[illegible]

GL01277

WRIGHT

1976 ENERGY USE

The following list provides energy usage of selected processes and their temperatures, based upon the Standard Industrial Classification (SIC) level, 1974. Also included are residential and commercial space conditioning and water heating requirements for 1976.

	Energy Use $\times 10^{12}$ Btu/Yr	Temperature
Residential		
Space heating	7,370	< 170°F
Water heating	1,534	< 170°F
Air conditioning	165	< 200°F
Commercial		
Space heating	4,535	< 170°F
Water heating	540	< 170°F
Air conditioning	468	< 200°F

TABLE I-9

LIST OF INDUSTRIAL PROCESS HEAT APPLICATIONS AND ANNUAL REQUIREMENTS (1974) FOUND FROM SURVEY

Industry - S.I.C. Group	Application Temperature Requirement		Process Heat Used for Application 10^{12} Btu/Yr.	10^{12} kJ/Yr.
	°F	°C		
1. Iron Ore-1011				
Pelletizing of Concentrates	2350-2500	1288-1371	37.2	39.2
2. Copper Concentrate-1021				
Drying	250*	121	1.7	1.8
3. Bituminous Coal-1211				
Drying (including lignite)	150-220*	66-104	18.	19.
4. Sand & Gravel-1442			None	
5. Potash-1474				
Drying Filter Cake	250*	121	1.03	1.09
6. Phosphate Rock-1475				
Calcining	1400-1600	760-871	0.71	0.75
Drying	450*	232	10.5	11.1
7. Sulfur-1477				
Frasch Mining	325-340	163-171	60.	63.
8. Meat Packing-2011				
Sausages & Prepared Meats-2013				
Scalding, Carcass Wash, and Cleanup	140	60	43.7	46.1
Singeing Flame	500	260	1.06	1.12
Edible Rendering	200	93	0.52	0.55
Smoking/Cooking	155	68	1.16	1.22
9. Poultry Dressing-2016				
Scalding	140	60	3.16	3.33
10. Natural Cheese-2022				
Pasteurization	170	77	1.28	1.35
Starter Vat	135	57	0.02	0.02
Make Vat	105	41	0.47	0.50
Finish Vat	100	38	0.02	0.02
Whey Condensing	160-200	71-93	10.2	10.8
Whey Drying	120*	49	2.94	3.10
Process Cheese Blending	165	74	0.07	0.07

TABLE I-9(Continued)

LIST OF INDUSTRIAL PROCESS HEAT

APPLICATIONS AND ANNUAL REQUIREMENTS (1974) FOUND FROM SURVEY

Industry - S.I.C. Group	Application Temperature Requirement °F	°C	Process Heat Used for Application 10^{12} Btu/Yr.	10^{12} kJ/Yr.
11. Condensed & Evaporated Milk-2023				
Stabilization	200-212	93-100	2.93	3.09
Evaporation	160	71	5.20	5.48
Spray Drying	350-400	177-204	3.58	3.78
Sterilization	250	121	0.54	0.57
12. Fluid Milk-2026				
Pasteurization	162-170	72-77	1.44	1.52
13. Canned Specialities-2032				
Beans				
Precook (Blanch)	180-212	82-100	0.40	0.42
Simmer Blend	170-212	77-100	0.24	0.25
Sauce Heating	190	88	0.20	0.21
Processing	250	121	0.38	0.40
14. Canned Fruits and Vegetables-2033				
Blanching/Peeling	180-212	82-100	1.88	1.98
Pasteurization	200	93	0.15	0.16
Brine Syrup Heating	200	93	1.02	1.08
Commercial Sterilization	212-250	100-121	1.67	1.76
Sauce Concentration	212	100	0.44	0.46
15. Dehydrated Fruits and Vegetables-2034				
Fruit and Vegetable Drying	165-185	74-85	5.84	6.16
Potatoes				
Peeling	212	100	0.33	0.35
Precook	160	71	0.47	0.50
Cook	212	100	0.47	0.50
Flake Dryer	350	177	1.09	1.15
Granule Flash Dryer	550	288	1.09	1.15

TABLE I-9(Continued)
LIST OF INDUSTRIAL PROCESS HEAT APPLICATIONS AND ANNUAL REQUIREMENTS (1974) FOUND FROM SURVEY

Industry - S.I.C. Group	Application Temperature Requirement °F	°C	Process Heat Used for Application 10^{12} Btu/Yr.	10^{12} kJ/Yr.
16. Frozen Fruits and Vegetables-2037				
Citrus Juice Concentration	190	88	1.33	1.40
Juice Pasteurization	200	93	0.27	0.28
Blanching	180-212	82-100	2.26	2.38
Cooking	170-212	77-100	1.41	1.49
17. Wet Corn Milling-2046				
Steep Water Evaporator	350	177	3.66	3.86
Starch Dryer	120*	49	3.03	3.20
Germ Dryer	350	177	1.92	2.03
Fiber Dryer	1000	538	2.93	3.09
Gluten Dryer	350	177	1.32	1.39
Steepwater Heater	120	49	0.77	0.81
Sugar Hydrolysis	270	132	1.89	1.99
Sugar Evaporator	250	121	2.74	2.89
Sugar Dryer	120*	49	0.16	0.17
18. Prepared Feeds-2048				
Pellet Conditioning	180-190	82-88	2.28	2.40
Alfalfa Drying	400*	204	16.8	17.7
19. Bread & Baked Goods-2051				
Proofing	100	38	0.84	0.89
Baking	420-460	216-238	6.40	6.75
20. Cane Sugar Refining-2062				
Mingler	125-165	52-74	0.59	0.62
Melter	185-195	85-91	3.30	3.48
Defecation	160-185	71-85	0.44	0.46
Revivification	750-1110	399-599	3.96	4.18
Granulator	110-130	43-54	0.44	0.46
Evaporator	265	129	26.39	27.84

TABLE I-9(Continued)

LIST OF INDUSTRIAL PROCESS HEAT

APPLICATIONS AND ANNUAL REQUIREMENTS (1974) FOUND FROM SURVEY

	Application Temperature Requirement		Process Heat Used for Application	
Industry - S.I.C. Group	°F	°C	10^{12} Btu/Yr.	10^{12} kJ/Yr.
21. Beet Sugar-2063				
Extraction	140-185	60-85	4.63	4.88
Thin Juice Heating	185	85	3.08	3.25
Lime Calcining	1000	538	2.98	3.14
Thin Syrup Heating	212	100	6.68	7.05
Evaporation	270-280*	132-138	30.8	32.5
Granulator	150-200	66-93	0.15	0.16
Pulp Dryer	230-280*	110-138	16.5	17.4
22. Soybean Oil Mills-2075				
Bean Drying	160	71	4.05	4.27
Toaster Desolventizer	215	102	6.08	6.41
Meal Dryer	350*	177	4.36	4.60
Evaporator	225	107	1.62	1.71
Stripper	212	100	0.30	0.32
23. Animal and Marine Fats-2077				
Continuous Rendering of Inedible Fat	330-350	166-177	16.5	17.4
24. Shortening and Cooking Oil-2079				
Oil Heater	160-180	71-82	0.72	0.76
Wash Water	160-180	71-82	0.12	0.13
Dryer Preheat	200-270	93-132	0.60	0.63
Cooking Oil Reheat	200	93	0.32	0.34
Hydrogenation Preheat	300	149	0.37	0.39
Vacuum Deodorizer	300-400	149-204	0.35	0.37
25. Malt Beverages-2082				
Cooker	212	100	1.53	1.61
Water Heater	180	82	0.53	0.56
Mash Tub	170	77	0.60	0.63
Grain Dryer	400*	204	9.18	9.68
Brew Kettle	212	100	3.98	4.20
26. Distilled Liquor-2085				
Cooking (Whiskey)	212	100	3.16	3.33
Cooking (Spirits)	320	160	6.27	6.61
Evaporation	250-290*	121-143	2.32	2.45
Dryer (Grain)	300-400	149-204	1.94	2.05
Distillation	230-250	110-121	7.69	8.11

TABLE I-9 (Continued)

LIST OF INDUSTRIAL PROCESS HEAT APPLICATIONS AND ANNUAL REQUIREMENTS (1974) FOUND FROM SURVEY

Industry - S.I.C. Group	Application Temperature Requirement °F	°C	Process Heat Used for Application 10^{12} Btu/Yr.	10^{12} kJ/Yr
27. Soft Drinks-2086				
Bulk Container Washing	170	77	0.21	0.22
Returnable Bottle Washing	170	77	1.27	1.34
Nonreturnable Bottle Warming	75-85	24-29	0.43	0.45
Can Warming	75-85	24-29	0.52	0.55
28. Cigarettes-2111				
Drying	220*	104	0.43	0.45
Rehumidification	220*	104	0.43	0.45
29. Tobacco Stemming & Redrying-2141				
Drying	220*	104	0.50	0.26
30. Finishing Plants, Cotton-2261				
Washing	200	100	15.4	16.2
Dyeing	200	100	4.5	4.7
Drying	275	135	22.2	23.4
31. Finishing Plants, Synthetic-2262				
Washing	200	93	35.9	37.9
Dyeing	212	100	15.2	16.0
Drying and Heat Setting	275	135	23.2	24.5
32. Logging Camps-2411			None	
33. Sawmills & Planing Mills-2421				
Kiln Drying of Lumber	300	149	63.4	66.9
34. Plywood-2435				
Plywood Drying	250	121	50.6	53.4
35. Veneer-2436				
Veneer Drying	212	100	57.8	61.0

TABLE I-9(Continued)
LIST OF INDUSTRIAL PROCESS HEAT
APPLICATIONS AND ANNUAL REQUIREMENTS (1974) FOUND FROM SURVEY

Industry - S.I.C. Group	Application Temperature Requirement °F	°C	Process Heat Used for Application 10^{12} Btu/Yr.	10^{12} kJ/Yr.
36. Wooden Furniture-2511				
Makeup Air and Ventilation	70	21	5.7	6.0
Kiln Dryer and Drying Oven	150	66	3.8	4.0
37. Upholstered Furniture-2512				
Makeup Air and Ventilation	70	21	1.4	1.5
Kiln Dryer and Drying Oven	150	66	0.9	0.9
38. Pulp Mills-2611 Paper Mills-2621 Paperboard Mills-2631 Building Paper-2661				
Pulp Digestion	370	188	253	267
Pulp Refining	150	66	175	185
Black Liquor Treatment	280	138	164	173
Chemicals Recovery-Calcining	1900	1038	96	101
Pulp and Paper Drying	290	143	383	404
39. Solid and Corrugated Fiber Boxes-2653				
Corrugating and Glue Setting	300-350	149-177	21.6	22.8
40. Alkalies & Chlorine-2812				
Mercury Cell (to be phased out by 1983)			6.4	6.8
Diaphragm Cell	350	177	82.1	86.6
41. Cyclic Intermediates-2865				
Ethylbenzene	350	177	3.	3.
Styrene	250-350	121-177	35.	37.
Phenol	250	121	0.45	0.47
42. Alumina-28195				
Digesting, Drying, Heating	280	138	113.2	119.4
Calcining	2200	1204	35.3	37.2

TABLE I-9 (continued)

LIST OF INDUSTRIAL PROCESS HEAT APPLICATIONS AND ANNUAL REQUIREMENTS (1974) FOUND FROM SURVEY

Industry - S.I.C. Group	Application Temperature Requirement °F	°C	Process Heat Used for Application 10^{12} Btu/Yr.	10^{12} kJ/Yr
43. Plastic Materials and Resins-2821				
Polystyrene, suspension process				
Polymerizer Preheat	200-215	93-102	0.102	0.107
Heating Wash Water	190-200	88-93	0.064	0.068
Drying	200	93	0.034	0.036
44. Synthetic Rubber-2822				
Cold SBR Latex Crumb				
Bulk Storage	80-100	27-38	0.179	0.189
Emulsification	80-100	27-38	0.086	0.091
Blowdown Vessels	130-145	54-63	0.865	0.912
Monomer Recovery by Flashing & Stripping	120-140	49-60	4.095	4.319
Dryer Air Temperature	150-200	66-93	3.663	3.864
Cold SBR, Oil-Carbon Black Masterbatch				
Dryer Air Temperature	150-200	66-93	0.506	0.534
Oil Emulsion Holding Tank	80-100	27-38	0.028	0.030
Cold SBR, Oil Masterbatch				
Dryer Air Temperature	150-200	66-93	1.09	1.15
Oil Emulsion Holding Tank	80-100	27-38	0.090	0.095
45. Cellulosic Man-made Fibers-2823				
Polyester	< 550	< 288	48.9	51.6
Nylon	< 535	< 279	41.7	44.0
Acrylic	< 250	< 121	23.5	24.8
Polypropylene	< 540	< 282	3.9	4.1
46. Noncellulosic Fibers-2824				
Rayon	< 212	< 100	37.8	39.9
Acetate	< 212	< 100	37.6	39.7
47. Pharmaceutical Preparations-2834				
Autoclaving & Cleanup	250	121	18.85	19.88
Tablet & Dry-capsule Drying	250	121	1.00	1.05
Wet Capsule Formation	150	66	0.05	0.05

TABLE I-9 (Continued)

LIST OF INDUSTRIAL PROCESS HEAT APPLICATIONS AND ANNUAL REQUIREMENTS (1974) FOUND FROM SURVEY

Industry - S.I.C. Group	Application Temperature Requirement °F	°C	Process Heat Used for Application 10^{12} Btu/Yr.	10^{12} kJ/Yr.
48. Soaps and Detergents-2841				
Soaps:				
Various Processes in Soap Manufacture	180	82	0.50	0.53
High-temperature Processes	490	254	0.002	0.002
Spray Drying	500*	260	0.001	0.001
Detergents:				
Various Low-temperature Processes	180	82	0.36	0.38
High-temperature Processes	500	260	0.001	0.001
Drum-Dried Detergents	350*	177	0.31	0.33
Spray-Dried Detergents	500*	260	0.019	0.020
49. Organic Chemicals, N.E.C.-2869				
Ethanol	200-250	93-121	6.	6.
Isopropanol	200-350	93-177	11.	12.
Cumene	250	121	1.	1.
Vinyl Chloride Monomer	250-350	121-177	9.	9.
50. Urea-2873215				
High-Pressure Steam-Heated Stripper	375	191	5.07	5.35
Low-Pressure Steam-Heated Stripper	290	143	0.89	0.94
51. Explosives-2892				
Dope (Inert Ingredients) Drying	300	149	0.006	0.006
Wax Melting	200	93	0.118	0.124
Nitric Acid Concentrator	250	121	0.070	0.074
Sulfuric Acid Concentrator	200	93	0.027	0.028
Nitric Acid Plant	200	93	0.223	0.235
Blasting Cap Manufacture	200	93	0.016	0.017

TABLE I-9(Continued)

LIST OF INDUSTRIAL PROCESS HEAT APPLICATIONS AND ANNUAL REQUIREMENTS (1974) FOUND FROM SURVEY

Industry - S.I.C. Group	Application Temperature Requirement		Process Heat Used for Application	
	°F	°C	10^{12} Btu/Yr.	10^{12} kJ/Yr.
52. Petroleum Refining-2911				
Crude distillation				
Atmospheric topping	650	343	275	290
Vacuum distillation	440-800	227-427	183	193
Thermal operations	555-1010	291-543	154	162
Catalytic cracking	1125	607	447	471
Delayed coking	900	482	225	237
Hydrocracking	515-810	268-432	91	96
Catalytic reforming	925	496	498	525
Catalytic hydrorefining	700	371	52	55
Hydrotreating	700	371	124	131
Alkylation	45-340	7-171	59	62
Hydrogen plant	1600	871	124	131
Olefins and aromatics	1200	649	124	131
Lubricants	Unavailable	--	25	26
Asphalt	"	--	96	101
Butadiene	250-350	121-177	60	63
53. Paving Mixtures-2951				
Aggregate Drying	275-325*	135-163	88.1	92.9
Heating Asphalt	325	163	4.93	5.20
54. Asphalt Felts & Coatings-2952				
Saturator	400-500	204-260	1.52	1.60
Asphalt Coating	300-400	149-204	1.23	1.30
Drying (Steam)	350	177	3.32	3.50
Sealant	300-400	149-204	0.57	0.60
55. Tires and Inner Tubes-3011				
Vulcanization	250-340	121-171	6.18	6.52
56. Plastics Products-3079				
Blow-molded Bottles				
High-Density Polyethylene	425	218	3.52	3.71

TABLE I-9(Continued)
LIST OF INDUSTRIAL PROCESS HEAT
APPLICATIONS AND ANNUAL REQUIREMENTS (1974) FOUND FROM SURVEY

Industry - S.I.C. Group	Application Temperature Requirement		Process Heat Used for Application	
	°F	°C	10^{12} Btu/Yr.	10^{12} kJ/Yr.
57. Leather Tanning and Finishing-3111				
Bating	90	32	0.094	0.099
Chrome Tanning	85-130	29-54	0.060	0.063
Retan, Dyeing, Fat Liquor	120-140	49-60	0.15	0.16
Wash	120	49	0.034	0.036
Drying	110*	43	2.05	2.16
Finishing Drying	110*	43	0.13	0.14
58. Flat Glass-3211				
Melting	2300-2700	1260-1482	50.1	52.8
Fabrication (including Tempering and Laminating)	1470-2000	799-1093	3.5	3.7
Annealing	930	499	5.9	6.2
59. Glass Containers-3221				
Melting-Firing	2700-2900	1482-1593	98.60	104.0
Conditioning	1500-2000	816-1093	42.25	44.56
Annealing	1200	649	12.81	13.51
Post Forming	1200	649	1.42	1.50
60. Hydraulic Cement-3241				
Drying	275-325*	135-163	8.0	8.
Calcining	2300-2700	1260-1482	468.0	494.
61. Brick and Structural Tile-3251				
Brick kiln	2500	1371	70.4	74.2
62. Clay Refractories-3255				
Refractories firing	3300	1816	9.0	9.5
63. Concrete Block-3271				
Low-Pressure Curing	165*	74	12.29	12.96
Autoclaving	360	182	5.42	5.72
64. Ready-Mix Concrete-3273				
Hot Water for Mixing Concrete	120-190	49-88	0.34	0.36
65. Lime-3274				
Calcining	1800	982	129.9	137.0
66. Gypsum-3275				
Kettle Calcining	330	166	10.0	10.5
Wallboard Drying	300	149	11.18	11.79

TABLE I-9 (Continued)

LIST OF INDUSTRIAL PROCESS HEAT APPLICATIONS AND ANNUAL REQUIREMENTS (1974) FOUND FROM SURVEY

Industry - S.I.C. Group	Application Temperature Requirement		Process Heat Used for Application	
	°F	°C	10^{12} Btu/Yr.	10^{12} kJ/Y
67. Treated Minerals-3295				
Expanded Clay & Shale				
Bloating Process	1800	982	29.1	30.7
Fuller's Earth				
Drying & Calcining	1100	593	6.37	6.72
Kaolin				
Calcining	1900	1040	1.4	1.5
Drying	230*	110	12.7	13.4
Expanded Perlite				
Drying	160*	71	0.22	0.23
Expansion Process	1600	871	1.7	1.8
Barium				
Drying	230*	110	0.34	0.36
68. Blast Furnaces and Steel Mills-3312				
High-Temperature Uses	2700	1482	3300	3480
69. Ferrous Castings				
Gray Iron Foundries-3321 (73% of heat)				
Malleable Iron Foundries-3322 (10% of heat)				
Steel Foundries-3323 (17% of heat)				
Melting in Cupola Furnaces	2700	1482	146	154
Mold and Core Preparation	300-475	149-246	117.7	124.1
Heat Treatment and Finishing	900-1800	482-982	16	17
Pickling	100-212	38-100	151	160
70 Primary Copper-3331				
Smelting and Fire-Refining	2000-2500	1095-1371	32.58	34.37
71. Primary Zinc-3333				
Pyrolytic Reduction	2400	1300	1.0	1.1
72. Primary Aluminum-3334				
Prebaking anodes	2000	1093	8.14	8.59
73. Galvanizing-3479				
Cleaning, Pickling	130-190	54-88	0.011	0.012
Galvanizing (melting zinc)	850	454	0.014	0.015

TABLE I-9(Continued)

LIST OF INDUSTRIAL PROCESS HEAT

APPLICATIONS AND ANNUAL REQUIREMENTS (1974) FOUND FROM SURVEY

Industry - S.I.C. Group	Application Temperature Requirement °F	°C	Process Heat Used for Application 10^{12} Btu/Yr.	10^{12} kJ/Yr.
74. Motors and Generators-3621				
Drying and Preheat	150	66	0.043	0.045
Baking	350	177	0.133	0.140
Oxide Coat Laminations	1500-1700	816-927	0.72	0.76
Annealing	1500	816	0.67	0.71
75. Motor Vehicles-3711				
Baking-Prime and Paint Ovens	250-300	121-149	0.29	0.31
Casting Foundry	2650	1454	23.	24.
76. Inorganic Pigments-2816				
Drying Chrome Yellow	200	93	0.075	0.079

* No special temperature required; requirement is simply to evaporate water or to dry the material.

FIGURE I-4

CUMULATIVE DISTRIBUTION OF PROCESS HEAT REQUIREMENTS

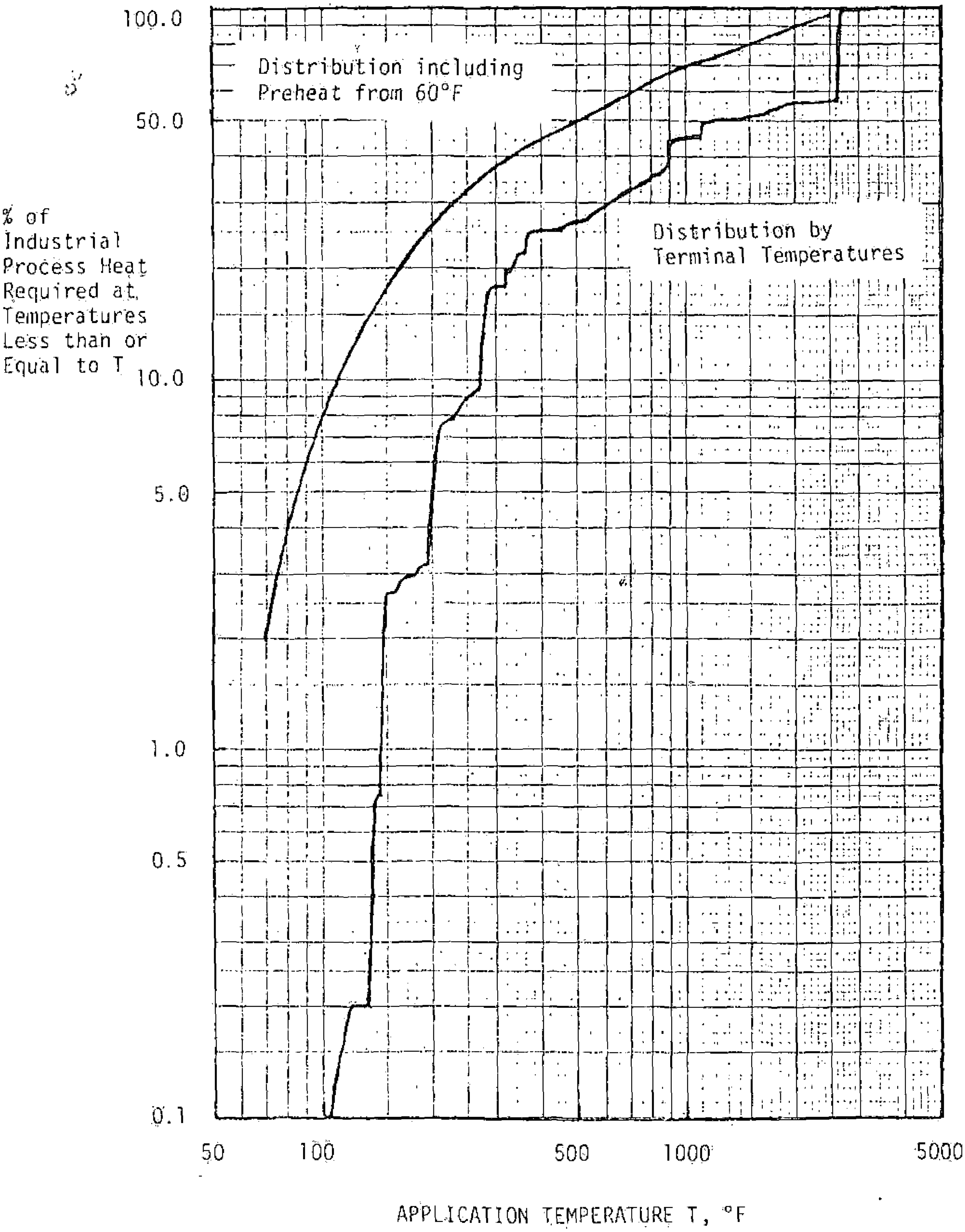

TABLE 1-10

SUMMARY OF PROCESS HEAT DATA BASE BY INDUSTRY

SIC Group	Industry	Process Heat Included Within Data Base 10^{12} Btu	 10^{12} kJ
10-14	Mining	129.14	136.22
20	Food & Kindred Products	318.93	336.41
21	Tobacco Products	1.36	1.43
22	Textile Mills	116.40	122.78
23	Apparel		
24	Lumber & Wood Products	171.80	181.21
25	Furniture	11.8	12.45
26	Paper & Allied Products	1,092.60	1,152.47
27	Printing & Publishing		
28	Chemicals	534.17	563.44
29	Petroleum Products	2,636.67	2,781.16
30	Rubber	9.70	10.23
31	Leather	2.52	2.66
32	Stone, Clay & Glass	990.94	1,045.24
33	Primary Metals	3,772.42	3,979.15
34	Fabricated Metal Products	0.03	0.03
35	Machinery		
36	Electrical Equipment	1.57	1.66
37	Transportation	23.29	24.57
38	Instruments		
39	Miscellaneous		
	TOTAL	9,813.34	10,351.11

The assembled information was analyzed and the candidate products were grouped in three categories according to potential for continued long-term growth in demand. Those in the group rated "best" projected annual growth rates of over 4%. Those rated average will probably have a growth rate close to the GNP, about 2-4% per year and the "poor" group will probably have only slight growth or a decrease in demand. The grouping is as follows:

A. Best (>4% per year)

Acetic Acid
Alumina
Aluminum
Butyl Alcohol
Caustic Soda
Chlorine
Citric Acid
Corn Starch/syrup (Fructose)
Ethylene Glycol
Ethylene Oxide
Hydrogen Peroxide
Magnesium
Peanut Oil
Sodium Chlorate
Soybean Oil
Paper Mill Products

B. Average (2-4% per Year)

Acetone
Adipic Acid
Ethanol
Glycerin
Isopropanol
Soda Ash
Tall Oil

C. Poor (<2% per Year)

Acetic Anhydride
Aluminum Sulfate
Casein
Cellulose Acetate
Cottonseed Oil
Dextrose
Lactic Acid
Penicillin
Potato Starch
Riboflavin
Turpentine
Viscose Rayon
Wood Rosin

Our summary appraisal of each product is as follows:

1) Acetone - Average. Methyl Methacrylate has become the largest market for Acetone and should continue to grow well. The market for acetone is mature, and could create an acetone surplus. An average growth rate is expected.

