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COOPERATIVE GEOCHEMICAL INVESTIGATION OF GEOTHERMAL RESOURCES IN THE IMPERIAL VALLEY AND YUMA AREAS

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INTRODUCTION

Geothermal resources may be an undeveloped supply of energy and water in the United States that may help to supplement growing shortages. Preliminary studies by the Geothermal Resources Group at the University of California at Riverside indicate that the Imperial Valley has a large geothermal potential. In order to delineate additional geothermal systems we have conducted a chemical and isotopic investigation of samples from water wells, springs, and geothermal wells in the Imperial Valley and Yuma areas. The results from this study should provide information so that additional geothermal systems may be developed for their water resources.

SODIUM-POTASSIUM-CALCIUM STUDIES

Fournier and Truesdell (1973) have shown that under favorable conditions sodium (Na), potassium (K), and calcium (Ca) concentrations in natural waters may be used to predict the last temperature of water-rock equilibration. They show that data for most geothermal fluids plot near a straight line on a graph of the function

$$F(T) = \log (Na/K) + \beta \log \{\sqrt{(Ca)}/Na\}$$

versus reciprocal of the absolute temperature. The value for β is 4/3 unless equilibrated temperatures are above 100°C, in which case it is 1/3. Lower values of F(T) indicate higher water-rock equilibration temperatures.

Na, K, and Ca concentrations of nearly 200 well water, spring water, hot spring, and geothermal fluid samples from the Imperial Valley area (Fig. 1, see back pocket) have been measured by atomic absorption spectrophotometry. Fournier and Truesdell's function (above) has been determined for each water sample and they are shown in Fig. 1 in red. Numbers in black are UCR sample numbers. These data are reported in Table 1.

In those few cases where the flow of geothermal brine to the surface is fast and takes place with little or no dilution or precipitation of dissolved constituents, we can calculate water-rock equilibrium temperatures. Five locations which may approach these criteria are listed in Table 2. In situ temperatures for most of the sample localities listed in Table 2 are not available. Therefore, actual in situ temperatures are not listed.

Table 1.

Chemical Analyses of Water Samples from the Imperial Valley and Yuma Areas

Sample #	Name	Location	Depth in meters	Sodium in ppm	Potassium in ppm	Calcium in ppm	F(T)	Observed Discharge Temperature in °C
1	Magnolia Union School	T13S R15E S33A	387-423 m	1120	9.01	29.0	2.11	53
3	Camp Dunlap	T11S R14E S1D		648	14.3	32.0	1.89	45
4	Rutherford Max Phegley	T13S R15E S34M	285-291 m	562	2.70	8.8	2.26	44
5	V Butters Reese	T13S R15E S24N	213 m	469	2.22	8.7	2.37	43
6	J. Ratliff	T13S R15E S23Q	396 m	954	8.97	29.0	2.01	56
7	Orita Stage Station	T13S R15E S34J	274 m	560	2.40	12.5	2.41	34
8	Holtville Ice Company	T15S R15E S35A	335 m	782	4.06	20.0	2.27	45
9	City of Holtville	T15S R15E S36D	255-260 m	328	1.69	15.0	2.70	29
10	Flowing Well near Niland	T11S R15E S17P		2265	42.6	150.0	1.89	25
11	John DePaoli	T15S R15E S26B	241-290 m	497	2.5	11.0	2.38	40
12	Youth Spa	T 9S R12E S 2B	192 m	1570	86.0	124.0	1.46	58
13	Gold Rock Ranch	T14S R20E S 9A	158 m	312	4.30	50.0	2.65	37
15	Watton Labor Camp	T16S R16E S14A	244 m	559	2.98	17.0	2.41	43
16	A. Fusi, Sr.	T15S R16E S29Q	164-188 m	236	1.29	7.1	2.64	31
17	Neidiffer	T15S R16E S27N	183 m	262	1.28	4.9	2.52	34
18	L.E. Foster	T15S R16E S23F	138-165 m	352	1.42	6.7	2.53	34
19	Dickerman and Butters	T13S R15E S13H	152 m	950	6.35	22.0	2.08	52
20	D. Starr	T15S R16E S22F	229 m	555	2.82	17.0	2.43	35
21	F. Strahm	T15S R16E S19E	254 m	280	1.11	6.5	2.66	36
23	R. Garewal	T15S R16E S15P	244 m	373	1.38	7.6	2.57	32
24	C.D. Allen	T15S R15E S14H	263 m	459	2.28	11.0	2.43	40
25	Shawner & Harman	T15S R15E S10G	140 m	665	4.31	22.0	2.30	32
26	Old Alamo Store	T16S R16E S15B	340 m	508	2.40	7.0	2.26	45
27	G. Hoyt	T15S R16E S 8E	145-149 m	521	2.43	16.0	2.49	31
28	H. Hoke	T15S R16E S 7J	202-212 m	428	1.90	9.1	2.46	36
29	Alamo School	T16S R16E S15B	263-267 m	394	1.51	10.0	2.60	37
30	A.W. Barnes	T15S R15E S10K	122 m	715	4.32	15.5	2.18	33
31	Gaddis W. Hansen	T14S R15E S34R	186 m	600	3.96	30.0	2.44	36
32	Jensen - V. Shaw	T14S R15E S34B	109 m	545	3.53	13.0	2.26	30

Table 1. (cont.)

