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CHEMISTRY, ORIGIN, AND POTENTIAL
OF GEOTHERMAL RESOURCES IN SOUTHWEST
NEW MEXICO AND SOUTHEAST ARIZONA

by

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ABSTRACT

On the basis of chemical geothermometry, there would appear to be 10-20 geothermal prospect areas in southwest New Mexico and southeast Arizona whose reservoir base temperature approaches the 150°C minimum for economic generation of electricity. The most promising of these prospect areas are either associated with Quaternary volcanics or are located along the margins of the deepest sedimentary basins. The thermal waters tend to be slightly saline (1000-3000 mg/ℓ) and enriched in silica and fluoride. The numerous hot spring areas in the Gila National Forest of southwest New Mexico do not appear to have a sufficiently high reservoir base temperature for electricity generation. However, the low salinity (<500 mg/ℓ) and high surface discharge temperature (up to 75°C) of these hot springs make them ideal for non-electric applications.

INTRODUCTION

To date, we have visited nearly all hot springs in Arizona and New Mexico, recorded the temperature and collect samples for chemical analysis. In addition, we have examined the chemistry of several thousand non thermal ground waters to establish background chemistry for comparison against thermal water chemistry. Standard methods of quantitative and qualitative geothermometry (see Truesdell, 1975 for a summary of techniques) have been applied to all waters and the resulting geotemperatures used to predict the subsurface temperature anticipated for each geothermal prospect area. The most promising geothermal areas are designated in Figure 1. Table 1 contains the chemistry of selected thermal waters from southwest New Mexico and southeast Arizona.

Geothermometry Techniques

The concept of chemical geothermometry is that the chemistry of geothermal fluids is controlled by temperature dependent water-rock reactions within the geothermal reservoir and that the water chemistry does not change appreciably as the water migrates from the geothermal reservoir to the surface sampling point. The validity of these assumptions is examined by Truesdell (1975).

The silica geothermometer of Fournier and Rowe (1966) can be quantatively expressed according to the equation of Truesdell (1975)

$$T\ SiO_2 = \frac{1315}{5.205 - \ell og_{10} SiO_2} - 273.15 \qquad (1)$$

where T SiO_2 is the silica geotemperature in degrees Celcius, and SiO_2 is expressed in parts per million. The NaKCa geothermometer of Fournier and Truesdell (1973) can be quantatively expressed according to the equation of Truesdell (1975)

$$T_{NaKCa} = \frac{1647}{\ell og_{10}(Na/K) + \beta\ \ell og_{10}(\sqrt{Ca}/Na) + 2.24} - 273.15 \qquad (2)$$

where T NaKCa is the NaKCa geotemperature in degrees Celcius, Na, K, and Ca are expressed in molal concentrations, and the value of β is determined by the following tests:

$\beta = 4/3$ for $\sqrt{Ca}/Na > 1$ and T NaKCa(β=4/3) < 100°C

$\beta = 1/3$ for $\sqrt{Ca}/Na < 1$ or T NaKCa(β=4/3) > 100°C.

The normal distribution of geotemperatures calculated by applying equations 1 and 2 to groundwaters of the Basin and Range province is given in Figures 2,3. The geotemperatures obtained by applying equations 1 and 2 to selected thermal waters from Arizona and New Mexico are given in Table 1.

Discussion

The most promising geothermal prospect areas on the basis of chemical geothermometry are shown in Figure 1. Many of these prospects are located along the flanks of the deep sedimentary basins of the Rio Grande Rift, an association which implies a tectonic origin for these thermal waters. These waters have apparently originated deep within the basin where they have been heated by the normal geothermal gradient, and then migrated to the surface along the basin bounding faults. If this is the case, the waters may have traveled a considerable lateral distance enroute to the surface so that the locations given in Table 1 and shown in Figure 1 may not accurately represent the location of the subsurface geothermal area.

There are at least ten separate localities in the Rio Grande Rift of southern New Mexico where geothermal waters leak to the surface, most of which are not designated individually in Figure 1.

