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# GEOLOGY MAP OF THE SAN EMIDIO GEOTHERMAL AREA

MASTER

Joseph N. Moore

December, 1979

Work performed under Contract No. EG-78-C-07-1701

**EARTH SCIENCE LABORATORY**
**University of Utah Research Institute**
**Salt Lake City, Utah**

ESL

Prepared for
U.S. Department of Energy
Division of Geothermal Energy

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## CONTENTS



## ILLUSTRATIONS

## INTRODUCTION

The San Emidio geothermal area is adjacent to the northern end of the Lake Range, approximately 15 miles south of Gerlach, Nevada (Figure 1). The Lake Range forms a tilted block, bounded on the west by steeply dipping Basin and Range faults. Associated with one of these faults are hydrogen sulfide seeps, acid alteration, and hot water wells, indicative of an active geothermal system (Garside, 1979).

During the mid-1970s, Chevron Resources Company initiated a broad-based exploration program of the San Emidio geothermal area that included detailed geophysical studies and deep exploratory drilling. The ongoing interpretation of these data by the Earth Science Laboratory as part of the Department of Energy/Division of Geothermal Energy's Industry Coupled Case Studies Program point out the need for additional geologic mapping, particularly on the eastern margin of the San Emidio Desert. This report summarizes our reconnaissance geologic work in this area.

## GEOLOGIC SETTING

The geology of the San Emidio area (Plates I and II) is dominated by a thick sequence of Tertiary volcanic and sedimentary rocks that accumulated on an irregular topographic surface cut into Mesozoic metamorphic rocks (Bonham, 1969; Dixon, 1977). Bonham (1969) included the San Emidio area in his regional reconnaissance of Washoe County and assigned the metasedimentary and metavolcanic rocks to the Nightingale Sequence of Triassic and Jurassic age.

The Tertiary rocks include an older volcanic and sedimentary assemblage assigned to the Pyramid Sequence of Miocene age, and a younger volcanic and sedimentary assemblage that may be correlative with the Truckee and Coal Valley Formations of late Tertiary age (Bonham, 1969). The regional distribution of the Tertiary assemblages, however, and their relationship to correlative sequences is not yet well understood.

The Nightingale Sequence of the Lake Range consists predominately of a thick succession of metamorphosed and folded argillaceous rocks intercalated with carbonate, sandy, and volcanic horizons. Low-grade regional metamorphism typical of the greenschist facies has converted the argillaceous rocks to slate and the original mineralogy to mixtures of chlorite, muscovite, biotite, quartz, and plagioclase. Quartz veins, common in many places along the west flank of the Lake Range, probably formed during this regional metamorphism.

The Pyramid Sequence of the Lake Range contains a lower, largely volcaniclastic assemblage of tuffaceous sandstones, mud flows, lava flows, and ash-flow tuffs, and a younger portion consisting of intermediate composition lava flows. The upper and lower parts of the Pyramid Sequence are separated through most of the northern Lake Range by a succession of ash-flow tuffs. Evans (personal communication, 1979), has dated three samples of pumice-rich ash-flow tuff from the Lake Range (see Plate I for the locations of samples 7c, 7d and 34, and Table 1). K-Ar dates of 17.9 $\pm$ 0.7 m.y., 16.9 $\pm$ 1.5 m.y., 16.2 $\pm$ 0.5 m.y., establish the age of these rocks as Miocene.

The lava flows of the Pyramid Sequence range in composition from andesite in the lower part of the sequence to andesite and dacite in the upper part (Table 2). Most of the flows are sparsely porphyritic, containing a few

TABLE 1

| Sample No. | Material Dated | Weight (gms.) | %K | Moles/gm $Ar^{40}$ ($X10^{11}$) Rad | $\%Ar^{40}$ atm | Age (M.Y.) |
|---|---|---|---|---|---|---|
| 1B | Amphibole | 1.01336 | 2.41 | 6.68 | 66 | $15.9\pm0.7$ |
| 7C | Amphibole | 1.92342 | 0.55 | 1.73 | 50 | $17.9\pm0.7$ |
| 7D | Amphibole | 1.93671 | 0.54 | 1.60 | 84 | $16.9\pm1.5$ |
| 34 | Plagioclase | 3.09707 | 0.66 | 1.88 | 28 | $16.2\pm0.5$ |

