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**GEOHERMAL ASSESSMENT OF THE MX
DEPLOYMENT AREA IN NEVADA**

Final Report, April 1, 1981—April 30, 1982

By
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June 1982

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University of Nevada, Las Vegas
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Las Vegas, Nevada

U. S. DEPARTMENT OF ENERGY
Geothermal Energy

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**Dennis T. Trexler, James L. Bruce,
Delores Cates, Cameron Covington**

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Prepared For The

**U.S. DEPARTMENT OF ENERGY
DIVISION OF GEOTHERMAL ENERGY
UNDER CONTRACT NO. DE-AC08-81NV10187**

ABSTRACT

A preliminary geothermal resource assessment of the MX deployment area in Nevada focused on Coyote Spring Valley in southeastern Nevada (DOE Contract No. DE-AC08-81NV10187). Initially, an extensive literature search was conducted and a bibliography consisting of 750 entries was compiled covering all aspects of geology pertaining to the study area (see Appendix B).

A structural study indicates that Coyote Spring Valley lies in a tectonically active area which is favorable for the discovery of geothermal resources. Hot water may be funneled to the near-surface along an extensive fracture and fault system which appears to underlie the valley, according to information gathered during the literature search and aerial photo survey.

A total of 101 shallow temperature probes were emplaced in Coyote Spring Valley. Three anomalous temperature points all lying within the same vicinity were identified in the north-central portion of the valley near a fault.

A soil-mercury study also identified one zone of anomalous mercury concentrations around the north end of the Arrow Canyon Range. This zone is approximately seven miles south of the anomalous temperature zone in the direction of flow of the White River flow system which runs underground through Coyote Spring Valley.

A literature search covering regional fluid geochemistry indicated that the three fluid samples taken from Coyote Spring Valley have a higher concentration of Na + K. These samples are probably related to volcanic units found near springs and wells in Coyote Spring Valley. During field work, seven fluid samples were collected in Coyote Spring Valley which also appear to be derived from volcanic units due to the presence of Ca-Mg or Na-K carbonate-bicarbonate.

A temperature gradient study of six test water wells indicates that only one geothermal well with a temperature of 35.5°C (96°F) exists in the central portion of the valley at the north end of Arrow Canyon Range near the zone of anomalous soil-mercury points. This area also lies along a fault which may serve as a conduit for geothermal fluids.

A cultural assessment of Coyote Spring Valley was performed prior to field work. During the literature search, it was discovered that human activity has taken place continuously in the Valley over the past 15,000 years. During field work, if cultural material was found, the site was recorded and another site was selected for drilling.

In conclusion, this preliminary study indicates that geothermal resources may exist in Coyote Spring Valley along the eastern border, however, stratigraphic test drilling must be performed to confirm the resource.

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INTRODUCTION

Geothermal assessment of the Missile X (MX) deployment area in Nevada and Utah began in mid-1980 when the U.S. Department of Energy received a request from the U.S. Department of Defense for technical assistance in developing alternate energy sources for the MX System. The U.S. Department of Energy contacted the Nevada State Geothermal Resource Assessment Team, currently the Division of Earth Sciences of the University of Nevada, Las Vegas for assistance in the Nevada portion of the study.

A preliminary project scope and budget were compiled by the Division of Earth Sciences technical staff for assessment of the entire MX deployment area covering over one million square kilometers or one-third the area of the state of Nevada (fig. 1), including several potential geothermal resources (fig. 2).

Funding was provided under an existing U.S. DOE contract, No. DE-AC08-79NV-10039 for preliminary project planning and data acquisition in order to meet early deadlines established by the U.S. Air Force (U.S.DOD). Funding restrictions were later imposed by the U.S. Air Force, reducing the original project scope to three sites, Coyote Spring Valley, Ely and Tonopah, Nevada. In particular, the proposed main operating base site at Coyote Spring Valley in Clark County, Nevada was to be the primary focus of study (fig. 3).

In April, 1981 a contract for \$1,196,240 for a 24-month geothermal resource assessment was awarded to the Division of Earth Sciences by the U.S. Department of Energy based upon U.S. Department of Defense requirements. This contract called for a complete study of the three areas described above, however, the contract performance would be based upon available funding from DOD. The initial incremental funding level was \$210,645 for a reconnaissance geothermal assessment study of Coyote Spring Valley and the adjacent Kane Springs Valley,

Figure 1. Index map of the original deployment area and study area.

Figure 2. Geothermal resources within the deployment area.

Figure 3. Location of proposed MX operation base, Coyote Spring Valley, Nevada

Figure 4. Tasks scheduled under this incremental funding included compilation of a bibliography, collection of available geologic data, regional and local lineament analysis, aerial photograph interpretation, regional two-meter temperature probe and soil-mercury surveys, and a regional and areal water chemistry study.

Further funding was not made available under Contract No. DE-AC08-81NV10187 because the current Administration postponed the proposed land basing mode of the MX System for further review and analysis. Therefore, geothermal assessment of the MX deployment area was restricted primarily to Coyote Spring Valley, and to a lesser extent, adjacent Kane Springs Valley (figs. 5, 6).

BASELINE DATA COLLECTION

A baseline data study of the MX deployment area was one of the preliminary tasks performed under U.S. DOE Contract No. DE-AC08-79NV10039 (fig. 7).

A bibliography was compiled of available geotechnical and geologic data within the deployment area and includes over 750 entries. A cross-reference key by subject matter was developed for the bibliography to increase its usefulness. Both the bibliography and the key are included in the Appendix.

Regional geologic or geotechnical data which could not be obtained through local sources was purchased, including several geologic reports and computer-enhanced false-color Landsat images of the MX deployment area. Figure 8 is a map showing the region covered by the satellite images.

A data exchange program was set up with the geotechnical subcontractor for the U.S. Air Force, however, much of the data was incomplete or not available. Figure 9 shows the areas for which geological data were obtained from the U.S. Air Force.

Figure 4. Location of Coyote Spring Valley study area.

Figure 5. Location of area of intensive study: Coyote Spring Valley.

Figure 6. Coyote Spring Valley looking east to the Meadow Valley Mountains.

Figure 7. Map showing the area of baseline data acquisition and bibliography.

Figure 8. Computer-enhanced false color Landsat images of the deployment area.

Figure 9. Areas for which U.S. Air Force data were made available.

REGIONAL GEOLOGY

Southeastern Nevada is an area of complex structure and lithology consisting of Paleozoic carbonate units thrust over each other (Stewart, 1980) which are partially covered by Tertiary volcanic and sedimentary rocks. Late Cenozoic Basin and Range faulting has further broken up the area. Figure 10 is a composite geologic map of the area compiled from several sources (Ekren and others, 1977; Longwell and others, 1965; Tschanz and Pampeyan, 1970).

Major lithologic units in the region around Coyote Spring Valley are carbonates of Paleozoic age; sandstone and shales are also interbedded with some of the carbonate sequences. Limestone is the major carbonate unit, although some large dolomite formations are also present. Carbonate rocks are divided into individual formations and units according to geologic reports on Clark and Lincoln counties (Longwell and others, 1965; Tschanz and Pampeyan, 1970).

Tertiary volcanic rocks and volcanic sediments overlie the Paleozoic units in the northern ranges which border Coyote Spring Valley. The Delamar Range northeast of Coyote Spring Valley is almost entirely covered with Tertiary volcanic rocks, and is also the source of many of these volcanic units (Noble, 1968). These Tertiary units also occur in the Sheep Range. Occurrences found in the western and eastern slopes of the Meadow Valley Mountains suggest that volcanic rocks covered most of this range. Uplift and erosion, however, have removed most of the Tertiary sequence from the western slope.

GEOLOGY OF COYOTE SPRING VALLEY

To improve the data base of Coyote Spring Valley, a geologic map was compiled from data provided by the U.S. Air Force's subcontractor (Fugro National Inc., 1980). Figure 11 shows the major lithologic units and structural features

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MILES
EXPLANATION

	Quaternary Alluvium		Carboniferous Limestones and Sediments
	Quaternary Playa and Lake Sediments		Devonian Limestones and Silurian Dolomites
	Tertiary Sediments		Ordovician Limestones and Undifferentiated Cambrian to Devonian Limestone
	Tertiary Rhyolite and Andesitic Volcanics with Volcaniclastic Members		Cambrian Limestones and Sediments
	Tertiary Basalts		Undifferentiated Precambrian Igneous and Metamorphic Rocks
	Tertiary Intrusives		Fault, dashed where inferred
	Medozoic Sediments		Thrust Fault, barbs on upper plate, dashed where inferred
	Permian Red Beds		Approximate Lithologic Contact

Figure 10. Regional geology of Coyote Spring Valley.