An additional four areas in west Texas are also shown to emphasize the association with deep sedimentary basins and active faults but are not treated further. These waters are characterized by NaKCa geotemperatures in the 150-200°C range and silica geotemperatures in the 80-120°C. The silica data do not appear to reveal much geothermal potential until it is realized that these waters have low silica because they have ascended through a very thick pile (see Figure 1) of sediments saturated by the silica deficient waters of the Rio Grande River. Application of mixing models to the Radium Springs data brings the silica geotemperature into agreement with the NaKCa geotemperatures. Thus most of the Rio Grande Rift thermal areas are likely to have a reservoir base temperature near or in excess of the 150°C minimum for economic generation of electricity.

A second group of thermal waters worth special mention are those located in the Gila area just west of the Rio Grande Rift in southwest New Mexico. Chemical analyses for several of the hottest springs are present in Table 1 but are omitted from Figure 1 as their NaKCa and silica geotemperatures are not sufficiently above regional background (Figures 2,3; see also Swanberg and Alexander, in press) to suggest the presence of a buried geothermal resource. However, these springs have a high surface discharge temperature (up to 75°C), very low amounts of dissolved solids (<500 mg/ℓ) and are quite numerous so that the Gila area is ideal for non electric applications of geothermal energy.

Two exceptions to the above generalizations are the Lower Frisco hot springs and the Clifton Known Geothermal Resource Areas (KGRA), located on either side of the New Mexico-Arizona border at about parallel 33°N. Both areas appear to have subsurface temperatures of about 150°C (Table 1).

A final feature of geothermal resources in southwest New Mexico and southeast Arizona is the presence of very promising geothermal prospects associated with Quaternary volcanic centers (Figure 1). Examples include Kilbourne Hole, New Mexico, east of Douglas, Arizona, and although it is not included in Figure 1, the Springerville area of Arizona. All of these areas are characterized by sodium bicarbonate water, and Na K Ca and silica geotemperatures near 150°C.

REFERENCES

Fournier, R.O., and Rowe, J.J., 1966, Estimation of underground temperatures from the silica content of water from hot springs and wet steam wells: Am. Jour. Sci., Vol. 264, p. 685-697.

Fournier, R.O., and Truesdell, A.H., 1973, An empirical Na-K-Ca geothermometer for natural waters: Geochem. Cosmochim. Acta., Vol. 37, 5, p. 1255-1275.

Swanberg, C.A. and Alexander, S., in press, The use of the water quality file, WATSTORE in geothermal exploration: An example from the Imperial Valley, California: Submitted to Geology.