Constants Used:

$\lambda_\beta = 4.962X10^{-10}/yr$

$\lambda_\varepsilon = 0.581X10^{-10}/yr$

$K^{40}/K_{Tot.} = 1.167X10^{-4}$Mole/Mole

$\frac{Ar^{40}}{Ar^{38}}$ spike $= 0.0525$

$\frac{Ar^{36}}{Ar^{38}}$ spike $=0.0306$

Analyst: S. Evans

TABLE 2
CHEMICAL COMPOSITION[a] AND TRACE ELEMENT ABUNDANCES (ppm)
OF LAVA FLOWS FROM THE PYRAMID SEQUENCE

| | 5 | 14 | 9 | 15 | 16 |
|---|---|---|---|---|---|
| $SiO_2$ | 57.02 | 55.54 | 61.55 | 59.62 | 62.72 |
| $TiO_2$ | 1.30 | 1.19 | .65 | .76 | .60 |
| $Al_2O_3$ | 16.96 | 18.21 | 16.89 | 17.30 | 17.21 |
| $Fe_2O_3$ | 8.04 | 6.79 | 6.03 | 6.63 | 4.88 |
| MnO | .17 | .11 | .16 | .10 | .13 |
| MgO | 2.12 | 2.57 | 2.49 | 1.99 | 1.53 |
| CaO | 5.35 | 7.05 | 4.66 | 4.82 | 4.10 |
| $K_2O$ | 2.58 | 1.97 | 2.72 | 2.37 | 2.53 |
| $Na_2O$ | 3.99 | 4.62 | 4.31 | 4.62 | 4.86 |
| $P_2O_5$ | .56 | .46 | .18 | .26 | .30 |
| $SO_3$ | .00 | .00 | .00 | .00 | .00 |
| LOI[b] | 1.59 | 1.64 | 1.14 | 1.28 | 1.33 |
| TOTAL | 99.68 | 100.15 | 100.78 | 99.45 | 100.19 |
| Nb | 10 | <5 | <5 | <5 | <5 |
| Zr | 155 | 135 | 125 | 180 | 155 |
| Y | 30 | 20 | 20 | 20 | 20 |
| Sr | 565 | 745 | 450 | 525 | 565 |
| Rb | 65 | 40 | 80 | 65 | 70 |
| Th | <5 | 10 | 5 | 5 | <5 |
| Pb | 10 | 10 | 15 | 5 | 5 |

a. Analyst - F. Brown
b. loss on ignition
5; Pyroxene andesite, $Tsv_1$
14; Pyroxene andesite, $Tsv_2$
9; Pyroxene andesite, Tvu
15; Pyroxene andesite, Tvu
16; Dacite, Tvu

phenocrysts of plagioclase and hypersthene accompanied in places by olivine. The accompanying cross section (Plate II) illustrates the general distribution of the flows within the northern part of the Lake Range. Although lava flows from the lower part of the sequence wedge out against topographic highs in the underlying Nightingale Sequence, the upper part of the Pyramid Sequence is continuous throughout most of the San Emidio area. About 15.9 $\pm$ 0.7 m.y. ago (Evans, personal communication, 1979, Table 1) these lava flows were overlain by the porphyritic lava flows that form Falcon's Ridge.

Intermediate composition volcanism continued sporadically after deposition of the Pyramid Sequence, producing local flows that are interbedded with the late Tertiary clastic rocks. Along the northwestern margin of the Lake Range these rocks overlie the Pyramid Sequence and the metasedimentary rocks of the Nightingale Sequence. Lake sediments related to Lake Lahontan (Bonham, 1969) and, locally, a thin veneer of alluvium overlie Tertiary rocks on the western margin of the Lake Range.

