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UTAH GEOLOGICAL AND MINERAL SURVEY

No. 191

EVALUATION OF LOW-TEMPERATURE GEOTHERMAL POTENTIAL IN UTAH AND GOSHEN VALLEYS AND ADJACENT AREAS, UTAH

PART II: WATER TEMPERATURE AND CHEMISTRY

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ABSTRACT

Geothermal reconnaissance techniques have identified five areas in Utah County warranting further investigation for low-temperature geothermal resources. One area in northern Utah Valley is along the Utah Lake fault zone and includes Saratoga Hot Springs. Water temperatures within this area range from 21 to 43°C. Common ion analyses as well as B and Li concentrations indicate waters sampled in this area are anomalous when compared to other samples from the same aquifer. Two other areas in southern Utah Valley also coincide with the Utah Lake fault zone. Common ion analyses, trace element concentrations, and Cl/HCO_3 ratios distinguish these areas from all other waters in this valley. Temperatures within these southern areas range from 21 to 32°C. All three thermal areas are possibly the result of deep circulation of meteoric water being warmed and subsequently migrating upward within the Utah Lake fault zone.

The Castilla Hot Springs area has been expanded by this study to include a spring located 3 mi further up Spanish Fork Canyon near the Thistle earthflow. A temperature of 50°C was recorded for this spring and chemistry is similar to Castilla.

In Goshen Valley, the fifth geothermal area identified, measured temperatures range from 20 to 27°C for some wells and springs. Chemical analyses, however, do not discern the location of low-temperature geothermal reservoirs.

INTRODUCTION

The Utah Geological and Mineral Survey (UGMS) has been conducting research to encourage the use of low-temperature geothermal resources in the State of Utah as per U.S. Department of Energy (DOE) contract DE-AS07-77ET28393. Prior to 1980, UGMS concentrated investigations on known geothermal areas along the Wasatch front from Utah Valley north to the Idaho-Utah state line. The concentration of studies in this region was to encourage development of known geothermal resources near major population centers of the state.

In February, 1980, evaluation of area-wide geothermal-resource potential for the following Wasatch Front Valleys was initiated: (1) Utah Valley, (2) Jordan Valley, (3) Ogden Valley, (4) Bear River Valley, (5) Malad Valley, and (6) Cache Valley. These areas were also chosen because of proximity to the major population centers.

The Utah Valley study was expanded to include Goshen Valley and other adjacent areas because of the presence of warm springs (fig. 1). The study was conducted in two parts. Part I consisted of a gravity survey (Davis and Cook, 1983). Part II includes:

1) a temperature survey of selected wells and springs, and

2) the chemical analysis of water from selected wells and springs.

It should be noted that this study is limited in scope, and the absence of evidence for additional resources doesn't eliminate the possibility they exist. Additional exploration may establish the existence of a deep resource(s).

GEOLOGIC AND STRUCTURAL SETTING

The geological and structural settings are presented in Part I and are not represented in this report.

GROUND WATER

Ground-water resources in Utah and Goshen Valleys have been studied by Hunt, Varnes, and Thomas (1953), Cordova (1962), Cordova and Subitzky (1965),

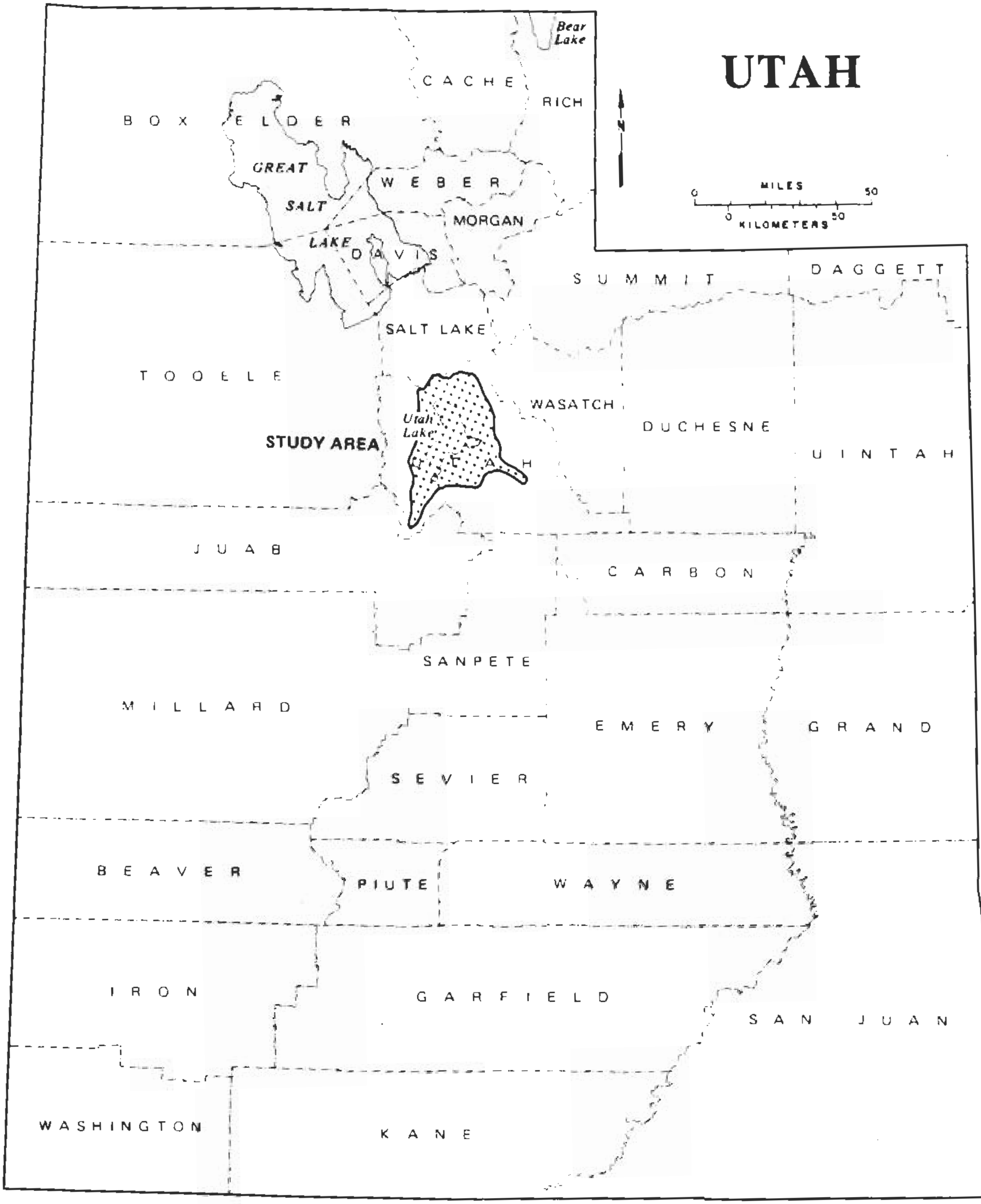

Figure 1. Index map of the study area in Utah County, Utah.

Cordova (1969 and 1970), Dustin and Merritt (1980), Appel, Clark, and Fairbanks (1982), Fairbanks (1982), and Clark and Appel (1984). The principal ground-water reservoir in northern Utah Valley is in basin fill and includes unconfined as well as confined aquifers (Clark and Appel, 1984). Unconfined aquifers occur in coarse grained, pre-lake Bonneville deposits near the mountains which grade into confined aquifers further from the mountains (Clark and Appel, 1984). Clark and Appel (1984) also report that unconfined water is present in flood-plain deposits along stream channels, in perched water-table aquifers in Lake Bonneville deposits in bench areas, and in the lower valley areas within a few feet of the land surface. They report that confined ground water is present in three aquifers: a shallow artesian aquifer in deposits of Pleistocene age, a deep artesian aquifer in deposits of Pleistocene age, and an artesian aquifer in deposits of either Quaternary or Tertiary age. These three confined aquifers can be separated locally, but varying thicknesses and lithology make them difficult to trace across the entire valley.

Ground water in northern Utah Valley generally moves from the mountain fronts to Utah Lake and the Jordan River (Clark and Appel, 1984). Downward movement occurs in the recharge areas along the mountain front; upward movement takes place under artesian conditions through confining beds from deeper aquifers or zones within aquifers to shallower aquifers or zones.

The three artesian aquifers described by Hunt, Varnes, and Thomas (1953) and reiterated on by Clark and Appel (1984) for northern Utah valley have been traced into southern Utah and Goshen valleys (Cordova, 1970). These artesian aquifers and their extensions into areas where they are unconfined consist of coarse- and fine-grained materials that vary widely in permeability from place to place. However, each aquifer is separated from the other by a definite zone of less permeable deposits (Cordova, 1970). These artesian aquifers in southern Utah Valley extend from beneath the highlands to beneath the lake plain whereas artesian conditions exist mainly in the eastern part of Goshen Valley. This suggests coarser grained material with no extensive confining beds is present in the western part of the valley (Cordova, 1970).

A fourth main aquifer is also present in Utah and Goshen valleys. This aquifer is found in Lake Bonneville Group sediments mainly under water-table conditions, but artesian conditions do exist in small areas east of Spring Lake, near Holiday Springs and Lincoln Point, as well as 5 miles south of Alberta (Cordova, 1970). Perched water occurs under the highlands.

Ground water in southern Utah Valley usually moves from the Wasatch Range and the highlands toward Utah Lake. Generally, in the artesian aquifers, water moves upward through confining beds into overlying aquifers. In Goshen Valley, the direction of movement is away from the bordering mountains and toward Utah Lake.

WATER SAMPLING PROCEDURE

The on-site analysis consists of: 1) pH; 2) alkalinity; 3) temperature; and 4) conductivity. The pH was measured by using a Corning-Orion Model 407A/F specific ion meter in conjunction with an Orion gel-filled Model 91-05 combination pH electrode. Generally, three readings were recorded and averaged as a final value. An error of $\pm$ .02 pH units is assumed for this measurement. A Hatch Titration Test Kit (Model ALAP) was used to analyze for alkalinity and a YSI Model 33 Temperature-Conductivity Meter was used to measure temperature and conductivity. Measurement uncertainties due to the meter are estimated to be $\pm 0.6^{o}$ C for temperature and 4.5% for conductivity (de Vries, 1982).

Three (two 570 ml and one 65 ml) polyethelene bottles were filled at each sampling location with water filtered through a GeoFilter Peristaltic Pump - Model #004 using 0.45 micron filter paper. This 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 HNO_3 to a final concentration of 20% HNO_3 for cation and anion analysis of elements presented in table 1 by an APL Inductively Coupled Plasma Quantometer (ICPQ). A 570 ml bottle was acidified with concentrated HCl to a final concentration of 1% HCl for SO_4 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 2.

TEMPERATURE SURVEY OF SELECTED WELLS AND SPRINGS

The location of 67 wells and springs where temperatures were measured by UGMS personnel are shown on plate 1. Temperatures range from 11 to 50°C. Temperatures at additional locations (wells and springs) obtained from other sources are also shown on plate 1. These temperatures range from 6 to 54.5°C. Nathenson and others (1982) define low-temperature geothermal resources as being no lower than 10°C above the mean annual air temperature at the surface, increasing by 25°C/km with depth to a maximum of 90°C. The mean annual air temperature in Utah County is about 10°C. Ground water with temperatures 20°C or greater is considered anomalous, may have low-temperature geothermal potential, and will be referred to as thermal.