Figure 11. Generalized geology of Coyote Spring Valley.

identified within the valley. Several linear traces were identified in aerial photographs but sufficient data were not available to label them as faults.

Valley fill units in Coyote Spring Valley are Tertiary and Quaternary alluvial and fluvial sediments. Data from water wells show that valley fill varies from 92 meters (300 ft) in the northern part of the valley to over 183 meters (600 ft) in the central portion. Data are unavailable on the thickness of valley fill units in the southern part of Coyote Spring Valley between the Arrow Canyon Range and the Las Vegas Range. It is probable, however, that valley fill units thin out in this area based on: (1) an east-dipping basement surface suggested by outcrops of basement units bordering the valley fill west of U.S. Highway 93; and (2) the lack of evidence for block faulting along the Las Vegas Range (fig. 10).

GEOGRAPHIC SETTING: COYOTE SPRING VALLEY

Coyote Spring Valley is located approximately 60 km (40 miles) north of Las Vegas, Nevada within the Basin and Range physiographic province (fig. 4). This area is characterized by elongate north-trending fault block mountains with intervening alluviated valleys. Coyote Spring Valley is bounded on the west by the Sheep Range and on the east by the Meadow Valley Mountains. Kane Springs Wash trends N50E and intersects Coyote Spring Valley immediately south of the Delamar Mountains. Coyote Spring Valley and Kane Springs Wash have significantly different trends, possibly reflecting two different structural controls. Kane Springs Wash, in fact, exhibits a trend markedly different than most valleys in the region.

STRUCTURE/LINEAMENTS/TECTONICS

The structural history and tectonic setting of Coyote Spring Valley is complex. Very little is known about tectonic patterns of pre-Cambrian age due to

the fact that there are only scattered remnants of pre-Cambrian age rocks in this region. Therefore, discussion will be limited to relatively recent structural phenomena.

Geologic features of the Basin and Range Province suggest it is a prime target for geothermal exploration and resource development since it is a region of higher than average heat flow. The crust is relatively thin as compared with the crust of surrounding provinces, (fig. 12). For example, the crust of the Basin and Range is estimated to be 20 to 35 km thick, whereas the crust of the Colorado Plateaus and Rocky Mountains is 35 to 50 km thick (Stewart, 1978). Regional uplift and extension is characteristic of the province. Although estimates of the amount of extension may vary considerably, a total extension of 72 km across the Great Basin appears to be a reasonable estimate (Stewart, 1971, 1978). The Great Basin is a tectonically active area, indicated by current seismicity, major faulting and volcanic activity which occurred during Cenozoic time (Press, 1960). The entire region is also underlain by a low seismic velocity layer believed to be in the upper mantle/lower crust. This low velocity zone probably indicates a less dense zone of partial melting (Stewart, 1978; Leeman and Rogers, 1970). It is hypothesized that plastic deformation occurs within this zone of partial melting. When deformation is transferred to the upper crust, the rocks of the upper crust undergo brittle deformation and develop joints and fractures which contain extensive, deep-seated, conduit systems. In the case of basement-controlled deformation, these conduits extend as far down as the zone of brittle deformation (fig. 13).

Sevier Orogenic Belt

The Sevier orogenic belt is an elongate north, northeast trending zone of folding and thrust-faulting which extends from eastern California across southern

Figure 12. Hypothetical east-west cross section of the western United States showing characteristics of the Great Basin which create an excellent geothermal target area: regional uplift and extension, thin crust, and low velocity partially melted zone of the upper mantle-lower crust. Inferred in this diagram is a regional high heat flow. Compiled from Stewart (1978), Barazangi, Scholz, and Sbar (1971), and Pakiser (1963).

Figure 13. Conceptualized left-lateral shear in the northeast-trending Pahrnagat lineament system in relation to brittle fracture and plastic flow. Fracture systems in the shear zone produce conduit systems ideal for localizing magma emplacement and allowing deep circulation of groundwater.

Nevada and continues northeastward into Utah. The thrusts are characterized by a west to east sense of movement with an average estimated displacement of 40 to 60 miles (Armstrong, 1968; Fleck, 1970; Longwell, 1960; Longwell, and others, 1965).

Evidence provided by clastic rocks, unconformities, and structural relationships suggests that deformation in the Sevier orogenic belt began in earliest Cretaceous time (140 m.y. ago) and continued until late Cretaceous (75 m.y. ago), with the primary episode of thrusting and folding occurring between 90 to 75 m.y. ago (Armstrong, 1968).

Figure 14 shows the location of Coyote Spring Valley with respect to the Sevier orogenic belt in southern Nevada. Due to the presence of the north-trending Gass Peak thrust in the northern Las Vegas Range, it is inferred that a fold belt exists beneath the alluvium of western Coyote Spring Valley (Tschanz and Pampeyan, 1970). This feature along with the north-plunging Arrow Canyon syncline in the northern Arrow Canyon Range reflects the local trend of a regional orogenic belt and probably controls the northerly trend of Coyote Spring Valley (Longwell, and others, 1965). It is hypothesized that both the Gass Peak thrust and the Arrow Canyon syncline are present beneath the alluvium of Coyote Spring Valley. Furthermore, the Arrow Canyon syncline and possibly the Gass Peak thrust may terminate against the Kane Springs fault of Tertiary age, thus creating a zone of increased permeability in the Paleozoic carbonate rocks.

Arrow Canyon Syncline

An important structural feature of the Sevier orogeny is located in the Arrow Canyon Range at the extreme southeast end of Coyote Spring Valley (figs. 14 and 15). Paleozoic carbonate rocks have been synclinally folded around a north plunging axis which lies along the eastern flank of the Arrow Canyon Range (Longwell, and others, 1965, plate 5).

Figure 14. Major structural and tectonic elements of Coyote/Kane region: GPT-Gass Peak thrust; ACS-Arrow Canyon syncline; LVSZ-Las Vegas Shear Zone; PLS-Pahranaagat lineament system; KSW-Kane Springs Wash volcanic center; TL-Timphaute lineament; CD-Caliente depression; CCC-Caliente caldera complex. Compiled from Armstrong (1968), Ekren et al. (1976), Ekren et al. (1977), Longwell et al. (1965), Noble (1968), Noble and McKee (1972), Rowan and Wetlaufer (1979), Shawe (1965), Tschanz and Pampeyan (1970).

Figure 15. Major structural features of the immediate Coyote/Kane study area. Compiled from Tschanz and Pampeyan (1970), Ekren et al. (1977), Ekren et al. (1976), Longwell et al. (1965), Noble (1968), Rowan and Wetlauffer (1979), Fugro International Inc. (1980).

The syncline plunges beneath the alluvium of Coyote Spring Valley and may continue northward along the east side of the valley. If, indeed, the syncline continues plunging northward beneath the valley fill, then somewhere at depth the syncline may be terminated against and/or has been dragged along the left-lateral shear zone of the Kane Springs Wash fault, which is associated with the Pahrnagat lineament system (Rowan and Wetlaufer, 1979).

Gass Peak Thrust and Fold Belt

The Gass Peak thrust is approximately 90 km (55 mi.) long and is terminated on both ends by strike-slip faults (figs. 14 and 15). From its southern termination along the Las Vegas Shear Zone (LVSZ) in Las Vegas Valley, the thrust trends east-northeasterly in the southern Las Vegas Range then curves abruptly, continuing northward through the Las Vegas Range (Longwell and others, 1965, plate 5). It is believed that north of the Las Vegas Range, the Gass Peak thrust and fold belt is present beneath valley alluvium on the east flank of the Sheep Range immediately west of Coyote Spring Valley (Tschanz and Pampeyan 1970, plate 3). The thrust may be terminated against a left-lateral strike-slip fault of the Pahrnagat lineament system as far north as the Menard Lake fault.

Las Vegas Shear Zone (LVSZ)

The Sevier orogenic belt, including the Gass Peak thrust and fold belt, intersect and are offset in a right-lateral sense by the northwest-trending Las Vegas Shear Zone. The LVSZ extends approximately 125 km (75 mi.) northwest from Lake Mead past the city of Las Vegas through Las Vegas Valley (fig. 14).

