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MASTER

GEOLOGY AND ALTERATION OF THE BALTAZOR HOT SPRINGS AND PAINTED HILLS THERMAL AREAS, HUMBOLDT COUNTY, NEVADA

Jeffrey B. Hulen

December, 1979

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

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

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

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ABSTRACT

The Baltazor Hot Springs KGRA and nearby Painted Hills thermal area are situated in Humboldt County, northwestern Nevada along the northwestern margin of the Basin and Range province.

The oldest rocks exposed in the Baltazor area are eugeosynclinal metasedimentary and subordinate metavolcanic rocks of Permian to Triassic(?) age intruded by Cretaceous diorite and quartz diorite. These are overlain by a thick volcanic and volcaniclastic sequence of Miocene through Pliocene age. Pre-Tertiary rocks are not exposed in the Painted Hills. Here, only Miocene to Pliocene volcanics and volcaniclastics crop out, and only the youngest of these can be confidently correlated with rocks of similar age and character in the Baltazor area.

Principal structures in the Baltazor area are intersecting high-angle normal faults which trend northerly and northwesterly. Quaternary landslides are dominant in the Painted Hills, although northerly- and northwesterly-trending high-angle faults are also present.

Hydrothermal alteration and mineralization at Baltazor and in the Painted Hills are of several different styles and ages. Copper-bearing quartz veins in pre-Tertiary rocks antedate Cenozoic volcanism and sedimentation. Wide-spread argillization, silicification, hematization and local mercury mineralization in the Painted Hills are probably pre-Pleistocene in age, even though coincident with a contemporary thermal anomaly. Small calcite-bearing opaline sinter deposits at Baltazor Hot Springs are probably genetically

related to chalcedony-calcite veins in adjacent mid-Miocene volcanics and Quaternary landslide debris.

Baltazor Hot Springs and associated thermal phenomena and alteration are controlled by the intersection of northerly- and northwesterly-trending high-angle normal faults. The Painted Hills thermal anomaly and alteration may be controlled both by high-angle faults and permeable Tertiary volcanic and volcaniclastic horizons. The heat source for thermal phenomena and alteration in both areas is probably deep fault-controlled fluid circulation coupled with an abnormally high regional thermal gradient.

INTRODUCTION

The Baltazor Hot Springs and Painted Hills thermal areas are situated, respectively, about five and sixteen miles southwest of Denio, in northwestern Humboldt County, Nevada (Fig. 1; Pl. I). Baltazor Hot Springs, site of a Known Geothermal Resource Area (KGRA), issues from a narrow playa separating two northerly-trending, westward-tilted fault blocks: the Pueblo Mountains on the west, and the Pine Forest Range, on the east. The intensely altered and iron-stained Painted Hills occupy the easternmost corner of McGee Mountain, a broad feature of low relief formed dominantly of Miocene rhyolite.

Suspecting a common heat source and structural control for the two thermal areas, Earth Power Production Company initiated geothermal exploration at Baltazor and in the Painted Hills in 1977. Their exploration program comprised literature review and photogeologic mapping (Gardner and Koenig, 1978), groundwater appraisal (Klein and Koenig, 1977), a microearthquake study (Senturion Sciences, 1977) and shallow- to moderate-depth thermal gradient drilling (Earth Power Production Company, 1978). Data generated by this program were submitted to the Earth Science Laboratory according to terms of the Industry Coupled Program of the Department of Energy/ Division of Geothermal Energy. Careful review of these data revealed a need in both areas for hydrothermal alteration mapping and additional geologic mapping. Results of this mapping, completed in mid-1979, are summarized in this report.

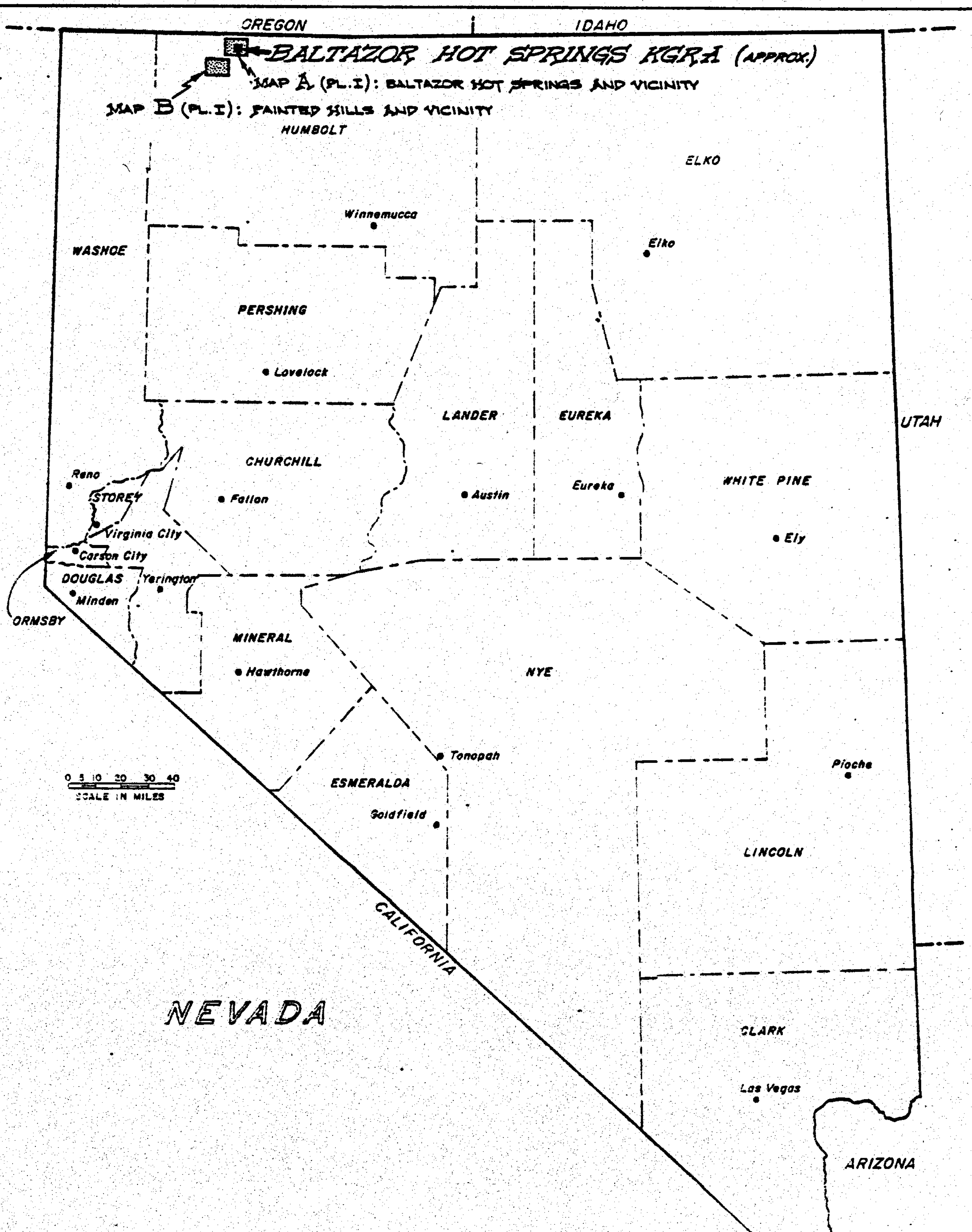

FIGURE 1. LOCATION MAP

GEOLOGIC SETTING

Baltazor Hot Springs and the Painted Hills are situated along the northwestern margin of the Basin and Range province. To the west, high volcanic plateaus, (including McGee Mountain) of northwestern Nevada and south-central Oregon form a transition zone between the Basin and Range and the Columbia Plateau (Bonham, 1969).

A generalized stratigraphic column for the northwestern Basin and Range and high volcanic plateaus to the west is presented in Figure 2. The oldest rocks are eugeosynclinal metasedimentary and metavolcanic rocks of Permian through Triassic(?) age (Willden, 1964; Walker and Repenning, 1965). These rocks are locally folded and intruded by Jurassic to Cretaceous plutons that are dominantly granodioritic to quartz dioritic in composition (Willden, 1964; Walker and Repenning, 1965; Harrold, 1972).