Sample #	Name	Location	Depth in meters	Sodium in ppm	Potassium in ppm	Calcium in ppm	F(T)	Observed Discharge Temperature in °C
33	James Birger Jr.	T14S R15E S27A	122 m	569	3.56	26.0	2.45	32
34	James Birger Sr.	T14S R15E S23M	229 m	456	2.34	8.7	2.35	40
35	Gisler-Bowman & Jeska	T14S R15E S15B	335 m	600	3.04	22.0	2.46	48
37	Sand Hills Rdside Rest	T16S R20E S27A	47 m	173	6.8	106.0	2.75	19
38	S. Stacey	T14S R16E S21B	133 m	332	1.55	7.6	2.53	32
39	Singh	T14S R16E S22D	213-216 m	879	5.84	31.0	2.22	42
40	Marvon Axler	T14S R16E S16K	122 m	273	1.49	13.0	2.73	25
41	Roy Schaffner	T15S R15E S 9Q	168 m	715	4.15	31.6	2.41	32
42	Joseph Birger	T14S R15E S 9M	117 m	999	6.22	52.0	2.33	31
43	M & F Feed Lot	T14S R15E S12M	357-376 m	865	8.98	33.0	2.06	52
44	Theodore Shank	T13S R15E S32D	305 m	848	4.53	19.0	2.2	44
45	Moiola Brothers Feed Lot	T14S R16E S11D	198 m	469	2.28	10.0	2.4	42
46	Frank Borchard	T14S R16E S 4K	139 m	332	1.49	4.8	2.42	38
47	Frank Borchard	T14S R15E S 4Q	119-139 m	352	1.50	6.2	2.48	37
49	M.J. Lunceford	T13S R15E S16Q	232 m	414	2.33	9.9	2.4	39
50	Mulberry School	T13S R15E S 3N	271 m	490	2.21	9.7	2.39	40
52	Tom Olesh	T13S R16E S 6P	91 m	579	3.56	23.0	2.41	32
53	Schoenman-A. Koluvek	T13S R16E S 6R	188 m	518	3.34	21.0	2.43	33
54	Taylor	T13S R15E S 1G	325-332 m	1110	10.29	43.0	2.04	55
55	P.J. Rebik	T12S R16E S31N	282 m	1180	8.65	37.0	2.06	39
56	Richard Cowell	T12S R15E S35A	93-105 m	456	3.28	19.0	2.43	33
57	Donald Brownell	T12S R15E S23M	87- 99 m	604	5.13	32.0	2.34	32
58	G.C. Brownell	T12S R15E S27R	131 m	342	3.19	19.0	2.48	34
59	J.M. Williams	T13S R15E S 5D	259-264 m	586	4.72	11.0	2.08	36
60	Wiest Store-Bob Gardner	T13S R15E S 5E	235-247 m	545	3.81	8.7	2.11	38
61	C.P. Ansiel	T16S R16E S 4F	268-287 m	614	2.28	11.0	2.38	35
62	A. Fusi Jr.	T15S R16E S30Q	271-286 m	425	1.79	9.0	2.48	40
63	Lester Bornt	T17S R16E S 9B	184-216 m	460	2.48	17.5	2.52	38
64	Neil Fifield	T14S R15E S 6B	364-393 m	1160	7.38	40.0	2.16	51
65	U.S.G.S. Oasis-E. Highline	T14S R16E S11H	87 m	394	2.24	12.0	2.48	35
66	Inspection Station 18 Winterhaven	T16S R21E S22K	107 m	174	3.9	32.7	2.65	26
67	Fred Carlson	T16S R21E S21L	142 m	153	4.17	74.3	2.88	27
70	Texaco, 18 & Sidewinder	T16S R21E S22N	98 m	160	4.5	76.2	2.84	28
71	UCR 127	T16S R17E S17B	429 m	1150	16.3	230.	2.32	83
73	Holly Hot Well	T10S R 9E S35M	418-604 m	1053	4.0	4.3	1.95	61
74	Truckhaven	T10S R10E S16E	366 m	1520	13.4	10.5	1.90	40
75	Texaco, Imperial Hwy.	T16S R 9E S36L	95 m	122	0.17	2.6	3.33	29

Table 1. (cont.)

Sample #	Name	Location	Depth in meters	Sodium in ppm	Potassium in ppm	Calcium in ppm	F(T)	Observed Discharge Temperature in °C
76	Miller's Service	T16S R 9E S35M	126-151 m	141	0.26	1.9	3.03	34
80	Plaster City #5	T16S R 9E S36H	18-116 m	83	1.35	17.7	3.04	29
81	J.L. Jessup	T16½S R10E S5F	50 m	528	6.3	19.7	2.13	29
82	W.E. Simpson	T17S R10E S11G	43- 91 m	89	3.70	25.0	2.69	29
83	Clifford Realty	T16S R 9E S25Q	27- 75 m	90	1.56	23.8	3.05	29
84	C.L. Smith	T16½S R10E S5M	43- 46 m	832	8.45	38.2	2.13	29
85	E. Robinson	T12S R 8E S 9A	44- 58 m	250	6.95	40.8	2.41	37
86	Octillo Dunning Mutual	T16S R 9E S25M	66-102 m	128	7.25	50.0	2.55	28
87	Henry Lazare	T18S R 7E S 8M	49- 61 m	110	0.29	1.2	2.89	38
88	Joe R. Jones	T16S R10E S32L	24- 30 m	125	2.10	46.3	3.07	28
89	DeAnza Trail Inn	T12S R 8E S15M	66 m	405	5.75	52.0	2.49	37
90	T.M. Jacobs #3	T12S R 9E S22B	366 m	550	2.10	36.8	2.79	39
91	T.M. Jacobs #2	T12S R 9E S23D	76-204 m	280	9.4	162.0	2.66	30
98	Massion SPA	T11S R13E S13D		6500	470.	453.	1.23	41
99	Desert Center Airport	T 5S R15E S 8G	69 m	149	1.50	8.9	2.71	30
101	C.C. Bowles #2	T12S R14E S14H	253-280 m	682	5.2	93.2	2.63	41
103	Brock Research	T16S R19E S32G	12- 73 m	190	5.8	109.	2.81	19
104	M. Guinn	T16S R19E S36Q	80 m	154	5.46	88.	2.81	21
105	O. Murray	T14S R 7E S18G	27 m	123	0.17	0.85	3.00	27
106	Agua Caliente Springs Prk.	T14S R 7E S18P		114	1.09	20.3	3.13	37
107	C.C. Bowles #1	T12S R15E S14L	76-113 m	1358	15.0	313.	2.42	29
108	Desert Tower	T17S R 9E S30K	44 m	119	7.62	129.	2.81	21
110	Border Check Station	T16S R21E S35Q	40- 52 m	139	3.55	112.	3.08	23
111	Fifield & Hoeppher	T13S R15E S34K	319 m	570	2.55	102.	2.99	44
112	Bob Emanuelli	T13S R16E S32A		518	2.65	10.0	2.32	41
113	V. C. Daly	T16½S R10E S5Q	15 m	942	5.00	4.1	2.00	27
114	R. Meyer - Dickerman	T13S R15E S12Q		545	3.30	7.0	2.11	36
115	Burnett	T13S R16E S 6F	187 m	530	2.60	31.6	2.65	28
116	D. Butters - J. C. Rivers	T13S R15E S 3Q	268 m	560	2.20	11.6	2.43	40
118	Cornish	T12S R 8E S22N	70 m	150	1.18	44.8	3.28	32
119	Al Williams	T12S R 8E S15E	45 m	221	1.39	18.6	2.90	36
120	Charles Peterson	T12S R 8E S 8K	80- 84 m	134	1.34	24.0	3.06	32
121	Paul H. Webber Jr.	T12S R 9E S21N	36- 39 m	1360	14.8	380.	2.48	27
123	Theweate, Circle T	T12S R 8E S 6R	95 m	97	1.04	42.0	3.38	36
124	John Balch, Ironwood Motel	T12S R 8E S 6N	62-101 m	91	1.57	19.5	2.99	37
125	Gravel Co., Nudie	T 9S R13E S20E	24 m	1340	70.8	146.	1.51	31
126	Gravel Co., Canal Rd.	T 9S R13E S21P	24 m	1015	54.6	126.	1.53	29
127	King SPA	T 8S R12E S36P	106 m	930	41.0	85.8	1.61	79
128	Brashford's	T 9S R12E S 1D	75 m	1070	57.0	148.	1.54	62
129	Hamming	T16S R10E S20R	21 m	435	0.52	8.8	3.01	28