The structural setting of the San Emidio area reflects a pattern of north- and east-trending faults related to Basin and Range tectonism. Major north-trending faults have rotated the Tertiary rocks eastward and appear to have localized the hydrothermal alteration along the western margin of the Lake Range. The distribution of faults on the eastern margin of the San Emidio Desert is illustrated on Plates I and II. A preliminary interpretation of seismic reflection data obtained by Chevron Resources Company suggests that vertical displacements as great as 10m may have occurred in this area since deposition of the late Pleistocene lake beds (Worthen, personal communication, 1979).

## ALTERATION

Since the late Tertiary, widespread hydrothermal activity has extensively altered the Cenozoic and Mesozoic rocks along the eastern flank of the San Emidio Desert and has deposited minor amounts of opal in fracture zones throughout much of the Lake Range. Bold, deeply dissected outcrops of intensely silicified and argillically altered Tertiary rocks, exposed along the northwest margin of the Lake Range, represent the oldest phase of Cenozoic alteration. The argillically altered horizons contain variable proportions of silica, montmorillonite, jarosite and clinoptilolite (Papke, 1969). These rocks may, in part, be altered volcanics.

A younger period of hydrothermal activity is represented by numerous calcium carbonate deposits that locally contain fragments of silicified rocks. These deposits are characterized by a pronounced northerly or easterly trending, nearly vertical fabric that distinguishes them from the more widespread tuffa mounds of the region. These calcium carbonate deposits may represent the feeder zones of hot spring deposits that were active in the past. Locally, quartz has filled the interstices between the calcite crystals in these deposits.

An even younger hydrothermal event is associated with a broad thermal anomaly on the eastern edge of the San Emidio Desert (Earth Science Laboratory, 1979). Hydrogen sulfide seeps related to this hydrothermal system have produced native sulphur occurrences (see for example the model of Schoen and others, 1974) and zones of intense acid leaching aligned along one of the steeply dipping range front faults. Shallow excavations along the fault have exposed coarsely crystalline caps of gypsum, formed by the circulation of meteoric water, above the native sulphur. Locally the sulphur is accompanied by traces of mercury (Bonham, 1969).

## CONCLUSIONS

Since mid-Tertiary time, the rocks on the eastern edge of the San Emidio Desert have undergone extensive hydrothermal alteration. The most recent alteration has produced intense acid leaching and small native sulphur deposits along a steeply dipping range front fault. These deposits reflect the continued evolution of hydrogen sulfide from near-surface thermal fluids related to a presently active hydrothermal system. The absence of recent igneous activity, the close association between the thermal fluids and range front faults, and the limited distribution of active thermal features suggest that the thermal fluids represent deep circulation of meteoric water.