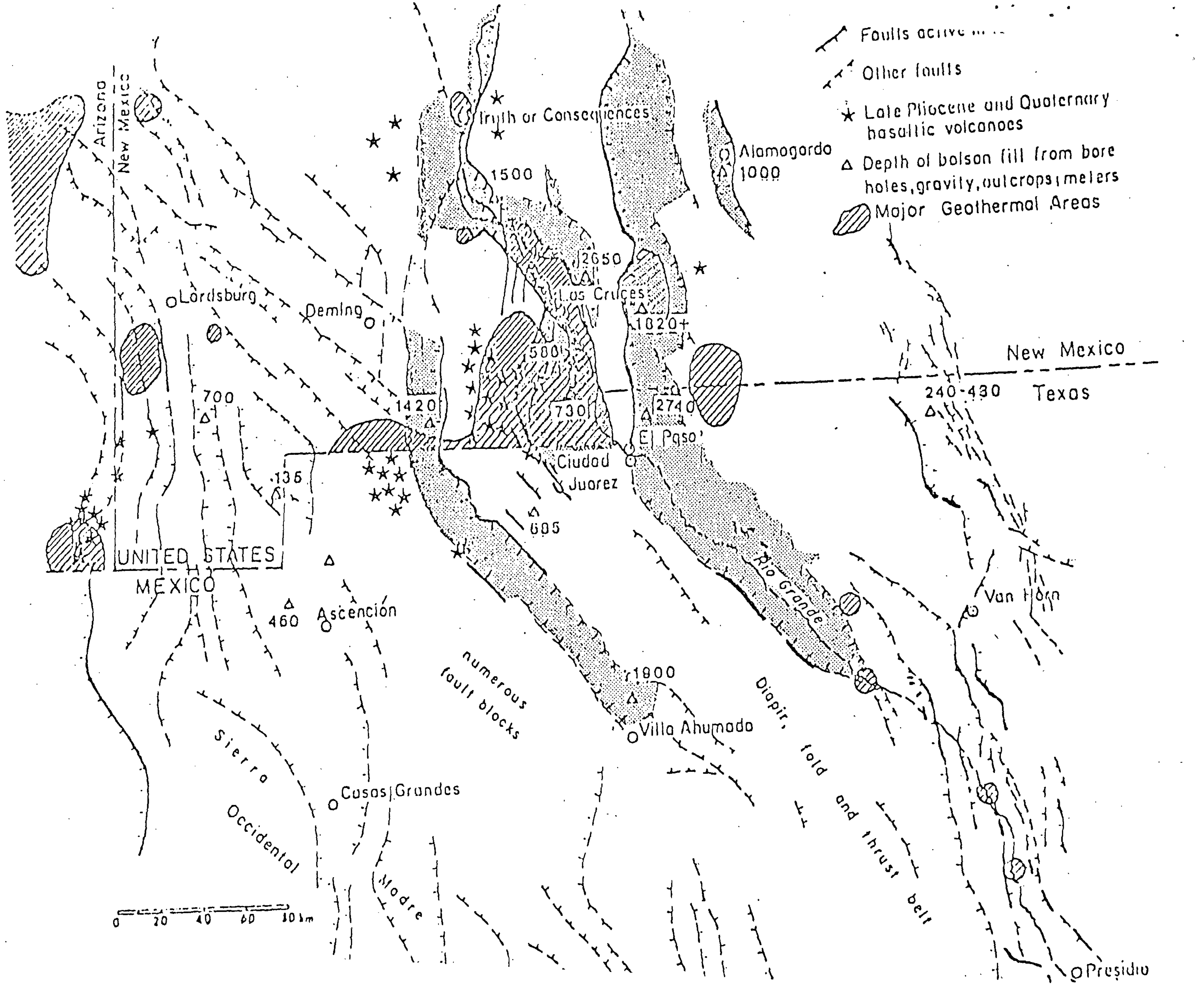
Truesdell, A.H., 1975, Summary of section III: Geochemical techniques in Exploration: Proc. 2nd U.N. Symp. on the Development and Use of Geothermal Resources, San Francisco, Calif., USA, 20-29, May, 1975, U.S. Govt. Printing Office, p. LIII-LXXIX.