The LVSZ is the southeast portion of a well-defined 600 km (375 mi.) northwest-trending zone of right lateral strike-slip faulting in southern and

southwestern Nevada which extends from Las Vegas to Pyramid Lake. The entire zone is commonly referred to as the Walker Lane-Las Vegas Shear Zone (WL-LVSZ) or more simply, the Walker Lane (WL).

Major thrust faults of the Sevier orogenic belt and isopach lines on Paleozoic strata have been correlated across the LVSZ indicating displacement of approximately 40-70 km (25-45 mi.) (Fleck, 1970; Stewart and others, 1968). Displacement is probably post Oligocene age, between 17 and 10 m.y. ago. The right-lateral strike-slip movement along the LVSZ is probably unrelated in time or space to the deformation of the Sevier orogeny (Fleck, 1970).

Spatial and temporal relationships of two volcanic fields in southern Nevada, the Black Mountain volcanic province and the Nye County volcanic province, are important with respect to the LVSZ. Similar chronologies and style of volcanism and structural deformation appear in the two provinces. These eruptions and deformations also seem to be coincident with right-lateral movement along the LVSZ. Therefore, the Las Vegas Shear Zone may have formed in response to crustal extension in the two volcanic provinces in a manner similar to the formation of a ridge-ridge transform fault (Liggett and Childs, 1974). The LVSZ may have formed in response to extensional forces acting upon the crust which induced volcanism and was accompanied by normal faulting. This interpretation supports Fleck's estimates of dates of movement along the LVSZ as approximately 17 to 10 m.y. ago (Fleck, 1970).

Burchfiel (1965) and Shawe (1965) agree that strike-slip movement is basement controlled in the Basin and Range. In his regional assessment of Basin and Range structure, Shawe contends that northwesterly-trending zones of right-lateral offset (such as the LVSZ) and northeasterly-trending zones of left-lateral offset (such as the Pahranaagat lineament system) are a conjugate system of strike-slip zones of deformation with roots in the upper mantle.

On a larger, more regional scale, the WL-LVSZ is more or less parallel to and has the same sense of movement as the San Andreas fault (Shawe, 1965; Atwater, 1970, fig. 14; Smith and Sbar, 1974). The San Andreas fault is the major transform fault between the North American and Pacific plates (Smith and Sbar, 1974, fig. 10). According to the authors, some of the relative motion between the Pacific and North American plates is probably being taken up by a soft boundary in the Basin and Range province. Much of the strain generated by the interactions of the two plates is apparently being released along the WL-LVSZ (Smith and Sbar, 1974).

Kane Springs Wash Fault

A prominent structural feature which may influence Coyote Spring Valley is the Kane Springs Wash fault (Tschanz and Pampeyan, 1970; Rowan and Wetlaufer, 1979; Ekren and others, 1977). This fault trends northeast and flanks the southern side of Kane Springs Wash (figs. 14 and 15). Ekren and others have interpreted the Kane Springs Wash fault "...to be a strike-slip or oblique-slip fault having a minimum of five miles of left-lateral displacement." A dip-slip component of unknown displacement is also believed to be present along the entire length of the fault about 40-48 km (25-30 mi.) (Tschanz and Pampeyan, 1970, plate 3).

The Kane Springs Wash fault is important because it increases the permeability of Paleozoic carbonate rocks presumed to be present in the subsurface of northern Coyote Springs Valley due to offsetting, deforming and fracturing.

Pahranagat Lineament System/Shear System

Left-lateral strike-slip faulting in the area around Coyote Spring Valley is not restricted to the Kane Springs Wash fault. Tschanz and Pampeyan (1970) mapped

and described three post-Miocene, northeast-trending left-lateral strike-slip faults in the Pahrnagat Range south of Alamo. Subsequently, these faults were grouped together and renamed the Pahrnagat shear system. Left-lateral displacement in the region is interpreted as Tertiary reactivation of a major right-lateral basement shear zone which developed during the Sevier orogeny. The right-lateral shear zone developed during a period when the crust was undergoing compressional deformation, and has been reactivated in Tertiary time as a left-lateral shear zone due to tensional deformation. These conclusions are based on the fact that 48 km (30 mi.) of apparent right-lateral off-set occur between thrust and fold belts of the once continuous Spotted Range and Pahrnagat Range. This major reactivated fault is named the Arrowhead Mine fault (Tschanz and Pampeyan, 1970, plate 3).

The Kane Springs Wash fault is associated with the Pahrnagat shear system, (now called the Pahrnagat lineament system, Rowan and Wetlaufer, 1979). This northeast-trending belt of left-lateral shear 25 km wide is one of eight major lineaments in Nevada (fig. 16). The Pahrnagat lineament system is subdivided into two parallel northeast-trending segments. Figure 16 shows two segments of the lineament system: a segment 30 km (19 mi.) long corresponds to the Pahrnagat shear system and a segment 85 km (53 mi.) long corresponds to the Kane Springs Wash fault. Traces of the lineament can be identified as far as 100 km (62 mi.) into Utah on the Landsat mosaic of the United States.

Although the Pahrnagat lineament system is poorly expressed in a regional gravity map (Rowan and Wetlaufer, 1979), it is enhanced in a total intensity aeromagnetic map of the Great Basin (fig. 16). The Pahrnagat lineament system coincides with a series of aeromagnetic highs extending into Utah which follow the northeast trend of the system.

A northeast trending lineament-like feature has been identified on ERTS imagery during air photo inspection (fig. 15). This feature lies within and is parallel

Figure 16. Aeromagnetic map of Nevada and adjacent areas showing total intensities greater than 2500 gammas and the eight major lineaments of Nevada. The extension of the Timpahute lineament system northeastward into Utah is clearly indicated by the linear pattern of the gamma pattern. TL is Timpahute lineament; PLS is Pahranagat lineament system. After Rowan and Wetlaufer (1979).

to the Pahrnagat lineament system. It was neither previously mentioned in the literature nor was it mapped. It cuts through alluvium and bedrock and appears to be about 80 to 95 km (50 to 60 mi.) in length extending from the southern Delamar Mountains to southwest of the Sheep Range. This lineament-like feature further emphasizes the presence of the Pahrnagat lineament system.

The Pahrnagat lineament system is a deep-seated phenomenon perhaps with origins in the upper mantle (Rowan and Wetlaufer, 1979; Ekren and others, 1977; Shawe, 1965). The northeasterly-trending zones of left-lateral offset (such as the Pahrnagat lineament system) and northwesterly trending zones of right-lateral offset (such as the LVSZ) are conjugate fault systems probably having roots in the upper mantle. It is inferred that the extensive left-lateral fracture system in the crust reflects an inherent zone of weakness in the upper mantle/lower crust.

If, indeed, the shear zone is deep-seated, and if there is a layer of partially melted upper mantle/lower crust, then we would expect to see volcanic activity localized along this shear zone: magmas generated in the upper mantle/lower crust would migrate upward along the fractures created by the shear zone. Also, geochemistry of volcanic rocks would indicate an upper mantle/lower crust source for magmatic fluids. Two major centers of volcanism are present within the Pahrnagat lineament system. Both will be discussed in context of the lineament system.

Fracture systems created by the deep-seated shear, in addition to funnelling magma to the surface or near surface, would also serve as conduits for geothermal fluids. Thus, it is reasonable to assume that geothermal systems are located along deep-seated shear zones. Such a system exists in Caliente, Nevada, and although Caliente is 100 km (60 mi.) northeast of Coyote Spring Valley, it is situated along the Pahrnagat lineament system.

Caliente Geothermal System

A lineament study conducted in northern and north-central Nevada indicated a definite correlation between occurrences of geothermal activity and northeast trending lineaments (Trexler and others, 1979). This correlation can also be applied to the northeast-trending Pahrnagat lineament system. The geothermal system in Caliente, Nevada lies immediately northeast of and in direct line with the 30 km section of the Pahrnagat lineament system, and north of the 85 km segment (figs. 14 and 16). The hottest temperature recorded in the Caliente region is 67°C (153°F) from a well at the Agua Caliente Trailer Park (Trexler and others, 1979).

Kane Springs Wash Volcanic Center

The Kane Springs Wash volcanic center described by Noble (1968) is partially situated within the Kane Springs Wash (fig. 14 and 15). Geographically, it is located in the southern Delamar Mountains approximately half the distance to Kane Springs Wash.