The metamorphic and igneous rocks were deeply eroded before being covered with a thick, highly variable sequence of volcanic and volcaniclastic rocks of Oligocene through Pleistocene age (Willden, 1964; Walker and Repenning, 1965; Bonham, 1969). Volcanics of this sequence vary in composition from basalt to rhyolite. They were erupted from numerous volcanic centers and were not all of regional extent. Associated sediments simultaneously accumulated in local basins. Thus regional correlation of many individual volcanic and sedimentary units cannot be confidently established.

The oldest Tertiary units, of Oligocene to early Miocene age, comprise tuffaceous sedimentary rocks, subordinate ash-fall and ash-flow tuff and

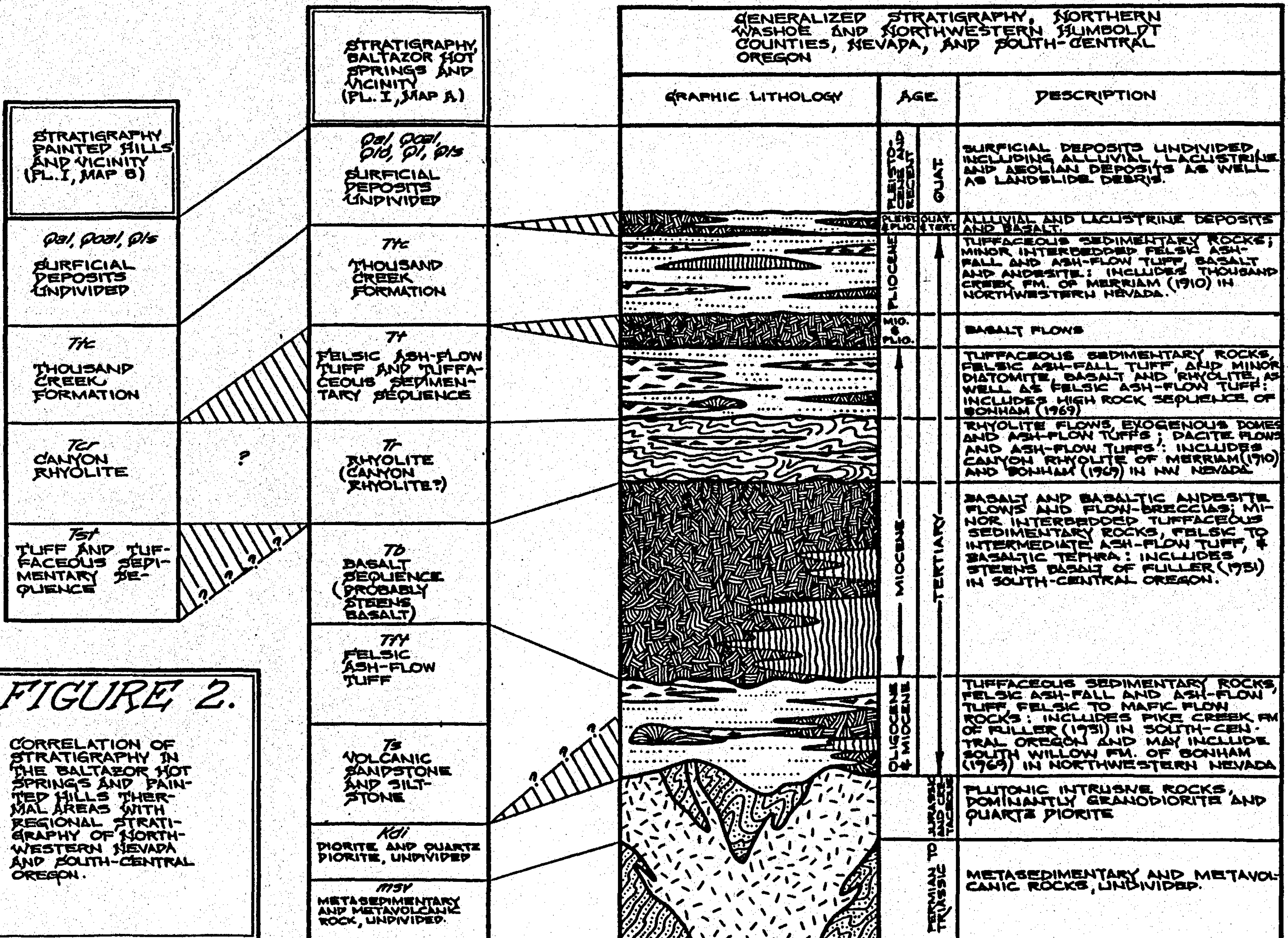

FIGURE 2.

CORRELATION OF STRATIGRAPHY IN THE BALTAZOR HOT SPRINGS AND PAINTED HILLS THERMAL AREAS WITH REGIONAL STRATIGRAPHY OF NORTHWESTERN NEVADA AND SOUTH-CENTRAL OREGON.

felsic to basic flow rocks of local extent. In northwestern Nevada, these flows include basalts and andesites of the South Willow Formation, which is no younger than 31.3 m.y. (K-Ar; Bonham, 1969). Tuffaceous sediments of the Pike Creek Formation (Fuller, 1931), in south-central Oregon, have been assigned an Oligocene to Miocene age by Walker and Repenning (1965). The Ashdown Tuff, a rhyolitic ash-flow tuff extensively exposed in the Pine Forest Range southeast of Baltazor Hot Springs, has yielded two K-Ar dates of 24 m.y. (Noble and others, 1970).

A thick (up to at least 5,000 ft) sequence of basalt and basaltic andesite flows of mid-Miocene age (Fuller, 1931; Evernden and others, 1964; Walker and Repenning, 1965; Bonham, 1969) rests with minor angular unconformity on the earlier Tertiary volcanics and sediments. In south-central Oregon, this sequence includes the Steens Basalt (Fuller, 1931) which has been radiometrically dated at 14.6 to 14.7 m.y. (Evernden and others, 1964).

The Miocene basalt and basaltic andesite sequence is unconformably overlain in south-central Oregon and northwestern Nevada by mid-Miocene flows, exogenous domes and ash-flow tuffs of rhyolitic to dacitic composition (Willden, 1964; Walker and Repenning, 1964; Bonham, 1969). These rocks include the Canyon Rhyolite sequence of the high volcanic plateaus of northwestern Nevada (Bonham, 1969), which is present in the Painted Hills area and probably present in the Baltazor Hot Springs area. Glass from a rhyolite flow in the Canyon Rhyolite has been radiometrically dated at 13.7 m.y. (McKee and Marvin, 1974).

The mid-Miocene rhyolitic and dacitic sequence (Fig. 2) is unconformably overlain by a highly variable middle to late Miocene (Willden, 1964; Walker and Repenning, 1965; Bonham, 1969) volcanic and volcaniclastic sequence. This sequence consists dominantly of tuffaceous sedimentary rocks, with subordinate felsic ash-flow and ash-fall tuffs, felsic to basic flow rocks and diatomite. In the high plateaus of northwestern Nevada, it forms Bonham's (1969) High Rock Sequence, which includes the locally diatomaceous late Miocene Virgin Valley Formation of Merriam (1910) and Wendell (1970).

Late Miocene and early Pliocene basalts unconformably overlie the late Miocene volcanic and sedimentary sequence throughout much of northwestern Nevada and south-central Oregon (Walker and Repenning, 1965; Bonham, 1969). These flows, which aggregate up to 1000 feet in northwestern Nevada (Bonham, 1969) are absent in the Baltazor Hot Springs and Painted Hills areas.

Tuffaceous sedimentary rocks, with subordinate interbedded felsic ash-fall and ash-flow tuffs and minor basalt and andesite, were deposited in local basins following emplacement of the Mio-Pliocene basalt. These sediments, of Pliocene age (Merriam, 1910; Walker and Repenning, 1965; Willden, 1964), are typified by the Thousand Creek Formation (Merriam, 1910) exposed in both the Baltazor Hot Springs and Painted Hills areas.

These Pliocene sedimentary sequences are locally conformably overlain by thin late Pliocene and/or early Pleistocene basalts and by contemporaneous semi-consolidated fluvial and lacustrine sediments. East of Baltazor Hot Springs, the Pliocene Thousand Creek Formation is capped by the Mesa basalt, dated radiometrically at 1.2 m.y. (McKee and Marvin, 1974, p. 3).