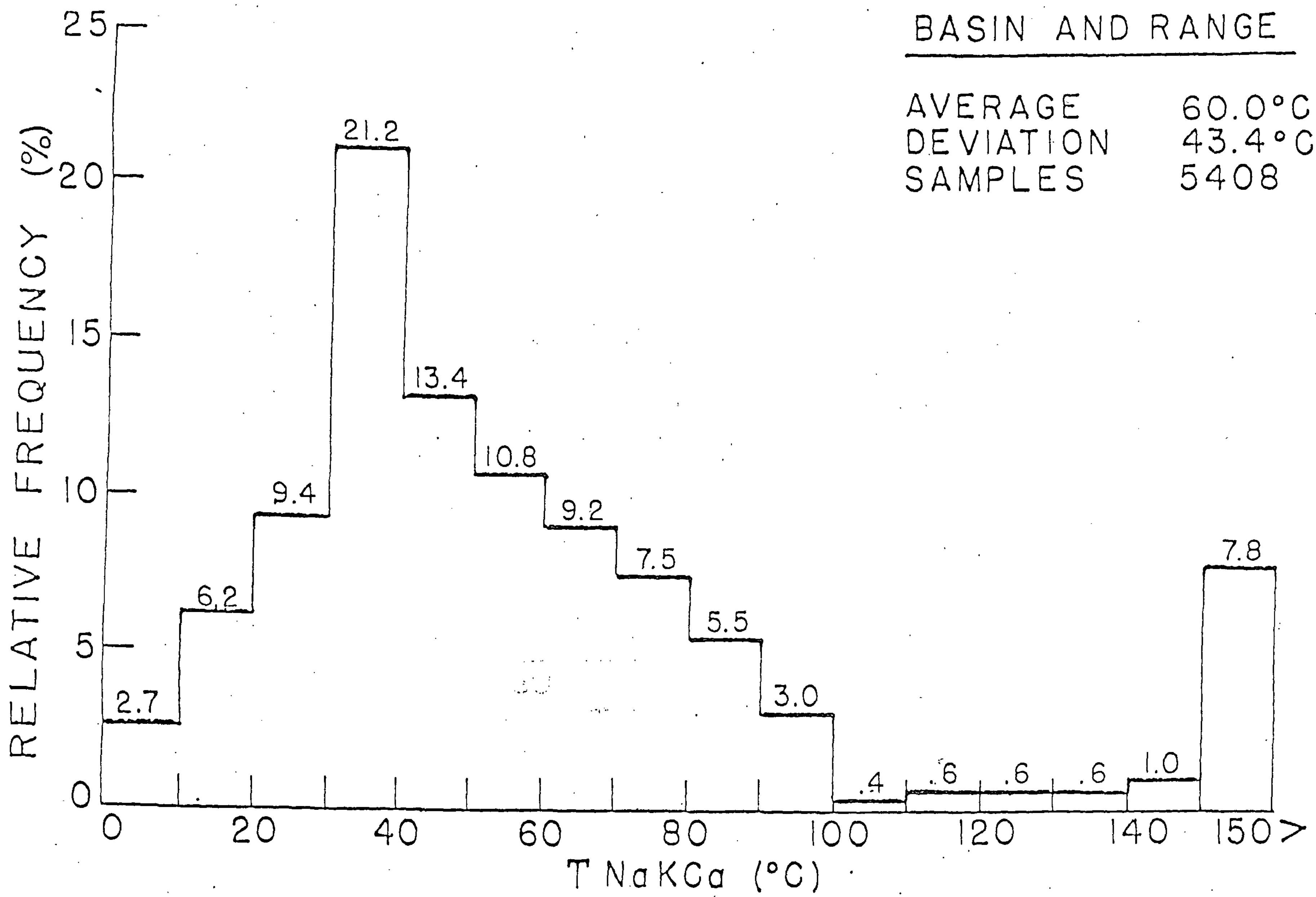
FIGURE CAPTIONS

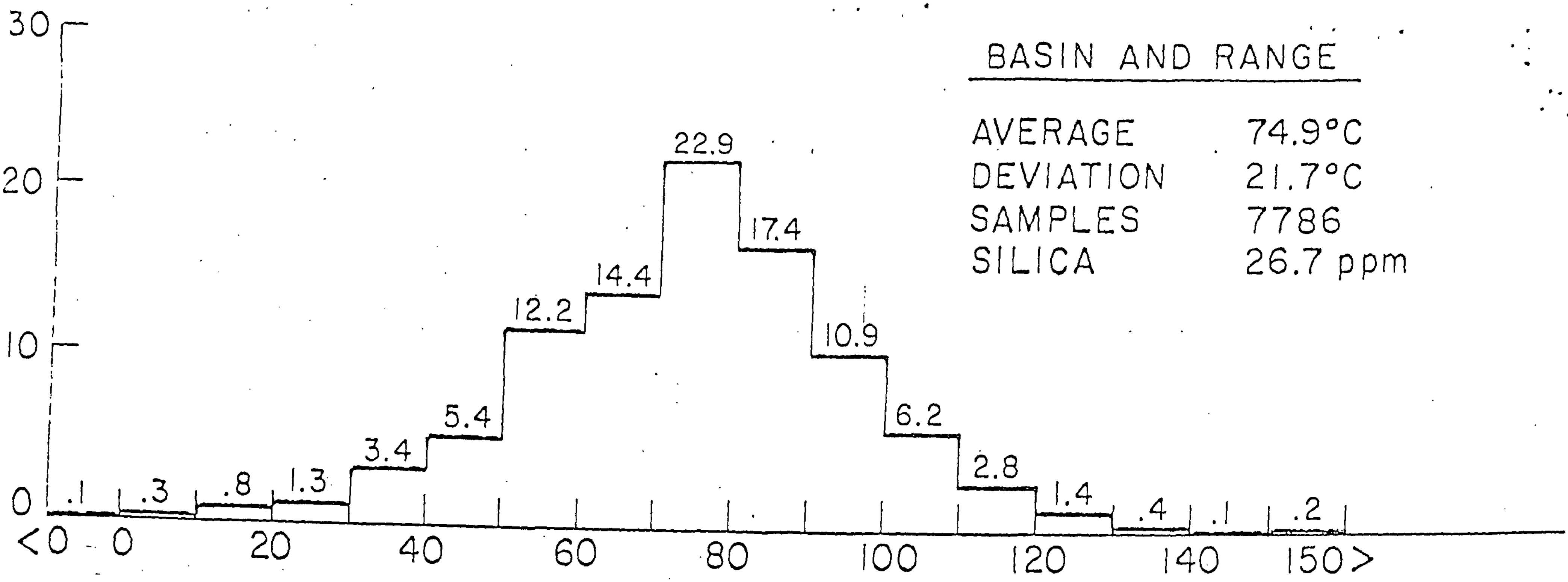
Figure 1. Association among high temperature geothermal resources (>150°C), active faults, deep sedimentary basins, and Quaternary basaltic volcanoes. All data except the geothermal areas are from a