The volcanic center is considered by Noble to be the youngest ash-flow sequence in south-central Lincoln County with a K/Ar age of 14 m.y. A basalt collected from the center has been dated about 13 m.y. (Hedge and Noble, 1971). The volcanic center is elongated east-west with a diameter of 13 to 19 km (8 to 10 mi.), and shows no apparent signs of resurgence (Noble, 1968; Ekren and others, 1977). No indications of hydrothermal activity or alteration have been reported from the volcanic center.

The Kane Springs Wash volcanic center lies north of the Kane Springs Wash fault and well within the area defined by Rowan and Wetlaufer (1979) as the Pahrnagat lineament system. It is believed that the northeast-trending Pahrnagat lineament system is a regional deep-seated zone of weakness which has

controlled the location and occurrence of the Kane Springs Wash volcanic center (Ekren and others, 1977). This may be partially substantiated by the fact that 13 m.y. old basalt collected from the volcanic center has Sr^{87}/Sr^{86} and Sr/Rb ratios indicative of an upper mantle source (Hedge and Noble, 1971). A basaltic magma generated in the upper mantle probably utilized the extensive fracture system produced by left-lateral shear to migrate through the crust and onto the earth's surface.

Caliente Caldron Complex

The Caliente cauldron complex named by Ekren and others (1977) lies immediately northeast of the north-easternmost extension of Kane Springs Wash, and south of Caliente in east-central Lincoln County. The complex is indicated on Figure 14 as a sub-circular, east-west elongated feature measuring 64 km (40 mi.) east to west and 29 km (18 mi.) north to south (Ekren and others, 1977). In an initial reconnaissance of the Caliente volcanic field, Noble and McKee (1972) identified a circular depression roughly 32 km (20 mi.) in diameter east of Caliente. They termed this feature the Caliente depression, but do not consider it to be genetically related to volcanism as the Caliente caldron complex is.

Dates obtained from ash-flow tuffs erupted from vents of the Caliente cauldron complex indicate a period of volcanism lasting from 21 to 17 m.y. ago, and possibly until 12 m.y. ago (Noble and McKee, 1972; Ekren, and others, 1977). As with the Kane Springs Wash volcanic center, Sr^{87}/Sr^{86} and Sr/Rb ratios of the Caliente caldron complex suggest an upper mantle source for the magmas. It is believed that the deep-seated lineament system controls the presence of both the Kane Springs Wash volcanic center and the Caliente cauldron complex (Ekren and others, 1977).

Timpahute Lineament

An east-trending structural feature termed the Timpahute lineament stretches across north-central Lincoln County (Ekren and others, 1976). The Timpahute lineament is approximately 350 km (218 mi.) long and lies approximately 72 km (45 mi.) north of Coyote Spring Valley extending into western Utah (fig. 14). The Timpahute and Pahrnagat lineaments are two of eight major lineaments in Nevada (Rowan and Wetlaufer, 1979). Figure 16 is a map of Nevada showing those eight major lineament systems. The Timpahute lineament is a deep-seated structure which greatly influenced and/or controlled the development and presence of several geologic, topographic, and structural features proximal to the lineament (Rowan and Wetlaufer, 1979; Ekren and others, 1977). These features include strike-slip faulting, magmatism, volcanism, and contrasting structural styles across the lineament. It is believed the Timpahute lineament is much older than Tertiary age and perhaps even as old as pre-Cambrian.

Normal Faulting (Basin and Range Faults)

Because of its relatively recent occurrence, normal extensional faulting created a substantial impact on the geomorphological, geological, and structural evolution of the Great Basin including Coyote Spring Valley. Basin and Range topography developed as a result of normal faulting; normal faulting developed as a result of regional extension and uplift (Stewart, 1978).

Extensional deformation began in the Great Basin in Miocene time approximately 17 m.y. ago, and was generally accompanied by volcanism (Stewart, 1978). Faulting has continued into modern times in the Great Basin and in Coyote Spring Valley, in particular.

LANDSAT IMAGE AND COLOR AIR PHOTO ANALYSIS

Several recent faults were identified in the Coyote/Kane system (fig. 15). Black and white air photos at a scale of 1:62,500 were carefully inspected, and offsets were noted especially in valley alluvium. Other geologic sources were consulted in order to verify the locations of these faults, and also to insure complete coverage of the valleys (Ekren and others, 1977; Stewart and Carlson, 1978; Tschanz and Pampeyan, 1970; Longwell and others, 1965; Fugro International, Inc., 1980).

Regional and localized lineaments were mapped on computer enhanced false color 1:250,000 scale Landsat images and were then transferred to 1:25,000 scale color air photos obtained from U.S. Air Force. It was hypothesized that regional and localized lineaments seen in the Landsat images could be related to structural trends seen within Coyote Spring Valley. In general, this hypothesis appeared to be valid. However, several trends paralleling regional lineament trends could not be positively identified as faults, and have been included in the figures as lineaments.

Localized Linear and Curvilinear Trends

Color air photos obtained from the U.S. Air Force were reviewed and interpreted for linear and curvilinear trends which could be related to regional or localized structures. The 1:25,000-scale color air photos were also used as base maps for plotting location data taken from ground surveys. The resolution and quality of the photos allowed very accurate point location.

Linear and curvilinear trends identified in the 1:25,000 scale air photos are shown in Figure 17. The majority of these trends were shown as lineaments in the geologic map of Coyote Spring Valley, Figure 11.

Figure 17. Localized linear and curvilinear features.

SHALLOW TEMPERATURE PROBE SURVEY

Shallow temperature anomalies were identified and mapped using thermistor probes buried to a depth of one to two meters. These surveys are most effective when probes are buried to depths at which the diurnal effects are insignificant, approximately 1.5 meters (Birman, 1969).

The thermistor probes are general-purpose vinyl-tipped probes, three meters long. They are encased in a two meter section of PVC plastic pipe for protection with the thermistor tip exposed in the end of the pipe. Small diameter holes (8-9 cm) were drilled to depths of two meters using a trailer mounted auger, Figure 18. The probe was placed in the hole and then the hole was backfilled. In general, the probes equilibrate within 24 hours, but are left in the ground longer to make sure equilibration has been reached.

Four probes were left in the ground to monitor seasonal variations in ground temperature over a six month period. A ground temperature variation of 4.5°C (8°F) was noted between field sessions using these four probes and other probes left between each session. The highest ground temperatures were noted during the August field session and the lowest, during the November field session. To simplify data interpretation, all temperatures were corrected to the August field session and adjusted for seasonal variations.

The coarse alluvium and intercalated caliche zones made drilling the holes for the thermistor probes extremely difficult, especially along the eastern and western edges of the intensive study area, Figure 19. Because numerous attempts to drill holes were unsuccessful in these areas, a truck-mounted drill rig (Mobil B52) was contracted for one day (fig. 20), and 19 holes (#44 - #62) were drilled in the areas of coarsest alluvium.

A total of 101 probes were implanted in the study area. Their locations are shown in Figure 21. The apparent random placing of the probes was caused by

Figure 18. Trailer-mounted post hole digger in operation.

Figure 19. Road cut on old highway illustration intercalated caliche (arrows) and coarse alluvium.

Figure 20. Truck-mounted drill rig.

Figure 21. Location map of two-meter temperature probes and soil sample points.

accessibility and lithology problems. Originally a 1.0 to 1.6 kilometer grid spacing had been planned, but as accessibility problems were encountered, this grid system had to be abandoned.

Table I lists the corrected temperatures of the thermister probes and also shows the correction factor used to normalize the temperatures to the August field session. Figure 22 shows the plotted temperatures of monitor probes left in the ground during the four field sessions and reflects the seasonal variations in the ground temperature.

Anomalous temperatures within the data set were derived by calculating the mathematical mean and plotting positive variances from this mean using frequency distribution plots. From these calculations, temperatures in excess of 29°C ($\pm 1.5^\circ\text{C}$) are considered anomalous.

From the data in Table I, a generalized contouring of the temperatures was developed (fig. 23). Anomalous zones were identified around points 70, 71 and 82 (fig. 21) in the northeastern portion of the study area, and along U.S. Highway 93. This anomalous zone lies near the junction of Kane Springs Valley and Coyote Spring Valley near zones of Holocene faulting (fig. 11).