The northwestern Basin and Range structural setting is dominated by two intersecting sets of high-angle faults (Willden, 1964; Walker and Repenning, 1965). Profound normal displacement on faults of one set, striking north to north-northeast, is responsible for the typical horst-and-graben and tilted fault-block topography of the region. A second set of faults strikes northwest to west-northwest. Although most faults of this second set are characterized by normal displacement, some may have a right-lateral strike-slip component (Lawrence, 1976).

The high volcanic plateaus of south-central Oregon and northern Nevada west of the Basin and Range are also disrupted by high-angle northerly and northwesterly-trending faults (Walker and Repenning, 1965; Bonham, 1969). Movement along these faults, however, is relatively minor. Bonham (1969) reports that lake beds of late Miocene age in the plateau area are essentially flat-lying, implying little or no deformation in the area since their deposition. Wendell (1970), however, documents broad, open folding in the late Miocene Virgin Valley Formation about 10 miles east of the Painted Hills.

STRATIGRAPHY

Figure 2 correlates regional stratigraphy of northwestern Nevada and south-central Oregon with local stratigraphy of the Baltazor Hot Springs and Painted Hills thermal areas. Correlations for the Baltazor area are taken from Rowe (1971), Burnham (1971) and Bryant (1970), and for the Painted Hills from Wendell (1970). Brief descriptions of all rock units mapped for this report accompany Plate I.

Baltazor Hot Springs and Vicinity (Pl. I; Map A)

The oldest rocks of the Baltazor area are Permian to Triassic(?) metasedimentary and subordinate metavolcanic rocks (msv) exposed in sec. 1, T.47N., R.28E. These are dominantly of greenschist, but locally higher, metamorphic grade (Burnham, 1971; Rowe, 1971). The metamorphics are intruded by mafic-rich, commonly prophyritic diorite and quartz diorite (Kdi). Age dates obtained for similar intrusives in the Pine Forest Range just outside the area mapped for this report range from 107 m.y. to 94 m.y.(Harrold, 1972). The diorite and quartz diorite of the mapped area, therefore, are tentatively assigned a Cretaceous age.

The metamorphics and intrusives in the Baltazor area are unconformably overlain by at least 4,000 ft of diverse Tertiary volcanic and volcaniclastic rocks. The oldest of these are a thin, discontinuous volcanic siltstone-sandstone unit (Ts) and overlying felsic ash-flow tuff (Tft) cropping out in sections 25 and 36, T.47N., R.29E.

These oldest Tertiary units are conformably overlain in the Baltazor area by up to 2,800 ft of thin olivine-augite basalt flows (Tb). These basalts have been correlated with the mid-Miocene Steens basalt of south-central Oregon (Fig. 2). Thin felsic to intermediate ash-flow tuffs are locally interbedded with the basalts, particularly in the upper 300 ft of the sequence. The uppermost of these tuffs (tf) and a distinctive andesite (an) found slightly higher in the sequence during this study are prominent marker horizons, although not previously mapped.

The basalt sequence is disconformably overlain in the Pueblo Mountains west of Baltazor Hot Springs (map A) by up to 400 feet of dense rhyolite and rhyolite flow-breccia (Tr). These rocks, on the basis of similarity to portions of the Canyon Rhyolite sequence (Fig. 2) exposed about ten miles southwest, have been assigned a probable mid-Miocene age by Burnham (1971).

Both the basalt (Tb) and rhyolite (Tr) units east of Baltazor Hot Springs (map A) are unconformably overlain by several hundred feet of rhyolitic to trachytic (Burnham, 1971) ash-flow tuffs (Tt). Volcaniclastic sediments are locally interbedded with the tuffs, particularly toward the base of the sequence. The tuffs may correlate with the mid- to Late Miocene Virgin Valley Formation (this rept., p. 8).

Volcanic conglomerates and sandstones of the Pliocene Thousand Creek Formation rest unconformably on--and were largely derived from--the ash-flow tuff sequence and underlying rhyolite in the Baltazor area. These coarser volcaniclastics grade westward into tuffaceous siltstones and mudstones interbedded with air-fall tuff.

Painted Hills and Vicinity (Pl. I; Map B)

The oldest rocks exposed in the Painted Hills form a sequence of semi-consolidated tuffaceous sedimentary rocks and interbedded felsic ash-flow and ash-fall tuffs (Tst) assigned a mid-Miocene age by Wendell (1970). Rocks of this sequence do not correlate with any exposed in the Baltazor Hot Springs area. A thin, densely welded, highly altered ash-flow tuff (wt) in the upper portion of the sequence was believed by Wendell (1970) to be Pleistocene in age. This tuff, however, has since been radiometrically dated by D. Langenkamp (in Gardner and Koenig, 1978) at 14 m.y. (mid-Miocene).

The mid-Miocene tuff and tuffaceous sedimentary sequence of the Painted Hills area is unconformably overlain by rhyolitic flows of the mid-Miocene Canyon Rhyolite (Wendell, 1970). These flows are similar to mid-Miocene rhyolitic flows (Tr) of the southern Pueblo Mountains in the Baltazor Hot Springs area (Fig. 2). If the Baltazor and Painted Hills rhyolitic flows are correlative, the tuff and tuffaceous sedimentary sequence (Tst) of the Painted Hills occupies the same stratigraphic position as the mid-Miocene basalt sequence of the Baltazor Hot Springs area. This relationship suggests southward thinning, pinching out, or downfaulting (or downwarping) of the basalt sequence south of the Baltazor area accompanied by pinching out or structural impedance of the tuffaceous sequence northward from the Painted Hills. Alternatively, but less likely, the two units may intertongue somewhere between the two areas.

The Pliocene Thousand Creek formation is well exposed in the Painted Hills area. Here the formation laps onto the mid-Miocene(?) tuff and tuffaceous sedimentary sequence (Tst) and onto the mid-Miocene Canyon Rhyolite (Tcr) flows above this sequence. The Thousand Creek formation of the Painted Hills comprises ash- and pumice-rich sandstone, conglomerate, and siltstone, tuffaceous mudstone, terrestrial and water-lain ash-fall tuffs and lapilli tuffs and minor non-welded ash-flow tuff. As in the Baltazor Hot Springs area, coarser clastics in the Thousand Creek Formation of the Painted Hills predominate near present topographic highs, while fine clastics become increasingly common basinward to the east.

STRUCTURE

Baltazor Hot Springs is situated just east of the westward-dipping Pueblo Mountains, the westernmost fault-block range at this latitude in the Basin and Range province (Pl. I; map A). The steep eastern face of the Pueblo Mountains in the Baltazor area is largely the result of pronounced normal displacement along moderate- to high-angle north to northeast-trending Basin and Range faults. These faults control the narrow valley separating the Pueblo Mountains from the similarly-tilted Pine Forest Range, to the southeast. They also doubtless represent a major control for thermal fluid flow in the vicinity of Baltazor Hot Springs. Over-steepening effected by these faults has led to subordinate low-angle faulting and landsliding.

A second set of normal faults in the Pueblo Mountains northwest of Baltazor Hot Springs has been recognized as a result of mapping the prominent andesite (an) and ash-flow tuff (tf) marker horizons in the upper part of the Miocene basalt sequence (Tb). These faults trend northwest, and are apparently near-vertical. The southernmost of these faults, in sections 3, 10, and 11, T.46N., R.28E., projects southeastward beneath younger fault blocks and Quaternary alluvial and lacustrine deposits directly through Baltazor Hot Springs. The location of the hot springs may be controlled in part by the intersection of the fault with previously discussed northerly-trending normal faults.

Quaternary landsliding dominates the structure of the Painted Hills area. Here, resistant rhyolites and coarse volcaniclastics have slumped over soft, commonly altered tuffs and tuffaceous sediments. Minor disruption has also occurred along northerly and northwesterly trending high-angle normal faults.

THERMAL PHENOMENA, HYDROTHERMAL ALTERATION, AND MINERALIZATION

Baltazor Hot Springs and the Painted Hills are situated within pronounced thermal gradient anomalies defined by Earth Power Production Company's (1978) shallow (≤100 m) drilling program. Near-surface gradients reach 290°C/km in the Baltazor area and roughly 400°C/km in the Painted Hills.

