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GEOTHERMAL RECONNAISSANCE OF A PORTION OF THE ESCALANTE VALLEY, UTAH

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Introduction

In February, 1981, the Utah Geological and Mineral Survey contracted with the Department of Energy to evaluate geothermal potential in the Escalante Valley region of Utah, an area proposed for a possible 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.

Physiographic Setting

The Escalante Valley is a typical Basin and Range valley encompassing an area of 2080 km^2 in Iron 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 40 km to the east. Principal communities within the valley include New Castle, Beryl Junction, and Modena; Lund, Beryl and Zane, small communities located along the Union Pacific Railroad, are also found in the study area. In addition, Thermo Hot Springs KGRA is situated in the valley.

Temperature Survey

Temperatures ranging from 12 to 78°C were recorded at 53 wells and springs in the study area (Figure 2). All water wells measured were less than 125 meters in depth. Excluding four temperatures recorded at Thermo Hot Springs (42 to 78°C) and a 60°C temperature recorded at a 3658 meter geothermal test well 9.5 kms southwest of Zane, all temperatures of 20^{0}C or greater were recorded northwest of the Union Pacific railroad line (Figures 2 and 3). Of those temperatures above 20^{0}C, the warmest (27 and 28^{0}C) are located northwest of Zane.

Chemical Survey

Forty-nine chemistry samples were collected and analyzed as part of this study (Figure 3). Results of the analyses are presented in Table 1. Total dissolved solids ranged from 276 to 5360 ppm. The distribution of these values are presented in Figure 4. Areas of relatively high total dissolved solids (greater than 1400 ppm) were found primarily in the vicinity of Zane (samples EV-115 through EV-119 and EV-150) and seem to have no correlation with distance from recharge areas (Figure 5). The total dissolved solids in this area are similar to total dissolved solids measured at Thermo Hot Springs (samples EV-151 through EV-154) (Figure 4).

Common ion analyses grouped by area are presented in the form of trilinear plots in Figures 6 through 13. A composite of all samples is presented in a trilinear plot in Figure 14. Sample compositions tend to cluster into three groups with respect to cations (Figure 14). Two groups are located near the Na + K apex and include samples EV-117, EV-118, EV-119, EV-150, EV-151, EV-152, EV-153, EV-154, EV-111, and EV-121. The remainder of the samples fall into a third group which has a relatively wide range of chemical compositions. With respect to anions, Thermo Hot Springs samples and the samples from the Zane area are each tightly clustered and, with the exception of EV-115, primarily located within the central portion of the trilinear plot (Figures 8 and 13). The result of these trilinear plots indicates the fluids sampled can be classified into three groups (Figure 14). Group one consists of all samples collected at Thermo Hot Springs while group two contains samples

EV-117 through EV-119 and EV-150 collected northwest of Zane. Group three is comprised of all other samples collected with the exceptions of EV-111 and EV-121 which do not fit into the aforementioned classifications. Sample EV-111 was collected from a geothermal test well 3658 meters deep which could explain the anomalous chemistry since all other samples were collected from shallow water wells (less than 125 meters in depth) or springs. At present, an explanation for the chemistry of sample EV-121 has not been determined.

Geothermometry

Chemical geothermometers were calculated for all chemistry samples collected in the Escalante Valley. Quartz (conductive), Chalcedony and Sodium-Potassium-Calcium (Na-K-Ca) geothermometers were used. Equations used and results obtained are presented in Table 2. The reliability of geothermometers depends on five assumptions which are applicable to both the silica and Na-K-Ca techniques (Fournier et al, 1974).

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 re-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.

Figure 15, a plot of observed temperatures versus Na-K-Ca geothermometer temperatures, indicates mixing has occurred in all samples tested. This, in addition to the lack of substantial proven low to moderate temperature geothermometer results, prompted only qualitative use of the results of this technique.

Na-K-Ca computed temperatures, with the exceptions of those samples collected at Thermo Hot Springs (EV-151 through EV-154), those samples (EV-118, EV-119, and EV-150) collected northwest of Zane and the sample (EV-111) from the geothermal test well (3658 meters in depth) varied from 28 to 68^{O}C (Table 2). Computed reservoir temperatures for EV-118, EV-119, and EV-150 were 94, 91 and 97^{O}C, respectively, indicating a possible geothermal anomaly. The four Thermo Hot Springs samples ranged from 120 to 127^{O}C while the geothermal test well value was 107^{O}C.

Fournier (1977) suggests that if the Na-K-Ca thermometer indicates a temperature of less than 100^{O}C, the silica temperature content of the water is a function of chalcedony solubility. For temperatures greater than 100^{O}C, the silica temperature should be calculated assuming the silica content is a function of quartz solubility. Both calcuations are presented in Table 2.

The chalcedony temperatures vary from 10 to 80^{O}C for all samples collected with Na-K-Ca geothermometer temperatures less than 100^{O}C. Four of the remaining five samples with Na-K-Ca temperatures greater than 100^{O}C were from Thermo Hot Springs. Quartz (conductive) geothermometer temperatures for these samples ranged from 128 to 131^{O}C, and correlated extremely well with the Na-K-Ca temperatures for the hot springs. The remaining sample with a Na-K-Ca temperature greater than 100^{O}C, from the geothermal test well, yielded a quartz (conductive) temperature of 106^{O}C, just 1^{O}C less than the computed Na-K-Ca temperature.

Temperature-Depth Measurements

Temperature-depth measurements in the Escalante Valley were completed in 22 "holes of opportunity." These holes consisted primarily of shallow abandoned water wells but included PVC cased holes from geotechnical investigations for the MX project and uncased mineralogical test holes. The background gradient in the valley, as determined by Clement and Chapman (1981), is 56.4^{0}C km^{-1}. Comparison of the temperature-depth measurements conducted for this study with the 56.4^{0}C background gradient indicates that at least two areas of elevated temperature exist in that portion of the Escalante Valley investigated.

In the first area, located north of the Union Pacific railroad tracks in the vicinity of Beryl and Zane, four temperature-depth measurements were conducted (EVG-1, EVG-2, EVG-3, and EVG-4) (Figures 16 and 17). A gradient of 138^{0}C km^{-1} was determined for EVG-4 which is congruous with a gradient of 132^{0}C km^{-1} determined in hole LD-1 by Clement and Chapman (1981) (Figure 16). A 70^{0}C km^{-1} gradient calculated for EVG-3 is in agreement with EVG-1 as well as ED-8 from Clement and Chapman (1981) which have gradients of 78^{0}C km^{-1} and 57^{0}C km^{-1}, respectively (Figure 16). Due to the shallow depth of EVG-2, the gradient calculated (46^{0}C km^{-1}) is only tentative, but its trend 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-7, EVG-8, EVG-9, and EVG-10 (Figure 16); gradients calculated are 114^{0}C km^{-1}, 60^{0}C km^{-1}, 63^{0}C km^{-1} and 114^{0}C km^{-1}, respectively (Figure 18). Locations EVG-7 and EVG-8 indicate ground water disturbance in the upper portions of the profiles and, therefore, calculated gradients are, to some extent, suspect.

Other temperature-depth profiles measured in the Escalante Valley either indicate disturbances due to ground-water flow or have gradients less than background. Locations of these profiles are presented in Figure 16 and the profiles themselves are presented in Figures 19 and 20.

Summary and Conclusions

Geothermal reconnaissance techniques used in the Escalante Valley have identified an area, in addition to Thermo Hot Springs, warranting further investigation as a low to moderate temperature geothermal resource. This area is northwest of Zane and is generally depicted by the locations of samples EV-118, EV-119 and EV-150 (Figure 3).

Measured water temperatures at these three sample locations ranged from 20 to 28^{o}C with total dissolved solids ranging from 1556 to 1730 ppm. Total dissolved solids measured at Thermo Hot Springs varied from 1495 to 1564 ppm. Trilinear plots of common ions delineate three groups, two of which are composed of samples from Thermo Hot Springs and the Zane area (EV-117, EV-118, EV-119, and EV-150). These two groups are very similar, especially with respect to cation composition.

The Na-K-Ca geothermometer temperatures for EV-118, EV-119, and EV-150 ranged from 91 to 97^{o}C; the temperatures computed for the remainder of the samples except for EV-151 to EV-154 (Thermo Hot Springs) and EV-111 (geothermal test well) ranged from 28 to 68^{o}C. Silica geothermometer temperatures indicated no anomalous values northwest of Zane which could be due to high silica contents in the rocks constituting the aquifer.

Temperature-depth measurements identified two areas, other than Thermo Hot Springs, of elevated temperature in the portion of the valley investigated. One is the area northwest of Zane. The highest gradient calculated is 138^{o}C km^{-1} which is more than double the background gradient. This temperature-depth profile is approximately 2 km southwest of sample location EV-150 with a recorded surface temperture of 28°C. The second area of elevated temperature is located approximately 5 km south of Beryl. However, two of the four gradients calculated for this area are suspect due to possible ground-water flow disturbance and none of the other exploration techniques employed in this investigation depict a possible geothermal resource in this area.

Further Study

The exploration techniques used in this study indicate a 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 to be expected.

References Cited

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TABLE 1

	COORDINATES LAT. LONG.	CADASTRAL COORDINATES	SAMPLE NUMBER	TEMP. °C	DEPTH (FEET)	DATE OF SAMPLE	ANALYSIS EXPRESSED AS PARTS PER MILLION (PPM) SiO_2	Fe	Ca	Mg	Na	K	HCO_3^-	SO_4	Cl	F	Dissolved Solids	COND. mmhos	pH	Salinity PPM	OTHER IONS OR REMARKS
	37°42'03" 113°41'00"	(C-36-16)6adc	EV-105	14		10-02-81	44	0.04	123	23	19	7	253	43	131	0.3	536	710	7.45	300	Sr=0.66
	37°43'04" 113°40'03"	(C-35-16)32bdb	EV-106	16		10-02-81	43	0.06	53	10	14	5	199	14	38	0.5	288	327	7.80	150	Sr=0.31
	37°44'38" 113°39'13"	(C-35-16)21bcc	EV-107	14	276	10-02-81	41		76	15	15	5	260	30	55	0.3	416	351	7.65	0	Sr=0.38
	37°44'13" 113°38'45"	(C-35-16)21dcc	EV-108	14	300	10-02-81	41	0.03	60	12	14	4	208	20	43	0.3	330	318	7.85	0	Sr=0.29, Zn=0.2
	37°50'09" 113°42'18"	(C-34-17)24bac	EV-109	17		10-03-81	54	0.14	68	9	21	8	177	58	20	0.6	318	365	7.90	0	Sr=0.43, Zn=0.4, Li=0.06
	37°46'36" 113°37'03"	(C-34-16)9aad	EV-110	12		10-05-81	41	0.13	118	20	18	6	218	49	118	0.3	604	444	7.55	100	Sr=0.50, Zn=0.6
	37°50'42" 113°37'42"	(C-34-16)22baa	EV-111	60		10-05-81	54	0.06	5	0.5	125	3	245	40	26	34	446	1280	9.10	300	W=0.2, Li=0.16, B=5.3
	37°48'34" 113°39'14"	(C-34-16)28dcc	EV-112	12	148	10-05-81	50	0.04	138	27	32	9	172	105	212	0.7	884	870	7.35	350	Sr=0.98, Zn=0.3, B=0.1
	37°48'34" 113°39'15"	(C-34-16)28ccc	EV-113	14	291	10-05-81	56	0.07	45	9	29	7	179	26	46	1.5	322	337	8.00	50	Sr=0.40
	37°49'13" 113°37'03"	(C-34-16)28bac	EV-114	14		10-05-81	55	0.03	41	9	33	7	176	29	42	1.6	344	348	7.75	0	Sr=0.42
N ⊗	37°54'39" 113°35'47"	(C-33-16)25bab	EV-115	15		10-16-81	50	0.10	693	131	585	30	210	1229	1674	1.9	5360	4210	6.99	2500	Sr=8.28, Li=1.02, B=1.2, Ti=0.1 Zn=0.2
M ⊗	37°55'29" 113°34'42"	(C-33-15)19bba	EV-116	16	141	10-16-81	45	0.21	186	30	204	12	277	382	346	1.5	1490	1630	7.69	500	Sr=1.13, Li=0.24, B=0.6, Ti=0.2 Zn=0.4
L ⊗	37°56'44" 113°33'20"	(C-33-15)8caa	EV-117	17	200	10-16-81	42	0.42	159	24	333	12	325	369	419	1.9	1700	2080	7.02	1100	Sr=0.99, Li=0.97, B=0.9, Ti=0.2 Zn=0.4

TABLE 1 continued

COORDINATES LAT. LONG.	CADASTRAL COORDINATES	SAMPLE NUMBER	TEMP. °C	DEPTH (FEET)	DATE OF SAMPLE	ANALYSIS EXPRESSED AS PARTS PER MILLION (PPM) SiO_2	Fe	Ca	Mg	Na	K	HCO_3^-	SO_4	Cl	F	Dissolved Solids	COND. mmhos	pH	Salinity PPM	OTHER IONS OR REMARKS
37°56'25" 113°36'51"	(C-33-16)11ccd	EV-118	27		10-16-81	49	0.03	140	18	343	34	318	367	447	3.1	1760	2770	7.15	1300	Sr=2.51, Zn=0.2, Ti=0.2, Li=1.06, B=1.1
37°56'44" 113°38'12"	(C-33-16) 14dcb	EV-119	20		10-16-81	52	0.05	145	14	335	34	371	376	402	3.9	1730	2360	7.05	1500	Sr=2.13, Zn=2.6, Li=1.07, Ti=0.2 B=1.0
38°14'11" 113°21'36"	(C-30-13)6bbb	EV-120	18		10-17-81	26	0.08	28	10	34	2.50	154	20	37	0.8	276	346	8.10	100	Ti=0.1, Sr=0.39, Zn= 0.6B=0.1
38°13'16" 113°17'12"	(C-30-13)11bbb	EV-121	16	323	10-18-81	55	0.10	31	5	84	2.50	209	77	30	0.8	426	445	7.90	0	Sr=0.35, Li=0.1, Zn=1.0, Ti=1.10 B=0.5
38°12'49" 113°20'00"	(C-30-13)8baa	EV-122	18	263	10-18-81	35	0.10	41	11	41	2.50	148	53	32	1.1	326	384	7.80	0	Sr=0.82 Zn=0.4, B=0.2
38°11'34" 113°20'35"	(C-30-13) 18ddd	EV-123	15	209	10-18-81	23	0.04	81	30	30	3	157	112	108	0.9	594	610	7.60	100	Sr=1.11, Ti=0.1, Zn=0.4
38°10'45" 113°19'32"	(C-30-13)20dda	EV-124	15		10-18-81	25	0.05	69	28	41	4	188	85	104	1.0	514	585	7.61	100	Sr=1.08, Ti=0.1, Li=0.05, Zn=0.4
38°11'58" 113°17'08"	(C-30-13)14bcc	EV-125	16		10-18-81	35	0.05	67	36	34	4	132	94	144	0.6	643	620	7.80	0	Sr=1.22, Ti=0.1, Li=.05, Zn=0.2 B=0.1
37°43'20" 113°41'53"	(C-35-17)25dcd	EV-126	14		10-01-81	41	0.03	85	15	25	5	186	24	112	1.0	492	419	7.20	100	Sr=0.53, Zn=0.3
37°43'15" 113°41'14"	(C-35-16)31bab	EV-127	14	200	10-01-81	48	0.06	70	13	15	6	167	13	86	0.3	446	368	7.25	250	Sr=0.41, Zn=0.6
37°42'12" 113°39'41"	(C-35-16) 32bdc	EV-128	14	254	10-01-81	35	0.15	138	23	17	6	321	37	97	0.3	610	660	7.10	300	Sr=0.56, Zn=3.3
37°42'12" 113°42'02"	(C-35-17)36dcc	EV-129	16		10-01-81	40		43	8	18	5	172	14	26	1.4	268	272	7.55	100	Sr=0.26
38°07'24" 113°24'11"	(C-31-14) 9bdb	EV-130	20		10-02-81	42	.025	95	17	43	2.5	307	24	60	0.5	482	421	7.08	200	Sr=0.57