Another anomalous zone adjacent to U.S. 93 is probably caused by radiant heating of the ground by the asphalt highway. A monitor probe, #49, left in the ground adjacent to the highway to test this hypothesis was destroyed between the August and November field sessions during highway maintenance work. An attempt to place a new probe in this location failed, but four probes, #96 thru 99 were located adjacent to the highway further north (fig. 21). A thermal zone adjacent to the highway was noted after reading these probes. However, these probes were located during the lower temperature field session, and also probably represent conductive heating by the highway.

TABLE I
COYOTE SPRING VALLEY
REGIONAL TWO-METER TEMPERATURE PROBE SURVEY

Probe No.	Temp. °C	Correction Factor*	Probe No.	Temp. °C	Correction Factor*
1	22.4	+3.6	29	22.5	+3.0
2	25.3	+3.0	30	25.0	+3.0
3	26.8	+3.0	31	24.9	+3.0
4	24.9	+3.0	32	26.5	+3.0
5	23.9	+3.0	33	26.0	+3.0
6	23.9	+3.0	34	26.0	+3.0
7	24.0	+3.0	35	25.0	+3.0
8	24.2	+3.0	36	23.6	+2.0
9	26.9	+3.0	37	23.5	+2.5
10	26.8	+3.0	38	24.9	+2.5
11	25.1	+3.0	39	24.3	+2.5
12	24.8	+3.0	40	23.5	+2.5
13	26.1	+3.0	41	24.4	+2.5
14	26.3	+3.0	42	24.3	+2.5
15	23.3	+3.0	43	26.2	+2.7
16	24.3	+3.0	44	29.0	0
17	25.8	+3.0	45	29.0	0
18	28.0	+3.0	46	30.5	+1.5
19	25.8	+3.1	47	31.0	+2.0
20	22.5	+3.0	48	30.0	+2.5
21	28.0	+3.0	49	31.0	+2.5
22	27.5	+3.0	50	30.0	+3.0
23	26.0	+3.0	51	30.0	+3.5
24	25.0	+3.0	52	30.0	+3.0
25	26.5	+3.0	53	27.0	+2.5
26	26.0	+3.0	54	28.2	+2.6
27	23.5	+3.0	55	25.9	+2.0
28	23.5	+3.0	56	29.6	+3.4

*All temperatures corrected to August, 1981 Field Session

TABLE I
(continued)
COYOTE SPRING VALLEY
REGIONAL TWO-METER TEMPERATURE PROBE SURVEY

Probe No.	Temp. °C	Correction Factor*	Probe No.	Temp. °C	Correction Factor*
57	30.0	?	85	26.5	+4.5
58	27.5	+2.5	86	28.0	+4.5
59	29.7	+2.2	87	27.9	+4.5
60	29.0	+2.8	88	27.5	+4.5
61	28.6	+2.2	89	28.0	+4.5
62	29.2	+2.8	90	27.7	+4.5
63	23.8	0	91	25.9	+4.5
64	27.6	0	92	26.4	+4.5
65	25.2	0	93	27.2	+4.5
66	25.6	0	94	26.8	+4.5
67	25.5	-	95	26.0	+4.5
68	28.5	-	96	26.7	+4.5
69	28.3	-	97	26.4	+4.5
70	28.8	-	98	26.0	+4.5
71	30.8	-	99	26.2	+4.5
72	26.0	-	100	26.6	+4.5
73	26.5	-	101	26.9	+4.5
74	28.5	-			
75	27.9	-			
76	26.9	-			
77	26.9	-			
78	28.1	+4.5			
79	26.7	+4.5			
80	27.2	+4.5			
81	27.9	+4.5			
82	28.3	+4.5			
83	27.4	+4.5			
84	27.5	+4.5			

*All temperatures corrected to August, 1981 Field Session

Figure 22. Variations in temperature probes during the four field sessions.

Figure 23. Generalized contour map of two-meter temperature probe data.

To positively prove or disprove this anomaly, a series of closely spaced probes should be emplaced in a line perpendicular to U.S. 93. The coarse alluvial character of the lithology in this region would require the use of the truck mounted auger rig, and access permits are required to enter the area west of the highway which is designated a wildlife preserve. Because of budget limitations, this was not performed.

SOIL-MERCURY SURVEY

Soil samples were collected from temperature probe holes at depths of 0.01-0.3 meters, 1.0 meter, and 2.0 meters and the cuttings were stored in plastic bags and labeled. A total of 85 samples were collected and analyzed for mercury content.

The theory behind this research method is that mercury vapor is released at temperatures in excess of 80°C (175°F), and will migrate upward until it encounters a clay rich zone where it is trapped. In a desert environment, clay-enriched zones are generally within the near surface (less than 0.3 m). If a soil horizon is developing, then the clay rich "B" horizon is sampled. The other samples collected at 1.0 and 2.0 meters were collected to see if the caliche layers within the alluvium might be inhibiting the migration of mercury vapor into the near-surface, clay-enriched zones.

Once the samples were returned to the office, they were prepared for analysis. Preparation included air drying the samples then passing them through an 80-mesh sieve. The sieved fraction was then used in the analysis phase. A Jerome Gold-Film Analyzer was used to analyze for mercury concentrations. The principles of the machine and techniques are described in McNerney and others (1972) and Matlick and Buseck (1976).

Figure 21 shows the location of the soil-mercury sample points; Figure 24 is a schematic of where the samples were collected within the two-meter temperature probe hole.

Mercury concentrations from the surface samples (0.01-0.3 m interval) are shown in Table II. Only a few samples showed any detectable mercury concentrations. The samples collected at the one-meter and two-meter intervals were analyzed for mercury following the completion of analysis of the surface samples. No concentrations of mercury above five parts per billion were found in the subsurface samples and thus no further work was done with them.

Figure 25 shows the location of those points with anomalous mercury concentrations. No major interpretations can be made from this data other than noting the clustering of anomalous mercury concentrations around the north end of the Arrow Canyon Range. Because this clustering is somewhat randomly scattered and has zones of no mercury concentrations it can not be considered an anomalous zone.

REGIONAL FLUID GEOCHEMISTRY

Coyote Spring Valley is located at the southern end of the White River regional flow system (Mifflin, 1968) which is a large drainage system in southeastern Nevada (fig. 26). The direction of flow which is largely underground is generally to the central part of the system and then southward into the Colorado River east of Las Vegas (fig. 27).

A total of 32 springs and wells were identified within the system, plus two outside the system (fig. 26); Table III presents the fluid chemistry of these springs and wells. Gross chemical characteristics of the regional fluids are shown on a trilinear plot, Figure 28, which includes samples from the Coyote study area

Figure 24. Approximate sample intervals of the soil mercury samples within the two-meter thermistor probe holes.

TABLE II
Coyote Valley Soil-Mercury Survey

Surface Samples

ppb = parts per billion; M = soil-mercury sample site
P = soil-mercury sample site/temperature probe site
* = results considered invalid due to heterogeneous contents of sample.

Sample #	ppb	Sample #	ppb	Sample #	ppb
P1	24	(P25)	105/31*	P54	0
P2	0	P26	0	P55	0
P3	0	P27	0	P56	0
P4	0	P28	0	P57	0
P5	0	P29	0	P58	0
P6	0	P30	0	P59	0
P7	0	P30a	0	P60	0
M8	21	P31	0	P61	0
P8	23	P32	20	P62	0
M9	0	P33	0	P63	0
P9	0	P34	0	P64	0
M10	0	P35	0	P65	27
P10	0	P36	0	P66	23
M11	0	P37	0	P67	0
P11	15	P38	0	P68	19
M12	0	P39	0	P70a	0
P12	12	P40	43	P70b	--
M13	21	P41	--	P71	0
P13	0	P42	0	P72	21
P14	16	P43	0	P73	35
P15	37	P44	0	P74	18
P16	16	P45	0	P75	61
P17	0	P46	0	P76	0
P18	0	P47	0	P77	0
P19	0	P48	0	P78	--
P20	0	P49	0		
(P21)	93/16*	P50	0		
P22	0	P51	0		
P23	0	P52	27		
P24	23	P53	27

Figure 25. Concentrations of mercury in surface soil samples.

Figure 26. Locations of major drainage systems, selected springs and wells in the White River regional flow system. Numbers refer to sample numbers in Table III.

Figure 27. Springs, wells, and the direction of groundwater movement in Coyote/Kane valleys. Compiled from Eakin (1966), Mifflin (1968a and 1968b), and Fugro International (1980).