## ACKNOWLEDGEMENTS

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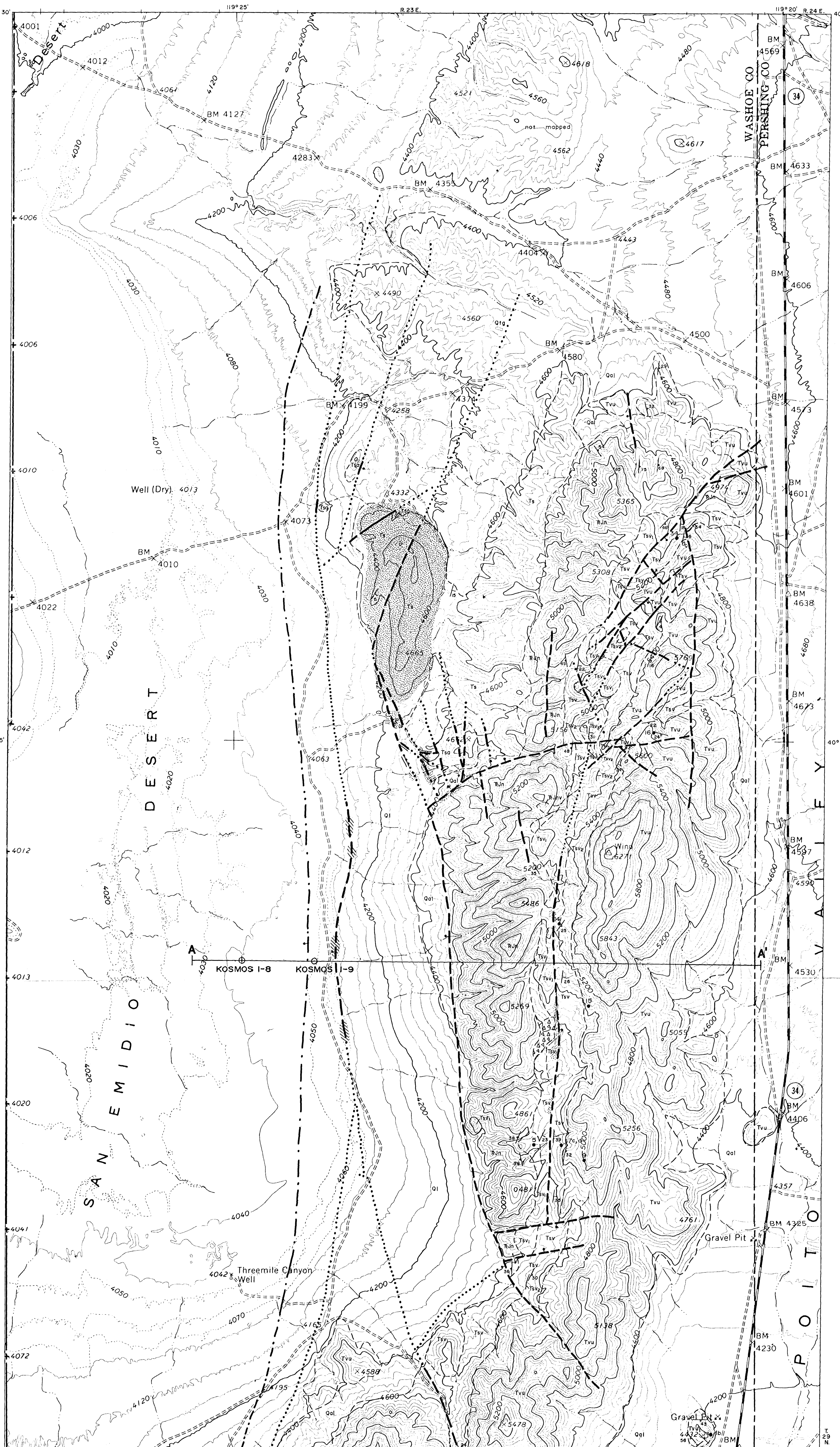
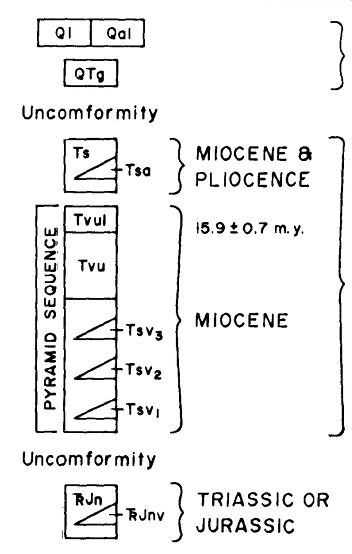



## Correlation of Map Units




Qal ALLUVIAL DEPOSITS (QUARTERNARY)

Ql LAKE DEPOSITS (QUARTERNARY)--Includes a thin veneer of talus and alluvium along the western edge of the Lake Range.

QTg TERRACE GRAVELS (QUARTERNARY)--Predominately sands and gravels.

Ts SANDSTONE AND CONGLOMERATE (MIOCENE AND PLIOCENE)--Sandstone, conglomerate, siltstone and intermediate composition lava flows. This unit is extensively silicified on the northwestern margin of the Lake Range.

Tsa Mafic Lava Flows--Dark gray intermediate composition lava flows.

PYRAMID SEQUENCE (MIOCENE)

Tvul Lava Flows of Falcons Ridge--Maroon to gray lava flows containing phenocrysts of plagioclase and hornblende. K-Ar age is 15.9±0.7 m.y.

Tvu Upper Part--Largely dark grey flows of intermediate composition containing sparse phenocrysts of plagioclase and hypersthene and, locally, olivine.