Baltazor Hot Springs, with measured temperatures fluctuating between 76°C and 98°C (Klein and Koenig, 1977) is the hottest of numerous thermal springs in this portion of northwestern Nevada. Thermal springs are absent in the Painted Hills, but warm ground and intermittent fumaroles have been reported (Wendell, 1970; Gardner and Koenig, 1978); neither phenomenon was observed during the present investigation.

Hydrothermal alteration and mineralization in the Baltazor Hot Springs area are of several different styles and ages. Permian to Triassic(?) metasedimentary and metavolcanic rocks contain abundant sericite, chlorite, epidote, albite, and calcite of metamorphic origin (Burnham, 1971; Rowe, 1971; Bryant, 1970). The metamorphics and intruding Mesozoic granitic rocks north of Baltazor Hot Springs are locally cut by veins and irregular masses of partially oxidized pyrite- and chalcopyrite-bearing milky quartz with accompanying phyllic and propylitic alteration. These veins and masses pre-date Tertiary volcanism and sedimentation.

Tertiary rocks in the Baltazor area are essentially unaffected by hydrothermal alteration except along the eastern front of the Pueblo Mountains near Baltazor Hot Springs. Alteration is most pervasive and intense in the landslide and range-front fault zone immediately west and north of the hot springs (Pl. I; Map A). This alteration is also present in scattered patches along fault and fracture zones for at least a mile west and 1 1/2 miles north of this zone. The intensity of the alteration diminishes northward and westward with distance from the hot springs.

Alteration at Baltazor is characterized by fine- to coarse-crystalline, locally chalcedony-bearing calcite veins, which are locally accompanied by bleaching and argillization of their host rocks. Most of the veins, which may be massive to delicately banded and vuggy, are less than 10 cm in thickness. One vein, however, trending north-northeast in the southwest corner of section 12, T.47N., R.28E., is approximately ten feet in maximum thickness. Masses of dense goethitic and hematitic jasperoid were commonly observed in float within and below these calcite vein zones. None of this jasperoid was seen in outcrop. The jasperoid is orange- to reddish-brown and commonly laced with calcite ± chalcedony veinlets. Locally the jasperoid contains irregular masses of bright yellow-green montmorillonitic clay. Irregular pods of this clay, up to 5 mm. in diameter, also occur in situ within and along the northerly-trending fault zone north-northeast of drill hole BZ-1500-7 (Pl. I; Map A).

A few small low mounds of frothy-appearing, light brownish-gray opaline sinter, incorporating abundant opalized plant debris, are distributed around Baltazor Hot Springs. Open spaces in the sinter are commonly coated or partially filled with cryptocrystalline calcite. Small chips of the sinter are common in the dense grassy vegetation surrounding the springs, suggesting that the vegetation may conceal additional sinter deposits.

The Painted Hills are named for a broad, irregular zone of altered and iron-stained Tertiary volcanics and sediments, primarily of the Pliocene Thousand Creek Formation. Alteration within this zone is dominated by pervasive, moderate to intense argillization, locally accompanied by weak to moderate flooding, veining, and open-space filling by various combinations of opal, chalcedony, and earthy iron oxides. Of the latter, finely-divided brick-red hematite is by far the most common. The extremely fine grain size of the hematite, and absence of associated sulfides or sulfide casts, suggests it is of primary rather than supergene origin. The upper surface of an irregular zone of hematite flooding south of the Painted Hills mercury prospect is apparently controlled largely by bedding in the Thousand Creek Formation. Hematite stained tuffs and tuffaceous sediments below 1,300 feet in drill hole McG-1500-2 (section B-B') may represent the plunging subsurface eastward projection of this zone.

The Painted Hills mercury prospect is situated on a silicified, argillized, and hematized northerly-trending, steeply-dipping fault zone (Pl. I; Map B). In the prospect area, trace to minor amounts of cinnabar occur along the fault zone as smears, films, and disseminated grains on fractures and slickensided fault sufaces. The cinnabar is locally covered by thin films of transparent botryoidal hyalite.

A second zone of intense alteration and hematite flooding is centered about a quarter mile southwest of the Painted Hills zone. The densely welded ash-flow tuff (wt) occupying most of this zone is strongly silicified and hematized. Silicification occurs both as a pervasive chalcedony flooding and as stockwork goethitic and hematitic jasper veinlets. Wendell (1970) reports the additional presence of an unidentified zeolite in the tuff.

This altered densely welded tuff has been dated at 14 m.y. (this rept., p. 11). This is probably the age of alteration rather than emplacement, since the tuff is consistently silicified and hematized throughout the mapped area (Pl. I; Map B). Thus, alteration of the tuff may predate other alteration in the Painted Hills area, which affects Pliocene rocks. Alteration of the tuff also apparently pre-dates the Miocene Canyon Rhyolite (Tcr). Exposures of the tuff in the southern margin of the mapped area are also silicified and iron-stained while the superjacent rhyolite is unaltered.

CONCLUSIONS

The present study indicates that structural control for Baltazor Hot Springs and its associated thermal gradient anomaly is the intersection of steeply-dipping northerly- and northwesterly-trending normal faults. Structural control for the Painted Hills thermal gradient anomaly is not clear. The few faults recognized in this area are insufficient to explain the observed extent and intensity of either the thermal gradient anomaly or spatially associated hydrothermal alteration. These phenomena could be controlled in part by favorable (permeable) beds in the Thousand Creek Formation. They could also be controlled by structures concealed beneath surficial deposits or obscured beyond recognition by argillic alteration and slumping in soft tuffaceous sediments.

The Baltazor Hot Springs and Painted Hills areas are situated within the Battle Mountain heat-flow high (Sass and others, 1971), which covers much of the central and northwestern Basin and Range. The absence of young rhyolitic volcanics at Baltazor and in the Painted Hills, together with the location of these areas in the Battle Mountain zone, suggest that deep circulation along faults, rather than shallow silicic magma, is the heat source for the thermal phenomena of both areas.

Hydrothermal alteration in the immediate Baltazor Hot Springs area diminishes in extent and intensity with distance northward and westward from the hot springs. Sinter deposits and veins cutting bedrock within the altered area are similar in composition. Many of the veins are vuggy and delicately banded, indicating deposition at shallow levels. These relationships suggest that the alteration is related to the presently active geothermal system.

Alteration in the Painted Hills area at least partially--and perhaps totally--predates present thermal activity. Although the alteration does largely coincide with a contemporary thermal anomaly, the youngest altered units are of Pliocene age. Quaternary alluvium is unaltered. Alteration in Quaternary landslides is restricted to individual clasts and blocks, and predates slumping.

Siliceous sinter deposits, indicating past reservoir temperatures of at least 180°C (Renner and others, 1975), are present at both Baltazor Hot Springs and Howard Hot Springs (D. Langenkamp, pers comm., 1979) about 18 miles southeast of Baltazor. Neither Baltazor Hot Springs, with temperatures of 76-98°C (Klein and Koenig, 1977), nor Howard Hot Springs, at 56°C (Mariner and others, 1974), however, are presently precipitating silica. This indicates a progressive cooling through time of the heat sources for both springs.

Springs are absent in the Painted Hills area, but widespread silicification indicates that presently exposed rocks have been extensively invaded by high-temperature thermal waters in the past. Although the water-table has dropped from former levels in the Painted Hills, the relationship of present to past deep subsurface temperatures in this area cannot be inferred from this silicification.

