AMAX EXPLORATION, INC.

A SUBSIDIARY OF AMAX INC.

GEOTHERMAL BRANCH

INTER-OFFICE MEMORANDUM

SUBJECT: Aurora Area, Mineral County, Nevada DATE: September 3, 1981

TO: J. E. Deymonaz and H. J. Olson

FROM: H. D. Pilkington

On July 23 and 24, 1981, I examined the Aurora Area, Mineral County, Nevada where Phillips Petroleum Company has recently formed a federal geothermal unit. The area is about 28 km north of Mono Lake, California and on strike with Mono Craters (Figure 1) and about 28 km southwest of Hawthorne, Nevada. The Aurora Unit (Figure 2) comprises 32 square miles (20,480 acres) of ground northeast of the old Aurora gold district.

Aurora Gold District

The Aurora district was discovered on August 22, 1860 (Hill, 1915) and remained active into the early 1900's. Minor intermittent production continued until 1940. The district is reported to have produced over 31 million dollars in gold and silver. There has been a strong resurgence in precious metals exploration in the area. Houston Minerals is currently developing an open-pit operation at the old Borealis Mine approximately one mile east of the northeastern corner of the Aurora Unit boundary. Thousands of new claims have been staked between the Houston Minerals mine site and the old Aurora gold district to the southwest (Figure 2). United Siscoe Mines, Ltd. holds some of the ground in the area east of the old Aurora camp.

Rock Descriptions

The oldest rocks exposed in the Aurora area have been mapped as the Excelsior Formation (Ross, 1961) of Permo-Triassic age. The rocks consist of flows, tuffs and volcanic breccias which range in composition from andesite to rhyolite. Epidote is very widespread, and serves to distinguish the Excelsior from altered Tertiary volcanic rocks. Two small outcrops of Excelsior Formation have been mapped (Figure 3) in intrusive contact with the Cretaceous granites.