Table 1. (cont.)

Sample #	Name	Location	Depth in meters	Sodium in ppm	Potassium in ppm	Calcium in ppm	F(T)	Observed Discharge Temperature in °C
130	Coyote Wells Union 76	T16S R10E S30R	30 m	115	1.62	38.5	3.14	24
131	L. D. Bement	T16S R10E S16B	32 m	5380	16.8	560.	2.34	29
133	Date City Store	T16S R16E S 3C	182 m	350	1.29	5.5	2.51	32
134	Linden Gravel Co.	T16S R16E S13B	247 m	840	5.25	24.5	2.21	49
135	Mets Feed Lot	T16S R16E S33D	244 m	625	3.12	5.6	2.05	31
136	Lechuga Store	T16S R16E S17Q		615	3.1	9.5	2.21	40
137	Schneider - Guthrie	T16S R16E S12N	251 m	315	1.6	7.0	2.50	42
138	Lazere Rock Shop	T18S R 8E S 8K	35 m	111	1.12	95.	3.56	21
139	Bill Ketchum	T18S R 8E S 8C	46 m	88	0.64	79.	3.79	11
140	Jacumba Airport Cafe	T18S R 8E S 9G	43 m	370	15.4	45.0	2.04	21
141	Raymond Resco	T18S R 8E S 9H	49 m	52	1.28	51.5	3.44	31
142	J. A. Bastenchury	T14S R15E S34R	110 m	1270	7.95	61.0	2.23	28
143	H. A. Foster	T14S R15E S28K	116 m	840	4.47	13.0	2.10	31
144	G. Mamer - T. B. Shank	T14S R15E S 9D	244 m	1090	6.2	31.0	2.17	31
145	K. K. Sharp	T15S R15E S13N	244 m	385	1.53	7.9	2.53	36
146	F. Grinello	T15S R15E S12G		425	1.85	6.2	2.36	38
147	J. Rohrer	T15S R16E S 1H	177 m	500	1.92	4160.	4.21	38
148	Coons	T14S R16E S27M		375	1.68	6.3	2.43	31
149	A. Jechims	T14S R16E S34E		470	1.72	8.2	2.46	33
150	Hazz Strang	T15S R15E S25A	266 m	858	3.95	17.0	2.22	44
151	Landmark Corp.	T13S R 9E S 2N	91-335 m	140	0.81	15.8	3.15	35
152	M. A. Smith	T12S R 8E S 6H	77- 88 m	272	1.59	53.8	3.12	31
153	A. Toner	T12S R 8E S10A	61 m	560	9.25	35.0	2.12	32
154	F. Axler	T14S R16E S21D	137 m	430	1.98	7.3	2.38	36
155	Chopenich	T14S R16E S16B	137 m	380	2.15	9.5	2.44	32
156	Q. O. Cattle Co.	T13S R16E S28R		592	4.75	11.9	2.09	37
157	A. Immel	T14S R16E S19N	346 m	900	6.22	27.0	2.15	51
158	R. N. Simon	T10S R10E S32N	15- 30 m	178	16.4	66.6	2.23	28
159	H. D. Currey	T16S R 9E S35A	107 m	108	1.23	18.0	3.05	29
160	G. Graham	T16½S R10E S5E	55 m	246	1.62	7.5	2.55	29
161	Jeanine Greene #1	T16S R10E S16D	32 m	3250	13.4	460.	2.45	28
162	Dollinger	T16S R10E S16K	91 m	3780	15.0	630.	2.48	30
163	Yuha Spring	T16½S R11E S6M		1460	9.0	25.3	2.10	25
164	J. Greene #2	T16S R10E S16D	32 m	3330	13.4	470.	2.46	29
165	Carrizo Creek Spring	T15S R 8E S12Q		650	10.1	166.	2.52	24
166	Mesquite Oasis, Palm Spring	T14S R 7E S25P		169	2.63	3.4	2.17	22
167	Gar Salzgeber	T15S R 8E S17D	34 m	125	1.7	21.0	2.93	29

Table 1. (cont.)

