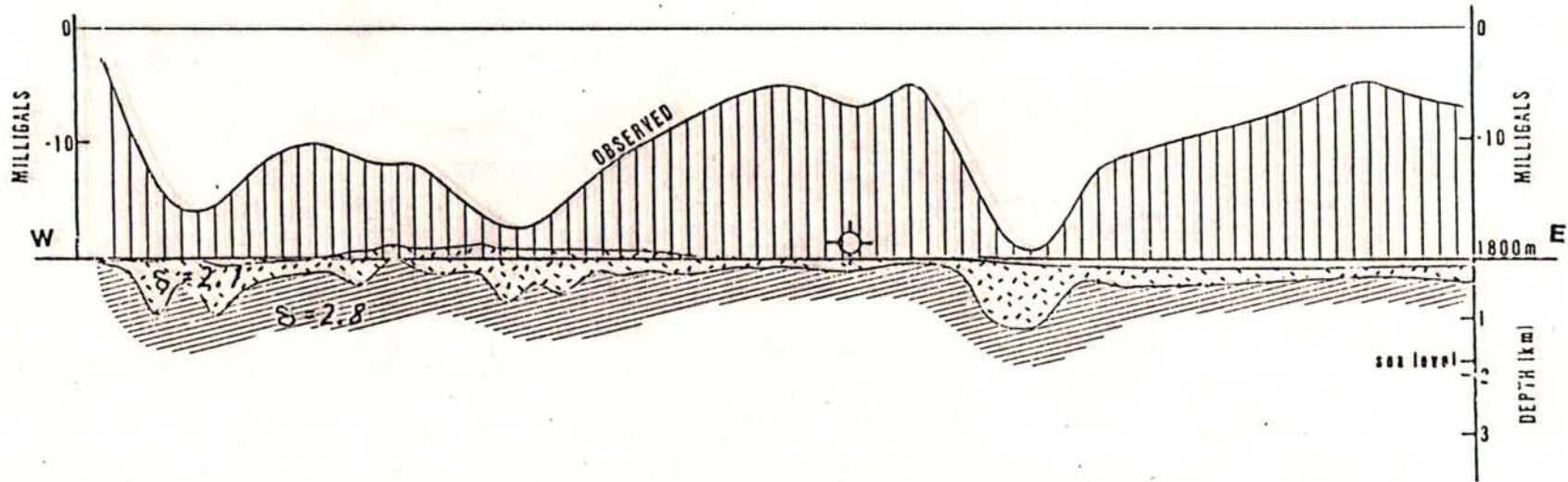
A gravity survey of 340 stations was conducted by AMAX and Microgeophysics in 1979 and Fred Berkman has been involved in the analysis of the data. Berkman prepared a residual gravity profile (Complete Bouguer) and depth analysis along an east-west line through well 66-8 (Figure 6) as reported by Lange, 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 (DI
LANDER & CHURCHILL. NV

FIGURÉ:
MERCURY (PPB) 120-160 ft.
SAMPLE TYPE: ..
ANALYTICAL METHOD: COLD 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**

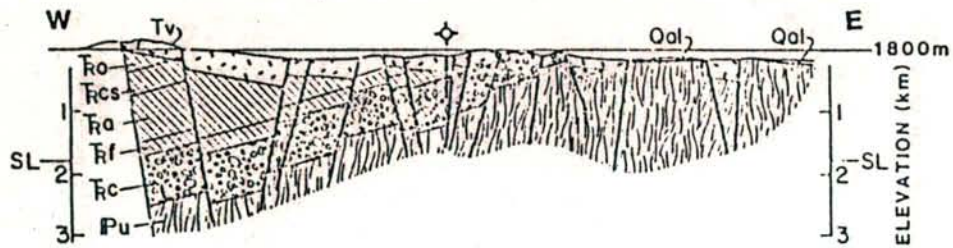


Figure 6. Gravity profile with automatic interpretation for densities (top) compared with geologic cross-section (bottom).

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').