2) Acetic Anhydride - Poor. "Growth prospects of acetic anhydride are little better than zero". Use of cellulose acetate textiles and plastics are declining.

3) Adipic Acid - Average. Modest annual growth in sales of nylon 616 fibers and plastics should assure a similar increase in adipic acid demand.

4) Alumina - Best. Growth in the aluminum and ceramics markets are expected to create increased demand for alumina.

5) Aluminum. Best. Continuing development of new aluminum products and processes should result in increased consumption.

6) Aluminum Sulfate. Poor. Steady reduction in demand over the past ten years due to increased reclamation and substitution of other coagulation agents.

7) Butyl Alcohol. Best. Butyl alcohol has good potential in the industrial coatings market and could profit greatly from a campaign against solvent pollution.

8) Casein. Poor. Once extensively used for glue and paper coating, now 60-70% is produced for edible use such as "low-fat" cottage cheese. Weakness of price in 1976 suggests adequacy of current supplies and impact of cheaper imports.

9) Caustic Soda. Best. Increasing use of caustic in the pulp and paper and the aluminum industries is resulting in greater demand.

10) Cellulose Acetate. Poor. Use of cellulose acetate textiles and plastics are declining and growth prospects are only nominal.

11) Chlorine - Best. A tight situation has developed between production capacity and actual industry needs and demand for chlorine is expected to increase.

12) Citric Acid. Best. Has a dominant position in the food acidulant market and demand should continue to increase.

13) Corn Syrup. Best. High fructose corn syrups are expected to have a rapid increase in demand.

14) Cottonseed Oil. Poor. Percapita consumption is down 55% from what it was in 1950. Total production fell from 2.0 billion lbs. in 1964 to 1.6 billion in 1973.

15) Dextrose - Poor. Demand for dextrose is down and the trend is expected to conntinue as increased production of fructose corn syrup (HFCS), replacin dextroses, becomes more popular.

16) Ethyl Alcohol - Average. Demand should grow at a modest rate as the economy improves. Production should not be limited by ethylene supplies and capacity should remain adequate.

17) Ethylene Glycol - Best. Experts anticipate continued growth in the anti-freeze and polyester fiber markets, although at somewhat less dramatic rates than in the recent past.

18) Ethylene Oxide - Best. Consumption will depend heavily on the ethylene glycol market. Increases are also expected in production of ethanolamines and glycol ethers.

19) Isopropanol - Average. Only low growth in demand over the next five years. Present capacity is considered to be adequate for several years to come.

20) Glycerin - Average. Glycerine is a mature product and, except for urethane polyols, growth in the use of glycerin based products is expected to be slow.

21) Hydrogen Peroxide - Best. New-uses for hydrogen peroxide appear very promising particularly in water treatment, uranium mining, and replacement of chromic acid and chromates.

22) Lactic Acid and Lactose - Poor. This market is small and the current price stability indicates the adequacy of supplies.

23) Magnesium - Best. There will be a continued tightness of magnesium supply with long-term demand remaining strong.

24) Peanut Oil - Best. Per capita consumption rose 30% from 1950 to 1970 and production increased from 86 million lbs. in 1962 to 214 million lbs. in 1973. This upward trend is expected to continue.

25) Penicillin - Poor. Although the market for anti-infectants is growing at 4-5% per year, the market is controlled by a small number of suppliers. Important basic patents will expire in the period 1976-85 which will permit the same of anti-infectants as generic drugs in bulk quantities.

26) Potato Starch - Poor. Sales of potato starch and flour fell from 1,100 million lbs. in 1966 to 273 million pounds in 1973, and no noteworthy growth n the market has been predicted.

27) Pulp and Paper - Best. Per capita consumption is steadily rising. Capacity expansion has not kept pace with annual growth in demand. Kraft pulp prouction has been increasing rather rapidly.

28) Riboflavin - Poor. The total market is small and while demand is on a plateau, price is weakening.

29) Soda Ash - Average. Prospects are somewhat ambiguous. Loss in capacity for synthetic soda ash has nearly been offset by new natural capacity. While operating economics of natural plants in the West are better than those of synthetic plants in the East, the latter are better situated to service Eastern markets. Overall growth in the soda ash industry is predicted to be modest.

30) Sodium Chlorate - Best. Experts predict that increased usage of sodium chlorate in the paper industry may occur in secondary brightening stages of paper bleaching in the new mills and for generating chlorine dioxide to replace chlorine in existing plants.

31) Soybean Oil. Best. Per capita consumption of soybean oil rose 210% between 1950 and 1970 and growth is expected to continue, although at more moderate rates.

32) Turpentine. Poor. Demand for turpentine has been on the decline since 1968 and only small growth potential appears likely for the future.

33) Viscose Rayon - Poor. Rayon accounted for 309 million lbs. of the U.S. man-made fiber production in 1967 but only 65 million in 1975. The increased cost of wood pulp is causing rayon to be less competitive with non-cellulose synthetic fibers.

34) Wood Rosin. Poor. Demand for wood rosin has been declining steadily over the past several years. Demand is expected to level off around present levels, and only modest growth is predicted in the future.

TABLE 3-1

ESTIMATED DEMAND/U.S. PRODUCTION REQUIREMENTS OF POTENTIAL PRODUCTS

(1000s of Short Tons per Year)

Product	GROWTH RATE-%	TOTAL PRODUCTION			INCREASE	
		1980	1990	2000	1980-1990	1990-2000
Acetic Acid	6.0	1,702	3,048	5,458	1,346	2,410
Acetic Anhydride	0 to 1	784	858	939	74	81
Adipic Acid	3.0	898	1,207	1,622	309	415
Alumina[1]	6.0	13,997	25,067	44,891	11,070	19,824
Aluminum[1]	6.0	8,571	15,349	27,488	6,778	12,139
Caustic	6.0	16,100	28,833	51,635	12,733	22,802
Cellulose Acetate	2.0	496	604	737	109	133
Chlorine	5.0	14,860	24,205	39,427	9,345	15,222
Ethylene Glycol	7.0	2,434	4,788	9,419	2,354	4,631
Ethanol[2]	2.5	221	283	362	62	79
Glycerin	2.0	206	251	306	45	55
Hydrogen Peroxide	5.0	124	202	329	78	127
Isopropanol	2.0	1,114	1,358	1,655	244	297
Magnesium[4]	8.0	427	922	1,991	495	1,069
Peanut Oil	6.0	160	287	514	127	227
Riboflavin	0 to 1	484	508	534	24	26
Soda Ash	2.0	8,517	10,382	12,655	1,865	2,273
Sodium Chlorate	7.0	262	516	1,014	254	498
Soybean Oil	5.0	5,063	8,246	13,433	3,184	5,186
Tall Oil	3.0	976	1,311	1,762	335	451
Corn Syrup(HFCS)	6.0	2,250	4,029	7,215	1,779	3,186
Paper Mill Prod.[3]	4.2	34,761	52,453	79,149	17,692	26,696
Acetone	4.0	1,205	1,784	2,640	579	856
Wood Rosin	1 to 2	271	315	365	44	50
Citric Acid	6.5	140	263	494	123	231
Ethylene Oxide	6.0	2,907	5,207	9,325	2,300	4,118
Turpentine[2]	1 to 2	29.0	33.6	39.0	4.6	5.4
Butyl Alcohol	12.0	315	977	3,036	633	2,058
Aluminum Sulfate	0 to 1	1,117	1,174	1,234	57	60

[1] Based on U.S. demand

[2] Millions of gallons

[3] Paper Mill products, except building paper

[4] Based on World demand

The annual growth rates and production requirements for the products that are average to best in projected growth rate are listed in table 3-1. The consumption (production) rates have been estimated from actual reported consumption for previous years using the predicted growth rates. The additional production requirements given do not include replacing existing facilities as they are shut-down. It should be pointed out that the predicted growth rates are only based on presently known facts with the assumption that no new major uses of the product come into being and the present general price structure and price ratios with competing products continue. While this assumption may be valid through 1980, it becomes less reliable in the years beyond 1980. Thus, the additional production requirements determined for 1980-2000 may be an order of magnitude only for some of these products.

Mont

GEOPHYSICAL INVESTIGATIONS AND THERMAL WATER CIRCULATION AT HUNTERS AND NORRIS HOT SPRINGS, MONTANA

By

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Introduction

Hunters and Norris Hot Springs (Fig. 1) were investigated by shallow (100 m depth or less) geophysical techniques as part of a preliminary geothermal assessment of Southwestern Montana sponsored by the U.S. Geological Survey. Hunters was studied by D.C. resistivity and Norris by resistivity and hammer seismic methods. Used in conjunction with geological and geochemical data, shallow geophysical observations may permit delineation of the connection between surface orifices and subsurface conduits, thus better defining the thermal water circulation system, aiding in assessment of the reservoir potential, and providing a target for drilling or deeper geophysical surveys.

Methods

D.C. resistivity equipment was constructed by the Montana State University Electronics Research Laboratory using a Datel DM 2000AR potential meter and Simpson 260 current meter. Ground current is furnished by up to 22 6v rechargeable batteries, and chrome alloy stakes serve as electrodes. Using the Wenner array and the Barnes Layer method, the instrument is capable of "seeing" 100 m deep. Arrays were kept parallel to power lines or other linear conductors in the vicinity. Electrode spacings were consistent with apparent depths of 20, 40, 60, 80, and 100 m. Stations were 50 m apart where feasible.

The hammer seismic survey utilized a Bison Signal Enhancement Seismograph Model 1570B. A heavier hammer head (18 lb.) and extra cable permitted signal penetration to about 70 m depth for the ground conditions encountered.

Geology and Geochemistry of the Hot Springs

Hunters Hot Springs discharges at 60°C and 5000 l/min, and Norris at 52.5°C and 400 l/min (Mariner and others, 1976). Geologic settings at the two hot springs are quite different. Hunters Hot Springs lie in folded and fractured Cretaceous Livingston Group andesitic sandstone, siltstone, and shale. Little or no soil covers the bedrock. The sandstones are poorly sorted and of low permeability except where fractured. At depth, thermal waters at Hunters probably travel through sandstone aquifers of pre-Livingston age (Chadwick and Kaczmarek, 1975). Norris Hot Springs issue from 0-30 m thick alluvium which covers a sequence of Precambrian felsic to mafic gneisses. Locally, erosion remnants of Tertiary granite-pebble conglomerate and breccia overlie the metamorphics (Andretta and Alsup, 1960). At Norris, thermal waters likely utilize fractures within the Precambrian crystalline rock.

Each spring site appears to be located at the intersection of major geologic structures. At Hunters, the axis of the northeast-trending, locally overturned Hunters anticline crosses the springs area (Fig. 2). Faults parallel the axis southwest of the hot springs (Richards, 1957). The anticline may represent a major deep-seated lineament or shear zone (strike-slip "shift zone" of Garrett, 1972) in the Precambrian basement. Intersecting this zone (Fig. 2) is a northwest-trending system of locally slickensided calcite-stilbite veins plus at least one fault (Weed, 1905; Richards, 1957; Stoll and Armstrong, 1958). The vein swarm extends sporadically to the Clyde Park area 30 km to the northwest, where optical grade calcite has been extracted. To the southeast, the veins are in line with the axis of the McLeod anticline (Hadley, 1972).

Norris Hot Springs lies along a postulated east-northeast trending fault or shear zone approximately paralleling Hot Springs Creek (labeled "cold creek" on Fig. 3). Evidence for the fault zone includes drag folding in the gneisses and deformation and offset of Tertiary conglomerate beds (Andretta and Alsup, 1960). The Precambrian foliation strikes N 35° W obliquely across the fault zone. Numerous small quartz veins trend northwestward across the area, as does an anticlinal axis in the Precambrian rocks. Also in the northwest alignment are the principal hot spring orifices and a warm spring 225 m to the southeast as shown on Figure 3.

Hot spring waters at both Hunters and Norris are high in sodium and bicarbonate and low in calcium (Mariner and others, 1976). Gas content at Hunters is unusual for Montana; methane makes up 64% by volume. Gas at Norris is principally nitrogen.

Chemical geothermometers yield low estimated thermal aquifer or "base" temperatures at both hot springs (Mariner and others, 1976). Waters from the principal orifice at Hunters indicate 114°C (quartz), 67°C (chalcedony), and 78°C (cation). Norris hot waters yield 130°C (quartz), 101°C (chalcedony), and 112°C (cation). If these estimates are correct, thermal waters from these springs are more suitable for non-electric power uses such as space heating or industrial or agricultural processing.

Geophysical Data and Interpretations

At Hunters Hot Springs, the shallow D.C. resistivity surveys delineate an apparent resistivity low centered on the northwestern group of orifices. The anomaly is roughly circular at 20 m depth (Fig. 4) but with increasing depth becomes more elongate in northwest and northeast directions. At 100 m apparent depth (Fig. 5), the anomaly can be aligned with two "favorable zones", one trending N 60° W and the other N 50° to 70° E. The pattern suggests that thermal water may be rising along two sets of fractures trending northwest and northeast respectively. These sets are subparallel to the calcite vein-fault-McLeod anticline system and the Hunters faulted anticline "shift zone" respectively. Hot water may be channeled to the surface by the intersection of these two zones. This intersection makes a favorable target for drilling to tap rising waters and to probe the geothermal system for possible higher temperature waters in aquifers at greater depth.

At Norris Hot Springs, apparent resistivity patterns at 20 m depth intervals to 100 m show a diffuse low centered over the alluvial valley of Hot Springs Creek. Figure 3 illustrates the position of resistivity contours for the depths of 20 and 100 m. At 20 m, a low of 20-30 ohm-m intensity encompasses the principal hot springs orifices, but at deeper levels the low is increasingly restricted to the center of the valley. The pattern may represent thermal water rising along the postulated Hot Springs Creek fault zone, or alternatively, hydrothermally altered bedrock or fault gouge unrelated to thermal activity. Seismic data cited below indicate that alluvium is too thin to produce this deeply

Figure 3. Apparent resistivity map, 20 and 100 m depths; Norris Hot Springs. Contours in ohm-m.

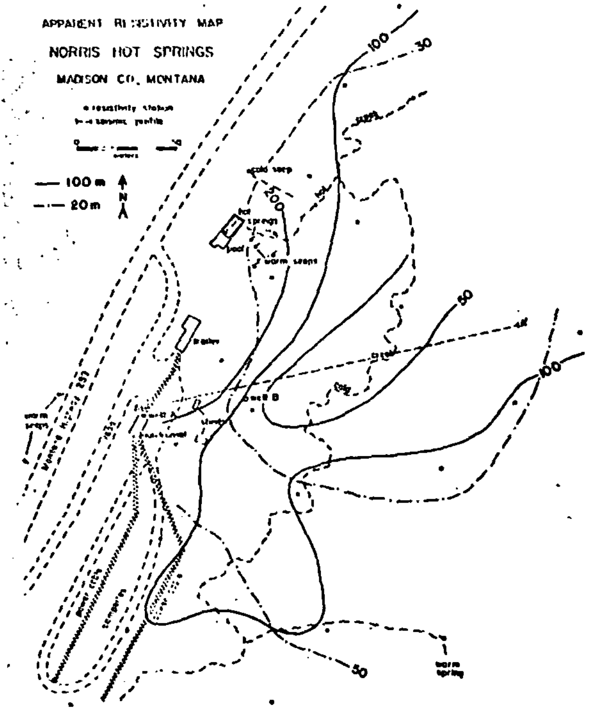
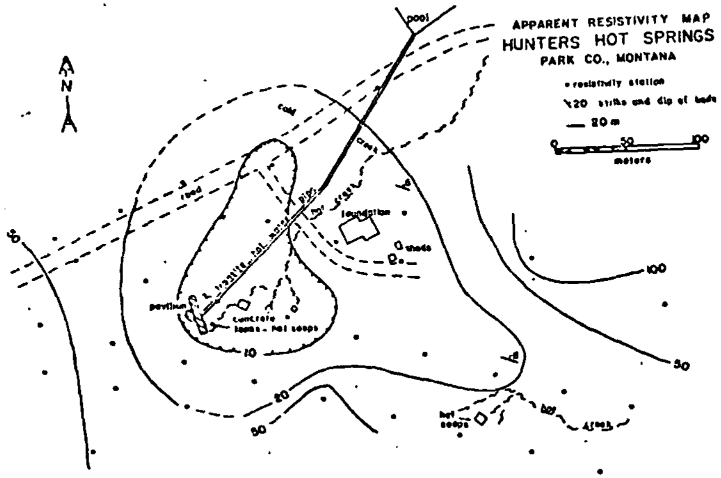


Figure 4. Apparent resistivity map, 20 m depth, Hunters Hot Springs. Contours in ohm-m.



penetrating anomaly. The widening of the anomaly near the surface could represent the path of rising, spreading thermal water.

The seismic profile (A-A' of Fig. 3) was run across the valley to include two shallow wells drilled for cold water supply. Well A bottomed in granitic rock and found very little water; well B struck warm (21°C) water in a sandy layer of alluvium at 14 m depth. Interpretation of the seismic pattern (Fig. 6) indicates that alluvium of 357-480 m/sec seismic velocity extends to about 30 m depth in the center of the valley. Two units of higher velocity beneath the alluvium are interpreted as types of Precambrian bedrock. The 1870 m/sec velocity material is probably feldspathic gneiss or possibly well-cemented granitic conglomerate. The 4450 m/sec material is probably mafic gneiss or quartzite. These interpretations are based on seismic traverses across known rock types. The seismic time-distance data suggest displacement of the "mafic" zone along a fault under the center of the valley. Thermal water may ascend along the intersection of the fault zone and the northwest-trending Precambrian anticlinal axis. The intersection might represent a favorable target for drilling.

Circulation Models

At both Hunters and Norris, geological and shallow geophysical data suggest that thermal waters rising from depth are controlled by the intersection of two major geologic structures. Depth of circulation may be estimated from geothermometric and gradient data.

Regional thermal gradient as indicated by deep drill holes south and east of Hunters (Am. Assoc. Petrol. Geols., 1973) averages about 29°C/km; gradient at Norris is probably about average for the crystalline rocks of Southwestern Montana (30°C/km based on limited data from Blackwell and Robertson, 1973). Enhancement of regional gradient by cooling igneous bodies is unlikely because igneous rocks in the Hunters and Norris areas are early Tertiary or older (Larsen and Simms, 1972; Kavanaugh, 1965).

If the chemical geothermometers are correct, depth of penetration of thermal waters is in the range 2.2 to 3.7 km at Hunters and 3.2 to 4.2 km at Norris. The high methane and low calcium content of Hunters waters suggests circulation at depth through natural gas-bearing sandstone aquifers or fracture systems and lack of extensive reaction with limestone aquivers or calcite veins. Norris waters are chemically rather similar to other Montana hot springs issuing from crystalline rock terrains and doubtless circulate through Precambrian metamorphic rocks and perhaps also Tobacco Root batholith rocks at depth.

Acknowledgments

This study was conducted under the U.S. Geological Survey Extramural Geothermal Research Program, Grant No. 14-08-0001-G-334 to Montana State University. Dr. Robert Leonard of the USGS coordinated the project and helped with all stages of investigation. Montana State University furnished laboratory, library, and office space and facilities. Field crew on the project, in addition to the co-authors, were Andrew Lockhart and Russell Patterson. Mr. Harold Johnson and Mr. M. Zankowski kindly allowed access to the Hunters and Norris properties, respectively. Stephan G. Custer reviewed the manuscript and made a number of useful suggestions.

Figure 6. Interpretation of seismic profile, Norris Hot Springs.

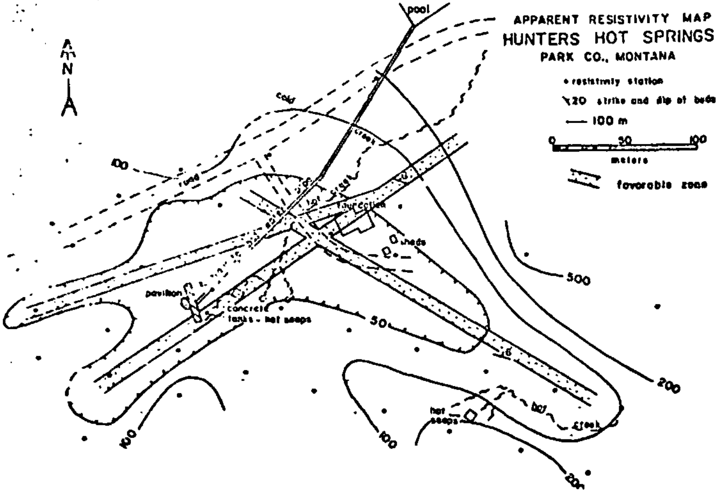
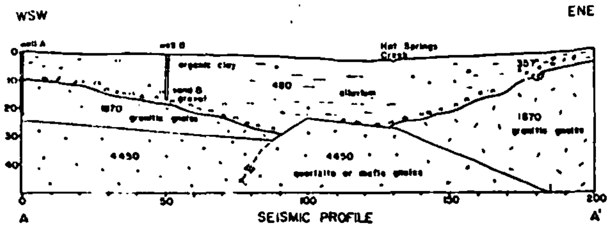


Figure 5. Apparent resistivity map, 100 m depth, Hunters Hot Springs. Countours in ohm-m.



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"Summary of 1977 GeoThermal Drilling – Western U.S."

"CGEH" #1 to 4845 ft. in granitic rock at a location near the center of a 15 sq. mile area of significant surface heat flow. Fractures located in the bottom 15 ft. of the well contain water of at least 362°F, and a wellhead temperature of 213°F was observed during a flow rate of 4500 B/D. The government has estimated the resource to be "of considerable magnitude, possibly 4,000 Mw".

