

GEOHERMAL ASSESSMENT OF A PORTION OF THE ESCALANTE VALLEY, UTAH

By Robert H. Klauk and Chad Gourley

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By Robert H. Klauk¹ and Chad Gourley²

ABSTRACT

In February 1981, the Utah Geological and Mineral Survey (UGMS) contracted with the Department of Energy (DOE) to evaluate the geothermal potential of an area proposed for a possible Missile Experimental (MX) operations base in the Escalante Valley region of Utah (DOE contract DE-AS07-77ET 28393). Exploration techniques employed included a temperature survey, chemical analysis of springs and wells, and temperature-depth measurements in "holes of opportunity." The highest water temperatures recorded in the area, with the exceptions of a 60°C (140°F) geothermal exploration hole and Thermo Hot Springs (42 to 78°C or 108 to 172°F), were 27 and 28°C (81 and 82°F) at two wells located northwest of Zane, Utah.

Total dissolved solid values in tested waters ranged from 276 to 5360 mg/l. Areas of relatively high total dissolved solids (greater than 1400 mg/l) were located primarily in the Zane area. Trilinear plots of common ion analysis of water samples collected resulted in three designated types as well as two individual anomalous values. Type III waters consist of all samples from Thermo Hot Springs, Type II waters consist of samples collected northwest of Zane, and Type I waters consist of all but two of the remaining samples. Of all trace elements tested for, lithium (Li) and boron (B) were present above detectable limits in most samples. Lithium values ranged from undetectable to 1.07 mg/l; values for samples in the Zane area ranged from 0.96 to 1.07 mg/l with the exception of EV-116 (0.26 mg/l). Zane area values also correlate with Thermo Hot Springs. Boron values of water samples ranged from undetectable to 1.2 mg/l. Boron concentrations in water from three wells sampled northwest of Zane ranged from 0.9 to 1.2 mg/l, which are similar to the 1.0 mg/l B values measured at Thermo Hot Springs.

Na-K-Ca geothermometer temperatures computed for the three samples northwest of Zane ranged from

100 to 120°C (212 to 248°F). All other Na-K-Ca temperatures computed for other water well samples were no greater than 74°C (165°F). Fournier (1977) suggests that if the Na-K-Ca thermometer indicates temperatures less than 100°C (212°F), the silica temperature of the water is a function of chalcedony solubility. For temperatures greater than 100°C (212°F), silica content is a function of quartz solubility. Quartz (conductive) temperatures for the three wells sampled northwest of Zane ranged from 96 to 104°C (205 to 219°F) and are comparable to the Na-K-Ca temperatures. Chalcedony temperatures ranged from 10 to 80°C (50 to 176°F) for the remainder of the water well samples.

Temperature-depth measurements were completed in 22 "holes of opportunity" in the study area. Gradients calculated ranged from isothermal to 138°C (280°F). The highest gradient was located 0.9 mi (1.5 km) west of sample location EV-150, which had the highest recorded water well temperature (28°C or 82°F).

Water temperatures, aqueous chemistry and temperature-depth data define a geothermal anomaly that may reflect a low-temperature geothermal resource. Further work is needed, however, to define the resource.

CONVERSION FACTORS

Water temperatures are reported in degrees centigrade (°C) with degrees Fahrenheit (°F) in parenthesis in the text. Water temperatures are reported only in (°C) in Figures and Tables. Water temperature can be converted from (°C) to (°F) by the following equation: °F = 1.8 (°C) + 32.

Chemical concentrations are given in milligrams per liter (mg/l) which is a unit expressing the solute per unit volume (liter) of water.

Gradients are given in degrees centigrade per kilometer and can be converted to degrees Fahrenheit per 100 feet by the following conversion: 18°C/km ≈ 1°F/100 feet.

Meters can be changed to feet in the Figures and Tables by the following equation: 1 m = 3.28 feet.

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INTRODUCTION

The Escalante Valley is a typical Basin and Range valley encompassing an area of 800 mi² (2080 km²) in Iron County and parts of Beaver and Washington Counties in southwestern Utah (Figure 1). Cedar City, the major metropolitan center in this part of the state, is located approximately 25 mi (40 km) to the east. Principal communities within the valley include Newcastle, Beryl Junction, and Modena; Lund, Beryl and Zane are small communities located along the Union Pacific Railroad and are likewise found in the study area. Thermo Hot Springs is also located in the valley. This study was undertaken to determine the existence of any unknown geothermal anomalies in the region.

The UGMS has been conducting research to advance the utilization of low-temperature geothermal resources in the State of Utah on a cost share basis with the U.S. Department of Energy (DOE contract DE-AS07-77ET 28393). In February 1981, the UGMS contracted with the Department of Energy to evaluate the geothermal potential in the Escalante Valley region of Utah, an area proposed for a possible Missile Experimental (MX) operations base. The exploration techniques employed during the study included:

- (1) Temperature survey of selected wells and springs;
- (2) chemical analysis of fluids from selected wells and springs;
- (3) temperature-depth measurements of selected holes of opportunity.

REGIONAL GEOLOGIC SETTING

The geology of southwestern Utah represents a long depositional history coupled with extensive igneous activity. During Late Precambrian time (oldest rocks exposed in area are Late Precambrian quartzites), the Cordilleran miogeosyncline was well developed (Stewart and Poole, 1974). Cambrian strata here are similar to that found in most areas of Utah; a basal sandstone (Prospect Mountain Quartzite) conformably overlain by a thin shale (Pioche Shale), which in turn is overlain by thick undifferentiated carbonates (Hintze, 1963a). Thick sequences of carbonates, with minor units of sandstone, siltstone, and shale, continued to be deposited throughout most of the remainder of the Paleozoic Era and include the Ordovician Pogonip Group, Eureka Quartzite, and Fish Haven Dolomite; the Silurian Laketown Dolomite; the Devonian Sevy Dolomite, Simonson Dolomite, Guilmette Formation, and Pilot Shale; the Mississippian Joana Lime-

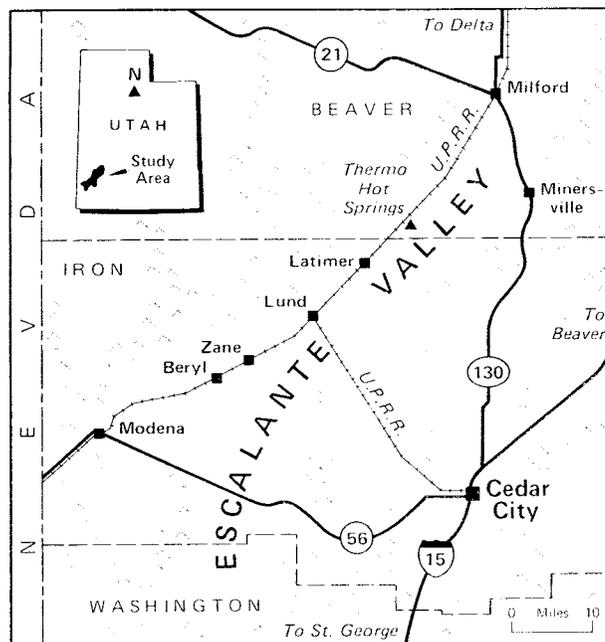


Figure 1. Location map of the Escalante Valley, Utah.

stone and Chainman Shale; the Pennsylvanian Illipah Formation and Ely Limestone; and the Permian Arcuturus Formation, Supai-Coconino-Toroweap Formations, and Kaibab Limestone.

During the Early Triassic, thick sediments of the miogeosyncline were uplifted to become the Mesocordilleran Highlands. The growth of these highlands was accomplished in a number of orogenic episodes affecting different areas through several geologic periods (Stokes, 1963). Sediment eroded from these highlands was deposited in marginal basins to the east. During Triassic and Jurassic time, thick sequences of siltstone, sandstone, conglomeritic sandstone and eolian sands were deposited; units include the Triassic Moenkopi Formation, Chinle Formation, Jurassic Navajo Sandstone, and San Rafael Group (Crosby, 1973; and Hintze, 1973). In Cretaceous time, the lenticular beds of coarse sandstone and conglomerate of the Iron Springs Formation were deposited. The Laramide Orogeny continued into the Early Tertiary, and the Claron Formation was deposited (Rowley and others, 1979).

An extensive volcanic sequence was extruded in southwestern Utah during the Middle Tertiary. Volcanic activity, which commenced in Late Eocene time, was "one of the most violent and intensive periods of volcanism in North America" (Stokes and Heylum, 1963). This sequence consists of intermediate calc-alkaline stratavolcanoes and regionally distributed ash-flow tuffs (Rowley and others, 1979). These volcanic rocks were deposited conformably

upon, and were sometimes interbedded with the Claron Formation (Mackin, 1947). Beginning 20 million years ago (Miocene time) the igneous activity shifted to alkalic basalt and alkalic rhyolite extrusives, a shift contemporaneous with the onset of Basin and Range faulting (Rowley and others, 1979). Fluvial and lacustrine deposits filled the developing basins concurrent with the volcanics.

REGIONAL STRUCTURAL SETTING

Southwestern Utah has a very diverse tectonic setting. A prominent structural feature in this area is the Wasatch tectonic hinge line (hereafter referred to as the Wasatch Line), which, for the most part, divides southern Utah into two distinct provinces: (1) the Basin and Range to the west and (2) the Colorado Plateau to the east. In southwestern Utah the Wasatch Line is thought to connect with the Las Vegas tectonic hinge line (hereafter referred to as the Las Vegas Line), which extends through southern Nevada forming a continuous fault system with the Garlock fault in southern California (Welsh, 1959). Associated with the Wasatch Line is a transition zone separating the relatively undeformed strata of the Colorado Plateau from extensively folded and thrust-faulted rocks of the Basin and Range. In the study area, Armstrong (1968) refers to the Sevier orogenic belt as the Wah Wah-Canyon Range sector. The thrust faults named in this sector consist of the Wah Wah, Frisco, Mineral Range, Pavant and Canyon Ranges (Armstrong, 1968). In southwestern Utah this belt varies from zero to tens of miles in width (Crosby, 1973). Kay (1951) indicates the Wasatch Line extends in a southerly direction from southwestern Utah, continuing through Arizona and into northern Mexico. This indicates that three important lines of disturbance converge in southwestern Utah, the northern branch being the main Wasatch Line, the southern branch being Kay's extension of the Wasatch Line, and the southwestern branch being the Las Vegas Line (Stokes, 1976). In addition, the Southern Great Basin volcanic or ignimbrite field clearly lies upon and parallels the Las Vegas Line (Stokes, 1976). In southwestern Utah, the northwest border of the Transcontinental arch, which extends northeasterly through the North American continent, also coincides with the Las Vegas Line.

GEOLOGY OF ESCALANTE VALLEY AND VICINITY

Stratigraphy and Igneous Rocks

The Escalante Valley is filled with unconsolidated to semi-consolidated alluvial, colluvial, lacustrine

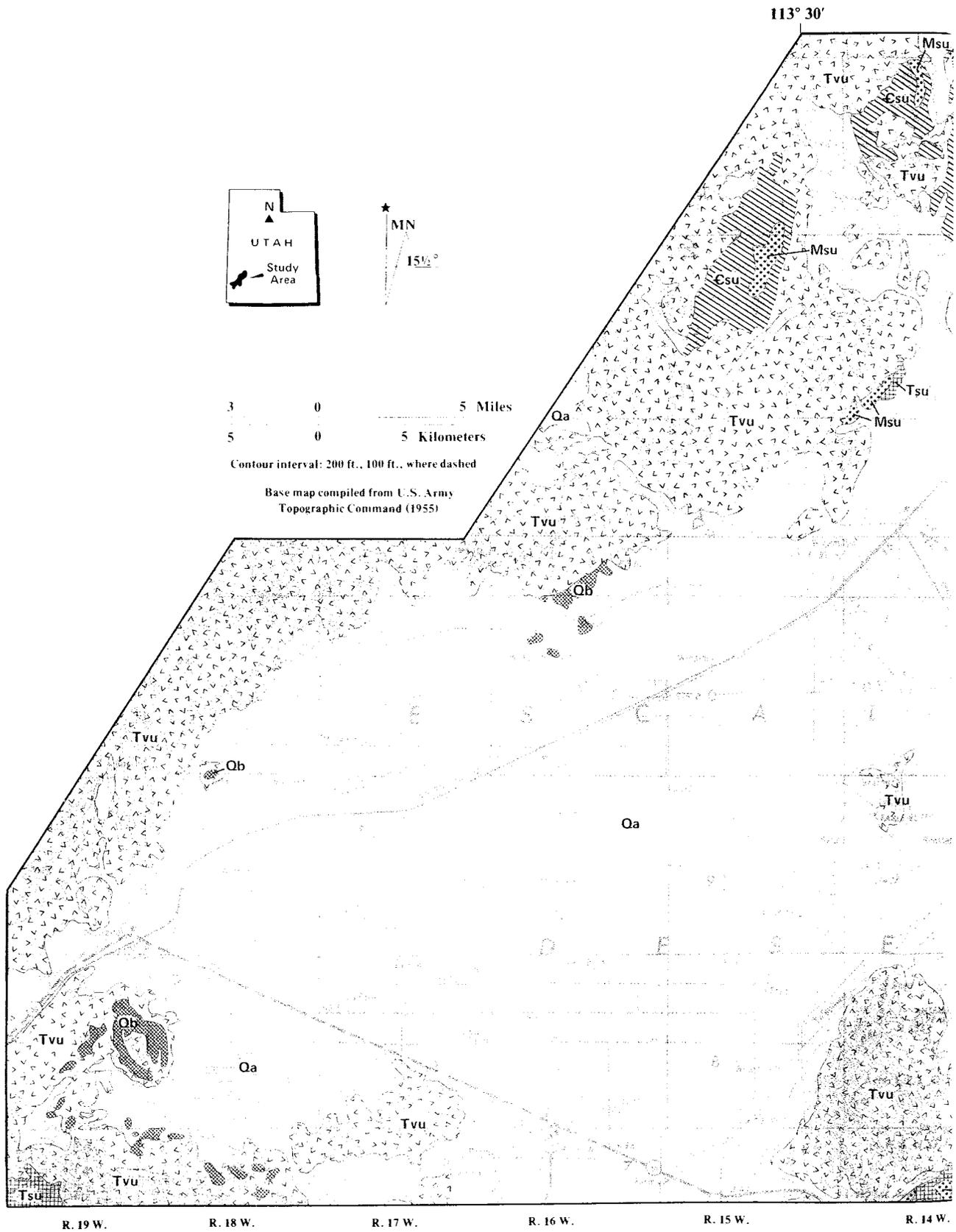
and aeolian deposits to a maximum thickness of approximately 1000 ft (305 m) (Mower, 1981). A gravity survey of the area conducted by Win Pe (1980) indicates unconsolidated sediments extend much deeper. Figure 2 illustrates the distribution of these sediments. The mountainous terrain surrounding the study area consists primarily of igneous deposits; Paleozoic and Mesozoic sediments are primarily limited to the areas northwest and southeast of the valley. To the northwest, Middle Cambrian to Early Pennsylvanian deposits are thrust over Early Triassic to Late Jurassic strata (Miller, 1966). To the southeast, Cretaceous rocks of the Iron Springs Formation and some limited exposures of the Tertiary Claron Formation are found.

Igneous rocks cropping out within the study area are principally volcanic, but outside the area, intrusive monzonite porphyry stocks are present to the south and southeast (Figure 2). The Escalante Desert lies between two regional, generally east trending, igneous belts: the Pioche-Marysvale belt to the north and the Delamar-Iron Springs belt to the south (Rowley and others, 1979) (Figure 3). The ages of these belts are thought to be 26 and 20 million years old, respectively. The composition of the igneous rocks in the study area is consistent with that previously mentioned for southwestern Utah; older calc-alkaline volcanics and younger rhyolitic and basaltic extrusives. Minor basalt flows are present to the west and southwest.

Structure

The Escalante Valley has been influenced by four significant geologic events: (1) large scale thrust-faulting of the Sevier orogeny; (2) east-west trending igneous activity; (3) Basin and Range tectonism; and (4) periods of intensive volcanism with associated intrusive activity.

A number of thrusts have been included in the Wah Wah-Canyon Range sector, but only the Blue Mountain thrust (in the Wah Wah Mountains) has been mapped in the vicinity of the Escalante Valley. The Blue Mountain thrust plate consists of Cambrian carbonates overriding Jurassic sandstone, forming a structurally complex zone about 15 mi (4.6 km) wide to the west of the Wah Wah thrust fault (Miller, 1963). The Blue Mountain thrust plate sequence is imbricated and, in places, overturned. At its easternmost exposure, this thrust dips below the Escalante Valley alluvium and therefore its eastern limit is not known (Miller, 1963). Although the Blue Mountain thrust can only be dated as post-Upper Jurassic, on the basis of regional relationships, it is part of a belt



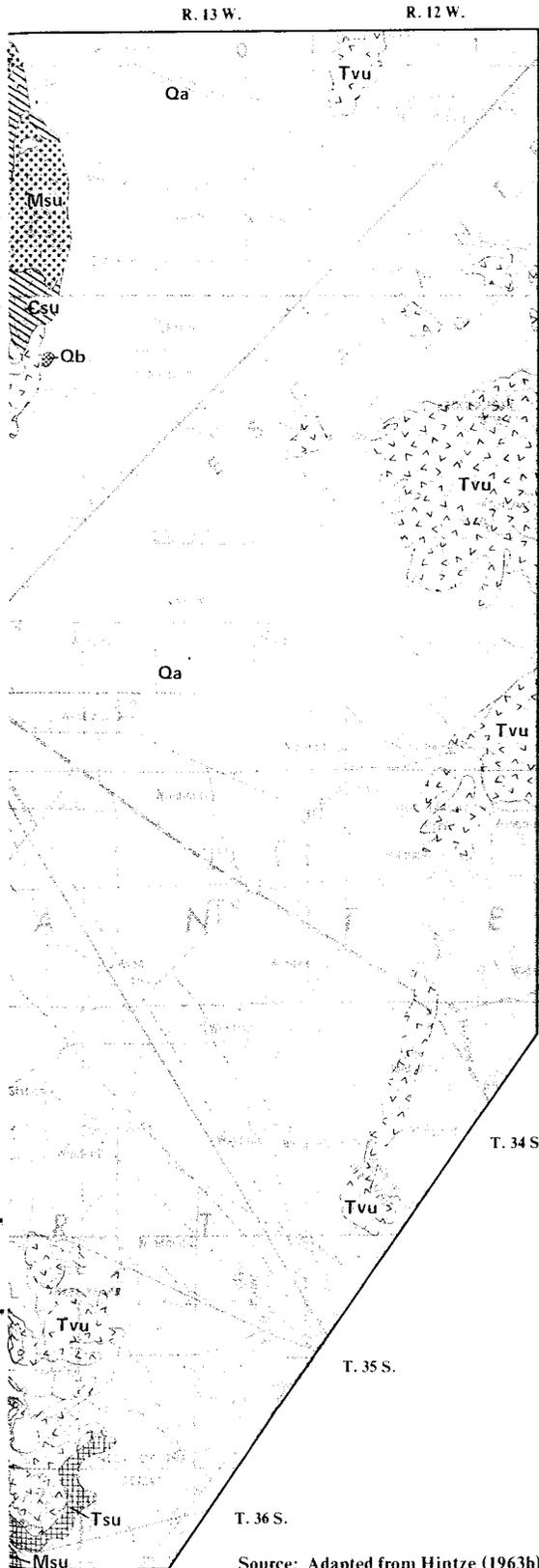


Figure 2.
Lithologic map of the Escalante Valley,
Iron and Beaver Counties, Utah.

EXPLANATION

- (Qa)  Quaternary alluvial deposits
- (Qb)  Quaternary basalts
- (Tvu)  Tertiary volcanic rocks and ignimbrites, undifferentiated
- (Tsu)  Tertiary sedimentary rocks, undifferentiated
- (Msu)  Mesozoic sedimentary rocks, undifferentiated
- (Csu)  Middle to Upper Cambrian sedimentary rocks, undifferentiated
-  Contacts between lithologic units

Source: Adapted from Hintze (1963b)

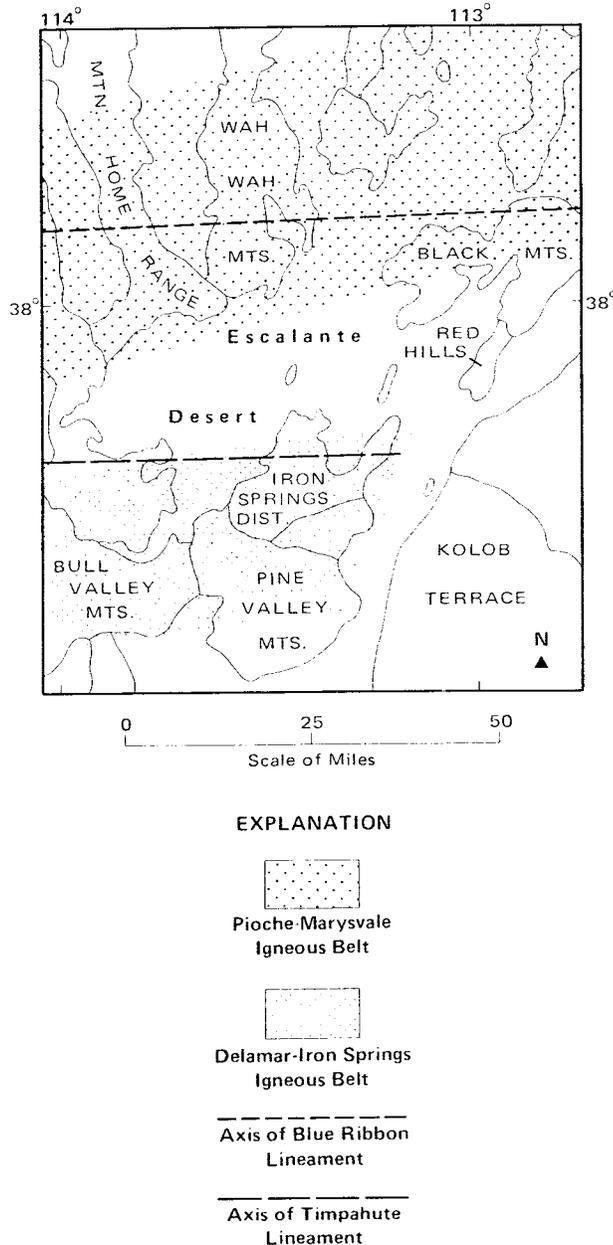


Figure 3. Major structural and physiographic features of the Escalante Desert and vicinity (modified after Rowley and others, 1979).

of Laramide age thrusts developed near the eastern border of the Great Basin (Miller, 1963).

The Pioche-Marysvale igneous belt and the Delamar-Iron Springs belt (mentioned previously as bordering the Escalante Desert to the north and south, respectively) are both thought to be structurally controlled (Rowley and others, 1979). Rowley and others (1979) also state that these belts contain most of the known volcanic centers, plutons, hot springs, igneous-related mineralized rocks and hydrothermally-altered rocks in southwestern Utah as well

as virtually all the known east-striking faults.

Two east-west oriented lineaments have been identified as extending into or through the Escalante Valley (Figure 3). The first is known as the Blue Ribbon lineament (Rowley and others, 1978) and is a feature approximately 15 mi (25 km) wide and 222 mi (360 km) long that extends from the central Sevier Plateau westward into Nevada. This lineament is located along the southern extent of the Pioche-Marysvale igneous belt; predominant movement along the east-striking faults appears to be dip-slip (Rowley and others, 1978). The second lineament, referred to as the Timpahute lineament, was defined by Ekren and others (1976) as extending from west of the Tempiute mining district in southeast Nevada to just east of the Utah-Nevada state line. Rowley and others (1979) have extended this lineament to the north side of the Delamar-Iron Springs igneous belt, as far east as Cedar City. Basin and Range tectonism is considered to have occurred more or less concurrently with the east-west trending igneous activity mentioned above. The orientation of the Basin and Range faults resulting from this tectonism is north-northeast (Rowley and others, 1979). In the Escalante Valley area, active faulting is considered to be younger than 10 m.y. ago; Anderson and Mehnert (1979) state that Pleistocene faults are abundant, and Anderson and Miller (1979) have located Quaternary faults in the Escalante Valley (Figure 4). Anderson and Bucknam (1979) report Holocene deformation resulting in at least 99 ft (30 m) of uplift in a 312 mi² (800 km²) area near Enterprise in the southern Escalante Valley, with faulting still active in the area.