TABLE 1 continued

COORDINATES LAT. LONG.	CADASTRAL COORDINATES	SAMPLE NUMBER	TEMP. °C	DEPTH (FEET)	DATE OF SAMPLE	ANALYSIS EXPRESSED AS PARTS PER MILLION (PPM) SiO_2	Fe	Ca	Mg	Na	K	HCO_3^-	SO_4	Cl	F	Dissolved Solids	COND. mmhos	pH	Salinity PPM	OTHER IONS OR REMARKS
38°04'37" 113°26'21"	(C-31-14)29aac	EV-131	20	150	10-02-81	33	.025	123	27	51	2.5	278	54	165	0.5	724	860	7.09	500	Sr=1.06, Li=0.05, B=0.1
38°00'18" 113°27'30"	(C-32-14)30bab	EV-132	18	112	10-02-81	32	0.20	165	53	88	6	132	219	321	0.9	1232	1300	7.11	900	Sr=1.57, Zn=0.4, Li=0.06, B=0.2
38°02'06" 113°19'03"	(C-32-13)9bdd	EV-133	14		10-03-81	28	.025	71	40	48	5	189	218	74	0.5	617	690	7.40	800	Sr=0.63, Zn=0.8
38°05'59" 113°21'39"	(C-31-13)23bbb	EV-134	13	65	10-05-81	41	0.10	158	155	221	8	244	973	290	0.7	2194	1710	7.12	1100	Sr=2.13, Li=0.10, B=0.5
38°03'56" 113°21'39"	(C-31-13)31bcc	EV-135	14	85	10-05-81	35	0.10	193	165	246	9	177	870	533	0.7	2480	2120	7.33	1100	Sr=2.31, B=0.4, Li=0.09
38°05'33" 113°22'18"	(C-31-14)24caa	EV-136	17	207	10-05-81	31	0.29	96	36	69	6	144	245	135	0.7	770	910	7.40	500	Sr=0.77, Zn=0.2, B=0.2
38°00'21" 113°25'56"	(C-32-14)21bcd	EV-137	19		10-05-81	51	0.15	61	26	39	8	220	61	53	1.3	402	462	7.62	100	Sr=0.91, Zn=0.7, Li=0.07, B=0.2
37°47'53" 113°55'17"	(C-34-19)31dcb	EV-138	21	392	10-06-81	37	0.03	67	10	59	5	230	97	58	2.5	478	610	7.45	300	Sr=0.51, Li=0.21, B=0.2
37°47'49" 113°53'32"	(C-34-18)32ccb	EV-139	16	293	10-06-81	42	0.25	65	7	53	7	203	64	33	2.6	372	411	8.01	100	Sr=0.30, Zn=1.4, Li=0.19, B=0.2
37°52'31" 113°49'16"	(C-33-18)20bdd	EV-140	20	230	10-06-81	58	0.10	41	11	21	7	282	26	37	0.5	304	780	7.91	400	Sr=0.30, Zn=0.3
37°55'30" 113°47'02"	(C-33-17)20cbb	EV-141	22	230	10-06-81	46	0.05	96	34	46	8	157	188	46	0.7	672	342	7.61	100	Sr=0.84, Zn=0.7, B=0.3
37°47'51" 113°28'06"	(C-34-14) 31cca	EV-142	12	233	10-14-81	52	0.53	29	15	37	6	191	45	25	0.6	340	312	7.46	100	Sr=0.59, Li=0.05, B=0.2, Tl=0.1 Zn=0.3
37°50'22" 113°19'30"	(C-34-13)16ccc	EV-143	15		10-15-81	27	0.07	64	43	31		177	196	33	0.4	580	580	7.23	200	Sr=0.90, Tl=0.1

TABLE 1 continued

COORDINATES LAT. LONG.	CADASTRAL COORDINATES	SAMPLE NUMBER	TEMP. °C	DEPTH (FEET)	DATE OF SAMPLE	ANALYSIS EXPRESSED AS PARTS PER MILLION (PPM) SiO_2	Fe	Ca	Mg	Na	K	HCO_3^-	SO_4	Cl	F	Dissolved Solids	COND. mmhos	pH	Salinity PPM	OTHER IONS OR REMARKS
37°57'51" 113°27'42"	(C-33-14)6bda	EV-144	15		10-19-81	38	0.34	210	67	90	6	149	296	493	1.2	1350	1390	7.00	1000	Sr=1.87, Ti=0.2, Zn=0.7, B=0.4 Li=0.06
37°46'23" 113°31'17"	(C-35-15)10bac	EV-145	13		10-22-81	41		50	20	18	3	165	70	34	0.5	372	350	7.61	0	Sr=0.56, B=0.2
37°46'23" 113°31'01"	(C-35-15)3dcc	EV-146	15		10-22-81	46		356	163	176	11	147	1003	528	0.6	2646	2320	7.31	1010	Sr=5.14, Zn=0.2, B=0.7, Li=0.21
38°09'46" 113°18'45"	(C-30-13)33abb	EV-148	13		10-28-81	41		106	83	72	10	178	188	289	1.2	1042	980	7.47	500	Sr=0.87, B=0.3, Li=0.14
38°10'13" 113°19'32"	(C-30-13)30caa	EV-149	15		10-28-81	11		96	38	57	5	186	157	132	0.9	686	740	7.51	0	Sr=1.49, Zn=0.1
37°56'25" 113°38'12"	(C-33-16)10ccc	EV-150	28	208	11-24-81	44	1.64	145	14	319	24	403	359	366	4.0	1556	2370	7.13	800	Sr=2.76, Ti=0.2, Mn=0.7, Zn=0.8 Au=0.2, Li=0.96, B=0.9

TABLE 2: Chemical geothermometers and surface temperatures for fluids in (°C) from the Escalante Valley, Utah
(*indicates magnesium correction used)

Sample No.	Qtz (Cond)	Chalcedony	Na-K-Ca	Meas. Temp
EV-105	96	66	38	14
EV-106	95	65	33	16
EV-107	93	62	28	14
EV-108	93	62	30	14
EV-109	106	76	49	17
EV-110	93	62	39	12
EV-111	106	76	107*	60
EV-112	102	72	41	19
EV-113	107	78	61	14
EV-114	106	77	64	14
EV-115	102	72	68*	15
EV-116	97	67	64	16
EV-117	94	64	39*	17
EV-118	101	71	94*	27
EV-119	104	74	91*	20
EV-120	74	42	51	18
EV-121	106	77	57	16
EV-122	86	55	47	18
EV-123	69	37	32	15
EV-124	72	40	37	15
EV-125	86	55	36	16
EV-126	93	62	30	14
EV-127	100	70	46	14
EV-128	86	55	35	14
EV-129	92	61	38	16
EV-130	94	64	32	20
EV-131	84	52	29	20
EV-132	82	51	46	18
EV-133	77	45	38	14
EV-134	93	62	56	13
EV-135	86	55	53	14
EV-136	81	50	54	17
EV-137	103	73	57	19
EV-138	88	58	40	21
EV-139	94	64	59	16
EV-140	109	80	60*	20
EV-141	104	74	72	22
EV-143	75	44	36	15
EV-144	90	59	43	15
EV-146	93	62	36	13
EV-145	98	68	50	15
EV-148	93	62	64	13
EV-149	43	10	34	15
EV-150	96	66	97	28
EV-151	130	102	123*	56
EV-152	130	102	125*	42
EV-153	131	104	127*	50
EV-154	128	100	120*	78

TABLE 2 (Continued)

Equations for Geothermometers used to compute subsurface temperatures given in Table 5 (SiO_2) in ppm

Quarts (conductive): $$T(^{o}C) = \frac{1309}{5.19 - \log SiO_2} - 273.15$$

Chalcedony: $$T(^{o}C) = \frac{1032}{4.69 - \log SiO_2} - 273.15$$

Na-K-Ca: (unit in molal)

$$T(^{o}C) = \frac{1647}{\log(Na/K) + B \log(Ca/Na) - 2.24} - 273.15$$

where B = 1/3 for T   100°C
       = 4/3 for T   100°C

Magnesium Correction

Temperature   70°C
R = 5 to 50   R = [mg/(mg+ca+K)] x 100 in equivalent units of concentration

Source: Fournier (1977)
Fournier and Potter II (1979)

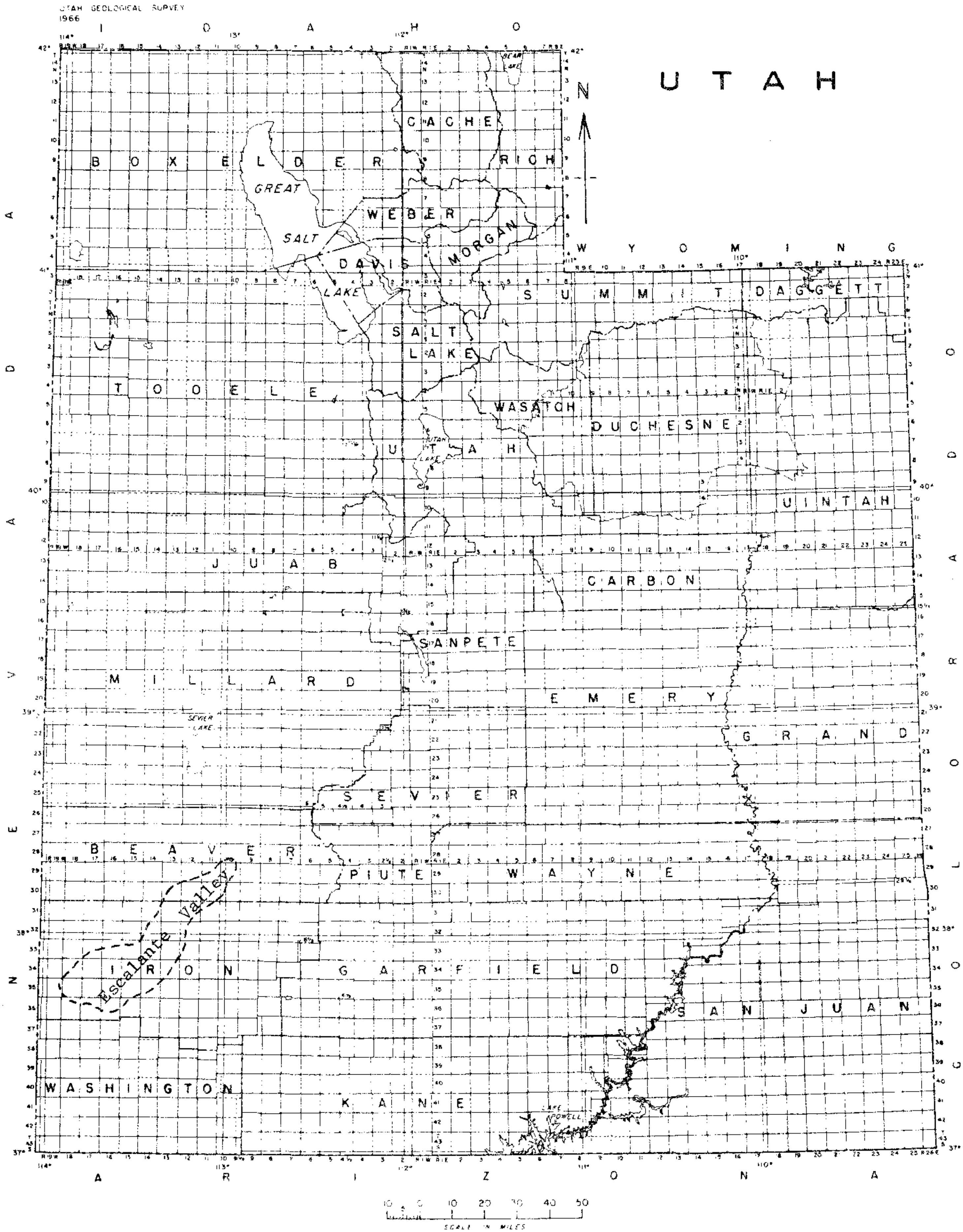
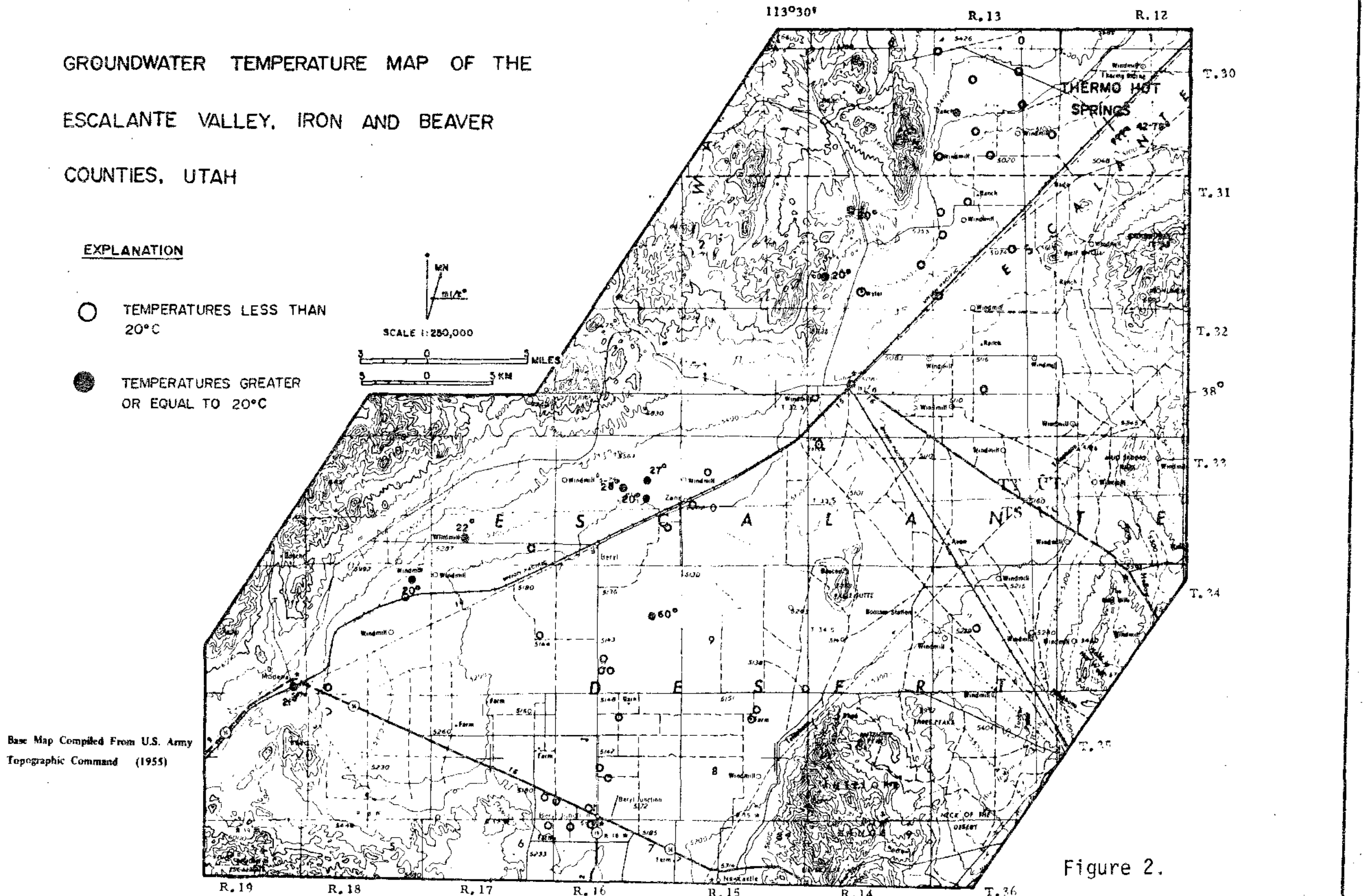


Figure 1. Index map showing the location of the Escalante Valley in Utah.