Tsv Lower Part--Largely fine- to medium-grained volcaniclastic rocks and mudflows. Includes lenses of lava flows and poorly welded ash-flow tuffs. Pumice-rich ash-flow tuffs near the top of Tsv contain approximately 7% phenocrysts mainly of plagioclase (6%) and traces of hypersthene opaque and augite. K-Ar ages on three samples 16.9± 1.5 m.y., 17.9 ± 0.7 m.y., and 16.2 ± 0.5 m.y.

$Tsv_3$ Upper lens--dark gray lava flow of intermediate composition containing sparse phenocrysts. Similar to $Tsv_1$.

$Tsv_2$ Middle lens--dark gray lava flow of intermediate composition containing sparse phenocrysts of plagioclase, augite and hypersthene.

$Tsv_1$ Lower lens--dark gray aphanitic to sparsely porphyritic lava flows and flow breccias containing phenocrysts of plagioclase and hypersthene.

RJn NIGHTINGALE SEQUENCE--(TRIASSIC AND JURASSIC)--Phyllites and metasandstones. Includes minor carbonate and volcanic (RJnv) horizons.

RJnv Metamorphosed volcanic rocks-white recrystallized lava flows containing relic phenocrysts of plagioclase, biotite, and aggregates of white mica.

## EXPLANATION OF MAP SYMBOLS

Strike and dip of bedding in sedimentary rocks

Strike and dip of foliation in volcanic rocks

Strike and dip of foliation in metamorphic rocks

Contact, dashed where approximately located, dotted where concealed

Fault, dashed where approximately located, dotted where concealed. Ball and bar on downthrown side