During Oligocene and Miocene time great thicknesses of ignimbrites as well as lava flows, volcanic mudflows, and blanket deposits of airfall and water-laid tuff were produced. Stokes and Heylum (1963), and Crosby (1973) suggest that parts of the Escalante Valley as well as other areas of southwest Utah are analogous to a collapsed caldera resulting from the removal of support within the earth's crust. According to Win Pe (1980) and Clement (1980) there is no strong geological and geophysical evidence to support this hypothesis.

Win Pe (1980) conducted a gravity survey of the Escalante Desert and vicinity. Results of the survey and the conclusions drawn follow. The dominant features in the valley are oriented northeast-southwest and are possibly controlled by the northeast trending features of Laramide Age. Northeast trending large gravity lows indicate three grabens in the vicinities of Newcastle, Lund, and Avon with characteristic Basin

and Range structure (Figure 5). The depth to bedrock in these three grabens is estimated to be 1.9 mi (3 km), 1.1 mi (1.8 km), and 1.3 mi (2 km), respectively. Two intermediate gravity lows, indicating grabens, are in the vicinities of South Beryl and East Modena; these structures are thought to have been shaped principally by east-west trending pre-Basin and Range igneous activity (Figure 5). Depths to bedrock in these two grabens is estimated to be 1.4 mi (2.2 km) and 0.8 mi (1.2 km) respectively. A gravity high over the Beryl area could be indicative of bedrock that has been complexly deformed by igneous intrusions at shallow depth (Figure 5). A northeast extension of this gravity high could be caused by the eastern margin of the Blue Mountain thrust.

Ground Water

That portion of the Escalante Desert investigated is underlain by consolidated rocks of Cambrian to Tertiary age as well as by unconsolidated to semiconsolidated rocks of Quaternary age. Mower (1981) has combined these lithologic units into three hydrologic units. Unit 1 consists of Quaternary unconsolidated to semiconsolidated gravel, sand, silt, and clay and forms most of what is considered to be the principal ground-water reservoir. The thickness of these deposits is estimated by Mower (1981) to be no greater than 1000 ft (305 m) although Win Pe's (1980) gravity modelling indicates a much greater depth. Unit 2 consists of Tertiary andesitic latitic ignimbrites and is an undeveloped part of the principal ground-water reservoir. This unit has an estimated maximum thickness of 500 ft (152 m). Unit 3 consists of Quaternary to Cambrian age limestone, siltstone, shale, sandstone, basalt, intrusive igneous rocks as well as unconsolidated to semiconsolidated sedimentary deposits and constitutes the remainder of the drainage basin. Table 1 presents a more complete hydrologic description of the units and Figure 6 depicts their areal extent.

Recharge to the principal ground-water reservoir totals approximately 48,000 acre-feet (59 hm³) annually. Of this, 31,000 acre-feet (38 hm³) is obtained by subsurface inflow from bedrock as well as surface and subsurface inflow from stream channels (Mower, 1981). The remaining 16,000 acre-feet (21 hm³) of recharge is received from irrigation, from direct precipitation, and from inflow outside the drainage basin.

Prior to the construction of wells for irrigation (before 1960), ground water in the principal aquifer migrated from the main recharge areas at the periphery of the valley floor to discharge areas extending to

the Milford area. Significant increases in pumping for irrigation has modified this flow pattern, resulting in an artificial ground-water boundary which extends northwest from a point northeast of Beryl Junction to a point northwest of Beryl (Figure 7). Primarily, ground water southwest of this boundary discharges in a large depression located in the vicinity of Beryl Junction; ground water northeast of the artificial boundary discharges, as before, to the northeast into the Milford area.

The direction of movement within the principal aquifer is generally from deeper zones of greater hydrostatic pressure through semiconsolidated beds to shallower zones of lesser pressure (Mower, 1981). Locally, however, this may be reversed if pumping has decreased the hydrostatic pressure sufficiently in the deeper zones, or if local recharge has increased the hydrostatic pressure sufficiently in the shallow zones.

KNOWN GEOTHERMAL AREAS

Thermo Hot Springs

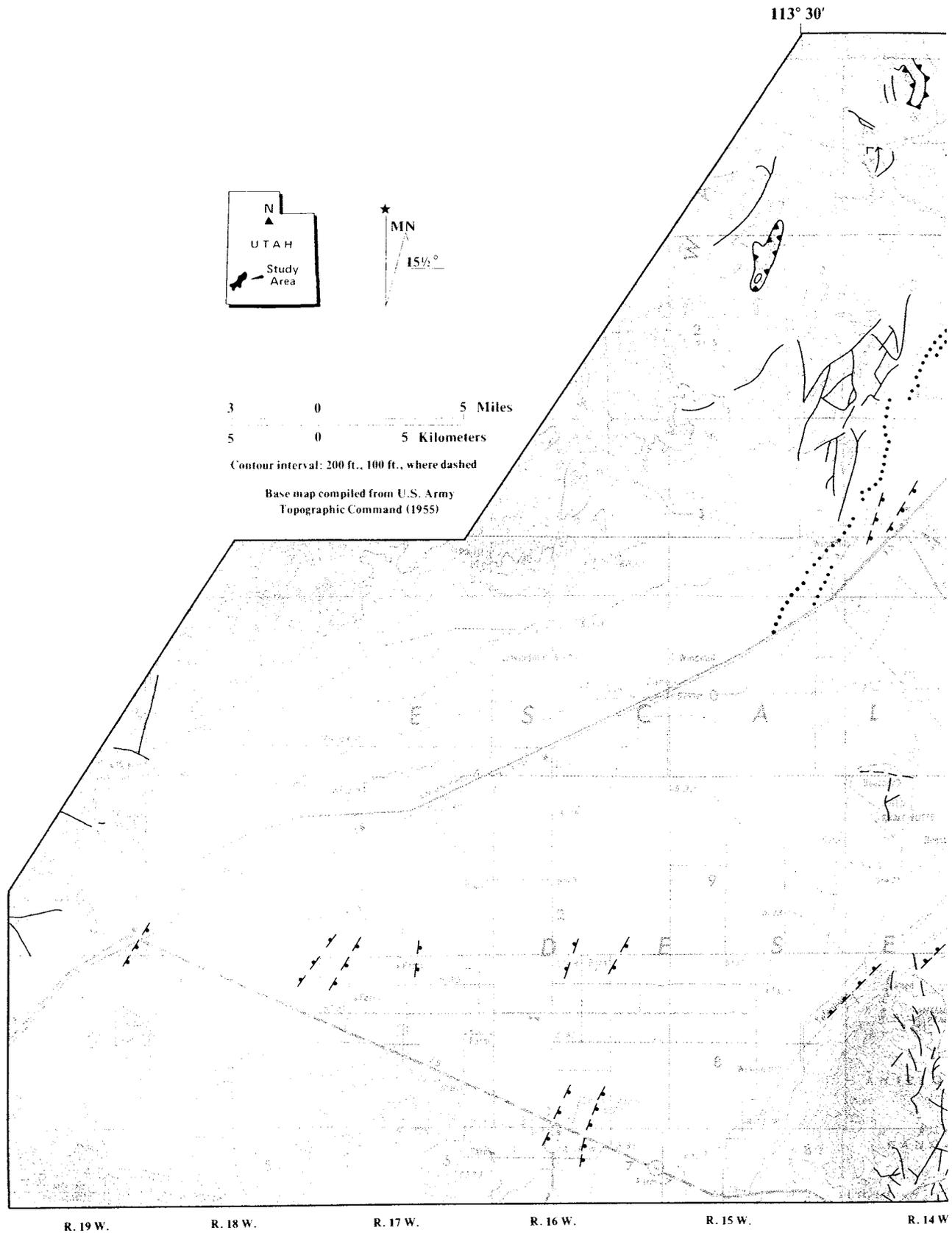
Thermo Hot Springs is located within that portion of the Escalante Valley included in this study. The springs issue along the sides and top of two NNE-trending en echelon calcareous travertine mounds that rise approximately 20 ft (6 m) above the valley floor (Mundorff, 1970). The southern mound, which has the most active spring system, is about 0.5 mi (0.8 km) long and from 856 to 905 ft (261-276 m) in width. UGMS personnel recorded temperatures at the springs ranging from 42 to 78°C (108 to 172°F).

The warm water issuing from the springs in the alluvium is thought to be meteoric, originating in the faulted mountains to the northwest or southeast (Mundorff, 1970). Thermo Hot Springs is thought to be at the site of intersecting, orthogonal faults which provide the conduits through which the heated meteoric water migrates from depth (Rowley, 1975).

Rush (1977) reported anomalously high thermal gradients for several shallow wells in the Thermo Hot Springs area. Two wells, 103 and 105 ft (31.5 and 32 m) in depth, adjacent to the springs exhibited gradients of 537 and 323°C/km, respectively. These gradients are constant throughout both profiles and could represent lateral flow in a near surface aquifer, and thus do not necessarily reflect temperatures to be expected at depth. The maximum temperatures recorded in these two wells were 28.4°C (83°F), (537°C/km well) and 21.7°C (71°F), (323°C/km well).

TEMPERATURE SURVEY

Ground-water temperatures in the Escalante



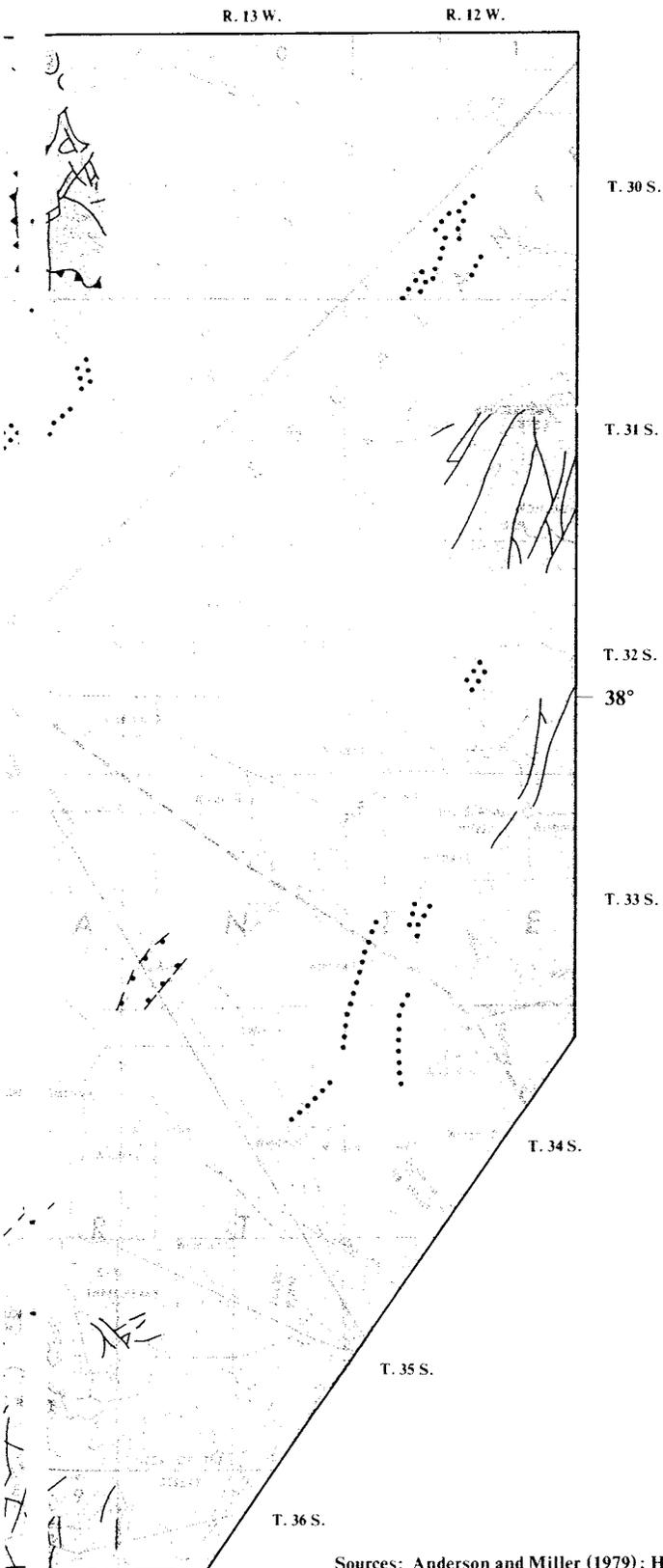
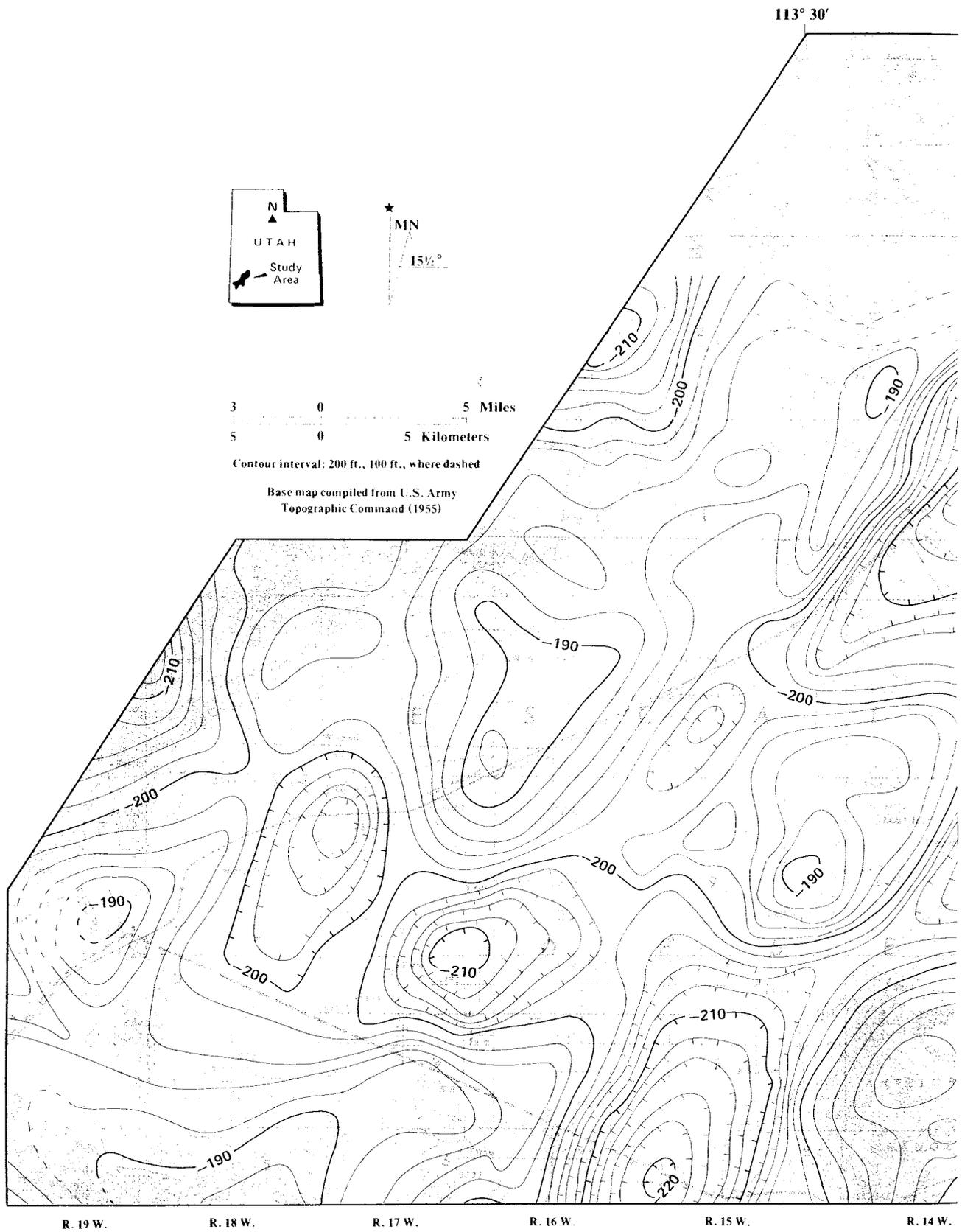


Figure 4.
Fault map of the Escalante Valley, Iron
and Beaver Counties, Utah.

EXPLANATION

- Fault, solid line where well exposed —
 dashed where inferred
- Suspected Quaternary faults
- ▲▲▲▲ Blue Mountain thrust fault
- Concealed fault, inferred by gravity —
 dots on down-thrown side

Sources: Anderson and Miller (1979); Hintze (1963); Win Pe (1980)



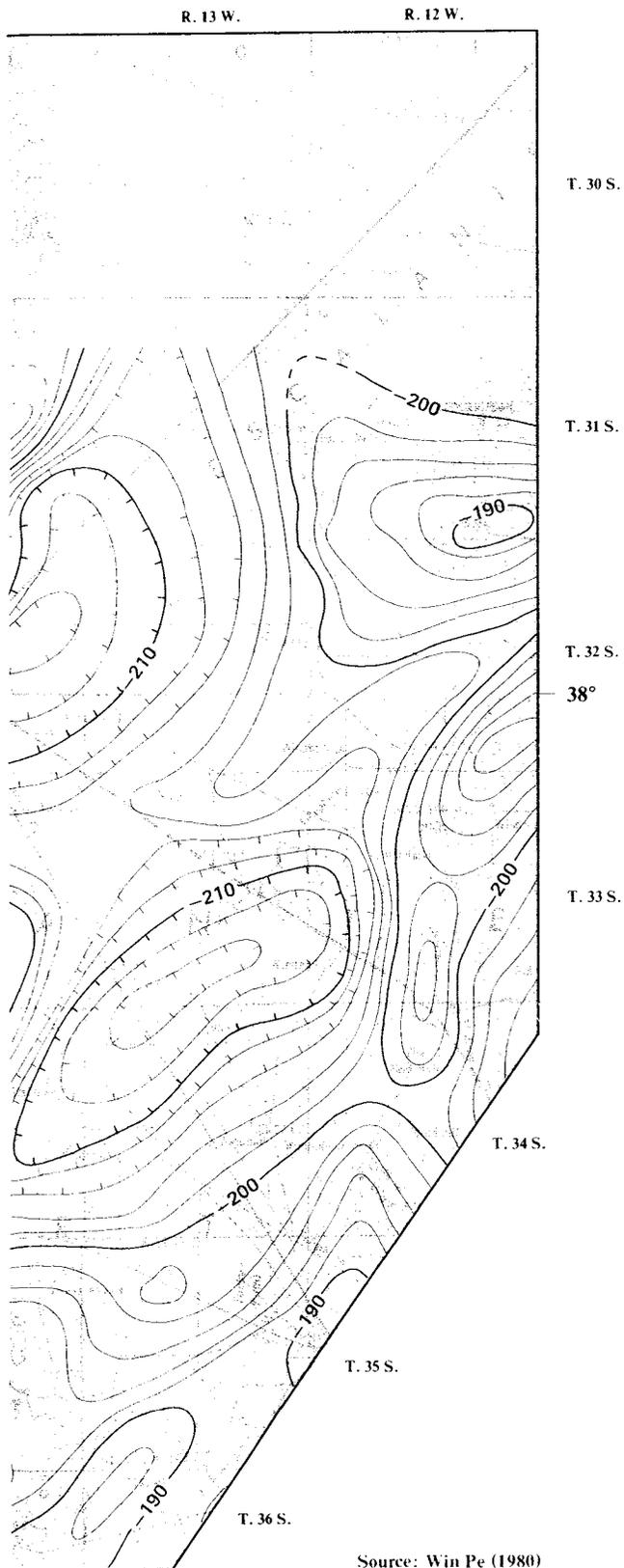
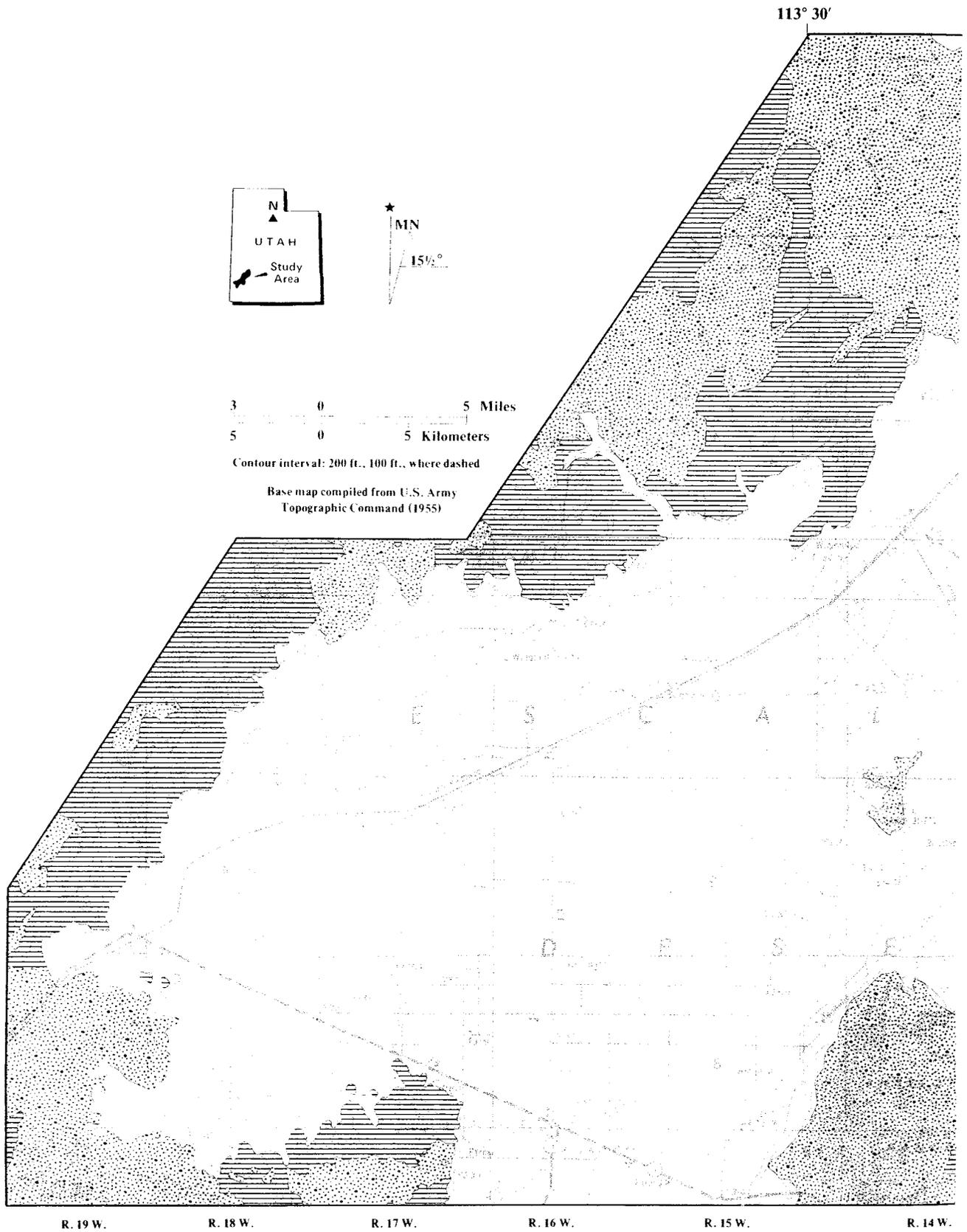


Figure 5.
Complete Bouguer gravity map of the
Escalante Valley, Iron and Beaver
Counties, Utah.