GROUNDWATER TEMPERATURE MAP OF THE ESCALANTE VALLEY, IRON AND BEAVER COUNTIES, UTAH



Base Map Compiled From U.S. Army Topographic Command (1955)

Figure 2.

WELL AND SPRING CHEMISTRY SAMPLE LOCATIONS, ESCALANTE VALLEY, IRON AND BEAVER COUNTIES, UTAH

EXPLANATION

O WELL LOCATIONS

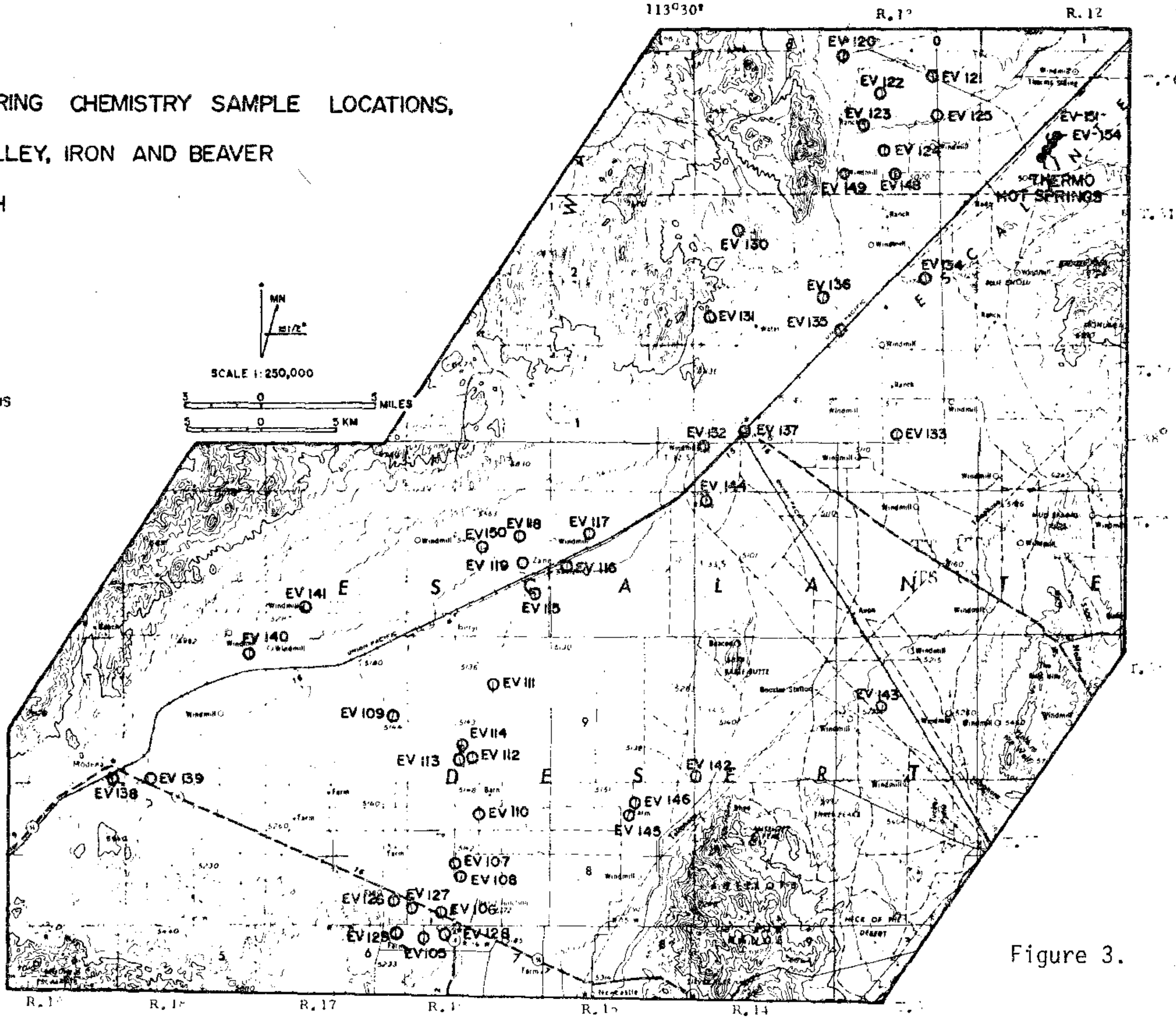
SPRING LOCATIONS

MN

SCALE 1:250,000

5 0 5 MILES

5 0 5 KM



Base Map Compiled From U.S. Army Topographic Command (1955)

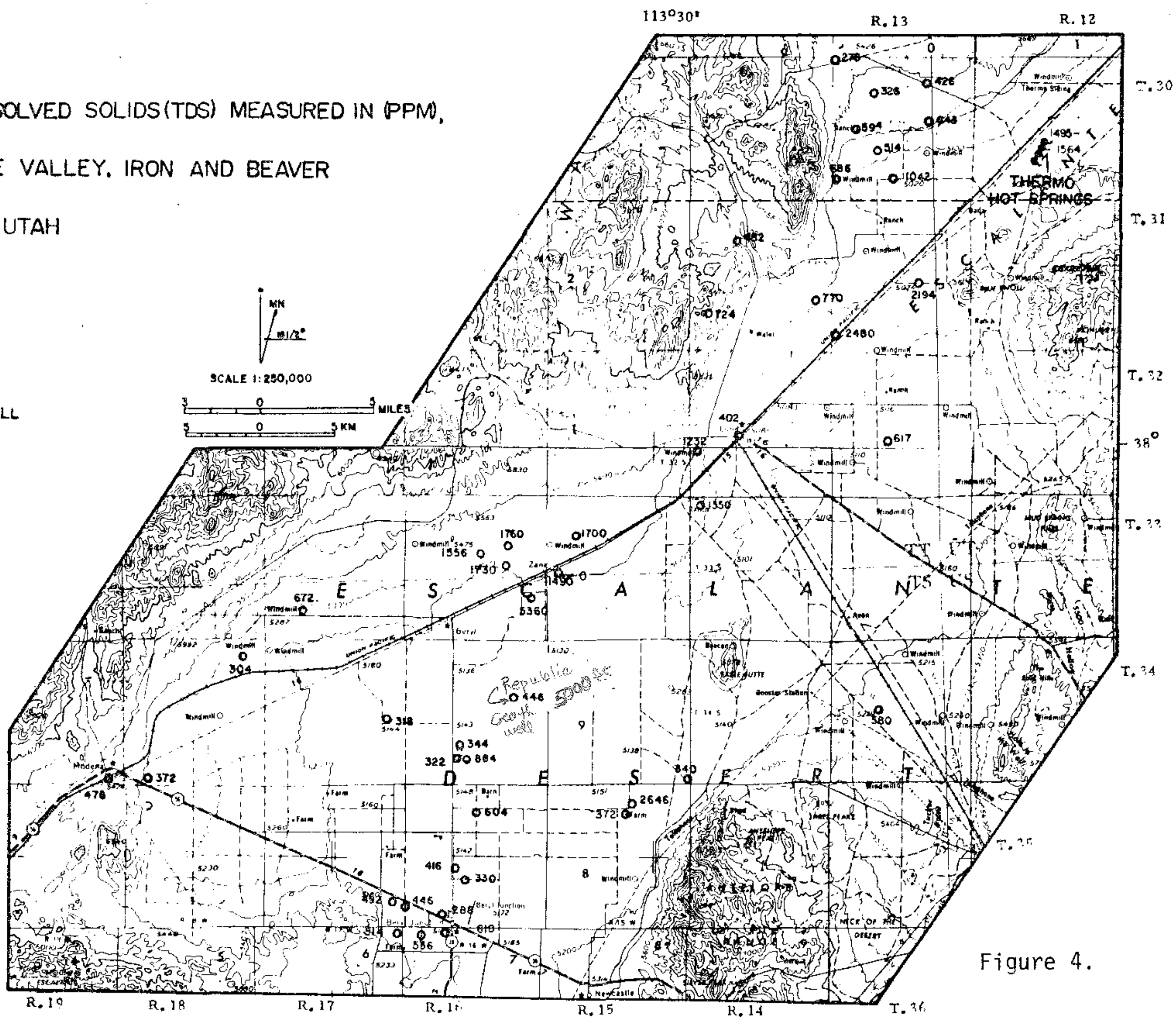
Figure 3.

TOTAL DISSOLVED SOLIDS (TDS) MEASURED IN (PPM), ESCALANTE VALLEY, IRON AND BEAVER COUNTIES, UTAH

EXPLANATION

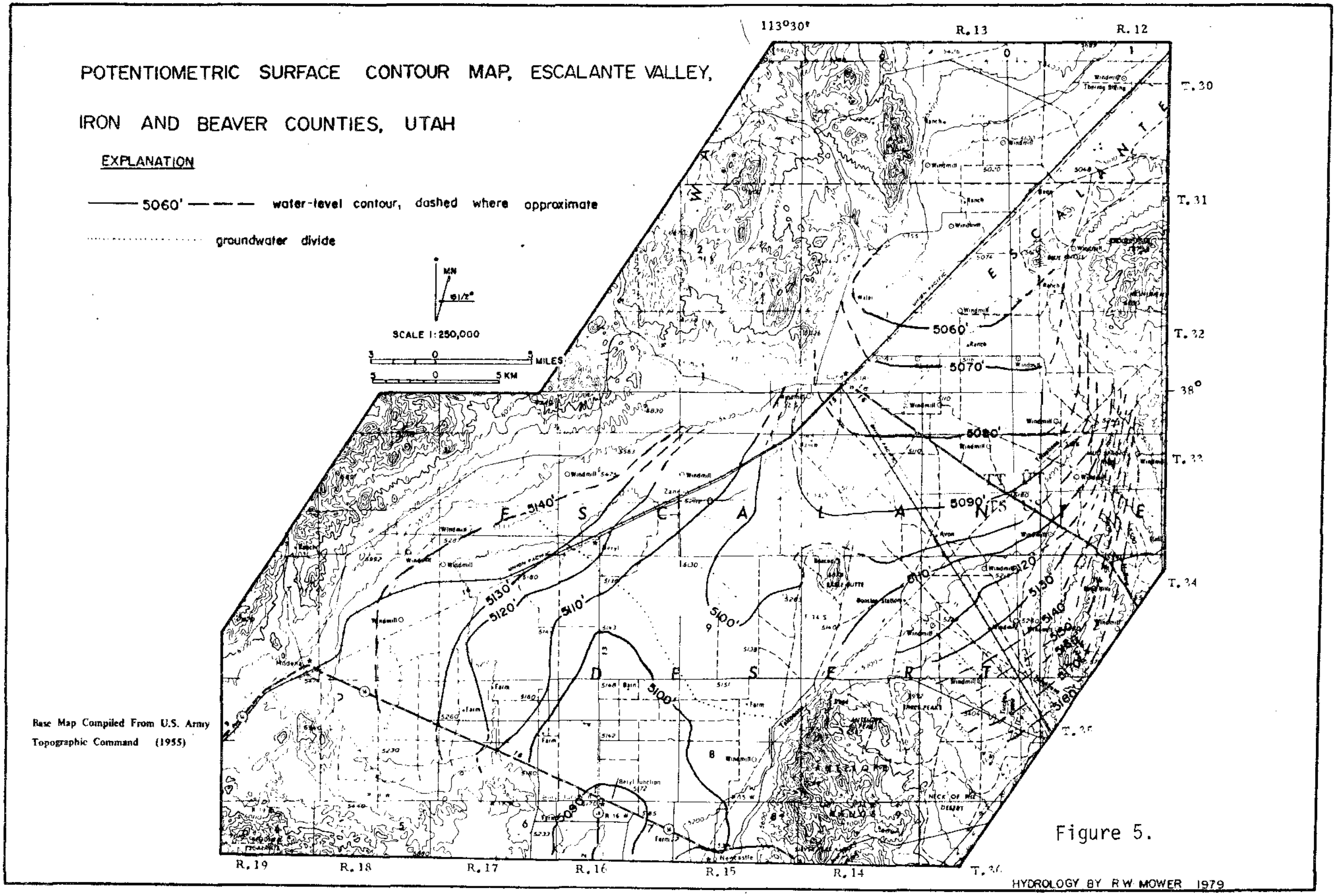
SPRING

WATER WELL



Base Map Compiled From U.S. Army Topographic Command (1955)

Figure 4.



POTENTIOMETRIC SURFACE CONTOUR MAP, ESCALANTE VALLEY,
IRON AND BEAVER COUNTIES, UTAH
EXPLANATION
5060' water-level contour, dashed where approximate
groundwater divide
MN
SCALE 1:250,000
MILES
KM
Base Map Compiled From U.S. Army Topographic Command (1955)
113°30'
R. 13
R. 12
T. 30
T. 31
T. 32
38°
T. 34
R. 19
R. 18
R. 17
R. 16
R. 15
R. 14
5060'
5070'
5080'
5090'
5100'
5110'
5120'
5130'
5140'
E S C A L A N T E
D E S E R T
Beryl
Beryl Junction
Lund
Newcastle
Zane
Avon
Modena
HYDROLOGY BY R W MOWER 1979

Figure 5.