Sample #	Name	Location	Depth in meters	Sodium in ppm	Potassium in ppm	Calcium in ppm	F(T)	Observed Discharge Temperature in °C
168	W. E. Martin	T15S R 8E S17E	38 m	133	1.76	23.5	2.94	29
169	H. S. Jackson	T11S R20E S15E	21 m	23	3.03	100.	3.38	24
170	USBR, 6-151	T16S R17E S 6J	46 m	405	3.9	24.0	2.44	33
171	Smith Bros.	T13S R18E S33A	207 m	1135	86.	78.9	1.34	71
172	Spanish Trails Mobile Home Park	T15S R16E S30M	473 m	828	3.90	32.2	2.42	43
173	City of Blythe #8	T6S R23E S29R	80-112 m	114	2.86	119.	3.22	23
174	City of Blythe #6	T6S R23E S33E	88- 97 m	131	2.00	136.	3.39	23
175	City of Blythe #11	T6S R23E S32E	128-154 m	108	1.37	55.5	3.33	26
176	Stanley Ragsdale	T5S R15E S27B	183	550	17.0	167.	2.32	33
177	Sunland Oil	T5S R15E S29L	198 m	118	2.20	20.5	2.82	30
178	East Blythe #5	T6S R23E S34M	133-138 m	88	1.37	42.0	3.27	24
179	East Blythe #1	T6S R23E S33L	93 m	119	1.37	84.	3.43	24
180	East Blythe #2	T6S R23E S33G	168-176 m	124	1.50	118.	3.48	24
181	Mesa Ranch	T6S R22E S 1N	148 m	158	2.00	52.0	3.09	28
182	Bill Murphy	T6S R22E S12F	85 m	340	4.40	120.	2.88	26
183	Riverside Co. Airport	T6S R22E S32E		260	2.92	21.4	2.59	31
184	Pacific Lighting Co. #2	T6S R22E S35R	99 m	155	2.20	35.0	2.93	26
185	Howard C. Brown	T5S R16E S 7M	198 m	166	2.20	14.0	2.66	35
186	Kaiser North Well	T3S R15E S 4F		195	2.75	10.6	2.46	29
187	Division of Highways	T5S R15E S27C	178 m	125	3.10	22.2	2.68	32
188	26th Ave., County Park	T2S R22E S18 Ariz	141 m	172	6.7	41.0	2.48	23
189	East Blythe, #3	T6S R23E S33K	107-124 m	94	1.30	72.	3.44	24
190	City of Blythe, #1	T6S R23E S32P	75- 99 m	167	3.20	122.	3.12	25
191	Mesa Verde #3	T6S R21E S36R	110 m	475	5.6	37.6	2.39	31
192	S &D Trailer Park	T5S R15E S23N	152 m	615	20.7	171.	2.22	34
193	Thurman Ragsdale	T4S R15E S17H	183 m	148	1.10	9.7	2.87	40
194	S & D Trailer Park	T5S R15E S23N	152 m	513	18.3	159.	2.28	34
195	H & M Citrus	T6S R22E S33F	59 m	410	5.15	58.	2.57	29
196	6th Ave. County Park	T6S R23E S12E	47 m	295	5.25	278.	3.06	20
197	Wiley Well Rest Area	T6S R20E S33C	518 m	10	14.4	69.	2.71	48
198	Lazy C. Trailer Park	T5S R15E S13		136	1.20	74.	3.43	30
200	In-Ko-Pah County Pk. Well	T17S R 8E S36H	30 m	80	7.9	155.	2.91	25
201	Murad Field Well	T10S R 6E S 5F	107 m	100	10.6	45.9	2.39	27
202	Murad Domestic Well	T10S R 6E S 9E	91 m	230	14.0	68.4	2.27	29

Table 1. (cont.)

Sample #	Name	Location	Depth in meters	Sodium in ppm	Potassium in ppm	Calcium in ppm	F(T)	Observed Discharge Temperature in °C
203	Desert Lodge Well	T11S R 6E S22A	226 m	90	3.7	15.1	2.54	29
204	Borrego Air Ranch Well	T11S R 7E S30F		220	8.7	53.	2.41	35
205	Half Hill Ranch Well	T12S R 8E S22E		150	3.1	10.1	2.43	35
206	Anza Borrego State Park Well	T10S R 5E S36A		45	6.5	34.3	2.64	32
207	Ranch Oasis	T12S R 9E S23D		400	9.8	55.1	2.28	30
208	Tamarisk Grove Campground	T12S R 6E S17C	61 m	410	16.0	66.5	2.12	34
209	Fuerte Del Mar	T8S R 9E S33J		160	1.9	8.6	2.59	32
210	Desert Shores Spring	T9S R 9E S15Q		1670	13.0	65.5	2.00	28

Table 2

WATER-ROCK EQUILIBRATION TEMPERATURES OF

SELECTED SAMPLE LOCATIONS

UCR Sample Number	Name	F(T)	Temperature from F(T)
98	Massion Spa	1.23	$\sim 200^{\circ}C$
125	Gravel Co., Nudie	1.51	$\sim 160^{\circ}C$
126	Gravel Co., Canal Rd.	1.53	$\sim 160^{\circ}C$
127	King Spa	1.61	$\sim 155^{\circ}C$
128	Brashfords	1.54	$\sim 160^{\circ}C$

If the flow of geothermal brine to the surface involves some precipitation and dilution by near surface cold waters we may in favorable cases be able to distinguish a geothermal component. We then have a geochemical tool which may allow us to identify suspected geothermal systems. Three such areas are shown in Fig. 1 in gold. They were identified by the fact that the F(T) values are near 2.00 or less. Two areas lie in West Mesa. The size and shape of each is unknown; consequently the gold areas in West Mesa were drawn in quite subjectively and the anomalies may, in fact, be shaped quite differently. The anomaly to the west of the Salton Sea shows a small oxygen isotope shift (see Coplen, 1972) adding further support that a geothermal system exists at depth in this region. The anomaly in the lower left hand corner of Fig. 1 corresponds with an anonalous body of high density contrast discovered by Getts and Biehler (1972). Clearly additional geophysical exploration is needed to verify whether or not these are economic geothermal resources.

The region in white in Fig. 1 has not been explored using this technique because of (1) lack of wells, and (2) lack of sample collection from available wells.

In order to gain additional information about the white areas in West Mesa we compiled a list of 39 locations which might provide water samples. These are listed in Table 3. In August 1973 we sampled as many of these as could be gotten to with the available equipment. Because of very hot weather and bad roads we were not able to get to about half the locations. We were able to sample about a dozen locations. These are listed in Table 1 with sample numbers above 199.