NEVADA

During 1977, the Carson Sink region near Fallon continued to be explored with slim hole drilling. Occidental Geothermal drilled the "Federal" #72-33 as a 3000 ft. observation well at Lee Hot Springs, where waters of 172°F flow from an area surrounded by sinter deposits. Meanwhile, 8 miles west of Fallon, where Chevron had previously drilled a 4306 ft. test well in 1974, they returned in 1977 to drill "Soda Lake" #44-5 to 4975 ft. as a relatively nearby second observation well.

Phillips drilled "Campbell-E" #1 as the first well in the Rye Patch KGRA area, located 70 miles to the northeast of Fallon. The well found temperatures exceeding 325°F at 1853 feet, and drilling was suspended. Six locations for additional wells are now being permitted, with a deeper drilling assessment of the indicated resource scheduled for this year.

IDAHO

Phillips also drilled two geothermal wells in Idaho. The "Christenson A" #1 was drilled to 8001 feet at a location 2 miles south of Crane Creek KGRA. About 90 miles further south, the "Lawrence D" #1 (9340 ft.) is located within the Castle Creek KGRA area on private lands adjacent to a federal lease they successfully bid on in November, 1975. Neither well has been reported to be a commercial discovery, and both are now suspended.

In southeastern Idaho, at the Raft River Project area, the Idaho National Engineering Lab drilled the "RRGI" #4 to 2840 ft. with the original intent of using it as an interior injection-pressure maintenance well. After having flow tested the well and further assessed the reservoir, it now appears that it may be deepened to become a fourth producer, with the programmed injecting wells relocated peripherally. A 5 Mw demonstration power plant is now under construction.

UTAH

At the Roosevelt KGRA, Thermal drilled "Utah State" #24-36 (6107 ft.) as a stepout well located 1.5 miles northeast of proven production. The well did not encounter sufficient fractures or heat, and it was converted to an observation well. Nearby, Phillips has been conducting long-term production testing of #54-3, and a 1 Mw Sprankle wellhead power plant is now being installed beside the well to run the injection pumps. Preliminary agreements were signed in December by Phillips, Utah Power and Light, and Rogers International for a 50 Mw power plant scheduled for operation in mid-1982. Independently, Thermal et al. and VTN Corp. are also working toward their having a 55 Mw plant in the Roosevelt area by 1982, having reportedly demonstrated a capacity of 12-14 Mw for a single well, #72-16.

In 1976 Union had to abort at 1151 ft. the drilling of their first well in the Cove Fort area due to lost circulation and hydrogen sulfide problems. After acquiring Department of Energy financial support, Union moved a rig back into Cove Fort in late 1977 and spudded "Cove Fort-Sulfurdale" #42-7. Local conditions have again proved troublesome, but this time drilling was suspended at 7735 ft. Test equipment is just now being moved in, although temperatures are reported to be less than anticipated.

Republic Geothermal drilled the first deep exploratory well in the Thermo Hot Springs area, located 30 miles southwest of Roosevelt. The "Escalante" #57-29 was drilled to 7288 ft. on federal land leased in a 1976 KGRA sale. Initial evaluation of the well indicates the natural flow rates are low, that temperatures of 350-400°F are present and that the fluid has a low salinity. Additional flow testing is presently being conducted. About 20 miles further south of Thermo, McCulloch drilled and suspended the "Jones" #1-8 at 5857 feet.

NEW MEXICO

In April, Los Alamos Scientific Laboratory began redrilling "GT-2", a geothermal well originally drilled in granitic basement to 9607 ft. as part of the Government Hot Dry Rock resource assessment of the Valles Caldera. After having successfully fractured EE-1, an offset well, the intent was to directionally redrill "GT-2" to intersect the same fracture and effect better fluid communication between the wells. The first re-

"CGEH" #1 to 4845 ft. in granitic rock at a location near the center of a 15 sq. mile area of significant surface heat flow. Fractures located in the bottom 15 ft. of the well contain water of at least 362°F, and a wellhead temperature of 213°F was observed during a flow rate of 4500 B/D. The government has estimated the resource to be "of considerable magnitude, possibly 4,000 Mw".

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"Summary of 1976 Geothermal Drilling – Western U.S."

NEVADA

In 1974 Phillips drilled the "Deserk Peak" #29-1 to a depth of 7662 feet at a location 5 miles southeast of Brady Hot Springs in Churchill County. After evaluation, Phillips returned in the fall of 1976 to drill the "Deserk Peak" #21-1 (4150 feet). This well is considered a commercial new field discovery, and the #21-2 confirmation well that immediately followed is reported to have a maximum temperature of 390°F. at a 3192 foot T.D. Additional drill sites are now being permitted. Twenty miles further southeast, Union was drilling three deep observation holes in the Stillwater area to depths of 2672 feet-5532 feet. A nearby 4237 foot well drilled in 1964 had a maximum temperature of 265°F. Elsewhere in Nevada, the "Rossi" #21-19 (5680 feet), was drilled and temporarily suspended by Chevron at Beowawe. The location is less than one mile southeast of their "Ginn" #1-13 drilled to 9563 feet in 1974.

OREGON

The one geothermal well drilled in 1976 was the Thermal Power "O'Connor Ranch" #1, located 12 miles south of Klamath Falls in the vicinity of shallow holes with 200°F. water at less than 300'. The "O'Connor" #1 was abandoned at 5842 feet after an unsuccessful attempt to recover lost drill pipe in the well.

IDAHO

The Idaho National Engineering Laboratory (INEL) continued exploration drilling in the Raft River Basin. The "RRGE" #2, originally drilled in 1975, was deepened from 5988 feet to 6543 feet, and the "RRGE" #3 was drilled in "birdfoot" fashion, meaning the original hole (5853 feet) and two directionally deviated lower redrills to 5532 feet and 5935 feet are all open to completion. The #3 well flows 800 gpm of 297°F. water. INEL also drilled two deep observation holes to 1222 feet and 1283 feet near Boise to help define the shallow intermediate-temperature geothermal resources of that area.

UTAH

Three additional development wells were successfully completed in the Roosevelt KGRA, site of a significant new field discovery in 1975. Phillips drilled #25-15 (7513 feet), their seventh geothermal well and sixth producer in that field. On nearby State leases within the same KGRA, Thermal Power completed the "Utah State" #14-2 (6108 feet) and #72-16 (1254 feet). Well #72-16, located near the controlling surface fault, hit steam at 300 feet, 700 feet and 1200 feet. Preliminary tests of #72-16 demonstrate a wellhead pressure of 355 psig and a temperature of 432°F. The indicated total mass flow rate is about 1 million #/hour.

OPERATOR	WELLS DRILLED	PRODUCIBLE	SUSPENDED	ABANDONED	OBSERVATION	TOTAL FOOTAGE DRILLED
Union	25	18	0	1	6	181,524
Aminoil	6	3	3	0	0	54,491
Republic Geothermal	7	6	1	0	0	47,836
McCulloch	3	1	1	1	0	28,074
Shell	3	1	0	2	0	24,307
Chevron	3	0	2	0	1	22,001
Magma	3	2	1	0	0	21,511
Phillips	3	3	0	0	0	14,855
Thermal Power	3	2	0	1	0	13,204
Idaho Nat. Eng. Lab.	4	2	0	0	2	12,179
Pacific Energy	1	1	0	0	0	10,550
Amax	3	0	0	0	3	5,868
Battelle Pac. NW Lab.	1	0	0	0	1	1,352
TOTALS:	65	39	8	5	13	437,752

TABLE #2, SUMMARY BY OPERATOR, 1976 GEOTHERMAL DRILLING, WESTERN U.S.

STATE	REGION	AREA	OPERATOR	WELLS	PROD.	SUSP.	ABD.	OBS.	FOOTAGE
Calif.	Imperial Valley	Westmorland	Republic Geothermal	6	6	0	0	0	40,916
		Brawley	Union	2	2	0	0	0	16,411
		East Mesa	Magma Power	2	2	0	0	0	14,851
		Heber	Union	5	2	0	0	3	29,633
			Chevron	1	0	0	0	1	7,089
	The Geysers	Main Geysers	Union	14	14	0	0	0	122,675
			Aminoil	2	2	0	0	0	20,967
			Pacific Energy	1	1	0	0	0	10,550
			McCulloch	1	1	0	0	0	10,153
		Castle Rock	Aminoil	3	1	2	0	0	21,963
			Shell	1	1	0	0	0	5,626
		Middletown	Aminoil	1	0	1	0	0	11,561
			Chevron	1	0	1	0	0	9,232
			Shell	1	0	0	1	0	8,250
		Cloverdale	Shell	1	0	0	1	0	10,431
		Mt. Konocti	Magma Power	1	0	1	0	0	6,660
		Calistoga	AMAX	3	0	0	0	3	5,868
	Mono Co.	Long Valley	Republic Geothermal	1	0	1	0	0	6,920
	Inyo Co.	Coso Hot Springs	Battelle Pac.NW Lab.	1	0	0	0	1	1,352
Nevada	Churchill County	Desert Peak	Phillips	2	2	0	0	0	7,342
		Stillwater	Union	3	0	0	0	3	11,654
	Lander Co.	Beowawe	Chevron	1	0	1	0	0	5,680
Oregon	Klamath Co.	Klamath Hills	Thermal Power	1	0	0	1	0	5,842
Idaho	Cassia Co.	Raft River	Idaho Nat.Eng.Lab.	2	2	0	0	0	8,991
	Ada Co.	Boise	Idaho Nat.Eng.Lab.	2	0	0	0	2	3,188
Utah	Beaver Co.	Roosevelt	Phillips	1	1	0	0	0	7,513
			Thermal Power	2	2	0	0	0	7,362
	Millard Co.	Cove Fort	Union	1	0	0	1	0	1,151
	Iron Co.	Beryl Junction	McCulloch	2	0	1	1	0	17,921

TABLE #1. SUMMARY BY STATES, 1976 GEOTHERMAL DRILLING, WESTERN U. S.

Earlier in the year Aminoil had unfortunately been less successful in adding production in the southeast part of the field where the "Davies Estates" #2 (8231 feet) and #3 (10,240 feet) reportedly both found adequate temperatures but insufficient steam flow.

The five exploratory wildcat wells drilled at distances further from known production at The Geysers do not appear as yet to have found commercial production (Figure 3). The Magma "Watson" #1, located on the south flank of Mt. Konocti, was suspended at 5437 feet with mechanical hole problems. The Shell "Hilary Farms" #1 (6500 feet) and "Bounsall" #1 (8250 feet) were both abandoned, having found insufficient temperatures at the depths drilled. Chevron has suspended the "Dry Creek" #1 at 8597 feet awaiting further evaluation, and Aminoil suspended the "B-J" #1 after having drilled to 10,228 feet. Nearby, in Napa County, Amax drilled three temperature observation holes.

Along the Sierran front of eastern California is the Long Valley Caldera (Figure 4). The area has recently been the site of extensive USGS geothermal resource investigations, and in spring of 1976 Republic Geothermal drilled the "Long Valley" #66-29 to 6920 feet as the first deep test well within the caldera. Bottom-hole temperatures were disappointingly low, less than 200°F., and the outlook for the eastern part of the caldera now appears severely limited.

About 120 miles south of Long Valley is the Coso Hot Springs area. Battelle Pacific Northwest Laboratory, operating under an ERDA contract, continuously cored the "BDSH" #1 observation hole to 1352 feet in granitic basement as part of a continuing evaluation of the hot dry rock potential suspected to exist under the Naval Weapons Center. At a depth of 1000 feet the hole had a reported temperature of at least 300°F.

SP

Geothermal Applications of the Madison (Papasapa) Aquifer System in South Dakota

Gries, JP

in Direct Utilization of Geothermal Energy: A Symposium
San Diego, 1978 DOE/DGE

Structure. As a result of later structural movements, the Madison has been downwarped into the Williston Basin to the north, and uplifted and eroded over the Black Hills. Its greatest depth in northwestern South Dakota about 7,000 feet.

Porosity and permeability. Three types of porosity occur, 1) normal intergranular porosity particularly in the dolomites, 2) joint and fracture porosity, and 3) solution openings ranging from slightly enlarged joints to caverns in which the drill may drop several feet. Permeability is also affected by the types of openings. It is not surprising that well yields vary widely.

In an effort to locate favorable areas for obtaining high yields, Sherwin Artus made electric log analyses of the Madison section in 150 wells in South Dakota. No consistent areal or vertical trends in porosity could be recognized, but a few better-than-average areas were delineated.

HYDROLOGY

Geological background. The Madison is noted throughout its areal extent for large artesian flows, and for the attendant drilling problems of well control and lost circulation.

Following retreat of the early Mississippian sea, the newly deposited carbonate terrain remained slightly above sealevel for a long period of time. A widespread karst topography was developed. Sufficient limestone was removed by solution and erosion to produce a surface relief of several tens of feet, and the insoluble clays and chert remained behind as a surficial blanket of red residual soil. Subsequent deposition buried the topography beneath several thousand feet of strata.

When the Black Hills were uplifted during the Laramide Orogeny, the sediments overlying the Madison were partly removed by erosion, and surface water was again able to enter the cavern system. Much surface water now filters down through bare limestone outcrops, but more spectacular infiltration occurs where streams crossing the Madison outcrops lose large volumes of water to sinkholes in the stream bed. Because all water now entering the sinks cannot be accepted by the hydrologic system, some of it breaks back to the surface as resurgent springs around the perimeter of the Black Hills. The position of these springs has shifted somewhat as erosion progressed, but the present-day sinkholes and springs are descendants of an earlier system.

The relationship between water losses to sinkholes and discharge from resurgent springs has been verified by ten years of stream gauging across the sinkhole zones and at the springs. The volume of water returned to the surface is greater than that lost to the sinkholes, indicating that the more important part of the recharge to the Madison aquifer is derived from rain and snowmelt which infiltrate the outcrop area.

Two other facts indicate that the outcrops around the Black Hills constitute the recharge area for the Madison aquifer in South Dakota and the eastern Powder River Basin in Wyoming . The potentiometric surface is highest adjacent to the outcrops, and the total dissolved solids increase down dip in all directions from the Black Hills uplift.

Little is known about the movement of water once it enters the artesian system. The potentiometric surface slopes away from the Hills, steeply at first, then becoming nearly flat under the central part of the state, so no definite directions of water movement can be inferred. Limited age-dating of the Madison water gives contradictory estimates of the rate of movement.

Potentiometric surface. Whereever possible the potentiometric surface surface map has been based on producing water wells, with either a direct measurement of static level or one calculated from the shut-in pressure. A few isolated drill-stem-tests have been used for control in the northwestern corner of the state. Except for a small anomalous area in Mellette County, a flowing Madison well can be anticipated whereever the formation is present and where the surface elevation is less than 2,400 feet.

Hydrologic characteristics. Little information is available on transmissivities, storage coefficients, or specific capacities of Madison wells in South Dakota. The following wide ranges of values have been compiled from wells in western South Dakota and northeastern Wyoming:

Specific capacity-0.1 to 10.6 gpm/foot of drawdown
Transmissivity - 400 to 89,000 gpd/foot
Storage coefficient - 5 x 10^{-5} to 1 x 10^{-4}

Yields. Recorded yields in the Black Hills area range from 80 gpm on the pump to over 1,000 gpm free flow. A discharge of 500 gpm, either by natural flow or pumping can be considered an average for a properly completed Madison well. Some wells would require acid fracturing to reach this figure.

Interference. It seems advisable to maintain a distance of half a mile between Madison wells in a well field; a mile would be better if engineering considerations permit.

Temperature. The Madison temperature map (Fig. 2) is based upon temperatures obtained directly from flowing or pumping wells, or from bottom-hole recorders on resistivity logs run in oil tests. In the case of flowing or pumping wells, water reaching the surface may be slightly lower than formation temperature when the upward movement of the water is slow, and wells in long service frequwntly yield water a few degrees warmer than the figures obtained on initial production tests.

Most deep oil tests in western South Dakota bottom in the Ordovician or the top of the Precambrian basement. Hence most bottom hole temperatures have been recorded deeper than the Madi-

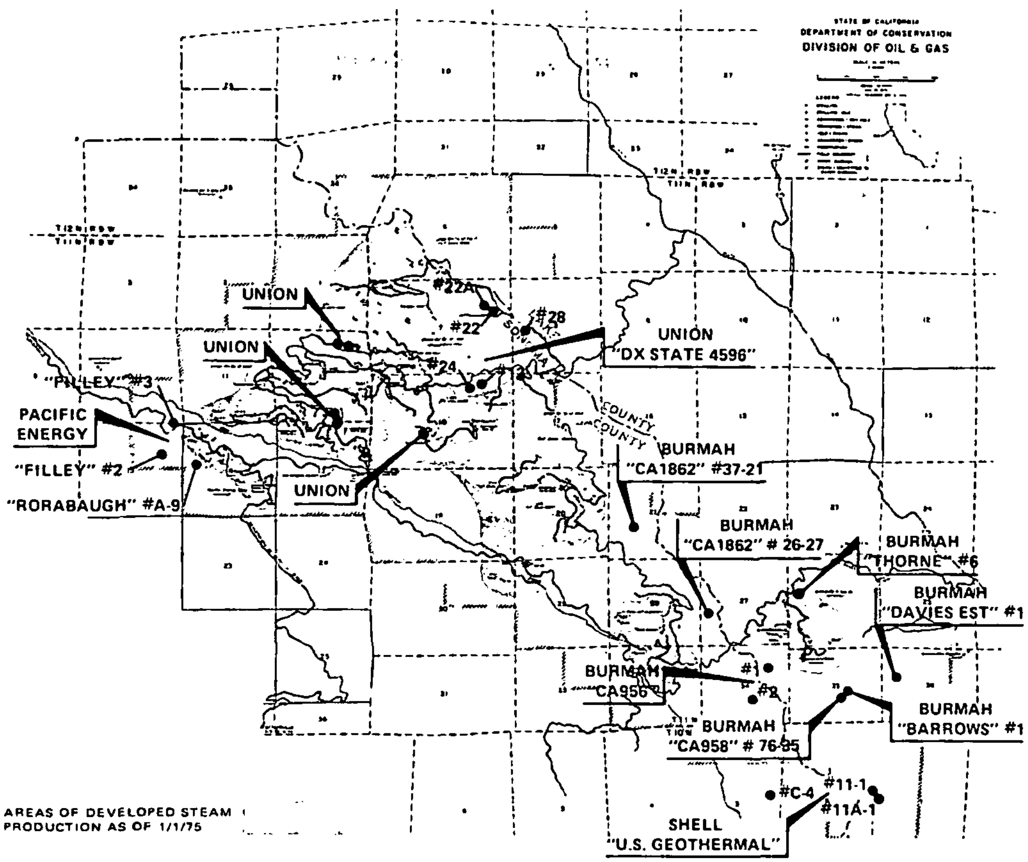

FIGURE 2. 1975 GEOTHERMAL WELLS, THE GEYSERS, CALIFORNIA

presented a reasonably active effort on the part of the Industry. The 80% success ratio of potentially productive wells is obviously extremely high and very encouraging. Represented in this success is both the fact that the Operators have now further perfected the drilling techniques, almost totally avoiding holes abandoned due to mechanical problems, and that the drilling targets in 1975 were predominantly of a relatively low risk. Hopefully, along with the development drilling in 1976, more wildcat wells will be drilled in presently unproven areas.

Dr. Smith, Vice President-Exploration, received his education as a geologist at Middlebury College and Indiana University. After spending a decade as an explorationist with Standard Oil Company of California, he has been with Republic Geothermal for the past year. Mr. Matlick, an exploration geologist-geochemist, joined Republic after completing his education at Arizona State University.

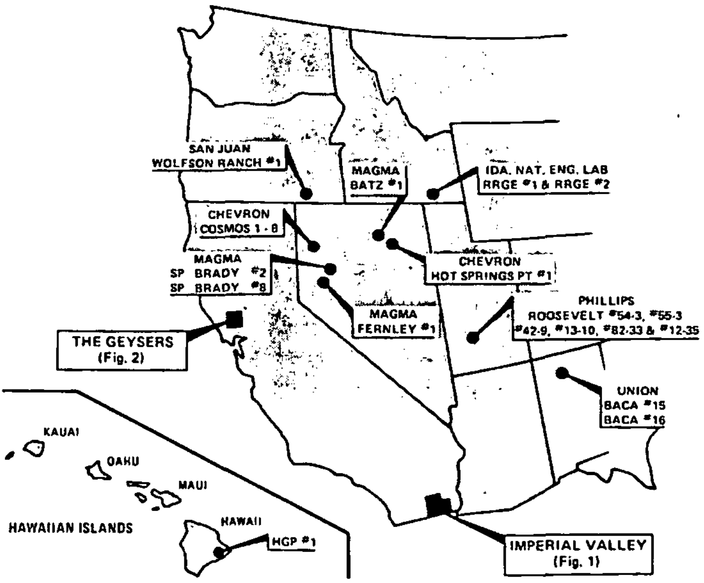

FIGURE 3. 1975 GEOTHERMAL WELLS, WESTERN U.S.

"Summary of 1975 Geothermal Drilling - Western U.S."

State	Region	Area	Operator	Wells	Prod.	Susp.	Abd	Footage
California	Imperial Valley	Brawley	Union	3	3	0	0	19,337
		East Mesa	Republic Geothermal	3	3	0	0	25,030
		East Heber	Republic Geothermal	1	0	1*	0	11,015
		Heber	Chevron	(3)	0	(3)	0	(10,374)
	The Geysers	(Main) Geysers	Union	10	9	0	1	81,208
			Pacific Energy	3	1	1	1	31,991
		Castle Rock Sprgs	Burmah	8	7	1*	0	60,279
			Shell	3	3	0	0	23,894
Oregon	Lake County	Crump Geyser	San Juan	1	0	0	1	7,510
Nevada	Churchill Co.	Brady H.W.	Magma	2	2	0	0	7,915
	Eureka Co.	Beowawe	Magma	1	0	0	1	5,447
	Lyon Co.	Fernley	Magma	1	0	0	1	3,668
	Eureka Co.	Hot Springs Pt.	Chevron	(1)	0	(1)	0	(2,335)
	Washoe Co.	San Emidio	Chevron	(1)	0	(1)	0	(4,013)
Idaho	Cassia Co.	Raft River	Ida. Nat. Eng. Lab	2	2	0	0	10,977
Utah	Beaver Co.	Roosevelt H.S.	Phillips	6	5	1	0	31,198
New Mexico	Jemez Mts.	Valles Caldera	Union	2	1	0	1*	12,507
Hawaii	Is. of Hawaii	Pahoa	Hawaii Geothermal Proj.	1	1(?)	0	0	6,445

* Temporarily

( ) Observation Holes

TABLE # 1. SUMMARY BY STATES, 1975 GEOTHERMAL DRILLING, WESTERN U.S.

Operator	Wells Drilled	Producible	Suspended	Abandoned	Total Footage Drilled
Union	15	13	0	2	113,052
Burmah	8	7	1	0	60,279
Republic Geothermal	4	3	1	0	36,045
Pacific Energy	3	1	0	2	31,991
Phillips	5	5	0	0	31,198
Shell	3	3	0	0	23,894
Magma	4	2	0	2	17,030
Chevron	(5)*	0	(5)*	0	(16,722)*
Ida. Nat. Eng. Lab	2	2	0	0	10,977
San Juan	1	0	0	1	7,510
Hawaii Geothermal Proj.	1	1(?)	0	0	6,445
TOTALS	46	37	2	7	338,421
	(51)		(7)		(355,143)

* Observation Holes

TABLE # 2. SUMMARY BY OPERATOR, 1975 GEOTHERMAL DRILLING, WESTERN U.S.

New Mex

HYDROLOGIC TESTING GEOTHERMAL TEST HOLE NO. 2

LASL

by

F. G. West, P. R. Kintzinger, and W. D. Purtymun

ABSTRACT

Analyses of drill-stem tests performed in Geothermal Test Hole No. 2 (GT-2) indicate that the jointed, but competent, rock tested can for geothermal project purposes be considered "dry." The intervals tested were selected by the use of geophysical logs so as to exclude occasional zones of intense fracturing.

I. INTRODUCTION

Geothermal exploratory hole GT-2 was drilled under contract to the Los Alamos Scientific Laboratory (LASL) as a part of the field evaluation of the "dry hot rock" concept. The geohydrologic data presented in this report were obtained from the crystalline basement rock section of the hole, specifically from a depth of 732 m (2404 ft) to the interim total depth of 1937 m (6356 ft). Data for the sedimentary section of the hole (0 to 732 m) and data derived during the drilling phase were given by Purtymun et al.[1]

The project hole is located on Fenton Hill 3.2 km (2 miles) northwest of La Cueva, Sandoval County, New Mexico. The site location is as follows: NE 1/4, Sec 13, T19N, R2E NMPM. The land surface elevation is 2648.7 m (8690 ft). The elevation of 2652 m (8701 ft) for the top of the drill-rig Kelly bushing will be used as the datum level for depths in the hole.