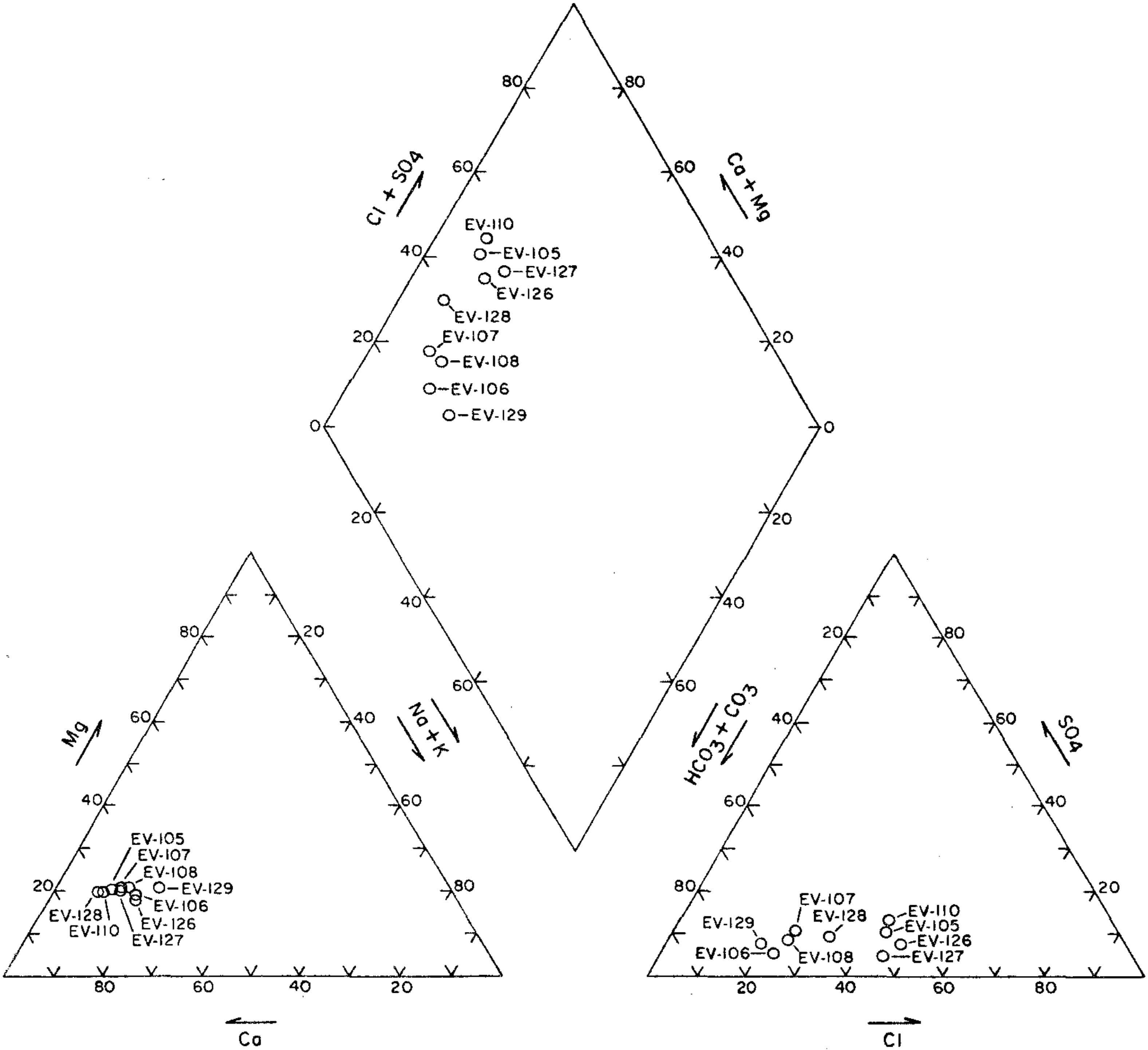


Figure 6. Piper diagram of common ions in samples collected in the Beryl and Yale Crossing U.S.G.S. topographic quadrangle map areas in the Escalante Valley, Utah. Chemical constituents are plotted as percentage of total milliequivalents.

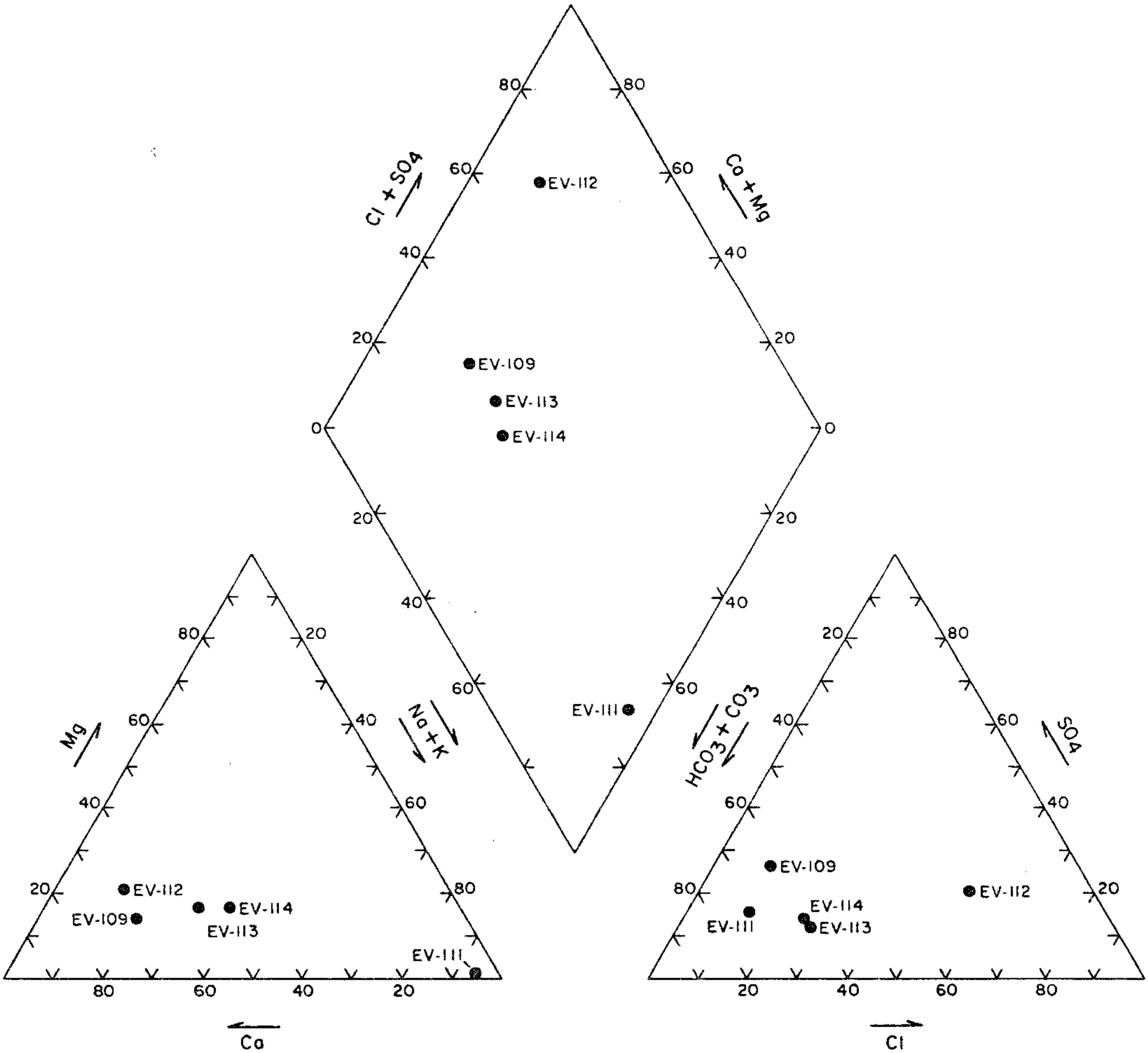


Figure 7. Piper diagram of common ions in samples collected in the Yale Crossing U.S.G.S. topographic quadrangle map area in the Escalante Valley, Utah. Chemical constituents are plotted as percentage of total milliequivalents.

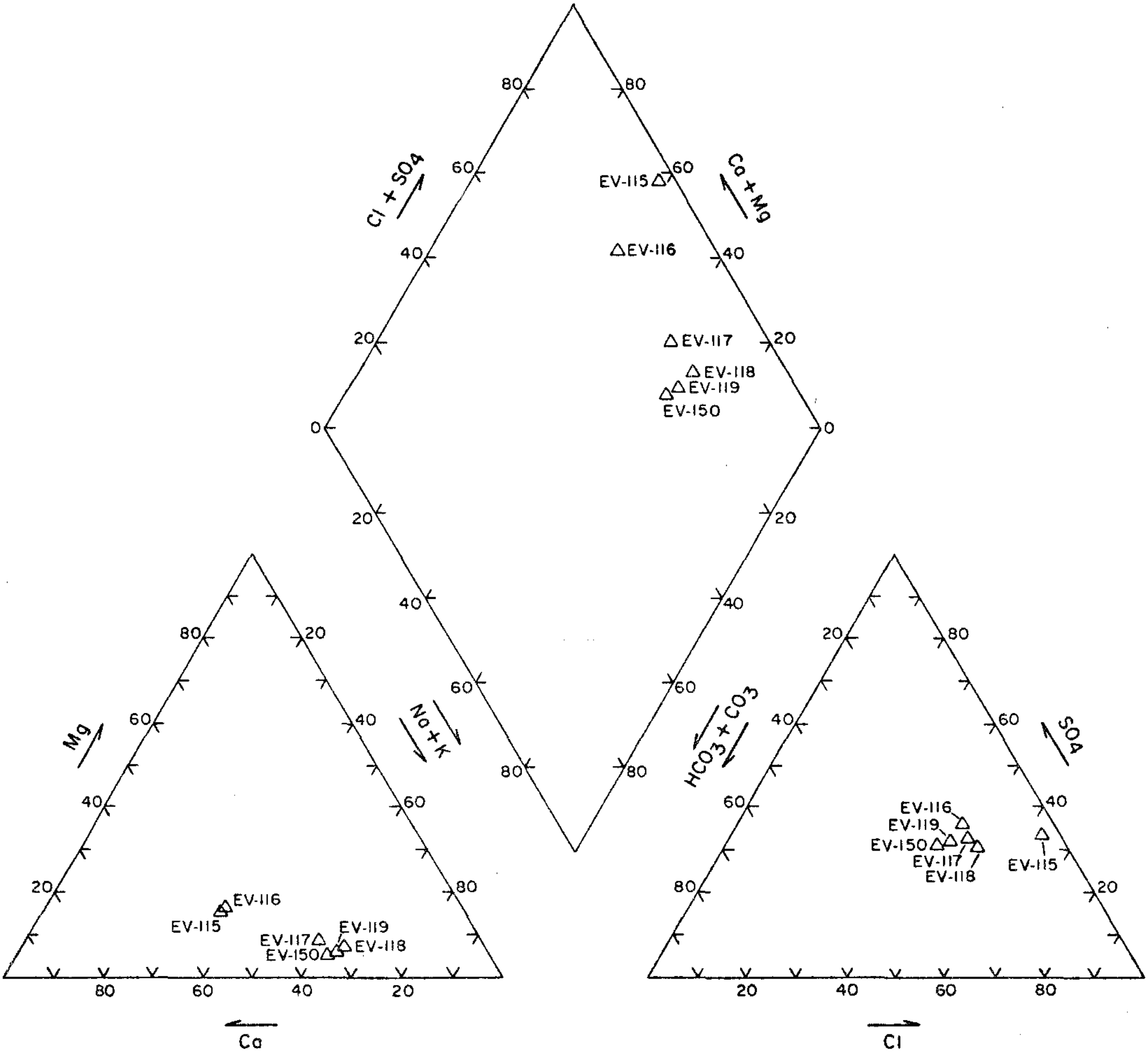


Figure 8. Piper diagram of common ions in samples collected in the Zane and Beryl U.S.G.S. topographic quadrangle map areas in the Escalante Valley, Utah. Chemical constituents are plotted as percentage of total milliequivalents.

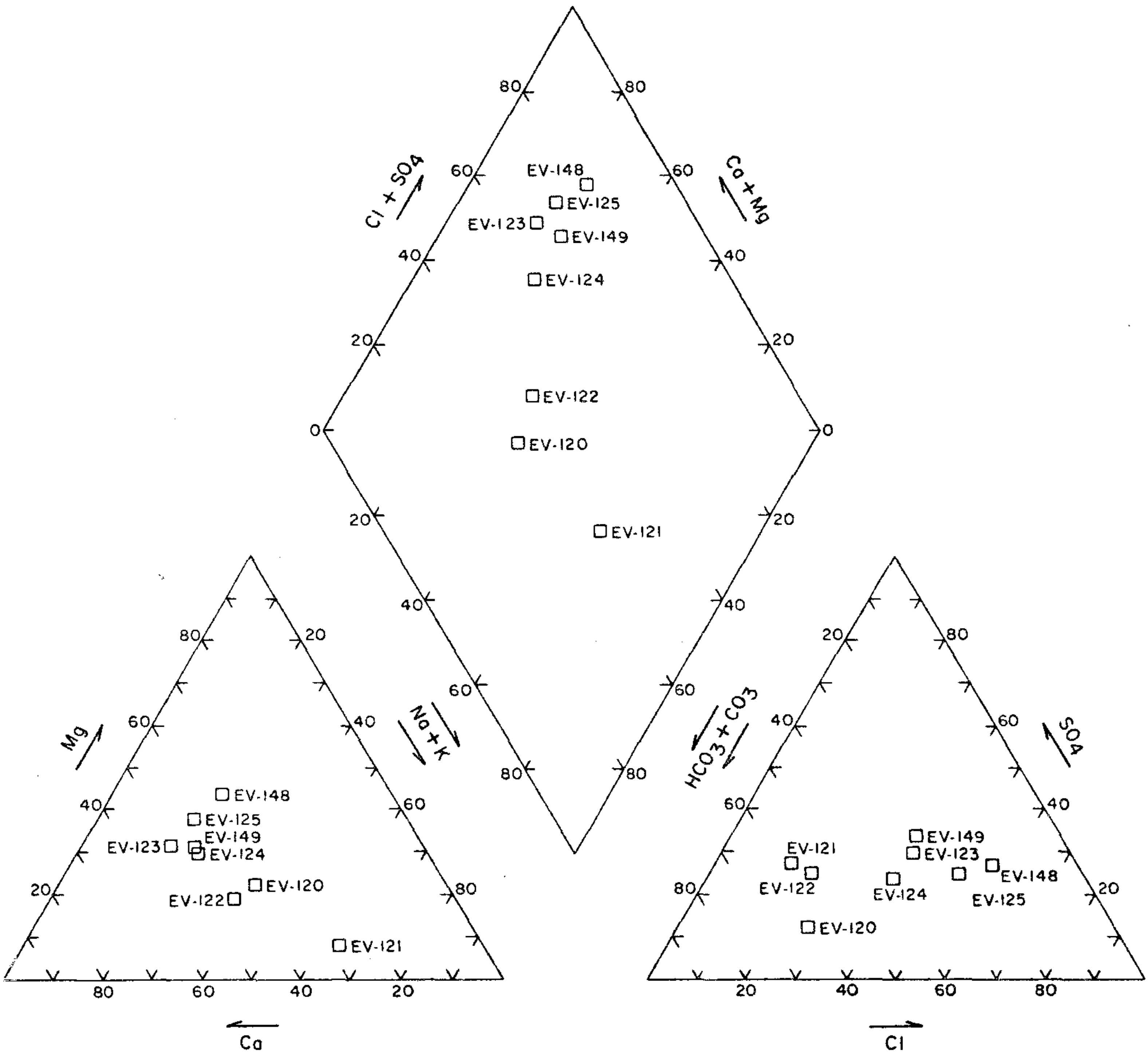


Figure 9. Piper diagram of common ions in samples collected in the Burns Knoll U.S.G.S. topographic quadrangle map area in the Escalante Valley, Utah. Chemical constituents are plotted as percentage of total milliequivalents.