The F(T) values for sample numbers 208 and 210 are 2.12 and 2.00, respectively. These relatively low F(T) values are suggestive of geothermal

TABLE 3

POSSIBLE WATER SAMPLE LOCATIONS IN THE WEST MESA AREA

Name	Location	Remarks
well	R12E T17S s10	
Coolidge Springs	R 9E T 9S s16	capped
artesian well	R 9E T 9S s15	sampled
artesian well	R 9E T 8S s33	sampled
Kane Spring	R11E T12S s21	dry in summer
Artesian well	R10E T11S s32	
springs	R 8E T17S s29	
Arsenic Springs	R 8E T17S s32	dry in summer
Iron Spring	R 7E T17S s25	
well	R10E T17S s19	
spring	R 8E T17S s12	
water well	R 8E T17S s36	sampled
spring	R 8E T17S s25	dry in summer
Rattlesnake Springs	R 7E T10S s36	
Ranch Oasis Well	R 9E T12S s23	sampled
well	R 6E T10S s 8	
well	R 6E T11S s22	sampled
Borrego Springs	R 7E T11S s 8	dry
well	R 7E T11S s 7	
well	R 7E T11S s30	sampled
well	R 8E T12S s 7	
well	R 8E T11S s 6	capped
seep	R 8E T15S s 4	
Well of the Eight Echoes	R 7E T15S s12	dry
Clark Well	R 7E T 9S s29	
well	R 7E T10S s19	capped
well	R 7E T10S s25	
spring	R 9E T10S s36	
well	R 9E T10S s26	
well	R 8E T12S s27	
Harper's Well	R10E T12S s26	
springs	R10E T12S s32	
springs	R 6E T16S s26	standing water only
Yaqui Well	Tubb Canyon quadrangle	dry
Blue Springs	R 6E T13S	
Five Palms Spring	Anza-Borrego Desert State Park on Shell Reef Quadrangle	
Toner Well	R 8E T12S s10	well pump not on
Four Palms Spring	R 9E T10S s22	dry
Seventeen Palms	R 8E T10S s35	dry

brines at depth. Thus, geophysical exploration should be encouraged in these areas.

The areas in blue in Fig. 1 are those which show no geothermal potential using the Na-K-Ca exploration technique. Thus, geothermal systems may exist in these areas but the leakage of brine from these systems is so low that we can't detect it in the near surface hydrologic system.

One of the problems that one must be aware of is that some surface waters yield an F(T) value less than 2.00, suggesting they are from a geothermal system when in fact they are not. Table 4 lists the sodium, potassium, calcium, and F(T) values for canal water, irrigation run-off water (Alamo River and New River), and the Salton Sea. The F(T) values for canal waters are 2.7 or greater, indicating water-rock equilibration temperatures of less than 70°C. However, the F(T) values for the Alamo River, New River, and Salton Sea are in the range of 1.7 to 2.4. An F(T) value of 1.7 yields a temperature of about 120°C. Thus, one must interpret the Na-K-Ca data with regard to possible recharge of irrigation run-off to the hydrologic system.

TABLE 4

CHEMICAL ANALYSES OF SURFACE WATER SAMPLES IN THE IMPERIAL VALLEY AND YUMA AREAS

Sample #	Name	Sodium in ppm	Potassium in ppm	Calcium in ppm	F(T)
68	New River at Keystone Rd.	1230	38	238	1.79
69	New River at Gentry	1570	35	350	2.06
72	All American and East Highline Canals	187	7.5	116	2.72
78	Coachella Canal and Hwy 78	193	5.0	115	2.89
94	Alamo River and Hwy 78	832	13.5	238	2.46
95	New River and Hwy 98	1870	65	212	1.67
96	Alamo River and Hwy 98	648	16	211	2.38
97	Central Main Canal and S80	192	7.5	111	2.71
102	Salton Sea, Obsidian Butte	13800	166	1000	1.96
109	Coachella and All American Canals	184	5.4	115	2.87
117	Salton Sea, Salton City	12500	79	1060	1.98

STABLE ISOTOPE STUDIES

The stable isotope studies in this research program are directed towards identification of the source of the water in the Mesa geothermal system. The stable isotopes of oxygen and hydrogen are employed in this study.

Six samples from the Mesa system (Table 5) were collected in 50-ml glass bottles for oxygen and hydrogen analysis. Since evaporation causes a change in the isotopic composition of the water samples, Polyseal caps which are leak free were employed.

Hydrogen isotope abundances have been determined on a 5-cm radius 180°-sector isotope ratio mass spectrometer (McKinney et al., 1950) from hydrogen quantitatively extracted from an aliquot of the water sample by reaction with hot uranium metal. Corrections have been made for H_3^+ contribution to the mass-3 ion beam (Coplen, 1970) and for mixing of the sample and standard gases due to glass valve leakage (Mook, 1968). The isotopic ratio D/H is reported in parts per thousand difference (^{o}/oo) from standard mean ocean water (SMOW), (Craig, 1961b). Thus:

$$\delta D\ (^{o}/oo) = \left[\frac{(D/H)_{sample}}{(D/H)_{SMOW}} - 1\right] 1000 \qquad (1)$$

The error in the hydrogen isotope analysis is ± 1 ^{o}/oo.

The oxygen isotopic composition of water samples was determined on a double-focusing double-collecting isotope ratio mass spectrometer (Coplen, 1973) by analyzing an aliquot of carbon dioxide which had been isotopically equilibrated with the water sample in a 25.0^{o}C temperature bath (Epstein

TABLE 5

OXYGEN AND HYDROGEN ISOTOPIC COMPOSITION OF WATER SAMPLES

FROM THE MESA GEOTHERMAL SYSTEM

Sample No.	Description	δD	δO^{18}
1	Shallowest aquifer (approx. 150ft deep)	-71	-7.81
2	Shallow aquifer (approx. 250ft deep)	-76	-8.68
3	Mesa 6-1 (2,600ft)	-100	-10.57
4	Mesa 6-1 (4,500ft)	-99	-10.19
5	Mesa 6-1 (5,500ft)	-108	-13.33
6	Mesa 6-1 (brine collected 1-16-73)	-103	-9.51

and Mayeda, 1952). Corrections were made after Mook (1968). The oxygen isotopic composition of water samples is reported relative to SMOW (Craig, 1961b) in the per mil notation:

$$\delta O^{18}\ (^{o}/oo) = \left[\frac{(O^{18}/O^{16})_{Sample}}{(O^{18}/O^{16})_{SMOW}} - 1 \right] 1000 \qquad (2)$$

The accuracy of the oxygen isotope analyses is ±0.1 $^{o}/oo$.