Many thermal temperatures have been recorded in Utah and Goshen valleys. As discussed in Part I of this study, many of these thermal springs and wells occur within the Utah Lake fault zone in Utah Valley. This zone is shown on plate 1 in Part I. Four isolated thermal wells are also located in eastern

Table 1: Limits of Quantitative Detection (LQD)[1] for Solution Analysis by the University of Utah Research Institute/Earth Science Lab Inductively Coupled Plasma Quantometer (ICPQ).

Element	Concentration (mg/l)
Na	1.250
K	2.500
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	1.250
Cr	0.050
Mn	0.250
Co	0.025
Ni	0.125
Cu	0.063
Mo	1.250
Pb	0.250
Zn	0.125
Cd	0.063
As	0.625
Sb	0.750
Bi	2.500
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	2.500

[1]LQD concentrations represent the lowest reliable analytic values for each element. Precision at the LQD is approximately $\pm$ 100% of the given value with a confidence level of 95.

Table 2. Water analyses for wells and springs in Utah and Goshen valleys and adjacent areas, Utah. Samples collected by the Utah Geological and Mineral Survey

(u - elements not present or not present in detectable concentrations.)

Sample #		SARA-1	SARA-2	SARA-3	P-1	P-2	P-3	P-4
Location		(C-5-1)25ccc 40°20'56" 111°54'19"	(C-5-1)25ccc 40°20'56" 111°54'17"	(C-5-1)25ccc 40°21'40" 111°54'13"	(D-9-1)14aad 40°02'20" 111°47'12"	(D-9-1)11acc 40°02'56" 111°47'41"	(D-9-1)1bcb 40°03'56" 111°47'10"	(D-8-1)35adc 40°04'43" 111°47'25"
Temp.	°C	41	43	42	15	14	13	18
pH		6.75	6.67	6.78	7.73	7.30	7.99	8.39
TDS	mg/l	1426	1436	1446	388	1520	220	200
HCO_3	mg/l	376	367	351	259	384	225	200
Na	mg/l	225	225	223	13	210	13	19
K	mg/l	23	23	24	3	7	5	5
Ca	mg/l	193	186	234	61	133	40	27
Mg	mg/l	48	48	49	33	82	16	13
Fe	mg/l	0.14	0.08	0.27	u	u	u	0.49
SiO_2	mg/l	25	25	25	32	38	32	37
Sr	mg/l	3.80	3.78	3.76	0.45	0.94	0.33	0.24
Ba	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Zn	mg/l	0.2	0.2	2.0	u	u	u	u
Li	mg/l	0.31	0.31	0.31	u	0.08	u	u
B	mg/l	0.4	0.4	0.4	u	0.4	u	u
F	mg/l	2.0	2.1	2.1	0.5	0.27	0.23	0.44
Cl	mg/l	339	329	325	21	140	10	8.5
SO_4	mg/l	422	424	417	31	604	15.8	13.5

Table 2. (continued)

Sample #		P-5	P-6	P-7	P-8	P-9	P-10	P-11
Location		(D-8-1)35cac 40°04'31" 111°47'58"	(D-8-1)26dad 40°05'20" 111°47'18"	(D-9-1)25caa 40°00'15" 111°46'37"	(D-9-1)23dcb 40°00'55" 111°47'42"	(D-9-2)19bab 40°01'34" 111°45'41"	(D-8-2)18ccc 40°06'53" 111°46'03"	(D-8-1)13aaa 40°07'41" 111°46'07"
Temp.	°C	16	15	14	13	14	20	16
pH		8.20	8.10	8.00	7.51	7.70	7.93	7.89
TDS	mg/l	240	200	200	400	400	260	292
HCO_3	mg/l	225	209	267	334	376	259	301
Na	mg/l	27	20	11	21	13	14	18
K	mg/l	4	7	u	u	3	7	7
Ca	mg/l	26	26	43	75	85	38	32
Mg	mg/l	15	13	23	30	30	25	28
Fe	mg/l	1.14	0.10	0.14	0.03	0.04	0.30	0.25
SiO_2	mg/l	45	48	18	21	28	49	49
Sr	mg/l	0.28	0.26	0.34	0.35	0.30	0.46	0.55
Ba	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Zn	mg/l	0.5	u	0.2	0.2	0.1	u	u
Li	mg/l	u	u	u	u	u	u	u
B	mg/l	u	u	u	u	u	u	u
F	mg/l	0.5	0.38	0.16	0.28	0.23	0.49	0.6
Cl	mg/l	12	8.20	15	44	30	15	11
SO_4	mg/l	26	15.8	14.8	48	43.8	28.4	27.3

Table 2. (continued)

Sample #		P-12	P-13	P-14	P-15	P-16	P-17	P-18
Location		(D-8-1)10bcb 40°08'17" 111°49'23"	(D-8-3)19cda 40°06'13" 111°38'43"	(D-9-3)7baa 40°03'19" 111°38'46"	(D-9-3)18caa 40°02'06" 111°36'38"	(D-8-2)32dda 40°04'22" 111°43'56"	(D-9-2)10dcb 40°02'43" 111°41'40"	(D-9-2)22cad 40°02'30" 111°42'08"
Temp.	°C	21	15	14	13	23	17	19
pH		7.99	7.99	7.50	7.51	7.89	7.40	7.71
TDS	mg/l	1040	480	420	240	580	340	300
HCO_3	mg/l	284	426	442	317	234	334	275
Na	mg/l	216	66	30	11	76	20	15
K	mg/l	21	6	4	u	24	u	u
Ca	mg/l	49	68	83	64	56	60	60
Mg	mg/l	59	29	34	23	27	26	17
Fe	mg/l	0.05	0.47	0.88	u	0.72	0.05	u
SiO_2	mg/l	25	24	20	9	68	16	19
Sr	mg/l	1.32	0.69	0.30	0.12	0.96	0.23	0.21
Ba	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Zn	mg/l	u	u	0.2	0.2	u	u	1.50
Li	mg/l	0.20	u	u	u	0.07	u	u
B	mg/l	0.4	u	u	u	0.2	u	u
F	mg/l	0.55	0.34	0.27	u	0.38	0.13	0.25
Cl	mg/l	280	70	26	7	180	38	28
SO_4	mg/l	239	38.4	57.6	19.5	24.8	34	18.8

Table 2. (continued)

Sample #		P-19	P-20	G-1	G-2	G-3	G-4	G-5
Location		(D-8-2)25bca 40°05'44" 111°40'08"	(D-8-2)16cbc 40°07'11" 111°43'10"	(D-5-2)29dbd 40°21'09" 111°44'25"	(C-5-1)15aac 40°23'19" 111°55'47"	(C-5-1)2cda 40°24'54" 111°55'06"	(C-4-1)25cda 40°26'13" 111°53'59"	(C-4-1)36aaa 40°26'05" 111°53'21"
Temp.	°C	20	14	12	16	13	15	17
pH		7.69	8.01	7.09	7.60	7.23	7.37	7.20
TDS	mg/l	500	240	410	620	940	440	400
HCO_3	mg/l	493	284	409	259	242	250	242
Na	mg/l	83	27	13	97	116	51	44
K	mg/l	7	5	3	8	6	5	3
Ca	mg/l	55	35	110	87	135	75	67
Mg	mg/l	28	15	30	32	38	22	28
Fe	mg/l	0.13	0.04	0.16	0.08	0.03	u	0.03
SiO_2	mg/l	20	40	8	17	42	14	19
Sr	mg/l	0.69	0.38	0.68	0.71	0.76	0.70	0.55
Ba	mg/l	1.0	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Zn	mg/l	0.3	u	0.5	0.5	0.2	u	0.2
Li	mg/l	u	u	u	u	0.06	u	u
B	mg/l	0.2	u	u	0.2	u	u	u
F	mg/l	0.40	0.35	0.30	1.10	0.48	0.80	0.42
Cl	mg/l	55	9	13	190	240	84	85
SO_4	mg/l	28.4	4.30	56.4	89.6	318	68.5	46

Table 2. (continued)

Sample #		G-6	G-7	G-8	G-9	G-10	G-11	G-12
Location		(D-5-1)17dca 40°22'45" 111°51'15"	(D-5-1)19bca 40°22'22" 111°53'04"	(D-5-1)20bcc 40°22'21" 111°52'12"	(D-6-2)17acc 40°17'25" 111°44'25"	(D-5-1)25cbd 40°21'07" 111°47'12"	(D-5-1)22bda 40°22'23" 111°49'20"	(D-7-3)7bbb 40°13'49" 111°39'12"
Temp.	°C	13	14	12	15	17	12	16
pH		7.87	7.65	7.52	7.84	7.65	7.45	7.02
TDS	mg/l	80	140	140	180	460	274	380
HCO_3	mg/l	117	175	167	225	225	217	376
Na	mg/l	7	9	7	21	37	8	31
K	mg/l	u	u	u	u	u	u	3
Ca	mg/l	25	31	31	29	67	56	63
Mg	mg/l	10	13	12	11	34	22	30
Fe	mg/l	u	0.20	u	0.21	1.95	u	0.40
SiO_2	mg/l	3	13	12	18	6	10	9
Sr	mg/l	0.21	0.32	0.26	0.43	0.90	0.41	1.04
Ba	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Zn	mg/l	u	u	u	u	0.2	0.3	u
Li	mg/l	u	u	u	u	u	u	u
B	mg/l	u	u	u	u	u	u	u
F	mg/l	0.25	0.26	0.27	0.30	0.28	0.25	0.34
Cl	mg/l	8.60	9.40	8.50	6.50	34	10	22
SO_4	mg/l	7.50	18.2	12.7	6.20	298	41.6	50.9

Table 2. (continued)

Sample #		G-13	G-14	G-15	G-16	G-17	G-18	G-19
Location		(D-8-2)3bba 40°09'29" 111°42'24"	(D-8-2)29aaa 40°05'59" 111°43'51"	(C-10-1)30dcc 39°54'34" 111°58'51"	(D-9-1)14ddb 40°01'42" 111°47'27"	(D-9-1)1ccc 40°03'27" 111°47'10"	(D-8-1)35dba 40°04'38" 111°47'32"	(D-7-2)32dad 40°09'47" 111°43'51"
Temp.	°C	15	24	17	16	15	15	15
pH		7.82	7.40	6.86	7.22	7.36	7.44	7.32
TDS	mg/l	340	300	3260	500	420	220	280
HCO_3	mg/l	367	284	83	309	284	200	284
Na	mg/l	79	42	93	103	15	24	37
K	mg/l	4	11	17	14	3	6	6
Ca	mg/l	21	34	543	37	85	36	31
Mg	mg/l	29	17	166	16	32	12	16
Fe	mg/l	0.48	0.44	u	u	0.07	0.08	0.24
SiO_2	mg/l	19	63	42	16	22	42	35
Sr	mg/l	u	0.35	4.24	0.69	0.47	0.30	0.43
Ba	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Zn	mg/l	u	u	0.6	0.2	0.3	0.4	u
Li	mg/l	0.05	u	0.06	0.13	u	u	u
B	mg/l	0.3	u	u	0.2	u	u	u
F	mg/l	0.71	0.48	0.15	0.70	0.25	0.40	0.44
Cl	mg/l	34	15	1100	100	28	8.50	13
SO_4	mg/l	6.20	26.6	433	41.6	49	16.6	4.30

Table 2. (continued)