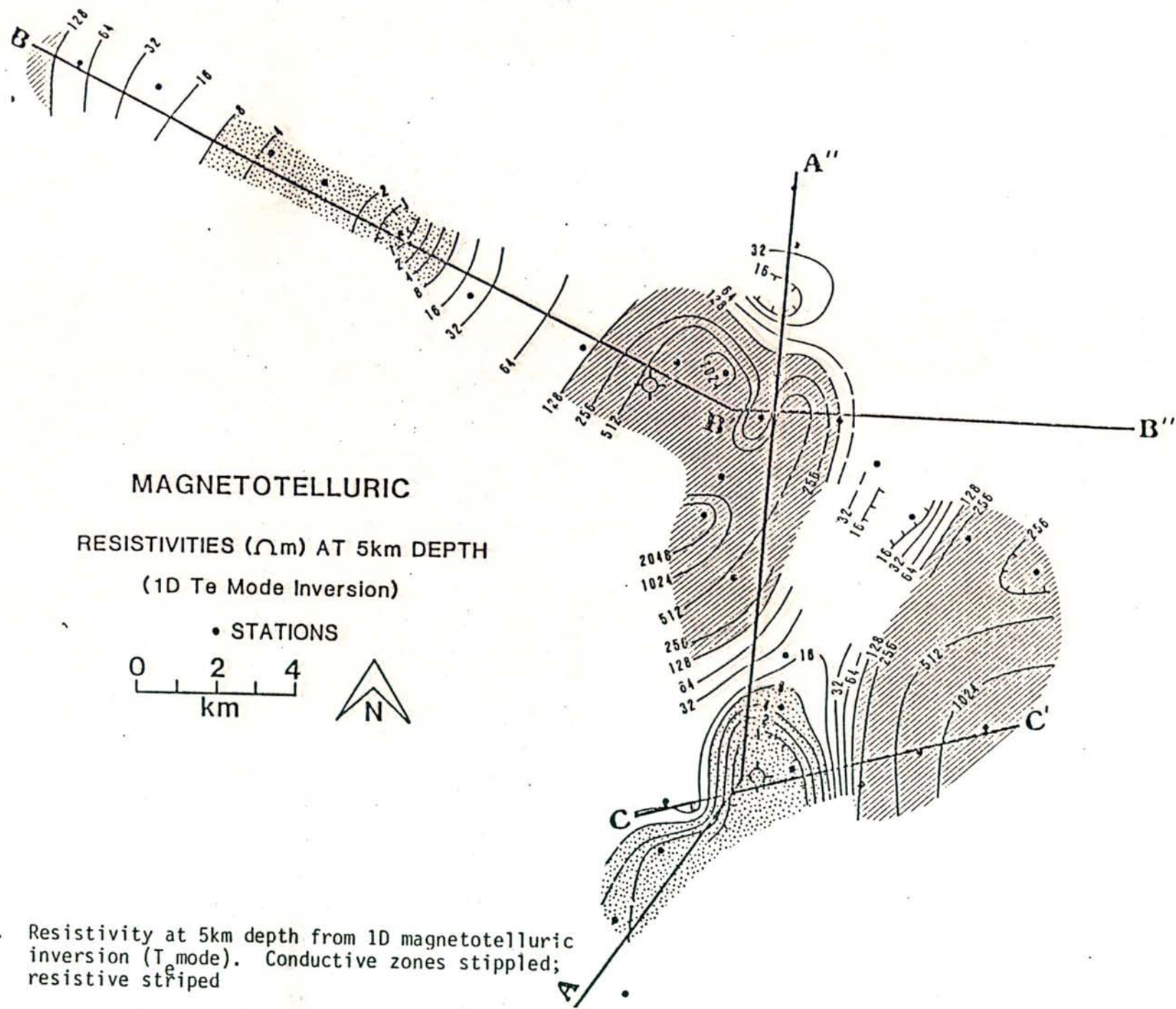


Figure 7. Resistivity at 5km depth from 1D magnetotelluric inversion (T_e mode). Conductive zones stippled; resistive striped