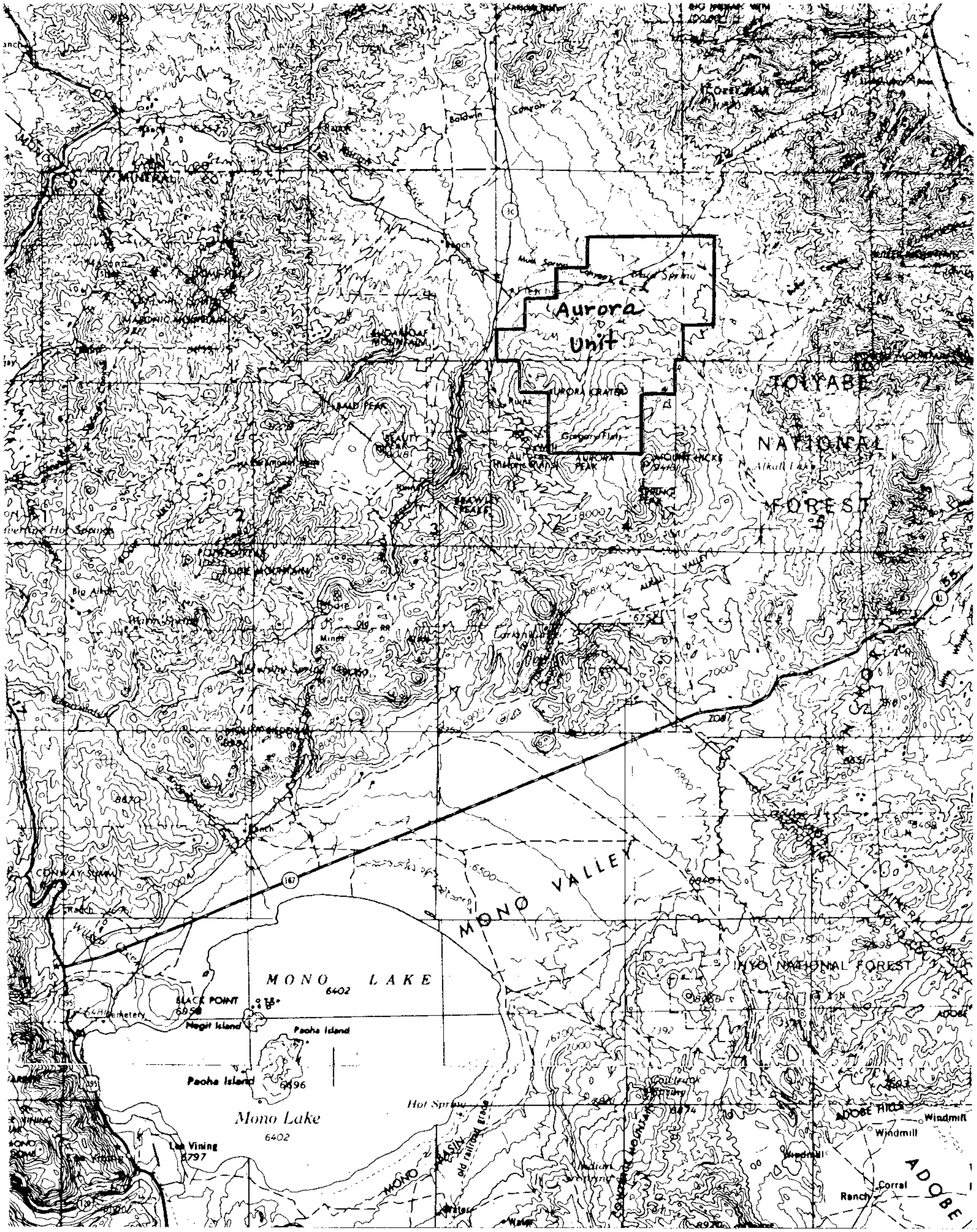

Figure 1. Map of California-Nevada border area showing Aurora Unit and its relation to Mono Lake, California.

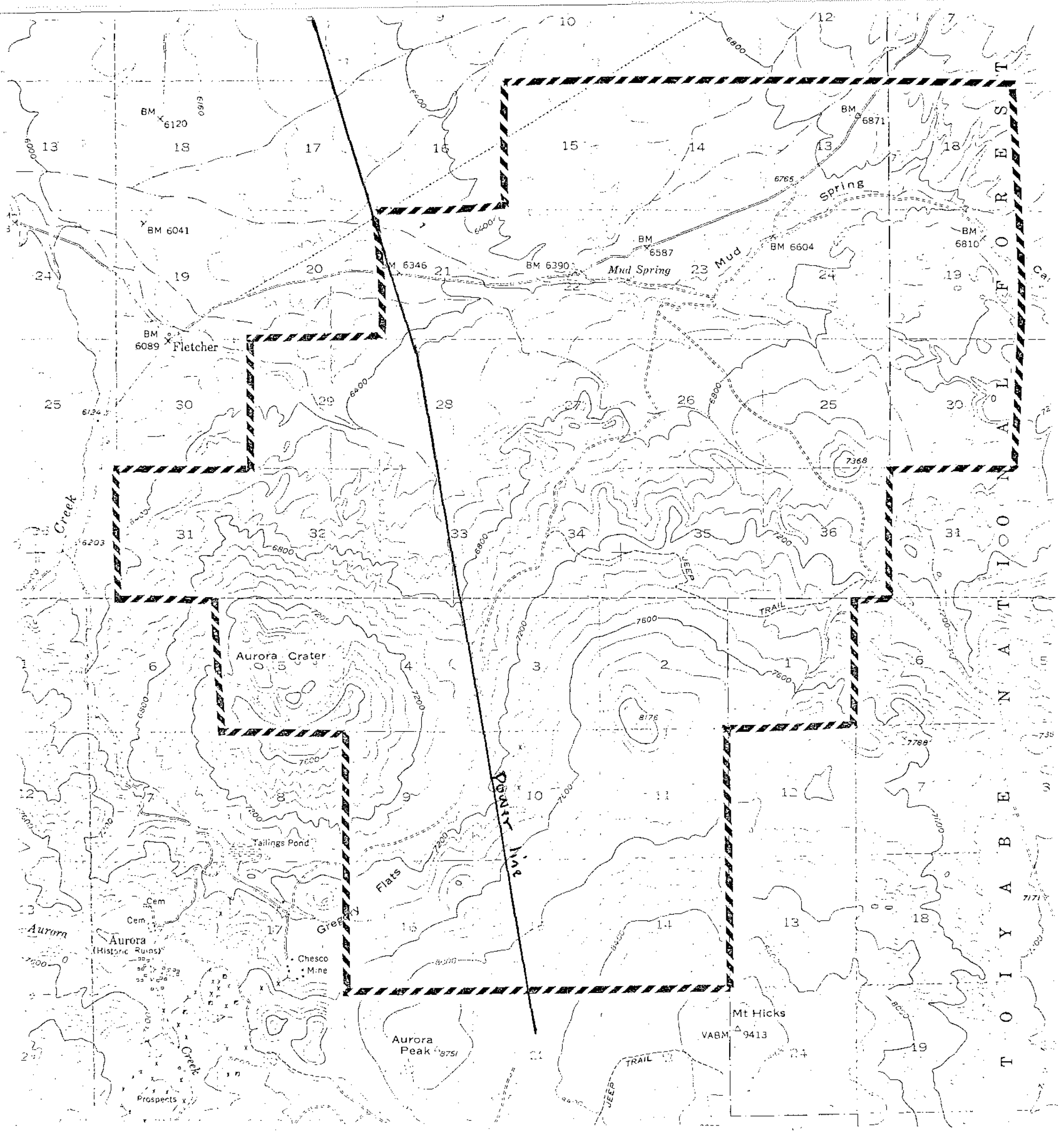

Figure 2. Aurora Unit boundary and local topography.

