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1978, pp. 349-351. https://doi.org/10.56577/FFC-29.349

in:

Land of Cochise (Southeastern Arizona), Callender, J. F.; Wilt, J.; Clemons, R. E.; James, H. L.; [eds.], New Mexico Geological Society 29 th Annual Fall Field Conference Guidebook, 348 p. https://doi.org/10.56577/FFC-29

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CHEMISTRY, ORIGIN AND POTENTIAL OF GEOTHERMAL RESOURCES IN SOUTHWESTERN NEW MEXICO AND SOUTHEASTERN ARIZONA

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INTRODUCTION

The author has visited nearly all of the hot springs in Arizona and New Mexico, recorded the temperature and collected samples for chemical analysis. In addition, the chemistry of several thousand non-thermal ground waters have been used 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 southwestern New Mexico and southeastern Arizona.

On the basis of chemical geothermometry, there appear to be 10 to 20 geothermal prospect areas in southwestern New

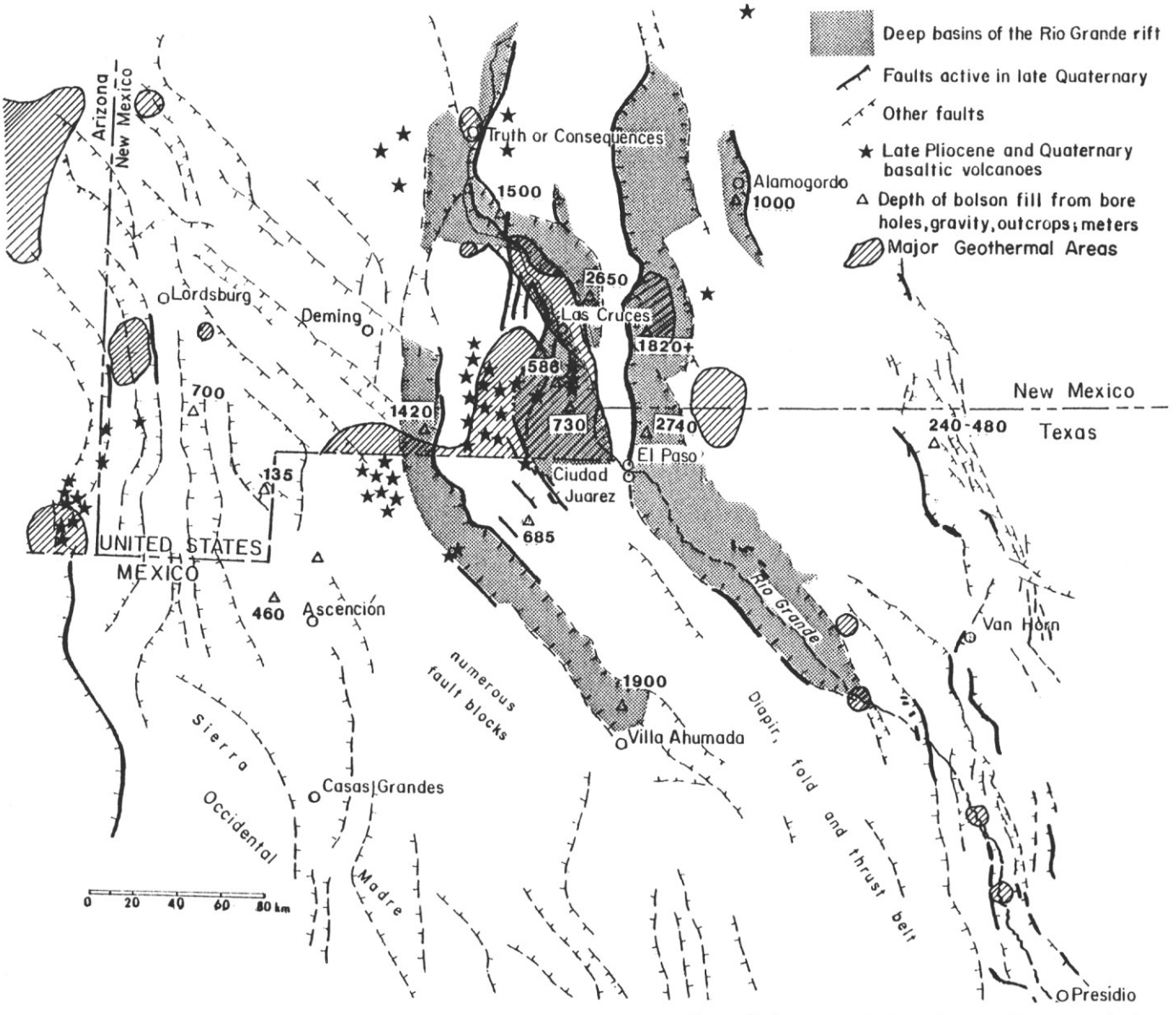

Figure 1. Association between high temperature geothermal resources (>150°C), active faults, deep sedimentary basins and Quaternary basaltic volcanoes. All data except the geothermal areas are from a forthcoming paper by W. Seager and P. Morgan on the Rio Grande rift (American Geophysical Union, in press)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

Table 1. Chemistry of selected geothermal waters from southwestern New Mexico and southeastern Arizona.