The project site is 3 km (2 miles) west of the ring fault zone which formed as a result of the collapse of the Valles Caldera. Faults associated with the Rio Grande rift valley are thought to be the locus of former volcanic activity.[2] One of these faults, the Jemez Springs fault zone, is some 5.1 km (3.2 miles) southeast of the site. The Jemez-Nacimiento Mountains area has been a structurally active area to varying degrees since Precambrian time. Evidence of structural activity after the last eruption of the Valles Caldera is seen along the Jemez Springs fault zone, the closest being the Virgin Canyon fault.[3] Some post-volcanism uplift may have taken place west of the Rio de Las Vacas in the Nacimiento Mountains. Fracture zones with unknown displacement were encountered in GT-2 as interpreted from drilling information and geophysical logs.

The hole penetrated some 137 m (449 ft) of volcanics, 238 m (780 ft) of Permian red beds, and 355 m (1165 ft) of Pennsylvanian-Mississippian shales and limestones before encountering granite at 732 m (2404 ft). The crystalline Precambrian rocks include granites, granodiorites, monzonites and some amphibolite. The textures have ranged from fine to coarse grained and the colors from pink to black. Appendix A contains a summary of drilling and geologic data by Pettitt.[4]

II. INFLUENCE OF FRACTURES ON HYDROLOGY

Knowledge of the hydrology of crystalline basement rocks has been limited for a combination of reasons. Most of the available knowledge is derived from mining operations with some small part coming from oil ventures. The relatively low permeability often found while mining in crystalline rocks has prompted the storage of oil and gas in old mines as well as in new excavations for this purpose.[5] However, when crystalline rocks are sufficiently fractured

Wyoming

Thermal Sprgs of Wyo.
Wyo Geol Surv Bull 60
1978

- Saratoga Hot Sprgs (17N, 84W, 13 bb) Carbon Co. — 2 Saratoga city pools, Saratoga Inn private pool, 3 small private pools-baths — 30°-54°C (avg. 48°) at flow rates of 120 gpm, ~~[illegible]~~ for city pool and 3-5 gpm for all others
- Douglas Warm Spring (31N, 71W, 8cd) Converse Co. — 30°C, 800 gpm — bathing (informal) and limited irrigation — oil wells in area commonly hit +30°C within 3000 ft of surface but no obvious heating mechanism
- Fort Washakie Hot Springs (1S, 1W, 2aad) Fremont Co. — 44°C, 150 gpm, natural pool, developed pool — bathouse — heat source probably natural gradient
- Little Warm Spring (41N, 107W, 14bbd) Fremont Co. — 25°C at 560 gpm — 1 private pool — possible volcanic heatsource 20 miles away

~~[illegible]~~

Thermopolis Co

- Van Norman Well (43N, 95W, 24cd) — 51°C at 25psi at depth of @500 ft. — heats 1 home + irrigation
- Maytag Well (43N, 95W, 24dc) — 54°C at 539 gpm to depth of 900 ft. — domestic + irrigation
- Sacajawea Well (43N, 95W, 25ab) — 52°C at 1220 gpm to depth of 900 ft. — large pool
- McCarthy Well (43N, 94W, 30cb) — 54°C at 583 gpm to 500 ft. — heat for 1 house
- ~~[illegible]~~
- Big Spring (43N, 94W, 31bc) Thermopolis Co — 56°C at 2908 gpm — several pools + bathhouse
- Auburn Hot Springs (33N, 119W, 23db) Lincoln Co — 62°C at 37 gpm — subsurface temps are up to 150°C or electrical generation potential — bath house
- De Maris Hot Springs (52N, 102W, 3bc) Park Co. — 27-36°C at @1700 gpm — pool
- Steele Hot Springs (32N, 107W, 16bbb) — Sublette Co. — 35.5°C at 20 gpm and 39°C at 5 gpm — pool
- Astoria springs (39N, 116W, 32daa) Teton Co — 37°C at +100 gpm — 2 large bathhouses + pool
- Granite Hot Spring (39N, 113W, 6dab) Teton Co — 41°C at 300 gpm — pool
- Huckleberry Hot Springs (48N, 115W, 20ba) Teton Co — 61°C at 300 gpm — possible subsurface temps of 150°C or commercial generating potential — pool + laundry
- Kelly Warm Springs (42N, 115W, 2baa) Teton Co. — 27°C at 16 cfs — natural pool
- Teton Valley Warm springs (42N, 115W, 11aa) Teton Co — 18°C at roughly 8000 gpm — natural pool + extensive irrigation
- Yellowstone Park area

Geothermal Resources Council, TRANSACTIONS, Vol. 2 July 1978

THE PAGOSA SPRINGS PROJECT--THE FIRST PERMITTED GEOTHERMAL WELLS IN IN COLORADO

RICHARD HOWARD PEARL, MICHAEL J. GALLOWAY, AND JAY D. DICK

Colorado Geological Survey
Denver, Colorado

ABSTRACT

The geothermal resources at two areas in Colorado-Pagosa Springs and Glenwood Springs-are being explored and developed for direct application uses.

At the first site, Pagosa Springs, any thermal waters developed will primarily be used to heat a new high school complex. Geological, hydrogeological, geophysical, and geothermometer studies were done in the region to fully delineate the reservoir. It was determined that the reservoir encompasses some 4 sq. kilometers and may have a temperature of 125°C.

Before drilling commences it was necessary to apply for permits from the Colorado Oil and Gas Conservation Commission, Water Quality Control Commission, and Air Quality Control Commission. All permits have been issued. To test the aquifer and to determine what legal hydrological conditions the thermal waters are occurring under, a 2-3 day aquifer test will be run.

Work done under U.S. Department of Energy, Division of Geothermal Energy contract No. EG-77-S-07-1678.

INTRODUCTION

With funding from the U.S. Department of Energy/Division of Geothermal Energy (DOE/DGE) the Colorado Geological Survey in 1977 initiated a two year exploration and development program leading to the development of the geothermal resources for direct application uses at two locations in Colorado. This paper discusses efforts to date and problems encountered. It was the intention of DOE/DGE for this to be an exploration and drilling project to bring the geothermal resources "on-line" as quickly as possible, therefore the project was designed to be a development project and not a paper study.

In 1973 the Colorado Legislature passed the Geothermal Resources Act which provides for the exploration, development, and production of geothermal resources in the State. This law required the Colorado Oil and Gas Conservation Commission to promulgate rules and regulations to govern the drilling of geothermal wells. The wells to be drilled during this project are the first wells permited under this law. As a result of this being the first geothermal project in Colorado the various state regulatory agencies are having to set new procedures or modify existing procedures for this development.

SITE SELECTION

The geothermal areas in Colorado which have potential for development were delineated by Barrett and Pearl (1978). Based on geochemical modeling of estimated reservoir temperatures Pagosa Springs and Glenwood Springs were selected for further exploration efforts to determine if the resources could be developed. Primarily due to local interest, Pagosa Springs was selected as the first site of investigation, and in the fall of 1977 geological and geophysical investigations started. Local officials plan that any thermal fluids developed will be used to heat a new high school complex, to be built on the south side of town, and/or for other purposes.

HYDROLOGY

Pagosa Springs is located in southwestern Colorado on the San Juan River, some 60 miles east of Durango. The town is named for the hot springs which are located along the south bank of the river across from the downtown section. The springs issue from Cretaceous Mancos Shale at a temperature of 54°C (Barrett and Pearl, 1976). The measured discharge of the spring is approximately 265 gpm(17 l/sec). The thermal waters are a sodium sulfate-bicarbonate type with 3200 mg/l total dissolved solids. Geothermometer analysis shows that the reservoir temperature ranges from 75°C to 125°C. Hydrogeological mapping by Galloway has determined that the area surrounding Pagosa Springs is a regional groundwater discharge area.

GEOLOGY AND GEOPHYSICS

Pagosa Springs is located on the eastern side of the San Juan drainage basin, which is bounded on the east and north by the San Juan Mountains. These mountains consist primarily of Tertiary volcanic flows and volcano-clastic rocks. The Archuleta anticlinorium, one of four major tectonic provinces in southwestern Colorado and northwestern New Mexico

(Ryder, 1977), is the dominant structural feature in the Pagosa Springs area. The anticlinorium, which forms a structural divide between the Chama Basin on the east and the San Juan Basin on the west continues southward to the Nacimiento uplift in New Mexico (Ryder, 1977).

Surface geological mapping of the Pagosa Springs area has been done by Dunn (1964), Hall (1971), Steven and others (1974), and Wood and others (1948). The major stratigraphic units in the area are the Mancos Shale and the Dakota Sandstone, both of upper Cretaceous age. Overlying the Precambrian basement may be up to 396 meters (1,300 feet) of Meszoic sediments. Numerous north, northwest trending faults are found throughout the region. The major fault, with up to 91 meters (300 feet) of displacement, is the northern extension of the Jacimiento fault of New Mexico. This feature is located approximately 2.4 km (1.5 miles) west of town.

To fully evaluate the geothermal reservoir, detailed geophysical surveys were conducted by personnel from Geophysics Fund, Inc. of the Colorado School Mines. They ran dipole-dipole and dipole-bipole resistivity, vibro-seis surveys and soil mercury analysis. Interperation of the data shows that a resistivity anomaly of 15-30 ohm-meters (background of 300-400 ohm-meters) surrounds the hot springs. Measured resistivity levels at the spring were higher than values mesured on either side of the spring. The resistivity surveys indicate that the geothermal reservoir encompasses an area of approximately 4 sq. km. (43,000 sq. feet). Located in and around the downtown section of Pagosa Springs are some 20 existing hot water wells. Based on interpretation of drillers logs and talking with the well owners it was determined that the existing wells are completed in the top of the Dakota Sandstone. Even though water from these wells is generally as hot as water from the spring, it is believed that the Dakota Sandstone is a secondary reservoir and that the primary reservoir lies at a greater depth. Since there are no indications of a definite heat source, it is assumed that deep circulation in an area of slightly enhanced geothermal grandient is the driving mechanism for this thermal area. Assuming a geothermal gradient of at least 30°C/km, a minimum circulation depth of 2-3 km (6,000-10,000 feet) would be required to produce 60°C-80°C water. This depth requires that most of the water circulation takes place in fractures of the Precambrian basement.

The results of the soil mercury surveys are inconclusive, but the possibility exists that an anomaly may occur south of the hot springs. There are no surface traces of faulting in the Pagosa Springs area but vibro-seis surveys indicate there may be several minor faults present in the subsurface.

In addition, 6 heat flow holes were drilled to more fully delineate the extent of the reservoir. Preliminary measurements indicatate that the gradients may range from 65°C/km to 130°C/km.

INSTITUTIONAL ISSUES

As required by the Geothermal Resources Act of 1973 application was made to the Colorado Oil and Gas Conservation Commission for permission to drill one exploration/production well and two observation wells at Pagosa Springs. The Act also requires that the Oil and Gas Conservation Commission submit the permit application to the Colorado Division of Water Resources for an assessment of the impact of the geothermal development on adjacent water resources. A public hearing was held before the Oil and Gas Conservation Commission on March 20, 1978, and the permit application approved.

Permit applications were also filed with the Water Quality Control Division and Air Quality Control Division of the Colorado Department of Health. Federal and State laws prohibit the addition of any substance to surface waters which might degrade their quality or raise their natural temperature by more than 1°C. To meet these requirements all produced fluids will be cooled prior to disposal in the San Juan River. The permit applications were filed in January, 1978 and approved in late March, 1978.

FUTURE PLANS

At the time this paper was submitted all permit applications had been approved. Bids from drilling contractors have been received and were awaiting financial review prior to issuing drilling contracts.

Due to economic considerations it is desirable that the exploration/production test well be drilled as near the proposed school site as possible. Since no land was leased for this project by local officals drilling is limited to available municipal, county, or school district property. There are two projected drill sites at the proposed school complex and one near existing hot water wells in the downtown section. The new school site is located on the fringe of the resistivity anomaly and the downtown site is over 1200 meters (.75 miles) from the proposed school site. While this is a potential problem it is not felt to be serious.

An exploration/pumping well will be drilled during the spring of 1978 to a maximum depth of 2,000 feet. Straddle packer and/or drill stem tests will be performed prior to setting the casing. A 2-3 day aquifer test will be run after the well is completed. At the present time it is planned that two observation wells, 400 and 2,000 feet deep, will also be drilled. These wells will be used during the aquifer test.

After completion of drilling and testing, the well will be turned over to either Archuleta County, the City of Pagosa Springs, or the School District for use in the Pagosa Springs area. School District officials intend to use the water to heat a proposed high school. Other uses will depend on temperature and volume of water encountered in the drilling program.

PROBLEMS

One of the major problems encountered is in attaining, in a timely manner the necessary permits. This is a combination of bureaucratic delay and the fact that this is a new permitting process for the State. The proposed well is neither a groundwater well nor a high temperature geothermal production well and therefore does not fit intc any single category.

Another problem, which could potentially have been much worse, is the availability of land. Because of ownership the drilling site is restrictec to two pieces of land, one at the proposed school site and the other in the county courthouse parkinc lot, 200 meters north of the spring.

Escalating drilling costs is the third major problem encountered. Bids received for the drillinc and completion of the three wells ranged from a low of $152,000 to a high of $500,000. Because of inflation and the high number of coal and uraniun exploration projects in the Colorado- Wyoming area, drill rigs of the required depth capacity are scarce and very expensive. The high costs may require trimming the program to the bare essentials.

CONCLUSION

It is anticipated that by carrying this projec through to completion that several important developments will have resulted. They are: 1, The respective state agencies will have become aware of some of the problems in regulating the development of geothermal resources; 2, Private companies and individuals will become aware of the time delays in getting the necessary permits; 3, Potential developers of low-temperature geothermal resources will become cognizant of the fact that many times the factor governing the location of the geothermal well is not the location of the resource but the land situation, especially where the resource is located either in or close to a community; and 4, A geothermal resource will be developed and put to beneficial direct application uses in a region where the natural energy supplies are declining.

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WYO.

Thermal Springs
of Wyoming
Wyo. Geol. Surv. Bull 60
Breckenridge + Hinckley
1978

For all these springs Montagne (1955) reports that the flow is stable all year.

At the surface the springs flow from the Miocene North Park Formation and overlying alluvium. However, chemical analyses (see below) indicate an origin in lower formations. The springs are aligned along a N.51E. trend, strongly suggesting structural control. Montagne (1955) has mapped a covered fault through the springs apparently based on this lineation. The extent and displacement of the assumed fault are both unknown because of the thicknesses of younger sediments and sparse subsurface information. Visher (1952), cites several examples of fault-controlled springs in the area (none hot) and notes flows up to 1300 gpm from such springs in the North Park Formation.

As diagrammed by Montagne, Paleozoic and Mesozoic sections thicken rapidly toward the north and east beneath the Miocene cover. Well records indicate that only 840 feet of sediments cover the granites beneath sec.24, T.16N., R.84W., eight miles south of the springs. But in sec.1, T.17N., R.84W., adjacent to the springs, it is 2740 feet just to the top of the Paleozoic section. Records further northwest demonstrate a continually thickening section.

Decker (1976) infers that the "normal" geothermal gradient is about .76° C/100 feet. If such a gradient were extended downward, a depth of some 7000 feet would be required to produce the maximum observed temperature of the Saratoga system. If we assume as a possible model the confinement of waters to the Paleozoic section, the required depth is readily attainable. In the Pass Creek Flats area north of Saratoga, the Paleozoic section is buried nearly 10,300 feet (using formational thicknesses from Visher, 1952). Given recharge of the section through outcrops along the northern Medicine Bow Mountains, water would escape from beneath the Mesozoic section where it thins and is faulted as at Saratoga. Such a model is admittedly based on several assumptions which cannot be proven now, but does present both hydrologic and geothermal conditions adequate to produce the Saratoga Hot Springs.

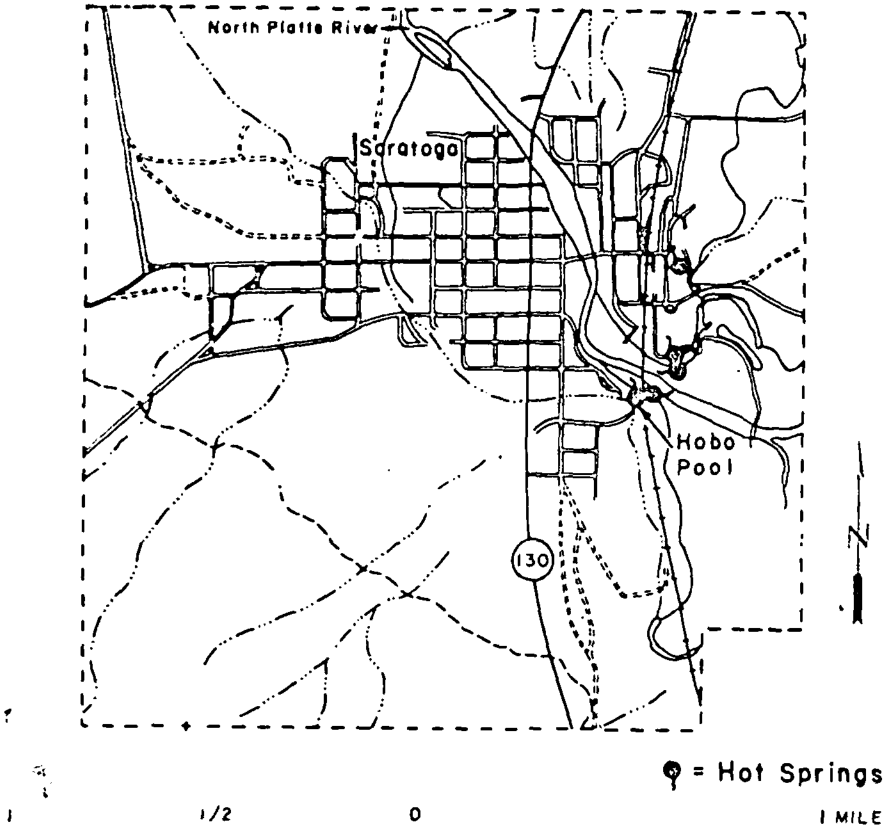

Figure 5. Hot springs at Saratoga

Table 2. Chemical analyses for Saratoga Hot Springs

(four analyses from Hobo Pool)

Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3	F	S	SiO_2	B
117	8.0	513	21.5	74.4		443	536				125	
123	6.3	321	60.2	20.1		470	535				63.7	
140	11	450	23	24	130	570	540	0	6.1	.075	63	1.7
125	9.0	453	29	0	77	568	511	6.5	6.5		62	1.1

TDS	Cond	pH	Na%	Hard	Tot CO_2	Date	Reference
1842							Knight, 1900
1702							Bartlett, 1926
1920	12900	8.9	70	380	87	7/20/76	State Lab No. 7-0285
1830		7.3		349		9/16/67	State Lab No. 1-68-49

Trace Element Analyses

As	Cu	Fe	Mn	Zn	Ba	Cd	Cr	Pb	Se	Ag	Hg	Ni
.05	.01	.05	<.05	<.02	<.5	<.01	<.1	<.1	<.001	<.5	<.001	<.01

Date	Reference
8/6/76	State Lab No. 7-1573

See Notes on the Chemical Analyses, page viii, for explanation of reported values.

Other springs issuing from the North Park Formation (Visher, 1952) show significant chemical differences from the Saratoga waters. Visher characterizes North Park waters as either calcium bicarbonate type, or, less commonly, calcium sulfate type. The Saratoga waters, however, are predominantly sodium sulphate and chloride types. North of Saratoga, water analyses of springs show a correlation with the Tensleep-Madison section. Montagne (1955) interprets rocks underlying Saratoga as consisting of Miocene sediments directly overlying Mesozoic and Paleozoic rocks. Chemical data from southeast Wyoming as a whole (U.S. Geological Survey, 1971) seem to preclude the Miocene section as a water source; but the Saratoga waters do not show exclusive affinity for any one of the lower formations. Geologic evidence of fault control seems to indicate that mixing of formational waters has occurred.

Converse County

DOUGLAS WARM SPRING

Location: Sec. 8cd, T.31N., R.71W.
Elevation: 4760 feet
Quadrangle: Chalk Buttes
Ownership: Private—Bill Weiss, Douglas, owner

Access: Seven miles south of Douglas on Esterbrook Road
Temperature: 30° C (7/29/76)
Flow: 800 gpm (Weiss, 1976)
Chemistry: One analysis, page 17

Thermal Springs of Wyoming

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Table 9. Chemical analyses for Hot Springs County

Spring	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3	F
Sacajawea Well	396	76	227	46	0	741	819	300	.1	
	340	79	270	40	0	760	840	300	0	5.4
McCarthy Well	350	76	270	40	0	760	830	300	0	4.4
"Bathtub Spring"	340	73	270	44	0	730	780	330	0	4.2
White Sulphur	383	80	253	45		784	773	308	.10	3.8
Spring	340	77	270	42	0	750	820	300	0	8.1
Black Sulphur Spg.	385	75	266	49		740	777	334	.10	3.8
Big Spring	315	113	83	91			556	84		
	315	113	258	91			556	355		
	385	76	262	49		766	769	328	.10	3.7
	380	67	280	53	0	740	777	314	0	3.0
	360	86	250	51	0	708	774	294	0	5.5
	310	71	250	37	0	710	730	300	0	6.8
Wind River Canyon Spring	146	50	41	7.4	0	377	276	39	.3	1.2
	140	49	40	6.7	0	390	290	38	0	1.3

Spring	S	SiO_2	B	Fe	TDS	Cond	pH	Na%	Hard
Sacajawea Well			.37			3170	6.6	27	
	<.001	35	.45	0	2390	3140	7.0	32	1200
McCarthy Well	<.001	36	.41		2380	3120	7.1	32	1200
"Bathtub Spring"	.001	39	.49		2330	3090	7.1	33	1100
White Sulphur		37		.05	2321	3090			1286
Spring	<.001	37	.45		2350	2990	7.0	32	1200
Black Sulphur Spg.		71		.05	2378	2990			1262
Big Spring		40		(2.45)*					
		40		(2.45)*					
		38		.08	2373				1274
		40		.06	2280	3150	6.4		1220
		35	.61	.04	2200	2860	7.0		1250
	.006	37	.54	0	2190	2960	6.9	33	1100
Wind River Canyon Spring		13	.12	.09	759	1150	8.0		570
	<.001	12	.10		800	1160	7.5	13	560

Spring	Tot CO_2	H_2S	Date	Reference
Sacajawea Well			4/21/69	State Lab No. 908058
	370		9/2/76	State Lab No. 7-1797
McCarthy Well	370		9/3/76	State Lab No. 7-1800
"Bathtub Spring"	360		9/3/76	State Lab No. 7-1801
White Sulphur		2.3	6/12/33	Lohr, 1940
Spring	370		9/2/76	State Lab No. 7-1799
Black Sulphur Spg.		1.4	6/12/33	Lohr, 1940
Big Spring	443			Darton, 1906
	443			Bartlett, 1926
		4.5	6/12/33	Lohr, 1940
			4/11/58	Lowry and Lines, 1972
			2/24/71	Lowry and Lines, 1972
	350		9/2/76	State Lab No. 7-1796
Wind River Canyon Spring			7/7/70	Lowry and Lines, 1972
	190		9/1/76	State Lab No. 7-1798

Trace Element Analyses (mg/l)

	As	Cu	Mn	Zn	Ba	Cd	Cr	Pb	Se	Ag
Sacajawea Well	<.05	<.01	<.05	<.02	<.5	<.01	<.1	<.1	<.001	<.5
Big Spring	<.05	<.01	<.05	<.02	<.5	<.01	<.1	<.1	<.001	<.5

	Hg	Ni	Date	Reference
Sacajawea Well	<.001	<.1	9/2/76	State Lab No. 7-1797
Big Spring	.001	<.1	9/2/76	No. 7-1796

See Notes on the Chemical Analyses, page viii, for explanation of reported values.