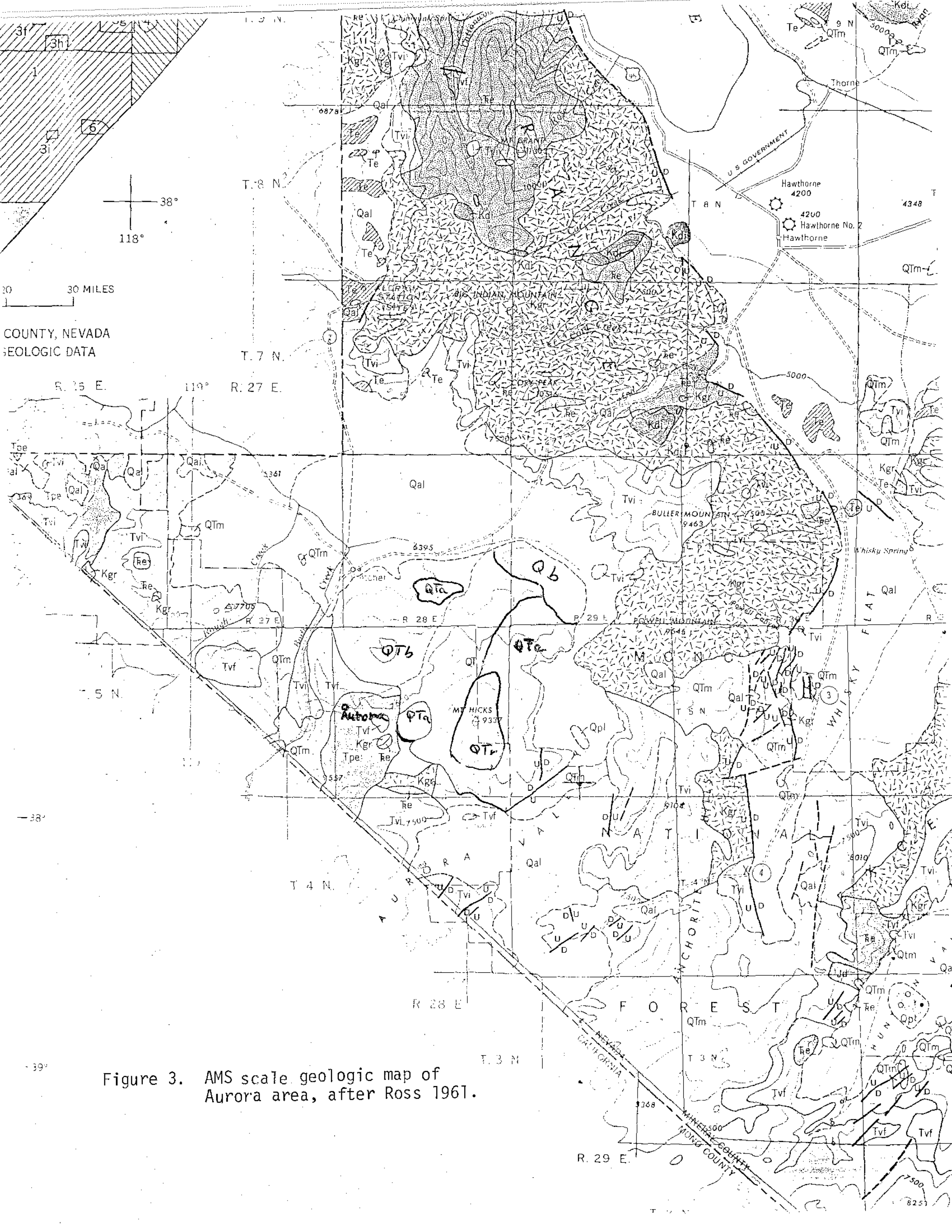

Figure 3. AMS scale geologic map of Aurora area, after Ross 1961.

Medium to coarse-grained granitic rocks of Cretaceous age crop out extensively in the Wassuk Range to the east and northeast of the Aurora area (Figure 3). Two small granitic masses protrude through the Tertiary volcanics southeast of Aurora. Typically the rocks are medium-grained, equigranular and consist of K-feldspar, plagioclase, quartz and biotite. In the field the granitic areas are easily identified because of characteristic color and weathering characteristics.

The Tertiary rocks of Mineral County have been divided into three units by Ross (1961). The older rocks, which are dominantly volcanic and generally altered, are referred to as pre-Esmeralda. The older rocks are overlain by the sediments and intercolated volcanics of the Esmeralda Formation (Robinson et al, 1968 and Pilkington, 1981). The younger, post-Esmeralda rocks are dominantly volcanic rocks which are generally unaltered.

In the Aurora area, the pre-Esmeralda rocks are a series of grayish-green altered biotite-quartz latites and andesites (Tpe on Figure 3) which lie unconformably upon the Cretaceous granites. The altered volcanics are the host rocks for Au-Ag mineralization in the district. The rocks exhibit a pervasive alteration consisting of quartz-calcite-sericite-chlorite-epidote (Hill, 1915). Adjacent to the veins the rocks are strongly silicified and contain abundant sericite and epidote. Intrusive into the biotite-quartz latite is a light-green andesite porphyry which has been subjected to the same type of alteration as the latite ash flows.