Location of fault based on seismic data

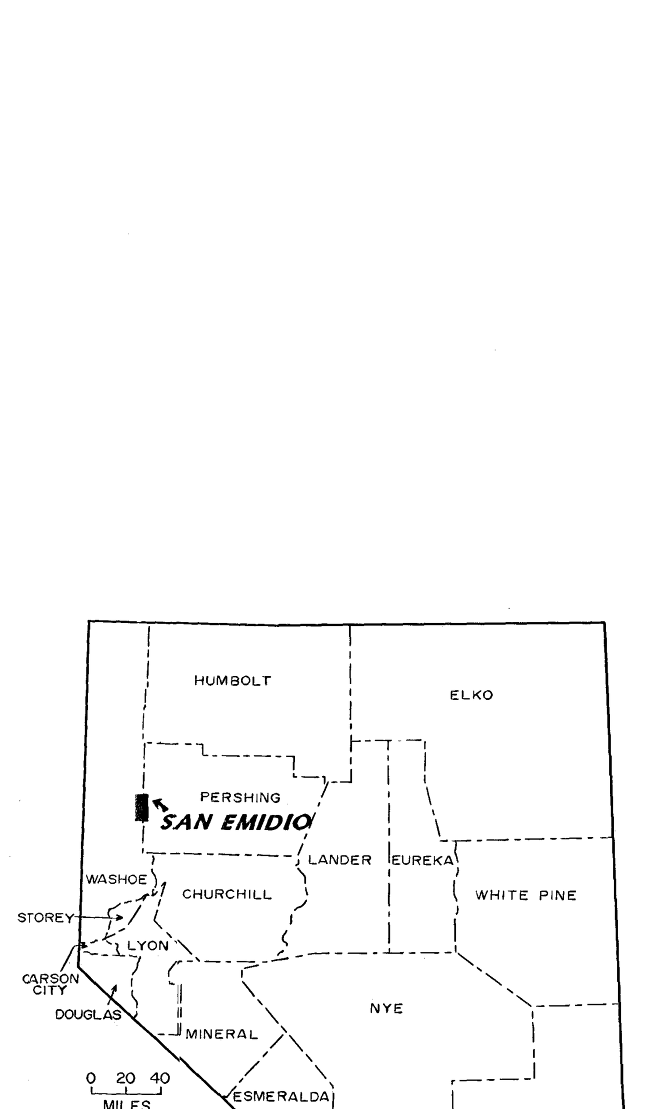
Landslide

Sample location

Native sulphur and intense acid leaching

Silicified and argillically altered

Carbonate deposits




SCALE 1:24,000

Geology by J.N. Moore assisted by M. Adams, 1979


APPROXIMATE MEAN DECLINATION, 1970

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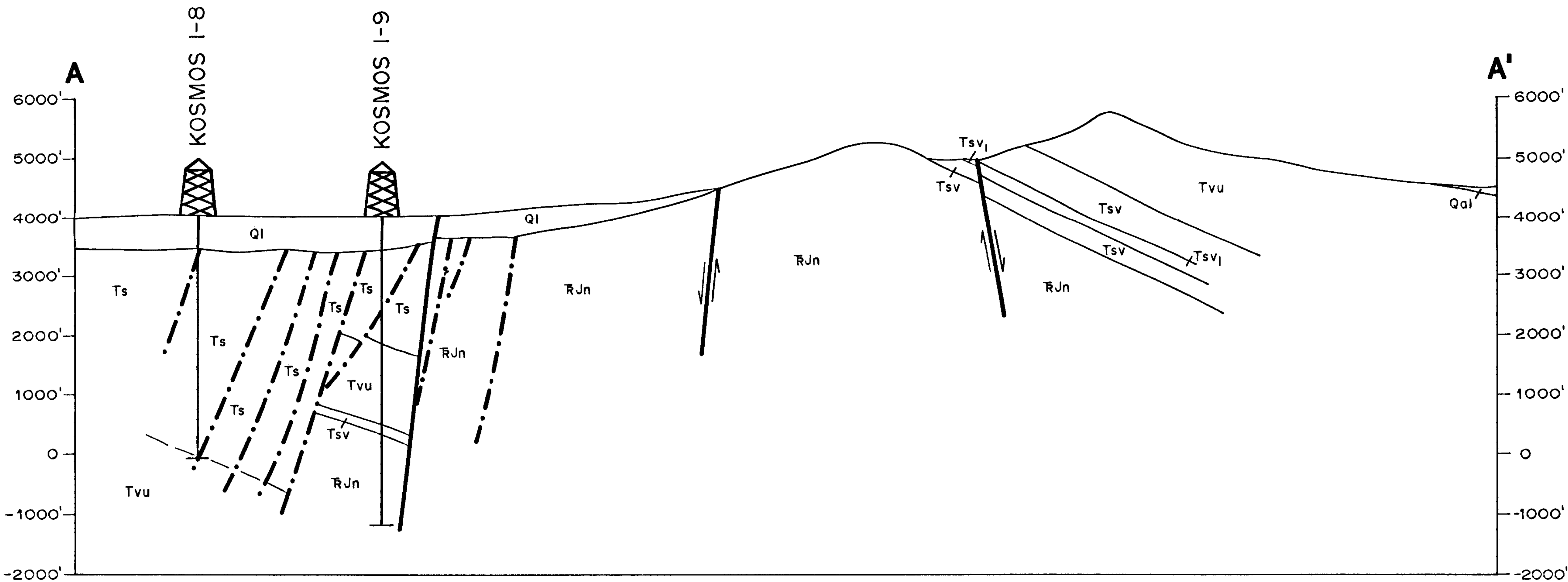
# GEOLOGY MAP OF THE SAN EMIDIO GEOTHERMAL AREA WASHOE AND PERSHING COUNTIES, NEVADA

PLATE I

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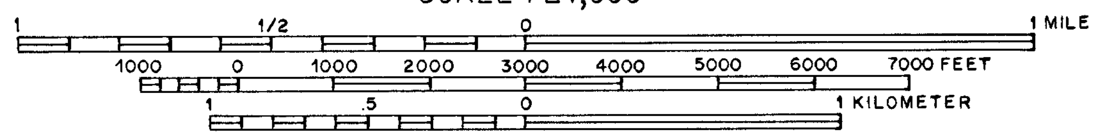


Geology by J. N. Moore assisted by M. Adams, 1979

# CROSS SECTION AA'
# SAN EMIDIO GEOTHERMAL AREA
# WASHOE AND PERSHING COUNTIES, NEVADA

PLATE II