forthcoming paper by W. Seager and P. Morgan on the Rio Grande Rift (J.G.R. in press) and is reproduced with the kind permission of the authors.

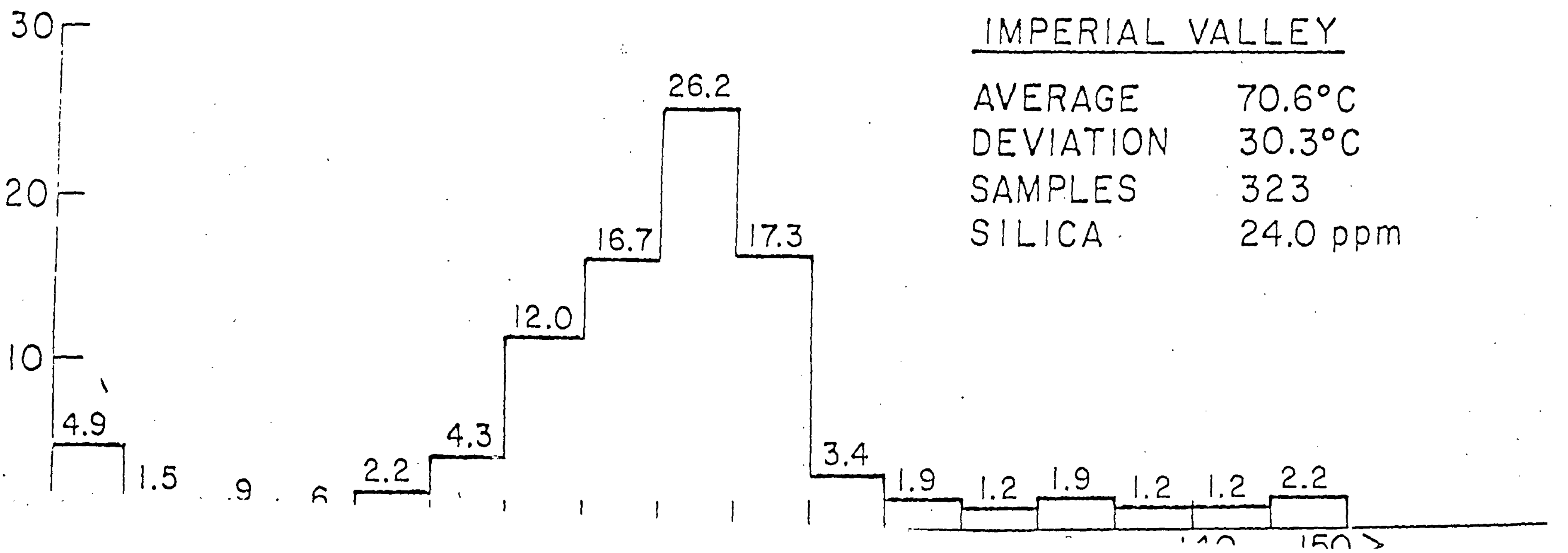
Figure 2. Histogram of T NaKCa obtained by applying equation 2 to groundwaters of the Basin and Range province.