WYO

Thermal Sprgs of Wyo
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Table 18. Chemical analyses for Teton County

Spring	Temp	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3
Huckleberry	45	9.5	.7	200	8.6	0	380	11	120	.1
	61	11	.4	200	8.6		360	9.9	92	0
	61	14	2	197	14	0	375	14	101	
	71	12	1.1	201	7.8		372	12	102	.1
Teton Valley	18	49	16	7.0	1.6	0	180	62	2.0	.5
Kelly	27	54	18	7.6	3.0	0	180	78	3.1	.3
Abercrombie	27	35	17	7.6	2.6	0	190	20	2.9	1.9
Boyles Hill	30	430	120	28	13	0	160	1600	3.9	0
Astoria	37	170	43	120	13	0	300	520	97	0
Granite	41	32	6.4	180	8.8	0	200	150	140	.5
	39	32	5.8	160	8.6		182	120	130	.2

Spring	F	S	SiO_2	B	TDS	Cond	pH	Na%	Hard
Huckleberry	9.9	<.001	170	.74	688	950	7.8	92	27
	8.7		110	.46	613	950	7.4		30
			118		837				
	10		124				7.1		
Teton Valley	.6	<.001	11	.07	248	403	8.2	7.5	190
Kelly	.9	<.001	18	.05	284	450	8.2	7.2	210
Abercrombie	.6	<.001	14	.10	192	348	8.3	9.5	150
Boyles Hill	.5	6.0	26	.06	2480	2380	7.6	3.7	1600
Astoria	.4	.04	26	.17	1160	1550	7.8	29	590
Granite	6.0	<.001	49	.61	670	1050	8.3	77	110
	5.3		48	.53	597	1050	8.0		100

Spring	Tot CO_2	Date	Reference
Huckleberry	190	9/21/76	State Lab No. 7-2615
		10/2/73	Cox, 1976
			Allen & Day, 1935
			White, 1972
Teton Valley	88	9/23/76	State Lab No. 7-2442
Kelly	90	9/21/76	State Lab No. 7-2445
Abercrombie	93	9/23/76	State Lab No. 7-2564
Boyles Hill	76	9/23/76	State Lab No. 7-2446
Astoria	150	9/22/76	State Lab No. 7-2614
Granite	96	9/22/76	State Lab No. 7-2568
		7/27/73	Cox, 1976

Trace Element Analyses (mg/l)

	As	Cu	Fe	Mn	Zn	Ba	Cd	Cr	Pb	Se
Huckleberry	.10	<.01	0	.06	<.02	<.5	<.01	<.1	<.1	<.001
Abercrombie	<.05	<.01	0	<.05	<.02	<.5	<.01	<.1	<.1	.002
Astoria	<.05	<.01	0	<.05	.33	<.5	<.01	<.1	<.1	<.001
Granite	<.05	<.01	0	<.05	<.02	<.5	<.01	<.1	<.1	<.001

	Ag	Hg	Ni	Date	Reference
Huckleberry	<.5	.029	<.1	9/21/76	State Lab No. 7-2615
Abercrombie	<.5	<.001	<.1	9/23/76	State Lab No. 7-2564
Astoria	<.5	<.001	<.1	9/22/76	State Lab No. 7-2614
Granite	<.5	<.001	<.1	9/22/76	State Lab No. 7-2568

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Carbon

WYO.

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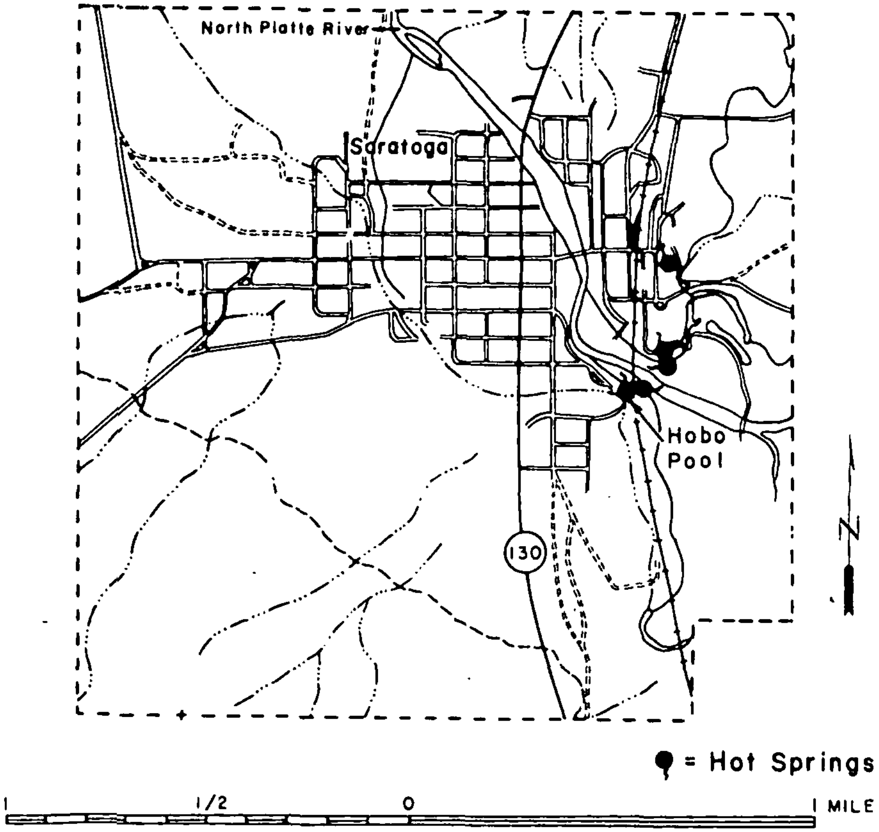

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Trace Element Analyses

As	Cu	Fe	Mn	Zn	Ba	Cd	Cr	Pb	Se	Ag	Hg	Ni
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Date	Reference
8/6/76	State Lab No. 7-1573

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Thermal Springs of Wyoming

Wyo Geol Surv Bull 60 — 1978

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	360	86	250	51	0	708	774	294	0	5.5
	310	71	250	37	0	710	730	300	0	6.8
Wind River										
Canyon Spring	146	50	41	7.4	0	377	276	39	.3	1.2
	140	49	40	6.7	0	390	290	38	0	1.3

Spring	S	SiO_2	B	Fe	TDS	Cond	pH	Na%	Hard
Sacajawea Well			.37			3170	6.6	27	
	<.001	35	.45	0	2390	3140	7.0	32	1200
McCarthy Well	<.001	36	.41		2380	3120	7.1	32	1200
"Bathtub Spring"	.001	39	.49		2330	3090	7.1	33	1100
White Sulphur		37		.05	2321	3090			1286
Spring	<.001	37	.45		2350	2990	7.0	32	1200
Black Sulphur Spg.		71		.05	2378	2990			1262
Big Spring		40		(2.45)*					
		40		(2.45)*					
		38		.08	2373				1274
		40		.06	2280	3150	6.4		1220
		35	.61	.04	2200	2860	7.0		1250
	.006	37	.54	0	2190	2960	6.9	33	1100
Wind River									
Canyon Spring		13	.12	.09	759	1150	8.0		570
	<.001	12	.10		800	1160	7.5	13	560

Spring	Tot CO_2	H_2S	Date	Reference
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		4.5	6/12/33	Lohr, 1940
			4/11/58	Lowry and Lines, 1972
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	350		9/2/76	State Lab No. 7-1796
Wind River				
Canyon Spring			7/7/70	Lowry and Lines, 1972
	190		9/1/76	State Lab No. 7-1798

Trace Element Analyses (mg/l)

	As	Cu	Mn	Zn	Ba	Cd	Cr	Pb	Se	Ag
Sacajawea Well	<.05	<.01	<.05	<.02	<.5	<.01	<.1	<.1	<.001	<.5
Big Spring	<.05	<.01	<.05	<.02	<.5	<.01	<.1	<.1	<.001	<.5

	Hg	Ni	Date	Reference
Sacajawea Well	<.001	<.1	9/2/76	State Lab No. 7-1797
Big Spring	.001	<.1	9/2/76	No. 7-1796

See Notes on the Chemical Analyses, page viii, for explanation of reported values.

WYO

Thermal Sprgs of Wyo
Wyo Geol Surv Bull 60

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Spring	Temp	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3
Huckleberry	45	9.5	.7	200	8.6	0	380	11	120	.1
	61	11	.4	200	8.6		360	9.9	92	0
	61	14	2	197	14	0	375	14	101	
	71	12	1.1	201	7.8		372	12	102	.1
Teton Valley	18	49	16	7.0	1.6	0	180	62	2.0	.5
Kelly	27	54	18	7.6	3.0	0	180	78	3.1	.3
Abercrombie	27	35	17	7.6	2.6	0	190	20	2.9	1.9
Boyles Hill	30	430	120	28	13	0	160	1600	3.9	0
Astoria	37	170	43	120	13	0	300	520	97	0
Granite	41	32	6.4	180	8.8	0	200	150	140	.5
	39	32	5.8	160	8.6		182	120	130	.2

Spring	F	S	SiO_2	B	TDS	Cond	pH	Na%	Hard
Huckleberry	9.9	<.001	170	.74	688	950	7.8	92	27
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	10		124				7.1		
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Boyles Hill	.5	6.0	26	.06	2480	2380	7.6	3.7	1600
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Granite	6.0	<.001	49	.61	670	1050	8.3	77	110
	5.3		48	.53	597	1050	8.0		100

Spring	Tot CO_3	Date	Reference
Huckleberry	190	9/21/76	State Lab No. 7-2615
		10/2/73	Cox, 1976
			Allen & Day, 1935
			White, 1972
Teton Valley	88	9/23/76	State Lab No. 7-2442
Kelly	90	9/21/76	State Lab No. 7-2445
Abercrombie	93	9/23/76	State Lab No. 7-2564
Boyles Hill	76	9/23/76	State Lab No. 7-2446
Astoria	150	9/22/76	State Lab No. 7-2614
Granite	96	9/22/76	State Lab No. 7-2568
		7/27/73	Cox, 1976

Trace Element Analyses (mg/l)

	As	Cu	Fe	Mn	Zn	Ba	Cd	Cr	Pb	Se
Huckleberry	.10	<.01	0	.06	<.02	<.5	<.01	<.1	<.1	<.001
Abercrombie	<.05	<.01	0	<.05	<.02	<.5	<.01	<.1	<.1	.002
Astoria	<.05	<.01	0	<.05	.33	<.5	<.01	<.1	<.1	<.001
Granite	<.05	<.01	0	<.05	<.02	<.5	<.01	<.1	<.1	<.001

	Ag	Hg	Ni	Date	Reference
Huckleberry	<.5	.029	<.1	9/21/76	State Lab No. 7-2615
Abercrombie	<.5	<.001	<.1	9/23/76	State Lab No. 7-2564
Astoria	<.5	<.001	<.1	9/22/76	State Lab No. 7-2614
Granite	<.5	<.001	<.1	9/22/76	State Lab No. 7-2568

See Notes on the Chemical Analyses, page viii, for explanation of reported values.

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THE PAGOSA SPRINGS PROJECT--THE FIRST PERMITTED GEOTHERMAL WELLS IN IN COLORADO

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ABSTRACT

The geothermal resources at two areas in Colorado-Pagosa Springs and Glenwood Springs-are being explored and developed for direct application uses.

At the first site, Pagosa Springs, any thermal waters developed will primarily be used to heat a new high school complex. Geological, hydrogeological, geophysical, and geothermometer studies were done in the region to fully delineate the reservoir. It was determined that the reservoir encompasses some 4 sq. kilometers and may have a temperature of 125°C.

Before drilling commences it was necessary to apply for permits from the Colorado Oil and Gas Conservation Commission, Water Quality Control Commission, and Air Quality Control Commission. All permits have been issued. To test the aquifer and to determine what legal hydrological conditions the thermal waters are occurring under, a 2-3 day aquifer test will be run.

Work done under U.S. Department of Energy, Division of Geothermal Energy contract No. EG-77-S-07-1678.

INTRODUCTION

With funding from the U.S. Department of Energy/Division of Geothermal Energy (DOE/DGE) the Colorado Geological Survey in 1977 initiated a two year exploration and development program leading to the development of the geothermal resources for direct application uses at two locations in Colorado. This paper discusses efforts to date and problems encountered. It was the intention of DOE/DGE for this to be an exploration and drilling project to bring the geothermal resources "on-line" as quickly as possible, therefore the project was designed to be a development project and not a paper study.

In 1973 the Colorado Legislature passed the Geothermal Resources Act which provides for the exploration, development, and production of geothermal resources in the State. This law required the Colorado Oil and Gas Conservation Commission to promulgate rules and regulations to govern the drilling of geothermal wells. The wells to be drilled during this project are the first wells permited under this law. As a result of this being the first geothermal project in Colorado the various state regulatory agencies are having to set new procedures or modify existing procedures for this development.

SITE SELECTION

The geothermal areas in Colorado which have potential for development were delineated by Barrett and Pearl (1978). Based on geochemical modeling of estimated reservoir temperatures Pagosa Springs and Glenwood Springs were selected for further exploration efforts to determine if the resources could be developed. Primarily due to local interest, Pagosa Springs was selected as the first site of investigation, and in the fall of 1977 geological and geophysical investigations started. Local officials plan that any thermal fluids developed will be used to heat a new high school complex, to be built on the south side of town, and/or for other purposes.

HYDROLOGY

Pagosa Springs is located in southwestern Colorado on the San Juan River, some 60 miles east of Durango. The town is named for the hot springs which are located along the south bank of the river across from the downtown section. The springs issue from Cretaceous Mancos Shale at a temperature of 54°C (Barrett and Pearl, 1976). The measured discharge of the spring is approximately 265 gpm(17 l/sec). The thermal waters are a sodium sulfate-bicarbonate type with 3200 mg/l total dissolved solids. Geothermometer analysis shows that the reservoir temperature ranges from 75°C to 125°C. Hydrogeological mapping by Galloway has determined that the area surrounding Pagosa Springs is a regional groundwater discharge area.

GEOLOGY AND GEOPHYSICS

Pagosa Springs is located on the eastern side of the San Juan drainage basin, which is bounded on the east and north by the San Juan Mountains. These mountains consist primarily of Tertiary volcanic flows and volcano-clastic rocks. The Archuleta anticlinorium, one of four major tectonic provinces in southwestern Colorado and northwestern New Mexico

(Ryder, 1977), is the dominant structural feature in the Pagosa Springs area. The anticlinorium, which forms a structural divide between the Chama Basin on the east and the San Juan Basin on the west continues southward to the Nacimiento uplift in New Mexico (Ryder, 1977).

Surface geological mapping of the Pagosa Springs area has been done by Dunn (1964), Hail (1971), Steven and others (1974), and Wood and others (1948). The major stratigraphic units in the area are the Mancos Shale and the Dakota Sandstone, both of upper Cretaceous age. Overlying the Precambrian basement may be up to 396 meters (1,300 feet) of Meszoic sediments. Numerous north, northwest trending faults are found throughout the region. The major fault, with up to 91 meters (300 feet) of displacement, is the northern extension of the Jacimiento fault of New Mexico. This feature is located approximately 2.4 km (1.5 miles) west of town.

To fully evaluate the geothermal reservoir, detailed geophysical surveys were conducted by personnel from Geophysics Fund, Inc. of the Colorado School Mines. They ran dipole-dipole and dipole-bipole resistivity, vibro-seis surveys and soil mercury analysis. Interperation of the data shows that a resistivity anomaly of 15-30 ohm-meters (background of 300-400 ohm-meters) surrounds the hot springs. Measured resistivity levels at the spring were higher than values mesured on either side of the spring. The resistivity surveys indicate that the geothermal reservoir encompasses an area of approximately 4 sq. km. (43,000 sq. feet). Located in and around the downtown section of Pagosa Springs are some 20 existing hot water wells. Based on interpretation of drillers logs and talking with the well owners it was determined that the existing wells are completed in the top of the Dakota Sandstone. Even though water from these wells is generally as hot as water from the spring, it is believed that the Dakota Sandstone is a secondary reservoir and that the primary reservoir lies at a greater depth. Since there are no indications of a definite heat source, it is assumed that deep circulation in an area of slightly enhanced geothermal grandient is the driving mechanism for this thermal area. Assuming a geothermal gradient of at least 30°C/km, a minimum circulation depth of 2-3 km (6,000-10,000 feet) would be required to produce 60°C-80°C water. This depth requires that most of the water circulation takes place in fractures of the Precambrian basement.

The results of the soil mercury surveys are inconclusive, but the possibility exists that an anomaly may occur south of the hot springs. There are no surface traces of faulting in the Pagosa Springs area but vibro-seis surveys indicate there may be several minor faults present in the subsurface.

In addition, 6 heat flow holes were drilled to more fully delineate the extent of the reservoir. Preliminary measurements indicatate that the gradients may range from 65°C/km to 130°C/km.

INSTITUTIONAL ISSUES

As required by the Geothermal Resources Act of 1973 application was made to the Colorado Oil and Gas Conservation Commission for permission to drill one exploration/production well and two observation wells at Pagosa Springs. The Act also requires that the Oil and Gas Conservation Commission submit the permit application to the Colorado Division of Water Resources for an assessment of the impact of the geothermal development on adjacent water resources. A public hearing was held before the Oil and Gas Conservation Commission on March 20, 1978, and the permit application approved.

Permit applications were also filed with the Water Quality Control Division and Air Quality Control Division of the Colorado Department of Health. Federal and State laws prohibit the addition of any substance to surface waters which might degrade their quality or raise their natural temperature by more than 1°C. To meet these requirements all produced fluids will be cooled prior to disposal in the San Juan River. The permit applications were filed in January, 1978 and approved in late March, 1978.

FUTURE PLANS

At the time this paper was submitted all permit applications had been approved. Bids from drilling contractors have been received and were awaiting financial review prior to issuing drilling contracts.

Due to economic considerations it is desirable that the exploration/production test well be drilled as near the proposed school site as possible. Since no land was leased for this project by local officals drilling is limited to available municipal, county, or school district property. There are two projected drill sites at the proposed school complex and one near existing hot water wells in the downtown section. The new school site is located on the fringe of the resistivity anomaly and the downtown site is over 1200 meters (.75 miles) from the proposed school site. While this is a potential problem it is not felt to be serious.

An exploration/pumping well will be drilled during the spring of 1978 to a maximum depth of 2,000 feet. Straddle packer and/or drill stem tests will be performed prior to setting the casing. A 2-3 day aquifer test will be run after the well is completed. At the present time it is planned that two observation wells, 400 and 2,000 feet deep, will also be drilled. These wells will be used during the aquifer test.

After completion of drilling and testing, the well will be turned over to either Archuleta County, the City of Pagosa Springs, or the School District for use in the Pagosa Springs area. School District officials intend to use the water to heat a proposed high school. Other uses will depend on temperature and volume of water encountered in the drilling program.

PROBLEMS

One of the major problems encountered is in attaining, in a timely manner the necessary permits. This is a combination of bureaucratic delay and the fact that this is a new permitting process for the State. The proposed well is neither a groundwater well nor a high temperature geothermal production well and therefore does not fit into any single category.

Another problem, which could potentially have been much worse, is the availability of land. Because of ownership the drilling site is restricted to two pieces of land, one at the proposed school site and the other in the county courthouse parking lot, 200 meters north of the spring.

Escalating drilling costs is the third major problem encountered. Bids received for the drilling and completion of the three wells ranged from a low of $152,000 to a high of $500,000. Because of inflation and the high number of coal and uranium exploration projects in the Colorado- Wyoming area, drill rigs of the required depth capacity are scarce and very expensive. The high costs may require trimming the program to the bare essentials.

CONCLUSION

It is anticipated that by carrying this project through to completion that several important developments will have resulted. They are: 1, The respective state agencies will have become aware of some of the problems in regulating the development of geothermal resources; 2, Private companies and individuals will become aware of the time delays in getting the necessary permits; 3, Potential developers of low-temperature geothermal resources will become cognizant of the fact that many times the factor governing the location of the geothermal well is not the location of the resource but the land situation, especially where the resource is located either in or close to a community; and 4, A geothermal resource will be developed and put to beneficial direct application uses in a region where the natural energy supplies are declining.

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Colo Geol Surv Bull 39
1975

Colo.

TABLE 4

ESTIMATED RESERVOIR TEMPERATURES (°C) AND GEOCHEMICAL DATA

(Geochemical data from Barrett and Pearl, 1976)

Geothermometer Models
q = quartz
c = chalcedony
a = amorphous
cr = cristobalite

Hot Spring	Spring Number	Date Sampled	Silica G.T.	Mixing Model T.	Mixing Model %	Na-K G.T.	Na-K-Ca G.T.	Most Likely Sub. Temp.	Discharge gpm.	T.D.S. mg/l	pH	Si mg/l	Na mg/l	K mg/l	Ca mg/l	Mg mg/l	B ug/l
Antelope W.S	44	8/75						35-52	3E	151	--	41	44	0.1	4	0.3	130
		10/75	41	49	36 cr	83	35		3E	150	8.9	39	43	0.3	1.7	0.6	130
Birdsie W.S.	45	8/76	52 cr	91	70 cr	102	36	35-52	15	168	8.6	50	42	0.5	4.0	0.1	140
Brands Ranch	5	7/76	42 c	43	1 c	199	171	42-55	80E	262	6.0	26	78	7.5	10	2.6	50
Brown's Grotto W.S.	22	6/76	49 cr	129	87 cr	123	89	50--100	3E	494	8.0	47	160	3.3	7.6	0.1	80
Canon City H.S.	26	9/75	35 c	40	3 c	187	70	--	5	1,230	6.3	22	190	15	190	62	190
		1/76	34 c	38	12 c	187	68		1	1,220	6.2	21	180	16	190	55	200
		4/76	34 c	38	12 c	188	72		2	1,210	6.1	21	190	15	170	61	200
Cebolla Hot Springs																	
Spring "A"	47	7/75	71 cr	125	72 cr	278	216	--	--	1,450	--	74	310	63	120	50	1,100
		10/75	65 cr	105	66 cr	248	215		3	1,440	6.8	66	310	64	120	50	1,100
		1/76	78 cr	163	80 cr	238	209		3	1,470	6.9	85	330	58	120	0	1,100
		4/76	82 cr	185	83 cr	252	220		3	1,450	6.4	92	310	66	120	--	1,100
Spring "B"	47	7/75	73 cr	145	78 cr	249	217		--	1,460	--	77	310	64	120	50	1,100
Spring "C"	47	7/75	74 cr	143	76 cr	250	217	--	--	1,460	--	79	300	63	130	51	1,100
Cement Ck. W.S.	16	7/75	30 c	53	61 c	232	45	30-60	--	401	--	19	36	5.8	75	22	60
		10/75	25 c	27	0 c	225	48		80	389	7.2	17	41	6	69	18	60
		1/76	25 c	27	0 c	225	46		60	398	7.0	17	40	6	73	18	70
		4/76	28 c	29	6 c	238	49		60	382	7.2	18	36	6.4	68	20	80
Chalk Creek H.S. Area:																	
Mt. Princeton H.S. "A"	21	7/75	110 q	194	78 q	149	56	150-200	--	245	--	60	57	2.1	11	0.5	20
		10/75	108 q	190	77 q	148	58		18	248	8.6	58	58	2.1	10	0.2	20
		1/76	105 q	186	77 q	151	58		20	244	7.9	56	57	2.2	11	0.9	20
		4/76	127 q	236	81 q	150	59		23	248	7.8	59	58	2.2	10	0.8	20
Mt. Princeton H.S. F	21	7/75	107 q	201	81 q	150	51	150-200	12	229	--	57	50	1.9	12	0.5	10
Hortense H.S.	21	7/75	118 q	164	57 q	146	94	150-200	--	340	--	72	93	3.2	4.5	0.5	40
		10/75	116 q	156	54 q	144	93		18	336	8.5	68	94	3.1	4.4	0.1	50
		1/76	120 q	164	56 q	141	97		18	351	8.2	74	100	3.1	4.0	0	40
		4/76	129 q	186	61 q	145	93		17	341	8.2	88	94	3.2	4.7	0	40
Hortense Hot Water Well	21	7/75	118 q	164	56 q	144	80	150-200	--	318	--	72	84	2.8	6.4	1	30

TABLE 4 (Cont.)