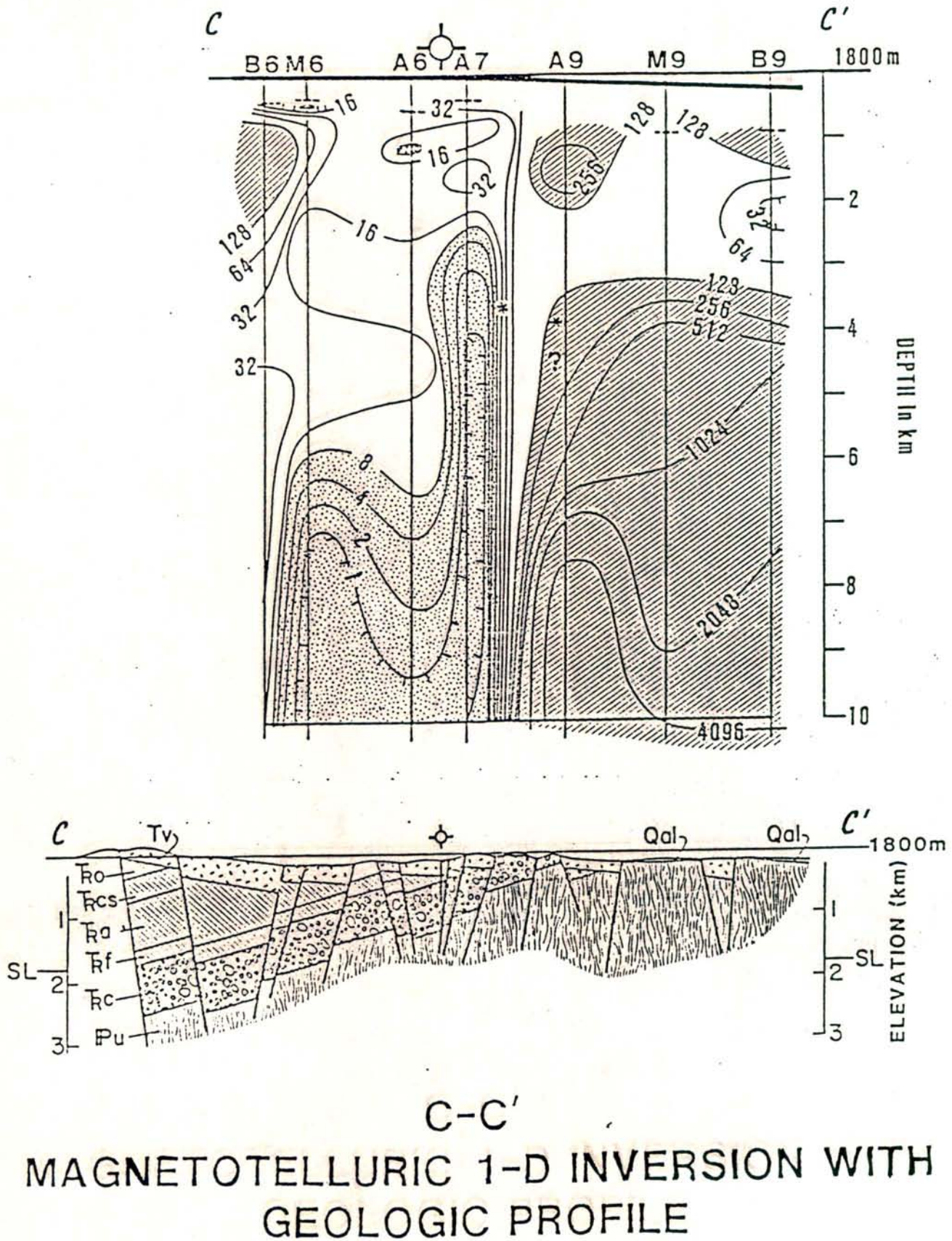