Figure 3. Histogram of T SiO_2 obtained by applying equation 1 to groundwaters of the Basin and Range province and the Imperial Valley. After Swanberg and Alexander (in press).


Other faults
Late Pliocene and Quaternary basaltic volcanoes
Depth of bolson fill from bore holes, gravity, outcrops, meters
Major Geothermal Areas
Arizona
New Mexico
Truth or Consequences
Alamogordo
1000
1500
2650
Las Cruces
1820+
Lordsburg
Deming
500
New Mexico
Texas
700
1420
730
2740
240-430
El Paso
Ciudad Juarez
135
605
UNITED STATES
MEXICO
460
Ascención
Van Horn
Rio Grande
numerous fault blocks
1800
Villa Ahumada
Diapir, fold and thrust belt
Sierra Occidental Madre
Casas Grandes
Presidio
0 20 40 60 80 km


BASIN AND RANGE
AVERAGE 60.0°C
DEVIATION 43.4°C
SAMPLES 5408
RELATIVE FREQUENCY (%)
25
20
15
10
5
0
2.7
6.2
9.4
21.2
13.4
10.8
9.2
7.5
5.5
3.0
.4
.6
.6
.6
1.0
7.8
0
20
40
60
80
100
120
140
150>
T NaKCa (°C)


BASIN AND RANGE
AVERAGE 74.9°C
DEVIATION 21.7°C
SAMPLES 7786
SILICA 26.7 ppm
30
20
10
0
.1
.3
.8
1.3
3.4
5.4
12.2
14.4
22.9
17.4
10.9
6.2
2.8
1.4
.4
.1
.2
<0
0
20
40
60
80
100
120
140
150>


IMPERIAL VALLEY
AVERAGE 70.6°C
DEVIATION 30.3°C
SAMPLES 323
SILICA 24.0 ppm
30
20
10
4.9
1.5
.9
2.2
4.3
12.0
16.7
26.2
17.3
3.4
1.9
1.2
1.9
1.2
1.2
2.2