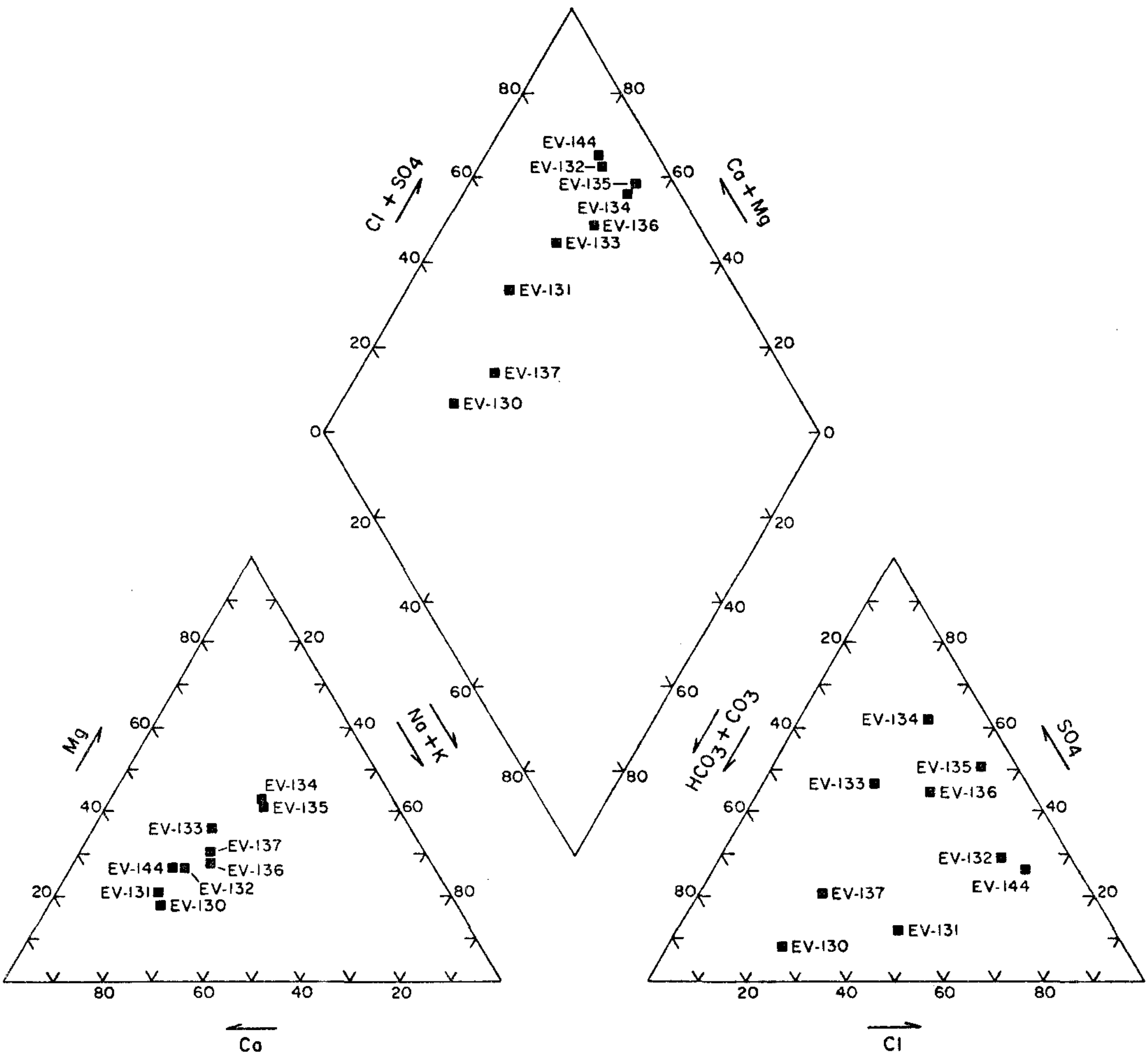


Figure 10. Piper diagram of common ions in samples collected in the Latimer, Lund and Avon NW U.S.G.S. topographic quadrangle map areas in the Escalante Valley, Utah. Chemical constituents are plotted as percentage of total milliequivalents.

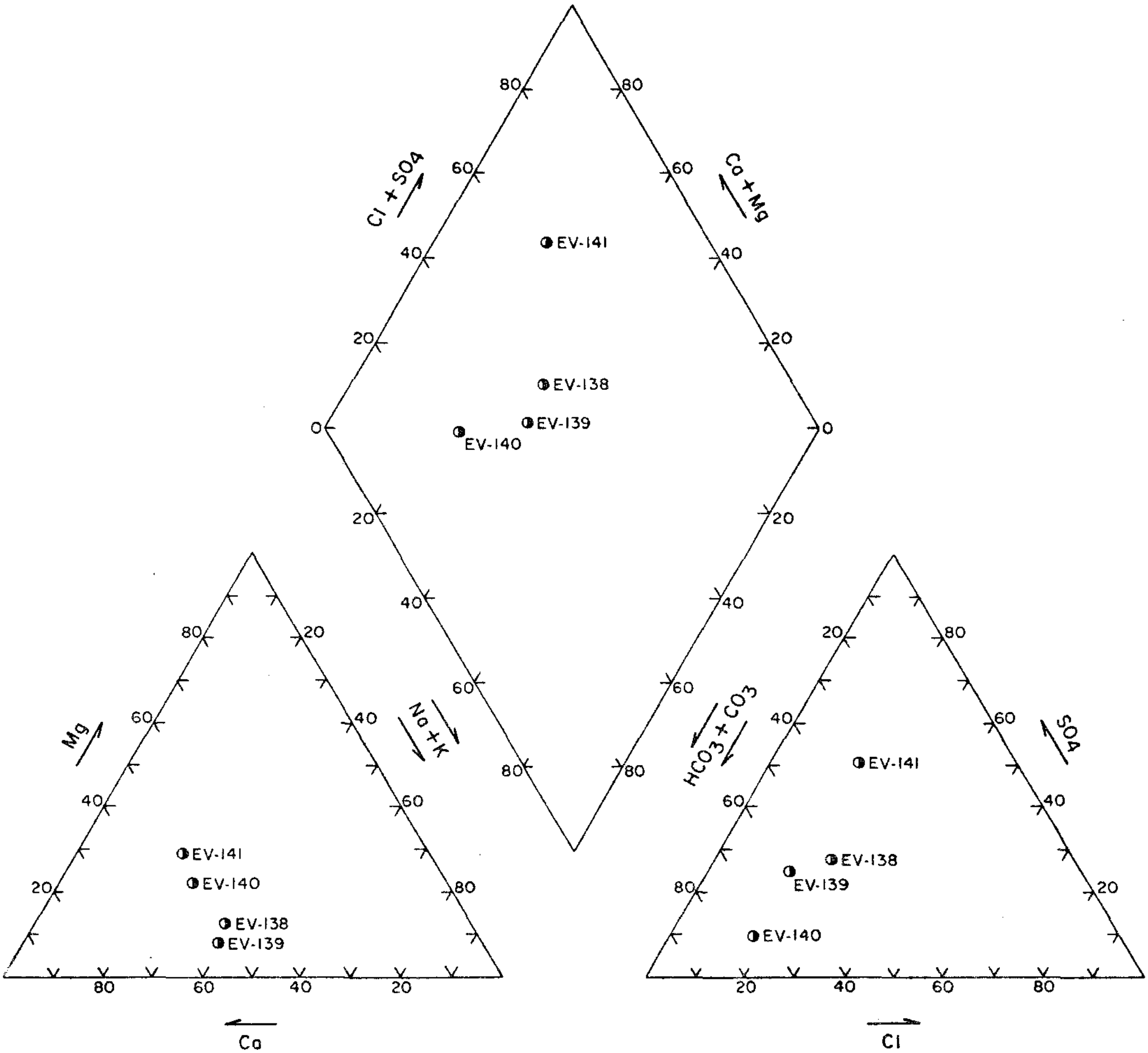


Figure 11. Piper diagram of common ions in samples collected in the Modena and Bannion Spring U.S.G.S. topographic quadrangle map areas in the Escalante Valley, Utah. Chemical constituents are plotted as percentage of total milliequivalents.

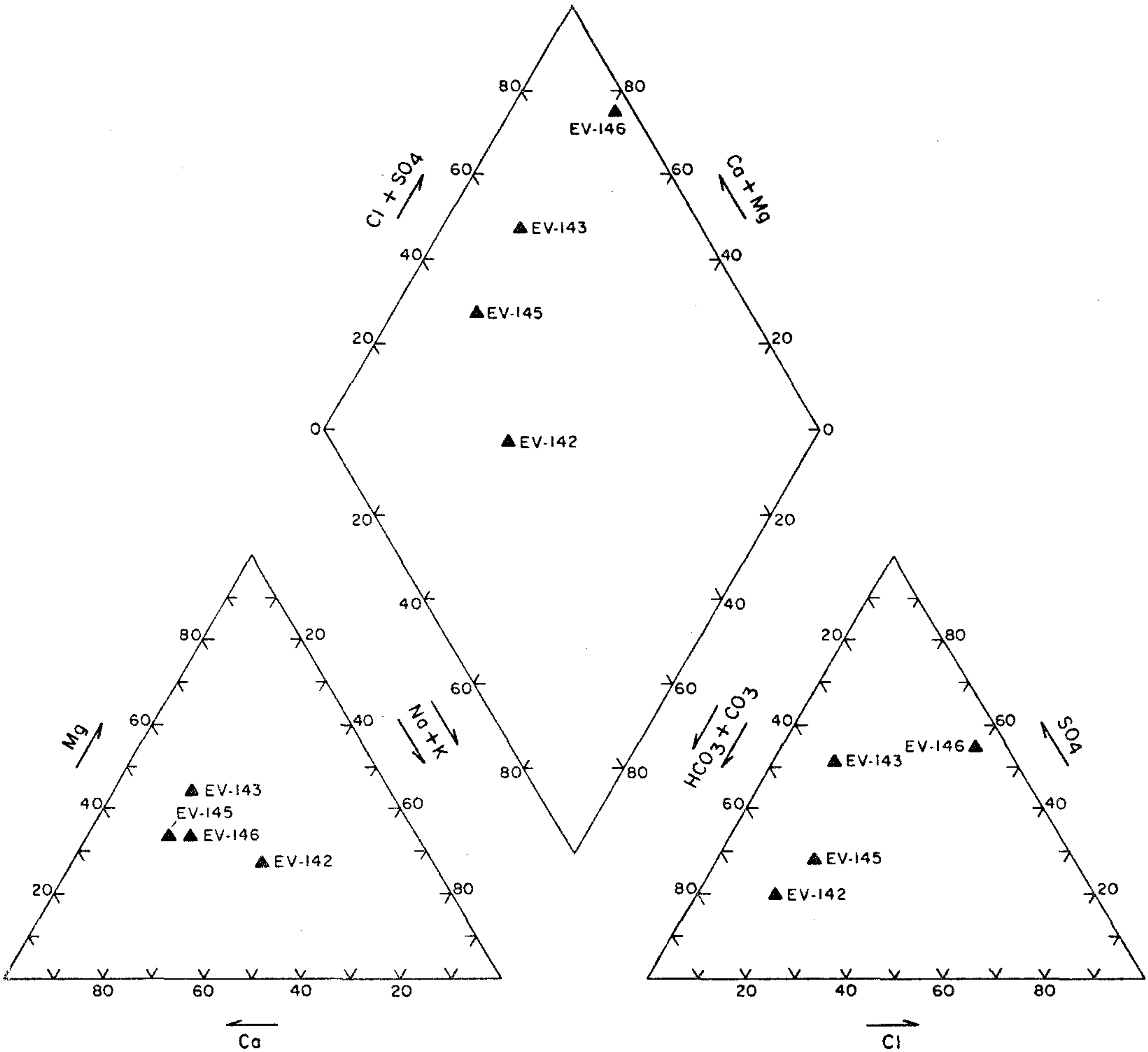


Figure 12. Piper diagram of common ions in samples collected in the Antelope Peak, Avon SE and Clark Farm U.S.G.S. topographic quadrangle map areas in the Escalante Valley, Utah. Chemical constituents are plotted as percentage of total milliequivalents.

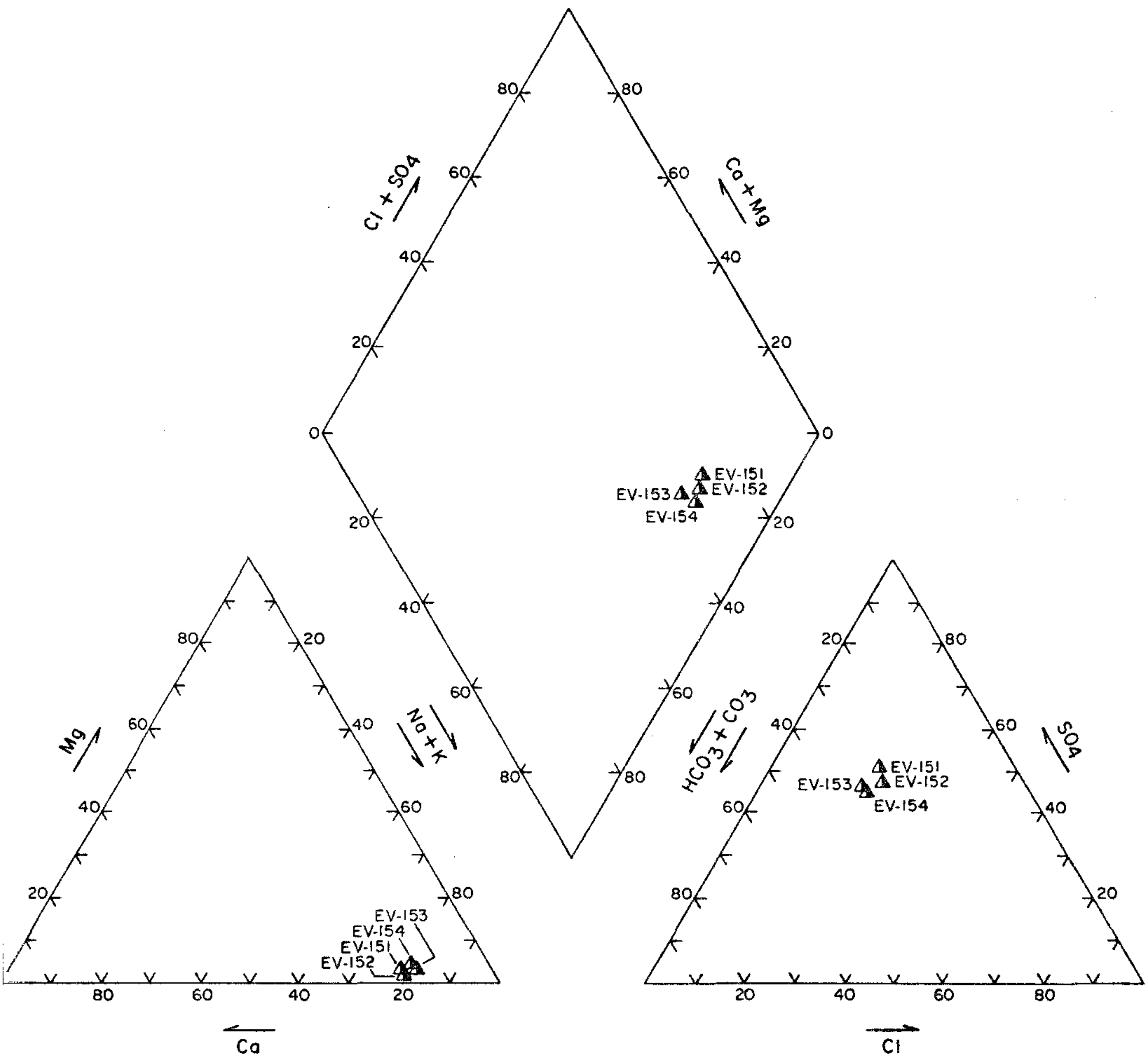


Figure 13. Piper diagram of common ions in samples collected at Thermo Hot Springs in the Escalante Valley, Utah. Chemical constituents are plotted as percentage of total milliequivalents.