SPRING/WELL LOCATION	VALLEY	Sample Number	TPC	PH	Ca	Mg	Na	K	Al	Li	NH ₄	Cl	SO ₄	CO ₃	HCO ₃	NO ₃	F	B	SiO ₂	N	TDS	CONDUCTANCE MICROMHOS/CM	COLLECTION DATE	SOURCES
Well 10N/66E-31a	Lake	1	15	7.8	54	5.7	7.4	1.9	-	-	-	9.6	6.4	0	189	1.2	0	0	-	-	203	322	8/63	Rush & Eakin 1963
Geyser Spring 9N/65E-4c	Lake	2	20	8.0	30	3.4	3.0	1.0	-	-	-	3.0	5.0	0	103	.6	0	0	13	-	115	181	8/63	Rush & Eakin 1963
Urrutia Well 10/63E-23aca	Cave	3	-	7.2	52	12	10	4.0	-	-	-	15	20	0	160	-	0.15	-	<0.01	>0.7	-	510	3/80	Ertec 1980
Cave Valley Spring 9N/64E-16bdb	Cave	4	-	7.74	17	4.0	5.1	0.6	-	-	-	3.2	9.5	0	80	-	0.08	-	<0.01	>0.7	1800	1800	3/80	Ertec 1980
Seeding Well 8N/64E-4abd	Cave	5	-	7.5	25	6.7	7.5	1.4	-	-	-	8.9	4.1	0	120	-	0.13	-	<0.01	0.4	-	4100	3/80	Ertec 1980
Harris Well 8N/64E-19bcb	Cave	6	-	7.4	49	13	6.2	0.9	-	-	-	2.5	5	0	200	-	0.08	-	< 0.01	1.2	-	-	3/80	Ertec 1980
Sidehill Spring 7N/64E-33cc	Cave	7	7	7.6	31	-	11	0.96	-	-	-	11	11	0	250	-	-	-	-	0.34	-	-	8/79	Ertec 1980
Horse Spring 6N/63E-19da	Cave	8	16	8.0	25	-	11	1.2	-	-	-	16	15	5.4	280	-	-	-	-	1.2	-	-	8/79	Ertec 1980
Bristol Well 3N/63E-21dba	Dry Lake	9	-	-	76	33	37	-	-	-	-	110	71	0	187	-	-	-	49	32	509	-	1915	Eakin 1963
Spring 3N/63E-31cc	Dry Lake	10	24	6.8	40	10	21	2.5	-	-	-	17	21	0	214	-	0.24	-	53	.4	-	470	8/79	Ertec 1979
Coyote Spring 2N/63E-13cba	Dry Lake	11	20	6.8	82	13	49	7.4	-	-	-	25	25	0	282	-	0.51	-	79	<0.1	-	550	8/79	Ertec 1979
Spring 2S/64E-bdb	Dry Lake	12	26	6.9	83	10	53	7.1	-	-	-	30	54	0	320	-	0.36	-	44	14	-	720	8/79	Ertec 1979
Well 3S/64E-12ca	Dry Lake	13	-	7.90	20.2	10.3	76.0	5.2	-	-	-	21.2	44.8	1.0	217.5	6.7	0.010	-	1.440	-	292.4	480	4/80	Ertec 1979
Spring 3N/57E-16d	Garden	14	11	6.7	67	24	17	3.4	-	-	-	10	21	0	327	-	0.3	-	32	0.9	-	430	6/80	Ertec 1980
Well 3N/58E-16a	Garden	15	8	7.1	34	30	10	4.1	-	-	-	6.1	15	0	249	-	0.3	-	32	1.4	-	365	6/80	Ertec 1980
Heizer Well 2N/58E-14c	Garden	16	-	7.4	44	10	22	2	-	-	-	8.5	28	0	205	-	0.1	-	14	2.7	-	430	6/80	Ertec 1980
Spring 1N/57E-20	Garden	17	12	7.0	111	20	43	3.9	-	-	-	18	78	0	390	-	1.3	-	66	0.0	-	660	6/80	Ertec 1980
Frieburg Mine Well 1N/57E-20	Garden	18	-	7.6	100	17	30	3	-	-	-	15	55	0	386	-	0.7	-	23	3.4	-	445	6/80	Ertec 1980
South Uhalde Well 1S/57E-26b	Garden	19	-	8.0	11	3.4	90	4	-	-	-	8.5	21	0	205	-	0.8	-	23	9.4	-	305	6/80	Ertec 1980
Oreana Spring 1N/61E-29ca	Coal	20	12	6.7	82	9.1	23	2	-	-	-	14	26	0	303	-	0.2	-	24	6.2	-	500	6/80	Ertec 1980
Pahroc Spring 3S/62E-25ab	Pahroc	21	15	7.0	28	7.6	13	5	-	-	-	12	12	0	151	-	-	-	23	0.6	-	190	5/80	Ertec 1980
Hiko Spring 4S/60E-22	Pahranagat	22	27	8.0	44.09	23.34	28.97	7.02	-	-	-	10.99	36.02	0	259.93	1.24	.570	-	33	-	-	494	3/62	Eakin 1962
Crystal Spring 5S/60E-10a	Pahranagat	23	27	8.0	45.09	23.46	22.99	5.08	-	-	-	8.15	26.90	0	272.14	1.24	.570	-	31	-	-	-	4/63	Eakin 1962
Ash Spring 6S/60E-36dd	Pahranagat	24	32	-	45.09	17.99	20.92	-	-	-	-	8.86	18.25	-	250.78	-	-	-	-	-	277	473	4/84	Eakin 1962

Table III. Fluid chemistry of selected springs and wells within and near the White River regional flow system.

SPRING/WELL LOCATION	VALLEY	Sample Number	T°C	PH	Ca	Mg	Na	K	Al	Li	NH ₄	Cl	SO ₄	CO ₃	HCO ₃	NO ₃	F	B	SiO ₂	N	TDS	CONDUCTANCE MICROMHOS/CM	COLLECTION DATE	SOURCES
Alamo Town Well 75/61E-3	Pahrnagat	23	-	-	56.11	13.98	143.99	-	-	-	-	28.01	101.83	17.10	414.92	-	-	-	-	-	-	1111	4/44	Eakin 1961
Frehner Well 75/61E-	Pahrnagat	26	-	-	73.15	30.88	177.02	-	-	-	-	56.72	167.15	-	543.05	-	-	-	-	-	-	1250	1942	Eakin 1962
Well 65/63E-12a	Delamar	27	-	7.95	21.2	5.2	42.9	2.7	-	-	-	5.10	25.6	.62	152.43	-	0.45	-	31.0	0.92	213	-	5/80	Ertec 1979
Willow Spring 105/64E-9d	Kane	28	-	7.2	17.0	4.0	47.6	4.5	-	-	-	23.0	26.7	0.1	130.3	1.8	0.9	-	58.6	-	265.0	380.0	11/80	Ertec 1980
Well, CK-WQ-2 115/62E-13bd	Coyote	29	-	7.7	37.4	27.0	32.1	2.9	-	-	-	16.4	35.4	0.4	257.7	1.2	0.2	-	18.9	-	299	563.0	11/80	Ertec 1980
Ertec Well, CE-DT-4 135/63E-23dd	Coyote	30	-	-	51	20	83	10.7	-	-	-	37.1	102	-	306.4	-	2.1	-	34	.21	491	-	11/80	Ertec 1980
Well, CK-WQ-5 145/65E-17aa	Mosope	31	-	7.5	114.6	60.2	225.0	25.1	-	-	-	143.4	394.2	0.6	579.2	0.0	1.5	-	37.8	-	1800	1792.0	11/80	Ertec 1980
Spring, CK-WQ-4 145/65E-17aa	Mosope	32	-	7.5	64.8	26.5	94.8	14.1	-	-	-	61.0	171.9	0.3	277.5	0.5	1.3	-	25.3	-	591.0	982.0	11/80	Ertec 1980
Well, CK-WQ-5 145/65E-17aa	Mosope	33	-	7.5	64.7	26.7	95.0	15.2	-	-	-	68.0	172.0	0.3	273.8	0.5	1.6	-	25.7	-	583.0	982.0	11/80	Ertec 1980
Well, CK-WQ-6 145/65E-23ac	Mosope	34	-	7.7	136.0	68.8	315.0	30.5	-	-	-	120.0	819.3	0.6	359.7	0.0	2.0	-	22.8	-	1800	2351.0	11/80	Ertec 1980

Table III. Continued.