Overlying the biotite-quartz latite in the Aurora district is a sequence of post-Esmeralda volcanic rocks (Tvf on Figure 3). The rocks have been termed felsic volcanics by Ross (1961) characterized by ash flow tuffs of rhyolitic to rhyodacitic compsotion. The rocks consist of 25 to 30 percent crystal fragments in a glassy groundmass with abundant shard structures. The crystal fragments include feldspars, quartz and biotite. The rocks are reported by Ross (1961) to contain some lithic fragments. The rocks exposed on the ridge west of Aurora Crater contain up to 10 percent lithic fragments and resemble the poorly welded ash flow tuff which overlies the Esmeralda Formation in the Fish Lake area (Pilkington, 1981). The ash flow tuffs appear to dip gently to the north-northwest and to rest upon an erosional surface cut into the pre-Esmeralda volcanics.

Resting unconformably upon the post-Esmeralda felsic rocks (Tvf) of Ross (1961) is a sequence of intermediate volcanic rocks of andesitic to rhyodacitic composition (Tvi on Figure 3). The rocks are various shades of gray and are characterized by the presence of phenocrysts of plagioclase, hornblende and/or biotite. The ferromagnesian minerals often show some effects of alteration or reaction. A considerable amount of erosion occurred after the outpouring of the intermediate volcanics and before the formation of the Mt Hicks and Aurora Crater complexes.

Large areas of Tertiary and Quaternary felsic to mafic volcanic rocks are found in the southern part of Mineral County (Ross, 1961). Extensive mapping in the Mono Lakes area of California by Gilbert et al, 1968, provides the framework necessary to unravel the younger volcanic events in the Aurora area.

In the area of Bodie Mountain approximately 16 km southwest of the Aurora camp Chesterman (1968) mapped a series of andesitic flow which have k/ar ages of 7.8 to 8.9 m.y. The rocks are thus early Pliocene in age and may correlate with rocks mapped as Tri on Figure 3. From about 7.5 to 4.5 m.y. ago the general area appears to have been quiescent, and the volcanism became widespread from 4 to 2 m.y. ago. In the Aurora area the late Pliocene activity was initiated by the formation of a central volcano complex at Mt. Hicks (Figure 2 and 3). The early eruptions were rhyolitic to andesitic in composition (QTr and QTa on Figure 3). Gilbert et al (1968) report a k/Ar age of 3.6 m.y. from sanidine in a perlitic rhyolite on the southeastern slope of Mt. Hicks. Olivine basalts poured out from both the Mt. Hicks volcanic crater and also from the Aurora Crater and has been dated at 1.6 m.y (Gilbert et al, 1968). The youngest basalt in the area crops out on the ridge west of Mud Spring Canyon and may be mid to late Pleistocene in age. Sediments are under the youngest basalt and overlying the QTb basalts of the Aurora complex.

Table I. Chemical Analyses of Waters from the Aurora - Mono Lake Area

	W11072 Twin Springs CS NWSW3T9NR26E	W11073 Flying M Ranch CW NWNW20T8NR26E	W11074 Mitchell CS SENE2ST7NR27E	W11075 Spring NENW2ST5NR23E
Temp ^{o}C	18.0	18.00	18.0	14.0
Flow	5.0	---	3.0	5.0
pH	8.01	7.18	7.82	8.19
Cl	9.2	8.3	7.8	16.0
F	0.1	0.2	0.2	0.2
SO_4	14.0	32.0	61.0	44.0
HCO_3	35.8	141.8	151.4	143.6
CO_3	0.0	0.0	0.0	0.0
SiO_2	41.0	73.0	42.0	52.0
Na	16.0	27.0	26.0	37.0
K	2.9	7.5	2.9	5.8
Ca	8.0	34.0	60.0	31.0
Mg	1.6	10.0	12.0	12.0
Li	0.0	0.0	0.0	0.0
B	0.0	0.0	0.0	0.0
Mo(ppb)	2.0	6.0	10.0	8.0
TDS	128.8	333.8	363.3	341.6
T_qSiO_2	95.0	118.0	96.0	104.0
T_cSiO_2	62.0	92.0	63.0	74.0
TNa-K	274.0	324.0	227.0	259.0
TNa-K-Ca 1/3	178.0	199.0	146.0*	174.0
TNa-K-Ca 4/3	59.0*	64.0*	28.0	61.0*
TNa-K-Ca-Mg	---	56.0	70.0	38.0