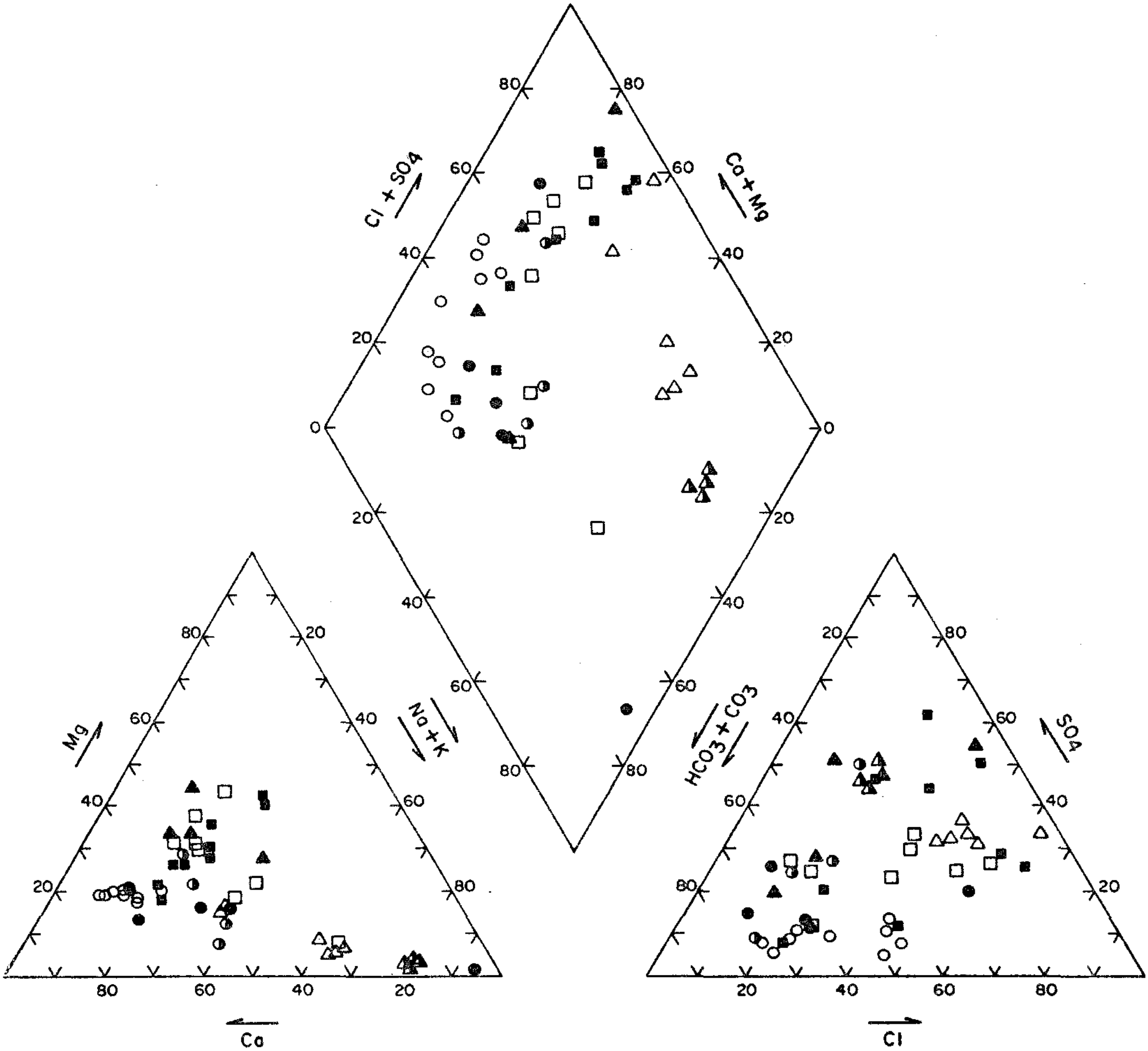


Figure 14. Piper diagram of common ions in all samples collected in the Escalante Valley, Utah. Chemical constituents are plotted as percentage of total milliequivalents. See Figures 6 through 13 for identification of individual samples.

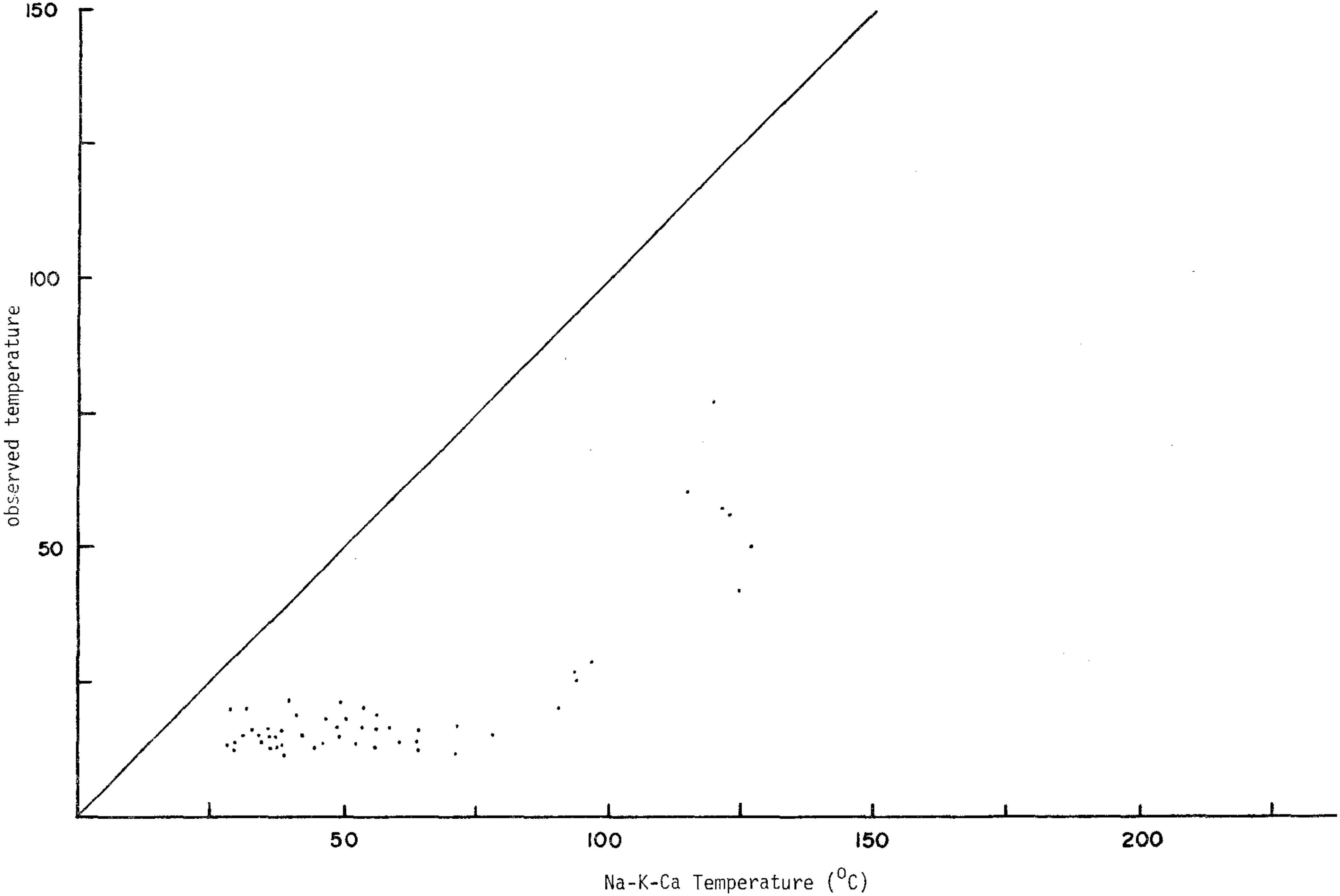


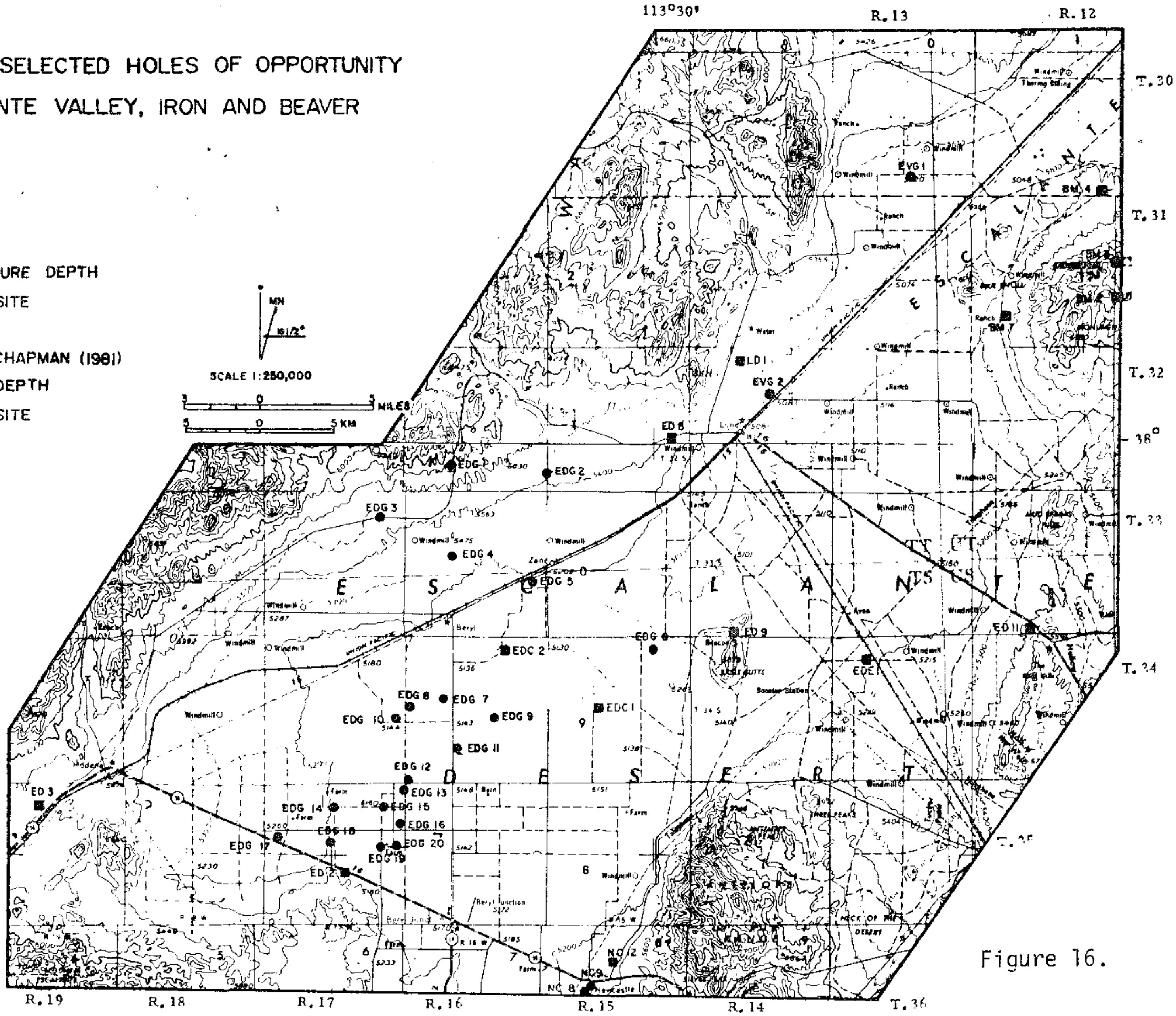
Figure 15. Plot of observed temperatures vs. cation geothermometer temperatures, showing deviation attributed to mixing with cold water.

LOCATIONS OF SELECTED HOLES OF OPPORTUNITY IN THE ESCALANTE VALLEY, IRON AND BEAVER COUNTIES, UTAH

EXPLANATION

● UGMS TEMPERATURE DEPTH MEASUREMENT SITE

■ CLEMENT AND CHAPMAN (1981) TEMPERATURE DEPTH MEASUREMENT SITE



Base Map Compiled From U.S. Army Topographic Command (1955)

Figure 16.

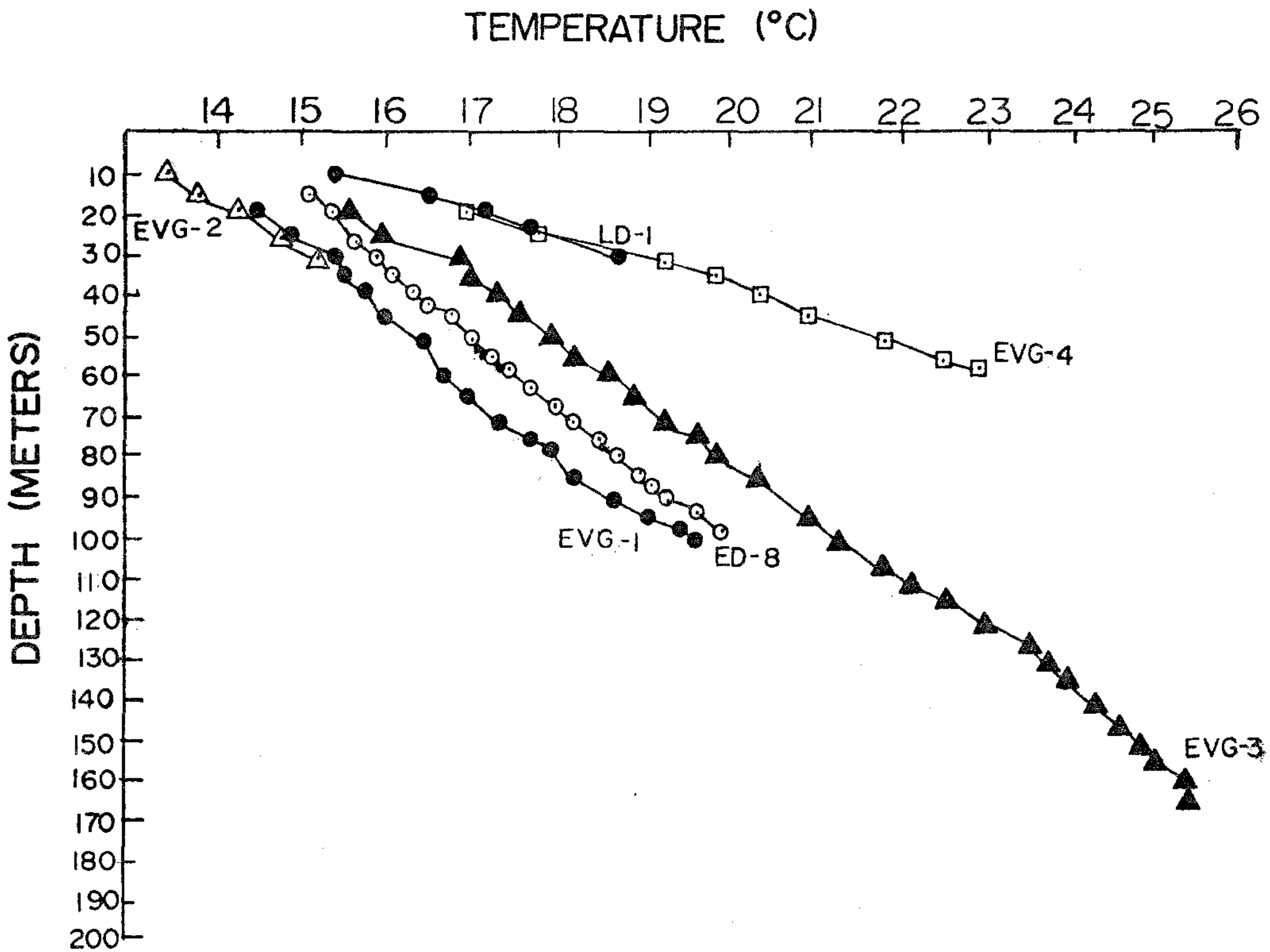


Figure 17. Temperature-depth profiles from holes of opportunity in the Escalante Valley, Utah. See Figure 16 for locations.