Hot Spring	Spring Number	Date Sampled	Silica G.T.	Mixing Model T.	Mixing Model %	Na-K G.T.	Na-K-Ca G.T.	Most Likely Sub. Temp.	Discharge gpm.	T.D.S. mg/l	pH	Si mg/l	Na mg/l	K mg/l	Ca mg/l	Mg mg/l	B ug/l
Chalk Creek Area Cont.																	
Woolmington Hot Water Well	21	8/75	--	---	--	156	47	150-200	--	143	--	1	40	1.7	11	0.6	20
Wright Hot Well(E.)	21	8/75	103 q	152	62 q	148	62	150-200	--	234	--	53	61	2.1	8.3	0.3	20
Wright Hot Well(W.)	21	7/75	116 q	172	64 q	145	77	150-200	--	313	--	68	73	2.5	5.8	0.3	30
Young Life Hot Well	21	7/75	116 q	188	71 q	135	68	150-200	--	259	--	71	60	2.3	8.5	0.3	20
Clark Artesian Well	30	9/75	40 q	61	65 q	280	159	25-50	12	1,210	6.8	11	250	18	75	45	100
Colonel Chinn Hot Water Well	14	4/76	41 c	43	1 c	183	170	--	--		6.5	25	570	41	110	32	1,700
Conundrum H.S.	15	9/75	40 cr	41	6 cr	187	4	40-50	50	1,910	--	38	44	3.4	500	1.4	30
Cottonwood H.S. Area:																	
Cottonwood H.S.	20	6/75	110 q	174	70 q	132	84	150-200	10E	370	--	60	110	2.8	6.2	0.5	90
Jumpsteady H.S.	20	6/75	108 q	180	74 q	133	79	150-200	--	356	--	58	100	2.6	6.4	0.6	90
		10/75	105 q	174	74 q	131	85		90	364	6.0	54	110	2.7	5.6	0.3	90
		1/76	109 q	182	74 q	131	83		50	368	8.2	58	110	2.7	5.9	0.3	110
		4/76	--	---	--	135	83		50	302	8.5	13	100	2.7	5.8	0	80
Merrifield Hot Water Well	20	6/75	97 q	174	77 q	141	68	150-200	--	301	8.8	48	81	2.5	9.5	0.8	80
Craig Warm Water Well	2	1/76	58 q	70 35	50 q 20 c	100	104	40-70	24	896	8.2	1.9	360	4.1	5.8	0.9	210
Dexter W.S.	36	4/76	--	19	36 a	278	91	20-50	50E	--	7.9	--	--	--	--	--	--
Don K. Ranch Artesian Well	29	9/75	42 cr	63	61 cr	219	190	--	25	1,700	6.5	40	400	50	160	66	560
Dotsero W.S.	10	9/75	--	--	--	104	113	32-45	500E	--	--	--	3,500	44	230	62	210
		1/76	16 c	27	36 c	135	144		525E	10,400	7.2	13	3,500	95	260	79	210
		4/76	16 c	29	26 c	104	112		800E	9,940	7.0	13	3,500	44	240	65	220
S. Dotsero W.S.	10	12/75	16 c	29	26 c	102	109	32-45	1,000E	9,040	7.0	13	3,100	37	250	54	190
Dunton H.S.	51	9/75	54 c	69	40 c	329	50	50-70	26	1,260	--	34	35	19	330	45	90
		1/76	51 c	65	39 c	328	47		25	1,340	7.0	32	34	21	360	43	110
		4/76	53 c	69	43 c	342	52		25	1,300	6.4	33	34	21	340	45	90
Dutch Crowley Artesian Well	39	8/76	63 c	65	7 c	271	16	70-80	75E	--	7.0	--	--	--	--	--	---
Eldorado Springs																	
Spring "A"	8	9/75	23 c	27	8 c	314	43	26-40	--	101	6.9	16	6.9	3.2	15	4.8	20
Spring "B"	8	9/75	21 c	26	10 c	320	45	26-40	--	84	6.7	15	6.3	3.1	12	2.9	20
		2/76	21 c	26	19 c	254	57		--	91	6.6	15	7.3	3.3	11	3.3	10
		4/76	21 c	26	1 c	311	46		--	84	6.6	15	6.7	3.0	11	3.0	30

TABLE 4 (Cont.)

Hot Spring	Spring Number	Date Sampled	Silica G.T.	Mixing Model		Na-K G.T.	Na-K-Ca G.T.	Most Likely Sub. Temp.	Discharge gpm.	T.D.S. mg/l	pH	Si mg/l	Na mg/l	K mg/l	Ca mg/l	Mg mg/l	B ug/l
				T.	$												
Eoff Artesian Well	40	8/76	47 cr	59	38 cr	221	56	40-60	50E	---	7.0	--	--	--	--	--	--
Florence Artesian Well	28	9/75	34 c	41	40 c	212	178	34-50	130	1,480	6.3	21	270	32	180	78	160
Freemont Natatorium H.S.	27	9/75	23 c	32	23 c	172	72	35-50	20	1,370	6.9	16	220	13	150	70	90
		1/76	21 c	32	23 c	174	73		20	1,300	6.8	15	210	13	140	67	80
		4/76	21 c	32	23 c	171	71		18	1,330	6.7	15	210	12	140	67	90
Geyser W.S.	52	9/75	58 c	113	80 c	183	160	60-120	25-200E	1,620	--	37	400	29	170	40	120
Glenwood Springs Area:																	
Big Spring	11	7/75	51 c	59	18 c	133	148	--	2,263	20,200	6.3	32	6,900	180	510	91	890
Drinking Spring	11	7/75	51 c	59	18 c	133	147	--	--	20,300	6.3	32	7,000	180	510	90	910
		10/75	47 c	49	3 c	131	145		--	20,200	6.5	29	6,900	170	530	88	880
		1/76	48 c	51	0 c	168	186		161	20,500	6.4	30	7,000	380	500	82	920
		4/76	48 c	51	0 c	135	149		140	18,800	6.4	30	6,600	180	480	15	870
Vapor Caves, Men's H.S.	11	9/75	45 c	49	3 c	129	143	--	5E	18,000	6.7	28	6,300	150	440	40	870
Graves Spring	11	9/75	51 c	77	46 c	133	144	--	5	21,500	7.0	32	7,000	180	770	150	1,000
Spring "A"	11	7/75	48 c	73	46 c	134	149	--	2-3E	17,600	6.3	30	6,000	160	410	88	800
Spring "B"	11	7/75	48 c	51	0 c	135	149	--	75	18,300	6.5	30	6,300	170	450	86	760
		10/75	44 c	47	9 c	131	145		75	18,400	7.0	27	6,400	160	490	79	830
		1/76	45 c	49	6 c	133	165		100	17,700	6.7	28	6,500	190	49	76	840
		4/76	45 c	49	6 c	135	151		110	17,800	7.0	28	6,300	170	360	86	840
Spring "D"	11	7/75	48 c	51	2 c	133	147	--	74	18,000	6.4	30	89	160	450	82	810
Railroad Spring	11	1/76	47 c	49	6 c	143	158	--	75	18,400	7.1	29	6,100	200	460	80	850
		4/76	47 c	49	6 c	138	152		75	18,200	6.5	29	6,200	180	460	86	890
Hartsel Hot Springs Spring "A"	19	6/75	63 c	85	44 c	162	152	55-85	--	2,280	--	41	680	33	120	20	560
Spring "B"	19	6/75	59 c	73	33 c	163	152	55-85	--	2,140	--	38	650	32	120	20	550
		10/75	55 c	79	46 c	163	153		40	2,260	7.0	35	670	33	110	20	540
		1/76	56 c	83	51 c	161	152		48	2,310	6.6	36	710	34	120	19	510
		4/76	58 c	87	53 c	163	153		50	2,330	6.6	37	670	33	120	21	380
Haystack Butte Warm Water Well	7	9/75	47 c	57	53 c	52	62	50	4E	1,200	8.0	29	510	1.3	2.5	0.7	740
Hot Sulphur Springs Spring "A"	6	7/75	86 q	109	63 q	169	171	75-150	--	1,200	6.6	35	430	25	14	3.7	570
		10/75	81 q	97	59 q	166	166		12	1,210	7.1	31	440	23	15	3.6	560
		1/76	81 q	97	59 q	165	165		12	1,220	6.9	31	450	23	15	3.2	480
		4/76	84 q	103	64 q	169	168		13	1,160	6.9	33	420	23	15	3.9	560
Spring "B"	6	7/75	86 q	113	67 q	169	169	75-150	1	1,200	6.7	35	430	24	15	3.1	570
Spring "C"	6	7/75	86 q	115	69 qr	170	170	75-150	3	1,210	6.8	35	440	25	15	3.5	530
		10/75	81 q	99	64 q	165	164		15	1,190	7.1	31	430	22	15	3.2	560

TABLE 4 (Cont.)

Hot Spring	Spring Number	Date Sampled	Silica G.T.	Mixing Model T.	Mixing Model %	Na-K G.T.	Na-K-Ca G.T.	Most Likely Sub. Temp.	Discharge gpm.	T.D.S. mg/l	pH	Si mg/l	Na mg/l	K mg/l	Ca mg/l	Mg mg/l	B ug/l
Hot Sulphur Springs Cont.																	
Spring "D"	6	10/75	80 q	97	63 q	167	166	75-150	23	1,190	7.1	30	430	23	16	3.0	570
Idaho Hot Springs																	
Spring "A"	9	7/75	66 cr	109	64 cr	231	210	--	21	2,020	--	68	500	80	140	36	350
		10/75	59 cr	95	63 cr	231	210		--	2,110	6.9	58	530	84	150	40	360
		2/76	71 cr	141	76 cr	225	204		--	1,950	6.7	74	490	71	130	34	300
		4/76	78 cr	171	81 cr	228	207		--	1,940	6.9	60	500	76	130	36	470
Spring "B"	9	7/75	66 cr	--	--	230	210	--	--	2,070	--	68	520	82	130	50	370
Spring "C"	9	7/75	47 cr	--	--	235	206	--	1	1,070	--	45	260	44	77	23	170
Lodge Well	9	10/75	59 cr	81	48 cr	231	210	--	30	2,070	6.9	58	520	82	150	38	360
Juniper H.S.	1	7/75	53 c	81	59 c	75	80	50-75	13	1,150	7.8	33	460	2.3	3.7	0.8	540
		10/75	47 c	73	61 c	67	76		14	1,160	8.0	29	480	2.0	2.9	0.4	550
		1/76	50 c	73	55 c	70	78		13	1,160	8.2	31	470	2.2	3.9	0.3	480
		4/76	51 c	81	61 c	69	78		18	1,150	7.9	32	460	2.1	3.3	0.3	520
Lemon H.S.	50	9/75	15 a	29	17 a	210	198	--	8	2,760	--	95	730	84	140	11	2,600
		1/76	17 a	31	15 a	203	192		10	2,810	6.5	100	780	80	150	10	490
		4/76	14 a	29	25 a	207	195		10	2,740	6.2	94	760	84	150	11	2,500
McIntyre W.S.	37	4/76	--	15	33 a	333	50	20-50	5E	---	7.9	--	--	--	--	--	--
Mineral Hot Springs																	
Spring "A"	31	6/75	70 c	87	38 c	206	90	70-90	100	643	--	48	130	14	57	14	360
		10/75	67 c	79	30 c	202	90		167	663	6.5	45	140	14	60	13	350
		1/76	69 c	83	34 c	199	89		70	658	7.0	47	140	15	57	13	370
		4/76	69 c	83	34 c	202	90		95	639	6.8	47	140	14	59	13	450
Spring "C"	31	6/75	72 c	93	43 c	197	91	70-90	--	723	--	50	150	14	60	14	370
Spring "D"	31	6/75	70 c	89	41 c	202	92	70-90	--	665	--	48	140	14	55	13	370
		10/75	67 c	79	30 c	198	91		--	690	6.5	45	150	14	59	13	350
		1/76	68 c	81	32 c	195	87		5E	657	6.5	46	140	14	56	13	340
		4/76	69 c	83	34 c	202	90		--	648	7.3	47	140	14	58	13	400
Orvis H.S.	48	9/75	73 c	99	54 c	179	93	--	-1	2,270	--	51	420	28	260	19	1,000
		1/76	82 c	127	66 c	183	97		-1	2,490	6.5	60	460	33	290	18	990
		4/76	75 c	107	54 c	187	93		-1	2,270	6.6	53	390	30	280	19	1,000
Ouray Hot Springs																	
Wiesbaden Vapor Caves "A"	49	9/75	61 c	51	4 c	196	32	70-90	--	1,580	--	40	120	11	350	8	150
Wiesbaden Vapor Caves "B"	49	9/75	47 c	111	75 c	198	32	70-90	2E	695	--	29	53	5	150	8.3	60
Wiesbaden Vapor Caves "C"	49	9/75	60 c	99	56 c	299	28	70-90	1E	1,380	--	39	110	8.9	300	8.8	160
		1/76	60 c	161	83 c	190	41		30E	1,430	--	39	110	9.1	310	8.5	170
		4/76	60 c	93	51 c	192	43		5E	1,390	7.1	39	110	9.4	310	8.9	170
Pool H.S.	49	9/75	69 c	77	16 c	191	39	70-90	125	1,650	6.7	47	110	9.2	370	8.9	200
		1/76	71 c	79	15 c	184	39		60	1,660	6.5	49	120	8.8	360	8.5	200
		4/76	71 c	79	15 c	192	39		200	1,640	7.3	49	110	9.4	360	8.8	200

TABLE 4 (Cont.)

Hot Spring	Spring Number	Date Sampled	Silica G.T.	Mixing Model T.	Mixing Model %	Na-K G.T.	Na-K-Ca G.T.	Most Likely Sub. Temp.	Discharge gpm.	T.D.S. mg/l	pH	Si mg/l	Na mg/l	K mg/l	Ca mg/l	Mg mg/l	B ug/l
Ouray Hot Springs Cont.																	
Uncompahgre H.S.	49	4/76	66 c	109	58 c	192	40	70-90	5	1,570	7.7	44	110	9.4	350	9.2	200
Pagosa Spgs, Big Spg	41	8/75	76 c	113	54 c	209	194	80-150	265	3.200	6.5	54	790	90	230	25	1,800
		10/75	--	--	-	209	194		226	--	6.9	--	780	87	210	23	1,700
		1/76	80 c	133	64 c	207	191		241	3,310	6.6	58	800	87	240	2.6	2,000
		4/76	81 c	139	66 c	210	193		260	3,040	6.5	59	730	85	230	24	2,300
Courthouse hot water well	41	8/75	74 c	113	56 c	210	193	75-125	30	3,300	6.5	52	780	89	250	25	1,800
Spa Hot Water Well	41	8/75	73 c	117	60 c	211	195	75-125	--	3,320	6.5	51	780	91	230	24	1,900
Paradise Hot Spring	53	9/75	39 a	45	4 a	247	252	--	26	6,070	--	150	1,800	360	160	27	9,300
		1/76	56 a	53	7 a	247	248		34	6,530	6.9	200	1,900	380	240	30	1,000
		4/76	39 a	43	1 a	245	250		30	6,180	6.8	150	1,900	370	170	28	4,300
Penny Hot Springs	13	9/75	15 a	35	25 a	199	93	60-90	10	2,820	--	96	400	38	410	50	700
		1/76	3 a	35	48 a	197	89		10	2,820	6.3	74	390	36	420	51	640
		4/76	39 a	45	2 a	202	92		10	2,750	6.3	150	380	38	390	53	690
Granges Spring	13	1/76	7 a	41	50 a	198	90	60-90	12	2,960	9.2	81	400	38	440	55	650
Pinkerton H.S. Area:																	
Spring "A"	55	9/75	78 q	127	81 q	231	205	75-125	54	3,990	--	28	750	120	510	79	3,000
		1/76	78 q	127	81 q	231	202		54	3,880	6.5	28	690	110	560	69	2,800
		4/76	78 q	133	82 q	234	206		54	3,770	6.4	29	720	120	530	72	2,800
Spring "B"	55	9/75	--	--	--	234	206	75-125	20	----	--	--	720	120	530	71	3,000
Mound Spring	55	9/75	79 q	139	84 q	234	206	75-125	8E	3,940	--	29	730	120	550	74	3,000
		1/76	78 q	137	85 q	235	206		5E	3,880	6.5	28	710	120	550	68	3,000
		4/76	78 q	137	85 q	235	207		5E	3,840	6.4	28	710	120	550	72	2,900
Poncha Hot Springs																	
Spring "A"	23	6/75	126 q	173	63 q	155	99	115-145	--	667	--	81	190	8	20	0.7	80
		10/75	119 q	157	60 q	154	140		--	678	8.0	71	200	8.1	17	0.5	70
		1/76	137 q	201	69 q	154	141		--	697	7.7	100	200	8.3	17	0.2	80
		4/76	137 q	201	69 q	159	145		200	654	7.5	77	190	8.7	17	0.2	60
Spring "B"	23	6/75	127 q	183	68 q	154	139	115-145	30E	655	--	83	190	7.8	18	0.5	70
Spring "C"	23	6/75	126 q	185	70 q	157	96	115-145	2	670	--	81	190	8.3	24	0.8	80
		10/75	119 q	169	68 q	156	142		3	660	8.0	71	190	8.1	17	0.4	70
		1/76	130 q	195	72 q	154	141		2	685	7.5	88	200	8.3	17	0.3	60
		4/76	136 q	209	73 q	158	144		4	655	7.5	79	190	8.6	17	0.4	150
Rainbow Hot Spring	42	9/75	41 cr	41	0 cr	68	22	40-50	45	161	--	39	45	0.2	2.1	0.2	50
Ranger Warm Spring	17	7/75	32 c	67	71 c	214	56	30-60	132	461	--	20	59	7.2	73	22	80
		10/75	28 c	29	1 c	216	66		250E	465	7.1	18	61	7.7	70	20	80
		1/76	30 c	45	49 c	218	60		225E	466	6.9	19	62	8.1	72	20	80
		4/76	30 c	45	49 c	217	60		175E	474	7.1	19	63	8.2	71	23	80

TABLE 4 (Cont.)

Hot Spring	Spring Number	Date Sampled	Silica G.T.	Mixing Model T.	Mixing Model %	Na-K G.T.	Na-K-Ca G.T.	Most Likely Sub. Temp.	Discharge gpm.	T.D.S. mg/l	pH	Si mg/l	Na mg/l	K mg/l	Ca mg/l	Mg mg/l	B ug/l
Rhodes W.S.	18	6/75	10 c	21	65 c	240	2	25-35	--	186	8.2	11	5.5	1	33	21	30
		10/75	13 c	23	41 c	222	10		200	194	6.5	12	8.6	1.2	32	19	20
Rico																	
Diamond Drill Hole	54	1/76	26 a	39	18 a	307	56	--	15	2,250	7.0	120	66	28	590	82	70
Big Geyser W.S.	54	9/75	22 a	31	19 a	297	57	--	8	2,750	--	110	78	30	680	98	80
		4/76	35 a	37	1 a	315	56		12	2,740	6.8	140	67	31	690	93	70
Geyser W.S.	54	9/75	22 a	35	15 a	301	59	--	14	2,790	--	110	80	32	680	100	80
Little Spring	54	9/75	26 a	35	15 a	305	58	--	13	2,790	--	120	76	5.6	620	110	90
		1/76	26 a	37	10 a	185	17		15	2,700	7.0	120	77	32	690	92	70
Routt Hot Springs																	
Spring "A"	3	7/75	136 q	225	75 q	170	154	125-175	33	552	7.6	97	160	9	13	0.4	280
		10/75	125 q	199	71 q	165	154		50	518	6.5	80	160	8.3	7.3	0.2	290
		1/76	129 q	209	73 q	167	155		25	521	9.3	86	160	8.5	7.7	0.1	260
		4/76	131 q	213	73 q	169	157		35	527	7.8	89	160	8.8	7.7	0.1	280
Spring "B"	3	7/75	136 q	231	76 q	170	159	125-175	30	539	7.1	98	160	9.1	7.8	0.5	280
Sand Dunes Hot Well	34	8/75	26 a	39	19 a	205	187	--	--	334	8.3	120	81	8.6	3.2	0.4	510
Shaws W.S.	33	8/75	8 a	26	32 a	101	103	30-60	34	406	9.3	83	130	1.5	0.9	0.6	130
		10/75	2 a	26	32 a	98	104		34	402	9.3	73	130	1.4	0.5	0.3	140
		1/76	17 a	28	19 a	101	83		52	424	9.0	100	130	1.5	2.7	0.7	120
		4/76	4 a	26	32 a	100	102		40	398	8.9	76	130	1.5	0.9	0.1	270
South Canyon H. S.																	
Spring "A"	12	7/75	66 c	123	67 c	138	137	100-130	12	794	7.1	44	280	8.2	7.0	1.0	210
		10/75	60 c	103	60 c	137	135		7	800	7.6	39	280	8.0	7.7	1.4	260
		1/76	67 c	127	68 c	140	137		9	783	--	45	270	8.2	7.9	2.2	290
		4/76	63 c	115	65 c	140	137		17	772	7.3	41	270	8.2	7.8	0.9	260
Spring "B"	12	7/75	65 c	119	66 c	139	137	100-130	1E	757	7.1	43	260	7.8	7.1	0.9	230
Splashland Hot Well	35		22 a	35	23 a	221	197	40-100	--	311	8.3	110	72	9.9	4.1	0.4	340
Steamboat Springs																	
Heart Spring	4	4/76	101 q	179	81 q	148	141	125-130	140	903	8.0	49	300	11	18	1	700
Sulphur Cave	4	4/76	60 q	79	79 q	181	188	125-130	10	4,530	6.5	18	1,600	110	90	24	2,900
Steamboat Spring	4	4/76	66 q	93	76 q	176	187	125-130	20	6,170	6.7	21	2,200	140	110	31	3,200
Stinking Springs	38	9/75	39 c	59	61 c	339	41	40-60	24	899	--	24	20	12	210	27	60
Swissvale Warm Spgs.																	
Spring "A"	25	6/76	32 cr	35	22 cr	214	48	35-50	125	--	7.0	-	-	-	-	-	-
Spring "F"	25	6/76	31 cr	47	69 cr	2	44	35-50	20	--	7.0	-	-	-	-	-	-
Trimble H.S.	56	9/75	--	34	47 a	197	97	45-70	1E	3,340	--	72	510	47	510	42	1,400
Tripp H.S.		9/75	--	30	39 a	198	99	45-70	--	3,240	--	69	500	47	470	41	1,500

TABLE 4 (Cont.)

Hot Spring	Spring Number	Date Sampled	Silica G.T.	Mixing Model T.	Mixing Model %	Na-K G.T.	Na-K-Ca G.T.	Most Likely Sub. Temp.	Discharge gpm.	T.D.S. mg/l	pH	Si mg/l	Na mg/l	K mg/l	Ca mg/l	Mg mg/l	B ug/l
Valley View Hot Spgs.																	
Spring "A"	32	6/75	34 c	37	4 c	356	12	40-50	--	252	--	21	3.5	2.5	51	15	8
		10/75	32 c	35	9 c	356	14		60E	249	6.5	20	3.7	2.6	50	14	10
		1/76	32 c	35	5 c	352	15		--	243	6.8	20	3.9	2.7	50	14	7
		4/76	32 c	35	9 c	375	15		--	234	7.5	20	3.3	2.8	50	14	310
Spring "B"	32	6/75	30 c	31	12 c	338	11	40-50	--	234	--	19	3.7	2.2	46	14	8
Spring "D"	32	10/75	25 c	29	33 c	360	11	40-50	120E	229	6.0	17	3.2	2.4	49	12	9
		1/76	28 c	31	25 c	346	16		75E	247	6.5	18	4.3	2.8	51	13	20
		4/76	28 c	31	29 c	389	10		75E	223	7.5	18	2.6	2.5	50	13	220
Wagon Wheel Gap																	
4UR Spring	43	10/75	75 cr	113	56 cr	206	194	--	30E	1,580	7.0	81	480	51	61	15	2,500
		1/76	81 cr	137	66 cr	204	191		30E	1,550	7.0	90	460	48	60	14	1,300
		4/76	77 cr	119	59 cr	200	188		28E	1,620	6.7	84	490	48	66	15	2,600
CF & I Spring	43	8/75	71 cr	117	64 cr	205	181	--	30	1,510	--	74	450	48	67	16	2,600
		10/75	66 cr	99	56 cr	203	184		50	1,520	6.4	68	460	47	68	15	2,500
		1/76	80 cr	157	76 cr	203	175		30	1,540	6.5	88	450	46	66	15	1,300
		4/76	66 cr	99	57 cr	206	181		32	1,470	6.4	67	430	46	68	15	2,600
Waunita Hot Springs																	
Spring "C"	46	7/75	143 q	213	66 q	179	163	175-225	--	557	--	110	150	10	11	0.2	70
		10/75	143 q	209	64 q	176	166		30	579	8.4	110	160	10	5.9	0	60
		1/76	157 q	247	71 q	174	159		55	613	8.5	140	160	9.8	11	0.3	60
		4/76	148 q	225	68 q	178	167		50	575	7.9	120	150	10	5.8	7.3	60
Spring "D"	46	7/75	153 q	291	83 q	175	165	175-225	--	594	--	130	160	10	6.0	0	70
Lower Waunita H.S.																	
Spring "B"	46	7/75	130 q	197	67 q	178	165	110-160	--	544	--	88	150	9.9	7.8	0.7	70
		10/75	123 q	181	64 q	176	163		20E	549	8.0	77	160	10	8.6	0.4	60
		4/76	129 q	195	67 q	179	165		25E	528	7.7	86	150	10	8.5	1.0	60
Lower Waunita H.S.																	
Spring "D"	46	7/75	129 q	209	73 q	179	166	110-160	--	535	--	86	150	10	6.9	0.5	70
Wellsville W.S.	24	6/75	32 cr	33	2 cr	213	49	35-50	--	470	--	32	51	6.2	79	24	100
		10/75	30 cr	33	7 cr	214	49		160	484	7.0	30	50	6.1	76	27	100
		1/76	31 cr	33	15 cr	216	48		175	482	7.1	31	49	6.3	81	25	100
		4/76	31 cr	33	15 cr	213	50		200	482	7.2	31	52	6.3	76	26	90

TABLE 1 (Cont.)