Region	Sample	Location	Latitude	Longitude	Temp.	Temp. Na-Ca-K	Temp. SiO_2	TDS	pH	Na	K	Ca	Fe	Mg	CO_3	HCO_3	Cl	SO_4	F	B	SiO_2	Commen
Rio Grande Rift																						
	256	Columbus Area	31° 47.7	107° 34.3	26.0	191.8°	136.4°	2748	7.36	881.0	75.4	65.2	.82	19.8	0	1565.7	338.9	423.6	3.99	1.78	98.5	
	B2	Radium Springs	32 30.1	106 55.7	53.0	223.4	118.1	3532	8.16	1135.9	167.0	118.6	.49	15.2	13.2	378.3	1593.6	263.2	4.44	.86	69.9	KGRA
	B5	Derry Springs	32 47.7	107 16.6	---	156.2	81.2	1240	8.23	323.9	18.8	47.1	<.10	15.8	0	366.1	151.0	376.6	5.90	.34	31.3	
	B10	Truth or Consequences	33 8.1	107 14.9	41.0	178.1	96.2	2688	7.80	791.5	63.0	143.9	<.10	17.9	0	162.3	1353.6	169.1	3.10	.35	44.3	
	B13	Sedillo Springs	34 2.2	106 56.2	34.0	58.5	72.5	284	8.48	56.1	3.1	17.2	<.10	4.3	0	162.3	10.3	50.0	2.02	.09	25.3	KGRA
		San Diego Mountain	32 37.0	106 58.0	---	232.5	105	4970	7.9	150.0	210	65	.04	5.3	0	675	880	1900	17.0	1.0	53.0	
		S. Tularosa	32 8.0	106 8.0	71.1	---	109	8740	---	---	---	542	---	108	---	---	6590	820	---	---	58.0	
		Chamberino	32 5.0	106 37.0	20	198	101	1400	7.5	300	45	110	.70	43	0	466	410	210	.3	---	49	
Gila Area																						
	29	Faywood Spring	32 33.3	107 59.7	58.8	78.4	97.2	492	7.74	90.8	8.2	35.6	.12	7.6	0	283.0	14.2	72.0	6.10	.01	45.2	
	31	Mimbres Spring	32 44.9	107 50.1	58.2	74.5	106.8	320	8.97	91.7	1.2	2.4	<.10	0	20.4	67.1	14.5	84.0	16.0	0	55.6	
	33	Gila Spring	33 12.0	108 12.6	66.3	77.3	120.5	416	8.15	129.7	3.1	10.4	<.10	.2	0	115.9	100.1	67.2	8.60	.02	73.3	KGRA
	150	Turkey Creek	33 6.5	108 24.0	74.6	56.2	116.5	236	8.66	61.1	1.5	6.8	.31	1.6	0	94.0	4.2	64.8	9.45	.12	67.7	
Quaternary Basalts																						
	W33	Kilbourne Hole	31 47.3	107 1.7	---	174.7	133.5	720	9.42	233.3	16.8	10.0	<.15	2.1	69.6	371.0	29.4	101.8	3.30	.49	93.5	KGRA
	338	Douglas	31 21.1	109 10.9	25.5	229	129	784	9.06	200.0	37.9	9.8	4.53	45.9	70.8	588.2	20.9	64.4	2.46	.11	86.5	
	112	Springerville	34 22.1	109 23.0	18	192	---	300	8.92	79.3	10.2	6.0	.30	5.1	0	107.4	81.2	5.8	2.46	.10	---	
Basin and Range																						
	P2	Lightning Dock	32 8.7	108 49.9	85.0	172.9	160.1	1116	7.71	333.6	23.5	22.0	.20	0.5	0	106.8	88.3	497.1	12.6	.48	147.5	KGRA
	J5	Lower Frisco	33 14.5	108 52.8	48.9	147.9	131.9	1280	7.79	406.0	18.8	54.3	<.10	6.9	0	107.4	574.3	90.3	1.80	.38	90.4	KGRA
	5	Clifton H.S.	33 4.8	109 17.8	48.0	180	153	14548	7.86	3585.9	243.9	925.8	.72	22.9	0	150.0	7484.5	0	3.50	1.51	131.4	KGRA
	7	Gillard H.S.	32 58.4	104 20.9	82.0	139	136	1244	8.04	410.8	13.2	20.0	<.10	.7	0	219.6	463.6	174.7	10.60	.40	97.9	KGRA
	11	Indian H.S.	33 0.2	109 54.0	46.5	100	95	3004	7.88	1022.6	12.9	92.8	<.10	10.3	0	101.2	1382	361.0	3.80	.70	43.5	
	15	Safford	32 50.7	109 33.6	43.5	106	116	1076	8.54	330.7	4.3	7.4	.10	1.3	13.2	233.0	203.0	295.8	10.6	.43	66.9	
	133	Lordsburg	32 13.7	108 30.7	33.0	150.6	91.2	816	7.86	216.1	11.7	28.0	.15	2.7	0	314.8	47.5	233.8	6.90	.46	39.6	

TABLE 1: Chemistry of Selective Geothermal Waters from Southwest New Mexico and Southeast Arizona.