Sample #		G-20	G-21	G-22	G-23	G-24	C-1	C-2
Location		(D-8-2)9adb 40°08'23" 111°42'53"	(D-8-3)2cbd 40°08'53" 111°41'20"	(D-8-2)13bba 40°07'40" 111°40'11"	(D-8-2)10abc 40°08'30" 111°42'24"	(D-8-2)31cdb 40°04'21" 111°45'43"	(D-9-1)35add 39°59'25" 111°47'12"	(C-10-1)9cdc 39°57'10" 111°57'02"
Temp.	°C	17	17	16	18	30	11	18
pH		7.40	7.60	7.40	7.65	6.68	7.12	6.96
TDS	mg/l	280	280	260	240	1724	296	1600
HCO_3	mg/l	292	292	292	284	476	334	209
Na	mg/l	25	18	13	20	464	5	106
K	mg/l	7	5	3	6	32	u	12
Ca	mg/l	58	47	59	46	88	63	177
Mg	mg/l	19	21	26	20	33	21	77
Fe	mg/l	0.23	0.60	0.94	0.46	0.13	u	u
SiO_2	mg/l	36	28	20	31	46	5	44
Sr	mg/l	0.52	0.55	0.41	0.52	2.02	0.16	2.19
Ba	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Zn	mg/l	u	u	0.2	u	u	0.1	u
Li	mg/l	u	u	u	u	0.38	u	0.06
B	mg/l	u	u	u	u	0.7	u	0.1
F	mg/l	0.40	0.29	0.18	0.32	1.1	0.4	0.16
Cl	mg/l	11	12	15	9.50	680	13	340
SO_4	mg/l	5.30	15.3	22.2	10.6	182	16.4	416

Table 2. (continued)

Sample #		C-3	C-4	C-5	C-6	C-7	C-8	C-9
Location		(C-10-1)28adb 39°55'07" 111°56'21"	(C-10-1)1ddcc 39°57'15" 111°55'33"	(D-10-1)21acb 39°56'05" 111°49'35"	(C-10-1)24ddc 39°55'34" 111°53'11"	(C-10-1)4cbb 39°58'23" 111°57'15"	(D-10-1)12bdd 39°57'42" 111°46'35"	(C-9-1)5ddb 40°03'23" 111°58'18"
Temp.	°C	27	15	17	17	18	13	15
pH		7.36	7.60	7.19	7.14	7.17	7.43	7.33
TDS	mg/l	740	2920	440	1100	700	260	460
HCO_3	mg/l	242	334	292	493	184	292	209
Na	mg/l	125	319	38	210	103	28	81
K	mg/l	18	14	3	19	13	3	10
Ca	mg/l	55	193	63	85	79	43	48
Mg	mg/l	27	188	32	55	25	20	17
Fe	mg/l	0.08	1.14	u	0.22	u	u	0.09
SiO_2	mg/l	60	44	29	44	51	18	47
Sr	mg/l	0.86	4.34	0.38	1.45	0.93	0.22	0.59
Ba	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	0.40	u	u	u	u	u
Zn	mg/l	u	u	u	0.3	u	0.1	u
Li	mg/l	0.09	0.21	u	0.09	0.06	u	0.06
B	mg/l	0.3	0.2	u	u	u	u	0.2
F	mg/l	0.44	0.46	0.29	0.50	0.27	0.18	0.45
Cl	mg/l	300	1200	75	400	190	13	110
SO_4	mg/l	34	182	50.9	142	127	17.6	59

Table 2. (continued)

Sample #		C-10	C-11	C-12	C-13	C-14	C-15
Location		(C-8-1)29dda 40°05'14" 111°57'28"	(C-8-1)20cdb 40°05'57" 111°58'14"	(D-8-3)3dca 40°08'53" 111°35'14"	(D-8-3)21bba 40°06'50" 111°36'45"	(D-8-3)22cab 40°06'25" 111°35'25"	(D-6-1)30baa 40°16'28" 111°53'18"
Temp.	°C	18	25	11	16	15	38
pH		7.34	7.31	7.06	7.47	7.12	7.35
TDS	mg/l	1840	776	300	260	280	1790
HCO_3	mg/l	217	334	351	334	301	351
Na	mg/l	369	125	13	15	12	260
K	mg/l	20	11	u	3	3	26
Ca	mg/l	119	78	76	52	58	236
Mg	mg/l	54	36	26	24	24	59
Fe	mg/l	u	u	0.04	0.29	0.62	u
SiO_2	mg/l	49	11	1	21	16	17
Sr	mg/l	1.64	1.05	0.21	0.23	0.28	5.34
Ba	mg/l	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u
Zn	mg/l	u	u	0.1	u	0.1	1.4
Li	mg/l	0.22	0.23	u	u	u	0.53
B	mg/l	0.3	0.3	u	u	u	0.6
F	mg/l	0.24	0.8	0.13	0.19	0.17	1.90
Cl	mg/l	650	210	10	8	14	460
SO_4	mg/l	277	94	36.9	19.5	26.6	499

Table 2. (continued)

Sample #		C-17	(THS)Thistle Hot Spring	(CE)Castilla Hot Spring (East)	(CW)Castilla Hot Spring (West)	(GWS)Goshen Warm Springs
Location		(C-5-1)24daa 40°21'58" 111°53'17"	(D-9-4)17 40°1'48" 111°30'42"	(D-9-4)18 40°2'16" 111°32' "	(D-9-4)18 40°2'18" 111°32' "	(D-10-1)8 39°57'30" 111°51'18"
Temp.	°C	15	50	36	36	21
pH		7.42	6.74	6.6	6.5	7.1
TDS	mg/l	140	3094	3640	7112	1298
HCO_3	mg/l	117	426	509	660	317
Na	mg/l	11	1117	970	1950	351
K	mg/l	u	22	70	117	20
Ca	mg/l	27	79	262	533	93
Mg	mg/l	11	13	43	81	37
Fe	mg/l	u	u	0.03	0.17	u
SiO_2	mg/l	7	42	31	35	22
Sr	mg/l	0.33	1.80	4.02	7.61	1.59
Ba	mg/l	u	u	u	u	u
Mn	mg/l	u	u	u	u	u
Zn	mg/l	u	u	0.2	2.30	u
Li	mg/l	u	0.17	0.63	1.32	0.17
B	mg/l	u	0.60	0.9	1.9	0.2
F	mg/l	0.28	1.40	2.9	2.6	1.0
Cl	mg/l	7.50	1300	2580	1035	1953
SO_4	mg/l	12.7	425	1516	984	95

Utah Valley from Salem north to Hardy (plate 1). Additionally, thermal water is evident throughout Goshen Valley. Three thermal wells are located in southern Goshen Valley immediately west of Long Ridge and the Long Ridge fault zone (plate 1; plate 2 in Part I). Goshen Warm Springs, located further to the northeast, is also located immediately west of this fault zone. Two isolated thermal wells (1 mi and 10 mi north of the town of Goshen) are also present in the valley. The Burgin Mine, west of Goshen Valley, also yields thermal water thought to migrate up the East Tintic thrust fault (Morris and Lovering, 1961).

Castilla Hot Springs (two springs) are located approximately 8 mi southeast of Spanish Fork, Utah (plate 1 and fig. 2). Temperatures measured at these two springs are 36^{o}C. A third spring, located approximately 3 mi further up the canyon, was discovered when the Thistle earthflow dammed the Spanish Fork River exposing the river bed below the slide. A small spring (here referred to as Thistle Hot Spring) was exposed in the river bed. The temperature of this spring was 50^{o}C. Small seeps ranging in temperature from 7.2 to 26.7^{o}C, were also noted in the stream bed from Thistle Hot Spring to the confluence with Diamond Fork Creek, a distance of approximately 1.7 mi (William Case, oral communication, May 16, 1983).

CHEMICAL ANALYSIS OF FLUIDS FROM SELECTED WELLS AND SPRINGS

Common Ion Analyses

Geochemistry can sometimes be an aid in identifying geothermal systems when temperatures do not reflect their existence. Geochemistry can also assist in evaluating identified systems with regard to recharge, flow paths, extent, and reservoir temperatures. For these reasons, chemical analyses were made on 68 water samples collected by the UGMS (table 2). Additionally, 28

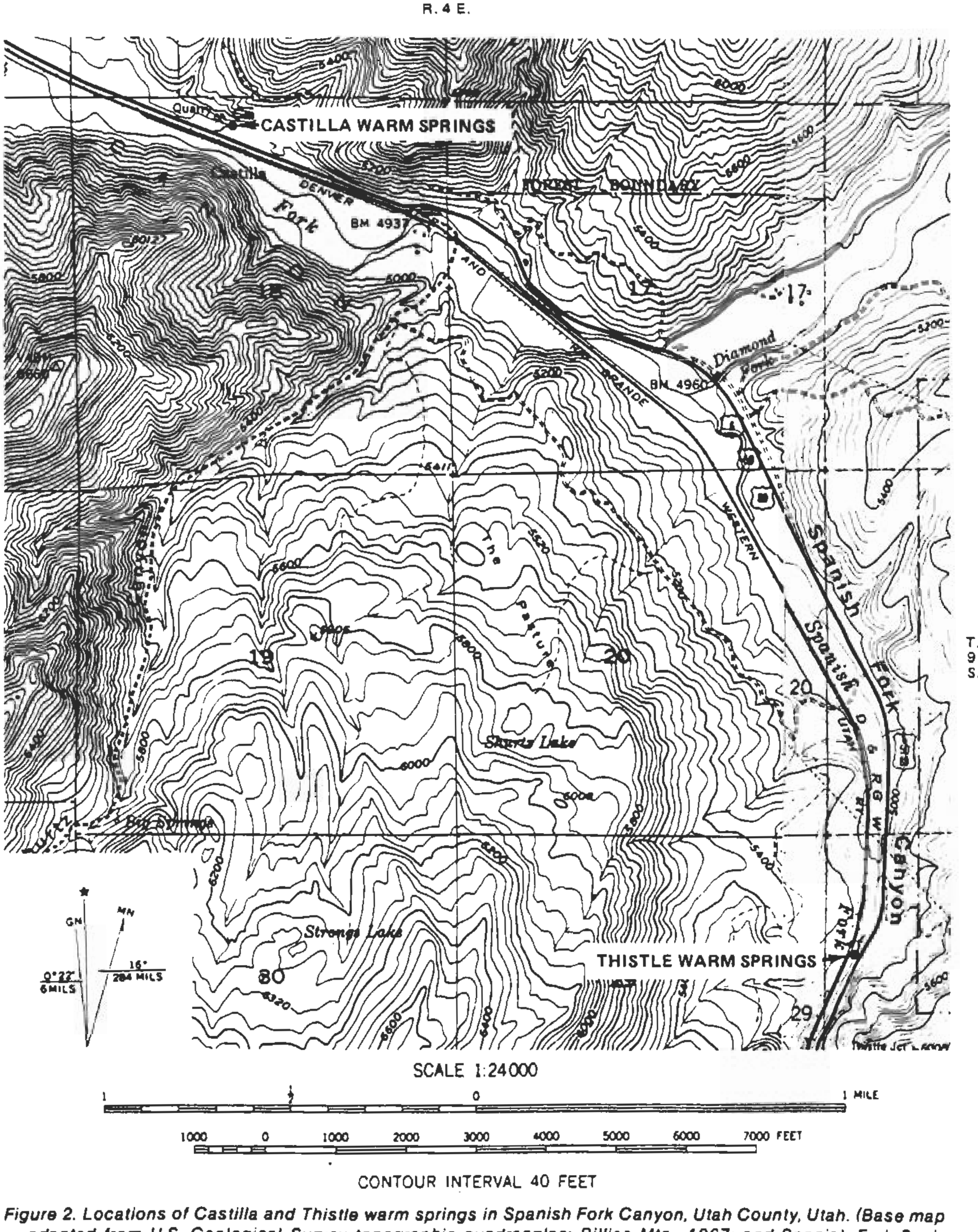

Figure 2. Locations of Castilla and Thistle warm springs in Spanish Fork Canyon, Utah County, Utah. (Base map adapted from U.S. Geological Survey topographic quadrangles: Billies Mtn., 1967; and Spanish Fork Peak, 1947.)

analyses were extracted from other reports (Cordova, 1969; Fairbanks, 1982; and U.S. Geological Survey Multiple Listing File, 1984). These analyses are presented in table 3 and locations are presented on plate 2.