Table I. Chemical Analyses of Waters from the Aurora - Mono Lake Area

	W11076 Ninemile Ranch SW NENW14T6NR27E	W11077 Mud Spring NESE22T5NR28E	W11078 Spring SWNE12T8NR27E	W11079 Spring SENW17T5NR27E
Temp°C	18.0	14.00	18.0	12.0
Flow	---	5.0	1.0	1.0
pH	7.99	7.68	9.3	8.35
Cl	16.0	20.0	13.0	9.7
F	0.2	0.3	0.4	0.3
SO_4	36.0	90.0	150.0	55.0
HCO_3	112.0	127.6	91.0	131.6
CO_3	0.0	0.0	4.0	0.0
SiO_2	88.0	68.0	43.0	24.0
Na	38.0	51.0	66.0	25.0
K	14.0	6.5	13.0	2.0
Ca	22.0	60.0	31.0	60.0
Mg	5.6	7.0	16.0	8.0
Li	0.0	0.1	0.1	0.0
B	0.3	0.3	0.0	0.0
Mo(ppb)	4.0	7.0	20.0	30.0
TDS	332.1	430.8	465.1	317.6
T_qSiO_2	127.0	115.0	97.0	75.0
T_cSiO_2	103.0	88.0	65.0	39.0
TNa-K	362.0	239.0	283.0	199.0
TNa-K-Ca 1/3	228.0	163.0	192.0	130.0
TNa-K-Ca 4/3	98.0	55.0	83.0	19.0
TNa-K-Ca-Mg	84.0	104.0	30.0	---

Table I. Chemical Analyses of Waters from the Aurora - Mono Lake Area

	W11080 Spring SW22T4NR26E	W11081 Spring NWNE22T5NR26E	W11175 Coyote Spring 14T3NR26E	W11176 Milk Ranch Spring SENE8T4NR27E
Temp^{o} C	12.0	12.00	15.0	10.0
Flow	1.0	2.0	10.0	2.0
pH	7.38	6.89	8.3	7.37
Cl	3.7	1.5	7.7	2.9
F	0.0	0.0	0.2	0.0
SO_4	0.0	0.0	0.0	0.0
HCO_3	35.6	21.2	227.8	42.8
CO_3	0.0	0.0	0.0	0.0
SiO_2	39.0	25.0	50.0	52.0
Na	6.0	4.1	23.0	10.0
K	1.7	0.7	3.9	3.4
Ca	8.0	6.0	44.0	4.0
Mg	1.7	1.6	21.0	1.7
Li	0.0	0.0	0.0	0.0
B	0.0	0.0	0.0	0.0
Mo(ppb)	0.0	0.0	0.0	0.0
TDS	95.7	60.2	377.9	116.9
T_qSiO_2	93.0	77.0	103.0	104.0
T_cSiO_2	60.0	40.0	72.0	74.0
TNa-K	326.0	268.0	267.0	351.0
TNa-K-Ca 1/3	185.0	155.0	166.0	212.0
TNa-K-Ca 4/3	36.0	17.0	40.0	73.0
TNa-K-Ca-Mg	80.0	55.0	26.0	52.0

Table I. Chemical Analyses of Waters from the Aurora - Mono Lake Area

	W11177 Hot Spring SENW9T4NR25E	W11178 Warm Spring NWSW16T4NR26E	W11179 Warm Spring 17T3NR28E	W11180 Spring SWNW20T2NR26E
Temp °C	40.0	26.00	22.0	14.0
Flow	5.0	150.0	5.0	3.0
pH	6.48	8.38	8.4	7.47
Cl	190.0	2.9	120.0	24.0
F	4.0	0.0	0.9	0.0
SO_4	880.0	0.0	0.0	12.0
HCO_3	1477.6	60.6	856.6	50.0
CO_3	0.0	1.6	2.4	0.0
SiO_2	---	52.0	100.0	18.0
Na	1200.0	14.0	360.0	15.2
K	60.0	2.8	22.0	2.1
Ca	100.0	10.0	32.0	17.0
Mg	19.0	0.9	53.0	1.4
Li	3.0	0.0	0.4	0.0
B	9.9	0.0	4.6	0.0
Mo(ppb)	0.0	0.0	0.0	0.0
TDS	3944.3	145.0	1555.7	108.2
T_qSiO_2	126.0	104.0	133.0	65.0
T_cSiO_2	---	74.0	111.0	27.0
TNa-K	164.0	285.0	178.0	375.0
TNa-K-Ca 1/3	164.0	179.0	164.0	195.0
TNa-K-Ca 4/3	---	53.0	136.0	28.0
TNa-K-Ca-Mg	88.0	128.0	---	135.0

Table I. Chemical Analyses of Waters from the Aurora - Mono Lake Area

	W11181 Artesian Well NENE28T3NR28E	W11165 Kirkwood Spring NESE10T3NR27E	W11166 Walford Well NENE27T3NR27E	W11167 Sulpher Artesian Well SWSE26T3NR27E
Temp ^{o}C	15.0	20.00	12.0	14.0
Flow	2.0	40.0	3.0	2.0
pH	7.89	8.52	8.43	9.8
Cl	8.6	6.6	21.0	17.0
F	0.2	0.2	0.3	0.7
SO_4	16.0	0.0	56.0	74.0
HCO_3	179.2	102.0	212.6	181.4
CO_3	0.0	6.0	4.8	151.6
SiO_2	49.0	53.0	54.0	36.0
Na	57.0	46.0	110.0	17.2
K	11.0	9.5	16.0	15.0
Ca	18.0	4.0	10.0	2.0
Mg	4.7	1.6	4.4	0.0
Li	3.0	0.0	0.0	0.1
B	9.9	0.0	0.4	1.1
Mo(ppb)	10.0	3.0	40.0	20.0
TDS	344.1	228.9	489.9	649.8
T_qSiO_2	102.0	105.0	105.0	90.0
T_cSiO_2	21.0	75.0	75.0	56.0
TNa-K	281.0	288.0	251.0	206.0
TNa-K-Ca 1/3	198.0	213.0	200.0	195.0
TNa-K-Ca 4/3	99.0	130.0	139.0	198.0
TNa-K-Ca-Mg	74.0	84.0	62.0	---