Figure 28. Chemical characteristics of selected springs and wells within or near the White River regional flow system.

(samples 28, 29, 30). Muddy River springs and wells are located immediately southeast of the study area in Moapa Valley and are numbered 31, 32, 33, 34. Several relationships are readily apparent from this plot. In general, fluids from springs and wells north of the Coyote/Kane study area (samples 1-26) contain relatively higher concentrations of $\text{Ca} + \text{Mg}$, and $\text{CO}_3 + \text{HCO}_3$ than do springs and wells located in Coyote/Kane Valleys (samples 27-29) and Moapa Valley (samples 30-34), indicating carbonate rock sources for these waters. On the other hand, fluids from the Coyote/Kane Valleys and Moapa Valley have a higher concentration of $\text{Na} + \text{K}$ and $\text{SO}_4 + \text{Cl}$, respectively. These higher concentrations of $\text{Na} + \text{K}$ and $\text{SO}_4 + \text{Cl}$ are probably related to the volcanic units found near the springs and wells in Coyote Spring and Kane Springs Valley. There are exceptions to these observations. Sample 29 was collected from the Ertec carbonate aquifer test well in Coyote Spring Valley, and plots within the same range of the other carbonate springs and wells. Samples 13 and 19 are north of Coyote/Kane Valleys, and although they are concentrated in $\text{CO}_3 + \text{HCO}_3$, they are also very high in $\text{Na} + \text{K}$. Sample 34 from Moapa Valley plots relatively high in $\text{SO}_4 + \text{Cl}$ and $\text{Na} + \text{K}$. Other thermal fluids in the Great Basin also plot in the general range of sample 34, which may indicate a thermal source for the Moapa Valley waters. Another explanation for the chemistry of sample 34 is that the water, as it flows from carbonate rocks, interacts with tuffaceous Tertiary sediments present in Moapa Valley, thereby increasing its $\text{Na} + \text{K}$ content.

Waters which border on being classified thermal (30°C or greater) are found throughout the White River Flow System. These fluids are found in the deep carbonate aquifer systems. Several springs with fluids derived from the carbonate aquifers are found north of the study area. It is theorized that these low temperature ($30\text{--}35^\circ\text{C}$) thermal fluids are heated by circulation within the

carbonate aquifers (Mifflin, 1968). The heat source within the carbonate aquifers may be the normal geothermal gradient or it may be a shallow magma body, or both.

The normal geothermal gradient in southeastern Nevada is approximately 25°C/km (1.37°F/100 ft.) (Garside and Schilling, 1979). In order for fluids to be heated to 30-35°C temperatures (86-95°F), the fluids would have to circulate to depths of approximately 1500 meters (4600 ft.). It is very possible, due to the complex geology of the region, that the carbonate aquifers extend to these depths.

It is also possible that thermal fluids pass near a shallow heat source. The community of Caliente, approximately 75 kilometers northeast of Coyote Spring Valley, has several shallow water wells with temperatures greater than 45°C (110°F). It is interpreted that these warm and hot water wells are derived from a shallow heat source (Trexler and others, 1980). Also, a major volcanic region (Noble, 1968) lies between Caliente and Coyote Spring Valley in the Delamar Mountains (fig. 14) and may have a shallow heat source associated with it.

Coyote Spring Valley

A data exchange was arranged between the Division of Earth Sciences (DES) and the U.S. Geological Survey Water-Resources Division (USGS-WRD) since both groups were working in the study area. A total of ten samples were collected by the two groups in Coyote and Kane Springs Valleys and the Sheep Range. Figure 29 shows the location and relative chemical compositions of seven of the ten samples. The three remaining samples are off the map west of SR-1, and their locations and relative compositions are shown in the inset in Figure 29. Table IV gives the chemical data of the ten fluid samples; their general associations and characteristics are shown in a trilinear plot, Figure 30. A hydrogen and oxygen

Figure 29. Location of springs and wells sampled in Coyote Spring Valley.

Table IV.
COYOTE SPRING VALLEY AND KANE SPRINGS VALLEY
WATER CHEMISTRY
(ppm)

Spring/Well	Sample #	TOC	pH	Ca	Mg	Na	K	Al	Li	Total Fe	Cl	SO ₄	CO ₃	HCO ₃	NO ₃	F	B	SiO ₂	Collection Date	Source
Coyote Spring Valley																				
Coyote Spring Well	CSV-1	15.3	7.8	37.5	30.0	36.0	3.1	<0.10	0.01	<0.05	22.0	46	0	259.0	4.0	0.46	0.26	21	11/81	DES
Ertec Well, CE-DT-4	CSV-2	35.5	7.7	46.0	20.0	78.0	11.0	-	0.13	<0.01	34.0	100	-	300.0	1.5	1.90	0.30	33	7/81	USGS
Kane Spring Valley																				
Willow Spring	KSV-1	17.4	7.5	20.5	2.7	56.0	4.6	<0.10	0.01	<0.05	22.3	34	0	140.3	8.4	1.10	0.33	65	11/81	DES
Grapevine Spring	KSV-2	18.4	7.3	75.0	22.0	17.0	2.3	<0.10	0.02	<0.05	26.9	40	0	275.5	7.5	0.86	0.22	22	11/81	DES
Kane Springs	KSV-3	16.4	7.2	43.5	13.0	20.0	5.9	<0.10	0.02	<0.05	16.6	14	0	205.3	6.7	2.80	0.18	60	11/81	DES
Boulder Spring Stock Tank	KSV-4	16.8	7.9	21.5	4.9	12.2	2.3	<0.10	0.01	<0.05	7.8	6	0	102.2	1.3	1.70	0.13	41	11/81	DES
Sheep Range																				
Morman Well	SR-1	11.5	7.6	81.0	40.0	11.0	.4	<0.01	1.80	1.00	19.0	5	<0.01	400.0	<0.01	.10	<0.01	16	10/81	USGS
Wiregrass Spring	SR-2	9.5	7.6	69.0	32.0	2.7	1.1	<0.01	1.30	1.00	3.0	5	<0.01	350.0	<0.01	.10	<0.01	12	10/81	USGS
White Rock Spring	SR-3	15.0	7.7	37.0	29.0	14.0	7.0	<0.01	1.70	1.00	9.5	5	<0.01	260.0	<0.01	.20	<0.01	47	10/81	USGS
Cow Camp Springs	SR-4	14.5	8.2	48.0	31.0	21.0	.7	<0.01	2.10	1.00	28.0	9	<0.01	280.0	<0.01	.20	<0.01	16	10/81	USGS

Sample collected by

DES - Division of Earth Sciences

USGS - Preliminary data from Water Resources Division,
United States Geological Survey, Nevada District

Figure 30. Trilinear plot of water chemistry data presented in Table III.

stable light isotope analysis was performed on six fluid samples, however, the results were not received until after this report was prepared. See Appendix A for details.

As seen in Figures 29, 30 and Table IV, all the samples are enriched in bicarbonate (HCO_3). Variations in the fluid chemistry are found in the cation component. These cation variations reflect the geologic conditions in which the fluids are found. Samples KSV-2, SR-1, SR-2, SR-3 and SR-4 are all derived from the carbonate units and reflect this in the chemistry as evidenced by the increased Ca or Mg.

The samples also appear to be derived from volcanic rocks (Ca-Mg or Na-K carbonate-bicarbonate). Samples KSV-1, KSV-3, and KSV-4 are found in the volcanic units and show an enrichment in either Na and K or similarities in the Ca, Mg, or Na + K component.

CSV-1 and CSV-2 are the two samples which do not fit the above generalities. CSV-1 reflects a more Mg character, such as a dolomite-derived fluid, however it is found within Tertiary lake sediments. The enriched Mg component may be derived from clays within the sediments or from some buried dolomitic units which the fluid passes through prior to being exposed at the surface. CSV-2 was derived from a highly permeable limestone aquifer, however it is enriched in Na + K, indicating a non-carbonate source. This sample is similar to the Na + K enriched fluids of the Moapa Valley area to the east (see sample numbers 31, 32, 33 34 on Table III).