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	Comment
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	

Mexico and southeastern 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 volcanic rocks or are located along the margins of the deepest sedimentary basins. The thermal waters tend to be slightly saline (1000-3000 mg/k) and enriched in silica and fluoride. The numerous hot spring areas in the Gila National Forest of southwestern New Mexico do not appear to have a sufficiently high reservoir base temperature for electricity generation. However, the low salinity (<500 mg/Q) and high surface-discharge temperature (up to 75°C) of these hot springs make them ideal for non-electric applications.

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 quantitatively expressed according to the equation of Truesdell (1975)

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

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 quantitatively expressed according to the equation of Truesdell (1975)

$$T_{NaKCa} = \frac{1647}{\log_{10}\left(\frac{Na}{K}\right) + \beta \log_{10}\left(\frac{\sqrt{Ca}}{Na}\right) + 2.24} - 273.15 \qquad (2)$$

where T NaKCa is the NaKCa geotemperature in degrees Celcius, Na, K and Ca are expressed in molal concentrations, and the value of f3 is determined by the following tests:

β= 4/8 for \a/Na > 1 and T NaKCa((3=4/3) < 100°C

β= 1/3 for "Ca/Na < 1 or T NaKCa((3=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 and 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 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

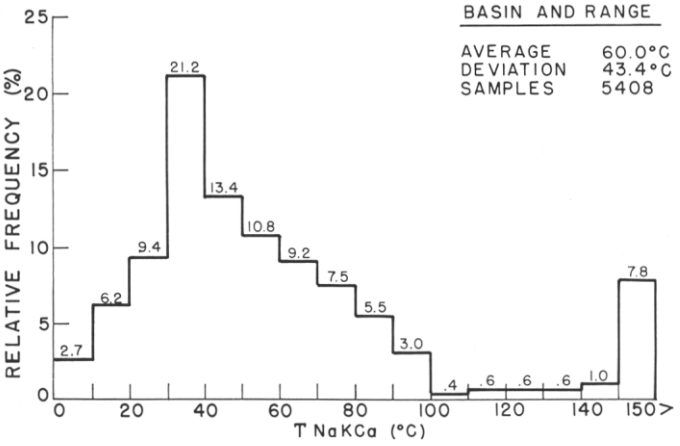

Figure 2. Histogram of T NaKCa obtained by applying equation 2 to groundwaters of the Basin and Range province.

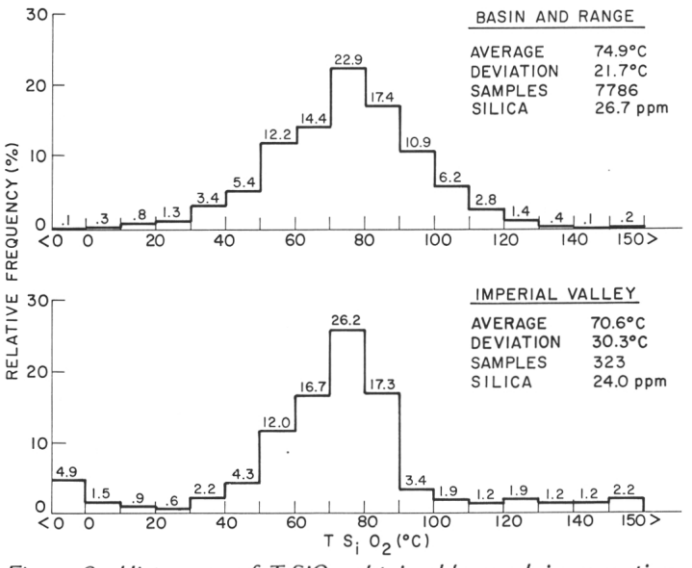

Figure 3. Histogram of T SiO_2 obtained by applying equation 1 to groundwaters of the Basin and Range province and the Imperial Valley. After Swanberg and Alexander (in press).