For the purpose of analysis and discussion, three areas have been designated. These areas are: (1) northern Utah Valley, (2) southern Utah Valley, and (3) Goshen Valley.

Northern Utah Valley--The area designated in this study as northern Utah Valley extends from the Traverse Mountains south to Provo Bay and from the Wasatch Mountains west to the Lake Mountains (plate 2). Common ion analyses for samples from this area are presented in a trilinear diagram in figure 3. Data plotted in figure 3 indicate the presence of two water types designated A and B, which are generally separable by anion type.

Type A water is calcium-magnesium bicarbonate-chloride-sulfate (Ca-Mg HCO_3-Cl-SO_4), calcium-sodium bicarbonate-chloride-sulfate (Ca-Na HCO_3OCl-SO_4), and calcium-sodium bicarbonate (Ca-Na HCO_3) in character, slightly acidic to slightly basic, and dilute. This water is enriched in Ca and Mg with respect to other cations and HCO_3 with respect to other anions. Type A water is similar to recharge in the northern Utah Valley area; from the Wasatch Mountains to the shallow confined, deep confined, and deeper confined aquifer of Tertiary(?) age (Fairbanks, 1982).

Type B water includes three samples collected at Saratoga Hot Springs (SARA 1, 2, and 3), and one from Pelican Point area (C-15). This water is calcium-sodium chloride-sulfate-bicarbonate in character (Ca-Na Cl-SO_4-HCO_3), slightly acidic to slightly basic, and slightly saline with total dissolved solid (TDS) concentrations ranging from 1428 to 1790 mg/l. Type B water is enriched in Ca plus Mg and SO_4 with respect to other common

Table 3. Water analyses for wells and springs from other sources in Utah and Goshen valleys, Utah County, Utah.

Blanks indicate concentrations not present with analyses.

Sample #		1[1]	2[1]	3[1]	4[1]	5[1]	6[1]	7[1]	8[1]
Location		(D-4-2)8cad-s	(D-5-2)16dab-s	(D-5-1)12ccd	(D-5-1)23abc	(D-5-1)17cdd	(D-5-2)27baa	(D-4-2)18bdd	(D-4-1)33caa
Temp. °C		11	16	13	14	12	20	10	14
pH		7.7	7.3	6.8	7.2	8.2	7.7	7.6	7.6
TDS	mg/l								
HCO_3	mg/l	378	376	240	212	124	278	152	238
Na	mg/l	13.0	11.0	5.8	9.2	7.5	20.0	6.6	51.0
K	mg/l	0.9	0.7	4.6	1.1	1.0	1.1	1.6	4.4
Ca	mg/l	99.0	93.0	67.0	52.0	23.0	59.0	41.0	96.0
Mg	mg/l	41.0	39.0	35.0	24.0	9.9	26.0	4.7	42.0
Fe	mg/l								
SiO_2	mg/l	9.6	9.2	14.0	11.0	13.0	11.0	14.0	33.0
B	mg/l	0.02	0.02	0.03	0.01	0.05	0.04	0.01	0.04
F	mg/l	0.2	0.5	0.4	0.2	0.2	0.4	0.3	0.1
Cl	mg/l	13.0	9.3	5.3	7.6	7.9	18.0	4.3	160.0
SO_4	mg/l	130.0	81.0	89.0	63.0	6.0	59.0	13.0	120.0

[1]Fairbanks, 1982.

[2]Cordova, 1969.

[3]U.S. Geological Survey multiple station listing, 1984.

Table 3. (continued)

Sample #		9[1]	10[1]	[2]Bird Isl. Warm Spring (BIS)	[2]Lincoln Pt. Warm Spring (LPS)	64[2]	65[2]	67[2]	68[2]
Location		(D-4-1)35baa	(D-5-1)10bdd	(D-7-1)26cs	(D-8-1)3dda	(C-11-1)6bdd	(C-8-1)32bcb	(C-8-1)35dcb	(C-9-1)3ddb
Temp. ^oC		12	18	23.9-30.0	31.7	18.9	14.4	13.9	14.4
pH		7.3	7.0	7.8	7.6	8.2	7.6	7.3	7.6
TDS	mg/l			6644	6140	332	647	1130	781
HCO_3	mg/l	364	358	610	751	151	229	248	215
Na	mg/l	18.0	8.9	1840	1510	25	155	171	171
K	mg/l	2.7	4.4	159	159	6.6	15	27	15
Ca	mg/l	79.0	85.0	276	451	43	45	126	56
Mg	mg/l	22.0	29.0	114	136	15	21	43	22
Fe	mg/l								
SiO_2	mg/l	16.0	19.0		21				
B	mg/l	0.04	0.05	2.3	1.7				
F	mg/l	0.2	0.3		2.8				
Cl	mg/l	11.0	8.5	2912	2530	55	188	400	244
SO_4	mg/l	37.0	63.0	700	940	29	96	124	98

Table 3. (continued)

Sample #		69[2]	70[2]	71[2]	72[3]	73[2]	74[3]	75[2]	76[3]
Location		(C-9-1)20dcc	(C-9-1)27acc	(C-9-1)26cdd	(C-9-1)34ccc	(C-10-1)1acd	(C-10-1)3ddb	(C-10-1)6cbd	(C-9-1)18cbc
Temp. °C		13.9	19.4	11.7	17.5	12.8	19.5	12.2	14.5
pH		7.5	7.5	8.6	6.6	8.1		8.6	7.4
TDS	mg/l	462	793	971	860	766	890	904	1300
HCO_3	mg/l	170	168	214	240	318	240	268	270
Na	mg/l	108	61	232	93	185	100	212	210
K	mg/l	8.2	13	30	14	27	17	20	32
Ca	mg/l	34	87	34	110	44	120	45	110
Mg	mg/l	11	46	43	59	32	57	52	51
Fe	mg/l				0.04				
SiO_2	mg/l				65		63	64	
B	mg/l				0.17		0.19		
F	mg/l				0.20		0.20		
Cl	mg/l	105	237	345	300	238	320	358	470
SO_4	mg/l	84	82	102	100	77	100	31	110

Table 3. (continued)

Sample #		78[2]	79[2]	[2]Burgin Mine (BM)	[2]Goshen Town Spring (GTS)
Location		(C-10-1)32ccc	(C-10-1)33aba	(C-10-2)15ddd	(C-10-1)36dcb
Temp. $^{\circ}C$		20.0	20.0	54.4	
pH		8.0	8.4	8.0	7.6
TDS	mg/l	491	1780	6610	1017
HCO_3	mg/l	190	120	646	243
Na	mg/l	36	185	1930	106
K	mg/l	9.9	32	180	10
Ca	mg/l	73	180	327	127
Mg	mg/l	24	85	75	43
Fe	mg/l				
SiO_2	mg/l	62		35	38
B	mg/l	0.02		4.7	0.1
F	mg/l	0.5		2.2	0.3
Cl	mg/l	86	686	3310	270
SO_4	mg/l	55	155	404	128

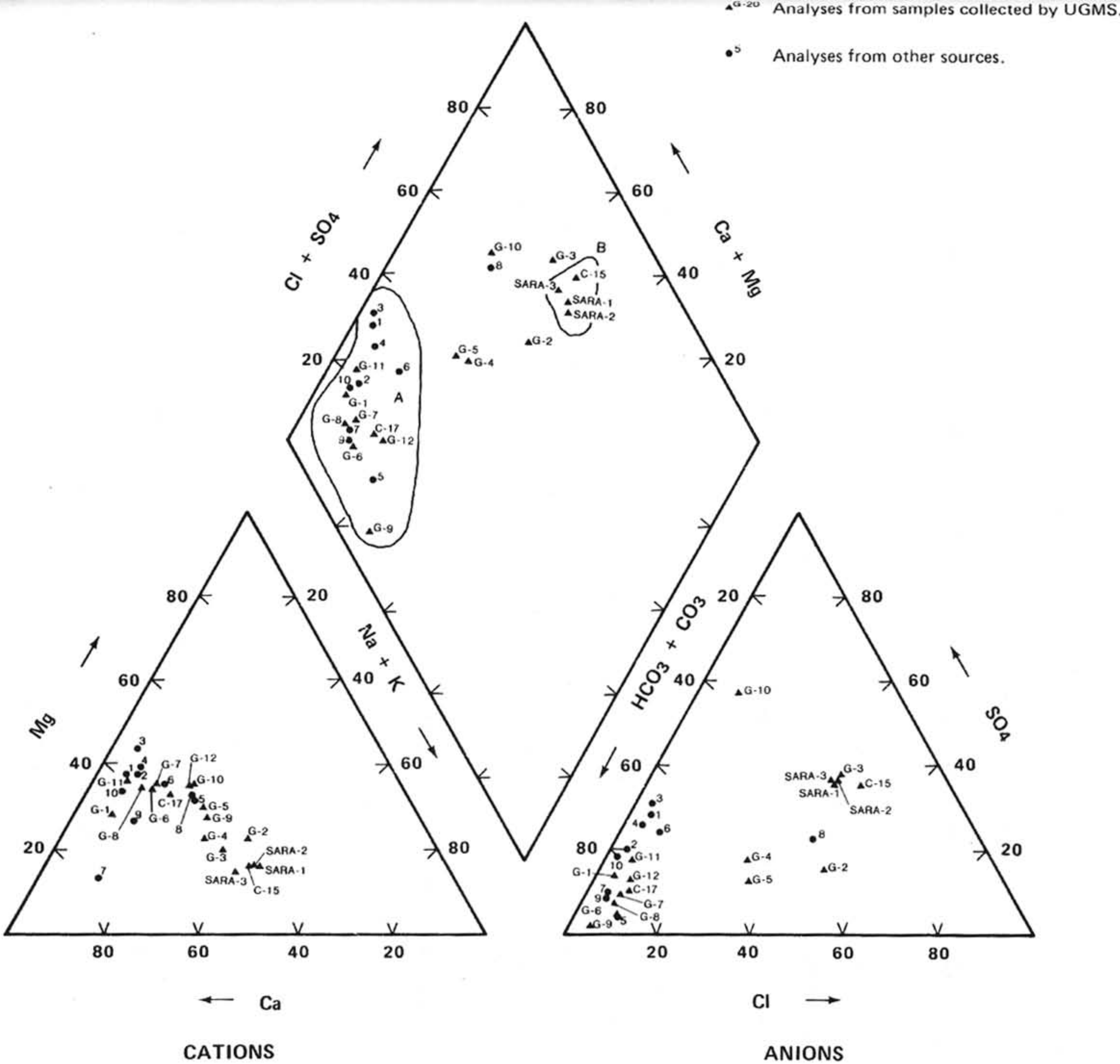

Figure 3. *Piper diagram of common ions from analyses for wells and springs in northern Utah Valley, Utah County, Utah. Chemical constituents are plotted as percentage of total milliequivalents. Letters indicate classification of water types.*

cations and anions, respectively. Total dissolved solids are considerably greater for type B water, which is reflected in higher concentrations of all common ions.