As discussed by Coplen (1972) the stable isotope technique is useful because the oxygen and hydrogen isotopic composition of precipitation differ in general from one locality to another due to differences in the temperature of formation, etc. Craig (1961a) found a linear correlation between δD and δO^{18} for meteoric water samples from all over the earth such that

$$\delta D = 8\delta O^{18} + 10$$

Samples from colder locations are more negative in δD and δO^{18} while precipitation from equatorial zones is closer to SMOW. If a geothermal system is sufficiently hot (150°C or so) oxygen in the rock can exchange with oxygen in the water in the system. The effect is to increase the O^{18} content of the water and decrease the O^{18} abundance of the rock. This is the "O^{18}-shift" discussed by Craig (1966). The quantity of hydrogen is so low in rock that the hydrogen isotopic composition of water in geothermal systems is not affected. Thus, the hydrogen isotopic composition can be used to "tag" water in a geothermal area.

Figure 2 is a plot of δD versus δO^{18}. It shows that most of the water samples from the Imperial Valley plot along a line which is the path of

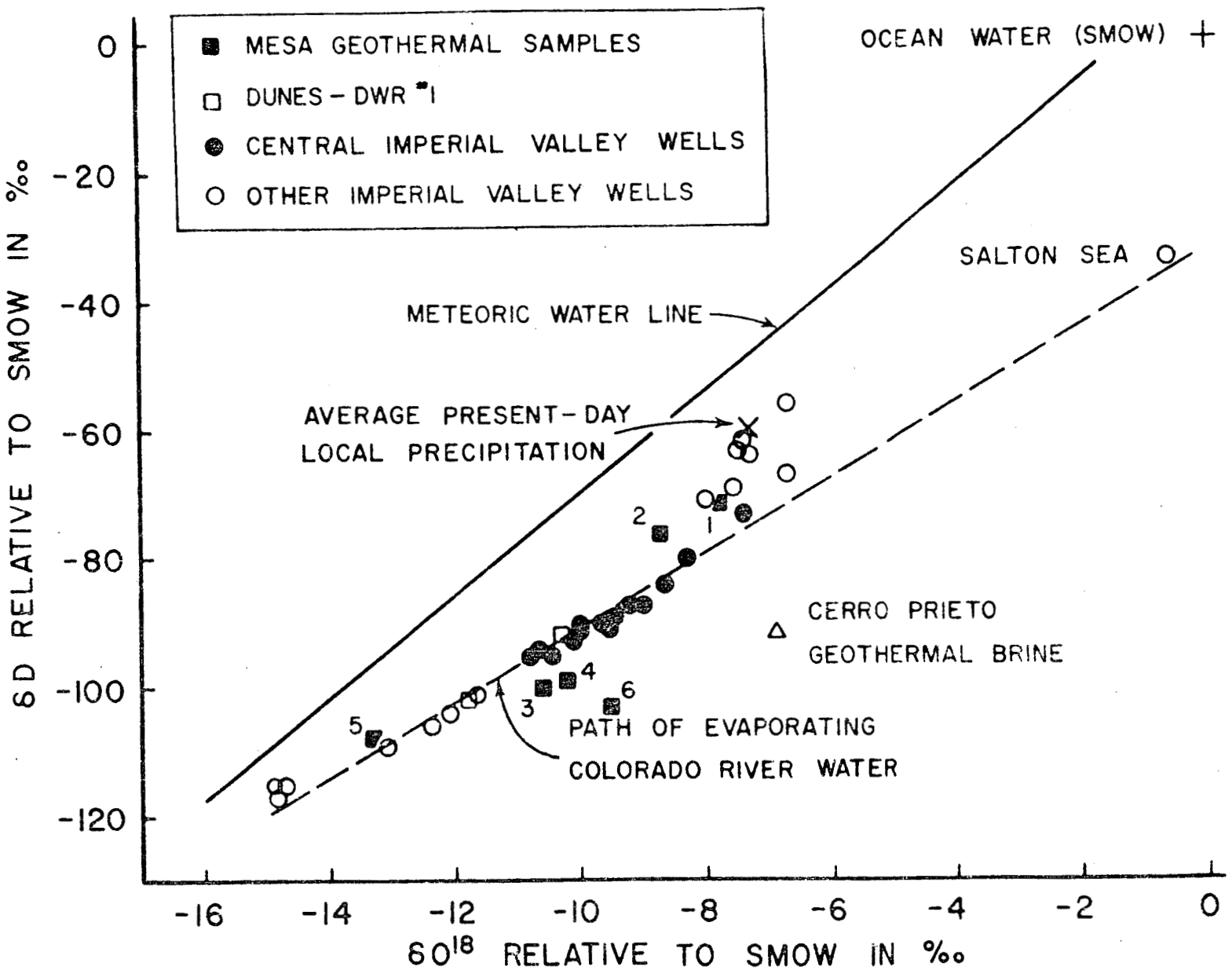
MESA GEOTHERMAL SAMPLES
DUNES - DWR #1
CENTRAL IMPERIAL VALLEY WELLS
OTHER IMPERIAL VALLEY WELLS
OCEAN WATER (SMOW)
SALTON SEA
METEORIC WATER LINE
AVERAGE PRESENT-DAY
LOCAL PRECIPITATION
CERRO PRIETO
GEOTHERMAL BRINE
PATH OF EVAPORATING
COLORADO RIVER WATER
1
2
3
4
5
6
0
-20
-40
-60
-80
-100
-120
δD RELATIVE TO SMOW IN ‰
-16
-14
-12
-10
-8
-6
-4
-2
0
δO18 RELATIVE TO SMOW IN ‰

FIG. 2

evaporating Colorado River Water. This suggests that most of the subsurface water in the Imperial Valley was derived from Colorado River water. The six samples from the Mesa system indicate the following:

1. Samples 1 and 2 are distinctly different in both oxygen and hydrogen isotopic composition than deeper samples. This suggests that the near surface ground water was not derived from the geothermal brine at depth. The isotopic composition of these shallow samples suggests that a large proportion of the near surface water was derived from local precipitation.
2. Samples 3, 4, and 5 obtained during drill stem tests of Mesa 6-1 plot very close to the evaporation line in Fig. 2. These samples are similar in isotopic composition to the deep water in the central Imperial Valley. The water in the Mesa geothermal system was derived from the same source, that is, Colorado River water. Samples 3 and 4 show a small oxygen isotope shift. The fact that there is little oxygen isotope shift suggests that the system may be considerably more open than the Cerro Prieto or Salton Sea systems. If this were the case, it would indicate that this should be a good system for withdrawal of water for desalting of water because of the relatively high permeability. Oxygen isotope analyses on the rock in this system should provide more information on this subject.
3. Sample 6 is brine and lies to the right of the evaporation line. It shows that a vapor depleted in O^{18} flashed from this brine, thus enriching the brine in O^{18}. This shows why it is important to obtain a sample of water for isotopic analysis before it flashes and not after.

Due to the success of the Na-K-Ca program we increased our effort in it and did not perform any tritium, C^{14}, or C^{13}/C^{12} measurements on Imperial Valley water samples.

CONCLUSIONS

The following significant results were determined in the course of this investigation:

1. A suspected geothermal area was found to the west of Truckhaven in West Mesa. Additional geophysical exploration is suggested to verify the existence of this anomaly.
2. A suspected geothermal area was found near the Yuha Basin. Again geophysical exploration is suggested to verify the existence of a geothermal system at depth.
3. Samples 208 and 210 are suggestive of geothermal systems at depth in West Mesa and merit additional investigation.
4. The near surface ground water in the Mesa system was not derived from the geothermal system at depth. The near surface ground water isotopically is very similar to local precipitation suggesting that a large proportion is local precipitation.
5. The water in the Mesa geothermal system was derived from Colorado River water. It was not derived from local precipitation.
6. The small oxygen isotope shifts of the samples from the Mesa system may suggest that the system is relatively open, such as the Wairakei geothermal system. Oxygen isotope analyses of the silicates to be undertaken in FY 74 should provide additional information on this subject.

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CENTRAL IMPERIAL VALLEY WELLS
OTHER IMPERIAL VALLEY WELLS
SURFACE WATERS

ERS IN BLACK ARE UCR SAMPLE NUMBERS

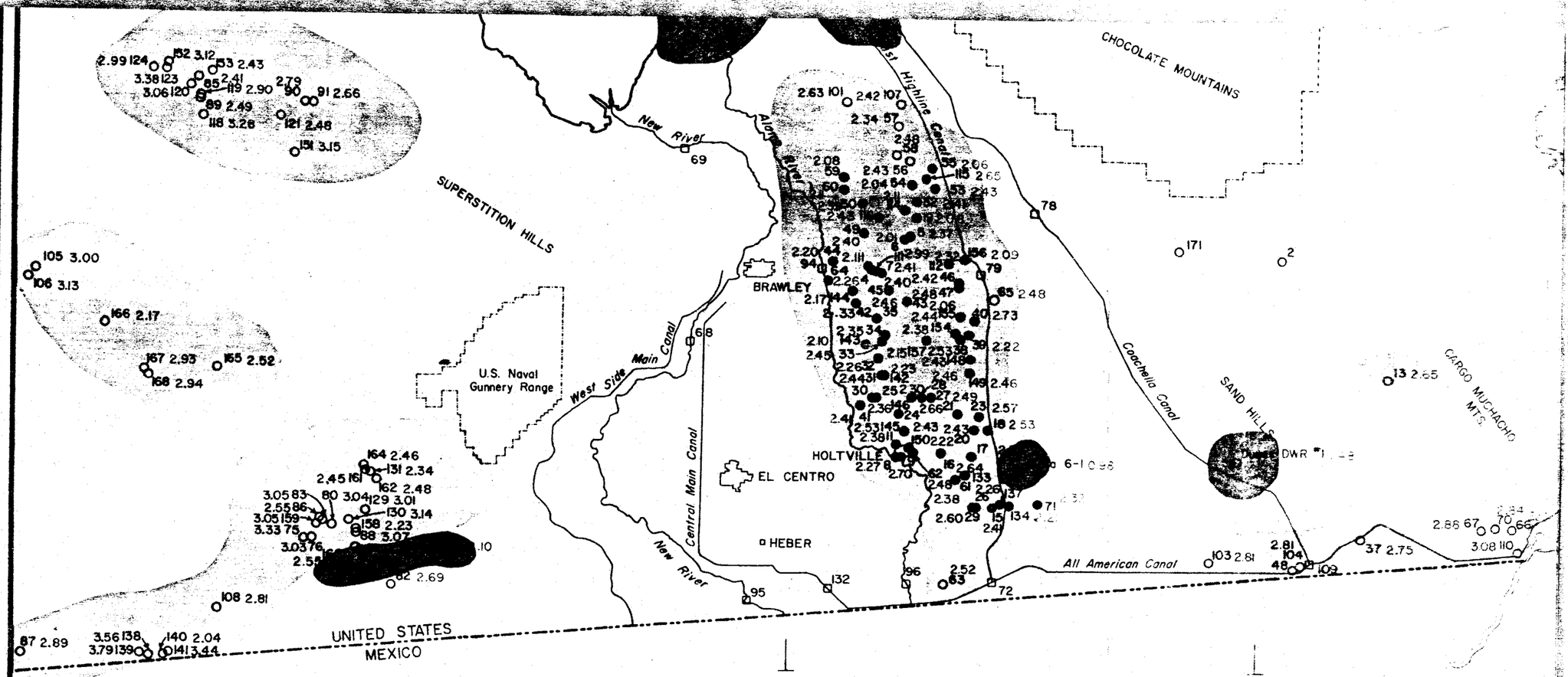
CONFIRMED GEOTHERMAL ANOMALY AS INDICATED BY THIS GEOCHEMICAL TECHNIQUE

SUSPECTED GEOTHERMAL ANOMALY AS INDICATED BY THIS GEOCHEMICAL TECHNIQUE

GEOTHERMAL ANOMALY NOT INDICATED BY THIS GEOCHEMICAL TECHNIQUE

VALUES IN RED ARE A FUNCTION OF SUBSURFACE TEMPERATURE CALCULATED FROM THE SODIUM, POTASSIUM, AND CALCIUM CONCENTRATIONS OF WELL WATER AND SPRING SAMPLES UTILIZING THE EQUATIONS OF FOURNIER AND TRUESDELL (1973).