Table I. Chemical Analyses of Waters from the Aurora - Mono Lake Area

	W11174 Murphy Spring NWSE24T4NR26E	W11635 Aurora Crater Spr. SW6T5NR28E	W11636 Travertine HS 34T5NR25E
Temp °C	17.0	14.0	40.0
Flow	50.0	1.0	2.0
pH	8.4	6.84	6.63
Cl	2.9	1400.0	200.0
F	0.0	0.0	4.4
SO_4	0.0	950.0	980.0
HCO_3	51.6	544.0	573.0
CO_3	0.4	0.0	0.0
SiO_2	44.0	77.0	83.0
Na	9.6	1400.0	1300.0
K	2.7	110.0	59.0
Ca	8.0	760.0	75.0
Mg	2.4	360.0	17.0
Li	0.0	6.3	3.0
B	0.0	65.0	1.0
Mo(ppb)	0.0	9.0	0.0
TDS	121.9	5672.3	3295.4
T_qSiO_2	98.0	121.0	124.0
T_cSiO_2	66.0	95.0	99.0
TNa-K	325.0	197.0	154.0
TNa-K-Ca 1/3	193.0	173.0	161.0
TNa-K-Ca 4/3	52.0	134.0	174.0
TNa-K-Ca-Mg	57.0	28.0	81.0

A small body of travertine was found in the southeastern quarter of S7T5NR28E. The travertine occurs almost one-quarter mile downstream from the spring orifice. Travertine is presently being deposited for about 50 yards downstream from the spring. The older travertine mound has been eroded somewhat, although most of the travertine appears to have formed in the bottom of the present valley. The 1978 reconnaissance exploration program collected a spring in the SW6, T5NR28E (W11635 in Table I) which is reported to have been depositing travertine. I did not attempt to locate the spring in section 6.

Hydrogeochemistry

The 1978 AMAX Exploration, Inc. reconnaissance geothermal exploration program collected a number of hydrogeochemical samples in the general area (Figure 4). The chemical analyses are shown in Table I. There is a wide diversity in the chemical nature of the waters (Figure 5) as seen when plotted on a trilinear diagram. The waters range from sodium-bicarbonate to sodium-sulphate to sodium-chloride waters. Quite a large number of the waters fall into the calcium-sodium-bicarbonate field (Figure 5).

Geochemically we might expect to see some difference in the waters from the different volcanic centers such as the Mono Lake area, the Bodie Mountain area and the Hicks Mountain-Aurora Crater area. However, on the trilinear diagram there are no apparent concentrations related to the above geographic areas.

The silica geothermometers for waters from the three geographic areas give equilibrium temperatures in the 104-133°C range. The alkali geothermometers (Table I) are 150 to 300°C. The waters contain varying amounts of Mg, and when the Mg correction is applied the resulting equilibrium temperatures (Table I) drop to the 30-128°C range. Therefore, in order to understand the chemical signatures of the waters a detailed examination of water-rock reactions and water mixing models will have to be used.

Geothermal Potential

The geothermal potential of the area rates high in terms of what we think a geothermal prospect should be. Geologically the area is situated in a young volcanic complex, the volcanism appears to be related to the Mono