Samples G-2, G-3, G-4, G-5, G-10, and 8 are not included with type A or B water for northern Utah Valley. Samples G-4 and G-5 are calcium-sodium bicarbonate-chloride-sulfate (Ca-Na HCO_3-Cl-SO_4) in character, slightly basic, and dilute. With respect to common ions, these two samples are enriched in Ca plus Mg and HCO_3. Samples G-4 and G-5 are not included with type A water because of significantly more enrichment in Cl; Cl concentrations for type A range from 6.5 to 22 mg/l, whereas concentrations for G-4 and G-5 are 84 and 85 mg/l, respectively. Samples G-4 and G-5 are similar to waters Fairbanks (1982) has determined to be recharge from the Traverse Mountains. Samples G-2, G-3, G-10, and 8 are calcium-sodium chloride-sulfate-bicarbonate (Ca-Na Cl-SO_4-HCO_3) in character, neutral to slightly basic and dilute. These samples are differentiated from type B waters by low TDS concentrations.

Southern Utah Valley--Southern Utah Valley extends from Provo Bay south to, and including, Santaquin and east of West Mountain to the Wasatch Range. Samples collected at Thistle Hot Spring and Castilla Hot Springs are also included. Common ion analyses of samples from the southern Utah Valley are presented in figure 4. The data plotted in figure 4 indicate two major types of water are present. These waters have been designated as types A and B.

Type A water is calcium-sodium bicarbonate-chloride-sulfate (Ca-Na HCO_3-Cl-SO_4), calcium-magnesium bicarbonate-chloride-sulfate (Ca-Mg HCO_3-Cl-SO_4), and sodium-calcium bicarbonate-chloride-sulfate (Na-Ca HCO_3-Cl-SO_4) in character. This water is slightly basic and dilute, with

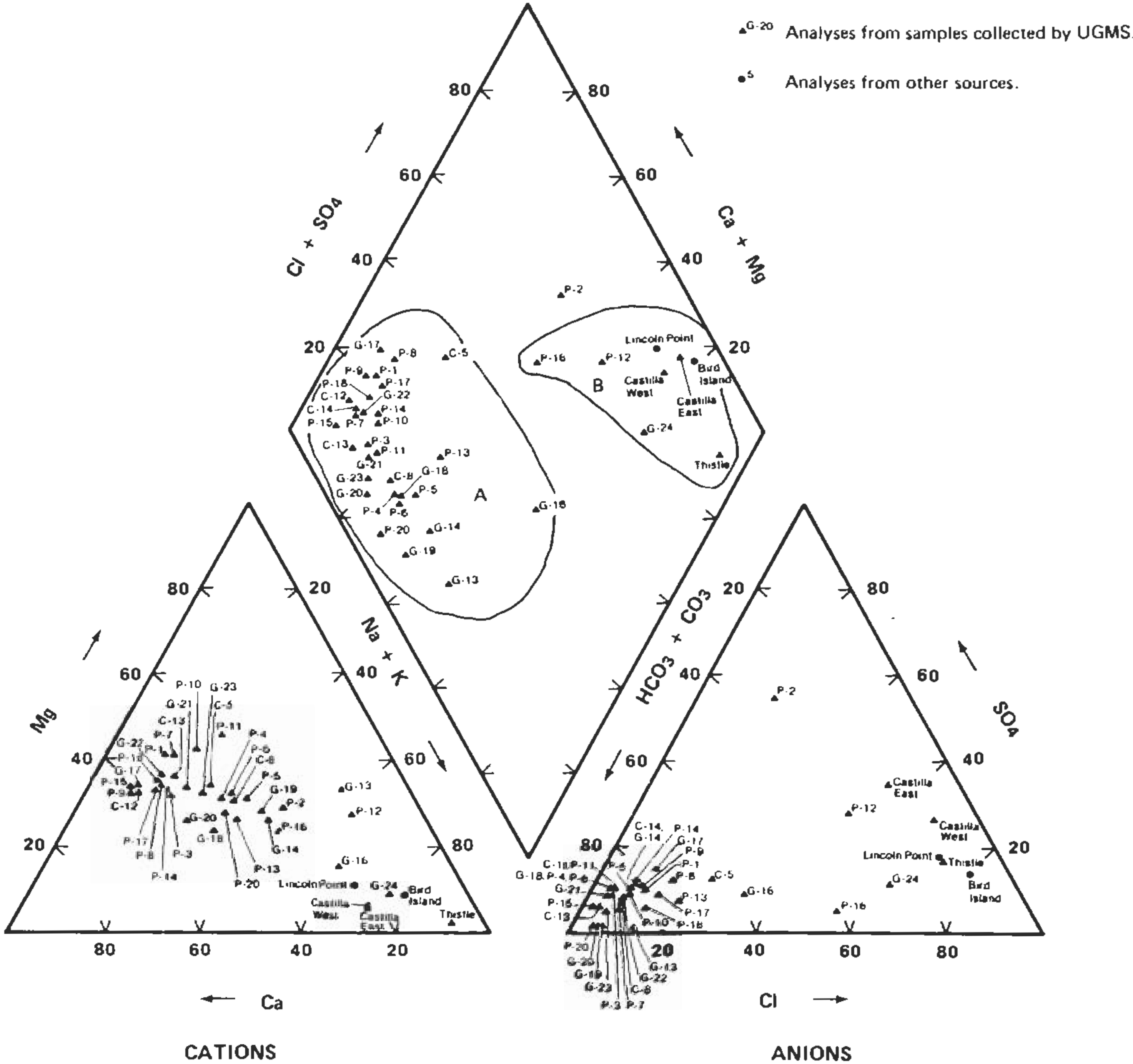

Figure 4. *Piper diagram of common ions from analyses for wells and springs in southern Utah Valley and Spanish Fork Canyon, Utah County, Utah. Chemical constituents are plotted as percentage of total milliequivalents. Letters indicate classification of water types.*

TDS concentrations ranging from 200 to 569 mg/l. This water type is primarily enriched in Ca with respect to other cations and HCO_3 to other anions.

Type B water includes Thistle and Castilla hot springs, Lincoln Point and Bird Island warm springs, and well locations P-12, P-16, and G-24 with temperatures of 21°, 23°, and 30°C, respectively. Type B water is sodium-calcium chloride (Ca-Ca Cl), sodium chloride-sulfate-bicarbonate (Na Cl-SO_4-HCO_3), and calcium-sodium chloride-sulfate-bicarbonate (Ca-Na Cl-SO_4-HCO_3) in character, slightly acidic to slightly basic, and dilute to moderately saline with TDS concentrations ranging from 580 to 7112 mg/l. All samples are enriched in Na with respect to other cations present. All samples, excluding P-12 and P-16, are enriched in Cl with respect to other anions; samples P-12 and P-16 are enriched in HCO_3 and SO_4, respectively. All type B water may to be thermally influenced; no sample has a temperature less than 21°C.

One additional sample, not included with the aforementioned water types, was collected in southern Utah Valley. Sample P-2 is calcium-sodium chloride-sulfate-bicarbonate (Ca-Na Cl-SO_4-HCO_3), slightly basic, and slightly saline with a TDS concentration of 1520 mg/l. Unlike sample P-16, however, P-2 is highly enriched in SO_4 and has a temperature of 14°C.

Goshen Valley--Common ion analyses presented in figure 5 for samples from Goshen Valley indicate ground water is primarily calcium-sodium chloride-sulfate-bicarbonate (Ca-Na Cl-SO_4-HCO_3) and sodium-calcium chloride-sulfate-bicarbonate (Na-Ca Cl-SO_4-HCO_3) in character. This water is slightly acidic to basic, and dilute to slightly saline with TDS concentrations ranging from 462 to 2920 mg/l. Waters are either enriched in Ca or Na with respect to other cations, whereas anion enrichment is commonly

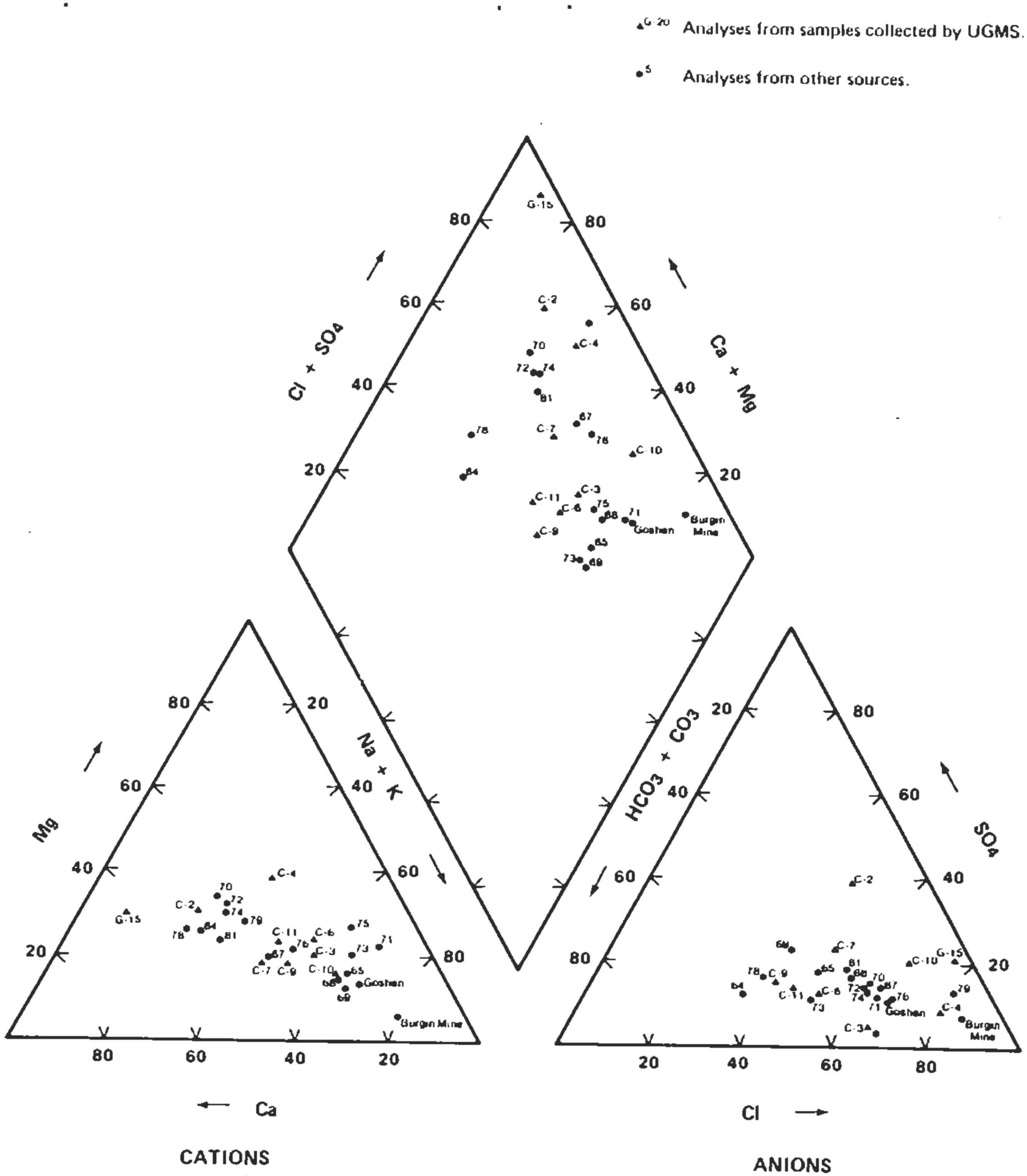

Figure 5. *Piper diagram of common ions from analyses for wells and springs in Goshen Valley and adjacent areas, Utah County, Utah.*

Cl; certain samples are enriched in either HCO_3 or Cl, however. Other samples collected are calcium-magnesium chloride (Ca-Mg Cl) (G-15), calcium-sodium chloride (Ca-Na Cl) (79), sodium-calcium chloride (Na-Ca Cl) (Burgin Mine), or calcium-sodium bicarbonate-chloride-sulfate (Ca-Na HCO_3-Cl-SO_4) (64) in character, slightly acidic to basic, and dilute to slightly saline with TDS concentrations ranging from 357 to 6610 mg/l.