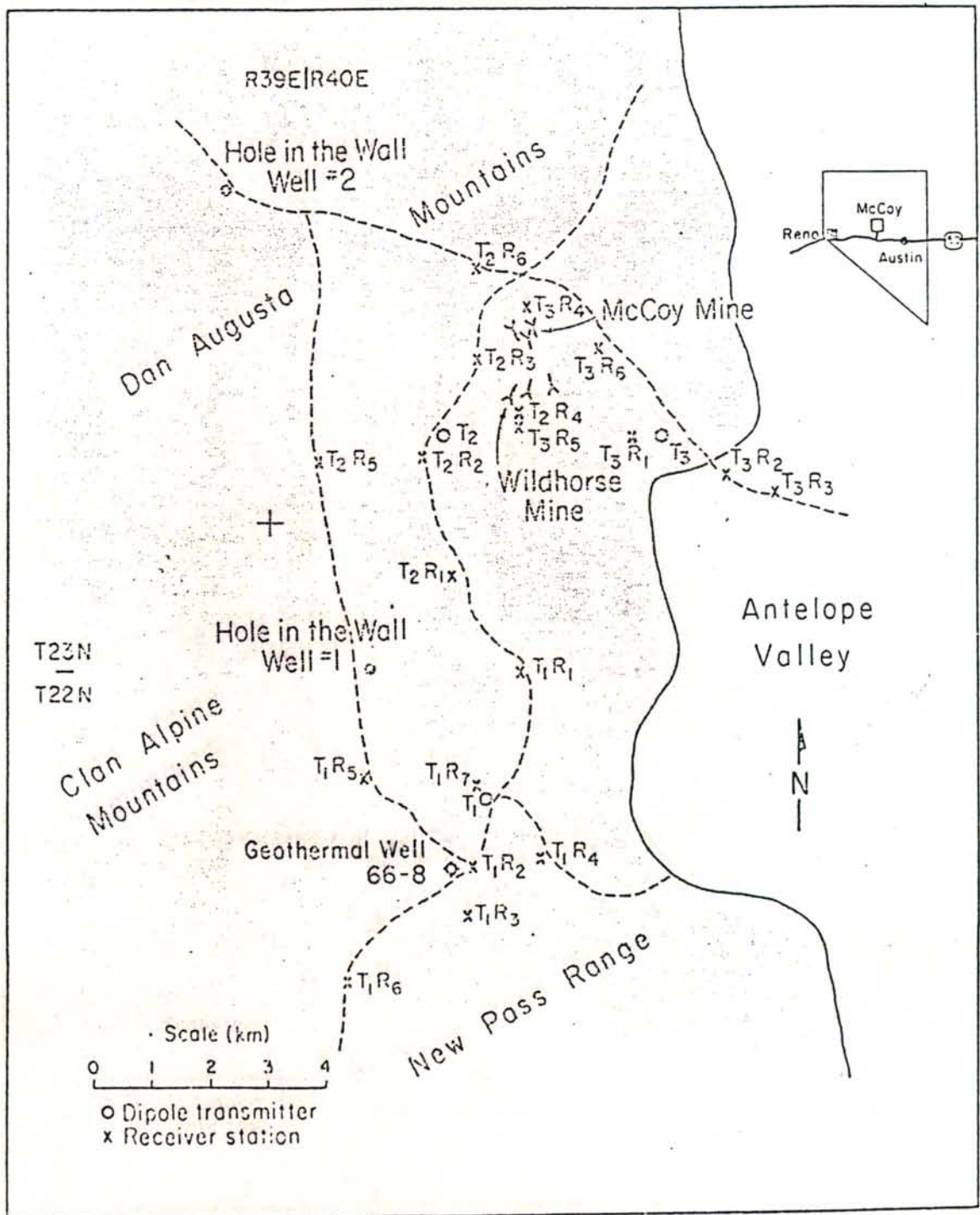