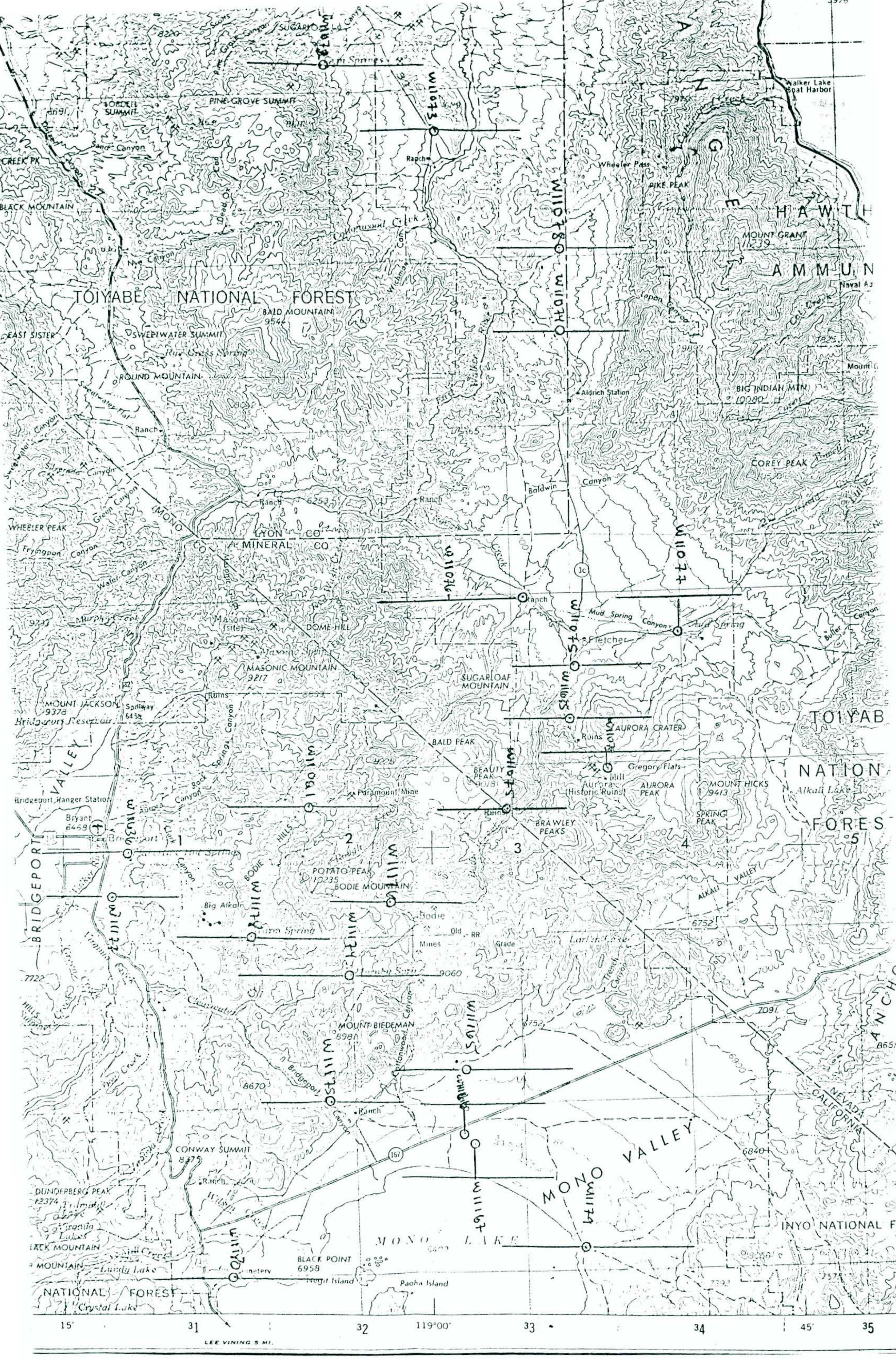

Figure 4. Hydrogeochemical sites in the Aurora area of Nevada and California.