Trace Elements and Other Geochemical Indicators

Trace element concentrations of Sr, Li, and B may be used for distinguishing thermal from non-thermal waters in Utah County. Individual concentrations of these elements appear to increase with either increasing temperature or increasing TDS and are considered anomalous when compared to individual concentrations from non-thermal samples within a particular area. Ratios of Cl/HCO_3, Cl/F, Na/Ca and Cl/B were also calculated for all samples in the study area. However, only definitive results were obtained with the Cl/HCO_3 ratio for southern Utah Valley.

Northern Utah Valley--Table 4 presents measured temperatures and trace element concentrations for northern Utah Valley waters. Concentrations of Li, B, and Sr may be useful, to a limited extent, for distinguishing thermal fluids. Lithium concentrations range from 0.31 to 0.53 mg/l for type B waters. Lithium concentrations, with the exception of G-3 (0.06 mg/l), are undetectable for all other samples, where reported. Boron concentrations range from 0.40 to 0.60 mg/l for type B waters. Concentrations for all other samples are 0.20 mg/l or less. Strontium concentrations for type B water range from 3.76 to 5.34 mg/l. Concentrations reported for other samples are not greater than 1.04 mg/l.

Table 4. Measured temperature, Li, B, and Sr concentrations for wells and springs in northern Utah Valley, Utah County, Utah

Sample No.	Temp (^{o}C)	Li (mg/l)	B (mg/l)	Sr (mg/l)
1	11		0.02	
2	16		0.02	
3	13		0.03	
4	14		0.01	
5	12		0.05	
6	20		0.04	
7	10		0.01	
8	14		0.04	
9	12		0.04	
10	18		0.05	
G-1	12	u	u	0.68
G-2	16	u	0.2	0.71
G-3	13	0.06	u	0.76
G-4	15	u	u	0.70
G-5	17	u	u	0.55
G-6	13	u	u	0.21
G-7	14	u	u	0.32
G-8	12	u	u	0.26
G-9	15	u	u	0.43
G-10	17	u	u	0.90
G-11	12	u	u	0.41
G-12	16	u	u	1.04
C-15	38	0.53	0.6	5.34
C-17	15	u	u	0.33
Sara 1	41	0.31	0.4	3.80
Sara 2	42	0.31	0.4	3.76
Sara 3	43	0.31	0.4	3.78

Blank indicates concentrations not present with analysis

U indicates concentrations, if present, are below the limits of quantitative detection for ICPQ analysis.

Southern Utah Valley--Table 5 presents measured temperatures, trace element and Cl concentrations, as well as Cl/HCO_3 ratios for wells and springs in southern Utah Valley and Spanish Fork Canyon. As with northern Utah Valley, some trace element concentrations may be indicative of thermal waters. The greatest concentrations of Sr (0.96 to 7.71 mg/l) are associated with those thermal samples included in type B water in figure 4. The greatest concentration of Sr in water not included with type B is 0.94 mg/l (C-5).

Lithium and B concentrations are greatest in type B waters. Concentrations of Li for these waters range from 0.07 to 1.32 mg/l. With the exception of G-16 (0.13 mg/l), concentrations for all remaining samples range from undetectable (less than 0.05 mg/l) to 0.08 mg/l. Boron concentrations for type B water range from 0.2 to 1.9 mg/l. With the exception of P-2 (0.4 mg/l), all other samples have B concentrations 0.3 mg/l or less.

Chloride concentrations in southern Utah Valley and vicinity may also be indicative of thermal waters. Concentrations for those samples included with type B water range from 180 to 2580 mg/l. Concentrations for all remaining samples range from 7 to 140 mg/l.

The Cl/HCO_3 ratio may also indicate the presence of thermally influenced water. Ratios for type B water range from 1.32 to 10.60. For all remaining samples, ratios range from 0.04 to 0.63. A plot of temperature versus Cl/HCO_3 ratios, presented in figure 6, illustrates the anomalous ratios calcuated for type B waters.

Goshen Valley--Strontium, Li, B, and Cl concentrations for samples collected and analyzed from Goshen Valley present no trends indicative of

Table 5. Measured temperatures, Cl/HCO_3 ratios, Li, B, Sr, and Cl concentrations for wells and springs in southern Utah Valley and Spanish Fork Canyon, Utah County, Utah

Sample No.	Temp(^oC)	Cl/HCO_3	Li(mg/l)	B(mg/l)	Sr(mg/l)	Cl(mg/l)
C-1	11	0.07	u	u	0.16	13
C-5	17	0.44	u	u	0.94	140
C-8	13	0.08	u	u	0.22	13
C-12	11	0.05	u	u	0.21	10
C-13	16	0.04	u	u	0.23	8
C-14	15	0.08	u	u	0.28	14
G-13	15	0.16	0.05	0.3	u	34
G-14	24	0.09	u	u	.35	15
G-16	18	0.56	0.13	0.2	0.38	75
G-17	15	0.17	u	u	0.47	28
G-18	15	0.07	u	u	0.3	8.5
G-19	15	0.08	u	u	0.43	13
G-20	17	0.06	u	u	0.52	11
G-21	17	0.07	u	u	0.55	12
G-22	16	0.09	u	u	0.41	15
G-23	18	0.06	u	u	0.52	9.5
G-24	30	2.45	0.38	0.7	2.02	680
P-1	15	0.14	u	u	0.45	21
P-2	14	0.63	0.08	0.4	0.94	140
P-3	13	0.08	u	u	0.33	10
P-4	18	0.07	u	u	0.24	8.5
P-5	18	0.09	u	u	0.28	12
P-6	15	0.07	u	u	0.26	8.2
P-7	14	0.10	u	u	0.34	15
P-8	13	0.23	u	u	0.35	44
P-9	14	0.14	u	u	0.30	30
P-10	20	0.10	u	u	0.46	15
P-11	16	0.06	u	u	0.55	11
P-12	21	1.70	0.20	0.4	1.32	280
P-13	15	0.28	u	u	0.69	70
P-14	14	0.10	u	u	0.30	26
P-15	13	0.04	u	u	0.12	7
P-16	23	1.32	0.07	0.2	0.96	180
P-17	17	0.26	u	u	0.23	38
P-18	19	0.18	u	u	0.21	28
P-19	20	0.19	u	0.2	0.69	55
P-20	14	0.05	u	u	0.38	9
THS	50	5.25	0.17	0.60	1.80	1300
CE	36	3.50	0.63	0.9	4.02	1516
CW	36	6.72	1.32	1.9	7.81	1035
LPS	31.7	5.79		1.7		2530
BIS	23.9-30.0	7.13		2.3		2912

Blank indicates concentration not present with analysis

U indicates concentrations, if present, are below the limits of quantitative detection for ICPQ analysis.

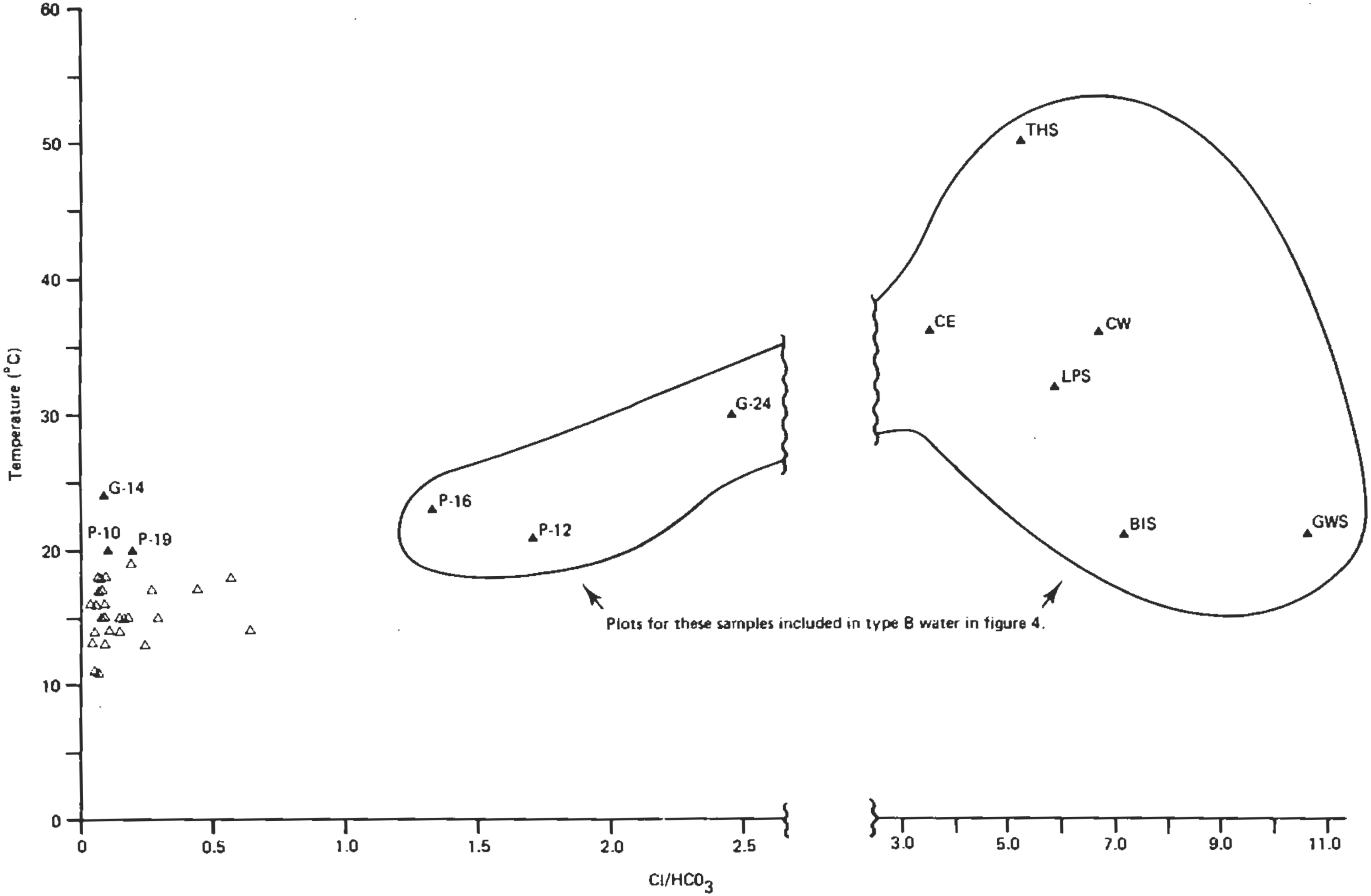

Figure 6. *Temperature versus Cl/HCO$_3$ ratios for well and spring samples from southern Utah Valley, Utah County, Utah.*

thermal waters. Furthermore, Cl/HCO_3, Cl/F, Na/Ca, and Cl/B ratios provide no definitive results.