	Thermal Areas	Areal Extent (mi^2)	Thickness (st.)	Temp. (°C) (midpoint)	Total Btu (10^{15})	Useable Btu (10^{15})
Fremt	Florence 28	1.0	200(S)	42	.0083	.0005
Fremt	Don K. Ranch 29	1.5	500(N)	45	.0353	.0021
Pueb	Clark Well 30	1.1	200(S)	40	.0083	.0005
	Mineral 31	10.1	1000(S)	70	.9406	.0564
	Valley View 32	1.05	1000(F)	50	.0593	.0036
Saguache	Shaw's 33	0.63	500(N)	45	.0148	.0009
Ala	Sand Dunes 34	1.5	500(N)	75	.0776	.0047
Ala	Splashland 35	1.5	500(N)	75	.0776	.0047
CONEJOS	Dexter/McIntyre 36/37	1.2	1000(F)	35	.0339	.0020
Arch.	Dutch Crowley/Stinking 38/39	1.52	200(S)	65	.0257	.0015
Arch.	Eoff Well 40	1.5	200(S)	50	.0169	.0010
Arch.	Pagosa 41	2.15	200(S)	80	.0485	.0029
Min	Rainbow 42	0.99	1000(F)	45	.0466	.0028
↓	Wagonwheel Gap 43	4.24	500(N)	115	.3789	.0227
↓	Antelope/Birdsie 44/45	2.38	500(N)	44	.0537	.0032
Gun	Waunita 46	1.4	200(S)	135	.0606	.0036
Gun	Cebolla 47	1.86	500(N)	60	.0700	.0040
OUR	Orvis 48	0.55	500(S)	75	.0285	.0017
OUR	Ouray 49	2.07	1000(F)	80	.2336	.0140
	Lemon 50	0.81	425(S&F)	43	.0149	.0009
Dolores	Dunton/Geyser/Paradise 51/52/53	1.16	400(S)	50	.0262	.0016
Dolores	Rico 54	1.74	1000(F)	63	.1407	.0084
La Plata	Pinkerton/Mound 55	0.98	180(S)	50	.0100	.0006
''	Tripp/Trimble 56	1.0	500(N)	58	.0357	.0021
					5.9142	.3549

(S) Stratigraphic reservoir
(F) Fracture reservoir
(N) unknown

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Geothermal Energy Development in Colorado: Processes, Promises + Problems by Barbara Coe
Colo Geol Surv Info Series 9
Denver 1978

TABLE 1

Resource Assessment of Hydrothermal Resources in Colorado

by Jay D. Dick and Richard H. Pearl

February, 1978 (unpublished)

	Thermal Spring Areas	Areal Extent (mi^2)	Thickness (ft.)	Temp. (°C) (midpoint of estimate)	Estimated Total Btu (10^{15})	Estimated Useable Btu (10^{15})
moffat	Juniper 1	1.01	200(S)	63	.0163	.0009
	Craig 2	1.3	500(N)	55	.0428	.0026
Routt	Routt 3	0.5	1000(F)	138	.1110	.0067
Routt	Steamboat 4	.52	250(S)	70	.0122	.0007
	Brand's Ranch 5	0.36	200(S)	49	.0039	.0002
Grand	Hot Sulphur 6	1.35	599(N)	75	.0698	.0042
Boulder	Haystack Butte 7	1.54	300(S)	40	.0174	.0010
Boulder	Eldorado 8	0.35	1000(S)	35	.0099	.0006
Clr Crk	Idaho 9	1.12	1000(F)	80	.1260	.0076
Eagle	Dotsero 10	0.84	250(S)	39	.0075	.0005
Garf -	Glenwood 11	1.32	250(S)	65	.0279	.0017
Garf	South Canyon 12	0.1	1000(S)	75	.0103	.0006
P -	Penny (Avalanche) 13	1.61	1000(F)	75	.1670	.0100
Delta	Colonel Chinn 14	1.55	200(S)	51	.0181	.0011
P -	Conundrum 15	0.45	500(N)	45	.0106	.0006
Gun	Cement Creek 16	1.1	150(S)	45	.0078	.0005
Gun	Ranger 17	1.11	150(S)	45	.0078	.0005
	Rhodes 18	1.53	1000(F)	35	.0432	.0026
	Hartsel 19	0.87	500(N)	70	.0409	.0025
Chaf	Cottonwood Creek 20	1.38	1000(F)	170	.3894	.0234
Chaf	Mt. Princeton 21	3.14	1000(F)	200	1.0632	.0638
Chaf	Browns Canyon 22	3.23	1500(S&F)	100	.7291	.0438
Chaf	Poncha 23	2.19	1000(F)	145	.5150	.0309
Chaf	Wellsville/Swissvale 24/25	0.94	240(S)	40	.0085	.0005
Fremont	Canon City 26	0.52	100(S)	50	.0029	.0002
↓	Freemont Natatorium 27	1.0	220(S)	43	.0095	.0006

Colo

Geo En Dev in Colo:
Processes, Promises +
Problems
Barbara Coe
Colo Geol Survey, ~~Dept of Natu Resources~~ Info Series 9
Denver 1978

TABLE 3
CURRENT USES OF GEOTHERMAL RESOURCES IN COLORADO
1978

Type of Use	County	Avg. °C temp	Avg. gpm	Name of Area
Swimming Pools	Moffat	35°	15	Juniper Hot Springs
	Routt	39°	140	Steamboat Hot Springs
	Grand	42°	50	Hot Sulphur Springs
	Boulder	25°	—	Eldorado Warm Springs
	Clear Creek	35°	15	Idaho Hot Springs
	Garfield	48°	74	Glenwood Hot Springs
	Gunnison	25°	70	Cement Creek Hot Springs
	Chaffee	52°	—	Cottonwood Creek Hot Springs
	Chaffee	50°	175	Mt. Princeton Hot Springs
	Chaffee	82°	18	Hortense Hot Springs
	Chaffee	60°	240	Poncha Hot Springs
	Saguache	30°	38	Shaws Warm Spring
	Alamosa	40°	-	Splashland Hot Water Well
	Archuleta	56°	245	Pagosa Hot Springs
	Mineral	52°	30	Wagon Wheel Gap Hot Springs
	Gunnison	76°	—	Upper Waunita Hot Springs
	Ouray	68°	60°	Ouray Hot Springs
	Ouray			Pinkerton Hot Springs
				Valley View Hot Springs
Baths				Juniper Hot Springs
				Hot Sulphur Springs
				Idaho Hot Springs
				Glenwood Hot Springs
				South Canyon Hot Springs
				Mineral Hot Springs
				Valley View Hot Springs
				Cebolla Hot Springs
	Ouray	52°	—	Orvis Hot Springs
				Ouray Hot Springs
	Dolores	42°	25	Dunton Hot Springs
	Dolores	43°	30	Paradise Hot Springs
	Ouray	53°	—	Weis baden Springs

~~[illegible]~~

— Younglife Hotwater well/Chaffee/82°C/—

Pool Hot Springs/Ouray/68°C/200g

— weis baden springs/Ouray/53°C/—

— Dunton Hot Spngs/Dolores/42°C/25

— paradise Wm Spngs/Dolores/43°C 30gpm

TABLE 8
CATEGORY II B
AREAS OF KNOWN ACTIVITY

Area Name	Number	Use	Distance	1975 Estimated Dwelling Units	1975 Estimated Natural Gas Demand $(10^{12}$Btu's$)$	2020 Estimated Dwelling Units	2020 Estimated Natural Gas Demand $(10^{12}$Btu's$)$	Estimated Usable Energy Available $(10^{12}$Btu's$)$	Estimated Usable Energy Available Per Year for 30 Years $(10^{12}$Btu's$)$
Glenwood	11	space heat Glenwood Springs	0	1,784	.32	3,796	.68	1.7	.06
Hartsel	19	space heat Fairplay	16	215	.04	271	.04	2.5	.08
Splashland	35	Alamosa	2	2,807	.50	8,083	1.44	4.7	.16
Sand Dunes	34	Baca Grande	14	225	.02	10,000	1.78	4.7	.16
Shaws	33	greenhouse	0	NA*	.02	NA	NA	.9	.03
Mineral/Valley View	31/32	space heat Saguache	12	226	.04	380	.06	60.0	2.00
		timber kiln			.04				
		barley melting			.22				
		potato flakes			.86				
Pagosa Springs	41	space heat Pagosa Springs	0	524	.09	1,481	.26	2.9	.10
Waunita	46	space heat Gunnison timber drying	22	1,880	.33	4,326	.77	3.6	.12

*Not applicable

TABLE 3 (Cont.)

Space Heating	Cottonwood Creek/Jump Steady Hot Springs - Mt. Princeton - cabins/House, resort
	Wright Hot Water Wells - 2 houses
	Poncha Hot Springs - 1 house
	Sand Dunes Swimming Pool Well - 1 house
	Ouray - 2 motels
	Pagosa Springs - approx. 10 buildings
	Upper Waunita Hot Springs - headquarters building
	Weisbaden - limited heating
Other	
Laundry	Hot Sulphur Springs
Greenhouses	Penny Hot Springs
	Wright Hot Water Wells
	Tripp Hot Springs
Algae Growing	Wellsville
Irrigation	Dutch Crowley
Bottled Water	Clark Artesian Well
	El Dorado Warm Spring
Fish Farming	Sand Dunes Hot Water Well Wellssville

SOURCES: Barrett and Pearl, 1978 and unpublished data from Dick and Galloway, 1978.

domestic -	Jump-Steady Hot springs Cement Creek Hortense upper Waunita
hydrotherapy	Orvis Hot spring
Sauna	Wagon Wheel Gap

Colorado

Geo, Energy Dev in Colo. Barbara Coe

— Pagosa Springs — geophysical tests, 1978, by Colo Geol Surv
— all 56 identified Thermal areas had CGS geochemical tests, 1978
— Mt. Princeton Hot springs — 2000 ft gradient test hole, 1975, Amax Exploration, Inc
— Pagosa Springs — 5 shallow gradient holes, 1977, CGS
— near Great Sand Dunes — exploratory geotherm well, 1974, Mapco, over 5500 ft.
— Pagosa Springs — exploratory well 2000 ft, CGS, 1978 (in progress)

An Appraisal of Colo's Geo Resources Barrett + Pearl

— Juniper Hot Springs (6N, 94W, 16cd) Moffat Co — 33-38°C at 13-18gpm — pool & baths
— Steamboat Springs (6N, 84W, 17abd) Routt Co. — 39°C at 140gpm — town pool
— Hot Sulphur Springs (1N, 78W, 3dc) Grand Co — 40-44°C at total of 50gpm - pool, baths, laundry
— Eldorado Warm Springs (1S, 71W, 25da) Boulder Co — 24°-26°C — - pool + bottled drinking
— Idaho Hot Springs (4S, 73W, 1ba) Clear Creek Co - 24° to 46°C at 1gpm to 30gpm - pool + baths
— Glenwood Hot Springs (6S, 89W, 9ad) Garfield Co — 44 to 51°C at about 74 gpm - pool
— Penny Hot Springs (10S, 88W, 4ba) Pitkin Co — 40-56°C @ 10-12gpm - small greenhouse
— Cement Creek Warm Spring (14S, 84W, 18cac) Gunnison Co. — 25°C at 60-80gpm - swimming +
— Cottonwood Hot Springs (14S, 79W, 21dca) Chaffee Co. — 46-58°C — heat 1 house domestic
— Jump-Steady Hot Springs (14S, 79W, 21ddb) Chaffee Co — 46-58°C — heat + domestic
— Mount Princeton Hot Spring (15S, 78W, 19bca) Chaffee Co - 44-56°C at 175gpm — heating + pool
— Wright Hot Water wells (15S, 79W, 24ca) Chaffee Co - 67-72°C — heat 2 houses & greenhouses
— Hortense Hot spring ~~well~~ (15S, 79W, 24bd) Chaffee Co — 82°C at 18gpm - domestic
— Young Life Hot Water Well (15S, 79W, 4b) Chaffee Co — 82°C — recreational use
— Poncha Hot Springs (49N, 8E, 15cb + 15bc) Chaffee Co - 50-71°C at total of 240gpm - limited heating & ~~mun~~ Salida municipal pool
— Wellsville Warm Spring (49N, 10E, 18) Chaffee Co — 28-33°C at 160-200gpm — fish raising + aquaculture
— ~~Clark Artes.~~
— Clark Artesian Well (21S, 65W, 1aab) Pueblo Co. — 25°C — bottled water
— Shaws' Warm Spring (41N, 6E, 33dd) Saguache Co — 30°C at 34-50gpm - private pool
— Sand Dunes Hot Water Well (41N, 10E, 27aa) Alamosa Co — 44°C — heat house + catfish tanks
— Splashland Hot Water well (38N, 10E, 34dd) Alamosa Co — 40°C — pool
— Dutch Crowley Artesian Well (32N, 2E, 18bbb) Archuleta Co — 70°C — irrigation
— Pagosa Springs (35N, 2W, 13cd) Archuleta Co — 54-58°C at 226-265gpm - pool + heating 10 commercial buildings
— Wagon Wheel Gap Hot Springs (41N, 1E, 35dd) Mineral Co — 55-57°C at 30gpm — pool & sauna
— Upper Waunita Hot Springs (49N, 4E, 11cc) Gunnison Co — 76°C — swimming, drinking, heating ranch
— Orvis Hot Spring (45N, 8W, 22cd) Ouray Co — 52°C — hydrotheraphy
— Pool Hot Springs (44N, 7W, 31) Ouray Co — 67-69°C at 60-200gpm — pool
— Weisbaden Springs (44N, 7W, 31) Ouray Co — 53°C - variable — baths, pool, heating
— Dunton Hot Springs (41N, 11W, 32) Dolores Co — 42°C at 25gpm — pool
— Paradise Warm Spring (40N, 12W, 1) Dolores Co — 40-46°C at 26-34 gpm — private pool

"Colorado's geothermal potential is expressed in the 127 thermal springs and wells (temps above 20°C) found throughout the western half of the state... the majority are associated with The Rio Grande Rift of the San Luis Valley and Upper Arkansas Valleys, and with the San Juan and La Plata Mountains of the southwestern part of Colorado... probable sub-surface temperatures range from lows of 20°C to 50°C at Dexter Warm Springs in the Southern San Luis Valley to highs of 150°C to 200°C at both Cottonwood Hot Springs and Mount Princeton Hot Springs area."

N-EV

Summary of Nevada Geothermal Activity (April 1978)

Dennis T. Trexler
Nevada Bureau of Mines and Geology

The majority of the thirty Known Geothermal Resource Areas within the state are under scrutiny by various companies. The KGRA's receiving the most intense activity at the present time are: 1) Beowawe, 2) Brady-Hazen (Desert Peak), 3) Soda Lake-Stillwater, ? 4) Hot Springs Point, 5) Humboldt (Rye Patch), 6) Steamboat Hot Springs and 7) San Emidio Desert. [illegible] + Phillips / 8) Southland Royalties Co. + Millican - from Texas a little been done Dixie Valley

Several areas which did not receive the intense drilling pressure, typical of the early sixties, have been explored since 1974. Two areas which are not KGRA's (Lee Hot Springs and Hot Springs Ranch) have been drilled and preliminary reports indicate that temperatures are not extraordinarily high in either area. The Lee Hot Springs area was drilled by Oxy Geothermal in 1978 and even with the lack of high temperatures the Navy has shown interest in the area for space heating at the Fallon Naval Air Station.

Areas capable of potential electrical production include Beowawe, Desert Peak and Steamboat Hot Springs. Drilling by Phillips Petroleum has confirmed the existence of a viable resource for electrical production at Desert Peak. Discussions are in progress with Sierra Pacific Power Co. for a joint effort to get the area on line.

A food dehydration plant is currently under construction at Brady's Hot Springs by Geothermal Food Processors. The project is being supported by DOE in the form of geothermal loan guarantee.

Recently a DOE grant for $30,000 has been obtained by operators of the Aqua Caliente Trailer Park, in Caliente, to expand the use of geothermal waters for space heating.

Areas of potential resource discovery in Nevada may be areas containing young volcanic rocks of intermediate to basaltic composition. Only two areas in

Nevada are considered as being igneous related geothermal systems (Smith and Shaw, 1975). The largest KGRA in Nevada (Soda Lake-Stillwater) has young basaltic volcanic rocks associated with Soda Lake and Upsal Hogback. Other areas with young volcanic rocks should be studied for their potential as geothermal areas.

Direct utilization of geothermal energy in the Reno area for space heating has doubled in the last 3 years. In 1975, 30 homes and 2 motels used geothermal energy for heating. At the present time there are 60 homes, 2 churches and 2 motels using the resource. The geographic distribution of the resource has been expanded to the north and south. Wells on the periphery of the known limits of the reservoir are having to drill to depths of 800-1000 feet to obtain sufficient heat for space conditioning.

Poor well design in several of the older systems allows for contamination of the geothermal resource by overlying cold water. These systems must be pumped intermittently during cold weather to maintain sufficient bore hole temperatures for space heating.

Lincoln

Wells 12,17,20,21	Wells in area generally <90°F
Spring 50	No correlative data
Wells 37-42	Other wells in area >100°F

Mineral

Spring 1	Waring location uncertain. Indicated as warm
Well 2	No correlative data

Nye

Spring 1	No correlative data
Spring 5,11	>100°F personal knowledge
Spring 27	Probably <94°F from nearby data
Spring 32	No correlative data
Well 39	In Darrough Hot Spring area. Hot water cemented off.
Spring 45	Waring, location uncertain
Well 101	No correlative data
Spring 102	Waring, location uncertain. No temp.
Springs 113,114	No data.

Pershing

Spring 4	No data from nearby springs
Spring 13	Numerous springs, Waring location vague
Spring 25	No data. Location questionable
Springs 36,38	Probably >94°F, in area of high temp. Drill hole 41B >100°F near spring w/141°F.

Washoe

Spring 7	>190°F Steamboat Springs area
Spring 9	>190°F Steamboat Springs area
Spring 26	Waring, location uncertain.
Spring 27	No data, map ref.
Spring 28	Waring, location uncertain.
Springs 30,31	Waring, no data
Spring 33	Waring, no data
Spring 34	Waring, no data
Spring 36	Waring, no data
Spring 38	No correlative temp. data
Spring 39	Waring, no data
Spring 40	Waring, no data
Spring 46	Waring, no data
Springs 55,56	Adjacent springs and wells >100°F
Well 57	
Spring 94	>100°F Garside
Well 95	?>100°F by association in Moana area
Well 98	>100°F north of Steamboat Springs
Spring 123	Remarks indicate boiling mud

White Pine

Spring 17	Waring, poor location, no data
Spring 27	Waring, poor location, no data
Spring 38	Waring, poor location, no data

APPENDIX A

Examination of 103 Springs and Wells with Inferred Temperatures

NOTES ON INDICATED TEMPERATURES

Carson City

Well 6C	Wells in same section have 112°F Temp.

Churchill

Spring 13	Waring, general location
Spring(M)14	No data
Spring 15	Waring general location
Spring 17	Waring, appears to be Dixie Hot Spring >100°F
Spring 33	Waring, no data
Well 36	Drill Hole to 3700' Temp. probably exceeds 100°F
Spring 49	Waring, probably incorrectly located

Clark

Spring 12	If same as Spring 11 Temp=90°F Discharge 3240gp
Spring 36	Apparently 81°F from adjoining data w/same name
Springs 95,96,97	No correlative data

Elko

Spring 26	Same location as Spring 25 Temp=194°F
Well 29	Same location as Well 28 Temp=138°F
Spring 31	No correlative data
Spring 38	No correlative data
Wells 41,44	No correlative data
Spring 55	Spring 2 miles away Temp=102°F
Spring 62	Spring in same section 70°F
Spring 63	No correlative data
Wells 70,71,72	Encountered hot water and were abandoned
Springs 74,75	No correlative data
Spring 78	No correlative data
Springs 87,88	Are located near Spring 86 Temp=149°F

Esmeralda

Well 12	No correlative data

Humboldt

Spring 12	Other spring and wells in area 200°F
Springs 19,20	No correlative data
Springs 41,42,55	Waring ref. Location uncertain
Spring 61	Waring ref. Location uncertain
Spring 72	In Double Hot Springs area probably >94°F
Springs 87,89	Location uncertain. No correlative data
Spring 27	Well in same sect. 85°F
Spring 29	Waring, location uncertain
Spring 32	Waring, location uncertain. Indicated as hot
Spring 43	Waring, location uncertain. Indicated as hot

Summary Rpt of Availability of
Geoth Data for Potential Direct Heat Application in Nev.
Dennis Trexler, 1977, Nev Bur M+G, Reno

TABLE 2

GEOTHERMAL DATA STATEWIDE WITH TEMPERATURES >35°C OR INDICATED AS HOT OR WARM

County	Spring	Well	Total Data Sheets	Chem. Analysis	Flow Rate	Depth	Other
Carson City	2(1)*	3(1)*	7	4	1	2	1
Churchill	5(11)	10(2)	28	5	10	8	23
Clark	(5)	3	8	2	0	3	4
Douglas	6	1	7	5	3	1	5
Elko	36(13)	5(3)	57	18	23	7	35
Esmeralda	7	1(1)	9	4	4	2	6
Eureka	33	9	42	24	22	5	22
Humboldt	55(11)	13	79	46	31	9	40
Lander	22(4)	5	31	16	16	2	21
Lincoln	4(1)	4(4)	13	7	2	5	6
Lyon	4	11(4)	19	12	6	10	7
Mineral	4(1)	6(1)	12	7	4	2	3
Nye	53(9)	20(2)	84	38	47	18	32
Pershing	27(5)	6(1)	39	19	14	2	21
Storey	1(mine)	-	1	-	-	-	1
Washoe	26(18)	45(2)	91	65	11	4	30
White Pine	7(3)	1	11	3	5	1	3
Total	292(82)	143(21)	538	275	199	81	260

* Temperature indicated as Hot or Warm

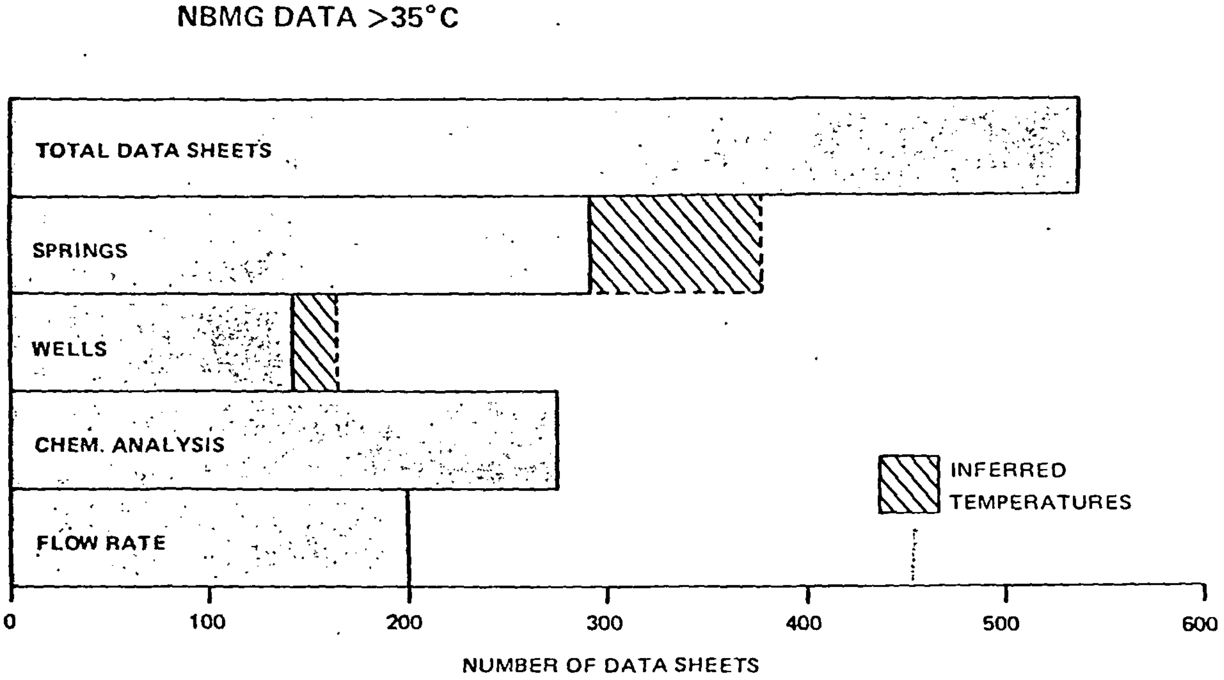


Figure 1. Graphic representation of the quantity and type of data in the NBMG Geothermal file.