EXPLANATION

Gravity contour interval - 2 milligals

Source: Win Pe (1980)



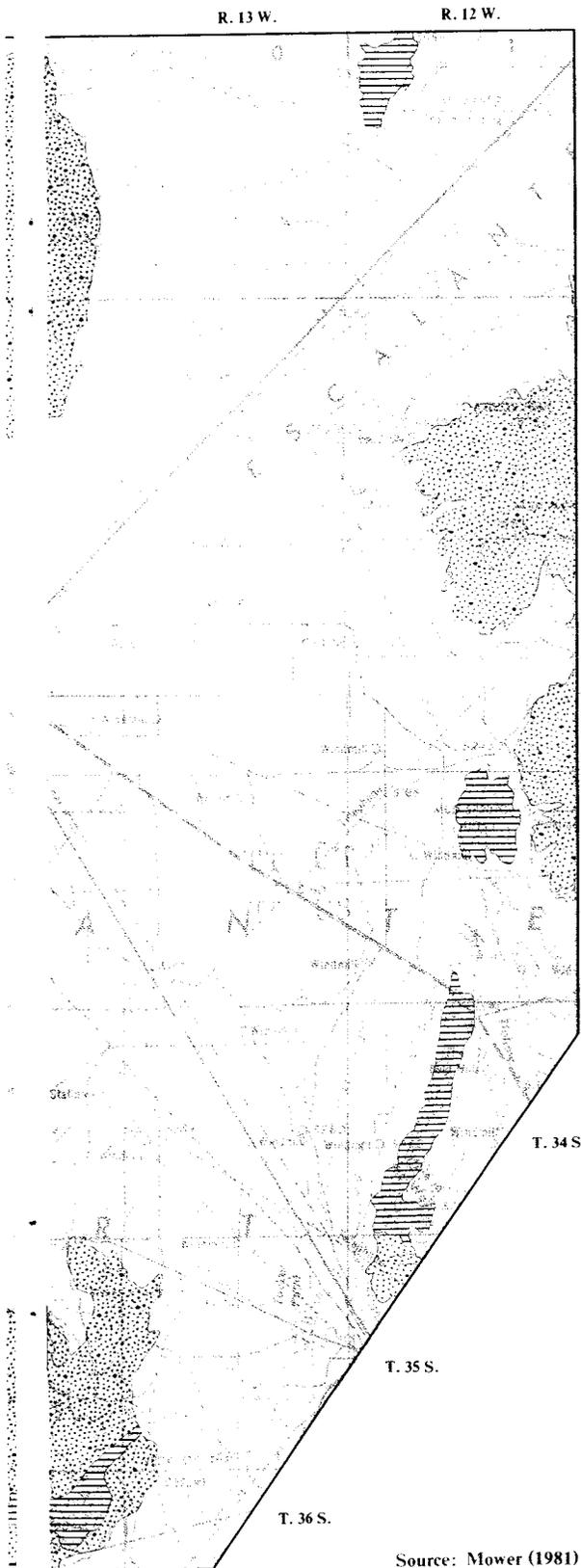


Figure 6.
Hydrologic units in the Escalante Valley,
Iron and Beaver Counties, Utah.

EXPLANATION

QUATERNARY

Unit 1

Unconsolidated to semiconsolidated deposits — gravel, sand, silt, and clay. Forms most of the principal ground-water reservoir

TERTIARY

Unit 2

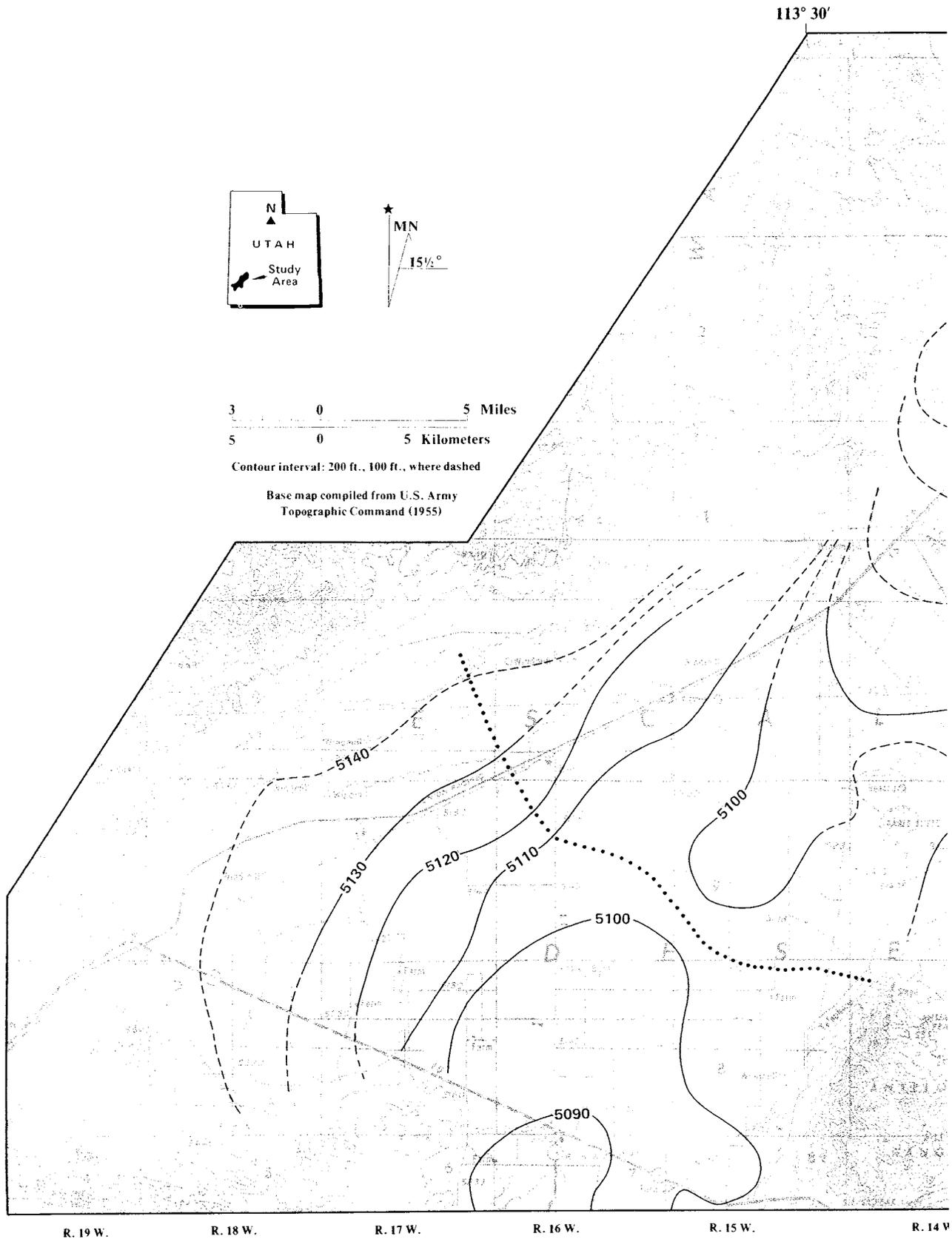
Andesitic — latitic ignimbrite

QUATERNARY TO CAMBRIAN

Unit 3

Limestone, siltstone, shale, sandstone, basalt, intrusive igneous rocks, unconsolidated to semi-consolidated deposits

Source: Mower (1981)



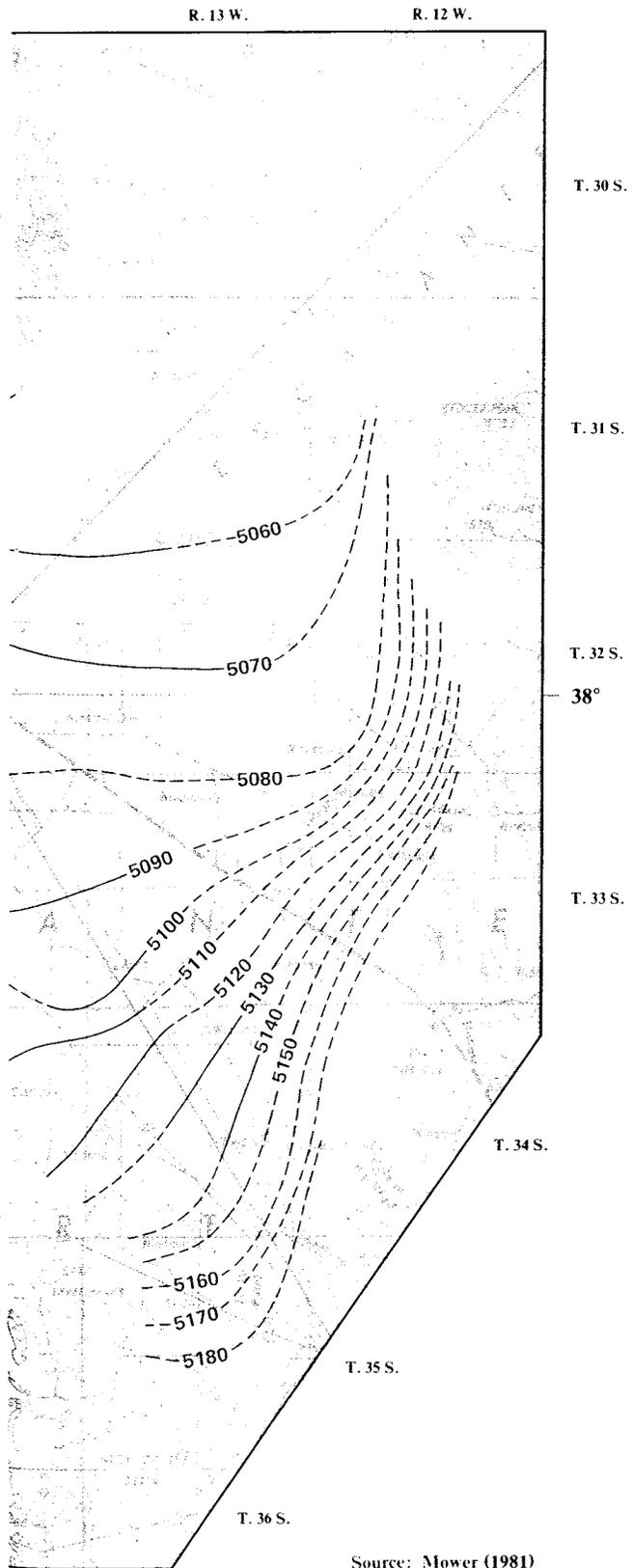


Figure 7.
Potentiometric surface contour map
Escalante Valley, Iron and Beaver
Counties, Utah.

EXPLANATION

- 5060 --- Water level contour (feet)
- Ground water divide

Source: Mower (1981)

Table 1. Hydrogeologic units and their qualitative hydrologic properties (from Mower, 1981).

Hydrogeologic units			
Unit	Geologic age	Lithology	Qualitative hydrologic properties
1	Quaternary	Unconsolidated to semi-consolidated gravel, sand, silt, and clay.	Forms most of the principal ground-water reservoir. Coarse-grained deposits, which crop out mainly around the perimeter of the area, probably accept large quantities of recharge from ephemeral flow resulting from storms. The sand and gravel, which generally are within 152 meters of the surface, readily yield water to wells. Clay and silt deposits restrict vertical movement, but they are not so extensive or impermeable as to prevent vertical movement between the coarser deposits. Thickness ranges from zero near the edge of the valley to probably more than 305 meters in the central part of the valley. The semiconsolidated deposits generally form the lowermost part of the principal ground-water reservoir. The semi-consolidated deposits are similar in most respects to the overlying unconsolidated deposits and usually it is difficult to distinguish between them.
2	Tertiary	Andesitic-latic ignimbrite	Between Modena and Enterprise considered as an undeveloped part of the principal ground-water reservoir. Probably accepts a moderate rate of recharge where fracture zones underlie saturated, unconsolidated deposits or are crossed by ephemeral streams. Would yield water to wells at varying rates depending upon the number and interconnection of the fractures intersected.
3	Quaternary to Cambrian	Limestone, siltstone shale, sandstone, basalt, intrusive igneous rocks, unconsolidated to semi-consolidated sedimentary deposits.	Bounds the principal ground-water reservoir. The Quaternary unconsolidated materials are thin surficial deposits; in places the older rocks contain well developed and interconnected open joints. Probably accepts moderate to large quantities of recharge and contributes large quantities of water to the principal ground-water reservoir at the southern margin of the valley and small to moderate quantities at the other margins. Would yield water to wells at varying rates, depending upon the number and interconnection of the fractures intersected.

Valley vary both areally and with depth. Wells are screened through most of the saturated section penetrated, and therefore temperatures recorded at the well head are an approximate average for the entire perforated section (Mower, 1981).

Temperatures ranging from 12 to 78°C (54 to 172°F) were measured at 53 wells and springs in the study area with a Yellow Springs Instrument (YSI) Model 33 Temperature-Conductivity Meter (Figure 8). All water wells measured were less than 410 ft (125 m) in depth. Excluding four temperatures recorded at Thermo Hot Springs (42 to 78°C or 108 to 172°F) and a 60°C (140°F) temperature recorded at a 3072 ft (2461 m) geothermal test well 6.2 mi (10 km) southwest of Zane, all temperatures of 20°C (68°F) or greater were recorded northwest of the Union Pacific railroad line (Figure 8). Of those temperatures above 20°C (68°F), the warmest (27 and 28°C or 81 and 82°F) are located northwest of Zane.

Six wells, with water temperatures of 20°C (68°F) or higher northwest of the Union Pacific railroad line were completed in what Mower (1981) describes as the principal aquifer. Well driller logs, which were available for only three of these wells, indicate screening only in the sand and gravel layers. Recharge to this area is from the northwest. Indications are, therefore, that the warm water encountered has its source somewhere to the northwest and these wells are intercepting lateral flow down gradient.

Of the remaining two warm wells (20°C or 68°F), one was completed in what Mower (1981) refers to as Unit 2 (an undeveloped part of the principal groundwater reservoir). The material consists of andesitic and latitic ignimbrites. This well was drilled horizontally 148 ft (45 m) into Unit 2. The other well was drilled at the mouth of Fishers Wash and is considered to be intersecting underflow from the wash.

WATER CHEMISTRY

Forty-nine water samples were collected and analyzed as part of this study (see Figure 9 for sample locations). The on-site analyses consisted of: (1) pH, (2) alkalinity, and (3) conductivity. A Corning-Orion Model 407A/F specific ion meter in conjunction with an Orion gel-filled Model 91-05 combination pH electrode was used to measure pH. Three readings were taken and the average was recorded as the final value. A YSI Model 33 Temperature-Conductivity Meter was used to measure conductivity. Alkalinity was measured using a Hach Alkalinity model AL-AP test kit.

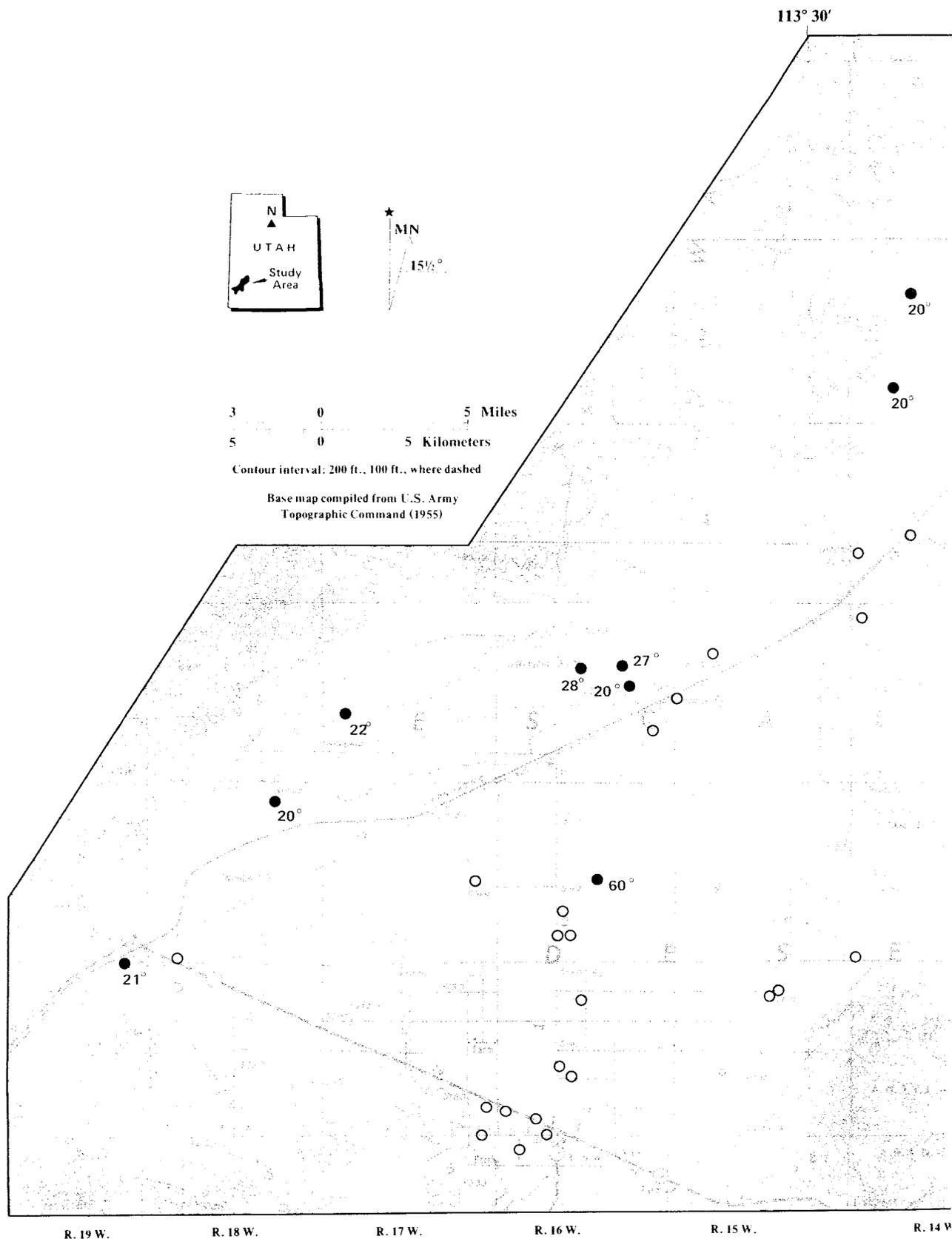
Three polyethylene bottles (two 570 ml and one 65 ml) were filled at each sampling location with water

filtered through a GeoFilter Peristaltic Pump - Model no. 004 using a 0.45 micron filter paper. That water was subsequently analyzed at the University of Utah Research Institute/Earth Science Laboratory (UURI/ESL). The 65 ml bottle was acidified with reagent grade HNO₃ to a final concentration of 20% HNO₃ for cation analysis of elements presented in Table 2 by an APL Inductivity Coupled Plasma Quantometer (ICPQ). A 570 ml bottle was acidified with concentrated HCl to a final concentration of 1 percent HCl for S₀4 analysis. The remaining bottle was unacidified and the water was analyzed for Cl, F, and total dissolved solids (TDS). Results of the analyses are presented in Table 3.

Table 2. Limits of quantitative determination (LQD) for solution analysis by the University of Utah Research Institute/Earth Science Lab Inductively Coupled Plasma Quantometer.

Element	Concentration (mg/l)
Na	1.25
K	2.50
Ca	0.250
Mg	0.500
Fe	0.025
Al	0.625
Si	0.250
Ti	0.125
P	0.625
Sr	0.013
Ba	0.625
V	1.25
Cr	0.050
Mn	0.250
Co	0.025
Ni	0.125
Cu	0.063
Mo	1.25
Pb	0.250
Zn	0.125
Cd	0.063
As	0.625
Sb	0.750
Bi	2.50
Sn	0.125
W	0.125
Li	0.050
Be	0.005
B	0.125
Zr	0.125
La	0.125
Ce	0.250
Th	2.50

Note: LQD concentrations represent the lowest reliable analytic values for each element. Precision at the LQD is approximately ± 100% of the given value with a confidence level of 95 percent.