DISCUSSION

Five areas are identified as warranting further investigation for low-temperature geothermal resources. The areas in northern and southern Utah valleys are in the immediate vicinity of the Utah Valley fault zone. Previously, Cleary (1978), based on geothermometer results, identified the Goshen Valley as warranting investigation for possible geothermal resources. The current investigation provided additional temperatures for a number of wells, some of which are in the vicinity of the Long Ridge fault (plate 2 in Part I). However, no correlation between temperatures and chemical analyses is evident, and no local target areas for further exploration have been identified.

The target area in northern Utah Valley are along the Utah Valley fault zone and includes Saratoga Hot Springs (plate 2). Wells and springs in this zone are included with type B water in figure 3. Temperatures of thermal samples in this zone range from 21 to 43°C. Furthermore, Li, B, and Sr concentrations are significantly greater for thermal samples.

Ten wells and springs have temperatures 20°C or greater in southern Utah Valley. However, only samples from five of these wells and springs provide chemical concentrations which may be indicative of higher temperatures at depth. All five samples are included with type B water in figure 4. These samples are located in two distinct areas, both being in the vicinity of the Utah Lake fault zone. The southernmost area includes well samples G-24 and P-16 and is in the vicinity of other thermal wells which do not exhibit anomalous chemistry. Strontium, Li, B, and Cl concentrations for G-24 and

P-16 are significantly greater than for all other samples (both thermal and non-thermal) in this part of southern Utah Valley. Additionally, the Cl/HCO_3 ratios distinguish G-24 and P-16 from other samples in the area.

A second area in southern Utah Valley includes Lincoln Point and Bird Island warm springs and well P-12. The springs were not located in the field, possibly due to Utah Lake flooding, but chemical analyses were available from other sources. All three analyses are included with type B water in figure 4. Strontium and Li concentrations were not available for Lincoln Point and Bird Island warm springs. However, concentrations for P-12 are much higher than concentrations for other wells in the vicinity (P-10, P-11, and G-19). Boron and Cl concentrations for P-12, Bird Island, and Lincoln Point warm springs are also significant when compared to P-10, P-11, and G-19. Furthermore, Cl/HCO_3 ratios identify this area as being anomalous.

Although the areas discussed are in different locations, all are in the immediate vicinity of the Utah Lake fault zone. Previous studies conducted throughout the Wasatch Front indicate low-temperature thermal systems along the front are convective, involving deep circulation of meteoric water. It appears that low-temperature thermal anomalies in the study area are also heated by deep circulation. Structure plays a significant role in these systems by providing the necessary conduits. All three of these designated thermal areas are considered to be controlled by the Utah Lake fault zone. Gravity modeling in Part I indicates depth to bedrock below the thermal areas is generally less than 2000 feet; this depth is much less beneath warm springs. Figure 7 presents a general model for these systems. This model involves meteoric water migration to depth, being warmed by the normal thermal gradient, and subsequently rising along the Utah Lake fault zone, coming into contact with a near-surface cold-water aquifer where mixing occurs and reduces

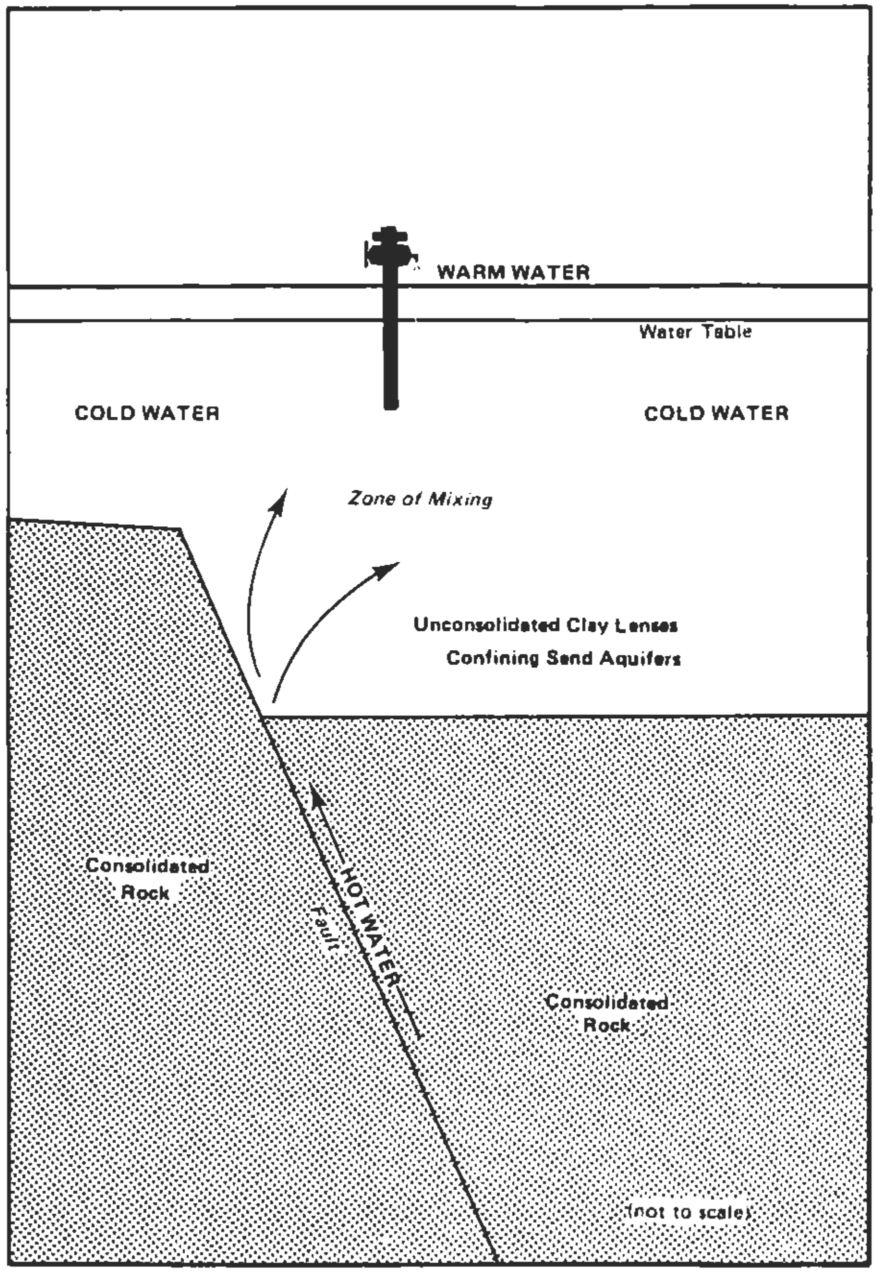

Figure 7. *Model depicting general convective system within the vicinity of the Utah Lake fault zone, Utah County, Utah.*

the temperature of the convecting water. Recharge to this system may be from the Wasatch Range to the east, or the Lake and/or Tintic Mountains to the west.

An expanded thermal area has been identified in Spanish Fork Canyon. Castilla Hot Springs was previously known and is located approximately 3 mi from the mouth of Spanish Fork Canyon. However, subsequent to the damming of the Spanish Fork River by the Thistle earthflow, a series of small, warm seeps and one spring were noted in the riverbed. The spring is located approximately 3 mi further up the canyon, immediately below the slide. This spring is referred to as Thistle Hot Spring and was sampled as part of this study. Chemically, Thistle is very similar to Castilla Hot Springs. Both samples collected at Castilla and the sample collected at Thistle are included with type B water in figure 2. Both springs being similar chemically may indicate a common reservoir is supplying both. Furthermore, this may indicate Spanish Fork Canyon is fault controlled, with the fault providing the conduit allowing the warm water to reach the surface.

Thermal water is widespread in Goshen Valley. Temperatures ranging from 20 to 27^{o}C were either measured by UGMS for this study or were reported in the literature by previous investigators. Furthermore, Cleary (1978) suggests that water as warm as 180^{o}C may exist at depth in this valley based on Na-K-Ca and SiO_2 geothermometers. Apart from Goshen Warm Springs and the Burgin Mine in the East Tintic Mountains, however, chemical analyses for samples collected in the valley do not clearly differentiate thermal from non-thermal waters. Goshen Warm Springs lies along the Long Ridge fault within a band of closely spaced gravity contours as reported in Part I. Modeling presented in Part I indicates Goshen Valley is a graben comprised of several large structural blocks as well as small structural blocks which are complexly faulted and tilted. Thus, the many faults associated with these blocks may form adequate conduits for the upward migration of thermal waters from depth which eventually mix with near-surface aquifers. This mixing may significantly alter the chemical concentrations of these thermal waters, thereby masking certain thermal characteristics and any geothermal system that may underlie Goshen Valley. A second explanation suggests thermal waters are leaking into the near surface aquifers throughout the Goshen Valley.

CONCLUSIONS

Five potential low-temperature geothermal resource areas are identified in Utah County. One area follows the general strike of the Utah Lake fault zone in northern Utah Valley. Two other areas, located in southern Utah Valley, are also in the vicinity of this fault zone. The discovery of Thistle Hot Spring and its chemical similarity with Castilla Hot Springs may indicate a common system. Warm water occurs in several areas of Goshen Valley, but distinguishable local warm areas are not identified in this study. It appears that all five thermal areas result from deep circulation of meteoric water which eventually convect to the surface or near surface through permeable conduits, such as fault zones.

All areas discussed have low-temperature geothermal characteristics. However, more site-specific exploration must be conducted to better determine the structural controls on each system, as well as the size, depth, chemistry, permeability, and temperatures of the reservoirs. This study is limited in scope and only geothermal anomalies in the near-surface unconsolidated aquifers are identified. The absence of evidence does not eliminate, however, the possibility additional resources exist. Further exploration may establish a deep resource(s) heretofore not identified.

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Appendix A
Well- and Spring-Numbering System

APPENDIX A

WELL- AND SPRING-NUMBERING SYSTEM

The system of numbering wells and springs in Utah is based on 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-hm^2); the quarters of each subdivision 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-hm^2) tract; the letter "S" preceding the serial number denotes a spring. Thus (C-36-16) 36abd-1 designated the first well constructed or visited in the SE1/4 SE1/4 NE1/4 sec. 36, T. 36 S., R. 16 W. If a well or spring cannot be located within a 10-acre (4-hm^2) 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 A1.