According to Mifflin (1968), the White River flow system flows through Coyote Spring Valley into Moapa Valley. Fluid characteristics in Coyote Spring Valley are similar to those found in Moapa Valley, which supports this theory. However, it's assumed that Moapa area fluids became enriched in Na and K after passing through Tertiary sediments and volcanics between Coyote Spring Valley and

Moapa Valley. If this were correct, then sample CSV-2 should be depleted in Na + K and enriched in Ca and Mg. The situation is just the opposite. CSV-2 is enriched in Na + K (see fig. 29) rather than Ca and Mg as would be expected in carbonate aquifers. One explanation for this discrepancy is that the fluid source is within a non-carbonate environment; the flow through the carbonate aquifers is so rapid that the fluids do not have time to alter their chemistry to a more Ca and Mg enriched fluid.

The increased SO_4 component also suggests a non-carbonate source area. When CSV-2 is compared to the other carbonate aquifer fluids in the area.

Another discrepancy about the CSV-2 sample is that other carbonate aquifer samples within the White River flow system are primarily calcium bicarbonate (Ca HCO_3) (Mifflin, 1968). The Na + K enrichment of CSV-2 would tend to indicate a probable sediment or volcanic origin, but the occurrence of this fluid within a carbonate aquifer does not fit the regional chemistry.

Additional work on the carbonate aquifer system in Coyote Spring Valley might better delineate the system's characteristics. Until this has been done, one can only speculate as to the Na + K enrichment of fluids extracted from a carbonate aquifer.

TEMPERATURE GRADIENT STUDIES: TEST WELLS

During the preliminary phase of the project, temperature gradient data were collected on six test water wells within the area. The first test well, approximately 200 meters deep, was drilled by the U.S. Air Force's geotechnical subcontractor and encountered 35°C (95°F) water. A temperature gradient profile was made on this well and five other shallow test holes, each approximately 30 meters deep.

Figure 31 shows the location of this six test holes and their bottom hole temperatures are shown in Table V. Figure 32 is the temperature profile of the 200-meter test well. No major temperature anomalies are found other than the 35°C waters in the deep test well. The 35°C waters are found in a carbonate bedrock aquifer. Similar temperatures were also seen in other carbonate bedrock aquifers within the region (Table III).

CULTURAL ASSESSMENT OF COYOTE SPRING VALLEY

Before conducting the shallow temperature probe survey, it was necessary to obtain a permit from the Bureau of Land Management in compliance with BLM requirements. An archaeological literature survey was also undertaken to reveal those areas which should be avoided during field work.

There is evidence that human activity has taken place continuously within or in the vicinity of Coyote Spring Valley over the past 15,000 years. Human cultural remains include aboriginal lithic and textile fragments, and most recently, wells from ranching starts in the early 1900's, three highways (one now closed), numerous dirt roads and tire tracks, surveyors' flags and stakes, seismic survey lines, and water wells drilled by Ertec.

A Class I Cultural Resources Inventory (Rusco and Kuffner 1981) establishes ten east-west transect lines covering 20 percent of the 9,600-acre study area, including major land forms of Coyote Spring Valley. Thirteen archaeological sites and the cockpit of a jet aircraft were revealed in the study area (fig. 33). Gypsum series and Pinto series of projectile points found in Coyote Spring Valley give firm evidence that the valley was occupied as long ago as 2,000 years. The Colorado River basin in southern Nevada has signs of human habitation as long ago as 11,000 to 13,000 years B.P., an age linked with the San Dieguito/Lake Mohave culture.

Figure 31. Location of temperature gradient test holes.

Table V

**GEOTECHNICAL BORINGS AND CARBONATE AQUIFER
TEST WELL IN COYOTE SPRING VALLEY**

<u>Well Identification</u>	<u>Depth in Feet</u>	<u>Temperature °C</u>
1. CE-B(0) 10W	100	22.8
2. CE-B(0) 5B	160	23.4
3. CE-B(0) 2(D)	160	25.0
4. CE-B(0) 14(NI)	100	23.0
5. CK-B IF	95	23.1
ETW*	665	34.9

***Carbonate Aquifer Test Well**

Carbonate Aquifer

Figure 32. Temperature gradient profile of carbonate aquifer test well, ETW.

The Anasazi tradition became established in the Virgin and Moapa valleys by 2,000 B.P. Its features include more permanent living structures, the beginnings of horticulture, and the use of Rose Spring/Eastgate style projectile points and ceramics. Rusco postulates that this group of people visited Coyote Valley to gather seasonal plants and raw materials for the manufacture of stone tools (Rusco and Kuffner, 1981). It appears that this large, stable population was replaced by the Numic speaking Southern Paiutes, the most recent aboriginal inhabitants of the area. The relationship between the Anasazi tradition and the Southern Paiutes is still in question.

During the study, 101 one-inch diameter, two meter temperature probes were implanted throughout Coyote Spring Valley. Upon arrival at the preselected probe sites, the ground was carefully inspected. If cultural material was found, the site was recorded and another spot was selected for drilling. Off-road activities were primarily restricted to old jeep trails, existing tire tracks, the bottom of washes, and seismic survey lines. Drilling with a Mobil B42 drill rig was confined to the eastern margins of the old and new U.S. Highway 93, the Moapa highway, and the adjacent east-west power line corridor. This larger scale drilling was done on previously disturbed ground.

A total of five prehistoric sites were recorded while implanting temperature probes and taking water samples. Four of these were located in Coyote Valley, the fifth was located at Grapevine Spring T7S/R67E, NE¼ of SW¼ of S.30. This last site was the only one on which tools were found. Several biface fragments were found, which were probably made from a nearby white chert outcrop. As with most of the sites in the Coyote/Kane Springs Wash area, abundant obsidian flakes were present. These obsidian flakes usually had cortex remnants, often enough to show that they were assayed pebbles. The artifacts indicate activities such as tool

manufacturing and hunting took place. The other four sites in Coyote Spring Valley appear to be material acquisition sites all within view of Pahanagat Wash. Three of these sites are characterized by assayed obsidian pebbles, along with some white and colored chert. All lie in an area north of the Moapa Highway, State Route 7, and south of Coyote Spring Valley. No tools were observed. The one site south of Highway 7 consisted of three unmodified white chert flakes adjacent to an abandoned burrow pit. All of these flakes were at least seven centimeters across the largest dimension.

In summary, the geothermal exploration project revealed five prehistoric sites. Due to the difficulties of drilling through caliche, the archeological site discovery based on drill sites was entirely random. This taken with Rusco's information and the amount of obsidian present indicates that more sites overlooking Pahanagat Wash will be discovered if a systematic survey of Coyote Spring Valley takes place. Field methods were useful to discover archaeological sites, and also to gather temperature probe data with a minimum impact on the ground surface.

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APPENDIX A: Results of five fluid isotope samples sent out for analysis and received after final report preparation: Coyote Spring Valley, Nevada.

Sample Designation	$^{18}\text{O}/^{16}\text{O}$ (‰ vs SMOW)	D/H (‰ vs SMOW)
CSV-1	-12.6	-106
KSV-1	-11.3	-105
KSV-2	-11.9	-99
KSV-3	-11.5	-97
KSV-4	-9.8	-80

Stable light isotope composition of waters from Coyote Spring Valley and Kane Springs Valley.

Appendix B

ANNOTATED BIBLIOGRAPHY

The bibliography represents publications (reports and maps) that pertain to the proposed MX deployment area of Nevada. The publications cover all aspects of geology and related subspecialties such as geochemistry, geophysics and hydrology. The bibliographic list has been annotated with key abbreviations which denote the type of specialty addressed (i.e. lithology, hydrology, etc.), the geographic area covered (region, county, etc.) and the geologic age, physiographic province or orogenic zone covered by the publications.

The abbreviations used and their meaning are presented below.

G	Geology	M	Mesozoic
Gp	Geophysics	C	Cenozoic
Gc	Geochemistry	T	Tertiary
H	Hydrology/Groundwater	Q	Quaternary
Fg	Fluid Geochemistry	Sob	Sevier Orogenic Belt
Wd	Well Data	Gb	Great Basin/Basin & Range
Gt	Geothermal/Heat Flow	Nts	Nevada Test Site
Tt	Tectonics	N	Nevada
S	Structure	NN	Northern Nevada
Hy	Hydrothermal	CN	Central Nevada
Li	Lithology	SN	Southern Nevada
Ap	Aerial Photography or Images	EN	Eastern Nevada
Si	Satellite Images	WN	Western Nevada
Cc	Carbonates	WUS	Western United States
V	Volcanics	Cc	Clark County
PC	Precambrian	Lic	Lincoln County
P	Paleozoic	Nc	Nye County

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