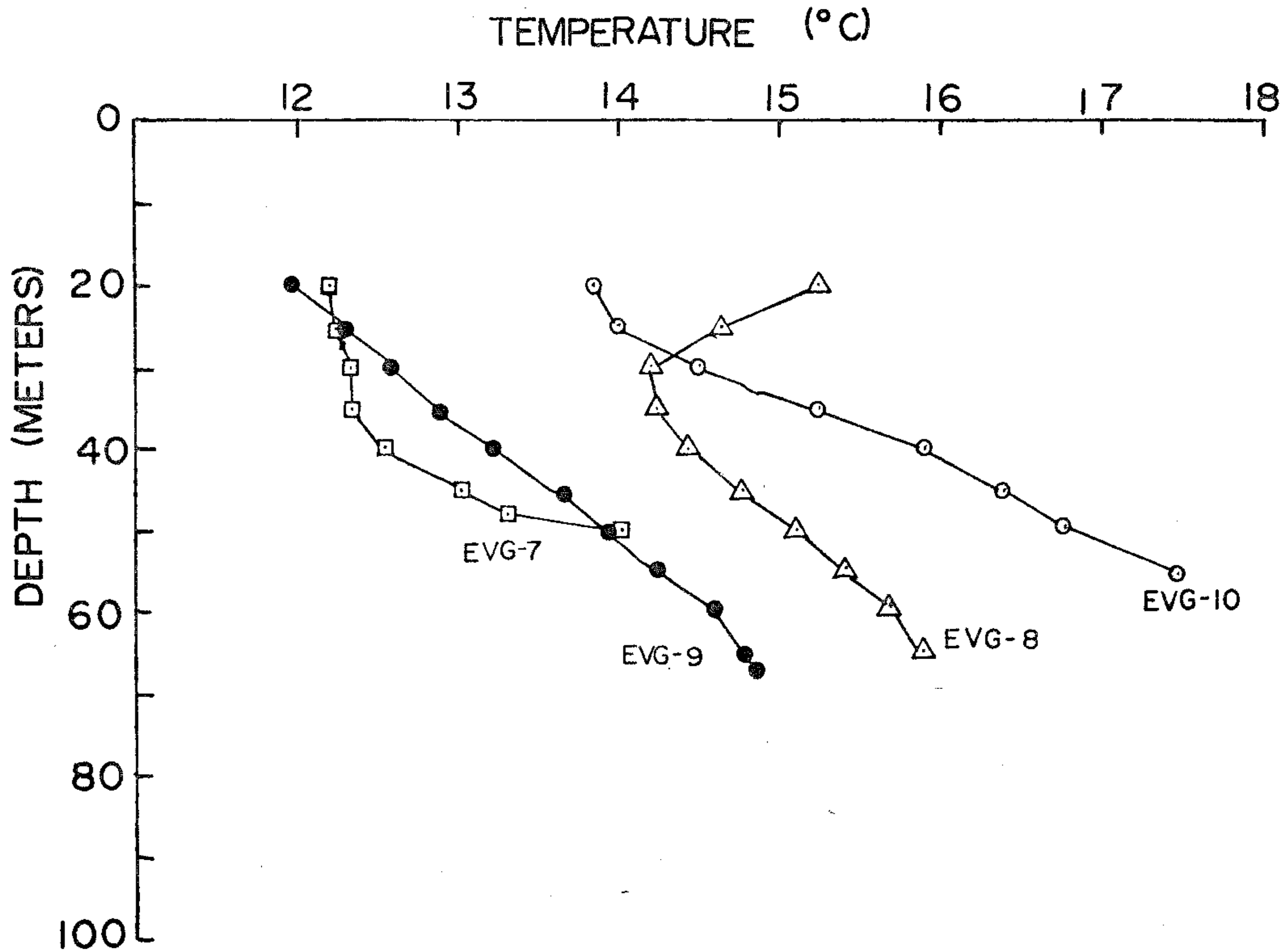


Figure 18. Temperature-depth profiles from holes of opportunity in the Escalante Valley, Utah. See Figure 16 for locations.

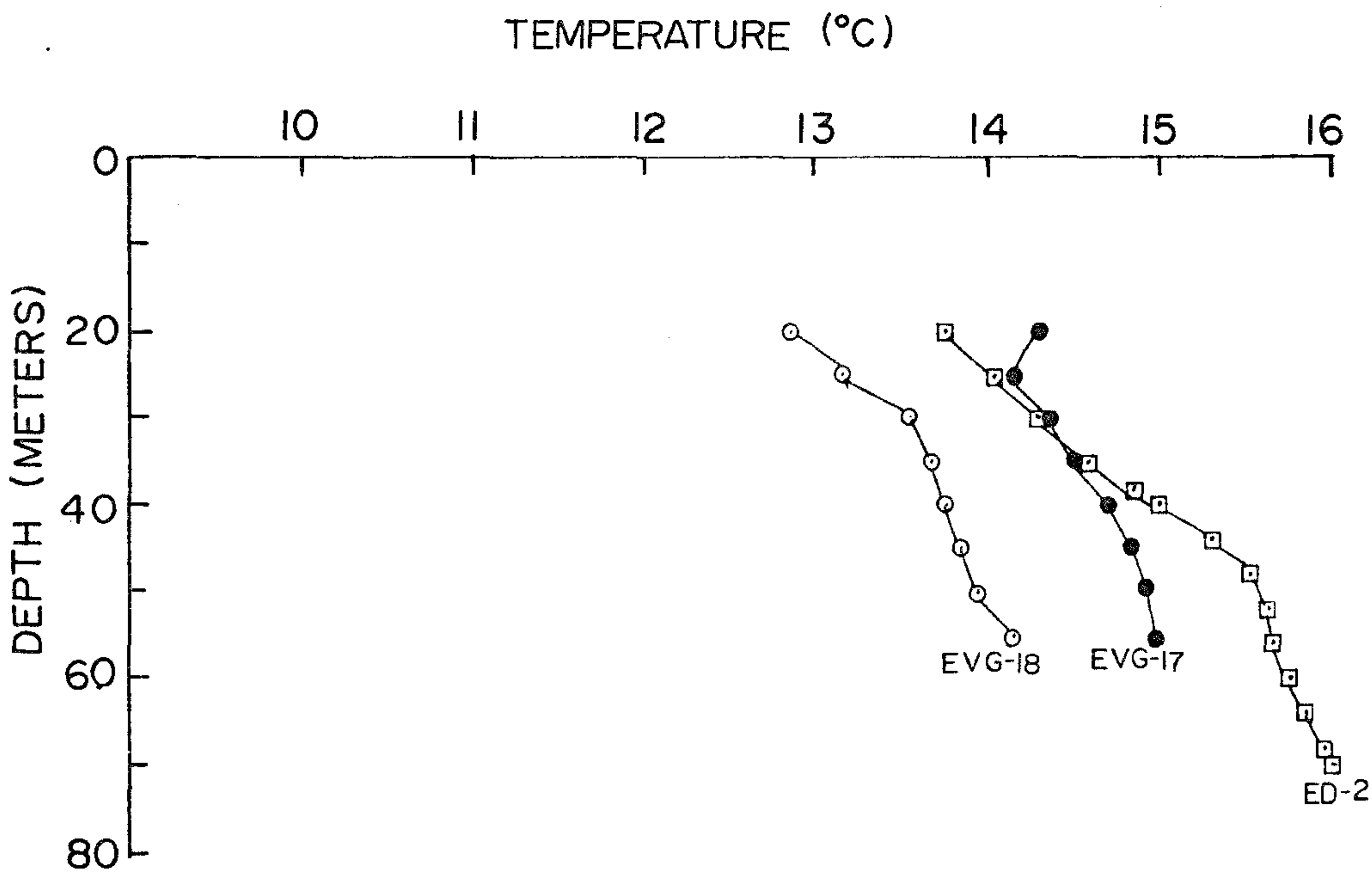


Figure 19. Temperature-depth profiles from holes of opportunity in the Escalante Valley, Utah. See Figure 16 for locations.

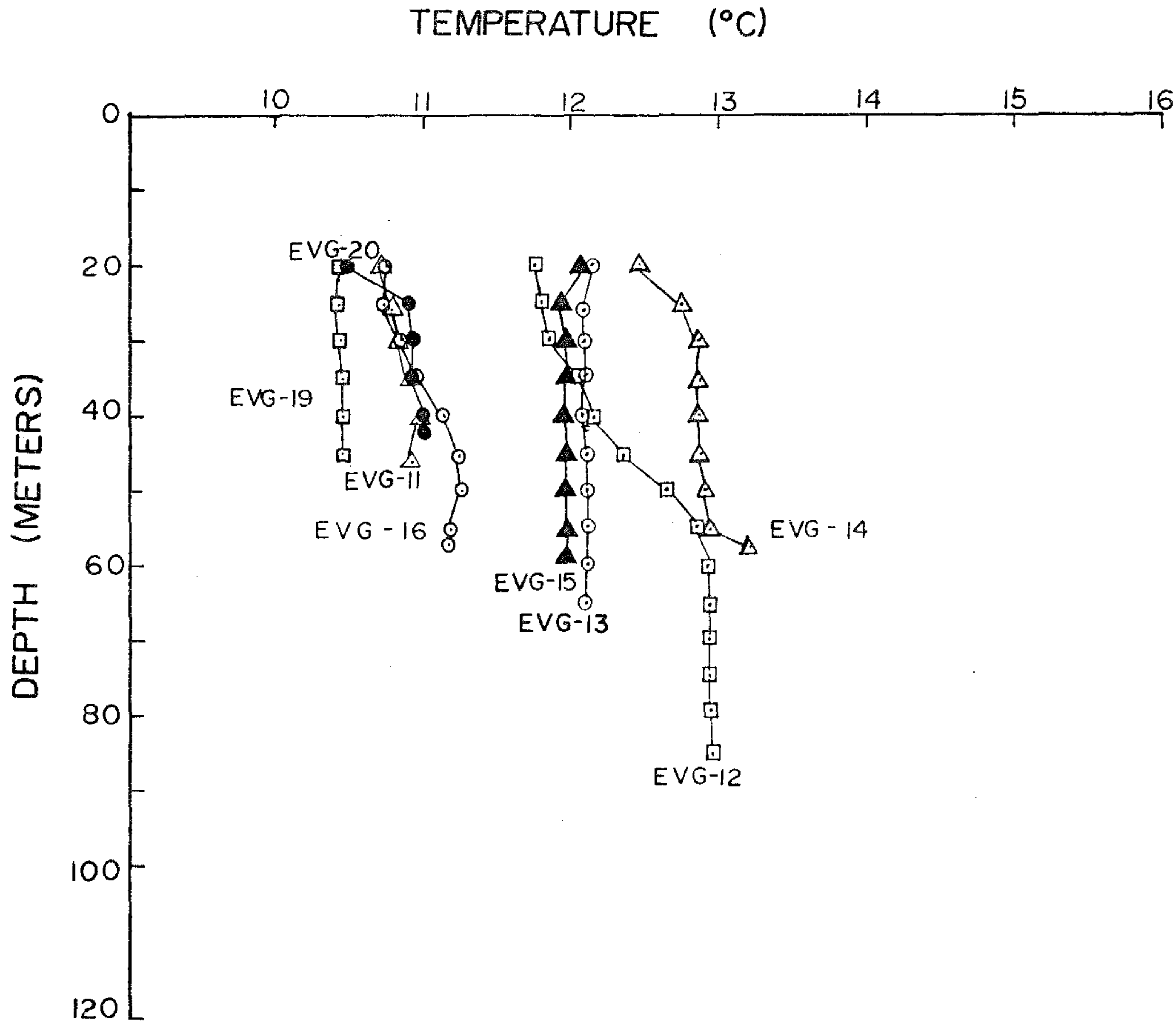


Figure 20. Temperature-depth profiles from holes of opportunity in the Escalante Valley, Utah. See Figure 16 for locations.