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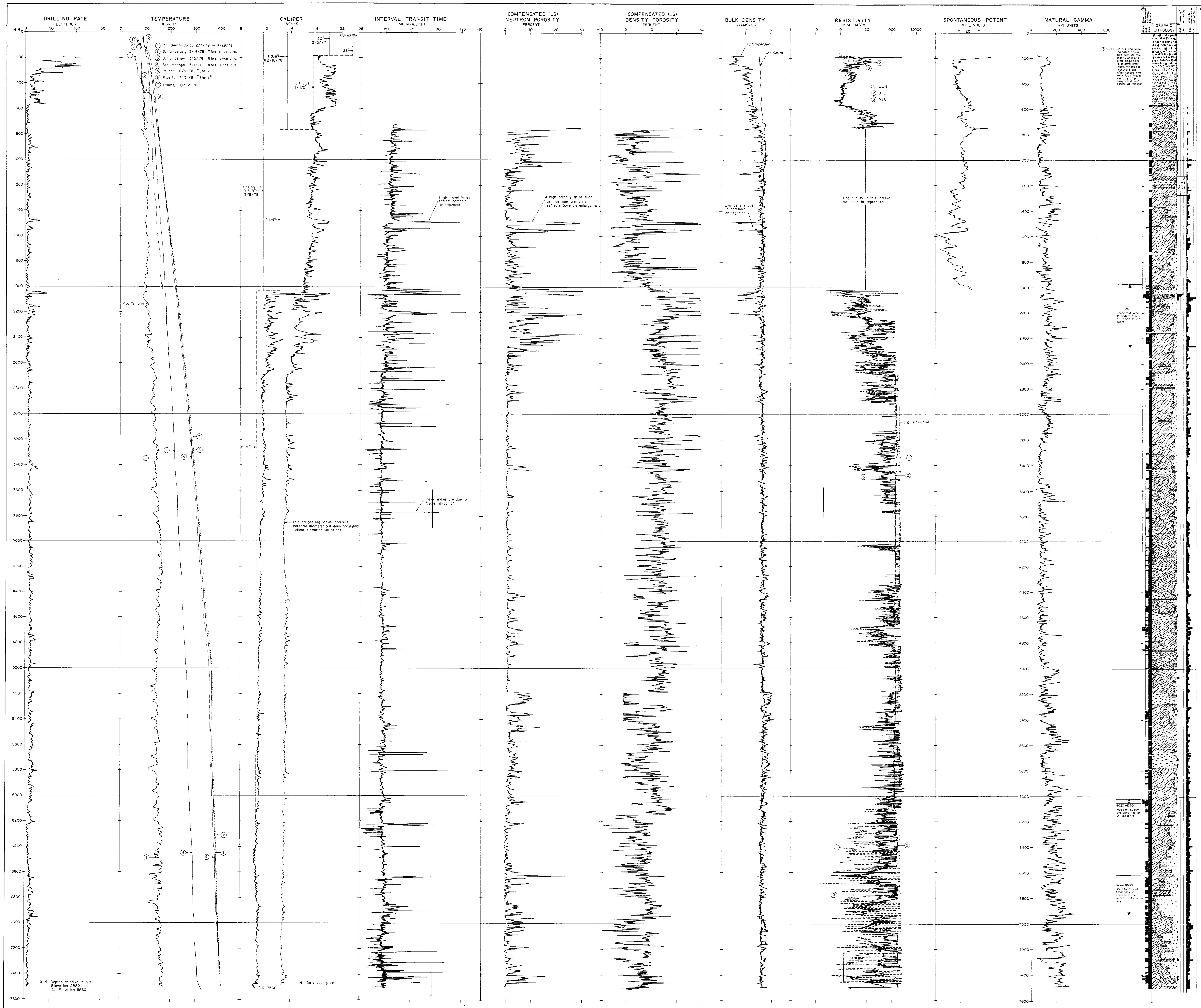


EXPLANATION

* GENERALIZED DRILL HOLE LITHOLOGY by J.B. Hulen	CORRELATIVE SURFACE LITHOLOGY (Nielson and others, 1978)
PUMICEOUS and PERLITIC ARKOSIC ALLUVIUM - Subrounded to angular grains up to 10mm (average 2-3mm) in diameter consisting of Pleistocene pumice and perlite, Precambrian gneiss and Tertiary granitic intrusive rock.	Qal Quaternary alluvium
ARKOSIC ALLUVIUM - Same as above with only traces of pumice and perlite.	Qal Quaternary alluvium
HORNBLENDE DACITE (ANDESITE?) PORPHYRY - 5-7% plagioclase phenocrysts, 1-5% (variable) hornblende phenocrysts embedded in a felted aphanitic groundmass of hornblende, plagioclase and dark opaque minerals with minor quartz and potassium feldspar.	Tmd(?) Tertiary microdiorite
BIOTITE-HORNBLENDE MICRODIORITE PORPHYRY - Subdiabasic texture. Micro-crystalline to fine-crystalline. 5-7% biotite, 15-20% hornblende, 5-7% potassium feldspar, 3-5% quartz, 3% apatite, 1% sphene, 1-2% dark opaque minerals, remainder plagioclase; commonly intensely hydrothermally altered and sulfide-bearing.	Tmd Tertiary microdiorite
LEUCOCRATIC GRANITE AND GRANITIC BANDS and SEGREGATIONS in GNEISS, UNDIVIDED Fine- to medium-crystalline; generally less than 0.5% (up to 5%) biotite (rarely with traces of hornblende), less than 0.5% dark opaque minerals, traces sphene, zircon, apatite; includes some alaskite and probable quartz - Kspar pegmatite.	Probably Tgr (Tertiary fine grained granite) and granitic bands and differentiates in P€bg (Precambrian banded gneiss)
BIOTITE-HORNBENDE QUARTZ MONZONITE GNEISS - Generally medium-crystalline, but varies from fine-(rare) to coarse-crystalline; variable composition; 7-30% (average 20%) hornblende, <1-20% (average 7%) biotite, 0-2% sphene, 0-1% apatite, trace zircon, 1-2% dark opaque minerals.	P€gn Precambrian hornblende gneiss (may include some hornblende rich layers in P€bg) (Precambrian banded gneiss)
FELDSPAR-QUARTZ-BIOTITE (±HORNBLENDE, ±SILLIMANITE) GNEISS - Fine- to medium-crystalline, poorly to well-foliated; principal constituents occur in highly variable ratios; biotite varies from 5-70%, hornblende from 0-40%, 0-15(?)% sillimanite, 0-5% sphene, 0-3% apatite, 0-2% dark opaque minerals, local traces garnet, zircon.	P€bg Precambrian banded gneiss

* For more detailed descriptions refer to Nielson and others (1978), Appendix II.