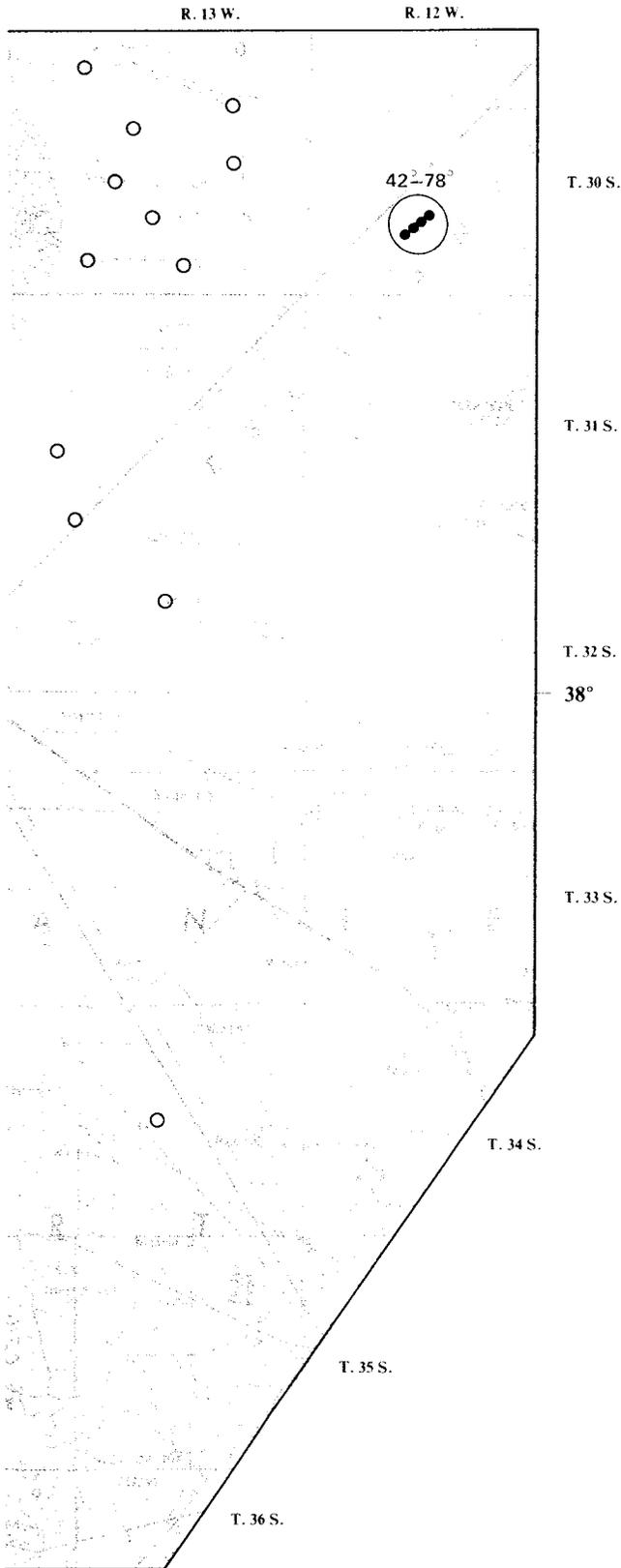
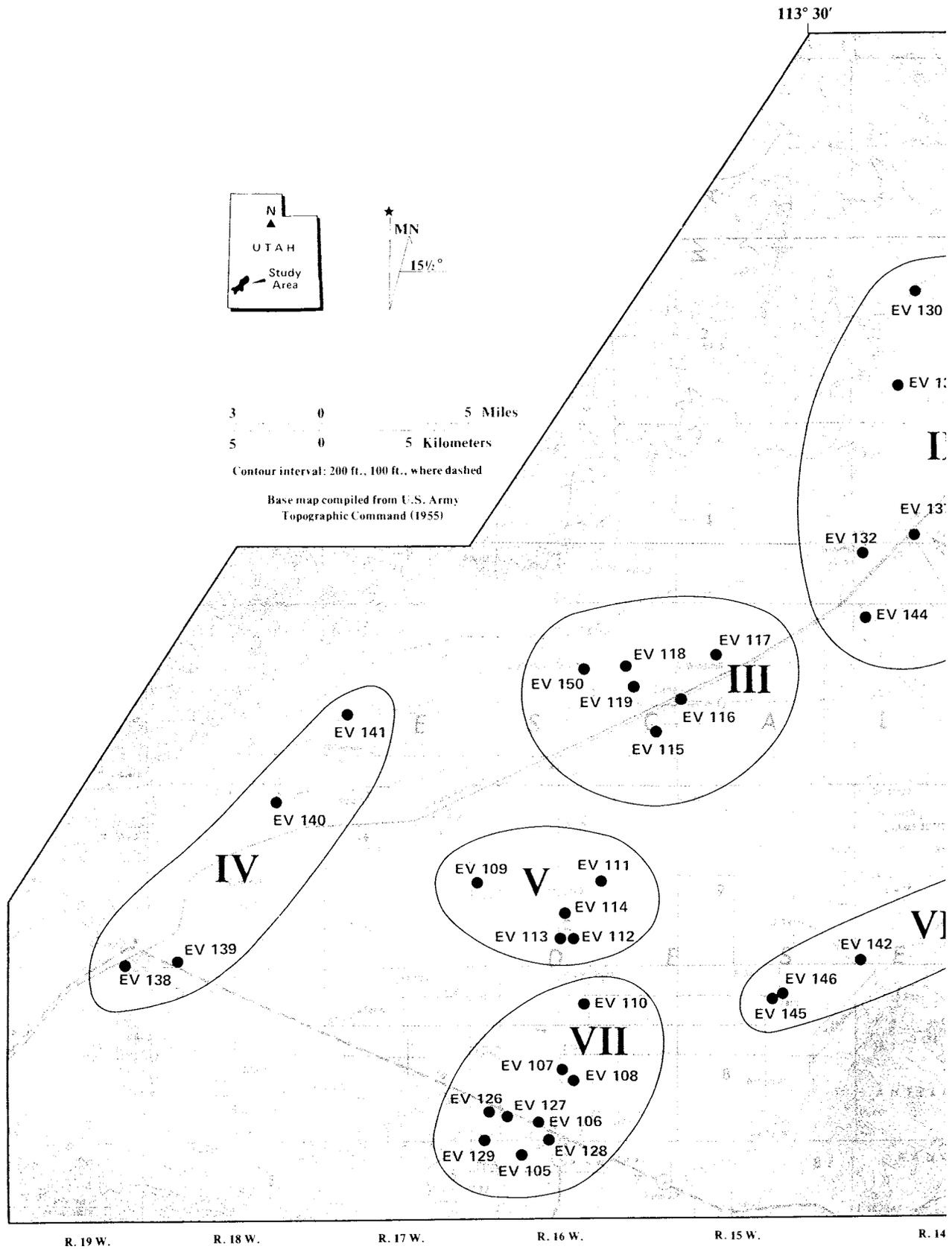


Figure 8.
Ground-water temperature map of the
Escalante Valley, Iron and Beaver
Counties, Utah.

EXPLANATION

- Temperatures < 20°C
- (circled) Thermo Hot Springs area
- Temperatures ≥ 20°C



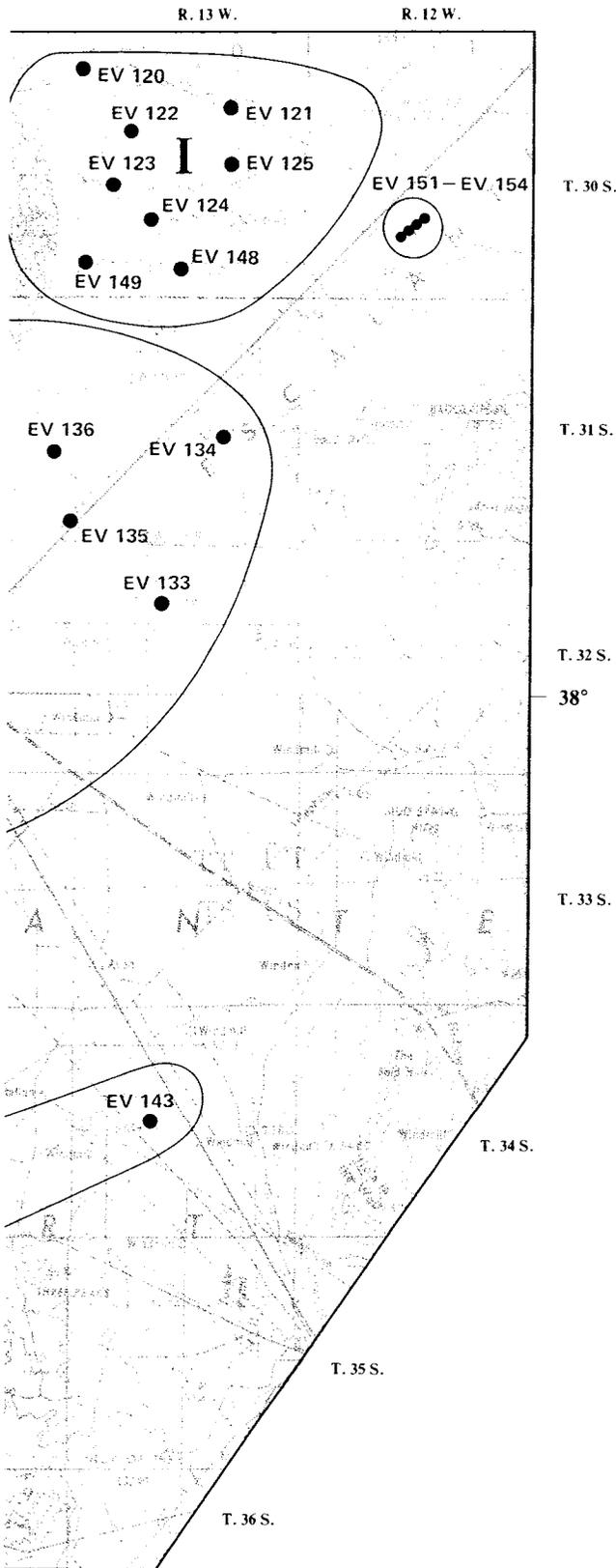


Figure 9.
Well and spring chemistry sample
locations Escalante Valley, Iron
and Beaver Counties, Utah.

EXPLANATION

- Well locations
- ⊙ Thermo Hot Springs area
- Ⓜ Area and area numbers of grouped samples

Table 3. Water analysis from wells and springs in the Escalante Valley, Utah.

Sample No.	EV-105	EV-106	EV-107	EV-108	EV-109	EV-110	EV-111
Location	(C-36-16)5bbc 37°42'03" 113°41'00"	(C-35-16)32bdb 37°43'04" 113°40'03"	(C-35-16)21bcc 37°44'38" 113°39'13"	(C-35-16)21dcc 37°44'13" 113°38'45"	(C-34-17)24bac 37°50'09" 113°42'18"	(C-35-16)9aad 37°46'36" 113°37'03"	(C-34-16)22baa 37°50'42" 113°37'42"
Temp. °C	14	16	14	14	17	12	60
pH	7.45	7.80	7.65	7.85	7.90	7.55	9.10
tds (mg/l)	536	288	416	330	318	604	446
HCO ₃ (mg/l)	275	209	275	217	183	234	259
Na (mg/l)	22	17	18	17	25	21	148
K (mg/l)	7	5	5	4	8	6	3
Ca (mg/l)	123	53	76	60	68	118	5
SiO ₂ (mg/l)	44	43	41	41	54	41	54
Mg (mg/l)	23	10	15	12	9	20	u
Fe (mg/l)	0.04	0.06	u	0.03	0.14	0.13	0.06
Ti (mg/l)	u	u	u	u	u	u	u
Sr (mg/l)	0.66	0.31	0.38	0.29	0.43	0.50	u
W (mg/l)	u	u	u	u	u	u	0.20
Mn (mg/l)	u	u	u	u	u	u	u
Zn (mg/l)	u	u	u	0.2	0.4	0.6	u
Li (mg/l)	u	u	u	u	0.06	u	0.16
B (mg/l)	u	u	u	u	u	u	5.30
F (mg/l)	0.3	0.5	0.3	0.3	0.6	0.3	34
Cl (mg/l)	131	38	55	43	20	118	26
SO ₄ (mg/l)	43	14	30	20	58	49	40

u = Elements not present or not present in detectable concentrations.

Table 3. Continued.

Sample No.	EV-112	EV-113	EV-114	EV-115	EV-116	EV-117	EV-118
Location	(C-34-16)28dcc 37°48'34" 113°39'14"	(C-34-16)28ccc 37°48'34" 113°39'15"	(C-34-16)28bac 37°49'13" 113°37'03"	(C-33-16)25bba 37°54'39" 113°35'47"	(C-33-15)19bba 37°55'29" 113°34'42"	(C-33-15)8caa 37°56'44" 113°33'20"	(C-33-16)11cdc 37°56'25" 113°36'52"
Temp. °C	12	14	14	15	16	17	27
pH	7.35	8.00	7.75	6.99	7.69	7.02	7.15
tds (mg/l)	884	322	344	5360	1490	1700	1760
HCO ₃ (mg/l)	192	184	184	258	292	401	376
Na (mg/l)	38	34	39	690	241	393	405
K (mg/l)	9	7	7	30	12	12	34
Ca (mg/l)	138	45	41	693	186	159	140
SiO ₂ (mg/l)	50	56	55	50	45	42	49
Mg (mg/l)	27	9	9	131	30	24	18
Fe (mg/l)	0.04	0.07	0.03	0.10	0.21	0.42	0.03
Ti (mg/l)	u	u	u	u	0.2	0.2	0.2
Sr (mg/l)	0.98	0.40	0.42	8.28	1.13	0.99	2.51
W (mg/l)	u	u	u	u	u	u	u
Mn (mg/l)	u	u	u	u	u	u	u
Zn (mg/l)	0.3	u	u	0.2	0.4	0.4	0.2
Li (mg/l)	u	u	u	1.02	0.24	0.97	1.06
B (mg/l)	u	u	u	1.2	0.6	0.9	1.1
F (mg/l)	0.7	1.5	1.6	1.9	1.5	1.9	3.1
Cl (mg/l)	212	46	42	1674	346	419	447
SO ₄ (mg/l)	105	26	29	122	382	369	367

u = Elements not present or not present in detectable concentrations.

Table 3. Continued.

Sample No.	EV-119	EV-120	EV-121	EV-122	EV-123	EV-124	EV-125
Location	(C-33-16)14dcb 37°56'44" 113°38'12"	(C-30-13)6bbb 37°14'11" 113°21'36"	(C-30-13)11bbb 37°13'16" 113°17'12"	(C-30-13)8baa 37°12'49" 113°20'00"	(C-30-13)18ddd 37°11'34" 113°20'35"	(C-30-13)20dda 37°10'45" 113°19'32"	(C-30-13)14bcc 37°11'58" 113°17'08"
Temp. °C	20	18	16	18	15	15	16
pH	7.05	8.10	7.90	7.80	7.60	7.61	7.80
tds (mg/l)	1730	276	426	326	594	514	643
HCO ₃ (mg/l)	351	158	217	167	167	200	138
Na (mg/l)	395	40	99	48	35	48	40
K (mg/l)	34	u	u	u	3	4	4
Ca (mg/l)	145	28	31	41	81	69	67
SiO ₂ (mg/l)	52	26	55	35	23	25	35
Mg (mg/l)	14	10	5	11	30	28	36
Fe (mg/l)	0.05	0.08	0.10	0.10	0.04	0.05	0.05
Ti (mg/l)	0.2	u	1.10	u	u	u	u
Sr (mg/l)	2.13	0.39	0.35	0.82	1.11	1.08	1.22
W (mg/l)	u	u	u	u	u	u	u
Mn (mg/l)	u	u	u	u	u	u	u
Zn (mg/l)	2.6	0.6	1.0	0.4	0.4	0.4	0.2
Li (mg/l)	1.07	u	0.1	u	u	u	u
B (mg/l)	1.0	u	0.5	0.2	u	u	u
F (mg/l)	3.9	0.8	0.8	1.1	0.9	1.0	0.6
Cl (mg/l)	402	37	30	32	108	104	144
SO ₄ (mg/l)	376	20	77	53	112	85	94

u = Elements not present or not present in detectable concentrations.

Table 3. Continued.

Sample No.	EV-126	EV-127	EV-128	EV-129	EV-130	EV-131	EV-132
Location	(C-35-17)25dcd 37°43'20" 113°41'53"	(C-35-16)31bab 37°43'15" 113°41'14"	(C-35-16)32bdc 37°42'12" 113°39'41"	(C-35-17)36dcc 37°42'12" 113°42'02"	(C-31-14)9bdb 38°07'24" 113°24'11"	(C-31-14)29aac 38°04'37" 113°26'21"	(C-32-14)30bab 38°00'18" 113°27'30"
Temp. °C	14	14	14	16	20	20	18
pH	7.20	7.25	7.10	7.55	7.08	7.09	7.11
tds (mg/l)	492	446	610	268	482	724	1232
HCO ₃ (mg/l)	217	192	384	184	367	334	159
Na (mg/l)	30	18	20	21	51	60	104
K (mg/l)	5	6	6	5	u	u	6
Ca (mg/l)	85	70	138	43	95	123	165
SiO ₂ (mg/l)	41	48	35	40	42	33	32
Mg (mg/l)	15	13	23	8	17	27	53
Fe (mg/l)	0.03	0.06	0.15	u	u	u	0.20
Ti (mg/l)	u	u	u	u	u	u	u
Sr (mg/l)	0.53	0.41	0.56	0.26	0.57	1.06	1.56
W (mg/l)	u	u	u	u	u	u	u
Mn (mg/l)	u	u	u	u	u	u	u
Zn (mg/l)	0.3	0.6	3.3	u	u	u	0.4
Li (mg/l)	u	u	u	u	u	u	0.06
B (mg/l)	u	u	u	u	u	u	0.2
F (mg/l)	1.0	0.3	0.3	1.4	0.5	0.5	0.9
Cl (mg/l)	112	86	97	26	60	165	321
SO ₄ (mg/l)	24	13	37	14	24	54	219

u = Elements not present or not present in detectable concentrations.

Table 3. Continued.

Sample No.	EV-133	EV-134	EV-135	EV-136	EV-137	EV-138	EV-139
Location	(C-32-13)9bdd 38°02'06" 113°19'03"	(C-31-13)23bbb 38°05'59" 113°21'39"	(C-31-13)31bcc 38°03'56" 113°21'39"	(C-31-14)24caa 38°05'33" 113°22'18"	(C-32-14)21bcd 38°00'21" 113°25'56"	(C-34-19)31deb 38°47'53" 113°55'17"	(C-34-18)32ceb 38°47'49" 113°53'32"
Temp. °C	14	13	14	17	19	21	16
pH	7.40	7.12	7.33	7.40	7.62	7.45	8.01
tds (mg/l)	617	2194	2480	770	402	478	372
HCO ₃ (mg/l)	208	292	200	159	234	250	209
Na (mg/l)	57	261	290	81	46	70	63
K (mg/l)	5	8	9	6	8	5	7
Ca (mg/l)	71	158	193	96	61	67	65
SiO ₂ (mg/l)	28	41	35	31	51	37	42
Mg (mg/l)	40	155	165	36	26	10	7
Fe (mg/l)	u	0.10	0.10	0.29	0.15	0.03	0.25
Ti (mg/l)	u	u	u	u	u	u	u
Sr (mg/l)	0.63	2.13	2.31	0.77	0.91	0.51	0.30
W (mg/l)	u	u	u	u	u	u	u
Mn (mg/l)	u	u	u	u	u	u	u
Zn (mg/l)	0.8	u	u	0.2	0.7	u	1.4
Li (mg/l)	u	0.10	0.09	u	0.07	0.21	0.19
B (mg/l)	u	0.5	0.4	0.2	0.2	0.2	0.2
F (mg/l)	0.5	0.7	0.7	0.7	1.3	2.5	2.6
Cl (mg/l)	74	290	533	135	53	58	33
SO ₄ (mg/l)	218	973	870	245	61	97	64

u = Elements not present or not present in detectable concentrations.

Table 3. Continued.

Sample No.	EV-140	EV-141	EV-142	EV-143	EV-144	EV-145	EV-146
Location	(C-33-18)20bdd 37°52'31" 113°49'16"	(C-33-17)20cbb 37°55'30" 113°:7'02"	(C-34-14)31cca 37°47'51" 113°28'06"	(C-34-13)16bcc 37°50'22" 113°19'30"	(C-33-14)6dba 37°57'51" 113°27'42"	(C-35-15)10bac 37°46'23" 113°31'17"	(C-35-15)3dec 37°46'23" 113°31'01"
Temp. °C	20	22	12	15	15	13	15
pH	7.91	7.61	7.46	7.23	7.00	7.61	7.31
tds (mg/l)	304	672	340	580	1350	372	2646
HCO ₃ (mg/l)	292	167	209	200	184	175	166
Na (mg/l)	25	54	44	37	106	21	208
K (mg/l)	7	8	6	u	6	3	11
Ca (mg/l)	41	96	29	64	210	50	356
SiO ₂ (mg/l)	58	46	52	27	38	41	46
Mg (mg/l)	11	34	15	43	67	20	163
Fe (mg/l)	0.10	0.05	0.53	0.07	0.34	u	u
Ti (mg/l)	u	u	u	u	0.2	u	u
Sr (mg/l)	0.30	0.84	0.59	0.90	1.87	0.56	5.14
W (mg/l)	u	u	u	u	u	u	u
Mn (mg/l)	u	u	u	u	u	u	u
Zn (mg/l)	0.3	0.7	0.3	u	0.7	u	0.2
Li (mg/l)	u	u	u	u	0.06	u	0.21
B (mg/l)	u	0.3	0.2	u	0.4	0.2	0.7
F (mg/l)	0.5	0.7	0.6	0.4	1.2	0.5	0.6
Cl (mg/l)	37	46	25	33	493	34	528
SO ₄ (mg/l)	26	188	45	196	296	70	1003

u = Elements not present or not present in detectable concentrations.

Table 3. Continued.

Sample No.	EV-148	EV-149	EV-150	EV-151	EV-152	EV-153	EV-154
Location	(C-30-13)33abb 38°09'36" 113°18'45"	(C-30-13)30caa 38°10'13" 113°19'32"	(C-33-16)10ccc 37°56'25" 113°38'12"	Thermo Hot Springs	Thermo Hot Springs	Thermo Hot Springs	Thermo Hot Springs
Temp. °C	13	15	28	56	42	50	78
pH	7.47	7.51	7.13	6.60	6.80	7.45	6.98
tds (mg/l)	1042	686	1556	1524	1564	1518	1495
HCO ₃ (mg/l)	192	200	476	392	401	401	401
Na (mg/l)	85	67	376	378	387	379	371
K (mg/l)	10	5	24	51	52	51	50
Ca (mg/l)	106	96	145	77	78	85	69
SiO ₂ (mg/l)	41	11	44	87	87	89	84
Mg (mg/l)	83	38	14	10	10	10	10
Fe (mg/l)	u	u	1.64	0.03	u	0.04	0.04
Ti (mg/l)	u	u	0.2	u	u	u	u
Sr (mg/l)	0.87	1.49	2.76	1.18	1.22	1.20	1.15
W (mg/l)	u	u	u	u	u	u	u
Mn (mg/l)	u	u	0.7	u	u	u	u
Zn (mg/l)	u	0.1	0.8	0.2	u	0.3	u
Li (mg/l)	0.14	u	0.96	1.21	1.26	1.23	1.18
B (mg/l)	0.3	u	0.9	1.0	1.0	1.0	1.0
F (mg/l)	1.2	0.9	4.0	6.5	6.5	5.6	6.0
Cl (mg/l)	289	132	366	222	222	220	222
SO ₄ (mg/l)	188	157	359	474	476	475	460

u = Elements not present or not present in detectable concentrations.

Total Dissolved Solids

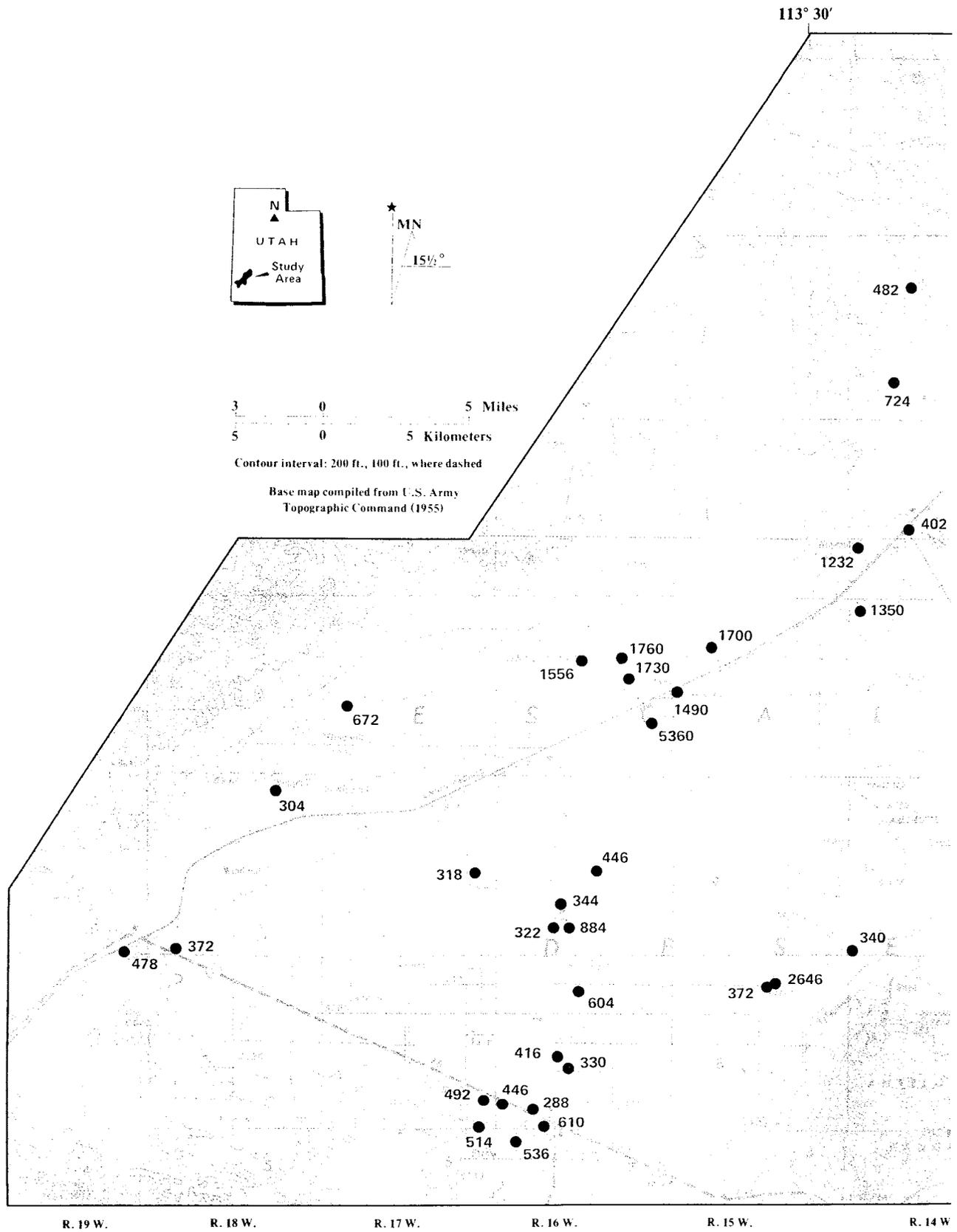
Mower (1982) reports that a sample from a particular well in the southern Escalante Valley area is a composite water sample because most wells are screened continuously from the water table downward. Commonly, total dissolved solids (TDS) concentrations are greatest at the water table and decrease with depth (Mower, 1982). Therefore, only very general observations can be presented with respect to TDS because the wells sampled vary with respect to screening depth below the water table.