37° 55' 44" 113° 36' 36"

J

MX SET 2

23 MXC-19 119

Sect. 14 T33S R.16W

ELEMENT		CONCENTRATION (PPM)
NA		335
K		34
CA		145
MG		14
FE		0.05
AL	<	0.625
SIO2		52
TI		0.2
P	<	0.625
SR		2.13
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		2.6
CD	<	0.063
AG	<	0.050
AU	<	0.100
AS	<	0.625
SB	<	0.750
BI	<	2.50
U	<	6.25
TE	<	1.25
SN	<	0.125
W	<	0.125
LI		1.07
BE	<	0.005
B		1.0
ZR	<	0.125
LA	<	0.125
CE	<	0.250
TH	<	2.50
TDS		1730
SO_4		376
Cl		402
F		3.9

Date 10-16-81

Temp 20.01 °C

Conductivity 2360 umhos/cm

Salinity 1.5‰ 1500 ppm

Alkalinity 540/15ml

PH 7.09

(7.05) 7.05

7.02

Ads HCO_3^- 371 mg/Liter

37°56'25" 113° 36'51"

K

MX SET 2

22 MXC-18 118

Sect. 11 T33So R16W

ELEMENT		CONCENTRATION (PPM)
NA		343
K		34
CA		140
MG		18
FE		0.03
AL	<	0.625
SIO2		49
TI		0.2
P	<	0.625
SR		2.51
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		0.2
CD	<	0.063
AG	<	0.050
AU	<	0.100
AS	<	0.625
SB	<	0.750
BI	<	2.50
U	<	6.25
TE	<	1.25
SN	<	0.125
W	<	0.125
LI		1.06
BE	<	0.005
B		1.1
ZR	<	0.125
LA	<	0.125
CE	<	0.250
TH	<	2.50
TDS		1760
SO_4		367
Cl		447
F		3.1

Date 10-16-81

Temp 26.5°C

Conductivity 2770 umhos/cm

Salinity 1.3‰ 1300 ppm

Alkalinity 45D/15ml

PH 7.12

(7.15) 7.18

7.19

Adj HCO_3^- (318) mg/liter

37°56'44" 113°33'20" L

MX SET 2

Section 8 T 33So. R 15W

21 MXC-17 1/7

ELEMENT		CONCENTRATION (PPM)
NA		333
K		12
CA		159
MG		24
FE		0.42
AL	<	0.625
SIO2		42
TI		0.2
P	<	0.625
SR		0.99
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		1.0
CD	<	0.06[illegible]
AG	<	0.050
AU	<	0.100
AS	<	0.025
SB	<	0.750
BI	<	2.50
U	<	6.25
TE	<	1.[illegible]5
SN	<	0.125
W	<	0.125
LI		0.97
BE	<	0.005
B		0.9
ZR	<	0.1[illegible]
LA	<	0.1[illegible]
CE	<	0.250
TH	<	2.50
TDS		1700
SO_4		369
Cl		419
F		1.9

Date 10-16-81

Temp. 17.0°c

Conductivity 2080 umhos/cm

Salinity 1.1‰ 1100 ppm

Alkalinity 480/15ml

PH 7.02

7.02

7.0° 7.02

Adj HCO_3 325 [illegible]

[illegible]

[illegible]

37°55'29" [illegible]°34'42"

M

MX SET 2

Location Sect 19 Town 33So. Range 15 West

20 MXC 16 /16

ELEMENT		CONCENTRATION (PPM)
NA		204
[illegible]		12
CA		186
MG		30
FE		0.21
AL	<	0.425
SIO2		45
TI		0.2
P	<	0.625
SR		1.13
BA	<	0.625
[illegible]	<	1.25
CR	<	[illegible]
MN	<	[illegible]
CO	<	[illegible]
NI	<	[illegible]
CU	<	[illegible]
MO	<	[illegible]
[illegible]	<	[illegible]
ZN		[illegible]
[illegible]	<	[illegible]
AG	<	[illegible]
[illegible]	<	[illegible]
[illegible]	<	[illegible]
[illegible]	<	[illegible]
[illegible]	<	[illegible]
[illegible]	<	[illegible]
TE	<	[illegible]
SN	<	0.125
[illegible]	<	[illegible]
LI		[illegible]
[illegible]	<	[illegible]
[illegible]		[illegible]
[illegible]		[illegible]
[illegible]	<	[illegible]
[illegible]		[illegible]
[illegible]	<	[illegible]
TDS		1490
> SO_4		382
> Cl		346
- F		1.5

Date 10-16-[illegible]1

Temp 16.0°C

Conductivity 1630 umhos/cm

Salinity .5‰ (500 ppm)

Alkalinity 35 /15 ml

PH 7.39

7.69 7.69

7.69

Adjusted HCO_3^- 277 mg/L

37°54'39" 113° 35'47"

N

MX SET 2

Location Section 25 Range 16 west

township 33 South

19 MXC-15 115

LEMENT		CONCENTRATION (PPM)
NA		585
K		30
CA		693
MG		131
FE		0.10
AL	<	0.625
SIO2		50
TI		0.1
P	<	0.625
SR		8.28
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		0.2
CD	<	0.063
AG	<	0.050
AU	<	0.100
AS	<	0.625
SB	<	0.750
BI	<	2.50
U	<	6.25
TE	<	1.25
SN	<	0.125
W	<	0.125
LI		1.02
BE	<	0.005
B		1.2
ZR	<	0.125
LA	<	0.125
CE	<	0.250
TH	<	2.50
TDS		5360
SO_4		1229
Cl		1674
F		1.9
adj HCO_3		210

This symbol means the Amount was below the detectable amount.

This is the lowest Level we can Detect.

Date 10-16-81

Temp 14.8°C

Conductivity 4210 umhos/cm

Salinity 2.5‰ 2500 ppm

Alkalinity 310/15ml → 258.79

PH 6.98
6.99
6.99

adj HCO_3^- = 210 mg/L

U. of U.

#19

GEOTHERMAL GRADIENT 37°56'21" 113°39'19"

Logged By C. Gourley
Date 12-1-81 Time 11:20
Air Temp. ______ °C
Probe Number 145
Depth Measured 57 m. OR 186 ft.

Hole ______ Sheet ______ Of ______
Location T.33s R.16w Ground Elevation 5257"
Description Sec.16
Wells: Driller ______ Date ______
Log Available ☐ Yes ☐ No Depth To Water 95.6'

DEPTH	Ω	TEMP.	REMARKS	DEPTH	Ω	TEMP.	REMARKS
0 m.	25.7	25.7	conversion to feet	0 FT.		76	degrees fahrenheit
10	15.580	15.038		32.8		59	
15	15.040	15.931	1.035 } Dry	49.2		60	
20	14.440	16.966	0.846 } Dry	65.6		62	
25	13.970	17.812	1.379 } Dry	82.0		64	
30	13.240	19.191	.458 } H_2O	98.4		66	
35	13.007	19.649	.735 } H_2O	114.8		68	
40	12.643	20.384	.769 } H_2O	131.2		69	
45	12.274	21.153	.665 } H_2O	147.6		70	
50	11.965	21.818	.685 } H_2O	164.0		71	
55	11.656	22.503		180.4		72	
57	11.510	22.833		186.9		74	

$\overline{\Delta T} = 159$

$\Delta T_{57-30} = 135$ °C/km

$\Delta T_{30-15} = 217$

U. of U.

#20

GEOTHERMAL GRADIENT 37° 59'05" 113° 39'20"

Logged By C. Gourley
Date 11-19-81 Time 1:50
Air Temp. 14.492 °C
Probe Number 145
Depth Measured 102 meters 334 ft.

Hole ______ Sheet ____ Of ____
Location T.32sR.16w Ground Elevation 5860
Description Sec. 28
Wells: Driller 1" PVC Uof U Date ____
Log Available ☐ Yes ☐ No Depth To Water ground level

DEPTH	Ω	TEMP.	REMARKS	DEPTH	Ω	TEMP.	REMARKS
0 m.	15.921	14.492	conversion to feet	o feet		58	degrees fahrenheit
10	16.142	14.145	°C	32.8		57	
15	15.986	14.389		49.2		57	
20	15.801	14.682		65.6		58	
25	15.674	14.886		82.0		59	
30	15.337	15.435		98.4		60	
35	15.237	15.601		114.8		60.5	
40	15.079	15.865		131.2		61	
45	14.912	16.148		147.6		62	
50	14.757	16.413		164.0		62.5	
55	14.591	16.701		180.4		63	
60	14.443	16.961		196.8		63	
65	14.270	17.268		213.2		64	
70	14.127	17.526		229.6		64	
75	13.981	17.791		246.0		65	
80	13.894	17.951		267.4		65	
85	13.643	18.419		278.8		65.5	
90	13.461	18.764		297.2		66	
95	13.295	19.064		311.6		66	
100	13.146	19.374		328.0		67	
102	13.111	19.443		334.56		67.5	

U. of U.

#21

37°57'11" 113°42'39"

GEOTHERMAL GRADIENT

Logged By M. Foreman

Date 11-19-81 Time 10:35

Air Temp. ______ °C

Probe Number 145

Depth Measured 163 (m) or 534 ft.

Hole ______ Sheet ______ Of ______

Location T.33sR.17w Ground Elevation 5461'

Description Sec. 12 Lehi Wood's well

Wells: Driller ______ Date ______

Log Available ☐ Yes ☐ No Depth To Water 95'

DEPTH	Ω	TEMP.	REMARKS	DEPTH	Ω	TEMP.	REMARKS
0 m.		20.4	conversion to feet	0 ft.		68	degrees fahrenheit
10 m	15.908	14.512		32.8		58	
15	15.541	15.101		49.2		59	
20	15.342	15.427		65.6		60	
25	15.050	15.914		82.0		60.5	
30	14.524	16.818		98.4		61	
35	14.450	16.948		114.8		61.5	
40	14.330	17.161		131.2		62	
45	14.161	17.464		147.6		62.5	
50	13.983	17.788		164		63	
55	13.805	18.116		180		64	
60	13.565	18.566		196.8		65	
65	13.414	18.854		213.2		65.5	
70	13.227	19.216		229.6		66	
75	13.046	19.571		246.0		67	
80	12.860	19.943		262.4		68	
85	12.672	20.324		278.0		69.0	
90	12.494	20.691		295.3		69.5	
95	12.297	21.105	360	311.6		70.5	
100	12.128	21.465	406	328.0		71	
105	11.941	21.871	0.330	344.0		72	
110	11.791	22.201	0.383	360.0		72	
115	11.620	22.584	0.382	377.2		73	
120	11.452	22.966	0.277	393.6		73.5	
125	11.332	23.243	0.216	410		74	
130	11.180	23.459	0.450	426.4		74.5	
135	11.049	23.909	0.337	442.8		75	
140	10.909	24.246	0.288	459.2		75.5	
145	10.791	24.534	0.284	475.6		76	
150	10.676	24.818		492.6		76.5	
155	10.590	25.032	0.341	508.4		76.5	
160	10.454	25.373		524.8		77	
163	10.450	25.386		534.6		77	

ΔT_{163-30} = ~~133°C~~ 64 °/km

ΔT_{250-15} 813

#1 Submersible 55m T 33S R15W SEC 8
El. 5245

Depth m	Temp °C	ΔT		
BHT 55	16.11		H_2O	Qal
		0.30		
45	15.81		H_2O	clay rich sand silt
		0.66		
35	15.15		air	
25	14.55	0.60	air	K=2

ΔT= 52 °C/km HF = 1.0 HFU
D(200) = 3.56 km

#2 Windmill w/ pumpjack SE/4 SE/4 Sec 6 T 33S R15W
El. 5285

BHT 59	17.11		H_2O	Same
		0.03		
55	17.08		H_2O	
45	16.36	0.72	Air	
		0.68		
35	15.68		Air	
25	14.88	0.80	air	

ΔT_{25-55} = 73.33 HF = 1.5

#3 SW/4 sec 31 T32N R15W Fugro? or USGS
El. 5360

BHT 30	14.94		Same
~~28~~		0.49	
25	14.45		
~~24~~		0.38	
20	14.07		

ΔT = 87 °C/km D200 = 2.13
HF = $\frac{87 \times 2}{100}$ = 1.7 HFU

#4 NW/4 sec 30 T32S R15W
Fugro Hole? El 5468

Depth m	°C	ΔT	
BHT 30	14.80		Bottom of hole in dacite K=6 Top in Qal K=2
		0.11	
25	14.69		
20	14.28	0.41	

D200 = 8.43 km
ΔT = 22 °C/km HF = $\frac{22 \times 6}{100}$ = 1.3 HFU

#5 Windmill
El 5225

			°C/km	
BHT 60	32.42			H_2O Qal
		>1.69	169	H_2O
50	30.73			
		>2.03	203	
40	28.70			H_2O
30	26.90	>1.80	180	H_2O
		>2.02	1010	air
28	24.88			
		>0.75	375	↓
26	24.13			
		>1.18	590	
24	22.95			
		>1.10	550	
22	21.85			
		>1.00	500	
20	20.85			
		>2.59	518	
15	18.26			
		>2.41	482	
10	15.85			

Dillon Williams
ΔT_{60-30} = $\frac{5.52}{30}$ × 1000 = 184 °C/km K=6.57 HF=12.1
D200 = 1.00 Km
ΔT_{30-20} = $\frac{6.05}{10}$ × 1000 = 605 °C/Km K=2 HF=12.1

#8 Culinary Well at Woods' house
16" casing w/ 2 [illegible] pumps - shut off 12 hrs.
Depth m °C ΔT °C/km
El. 5203

Depth		ΔT
BHT 60	20.43	
		> 0.01
55	20.42	
		> 0.00
50	20.42	
		> 0.25
45	20.17	
		> 0.05
40	20.12	
		> 0.12
35	20.00	
		> 0.09
30	19.91	
		> 0.11
25	18.80	
		> 0.74
20	18.06	
		> 0.76
15	17.30	
10	16.54	

H_2O → Air

$\Delta T_{25-15} = 150$ °C/km
HF = 3.0 HFU
$D_{200} = 1.23$ Km

#9 El. 5185

Depth		ΔT
BHT 24	16.23	
		> 0.00
22	16.23	
		> 0.21
20	16.02	
		> 0.62
18	15.40	
		0.50
15	14.90	
10	13.90	

$\Delta T_{20-15} = 224$ °C/km
H_2O → Air
HF = 4.5 HFU
$D_{200} = 0.83$ km

#22 Windmill measured in water filled pump tube
El 5300 T33S R17W 4cc
Depth m °C ΔT °C/km

Depth		ΔT	°C/km
BHT 53	20.00		
		> 0.50	168
50	19.50		
		> 0.56	112
45	18.94		
		> 0.69	138
40	18.25		
		> 0.80	160
35	17.45		
		> 0.95	190
30	16.50		
		> 0.84	168
25	15.66		
		> 1.01	202
20	14.65		
		> .95	190
15	13.70		
		> 0.80	160
10	12.90		

H_2O ↓

335
.5
167.5

$\Delta T_{53-20} = 162$ °C/km HF = 3.2 $D_{200} = 1.14$ km

#23 Irrigation - Wood, w. center pivot El 5193

Depth		ΔT
BHT 50	20.64	
45	20.62	
40	20.62	
35	"	
30	"	
25	17.90	
		> 0.85
20	17.05	
		> 0.95
15	16.10	
10	15.80	

H_2O → Air

$\Delta T_{25-15} = 180$ °C/km
HF = 3.6
$D_{200} = 1.03$ Km

T 37S R15W Sec 1 NE/4 NW/4
top of Wasatch 2610
T.D. 6762
Flowed from 3375-3898 10,000 bbl/hr

T 37S R11W Sec 9 NE/4 NE/4
TD 5996

5-10 BWPH from 5100' TD

Tops: Virgin 0
Moenkopi 100
Timpoweap 540
Kaibab 746
Toroweap 905
Coconino 2477
Pakoon 3418
Callvill 4664
Redwall 5070
Devonian 5784

#6 Windmill measured in water filled pump tube
Qal El. 5314

	Depth m	T °C	ΔT	°C/km
BHT	44	17.30		
			>0.32	80
	40	16.98		
			>0.39	78
	35	16.59		
			>0.35	70
	30	16.24		
			>0.27	54
	25	15.97		
			>0.43	86
	20	15.54		
			>0.29	58
	15	15.25		
			>0.36	72
	10	14.89		

$\Delta T_{44-20} = 73$ °C/km HF = 1.5 HFU D_{200} = 2.52 km

#7 Windmill Turned off for 24 hrs.
El 5215

	Depth	T	ΔT	°C/km	
BHT	37	29.42			
			>0.10	50	H_2O
	35	29.32			
			>0.27	135	H_2O
	33	29.05			
			>0.24	120	H_2O
	31	28.81			
			>2.09	1045	H_2O
	29	26.72			air
			>1.41	705	
	27	25.31			
			>0.87	435	
	25	24.44			
			>1.25	625	
	23	23.19			
			>1.30		
	21	21.89			
			>-.06		
	20	21.95			
	15	21.50			
	10	19.65			

HF = 13.8 HFU

ΔT_{20-31} = 6.92 = 692 °C/km

D_{200} = 1.83 km ΔT_{31-37} = 101 °C/km