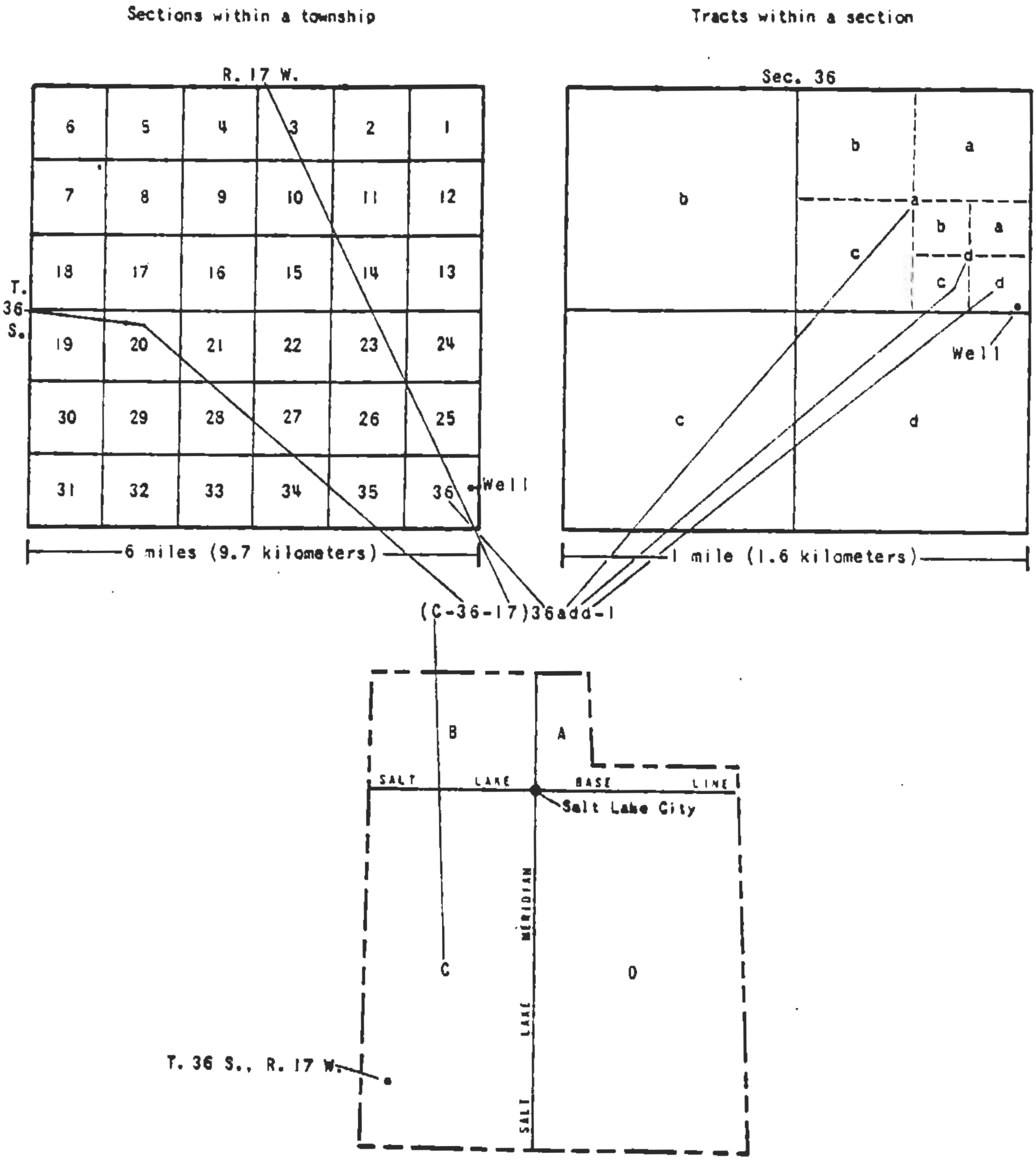


Figure A-1. Well-, and spring-, and other data site-numbering system used in Utah.

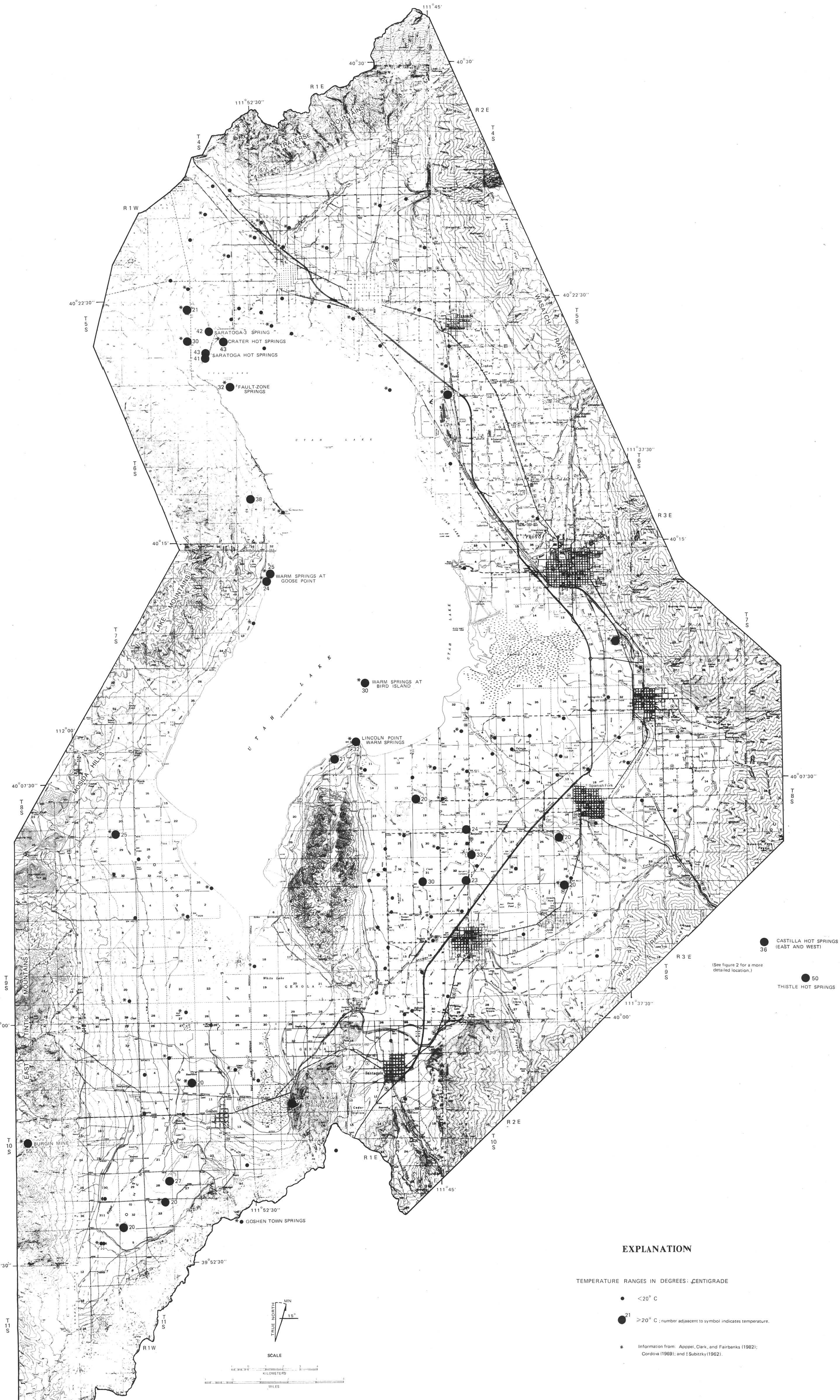
Appendix B
Conversion Factors

CONVERSION FACTORS

Water temperatures are reported in degrees centigrade (^{o}C) in this report. Water temperatures can be converted from (^{o}C) to (^{o}F) by the following equation: $^{o}F = 1.8\ (^{o}C) + 32$.

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

GROUND-WATER TEMPERATURE MAP FOR UTAH AND GOSHEN VALLEYS AND ADJACENT AREAS, UTAH



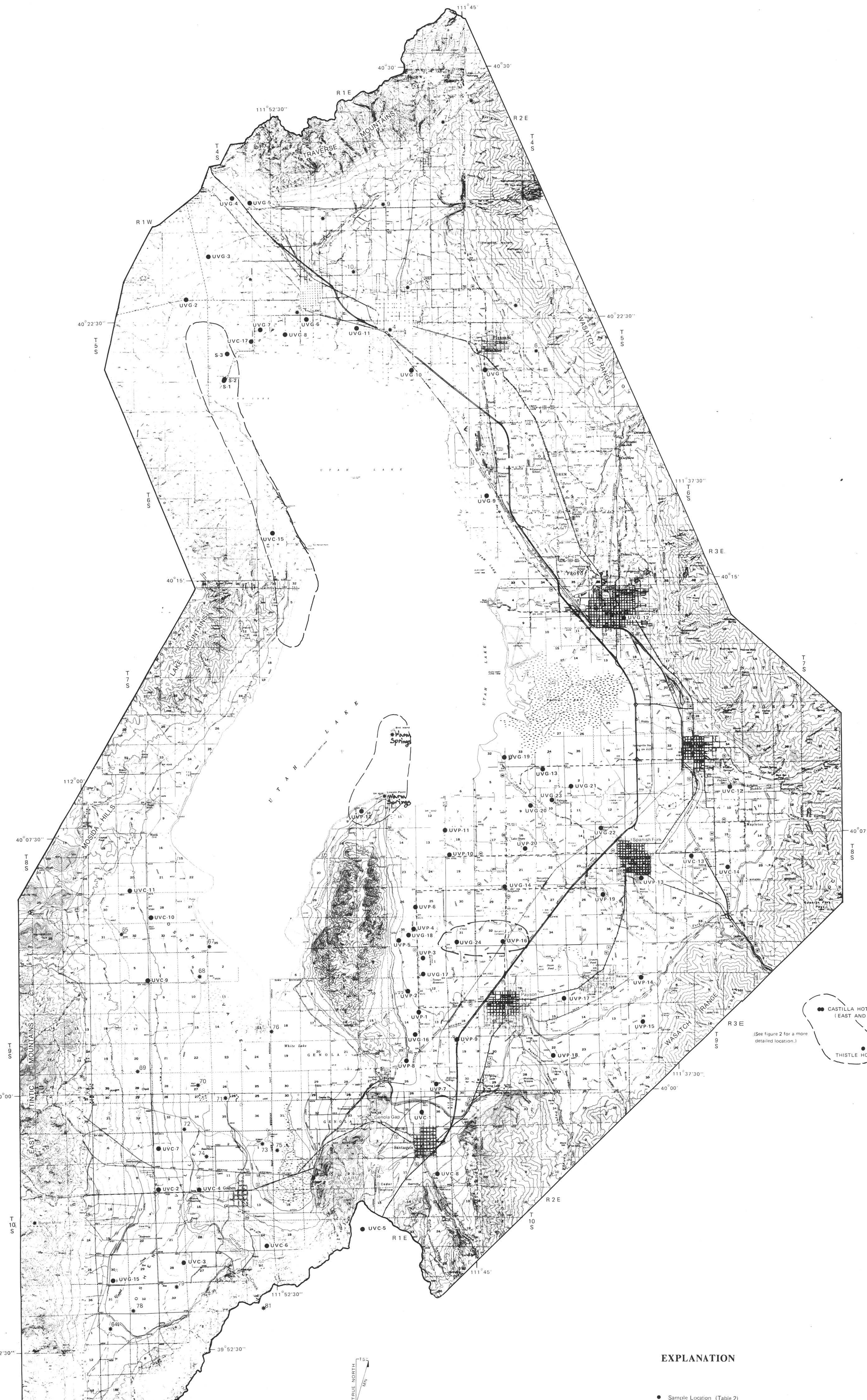
EXPLANATION

TEMPERATURE RANGES IN DEGREES CENTIGRADE

- • <20° C
- ● 21 ≥20° C ; number adjacent to symbol indicates temperature.
- * Information from: Apppel, Clark, and Fairbanks (1982); Cordova (1969); and Subitzky (1962).

BASE MAP: COMPOSITE OF U.S. GEOLOGICAL SURVEY 7½ MINUTE QUADRANGLE MAPS OF UTAH AND GOSHEN VALLEYS AND VICINITY.

WELL AND SPRING SAMPLE LOCATIONS IN UTAH AND GOSHEN VALLEYS AND ADJACENT AREAS, UTAH



EXPLANATION

- ● Sample Location (Table 2)
- • Sample Location (other sources - Table 3)
- ◯ Potential Low-temperature Geothermal Resource Area

SCALE

BASE MAP: COMPOSITE OF U.S. GEOLOGICAL SURVEY 7½ MINUTE QUADRANGLE MAPS OF UTAH AND GOSHEN VALLEYS AND VICINITY.