TDS concentrations ranged from 276 to 5360 mg/l in the study area. Distribution of these values within the designated sampling areas is presented in Figure 10. Generally, TDS concentrations are less than 1000 mg/l (the lower extent of USGS classification of slightly saline waters) with the exceptions of isolated wells, area III in Plate 7 and Thermo Hot Springs. The values greater than 1000 mg/l from the isolated wells could result from recycling of irrigation water with higher TDS concentrations (Mower, 1982). The consistently high values from all samples collected in area III are thought to preclude irrigation water recycling and could be the result of recharge from bedrock fault(s) or jointing. TDS will be discussed further in the following section entitled "Common Ion Analysis."

Common Ion Analysis

Common ion analyses, grouped by geographic area in the Escalante Valley, are presented in trilinear diagrams in Figures 11 through 18. A composite trilinear diagram of all samples is presented in Figure 19. Data plotted in Figure 19 indicate there are three general types of water present in the study area. Type I waters, which comprise the majority of samples collected, consist of calcium-sodium bicarbonate-chloride-sulfate (Ca-Na HCO₃-Cl-SO₄), calcium-sodium chloride-sulfate-bicarbonate (Ca-Na Cl-SO₄-HCO₃), and calcium-sodium chloride-sulfate (Ca-Na Cl-SO₄) character. These waters are found throughout the valley and are not concentrated in one geographic location. The Ca-Na HCO₃-Cl-SO₄ and Ca-Na Cl-SO₄-HCO₃ waters are basic and dilute to slightly saline, with TDS values ranging from 268 to 2194 mg/l. Samples EV-144, EV-135, and EV-115 are Ca-Na Cl-SO₄ in character and are slightly to moderately saline with TDS values of 2330, 2480, and 5360 mg/l respectively. EV-115 is anomalous in that the TDS concentration is more than twice that of any other sample.

Type II waters consist of samples EV-117, EV-118, EV-119, and EV-150, are sodium-calcium chloride-sulfate-bicarbonate (Na-Ca Cl-SO₄-HCO₃) in character and are located in area III on Plate 7. These waters



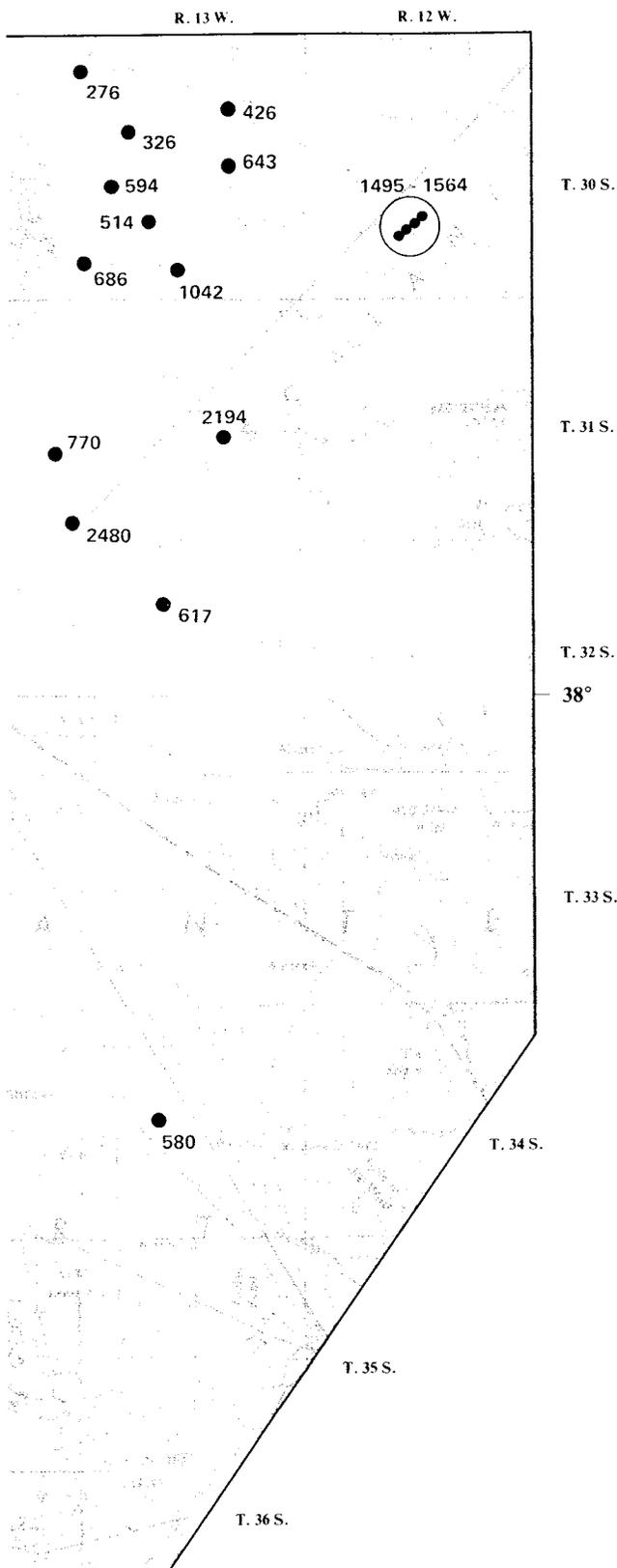


Figure 10.
Total dissolved solids (TDS) measured in
the Escalante Valley, Iron and Beaver
Counties, Utah.

EXPLANATION

- Location: Values in milligrams per liter
- Thermo Hot Springs area

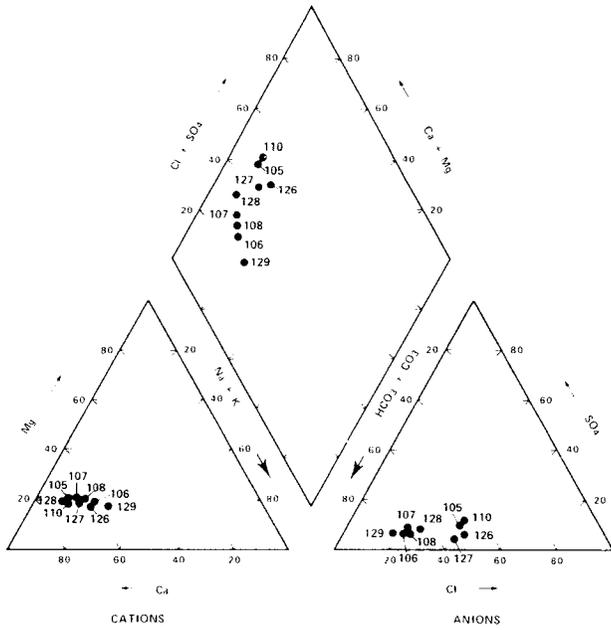


Figure 11. Piper diagram of common ions in samples collected from Area VII (Figure 9) in the Escalante Valley, Utah.

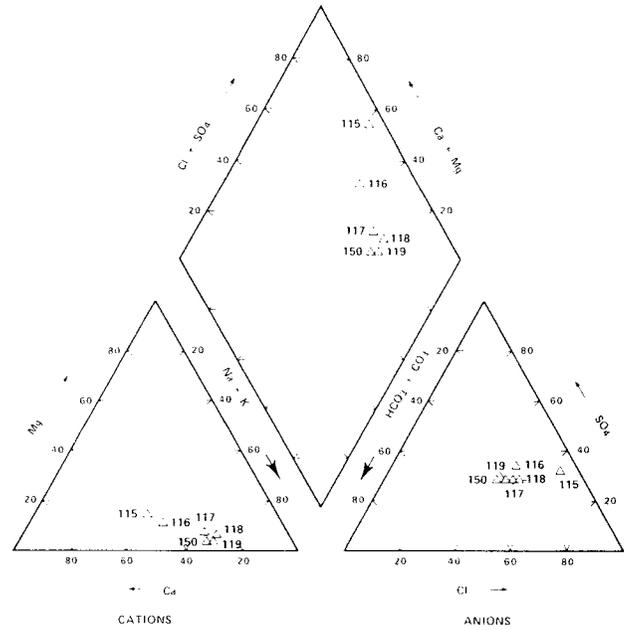


Figure 13. Piper diagram of common ions in samples collected from Area III (Figure 9) in the Escalante Valley, Utah.

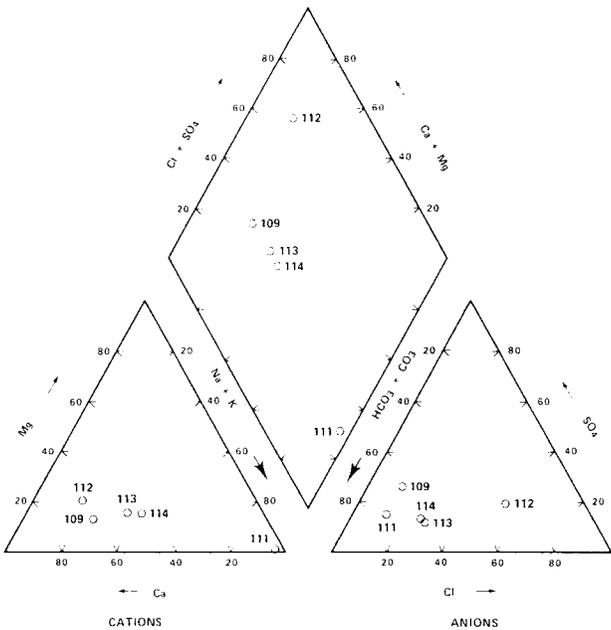


Figure 12. Piper diagram of common ions in samples collected from Area V (Figure 9) in the Escalante Valley, Utah.

are slightly basic and slightly saline with TDS concentrations ranging from 1556 to 1760 mg/l. All four samples are enriched in Na and K with respect to other cations. EV-117 and 118 are enriched with respect to other anions while EV-119 and EV-150 (the warmest well water measured) are enriched with

SO₄. Type III waters constitute four samples (EV-151, EV-152, EV-153, and EV-154) collected at Thermo Hot Springs (Figure 9). Thermo water is sodium-calcium chloride-sulfate-bicarbonate (Na-Ca Cl-SO₄-HCO₃) in character and enriched in Na, K, and SO₄ with respect to other cations and anions present. TDS concentrations ranged from 1495 to 1564 mg/l indicating the water is slightly saline while pH values ranged from slightly basic to slightly acidic.

In addition to three major types, two other wells (EV-111 and EV-121) provided water samples with significantly different chemistries (Figures 11 and 13). EV-121 is sodium-calcium bicarbonate-chloride-sulfate (Na-Ca HCO₃-Cl-SO₄) in character, basic, with a TDS concentration of 426 mg/l. This water is enriched in Na and HCO₃ with respect to other cations and anions present. EV-111 was sampled from a geothermal test well 8072 ft (2461 m) in depth. The 60°C (140°F) temperature measured is accountable by the normal geothermal gradient for this part of the Basin and Range province. The chemical character of the water is sodium bicarbonate-chloride-sulfate (Na HCO₃-Cl-SO₄), basic, with a TDS concentration of 446 mg/l. The water is highly enriched in Na and HCO₃ with respect to other cations and anions and could be indicative of deep basin ground water circulation and not be considered as having geothermal resource potential.

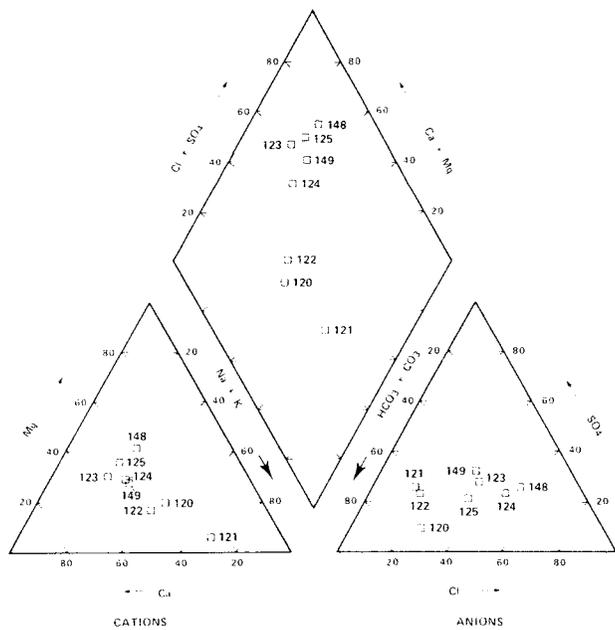


Figure 14. Piper diagram of common ions in samples collected from Area I (Figure 9) in the Escalante Valley, Utah.

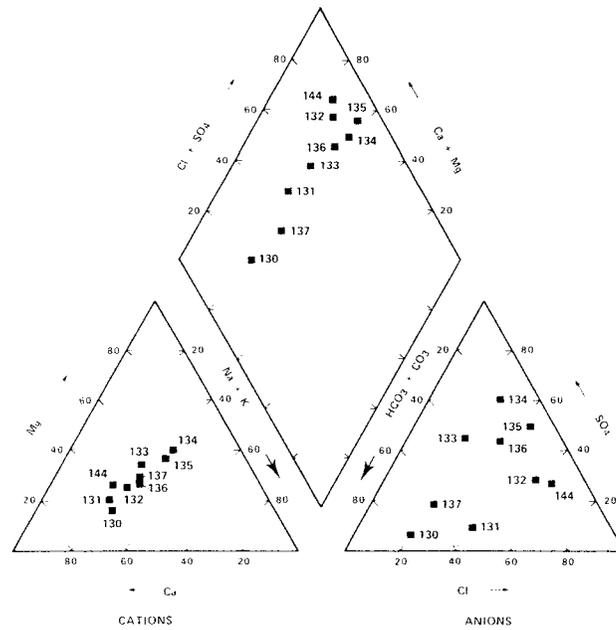


Figure 15. Piper diagram of common ions in samples collected from Area II (Figure 9) in the Escalante Valley, Utah.

Silica (SiO₂)

Silica concentrations ranged from 11 to 58 mg/l for wells sampled in the Escalante Valley while values for Thermo Hot Springs were between 84 and 89 mg/l. Water with lower concentrations (less than 40 mg/l) were principally to the northeast in areas I and II in Figure 9, west and southwest, respectively, from Thermo Hot Springs. With the exception of Thermo Hot Springs, no obvious anomalous silica values were noted in the study area.

Other Elements

Elements present in sufficient amounts to be detected by the University of Utah Research Institute/ Earth Science Laboratory using an ARL Inductively Coupled Plasma Quantometer (ICPQ) or other methods consist of: iron (Fe), strontium (Sr), zinc (Zn), lithium (Li), boron (B), and fluoride (F) (see Table 2 for the Limits of Quantitative Determination (LQD) for solution analysis by the ICPQ). It should be noted, however, that not all samples contained sufficient amounts of Fe, Li, Sr, B, Zn, W, Ti, and Mn to reach detection limits. Of the aforementioned elements, Li and B are present in sufficient concentrations in 5 samples from area III (area with the highest well water temperatures measured in the study area) to indicate a possible geothermal anomaly (Figure 9).

Lithium (Li) values for wells sampled in areas I, II, and IV through VIII on Figure 9 ranged from undec-

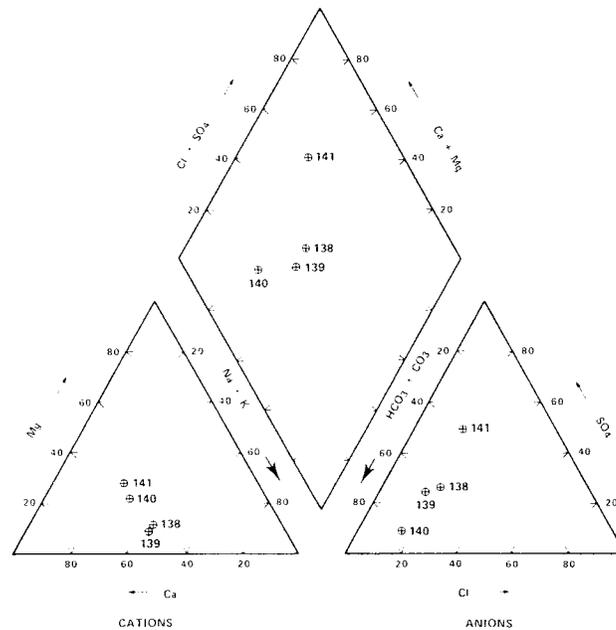


Figure 16. Piper diagram of common ions in samples collected from Area IV (Figure 9) in the Escalante Valley, Utah.

tectable to 0.21 mg/l. Except for sample EV-116 (Li=0.26 mg/l), Li concentrations for samples in area III ranged from 0.96 to 1.07 mg/l, a significant increase relative to values measured in other water well samples. Li concentrations for Thermo Hot Springs were higher, ranging from 1.18 to 1.26 mg/l, but were still similar to those measured in area III. Boron (B) values in all water wells sampled ranged from un-

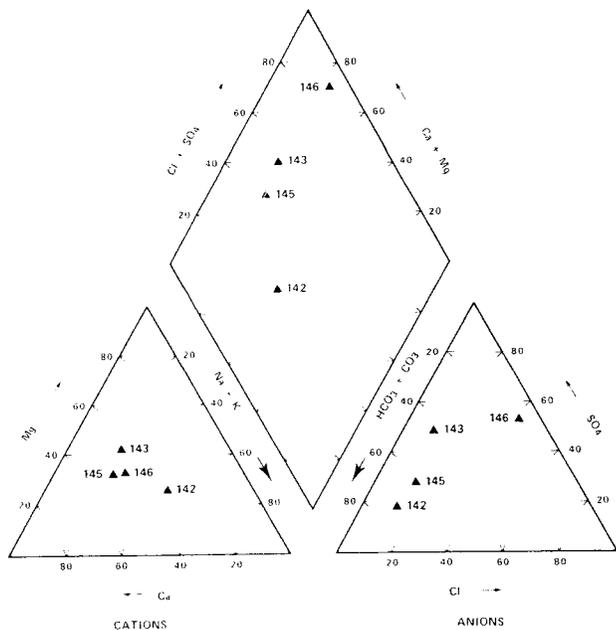


Figure 17. Piper diagram of common ions in samples collected from Area VI (Figure 9) in the Escalante Valley, Utah.

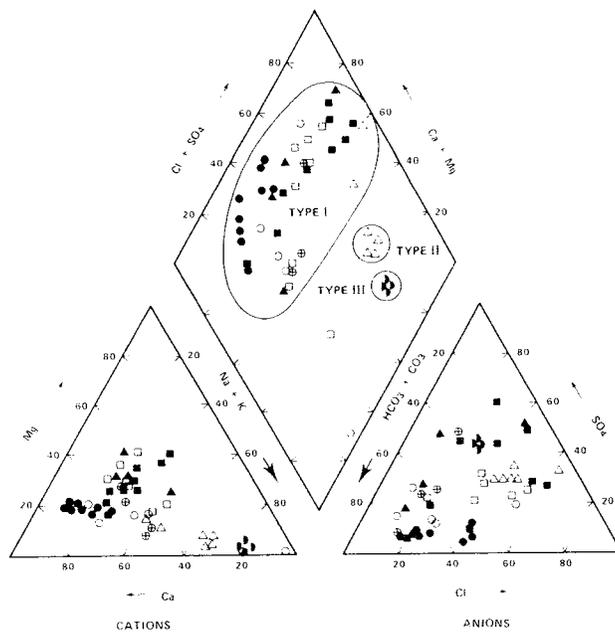


Figure 19. Piper diagram of common ions in all samples collected in the Escalante Valley, Utah.

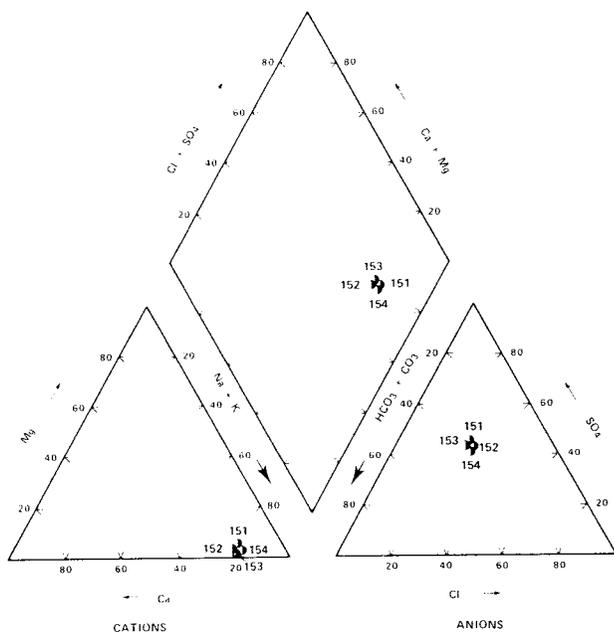


Figure 18. Piper diagram of common ions in samples collected from Thermo Hot Springs (Figure 9) in the Escalante Valley, Utah.

detectable to 1.2 mg/l. The four samples collected at Thermo Hot Springs all had concentrations of 1.0 mg/l while the deep geothermal exploration well sampled contained 5.3 mg/l of B. Of all water wells sampled, area III contained the greatest concentrations of B; values for all samples except EV-116 (0.6

mg/l) ranged from 0.9 to 1.2 mg/l, which are similar to the values measured at Thermo Hot Springs. The B/Cl ratios (conservative element ratio) for samples EV-118, EV-119, and EV-150 in area III were very similar relative to the ratios for other samples in the area. This indicates that either no mixing is occurring between warm and cold waters in this area, or that mixing has occurred prior to interception by these wells.

Figure 20, a plot of Li versus B values for all samples collected in the Escalante Valley, denotes that samples EV-115, 117, 118, 119, and 150 in area III are similar to Thermo Hot Springs samples and quite dissimilar to EV-116, as well as to all other samples collected in the valley. This indicates that part of area III is chemically anomalous to the other areas of the valley sampled and because of the chemical similarity with Thermo Hot Springs, suggests a geothermal anomaly.

Geothermometry

Chemical geothermometers were calculated for all water samples collected in the Escalante Valley. Quartz (conductive), chalcedony and sodium-potassium-calcium (Na-K-Ca) Mg corrected geothermometers were used. Equations used and results obtained are presented in Table 4. The reliability of geothermometers depends on five assumptions which are applicable to both the silica and Na-K-Ca techniques (Fournier and others, 1974).