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 ranging from 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 fig. 1) of sediments saturated by the silica deficient waters of the Rio Grande. Application of mixing models to the Radium Springs data brings the silica geotemperature into agreement with the NaKCa geotemperatures. Thus most thermal areas of the Rio Grande rift 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 southwestern New Mexico. Chemical analyses for several of the hottest springs are presented in Table 1 but are omitted from Figure 1, as their NaKCa and silica temperatures are not sufficiently above regional background (fig. 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/k) and are quite numerous; the Gila area is therefore 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 latitude 33°N. Both areas appear to have subsurface temperatures of about 150°C (Table 1).

A final feature of geothermal resources in southwestern New Mexico and southeastern Arizona is the presence of very promising geothermal prospects associated with Quaternary volcanic centers (fig. 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 NaKCa and silica geotemperatures near 150°C.

ACKNOWLEDGMENTS

I would like to thank the water resources division of the U.S. Geological Survey for making available the WATSTORE file. Chemical analyses were performed by Mr. Andrew Bristol and his staff at the Soil and Water Testing Laboratory Department of Agronomy at New Mexico State University. The work was partially funded by State of New Mexico Energy Institute grant ERB 75-117 and U.S. Geological Survey grant 14-08-0001-G-348.

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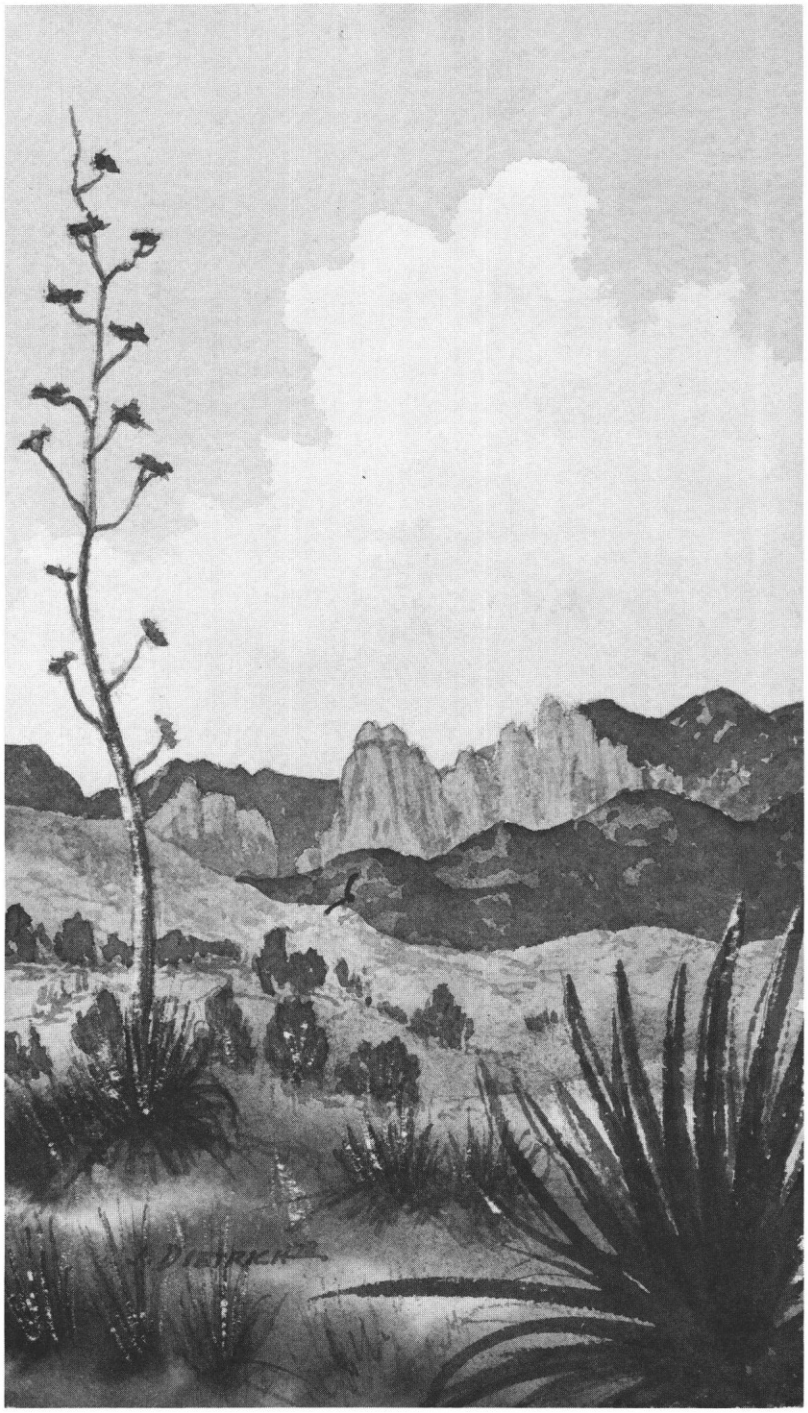
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