Figure 8. MT section (T_e mode, 1D inversion) along Line C, compared with geologic section



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

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

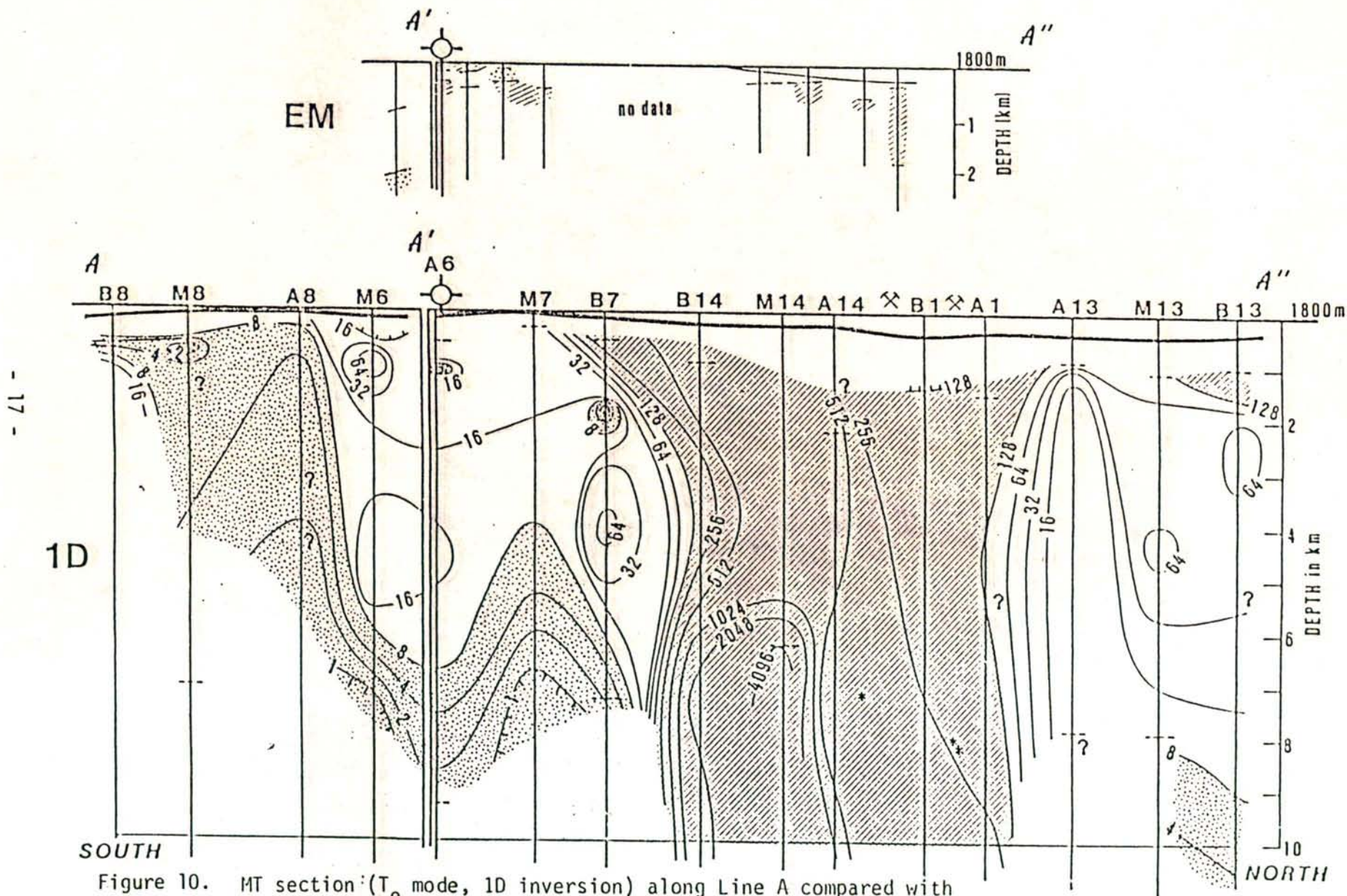


Figure 10. MT section (T mode, 1D inversion) along Line A compared with available EM data, after Lange, 1980.

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 encountered 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 $+50^{\circ}\text{C}$ 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 $+50^{\circ}\text{C}$ water at 500 feet is going out into formation somewhere near the bottom of hole so that hole is isothermal below 500 feet.

BIBLIOGRAPHY

- Adams, Mike, Moore, J. N. , Struhsacker, Eric, 1980, Preliminary geologic map McCoy area, Nevada: Unpublished UURI map.
- Dellechaie, F., 1977, Hydrogeochemistry McCoy geothermal prospect: AMAX Exploration, Inc., I.O.M.
- Lange, A. L., 1980, The McCoy, Nevada geothermal prrospect: Paper presented at Soc. Exploration Geophysicist Ann. Mtg.
- McKee, E. H. and Steward, J. H., 1971, Stratigraphy and K-AR ages of some Tertiary tuffs from Lander and Churchill Counties, Nevada: U. S. Geological Survey Bull 1311-B.
- Olson, H. J., Dellechaie, F., Pilkington, H. D. and Lange, A. L., 1979, the McCoy geothermal prrspect a status report of a possible new discovery in Churchill and Lander Counties, Nevada: Geothermal Resources Council Transactions Vol. 3.
- Pilkington, H. D., 1980, Geochemical study drill cuttings, McCoy: AMAX Exploration, Inc., I.O.M.
- Shenker, A. E., 1980, Summary hydrogeochemistry from McCoy Well 66-8: AMAX Exploration, Inc., I.O.M.
- Stewart, J. H. and McKee, E. H., 1977, Geology and mineral deposits of Lander County, Nevada: Nevada Bur. Mines and Geology, Bull. 88.
- Terraphysics, 1980, Telluric-Magnetotelluric survey at McCoy prospect, Churchill County, Nevada: AMAX Exploration, Inc., Report

- Wilden, R. and Speed, R. C., 1974, Geology and Mineral deposits of Churchill County, Nevada: Nevada Bur. Mines and Geology, Bull. 83.
- Wilt, M., Haught, R. and Goldstein, N. E., 1980, An electromagnetic (EM-60) survey of the McCoy geothermal prospect, Nevada: Lawrence Berkley Laboratory, Univ. of California, Berkley Rept. 66a.