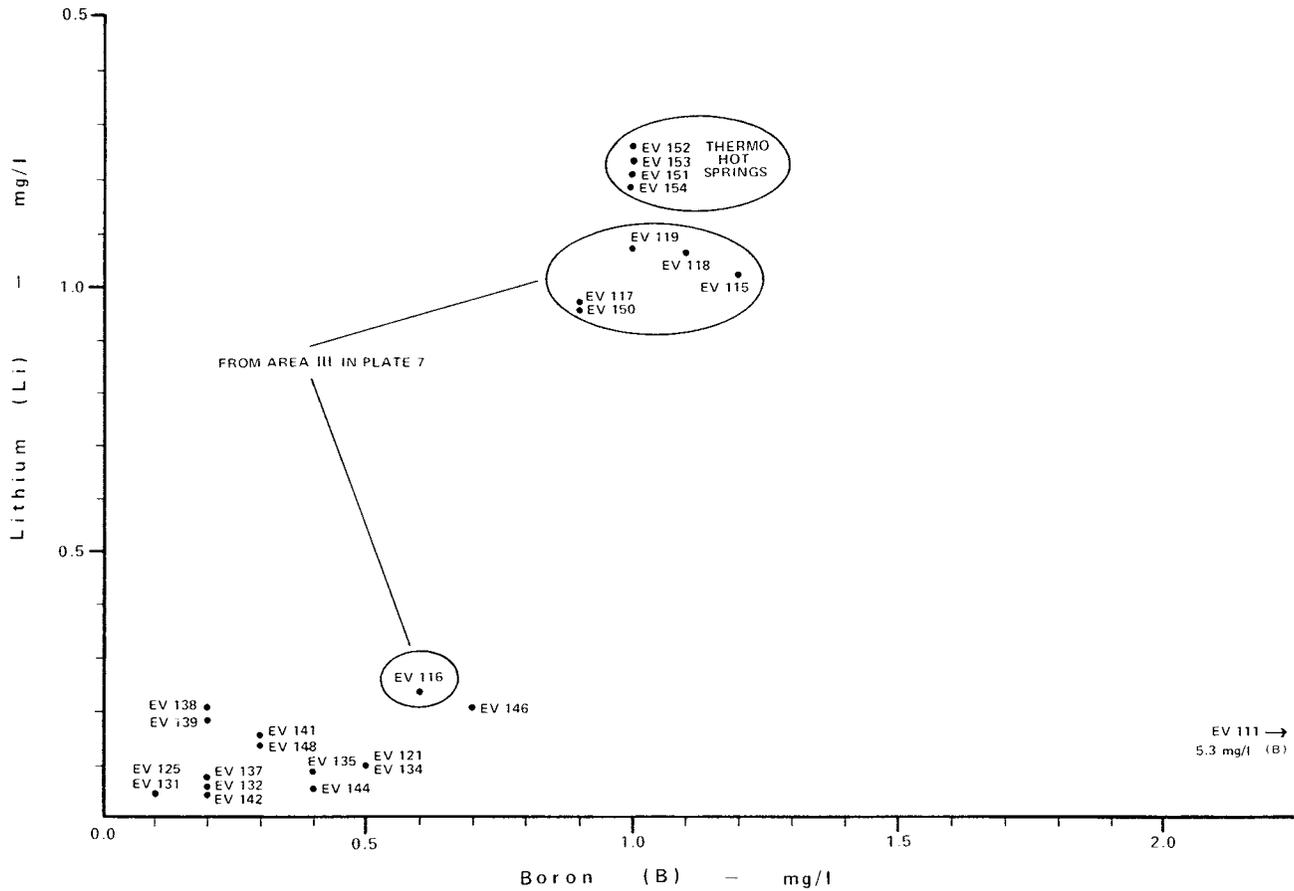


Figure 20. Plot of Lithium (Li) versus Boron (B) values for only those samples where both elements were present in detectable limits in the Escalante Valley, Utah.

These assumptions are:

1. Temperature-dependent reactions occur at depth;
2. all constituents involved in the temperature-dependent reactions are sufficiently abundant;
3. water-rock chemical equilibrations occur at the reservoir temperature;
4. little or no equilibration or change in composition occurs at lower temperatures as the water flows from the reservoir to the surface;
5. the hot water coming from deep in the system does not mix with cooler, shallow ground water.

Lack of proven low-to-moderate temperature geothermometer results, prompted only qualitative use of the results of this technique.

Na-K-Ca temperatures (Mg corrected) for all water well samples, with the exceptions of EV-118, EV-119, and EV-150 in area III on Figure 9, as well as EV-111 in area V, ranged from 28 to 68°C (82 to 154°F) (Table 4). Computed temperatures for EV-111 (the deep geothermal exploration well),

EV-118, 119, and 150 were 103, 120, 100, and 115°C (217, 248, 212, and 239°F), respectively. Temperatures for Thermo Hot Springs ranged from 120 to 127°C (248 to 261°F). The occurrence of warm springs with different temperatures and similar chloride content suggests conductive cooling is occurring. Thermo Hot Springs has Cl values ranging from 220 to 222 mg/l which would suggest conductive cooling is occurring in this geothermal system. Also, B/Cl ratios are similar and therefore indicative of a non-mixing environment. Therefore, if re-equilibration has not occurred subsequent to the warm water leaving the reservoir, the Na-K-Ca temperatures calculated for Thermo Hot Springs should be relatively accurate. Since samples EV-118, 119, and 150 were collected from water wells that are screened at sand and gravel layers in the principal aquifer within the valley, it is highly conceivable that thermal water has mixed with cold water. B/Cl ratios indicate these samples are very similar and therefore suggest no mixing has occurred. Therefore, it is thought mixing has occurred previously, and the mixed water has moved

Table 4. Chemical geothermometers with magnesium correction where applicable and surface temperatures for fluids in (°C) from the Escalante Valley, Utah.

Sample No.	Qtz (Cond)	Chalcedony	Na-K-Ca	Meas. Temp.
EV-105	96	66	37	14
EV-106	95	64	40	16
EV-107	93	62	35	14
EV-108	93	62	32	14
EV-109	105	76	52	17
EV-110	93	62	33	12
EV-111	105	76	115	60
EV-112	102	72	46	19
EV-113	107	78	57	14
EV-114	106	77	62	14
EV-115	102	72	68	15
EV-116	97	67	66	16
EV-117	94	63	39	17
EV-118	101	71	103	27
EV-119	104	74	120	20
EV-120	74	42	K not detected	18
EV-121	106	77	K not detected	16
EV-122	86	55	K not detected	18
EV-123	69	37	26	15
EV-124	72	40	39	15
EV-125	86	55	38	16
EV-126	93	62	37	14
EV-127	100	70	41	14
EV-128	86	55	30	14
EV-129	92	61	46	16
EV-130	94	63	K not detected	20
EV-131	83	52	K not detected	20
EV-132	82	51	41	18
EV-133	77	45	46	14
EV-134	93	62	59	13
EV-135	86	55	59	14
EV-136	81	49	49	17
EV-137	103	73	60	19
EV-138	88	57	49	21
EV-139	94	63	58	16
EV-140	109	79	58	20
EV-141	98	68	52	22
EV-142	104	74	65	12
EV-143	75	44	K not detected	15
EV-144	90	59	38	15
EV-145	93	62	30	13
EV-146	98	68	92	15
EV-148	93	62	61	13
EV-149	42	10	42	15
EV-150	96	66	100	28
EV-151	130	102	123	56
EV-152	130	102	124	42
EV-153	131	103	124	50
EV-154	128	100	117	78

Equations for geothermometers used to compute subsurface temperatures

$$\text{Quartz (conductive): } t(^{\circ}\text{C}) = \frac{1309}{5.19 - \log \text{SiO}_2} - 273.15$$

$$\text{Chalcedony: } t(^{\circ}\text{C}) = \frac{1032}{4.69 - \log \text{SiO}_2} - 273.15$$

$$\text{Na-K-Ca: } t(^{\circ}\text{C}) = \frac{1647}{\log(\text{Na/K}) + B[\log(\text{Ca}^{1/2}/\text{Na}) + 2.06] + 2.47} - 273.15$$

where B = 1/3 for t > 100°C

where B = 4/3 for t < 100°C

SiO₂, Na, K, and Ca values in mg/l

Magnesium Correction:

Temperature \geq 70°C

R \geq 50 R = [Mg/(Mg + Ca + K)] x 100

Mg, Ca, and K are in equivalent units of concentration

Sources: Fournier (1981); Fournier and Potter (1979).

down gradient through the aquifer and subsequently been intercepted by the wells. Mixing of warm and cold water decreases the warm water temperature, which commonly causes HCO_3 and SO_4 to increase, as well as K to decrease relative to Na and Ca to increase relative to Na unless CaCO_3 precipitates (Fournier, 1981). HCO_3 and SO_4 values of these three samples are significantly higher than concentrations in sample EV-141 which is in a similar environment, also indicating mixing has occurred. If, in fact, K has decreased relative to Na, and Ca has increased relative to Na, then the Na-K-Ca temperature calculated for these samples are, in fact, low.

Fournier (1977) suggests that if the Na-K-Ca geothermometer indicates a temperature of less than 100°C (212°F), the silica content of the water is a function of chalcedony solubility. For temperatures greater than 100°C (212°F), the silica temperature should be calculated assuming the silica content is a function of quartz solubility. In Iceland, Arnorsson (1975) found that when undissociated silica is less than 60 mg/l, the silica temperature refers to equilibrium with chalcedony and between 60 and 250 mg/l, it has not been determined whether chalcedony or quartz governs the amount of silica in the system. Due to the lack of consensus regarding which form of silica governs concentrations from temperatures between 100 and 180°C (212 and 356°F), both chalcedony and quartz temperatures are given in Table 4.

Chalcedony temperatures range from 10 to 79°C (50 to 174°F) for samples with Na-K-Ca temperatures less than 100°C (212°F). Quartz (conductive) temperatures for the remainder of the samples, which include EV-111 (deep geothermal exploration well), EV-118, EV-119, and EV-150 (Area III on Figure 9), and EV-151 through EV-154 (Thermo Hot Springs), range from 96 to 131°C (205 to 268°F). Thermo Hot Springs values are quite similar to the derived Na-K-Ca temperatures which are considered to be relatively similar to temperatures expected at depth in the reservoir. Quartz (conductive) temperatures for samples EV-118, EV-119, and EV-150 in area III on Figure 9 were 101, 104, and 96°C (214 , 219 , and 205°F), respectively. These temperatures (with the exception of EV-119) are very similar to those calculated with the Na-K-Ca geothermometer.

Attempts were made to apply the mixing model of Truesdell and Fournier (1977) to samples EV-118, EV-119, and EV-150. These attempts proved futile in all but one case (EV-118) due to the silica values being too low and/or the temperatures being too low for the model to be applicable. The results of model-

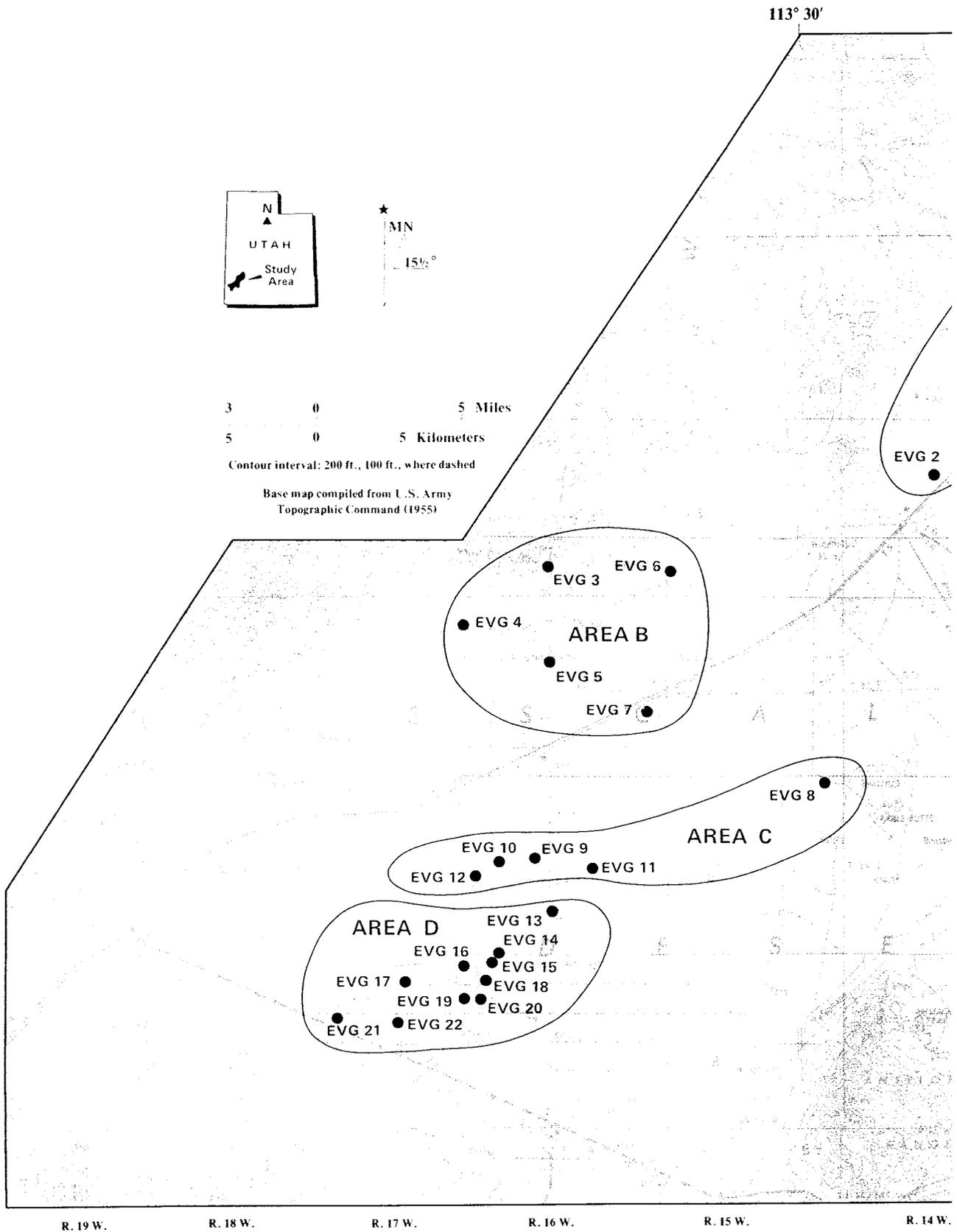
ing sample EV-118 indicated a reservoir temperature of 128°C (262°F) could be expected. This temperature seems reasonable because the Na-K-Ca temperatures are considered to be low due to mixing, and this temperature is comparable to those expected at depth at Thermo Hot Springs.

TEMPERATURE-DEPTH MEASUREMENTS

Temperature-depth measurements, and the subsequent temperature gradients derived thereof, are useful in exploration for geothermal resources since they can allow for detection of thermal anomalies (Laughlin, 1982). Temperature gradients are affected by heat flow and thermal conductivity. Heat flow is the conductive transfer of heat from the earth's interior and therefore the surface expression of geothermal conditions at depth. For a given heat flow, the temperature gradient is inversely proportional to the thermal conductivity of the material through which the heat is being transmitted by conduction (Kappelmeyer and Haenel, 1974). At shallow depths, temperature gradients are affected by surface conditions such as temperature and precipitation. These effects are eliminated below 98 ft (30 m) in depth (Kappelmeyer and Haenel, 1974). Topography and in some exceptional cases sedimentation and denudation also have an affect on temperature gradients (Kappelmeyer and Haenel, 1974). Also, temperature measurements are strongly influenced by the movement of ground water (sometimes to depths of hundreds of meters) and it should always be recognized that temperature gradients are meaningful only for conductive heat transfer and that vertical, as well as horizontal, convection can upset the extrapolation of temperature information (Laughlin, 1982; Lumb, 1981).

Temperature-depth measurements in the Escalante Valley were completed in 22 "holes of opportunity" (Figure 21). Temperature-depth profiles of these measurements are presented in Figures 22 through 29. Locations by latitude and longitude, elevation, interval of gradient calculation, and calculated gradient are presented in Table 5. These "holes of opportunity" are primarily shallow abandoned water wells but include PVC cased holes from geotechnical investigations for the MX project and uncased mineral exploration holes.

Temperatures in holes were measured with a thermistor probe connected by a four wire configuration to a digital ohmmeter. A Fenwal K212E thermistor probe with a nominal resistance of 10,000 ohms at 20°C (68°F), power dissipation of 50m WK^{-1} in still water, and a response time of 5 seconds was used.



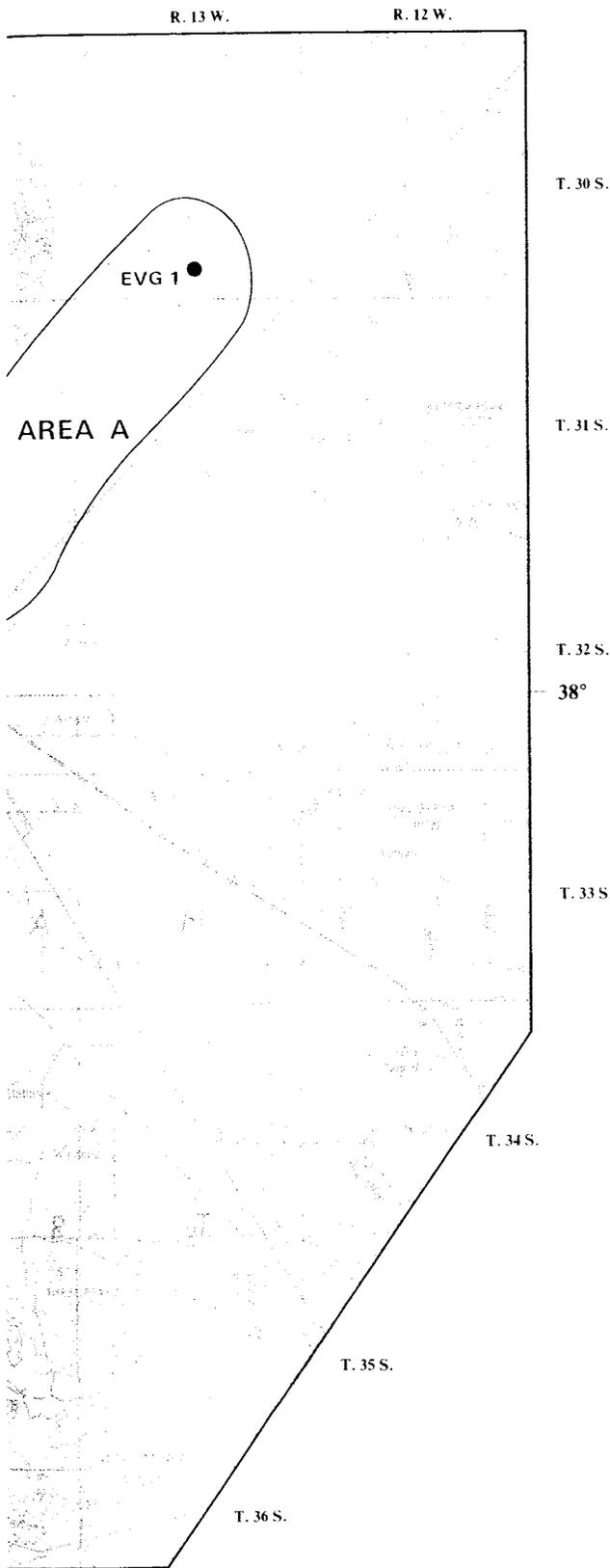


Figure 21.
Locations of UGMS selected holes of opportunity in the Escalante Valley, Iron and Beaver Counties, Utah.

EXPLANATION

- Temperature-depth measurement site

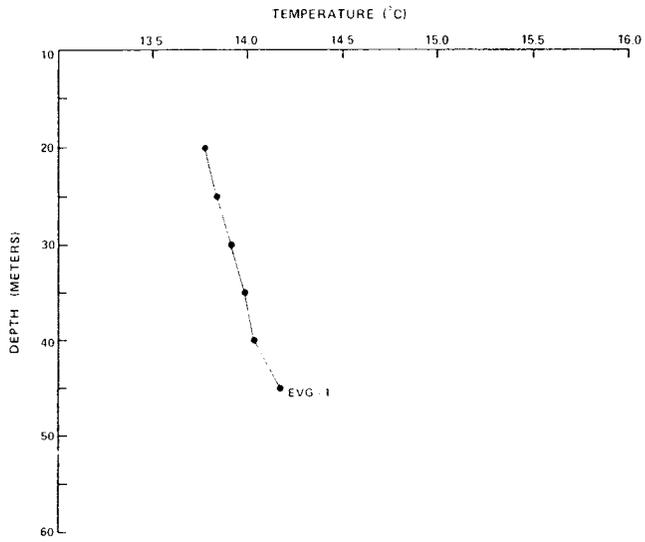


Figure 22. Temperature-depth profile of a "hole of opportunity" logged in Area A (Figure 21) in the Escalante Valley, Utah.

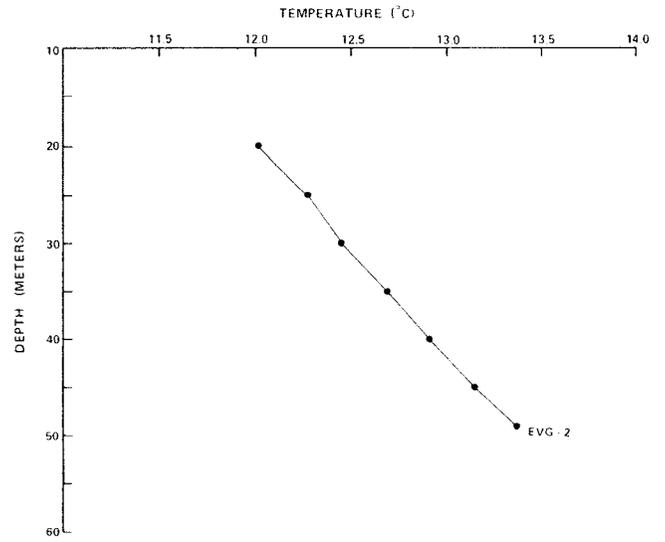


Figure 23. Temperature-depth profile of a "hole of opportunity" logged in Area A (Figure 21) in the Escalante Valley, Utah.

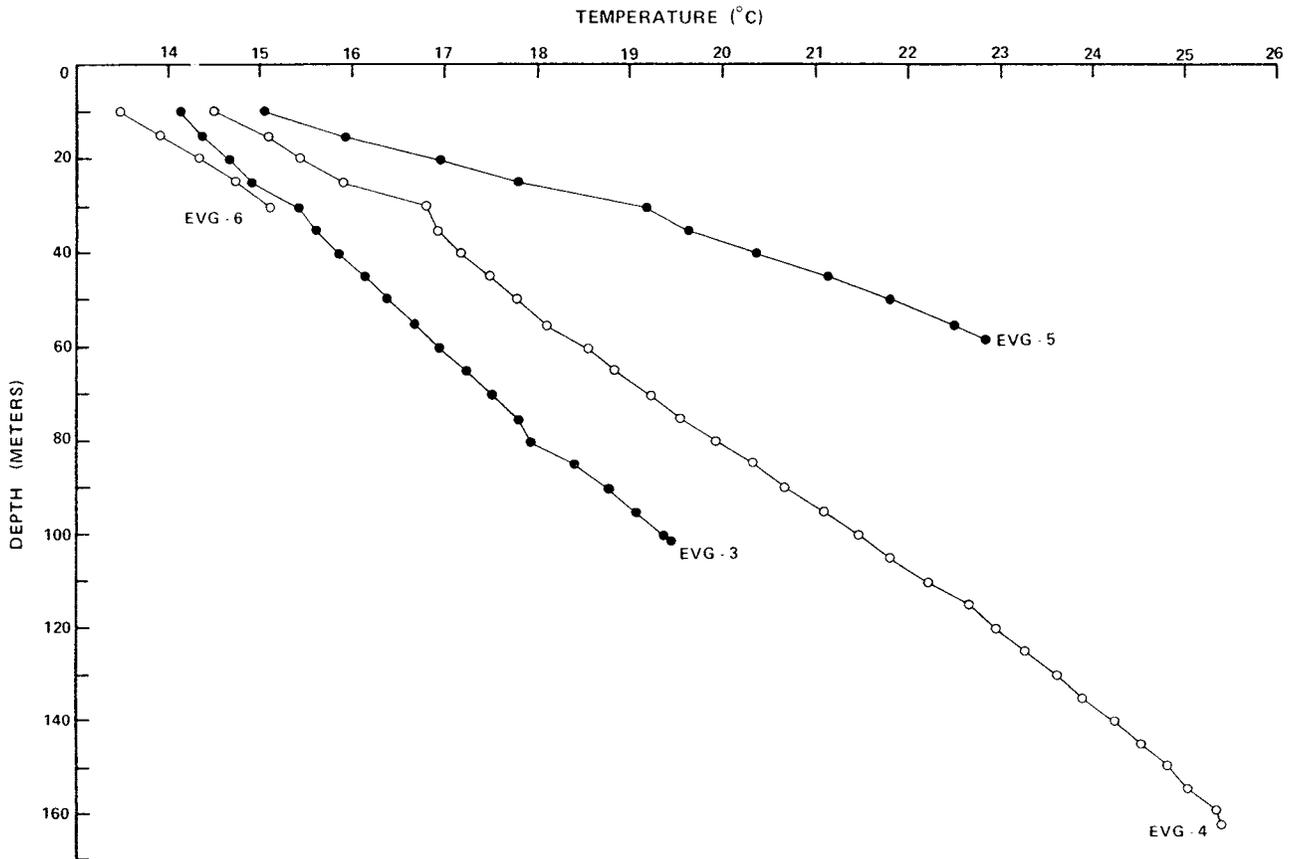


Figure 24. Temperature-depth profiles of "holes of opportunity" logged in Area B (Figure 21) in the Escalante Valley, Utah.