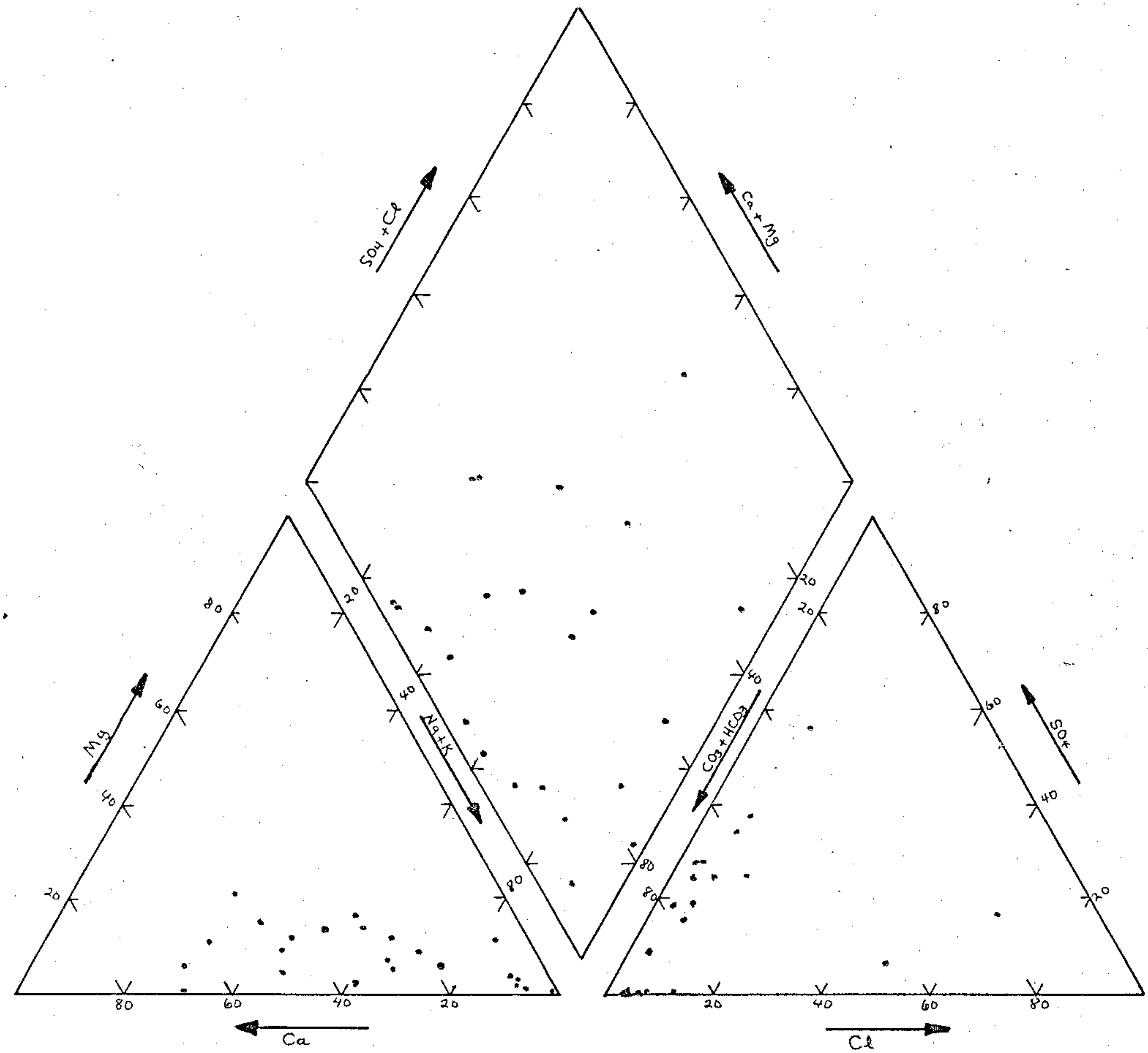

Figure 5. Trilinear plot for waters in the Aurora area, Nevada.

Lake tectonic subsidence feature. Furthermore, the Aurora area lies on the northward projection of the line of recent volcanic features which extend from Long Valley northward through the Inyo domes and Mono domes. The volcanism becomes progressively younger as you move northward. Geologically then, the area looks extremely good.

Geochemically the area is difficult to evaluate. The silica and alkali geothermometers yield divergent equilibrium temperatuares. The temperature discrepency may be explained by mixing of large volumes of meteoric waters or may be related to water-rock reactions. Until we understand what the water chemistry is trying to tell us we should place greater emphasis on the geological attributes of the area.

Recommendations

The geothermal potential of the area looks good and AMAX should undertake sufficient reconnaissance in the area, especially between Mono Lake and the Aurora area, to determine where to establish a land position. The reconnaissance should include geological studies, geochemical studies and heatflow studies.

The Aurora area has been the scene of a great deal of mineral exploration the past two years and a large number of mineral exploration holes should be available for probing. There may be active exploration in the Bodie area of California as well. All published temperature gradient data should be compiled as well since that may be the only source of data in the Mono Lakes area.

There may be a great deal of information available from Houston Minerals. Hydrosearch out of the Reno office has been employed to do the hydrological studies of the water needed for the mine and mill being constructed northeast of the Aurora Geothermal Unit. Several tens of test wells have been drilled and flow tested. Perhaps something could be worked out with Houston to allow us to run a temperature survey in the wells. If the Hydrosearch report can be examined it will tell us a great deal about the local hydrological regime.

H. D. Pilkington

HDP/c

REFERENCES

Bailey, R. A., Dalrymple, G. B., and Lonphere, M. A., 1976, Volcanism structure and geochronology of Long Valley Caldera, Mono County, California; Jour. Geophysical Res. vol. 81, p. 725-744.

Chesterman, C. W., 1968, Volcanic geology of the Bodie Hills, Mono County, California, in Coats, R. R., Hoy, R. L., and Anderson, C. A. eds, Studies in volcanology, a memoir in honor of Howell Williams; Geol. Soc. America Mem. 116, p. 45-68.

Gilbert, C. M., Christensen, M. N., Al-Rorvir, Y. and Lajoie, K. R., 1968, Structural and volcanic history of Mono Basin, California-Nevada, in Coats, R. R., Hoy, R. L. and Anderson, C. A., eds., Studies in volcanology, a memoir in honor of Howell Williams; Geol. Soc. America Mem. 116, p. 275-329.

Hildreth, W., 1979, The Bishop Tuff: Evidence for the compositional zonation in silica magma chambers, in Chopin, C. E. and Elston, W. E., eds, ashflow tuffs; Geol. Soc. America Special Paper 180, p. 43-75.

Hill, J. M., 1915, Some mining districts in northeastern California and northwestern Nevada; U. S. Geological Survey Bull. 594.

Robinson, P. T., McKee, E. H. and Moiola, R. J., 1968, Cenozoic volcanism and sedimentation, Silver Peak region, western Nevada and adjacent California, in Coats, R. R., Hoy, R. L. and Anderson, C. A., eds, Studies in volcanology, a memoir in honor of Howell Williams; Geol. Soc. America, Mem. 116, p. 577-611.

Ross, D. C., 1961, Geology and mineral deposits of Mineral County, Nevada; Nevada Bur. of Mines Bull. 58.

Pilkington, H. D., 1981, Geology of the Fish Lake area, Esmeralda County, Nevada; AMAX Exploration, Inc. report.