LOG COMPOSITE OF UTAH STATE GEOTHERMAL WELL

52-21

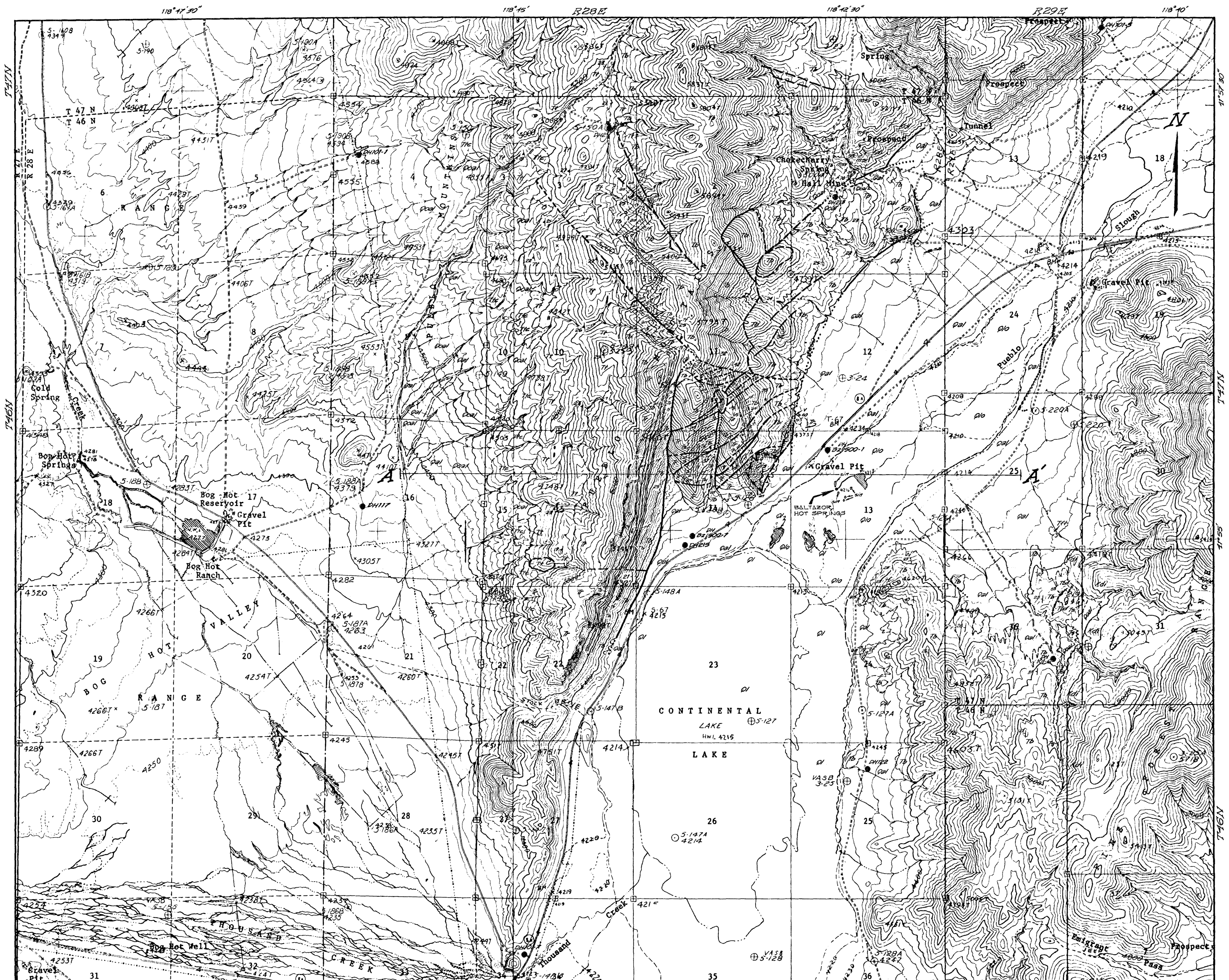
GETTY OIL COMPANY

ROOSEVELT HOT SPRINGS, KGRA

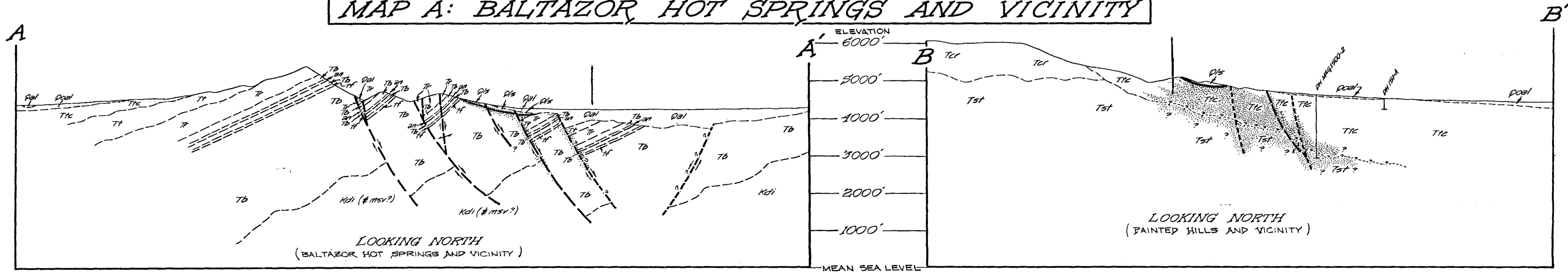
BEAVER COUNTY, UTAH

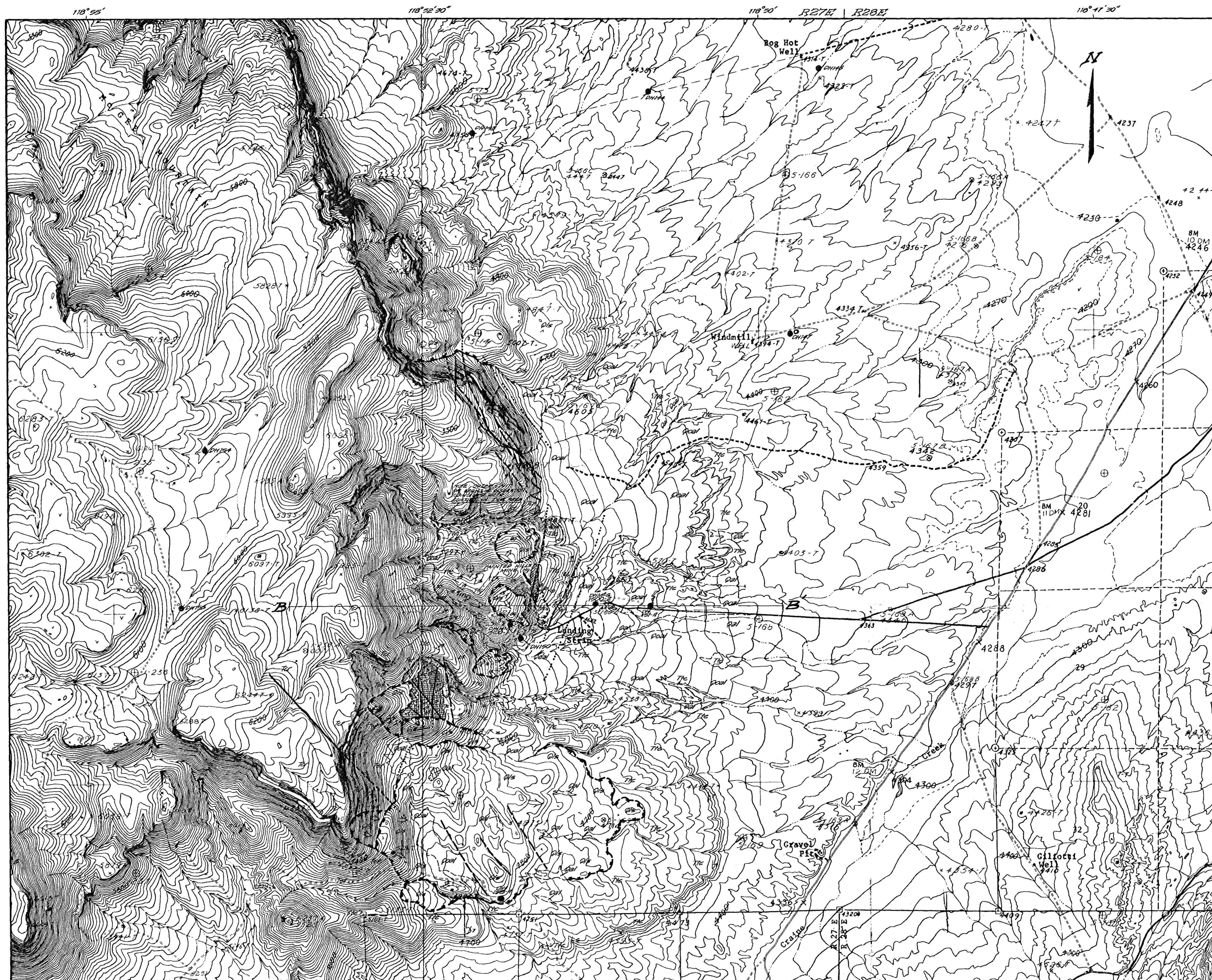
NOVEMBER 1978

EARTH SCIENCE LABORATORY
UNIVERSITY of UTAH RESEARCH INSTITUTE



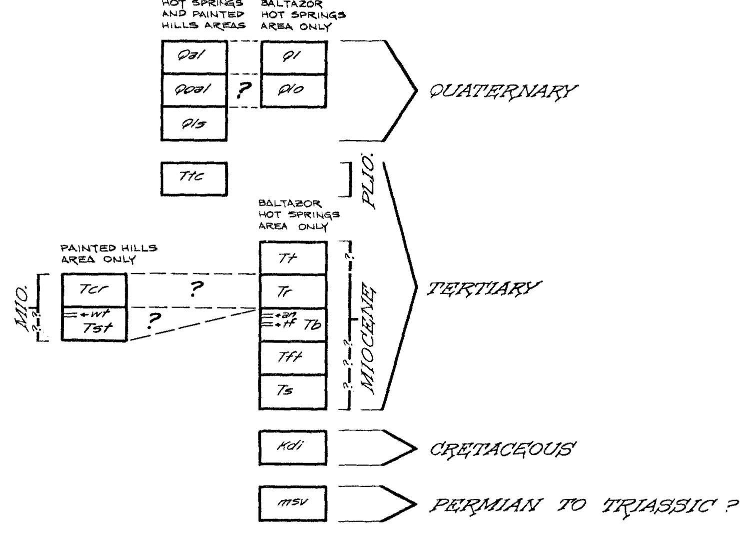
MAP A: BALTAZOR HOT SPRINGS AND VICINITY





MAP B: PAINTED HILLS AND VICINITY

CORRELATION OF MAPPED UNITS



DESCRIPTION OF MAPPED UNITS

Qal ALLUVIAL DEPOSITS (QUATERNARY)

Qoal OLDER ALLUVIAL DEPOSITS (QUATERNARY)

Ql LACUSTRINE (PLAYA) DEPOSITS (QUATERNARY)

UNCONSOLIDATED CLAY AND SILT

Qlo OLDER LACUSTRINE (PLAYA) DEPOSITS (QUATERNARY)

UNCONSOLIDATED CLAY AND SILT; PARTIALLY REWORKED -- INCLUDES MINOR FLUVIAL AND AEOLIAN DEPOSITS.