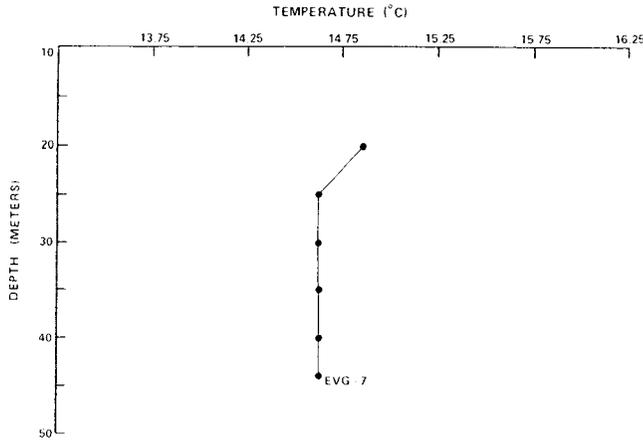


Figure 25. Temperature-depth profile of a "hole of opportunity" logged in Area B (Figure 21) in the Escalante Valley, Utah.

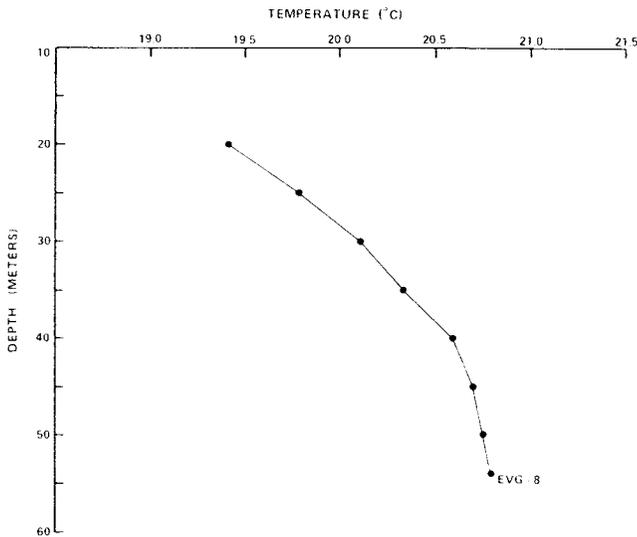


Figure 26. Temperature-depth profile of a "hole of opportunity" logged in Area C (Figure 21) in the Escalante Valley, Utah.

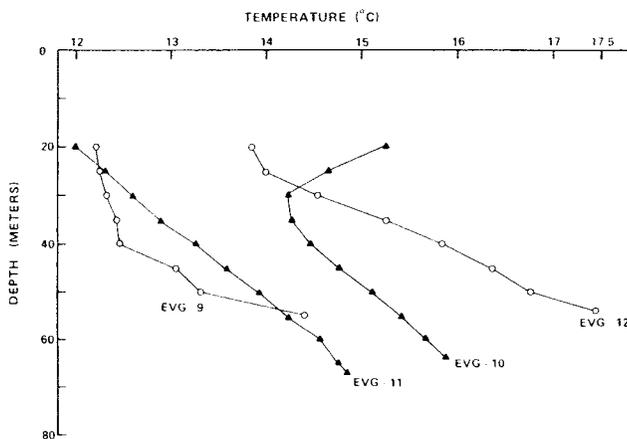


Figure 27. Temperature-depth profiles of "holes of opportunity" logged in Area C (Figure 21) in the Escalante Valley, Utah.

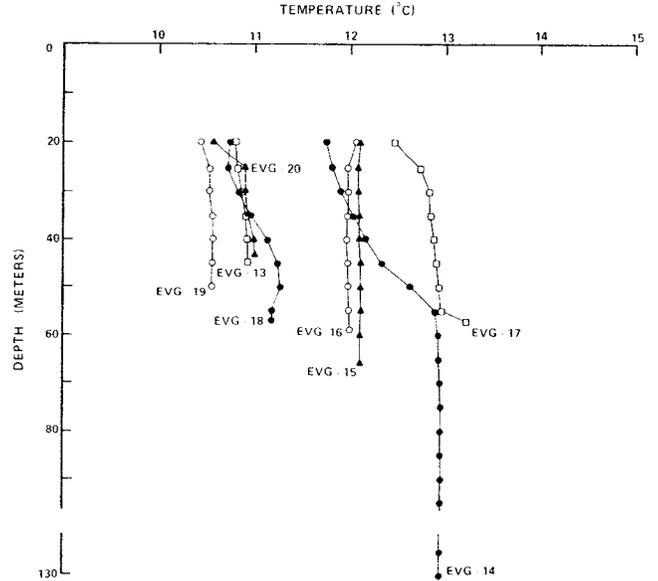


Figure 28. Temperature-depth profiles of "holes of opportunity" logged in Area D (Figure 21) in the Escalante Valley, Utah.

Temperature readings were taken at 16 ft (5 m) intervals, after the temperature had stabilized at each position. All but hole EVG-3 appeared to be completed in valley alluvium. EVG-3 is a thermal gradient test well drilled into a rhyolite-quartz latite tuff. The gradient holes logged ranged in depth from 98 to 344 ft (30 to 105 m). Ideally gradients should be calculated only for holes greater than 197 ft (60 m) in depth (Chapman, oral communication, 1982). However, shallower holes can be used to locate areas of near-surface heat accumulation. In any case, near surface temperature-depth profiles should not be used for

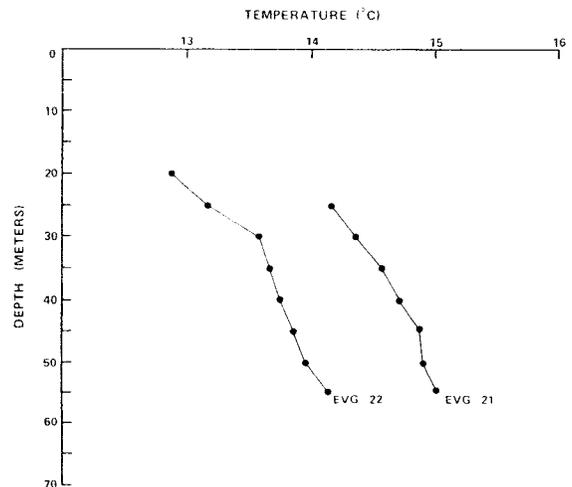


Figure 29. Temperature-depth profiles of "holes of opportunity" logged in Area D (Figure 21) in the Escalante Valley, Utah.

Table 5. Geothermal gradient data for 22 "holes of opportunity" logged in the Escalante Valley, Utah.

Locality	Site	N. Latitude	W. Longitude	Elevation (Meters)	Depth interval for gradient calc. (Meters)	Calculated gradient (°C/Km)
Burns Knoll	EVG- 1	38°09'46"	113°18'06"	1566	20-44	16 ± 5
Lund	EVG- 2	38°01'57"	113°24'45"	1548	20-49	46 ± 3
Beryl	EVG- 3	37°59'05"	113°39'20"	1744	30-100	57 ± 5
	EVG- 4	37°57'11"	113°42'39"	1665	30-160	70 ± 3
	EVG- 5	37°56'21"	113°39'19"	1603	30-57	138 ± 10
	EVG- 6	37°58'52"	113°34'50"	1646	10-30	83 ± 4
	EVG- 7	37°54'51"	113°35'48"	1576	25-44	1 ± 1.5
Avon N.W.	EVG- 8	37°52'44"	113°29'02"	1556	20-45	52 ± 9
Yale Crossing	EVG- 9	37°50'31"	113°39'53"	1565	25-55	94 ± 44
	EVG-10	37°50'26"	113°41'18"	1566	40-64	60 ± 3
	EVG-11	37°50'15"	113°37'41"	1563	20-67	63 ± 4
	EVG-12	37°50'04"	113°42'12"	1570	25-50	114 ± 10
	EVG-13	37°49'00"	113°39'14"	1566	20-45	6 ± 3
	EVG-14	37°47'42"	113°41'17"	1570	20-55	32 ± 7
	EVG-15	37°47'38"	113°41'29"	1572	20-65	0 ± 1
	EVG-16	37°47'21"	113°42'39"	1547	25-55	0 ± 1
	EVG-17	37°46'50"	113°44'48"	1581	30-55	5 ± 1
	EVG-18	37°46'24"	113°41'45"	1573	25-45	26 ± 4
	EVG-19	37°46'24"	113°42'36"	1576	25-45	2 ± 1
	EVG-20	37°46'23"	113°42'00"	1573	25-40	6 ± 4
Heist	EVG-21	37°45'45"	113°47'24"	1595	25-45	35 ± 3
	EVG-22	37°45'41"	113°45'06"	1584	15-30	73 ± 9

linear projections of temperature at depth (Greider, 1976). In the study, gradients were calculated for all holes deeper than 147 ft (45 m) using linear regression; topographic corrections were not employed.

The background gradient in the valley, as determined by Clement (1980), is 56.4°C km⁻¹. Comparison of the temperature-depth measurements conducted for this study with the 56.4°C km⁻¹ background gradient indicates that at least two areas of elevated temperature exist in the investigated portion of the Escalante Valley.

In the first area, located north of the Union Pacific railroad tracks in the vicinity of Beryl and Zane, four temperature-depth measurements were logged (EVG-3, EVG-4, EVG-5, and EVG-6). See Figure 21 for the locations of these holes and Figure 24 for the temperature-depth profiles. Gradients of 57°C km⁻¹, 70°C km⁻¹, 138°C km⁻¹, and 83°C km⁻¹ were determined for these sites, respectively. These gradients concur with gradients of 78°C km⁻¹ and 132°C km⁻¹ reported by Clement (1980) for an area between 5.5 and 9.3 mi (9 and 15 km) north-northeast of gradient location EVG-6 (Figure 21). EVG-6 is not as deep as other holes, but the gradient calculated (83°C km⁻¹) is consistent with other temperature-depth profiles measured in this area.

A second area with gradients greater than background is located south of Beryl and includes "holes of opportunity" numbered EVG-9, EVG-10, EVG-11, and EVG-12; gradients calculated are 94°C km⁻¹, 60°C km⁻¹, 63°C km⁻¹, and 114°C km⁻¹, respectively. See Figure 21 for locations and Figure 27 for temperature-depth profiles. The profiles for EVG-9 and EVG-10 indicate ground water disturbance and, therefore, calculated gradients are suspect.

A third area in the vicinity of Beryl Junction, although not exhibiting elevated temperatures, presents a very complex and disturbed ground-water system. The ground-water aquifer in this area is characterized by a large cone of depression caused by heavy pumping for irrigation which has altered the regional flow pattern (Figure 7). Temperature-depth profiles EVG-13, EVG-18, EVG-19, and EVG-20 are somewhat erratic, but generally isothermal (Figure 28). See Figure 21 for locations. Temperature-depth profiles EVG-14, EVG-15, EVG-16, EVG-17, slightly up-gradient in the cone of depression, are also isothermal, but the temperatures are higher (Figure 28). Other temperature-depth profiles measured in the Escalante Valley either indicate disturbances due to ground-water flow or have gradients less than background.

SUMMARY AND CONCLUSIONS

Geothermal reconnaissance techniques used in the Escalante Valley have identified an area warranting further investigation as a possible low-to-moderate temperature geothermal resource. This anomaly, northwest of Zane, within area III in Figure 9, is generally depicted by sample locations EV-118, EV-119, and EV-150 in area III on Figure 9. Recorded water temperatures for EV-118, EV-119, and EV-150 were 20, 27, and 28°C (68, 81 and 82°F), respectively. Total dissolved solids (TDS) content is greater than 1000 mg/l for all wells sampled in area III which is anomalous with the other areas sampled in which concentrations were generally less than 1000 mg/l.

Common ion analysis of water samples delineates three general types of water in the study area. Type I waters are calcium-sodium bicarbonate-chloride-sulfate, calcium-sodium chloride-sulfate-bicarbonate and calcium-sodium chloride-sulfate in character. Type II waters consist of samples EV-117 through EV-119 and EV-150 in area III and are sodium-calcium chloride-sulfate-bicarbonate in character. Type III waters constitute the four samples collected at Thermo Hot Springs and are also sodium-calcium chloride-sulfate-bicarbonate in character. However, Type II waters have significantly higher concentrations of Ca and Cl.

Trace element analyses show two indicator elements in concentrations favorable for the presence of warm water. Lithium values of some wells in area III (EV-115, EV-117, EV-118, EV-119, and EV-150) range from 0.96 to 1.07 mg/l. These concentrations are similar to those at Thermo Hot Springs which range from 1.18 to 1.26 mg/l. All other samples contained no Li values greater than 0.21 mg/l. Boron values for samples EV-118, EV-119, and EV-150 are 1.1, 1.0 and 0.9 mg/l respectively, and are similar to the 1.0 mg/l value determined for all Thermo Hot Springs samples. Except for samples EV-111 (geothermal test well), EV-115, and EV-146 in area VI, B values were less than 0.61 mg/l for all remaining samples.

Na-K-Ca (Mg corrected) temperatures computed for samples EV-118, EV-119, and EV-150 were 103, 120, and 100°C (217, 248, and 212°F), respectively. Temperatures computed for Thermo Hot Springs using this geothermometer ranged from 117 to 127°C (243 to 261°F). All other samples, with the exception of EV-111 (geothermal exploration well), provided computed temperatures no greater than 74°C (165°F). Quartz (conductive) geothermometer temperatures calculated for Na-K-Ca temperatures

greater than 100°C (212°F) for EV-118, EV-119, and EV-150 ranged from 96 to 104°C (205 to 219°F) which are consistent with the Na-K-Ca temperatures. The Truesdell and Fournier (1977) mixing model applied to sample EV-118 indicates a potential reservoir temperature of 128°C (262°F) could possibly be expected at depth. This temperature is similar to reservoir temperatures computed for Thermo Hot Springs.

Temperature-depth measurements conducted in the Escalante Valley have identified two areas, other than Thermo Hot Springs, of elevated near surface temperature. One area is northwest of Zane and the other area is approximately 3.1 mi (5 km) south of Beryl. In the area northwest of Zane, the highest gradient calculated is 138°C km⁻¹ which is more than double the background gradient. This temperature-depth profile is located approximately 0.9 mi (1.5 km) west of sample location EV-150 which had a recorded temperature of 28°C (82°F). In the second area of elevated temperature, two of the four gradients calculated appear to be disturbed by ground water flow. The other exploration techniques employed during this investigation do not indicate a geothermal anomaly at this location.

PROPOSED GEOTHERMAL MODELS FOR THE ZANE AREA

Model I of the geothermal anomaly indicated northwest of Zane involves meteoric water migration to depth, being warmed by the normal thermal gradient and then rising along a permeable fault zone, coming in contact with a near surface cold water aquifer where mixing occurs and reduces the temperature of the water recorded in the wells sampled (Figure 30). A fault in the vicinity of Zane which may be the conduit for the warmed water, is indicated by Win Pe's (1980) complete Bouguer gravity map of the Escalante Valley (Figure 4). The gravity data indicate a gravity high over the Beryl area which extends to the vicinity of Zane. The southeast border of this gravity high indicates a northeast-southwest striking normal fault, downdropped to the southeast, which extends through the area encompassed by samples EV-118, EV-119, and EV-150.

Model II entails warmed meteoric water migrating up a permeable fault zone and infiltrating a fractured bedrock high and eventually mixing with a cooler, shallow aquifer (Figure 31). Model III involves hot water mixing with cooler water, migrating downgradient and being forced nearer to the surface by the less permeable bedrock high (Figure 32). The warm water is then intercepted by water wells such as EV-118, 119, and 150. This model is modified from

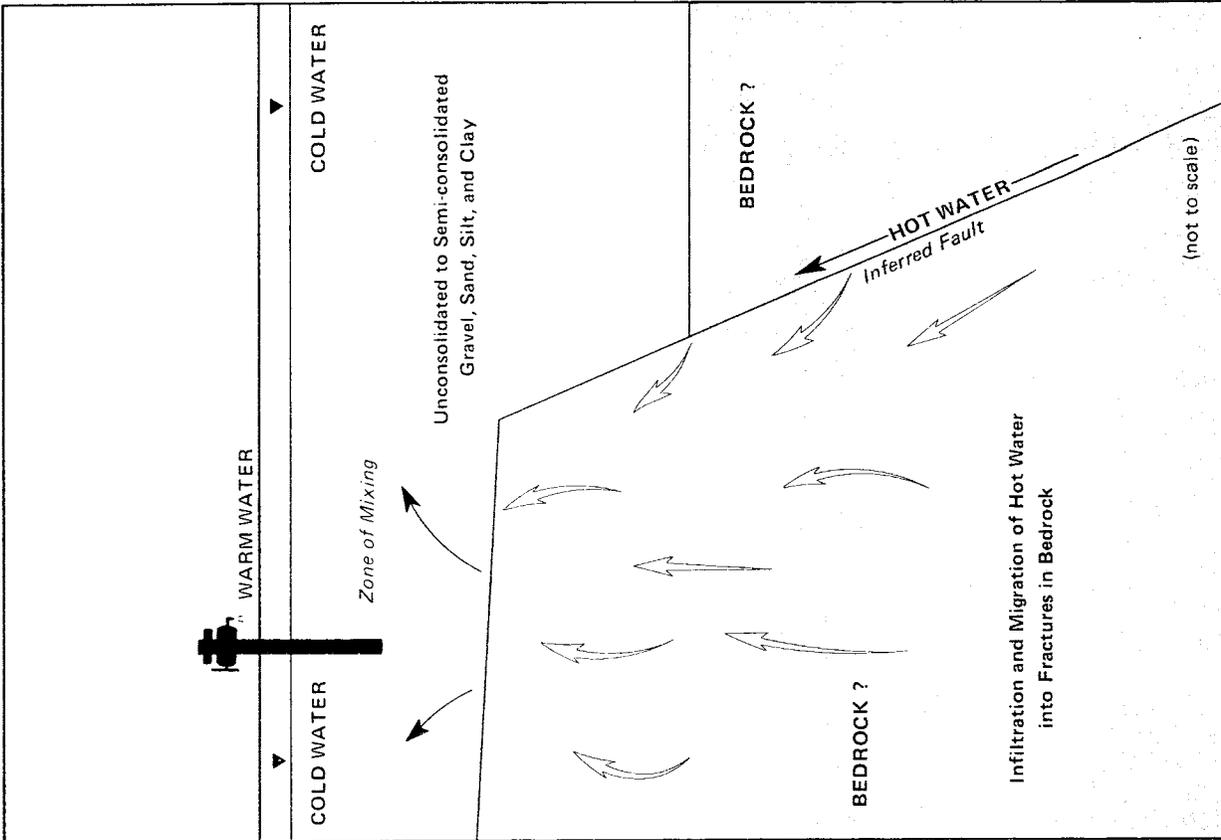


Figure 30. Model I proposed for the geothermal anomaly northwest of Zane, Iron County, Utah.

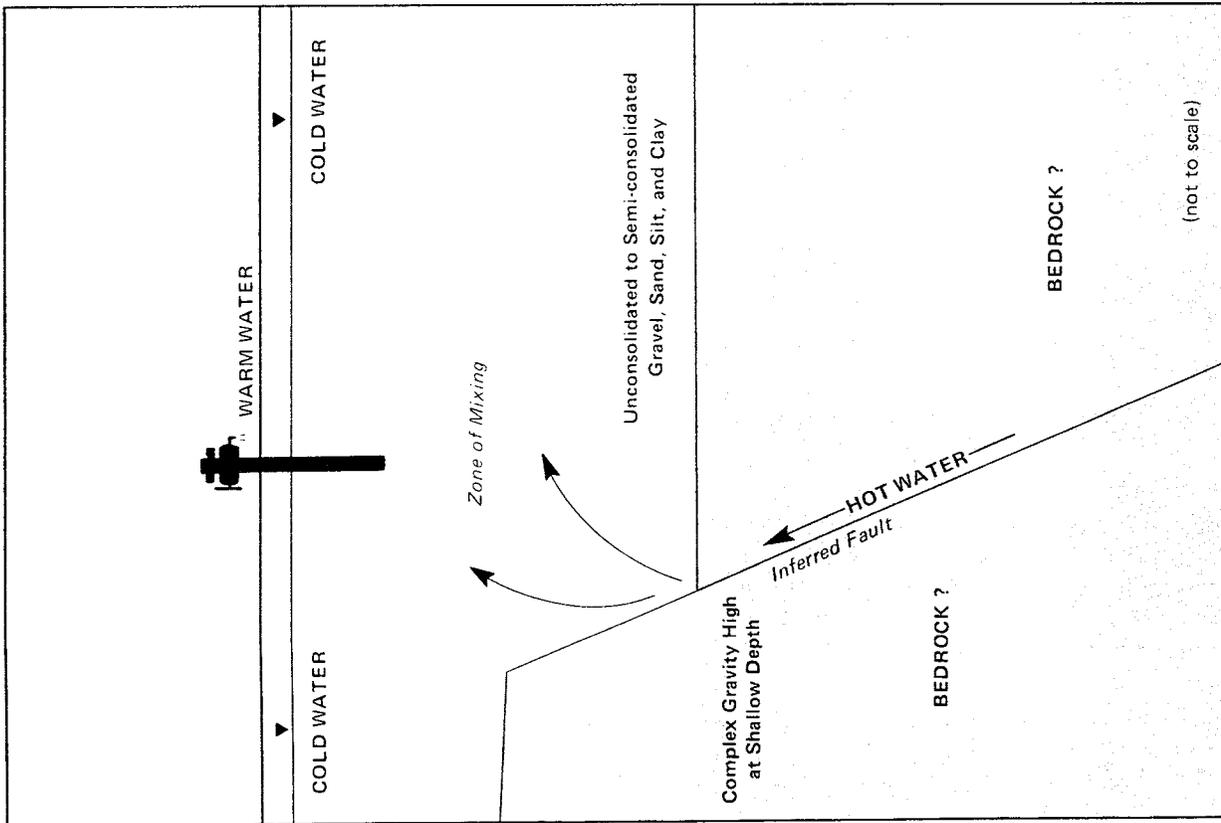


Figure 31. Model II proposed for the geothermal anomaly northwest of Zane, Iron County, Utah.