PREPARED BY TYLER COPLEN AT THE UNIVERSITY OF CALIFORNIA, RIVERSIDE, FOR THE U.S.D.I., BUREAU OF RECLAMATION UNDER CONTRACT NUMBER 14-06-300-2389, JUNE 30, 1973.



● CENTRAL IMPERIAL VALLEY WELLS
○ OTHER IMPERIAL VALLEY WELLS
□ SURFACE WATERS

NUMBERS IN BLACK ARE UCR SAMPLE NUMBERS

CONFIRMED GEOTHERMAL ANOMALY AS INDICATED BY THIS GEOCHEMICAL TECHNIQUE

SUSPECTED GEOTHERMAL ANOMALY AS INDICATED BY THIS GEOCHEMICAL TECHNIQUE

GEOTHERMAL ANOMALY NOT INDICATED BY THIS GEOCHEMICAL TECHNIQUE

MILES 5 0 5 10 15 20
KILOMETERS 5 0 5 10 15 20 25 30

VALUES IN RED ARE A FUNCTION OF SUBSURFACE TEMPERATURE CALCULATED FROM THE SODIUM, POTASSIUM, AND CALCIUM CONCENTRATIONS OF WELL WATER AND SPRING SAMPLES UTILIZING THE EQUATIONS OF FOURNIER AND TRUESDELL (1973).

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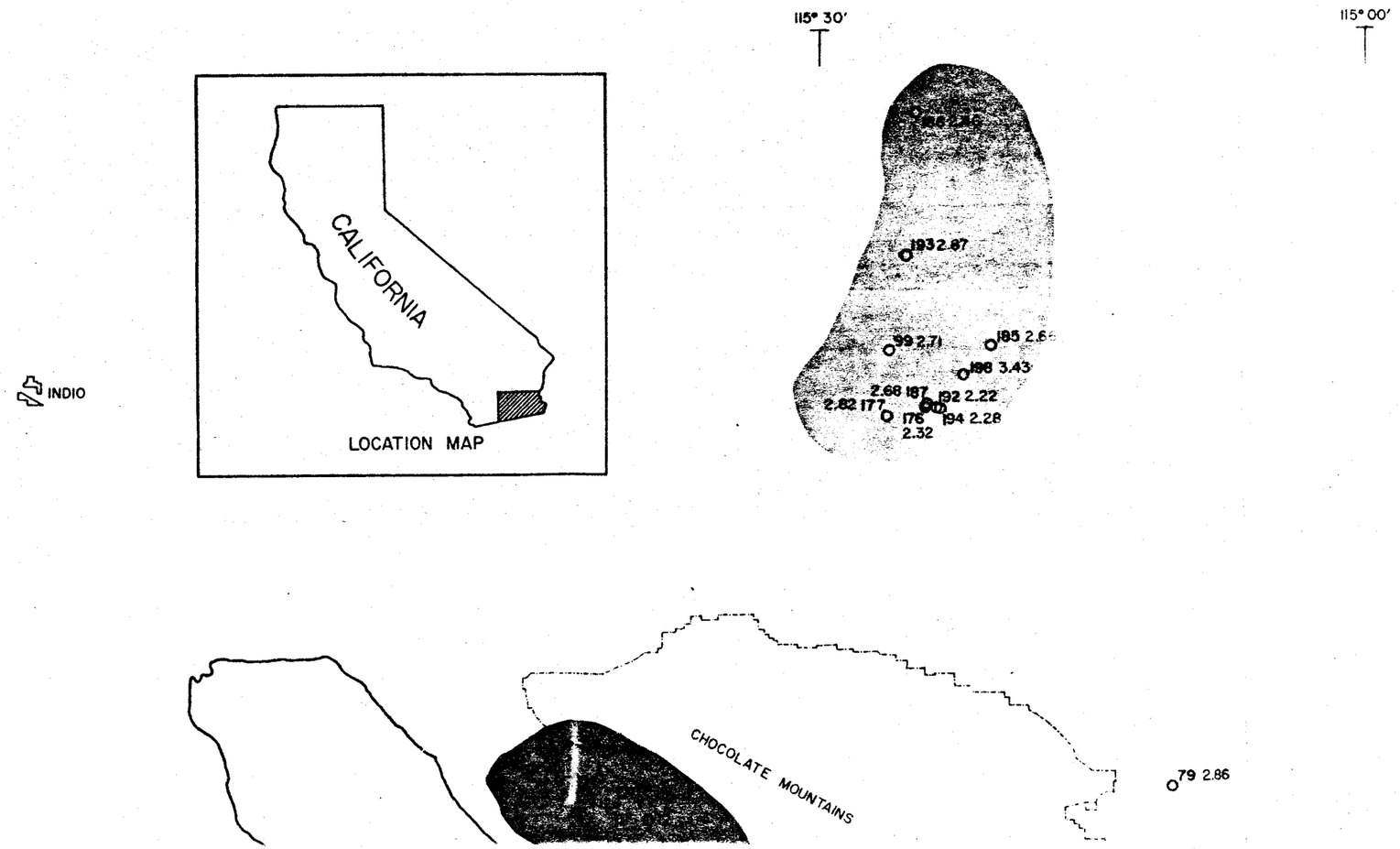
Sample numbers 200 to 210
are not shown on this map.

IDENTIFICATION OF GEOTHERMAL ANOMALIES UTILIZING THE SODIUM-POTASSIUM-CALCIUM GEOCHEMICAL TECHNIQUE IN THE IMPERIAL VALLEY AREA OF CALIFORNIA