Qls LANDSLIDE DEBRIS (QUATERNARY)

CHAOTIC RUBBLE IN WHICH INDIVIDUAL ROCK UNITS CANNOT BE READILY MAPPED.

Ttc THOUSAND CREEK FORMATION (PLIOCENE)

LIGHT GRAY TO BUFF, POORLY SORTED, ASH AND PUMICE-RICH SILTSTONE, SANDSTONE, AND CONGLOMERATE, TUFFACEOUS MUDSTONE, AIR-FALL AND WATER-LAIN TUFF AND PUMICE LAPILLI TUFF AND NON-WELDED VITRIC TO VITRIC-LITHIC ASH-FLOW TUFF; COARSER-GRAINED UNITS PREDOMINATE NEAR PRESENT TOPOGRAPHIC HIGHS; FINE WATER-LAIN TUFFS AND TUFFACEOUS MUDSTONES BECOME PROGRESSIVELY DOMINANT BASINWARD.

Tt FELSIC ASH-FLOW TUFF AND TUFFACEOUS SEDIMENTARY SEQUENCE (MIOCENE?)

LIGHT GRAY, REDDISH-GRAY, GRAYISH-BROWN, PINKISH-BROWN AND YELLOWISH-BROWN, NON-WELDED TO DENSELY WELDED, RHYOLITIC TO TRACHYTIC, VITRIC TO VITRIC-CRYSTAL ASH-FLOW TUFFS WITH MINOR INTERBEDDED TUFFACEOUS MUDSTONE, SILTSTONE, SANDSTONE AND CONGLOMERATE; CRYSTALS IN THE TUFFS ACCOUNT FOR <1-20 VOLUME PER CENT AND COMPRISE ANORTHOCLASE, SANIDINE, QUARTZ, BIOTITE, AND MAGNETITE-ILMENITE (TRACE AMOUNTS OF AEGERINE AND RIEBECKITE ARE LOCALLY PRESENT); SEDIMENTARY UNITS CONCENTRATED IN LOWER PORTION OF SEQUENCE.

Tr RHYOLITE OF BALTAZOR HOT SPRINGS AREA (MIOCENE)

LIGHT TO MEDIUM REDDISH-GRAY TO PURPLISH-GRAY RHYOLITE AND RHYOLITE FLOW-BRECCIA, DENSE TO VESICULAR, LOCALLY SPHERULITIC AND LITHOPHYSAL, COMMONLY FLOW-FOLIATED; LESS THAN 1 VOLUME PER CENT PHENOCRYSTS, DOMINANTLY EUHEDRAL SANIDINE WITH MINOR EUHEDRAL QUARTZ; VERY RESISTANT, TYPICALLY FORMING RIDGES AND CAPROCKS.

Tcr CANYON RHYOLITE OF PAINTED HILLS AREA (MIOCENE)

SAME DESCRIPTION AS RHYOLITE OF BALTAZOR HOT SPRINGS (Tr), BUT ALSO INCLUDING LIGHT TO MEDIUM GRAY PERLITE AND DARK GRAY RHYOLITIC VITROPHYRE; AGE RELATION TO RHYOLITE OF BALTAZOR HOT SPRINGS AREA UNKNOWN.

Tst TUFF AND TUFFACEOUS SEDIMENTARY SEQUENCE (MIOCENE?)

LIGHT GRAY, BUFF AND PINK, POORLY SORTED AND POORLY INDURATED VOLCANIC SILTSTONES, SANDSTONES, AND CONGLOMERATES INTERBEDDED WITH VITRIC AIR-FALL TUFFS AND NON-WELDED TO DENSELY WELDED VITRIC ASH-FLOW TUFFS MOST OF THE UNIT IS EASILY ERODED, FORMING SLOPES COVERED WITH TALUS FROM OVERLYING CANYON RHYOLITE (Tcr)

→wt WELDED TUFF MARKER HORIZON: MEDIUM TO DARK BROWNISH-RED DENSELY WELDED FELSIC VITRIC ASH-FLOW TUFF; PROMINENT EUTAXITIC TEXTURE; 5% CRYSTALS, DOMINANTLY SANIDINE WITH MINOR QUARTZ, BIOTITE AND MAGNETITE; INVARIABLY MODERATELY TO INTENSELY SILICIFIED AND HEMATIZED.

Tb BASALT SEQUENCE (MIOCENE)

THICK SEQUENCE (ABOUT 2500 FEET IN THE BALTAZOR HOT SPRINGS AREA) OF THIN (AVERAGE LESS THAN 30 FEET) DENSE TO VESICULAR OLIVINE-AUGITE BASALT AND PORPHYRITIC BASALT FLOWS AND FLOW-BRECCIAS; VERY MINOR INTERBEDDED BASALTIC TEPHRA AND THIN (4-30 FEET) FELSIC TO INTERMEDIATE ASH-FLOW TUFFS AND RARE THIN (LESS THAN 5 FEET) VOLCANIC SILTSTONES AND SANDSTONES; BASALTIC UNITS ARE MEDIUM TO DARK GRAY AND COMMONLY WEATHER TO MEDIUM GRAYISH-RED TO GRAYISH-PURPLE; PORPHYRITIC BASALTS CONTAIN TABULAR LABRADORITE PHENOCRYSTS WHICH IN SOME BEDS REACH 4 cm. IN LENGTH; VESICULAR BASALT UNITS COMMONLY CONTAIN CALCITE ± STILBITE-NATROLITE AMYGDULES.

→an ANDESITE MARKER HORIZON: DENSE, MEDIUM-GRAY PILOTAXITIC HORNBLENDE ANDESITE; STRONGLY FLOW-FOLIATED IN OUTCROP -- FOLIATION LOCALLY HIGHLY CONTORTED; FLOW LAMINAE COMMONLY DISCONTINUOUS, RESEMBLING COMPRESSED PUMICE LAPILLI

→tf ASH-FLOW TUFF MARKER HORIZON: PARTIALLY WELDED (LIGHT GRAY TO PINKISH-GRAY) TO DENSELY WELDED (DARK GRAY, VITROPHYRIC) VITRIC TO VITRIC-CRYSTAL DACITE(?) ASH-FLOW TUFF; UP TO 25% CRYSTALS, DOMINANTLY ANDESINE WITH MINOR SANIDINE, AUGITE, HYPERSTHENE, BIOTITE AND MAGNETITE.

Tft FELSIC ASH-FLOW TUFF (MIOCENE?)

VERY LIGHT REDDISH-BROWN, PARTIALLY WELDED TO DENSELY WELDED FELSIC VITRIC TO VITRIC-CRYSTAL ASH-FLOW TUFF; UP TO 10% SANIDINE CRYSTALS, 3% QUARTZ CRYSTALS, AND 5% LITHIC FRAGMENTS.

Ts VOLCANIC SANDSTONE AND SILTSTONE (MIOCENE?)

VERY LIGHT GRAY TO ORANGE- OR BROWNISH-GRAY VOLCANIC SANDSTONE AND SILTSTONE; REDDISH-BROWN BAKED ZONE AT TOP OF UNIT WHERE OVERLAIN BY BASALT (Tb)

Kdi DIORITE AND QUARTZ DIORITE, UNDIVIDED (CRETACEOUS?)