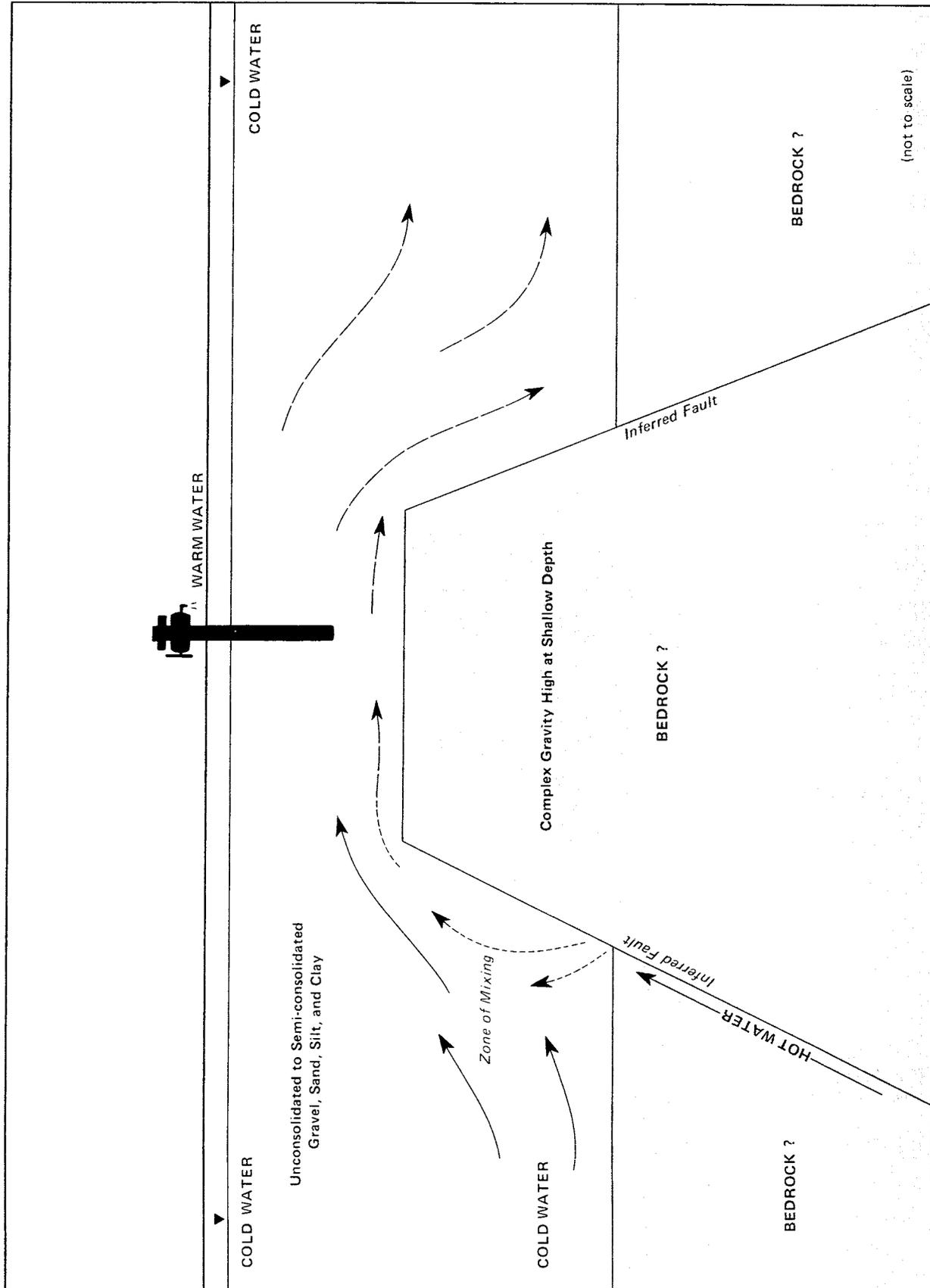


Figure 32. Model III proposed for the geothermal anomaly northwest of Zane, Iron County, Utah.

the one proposed by Morgan and others (1981) for the Rio Grande Rift geothermal resources.

FURTHER STUDY

The exploration techniques used in this study indicate that a low-to-moderate temperature geothermal anomaly exists northwest of Zane. Further research is needed to determine the source of the thermal fluids, to delineate the distribution of these fluids in the near surface, and to determine the maximum temperature.

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APPENDIX A
WELL- AND SPRING-NUMBERING SYSTEM

WELL- AND SPRING-NUMBERING SYSTEM

The system of numbering wells and springs in Utah is based on the cadastral land-survey system of the U.S. Government. The number, in addition to designating the well or spring, describes its position in the land net. By the land-survey system, the State is divided into four quadrants by the Salt Lake Base Line and Meridian, and these quadrants are designated by uppercase letters as follows: A, northeast; B, northwest; C, southwest; and D, southeast. Numbers designating the township and range (in that order) follow the quadrant letter, and all three are enclosed in parentheses. The number after the parentheses indicates the section, and is followed by three letters indicating the quarter section, the quarter-quarter section, and the quarter-quarter-quarter section, — generally 10 acres (4 hm²); the quarters of each sub-

division are designated by lowercase letters as follows: a, northeast; b, northwest; c, southwest; and d, southeast. The number after the letters is the serial number of the well or spring within the 10-acre (4-hm²) tract; the letter "S" preceding the serial number denotes a spring. Thus (C-36-16) 36 add -1 designated the first well constructed or visited in the SE1/4SE1/4NE1/4 sec. 36, T. 36 S., R. 16 W. If a well or spring cannot be located within a 10-acre (4-hm²) tract, one or two location letters are used and the serial number is omitted. Other sites where hydrologic data were collected, are numbered in the same manner, but three letters are used after the section number and no serial number is used. The numbering system is illustrated in figure A-1 (after Mower, 1982).

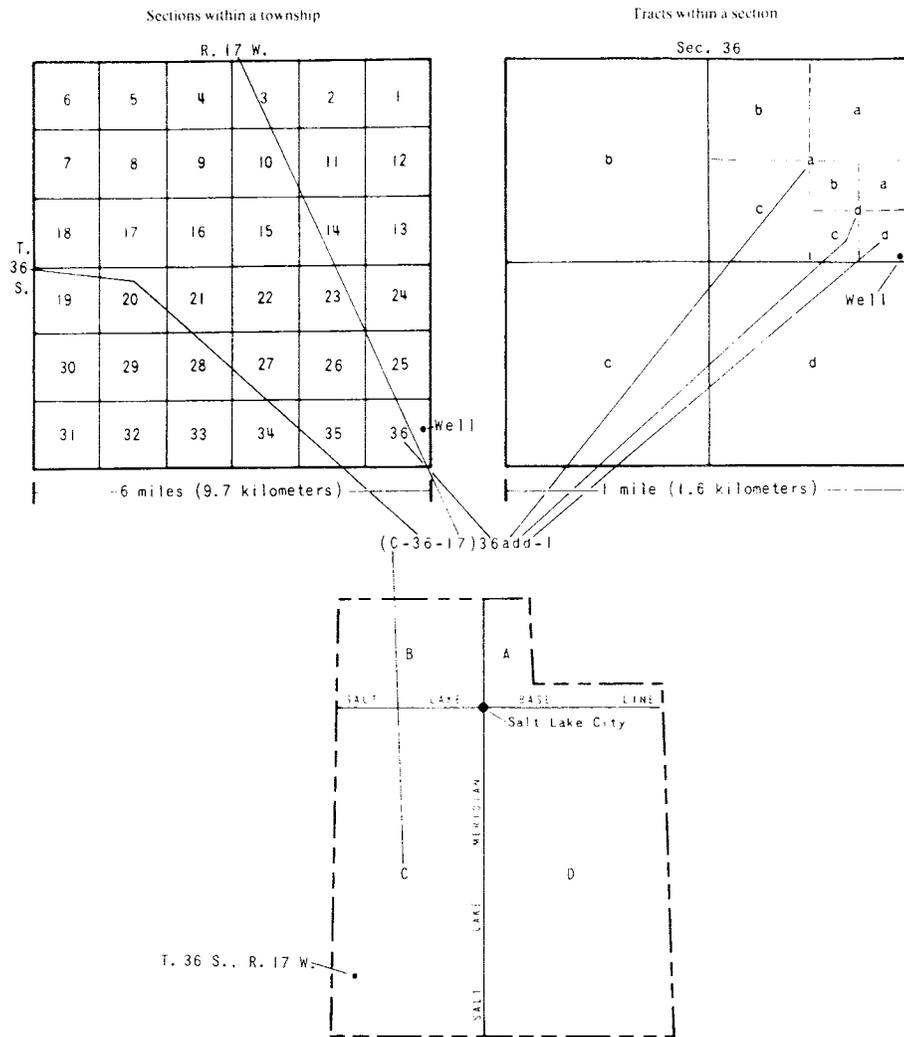


Figure A-1. Well-, spring-, and other data site-numbering system used in Utah.

APPENDIX B
TEMPERATURE-DEPTH PROFILE DATA

B-2

Area: Iron County, Utah
Cadastral: T34S/R16W.S18 cdb
Site Name: Escalante Valley EVG-1
Latitude: 37° 09' 46" N.
Longitude: 113° 18' 06" W.
Elevation: 1566 ± 0.7m
Depth to Water: 10m ± 2.5
Depth Range (Grad. Calc.): 20 - 44
Gradient: 16 ± 5 C/km
Drilling Completed by:
Thermal Logging Date: 10-28-81

Depth (m)	T (C)
0	16.79
10	13.89
15	13.78
20	13.78
25	13.84
30	13.92
35	13.99
40	14.04
44	14.18

B-4

Area: Iron County, Utah
Cadastral: T32S/R16W/S28 ccc
Site Name: Escalante Valley EVG-3
Latitude: 37° 59' 05" N.
Longitude: 113° 39' 20" W.
Elevation: 1744 ± 0.7m
Depth to Water: 25m ± 2.5
Depth Range (Grad. Calc.): 30 - 100m
Gradient: 57 ± 5 C/km
Drilling Completed by: 10-2-78
Thermal Logging Date: 11-19-81

Depth (m)	T (C)
0	14.49
10	14.15
15	14.39
20	14.68
25	14.89
30	15.44
35	15.60
40	15.87
45	16.15
50	16.41
55	16.70
60	16.96
65	17.27
70	17.53
75	17.79
80	17.95
85	18.42
90	18.76
95	19.08
100	19.37
102	19.44

B-3

Area: Iron County, Utah
Cadastral: T32S/R14W/S10 cbd
Site Name: Escalante Valley EVG-2
Latitude: 38° 01' 57" N.
Longitude: 113° 24' 45" W.
Elevation: 1548 ± 0.7m
Depth to Water: 10m ± 2.5
Depth Range (Grad. Calc.): 20 - 49m
Gradient: 46 ± 3 C/km
Drilling Completed by:
Thermal Logging Date: 11-17-81

Depth (m)	T (C)
0	17.59
10	11.75
15	11.79
20	12.01
25	12.27
30	12.45
35	12.69
40	12.91
45	13.15
49	13.37

B-5

Area: Iron County, Utah
Cadastral: T33S/R17W/S2 ddc
Site Name: Escalante Valley EVG-4
Latitude: 37° 57' 11" N.
Longitude: 113° 42' 39" W.
Elevation: 1665 ± 0.7m
Depth to Water: 25m ± 2.5
Depth Range (Grad. Calc.): 30 - 160m
Gradient: 70 ± 3 C/km
Drilling Completed by: 9-?-81
Thermal Logging Date: 11-19-81

Depth (m)	T (C)
0	14.51
10	14.51
15	15.10
20	15.43
25	15.91
30	16.82
35	16.95
40	17.16
45	17.46
50	17.79
55	18.12
60	18.57
65	18.85
70	19.22
75	19.57
80	19.94
85	20.32
90	20.69
95	21.10
100	21.47
105	21.81
110	22.20
115	22.58
120	22.97
125	23.24
130	23.60
135	23.91
140	24.25
145	24.53
150	24.82
155	25.03
160	25.37
163	25.39

B-6

Area: Iron County, Utah
Cadastral: T33S/R16W/S2 bbb
Site Name: Escalante Valley EVG-5
Latitude: 37° 56' 21" N.
Longitude: 113° 39' 19" W.
Elevation: 1603 ± 0.7m
Depth to Water: 30m ± 2.5
Depth Range (Grad. Calc.): 30 - 57m
Gradient: 138 ± 10 C/km
Drilling Completed by:
Thermal Logging Date: 12-1-81

Depth (m)	T (C)
0	-
10	15.04
15	15.93
20	16.97
25	17.81
30	19.19
35	19.65
40	20.38
45	21.15
50	21.82
55	22.50
57	22.83

B-7

Area: Iron County, Utah
Cadastral: T32S/R15W/S31 bbb
Site Name: Escalante Valley EVG-6
Latitude: 37° 58' 52" N.
Longitude: 113° 34' 50" W.
Elevation: 1646 ± 0.7m
Depth to Water: 25m ± 2.5
Depth Range (Grad. Calc.): 10 - 30m
Gradient: 83 ± 4 C/km
Drilling Completed by:
Thermal Logging Date: 11-20-81

Depth (m)	T (C)
0	-
10	13.47
15	13.91
20	14.36
25	14.72
30	15.14

B-8

Area: Iron County, Utah
Cadastral: T33S/R16W/S24 cca
Site Name: Escalante Valley EVG-7
Latitude: 37° 54' 51" N.
Longitude: 113° 35' 48" W.
Elevation: 1576 ± 0.7m
Depth to Water: 25m ± 2.5
Depth Range (Grad. Calc.): 25 - 44m
Gradient: 0.62 ± 2 C/km
Drilling Completed by:
Thermal Logging Date: 11-24-81

Depth (m)	T (C)
0	12.94
10	15.75
15	15.61
20	14.86
25	14.63
30	14.63
35	14.63
40	14.63
44	14.64

B-10

Area: Iron County, Utah
Cadastral: T34S/R16W/S17 cda
Site Name: Escalante Valley EVG-9
Latitude: 37° 50' 31" N.
Longitude: 113° 39' 53" W.
Elevation: 1565 ± 0.7m
Depth to Water: 8m ± 2.5
Depth Range (Grad. Calc.): 25 - 55m
Gradient: 94 ± 44 C/kmest. 72 C/km
Drilling Completed by:
Thermal Logging Date: 11-9-81

Depth (m)	T (C)
0	-
10	12.06
15	12.15
20	12.19
25	12.26
30	12.32
35	12.44
40	12.56
45	13.06
50	13.31
55	14.41

B-11

B-9

Area: Iron County, Utah
Cadastral: T34S/R15W/S1 bac
Site Name: Escalante Valley EVG-8
Latitude: 37° 52' 44" N.
Longitude: 113° 29' 02" W.
Elevation: 1556 ± 0.7m
Depth to Water: 10m ± 2.5
Depth Range (Grad. Calc.): 20 - 45m
Gradient: 52 ± 9 C/km
Drilling Completed by:
Thermal Logging Date: 11-11-81

Depth (m)	T (C)
0	12.39
10	18.59
15	19.01
20	19.42
25	19.79
30	20.12
35	20.34
40	20.60
45	20.71
50	20.76
54	20.80

Area: Iron County, Utah
Cadastral: T34S/R16W/S18 cdb
Site Name: Escalante Valley EVG-10
Latitude: 37° 50' 26" N.
Longitude: 113° 41' 18" W.
Elevation: 1566 ± 0.7m
Depth to Water: 10m ± 2.5
Depth Range (Grad. Calc.): 40 - 64m
Gradient: 60 ± 3 C/km
Drilling Completed by: 5-10-76
Thermal Logging Date: 10-26-81

Depth (m)	T (C)
0	17.23
10	15.52
15	15.61
20	15.26
25	14.66
30	14.25
35	14.29
40	14.47
45	14.78
50	15.11
55	15.43
60	15.68
64	15.89

B-12

Area: Iron County, Utah
Cadastral: T34S/R16W/S22 abb
Site Name: Escalante Valley EVG-11
Latitude: 37° 50' 15" N.
Longitude: 113° 37' 41" W.
Elevation: 1563 ± 0.7m
Depth to Water: 9m ± 2.5
Depth Range (Grad. Calc.): 20 - 67m
Gradient: 63 ± 4 C/km
Drilling Completed by:
Thermal Logging Date: 10-30-81

Depth (m)	T (C)
0	12.96
10	11.58
20	12.00
25	12.31
30	12.60
35	12.91
40	13.27
45	13.60
50	13.93
55	14.24
60	14.59
65	14.78
67	14.84

Area: Iron County, Utah
Cadastral: T34S/R17W/S24 bdb
Site Name: Escalante Valley EVG-12
Latitude: 37° 50' 04" N.
Longitude: 113° 42' 12" W.
Elevation: 1570 ± 0.7m
Depth to Water: 9m ± 2.5
Depth Range (Grad. Calc.): 25 - 50m
Gradient: 114 ± 10 C/km
Drilling Completed by: 12-9-74
Thermal Logging Date: 11-9-81

Depth (m)	T (C)
0	12.71
10	13.12
15	13.72
20	13.85
25	13.99
30	14.55
35	15.26
40	15.85
45	16.37
50	16.76
54	17.45

B-13

Area: Iron County, Utah
Cadastral: T34S/R16W/S28 bcc
Site Name: Escalante Valley EVG-13
Latitude: 37° 49' 00" N.
Longitude: 113° 39' 14" W.
Elevation: 1566 ± 0.7m
Depth to Water: 10m ± 2.5
Depth Range (Grad. Calc.): 20 - 45m
Gradient: 6 ± 3 C/km
Drilling Completed by: 2-4-75
Thermal Logging Date: 11-5-81

Depth (m)	T (C)
0	17.24
10	12.26
15	10.74
20	10.79
25	10.82
30	10.85
35	10.93
40	10.93
45	10.93

B-14

B-15

Area: Iron County, Utah
Cadastral: T34S/R16W/S31 ccd
Site Name: Escalante Valley EVG-14
Latitude: 37° 47' 42" N.
Longitude: 113° 41' 17" W.
Elevation: 1570 ± 0.7m
Depth to Water: 17m ± 2.5
Depth Range (Grad. Calc.): 20 - 55m
Gradient: 32 ± 7 C/km
Drilling Completed by: 6-21-76
Thermal Logging Date: 11-5-81

Depth (m)	T (C)
0	12.35
10	12.40
15	13.39
25	11.81
30	11.90
35	12.04
40	12.17
45	12.33
50	12.64
55	12.90
60	12.92
65	12.92
70	12.94
75	12.95
80	12.94
85	12.95
90	12.96
95	12.95
100	12.95
105	12.95
110	12.95
115	12.95
120	12.95
125	12.95
130	12.95

B-16

Area: Iron County, Utah
Cadastral: T35S/R16W/S6 bbc
Site Name: Escalante Valley EVG-15
Latitude: 37° 47' 38" N.
Longitude: 113° 41' 29" W.
Elevation: 1572 ± 0.7m
Depth to Water: 6m ± 2.5
Depth Range (Grad. Calc.): 20 - 65m
Gradient: 0 ± 1 C/km
Drilling Completed by: 4-23-49
Thermal Logging Date: 11-3-81

Depth (m)	T (C)
0	15.61
10	13.01
15	13.01
20	12.10
25	12.09
30	12.09
35	12.10
40	12.10
45	12.11
50	12.11
55	12.11
60	12.11
65	12.11

B-17

Area: Iron County, Utah
Cadastral: T35S/R17W/S1 bcc
Site Name: Escalante Valley EVG-16
Latitude: 37° 47' 21" N.
Longitude: 113° 42' 39" W.
Elevation: 1574 ± 0.7m
Depth to Water: 10m ± 2.5
Depth Range (Grad. Calc.): 25 - 55m
Gradient: 0 ± 1 C/km
Drilling Completed by: 8-22-51
Thermal Logging Date: 11-2-81

Depth (m)	T (C)
0	14.09
10	12.70
15	12.59
20	12.08
25	11.98
30	11.98
35	11.97
40	11.97
45	11.97
50	11.97
55	11.98
59	12.00

B-18

Area: Iron County, Utah
Cadastral: T35S/R17W/S3 ccc
Site Name: Escalante Valley EVG-17
Latitude: 37° 46' 50" N.
Longitude: 113° 44' 48" W.
Elevation: 1581 ± 0.7m
Depth to Water: 23 m ± 2.5
Depth Range (Grad. Calc.): 30 - 55m
Gradient: 5 ± 1 C/km
Drilling Completed by: 3-12-47
Thermal Logging Date: 11-13-81

Depth (m)	T (C)
0	11.39
10	12.04
15	12.24
20	12.46
25	12.73
30	12.81
35	12.85
40	12.88
45	12.90
50	12.93
55	12.95
57	13.21

B-19

Area: Iron County, Utah
Cadastral: T35S/R17W/S1 ddc
Site Name: Escalante Valley EVG-18
Latitude: 37° 46' 24" N.
Longitude: 113° 41' 45" W.
Elevation: 1573 ± 0.7m
Depth to Water: 18m ± 2.5
Depth Range (Grad. Calc.): 25 - 45m
Gradient: 26 ± 4 C/km
Drilling Completed by: 4-24-65
Thermal Logging Date: 11-10-81

Depth (m)	T (C)
0	-
10	10.18
15	10.74
20	10.77
25	10.73
30	10.85
35	10.97
40	11.14
45	11.24
50	11.27
55	11.19
57	11.19

B-20

Area: Iron County, Utah
Cadastral: T35S/R17W/S12 bcc
Site Name: Escalante Valley EVG-19
Latitude: 37° 46' 24" N.
Longitude: 113° 42' 36" W.
Elevation: 1576 ± 0.7m
Depth to Water: 38m ± 2.5
Depth Range (Grad. Calc.): 25 - 45m
Gradient: 2 ± 1 C/km
Drilling Completed by:
Thermal Logging Date: 11-2-81

Depth (m)	T (C)
0	-
10	10.28
15	10.45
20	10.44
25	10.54
30	10.54
35	10.57
40	10.58
45	10.58
50	10.58

B-21

Area: Iron County, Utah
Cadastral: T35S/R17W/S12 acc
Site Name: Escalante Valley EVG-20
Latitude: 37° 46' 23" N.
Longitude: 113° 42' 00" W.
Elevation: 1573 ± 0.7m
Depth to Water: 20m ± 2.5
Depth Range (Grad. Calc.): 25 - 40m
Gradient: 6 ± 4 C/km
Drilling Completed by: 5-4-60
Thermal Logging Date: 11-11-81

Depth (m)	T (C)
0	11.11
10	10.62
15	10.39
20	10.58
25	10.90
30	10.91
35	10.92
40	10.99
44	10.99

B-22

B-23

Area: Iron County, Utah
Cadastral: T35S/R17W/S18 abd
Site Name: Escalante Valley EVG-21
Latitude: 37° 45' 45" N.
Longitude: 113° 47' 24" W.
Elevation: 1595 ± 0.7m
Depth to Water: 44m ± 2.5
Depth Range (Grad. Calc.): 25 - 45m
Gradient: 35 ± 3 C/km
Drilling Completed by:
Thermal Logging Date: 11-10-81

Area: Iron County, Utah
Cadastral: T35S/R17W/S16 aca
Site Name: Escalante Valley EVG-22
Latitude: 37° 45' 41" N.
Longitude: 113° 45' 06" W.
Elevation: 1584 ± 0.7m
Depth to Water: 26m ± 2.5
Depth Range (Grad. Calc.): 15 - 30m
Gradient: 73 ± 9 C/km
Drilling Completed by: 11-7-80
Thermal Logging Date: 11-13-81

Depth (m)	T (C)
0	19.61
10	14.92
15	14.46
20	15.21
25	14.17
30	14.36
35	14.56
40	14.70
45	14.87
50	14.92
55	15.00

Depth (m)	T (C)
0	13.98
10	12.12
15	12.45
20	12.88
25	13.16
30	13.57
35	13.66
40	13.76
45	13.86
50	13.96
55	14.14