MEDIUM TO DARK GRAY TO GREENISH-GRAY; GENERALLY MEDIUM-GRAINED BUT MAY BE FINE-GRAINED AT PLUTONIC MARGINS; HYPIDIOMORPHIC-GRANULAR, LOCALLY PORPHYRITIC; LOCALLY FOLIATED; MAJOR ACCESSORY MINERALS INCLUDE BIOTITE, HORNBLENDE, MAGNETITE AND CLINOPYROXENE IN VARIABLE RATIOS; COMMONLY EPIDOTIZED; INCLUDES DARK GREENISH-GRAY ANDESITE PORPHYRY AND LIGHT GRAY TO PINKISH-GRAY APLITE DIKES

msv METASEDIMENTARY AND METAVOLCANIC ROCKS, UNDIVIDED (PERMIAN TO TRIASSIC?)

LIGHT-COLORED QUARTZ-SERICITE ± CHLORITE SCHIST AND PHYLLITE WITH MINOR METAQUARTZITE, GREENSTONE, MUSCOVITE-GARNET SCHIST, AND FELDSPAR-QUARTZ-BIOTITE GNEISS.

MAP SYMBOLS

CONTACTS: LONG DASHES WHERE APPROXIMATELY LOCATED; SHORT DASHES WHERE INFERRED.

FAULTS: LONG DASHES WHERE APPROXIMATELY LOCATED; SHORT DASHES WHERE INFERRED; DOTTED LINE WHERE CONCEALED; BROKEN DOTTED LINE WHERE INFERRED AND CONCEALED.

BOUNDARY OF LANDSLIDE (Qls); DASHED WHERE APPROXIMATELY LOCATED; ARROWS INDICATE DIRECTION OF MOVEMENT.

25 STRIKE AND DIP OF SEDIMENTARY BEDS AND OF INDIVIDUAL BASALT FLOWS IN THE MIOCENE BASALT SEQUENCE (Tb) OF THE BALTAZOR HOT SPRINGS AREA

STRIKE AND DIP OF HORIZONTAL SEDIMENTARY BEDS.

50 STRIKE AND DIP OF FLOW FOLIATION IN VOLCANIC FLOW ROCKS AND OF COMPACTION FOLIATION IN ASH-FLOW TUFFS.

58 STRIKE AND DIP OF SCHISTOSITY IN METAMORPHIC ROCKS.

STRIKE AND DIP OF VERTICAL SCHISTOSITY.

● DH101-7 THERMAL GRADIENT DRILL HOLE

SPRING DEPOSITS AND ALTERATION

BALTAZOR HOT SPRINGS AND VICINITY

sin OPALINE SINTER; LIGHT BROWNISH-GRAY TO MEDIUM GRAY; GENERALLY POROUS; INCORPORATES ABUNDANT OPALIZED PLANT DEBRIS; OPEN-SPACES MAY BE LINED OR PARTIALLY FILLED WITH WHITE TO LIGHT GRAY CRYPTOCRYSTALLINE CALCITE (CALICHE?)

APPROXIMATE AREA OF PERVASIVE DEVELOPMENT OF CALCITE ± CHALCEDONY VEINS AND VEINLETS, COMMONLY ACCOMPANIED BY WEAK TO MODERATE CLAY-CALCITE ALTERATION OF HOST ROCKS; GOETHITIC TO HEMATITIC JASPEROID OBSERVED IN FLOAT WITHIN THIS ZONE, BUT NOT *IN SITU*.

v 60 CHALCEDONY-CALCITE VEIN; WHITE TO LIGHT GRAY; CALCITE IS COARSE- TO VERY COARSE-CRYSTALLINE AND LOCALLY CRUDELY BANDED; CHALCEDONY GENERALLY SHOWS DELICATE BANDING PARALLEL TO CRUDE BANDING IN CALCITE; A FEW ANGULAR CLASTS OF CHALCEDONY ARE IMBEDDED IN THE CALCITE, INDICATING MULTIPLE PERIODS OF CHALCEDONY DEPOSITION.

qtz MASSIVE PYRITE- AND CHALCOPYRITE-BEARING QUARTZ; WHITE TO LIGHT GRAY; SULFIDES ARE PARTIALLY OXIDIZED, YIELDING VARIOUS COMBINATIONS OF GOETHITE, PITCH LIMONITE, HEMATITE, MALACHITE, AZURITE, AND CHRYSOCOLLA; PRE-DATES TERTIARY VOLCANISM AND SEDIMENTATION.

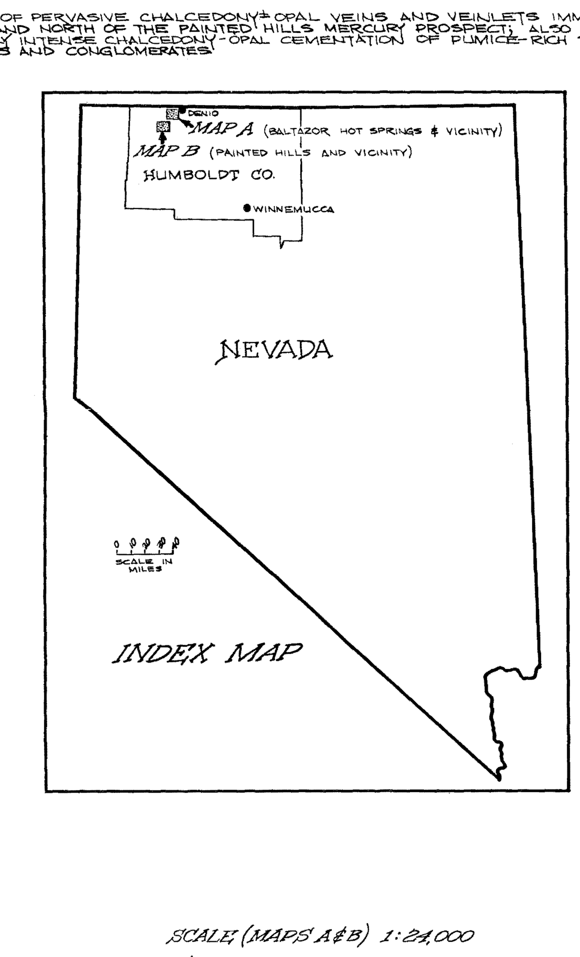
PAINTED HILLS AND VICINITY

OUTER LIMITS OF PERVASIVE, MODERATE TO INTENSE ARGILLIC ALTERATION; INCLUDES PATCHY GOETHITE AND HEMATITE STAINING AND LOCAL SILICIFICATION; CALCITE VEINLETS APPEAR TOWARD THE PERIPHERY OF THIS ZONE.

INTENSE HEMATIZATION, INTENSE ARGILLIC ALTERATION, AND WEAK TO MODERATE SILICIFICATION (OPAL AND CHALCEDONY); ALTERED ROCKS OF THIS ZONE ARE STAINED BRIGHT BRICK-RED BY FINELY-DIVIDED HEMATITE.

INTENSE SILICIFICATION AND INTENSE HEMATIZATION OF DENSELY WELDED ASH-FLOW TUFF HORIZON (wt) IN MIOCENE(?) TUFF AND TUFFACEOUS SEDIMENTARY SEQUENCE (Tst)

ZONE OF PERVASIVE CHALCEDONY ± OPAL VEINS AND VEINLETS IMMEDIATELY EAST AND NORTH OF THE PAINTED HILLS MERCURY PROSPECT; ALSO INCLUDES LOCALLY INTENSE CHALCEDONY-OPAL CEMENTATION OF PUMICE-RICH SANDSTONES AND CONGLOMERATES



SCALE (MAPS A & B) 1:24,000

PLATE I. GEOLOGIC AND HYDROTHERMAL ALTERATION MAPS, BALTAZOR HOT SPRINGS AND PAINTED HILLS THERMAL AREAS HUMBOLDT COUNTY, NEVADA

GEOLOGY BY J. B. HULEN
1979

EARTH SCIENCE LABORATORY
UNIVERSITY OF UTAH RESEARCH INSTITUTE