NV

SITE: BRADY HOT SPRINGS, NV

GEOTHERMAL DEVELOPMENT STATUS

PRESENT DEVELOPMENT STATUS	PROJECTED OR PLANNED DEVELOPMENT
Several companies have been drilling in the area since 1959. Magma Power Company drilled several shallow wells between 1959 and 1961. Earth Energy, Inc. drilled a well to 1,519 m (5,062 feet) in 1964. By August 1975, Phillips and Union drilled deeper than 2,100 m (7,000 feet) and Magma had drilled 2 wells to 1,050 m (3,500 feet) and 1,350 m (4,500 feet) near the old holes.(4) By February 1977, Southern Union Products Co. suspended operations, and Standard Oil of California had drilled a producing well.(17) One 1,500 m (4,921 foot) well had a temperature of 214°C and a high flow rate.(20) Phillips has new high flow rate wells east of the old Brady Magma wells.(20) In March 1977, ERDA received an application for $3,046,000 million in loan guarantees by Geothermal Food Processors, Los Angeles, CA to build a dehydration plant at the site. Geothermal energy would be used to dehydrate food products and to operate a 490 kw binary cycle power plant for the food processing plant.(38) Total project cost would be $4.96 million. The loan would be granted by the Nevada National Bank.(25) The USGS reports that the flow rate of Brady Hot Springs is low. A downhole temperature of 200°C has been recorded. However, when the well was flowed the fluid temperature was less than 200°C.(47) At Desert Peak which is southeast of Brady Hot Springs, Phillips has reported that temperatures from the deepest well, which was ∿2,133 m (∿7,000 feet), were >250°C. There was some steam from the well. The USGS assumes that the Desert Peak geothermal system is separate from the Brady Hot Springs System.(47)	

SITE: BRADY HOT SPRINGS, NV (REGION 4)

SUMMARY

TEMPERATURE °C

Surface: 98 Subsurface: 214

TOTAL DISSOLVED SOLIDS (PPM): 2,450 (4)
ESTIMATED ELECTRIC ENERGY POTENTIAL (MWe 30 YEARS): 393 (7) 1000 (20)
TYPE OF OVERLAYING ROCK: Hard
ESTIMATED DEPTH TO TOP OF RESERVOIR (METERS): 500

DESCRIPTION OF KGRA

Total KGRA Acres:	98,508		
Total Federal Acres:	59,358 (49)	Total State and Private Acres:	39,150 (49)
Federal Acres Leased:	26,049 (49)	State and Private Acres Leased:	

GEOTHERMAL DEVELOPMENT STATUS:

Numerous wells have been drilled.(4,17) The wells have high flow rates.(20) ERDA has received an application for a loan guarantee to build a dehydration plant which would use geothermally-derived electricity to dehydrate products.(25) Philips has drilled one ~2,133 m (~7,000 foot) liquid and steam producing well which had temperatures >250°C.(47)

LOCAL AND STATE ATTITUDE TOWARD GEOTHERMAL DEVELOPMENTS:

County concerned with maintaining open areas in natural state, but receptive to controlled development.(4) Mild constraints and brief delays can be expected. Special use permit required.(1A)

LAND USE AND POPULATION:

Rural population, agriculture, some recreation and mining.

COMMENTS AND CRITICAL ISSUES:

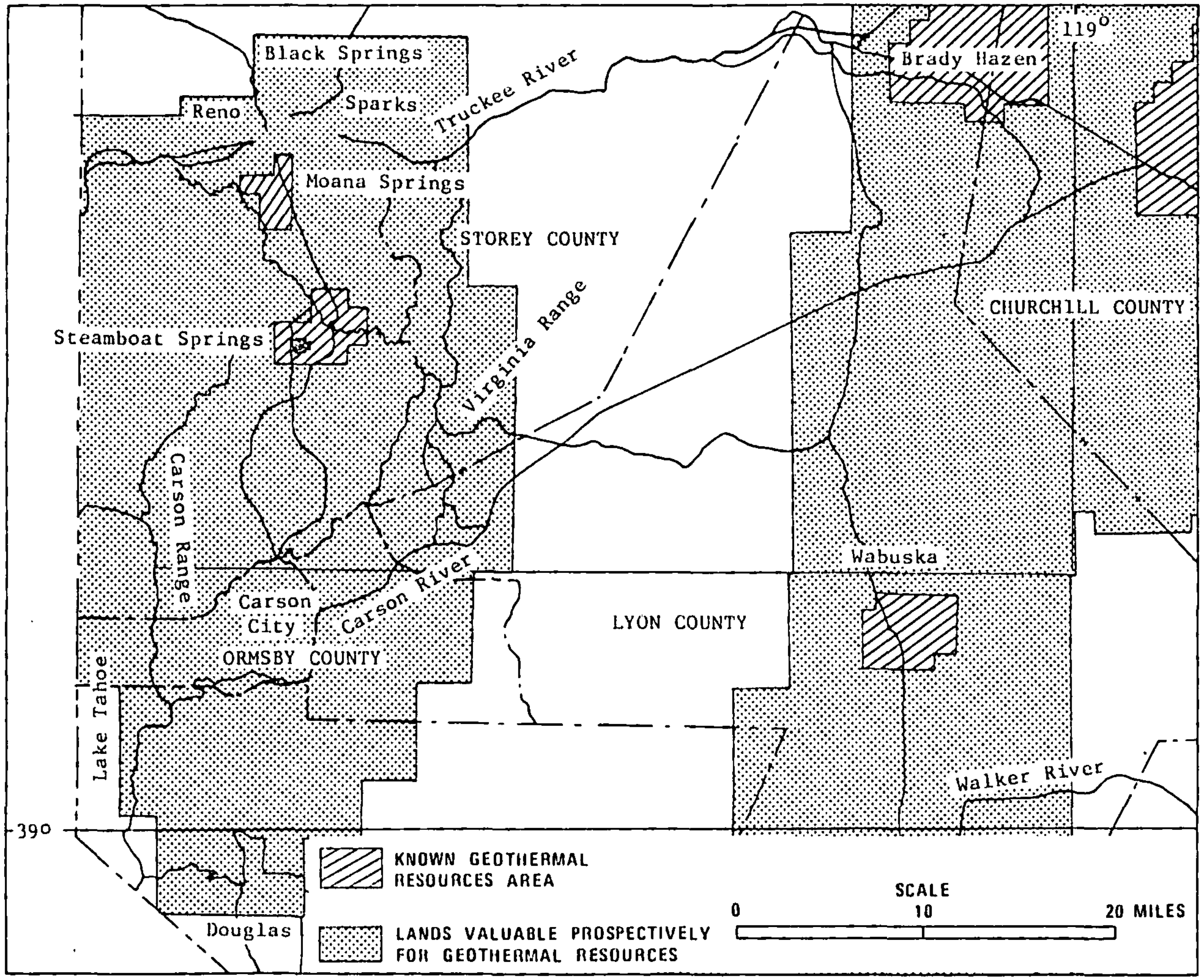
Surface water not available.(4) As of August 1975, all exploration occurred on private property.(1A) BLM has prepared an environmental analysis of the area.(4) There is some evidence of recent seismic activity.(6)

NEV

SITE: STEAMBOAT SPRINGS, NV

GEOTHERMAL DEVELOPMENT STATUS

PRESENT DEVELOPMENT STATUS	PROJECTED OR PLANNED DEVELOPMENT
In addition to several older wells, 6 wells ranging in depth from 156-549 m (520-1,830 feet), were drilled by Nevada Thermal Power Co. between 1954-1961. Eight diamond drill holes shallower than 1,000 feet were drilled by USGS.(4) One well 217.5 m (725 feet) deep recorded 185°C (365°F). It flowed more than 775 lpm (200 gpm) for over two weeks and then declined (probably due to both decline of pressure and deposition of calcite).(4) Many shallow wells are used for space heating.(20) Industries involved in development as of February 1977 are Magma and Southern Union Production.(20) By February 1977, no deep wells had been drilled.(20)	Possible deep drill hole to test higher enthalpy regime; and possible continued drilling of hot water wells projected through 1977-1979.(27) Significant space heating potential in Reno.(20)



SITE: STEAMBOAT SPRINGS, NV

NV

SITE: BEOWAWE, NV

GEOTHERMAL DEVELOPMENT STATUS

PRESENT DEVELOPMENT STATUS	PROJECTED OR PLANNED DEVELOPMENT
As of August 1975, the deepest well drilled was 2915 m (9,563 feet).(4) By June 1976, more than 12 holes were drilled, with Magma Power (Chevron) planning additional holes.(2) By February 1977, 1 well had been drilled by Standard Oil of California.(17) (As of February 1977, 13 deep wells were drilled).(20) Phillips has also been involved in development.(20) By June 1977, the deepest well (which was drilled by Chevron) had a downhole temperature of ∿214°C. A 213 m (700 foot) well drilled by Magma had the same downhole temperature.(47) Vandalized Magma wells have been running wild for the past 2 to 3 years.(47) Chevron has drilled one dry hole.(47)	

NEV

Beowawe

SITE: BEOWAWE, NV (REGION 4)

SUMMARY

TEMPERATURE °C
Surface: 226 Subsurface: 240

TOTAL DISSOLVED SOLIDS (PPM): 1,200(4)
ESTIMATED ELECTRIC ENERGY POTENTIAL (MWe 30 YEARS): 624(7) 500-1000(20)
TYPE OF OVERLAYING ROCK: Hard
ESTIMATED DEPTH TO TOP OF RESERVOIR (METERS): 1,000

DESCRIPTION OF KGRA
Total KGRA Acres: 33,225(49)
Total Federal Acres: ~ 16,530(49)
Federal Acres Leased:
Total State and Private Acres: ~ 1/2(1A)
State and Private Acres Leased:

GEOTHERMAL DEVELOPMENT STATUS:

As of February 1977, 13 deep wells have been drilled.(20)

LOCAL AND STATE ATTITUDE TOWARD GEOTHERMAL DEVELOPMENTS:

Development is generally welcome. A use permit for land is required. Mild constraints and brief delays may be expected.(1A) Development has been delayed by legal problems.(20)

LAND USE AND POPULATION:

Sparsely populated desert. Mining, grazing and irrigated agriculture.(4)

COMMENTS AND CRITICAL ISSUES:

A water shortage exists.(1A) BLM has prepared a regional environmental analysis.(4)

Geothermal Resources Council, TRANSACTIONS, Vol. 2 July 1978

GEOTHERMAL DEVELOPMENT IN RENO

David J. Atkinson

Hydrothermal Energy Corporation

Reno is a pleasant small city in western Nevada, close to the northern California border. The city's character is schizophrenic: there is always a large transient population of tourists, enjoying the casinos, the entertainment and the local countryside; but there is also a very distinctive and rapidly growing city that has spread far from the entertainment centers and is involved in a different life style. Reno has become recognized as one of the more attractive small cities of the west and its growth rate has accelerated so much that the value of issued building permits recently attracted national attention. Five major new hotels will open in 1978.

This sketch of Reno is important in understanding that Reno is a prime candidate for large-scale use of the hot water underlying the southern part of the city, in the Moana district.

Starting around 1950, about forty wells have been successfully developed to heat homes, apartments, motels and swimming pools. Most of the wells are a few hundred feet deep and the water is generally in the range 140 - 190°F., with about 1100 ppm. TDS.

Most of these small systems have a downhole loop heat exchanger, a U-shaped copper pipe suspended in the well, through which city water is circulated. In a few cases, geothermal water is pumped through the heating system directly and then disposed to the storm sewers, often via a swimming pool.

In the past few years, heating with natural gas (which is standard in Reno) has become dramatically more expensive. The local utility has proposed moratoriums on new hook-ups, and the danger of periodic cutoffs in gas supply to users has become very real.

Consequently, interest in low temperature geothermal applications has increased. In the first few weeks of spring, 1978, for example, five new systems were being worked on.

However, in the context of a small city in a stage of rapid growth, in an energy-poor location, this kind of small-scale, piecemeal use of the geothermal resource is clearly very wasteful and inefficient.

Looking at the situation in broader perspective, the Moana resource is one of a series of known geothermal areas spread along a N and NW-trending zone that passes north of Mono Lake, through Bridgeport, Grover, Genoa, Steamboat, Moana, and on beyond Reno.

The closeness of Steamboat Springs, eight miles south of Moana, obviously raises the question: can hot water from there be piped to Reno and used with economic success?

At Steamboat Springs, temperatures in the reservoir are high enough for power generation. But in the marginal zones, water around boiling point is probably available and might be transported to Reno, either just below boiling point or above it, under pressure.

At Moana itself, chemical geothermometry indicates equilibration near 260°F., much hotter than any water so far encountered in the relatively shallow drilling of aquifers in the alluvium of the valley.

The possibility of using these higher temperature fluids at Moana and from Steamboat, means that one can envision a much broader spectrum of possible applications than the space heating which has been the chief application to date.

An understanding of the mechanics of the Moana geothermal system becomes important.

Valley fill in the Reno area is generally between 600 and 2,000 feet thick. It consists of very young gravels, sands and clays. The hot water presently used at Moana generally comes from shallow aquifers in this sequence, usually below a characteristic blue clay aquiclude.

This sequence is underlain by Tertiary volcanics, principally andesite. Gravity surveys give a direct indication of the varying depth to the top of the volcanics and, in combination with a detailed structural analysis, show that the shallow hot water reservoirs in the valley fill overlie part of a clearly defined horst. The correlation between the gravity pattern and a map of observed water temperatures is striking.

Analysis of fault and fracture patterns shows three main sets trending roughly N, N 40° E and N 35° W. The sense of relative displacement on these leads to the conclusion they are conjugate shears (N 40° E and N 35° W) bisected by north-south extension fracturing, in response to a maximum principal stress direction trending horizontally north-south, and a minimum principal stress direction trending east-west.

One can formulate a model of the geothermal system at Moana by using the details of a structural analysis along these lines applied to the specific conditions at Moana, and combining it with temperature measurements, chemical analysis, and geophysical and hydrogeologic data.

From the details of this model one can select target zones in which to seek higher temperature water and high production rates, for example where fault intersections in the relatively shallow volcanics may provide high fracture permeability.

Given this understanding of the geothermal system at Moana, and its location in a rapidly growing city, one asks the question: how can this resource be effectively used to provide lower cost, locally derived energy to Reno, and to demonstrate the feasibility and advantages of similar developments in the numerous other localities where low temperature geothermal resources lie close to residential and business centers.

In Reno the obvious market for space- and water-heating has already begun to expand from its tiny beginning. There are many existing apartment and business complexes that are large enough energy users to be attractive retrofit candidates. Detailed analyses of some of these show that retrofitting is technically feasible, and would provide an attractive return both to developer and user. New complexes and new casinos form other targets.

Finding and using the higher temperature water indicated by chemical geothermometers and by temperature gradients would make possible absorption refrigeration and some industrial applications, helping to balance out the seasonal variation of heat use in space heating.

Auxiliary use in pools and spas are obvious ways to continue extracting usable heat from the disposal water of space- and water-heating systems. Other promising uses include greenhouse flowers and vegetables and possibly fish-farming and other kinds of aquaculture. The appropriate combinations of uses depend on the geography of specific target complexes in the city.

Here in Reno, and in many other places where a similar opportunity exists, the need is for an appraisal of how to use the opportunity fully; how to develop and manage the resource itself, the extraction and distribution systems, and the different types of applications and combinations of uses.

The critical need is to develop and execute plans based on accurate assessments of the resource, the market, and the economic incentive for development. Technical and institutional problems have to be handled, and local people need to be brought to support the program through a real understanding of the situation, and their own advantage.

Without such large-scale planning, and the clear demonstration of the economic incentives to the developer of the resource, the distributor, the users, and to the local people, development of these low temperature geothermal resources will continue to be slow, piecemeal and inefficient.

Acknowledgement

This work was done as part of a program of geothermal exploration and development for Supron Energy Corporation of Dallas. My sincere thanks are extended for permission to present the results.

H.T. [illegible] Flat lying. 5000 ppm fluids in flat lying aq. Caused short circuit

← due downward cond. of heat.

Geothermal Resources Council, TRANSACTIONS, Vol. 2 July 1978

NEV

THE USE OF SHALLOW AND DEEP TEMPERATURE GRADIENTS IN GEOTHERMAL EXPLORATION IN NORTHWESTERN NEVADA USING THE DESERT PEAK THERMAL ANOMALY AS A MODEL

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Phillips Petroleum Company, Geothermal Operations
P. O. Box 10566, Reno, Nevada 89510

54 T.G. holes

The Desert Peak thermal anomaly is located about 50 miles east of Reno, Nevada. It was discovered while drilling temperature-gradient holes near Brady's Hot Springs. This anomaly covers about 100 square miles, making it the largest known thermal anomaly in Nevada. It has a complex outline as it is a composite feature over at least two apparently separate thermal systems. The internal structure is also complex and intense with temperature gradients of from 30 to 60°F/100 feet being common in the heart of the anomaly. Fifty-four temperature-gradient holes deeper than 180 feet have been drilled by Phillips Petroleum to define this anomaly.

The Desert Peak thermal anomaly, along with the Steamboat thermal anomaly, are unique among the larger thermal anomalies in western Nevada in that they are centered on horsts. All other presently known northwestern Nevada thermal anomalies are centered within the basins or along range-front faults. In spite of this unique feature the Desert Peak area has many thermal similarities with such northwestern Nevada geothermal prospects as Humboldt House, Soda Lake, Steamboat, and San Emidio. At the present time Desert Peak can be used as a possible model for these areas.

During the early stages of temperature-gradient drilling at Desert Peak most of the holes were drilled to a depth of 500 feet, however, as the drilling progressed it became apparent that the temperature profiles usually showed no significant changes between depths of 300 and 500 feet. Therefore, with a few exceptions, the last 43 temperature-gradient holes were limited to about 300 feet in depth. In hindsight, had all the temperature-gradient holes been limited to a depth of 200 feet the results of the exploration program would not have changed. An isothermal map at a depth of 200 feet shows an anomaly identical to the temperature-gradient map. In fact, the 100-foot-depth isothermal map also quite accurately outlines this intense anomaly. The Desert Peak thermal anomaly is so intense that for exploration purposes heat flow calculations offer no advantages over simple temperature gradients.

Much additional shallow temperature-gradient work in the basins and low-relief ranges of western Nevada suggests that shallow temperature-gradient holes need not exceed 200 to 300 feet in depth for preliminary exploration purposes.

Well 29-1 was the first deep test at Desert Peak and is located in the heart of the thermal anomaly where the shallow temperature gradients exceed 25°F/100 feet. The location is also within a large roving dipole and magnetotelluric anomaly with resistivities reported to be less than 5 ohmmeters to depths of several thousand feet. The temperature profile of well 29-1 shows a temperature gradient reversal at a depth of 700 feet and an estimated bottomhole temperature of 330°F at 7660 feet. This reversal is believed to be caused by a subhorizontal thermal aquifer which became active about 3000 years ago (Blackwell 1975).

Well 29-1 did not intersect a reservoir, clearly proving that the aquifer extended beyond any reservoir boundaries. Well 29-1 clearly demonstrates that the near-surface temperature gradients and electrical methods are unreliable when located over unexpected shallow thermal aquifers.

It was decided that drilling slim holes, which will be referred to as strat. tests, from 1000 to 2000 feet deep would be the best, cheapest, and possibly the only way to "see" through this aquifer.

To date, eight strat. tests ranging in depth from 1293 to 2000 feet have been drilled at Desert Peak. The temperature profiles in these holes are highly variable and have been extremely valuable in understanding the hydrogeology and geology of the area. With these strat. tests it is possible to construct a temperature cross section which removes the near-surface effects of the thermal aquifer and clearly shows where deep tests should be located. Based on this information wells B21-1 and B21-2 were drilled. Both are producers.

The strat. tests have shown at least three near-surface thermal aquifers to be present within the thermal anomaly. The tops of these aquifers range in depth from 200 to 900 feet, the thickness of the aquifers varies from a few feet to 1000 feet, and the temperature ranges from 108 to 300°F. With this information it is clear that the shallow temperature data over much of the anomaly is controlled by the aquifer temperature and depth, not by proximity to a deep reservoir Generally temperature gradients in excess of 15°F/100 feet at Desert Peak indicate that a shallow thermal aquifer is controlling the near-surface thermal gradient.

Recent deeper drilling at the Humboldt House, Soda Lake, San Emidio, and Steamboat thermal anomalies shows that similar thermal aquifers are common in northwestern Nevada. These complications, which often occur below a depth of 500 feet, mean that heat flow values will be as misleading as simple temperature gradients in properly locating deep wells. Experience to date in these other northwestern Nevada geothermal areas suggests that areally extensive shallow temperature gradients in excess of 10 or 15°F/100 feet should be interpreted as a warning that shallow thermal aquifers are probably present. Electrical methods in these other areas also appear to give misleading and suspect results, especially when there is much water-saturated clay at or near the surface.

Comparison of the two producing wells, B21-1 and B21-2, with nearby strat. tests demonstrates that the temperature gradients measured beneath the aquifers may be accurately extrapolated to reservoir temperatures. However, geological complications do not presently allow prediction of the depth to the reservoir. Well B21-2 proves that these shallow thermal aquifers can overlie the reservoir.

Projecting all the strat. test bottom-hole gradients suggests that an area of four square miles is underlain by 400°F temperatures at a depth of 4000 feet or less, and an area of about 10 square miles is underlain by 400°F temperatures at a depth of 5000 feet or less. This data also shows the deep thermal anomaly to be offset about two miles northeast of the heart of the near-surface thermal anomaly.

In conclusion:

1) Temperature-gradient holes need not be deeper than 200 to 300 feet to outline the Desert Peak thermal anomaly. This also appears to be the case for most of northwestern Nevada when the holes are located in basins or horsts of low relief.

2) The presence of subhorizontal thermal aquifers at Desert Peak and other areas in northwestern Nevada make locating deep and expensive geothermal tests on shallow temperature-gradient data very risky. Electrical techniques and/or the present methods of interpreting electrical data do not appear to be capable of recognizing these aquifers. Experience to date suggests that these aquifers are often misinterpreted as being reservoirs at greater depths, especially when highly conductive material is present at or near the surface.

3) At Desert Peak and other intense thermal anomalies in northwestern Nevada, heat flow determinations offer no advantage over simple thermal gradients for exploration purposes.

4) Slim-hole strat. tests from 1000 to 2000 feet deep offer the best and cheapest means to "see" through these aquifers and to properly locate deep geothermal tests.

5) At Desert Peak it is possible to accurately project the depth to reservoir temperatures based on strat. test information obtained below the thermal aquifers. However, additional complications make it difficult to predict the depth to the actual reservoir.

6) At Desert Peak the heart of the deep thermal anomaly lies about two miles northeast of the heart of the shallow thermal anomaly.

7) The technique of using shallow temperature-gradient holes to outline thermal anomalies and strat. tests to locate deep geothermal tests within the anomalies appears to work well in northwestern Nevada. In other provinces, such as the Snake River Plain in Idaho or the Franciscan terrain in California, other exploration tools and techniques appear to be required.

References:

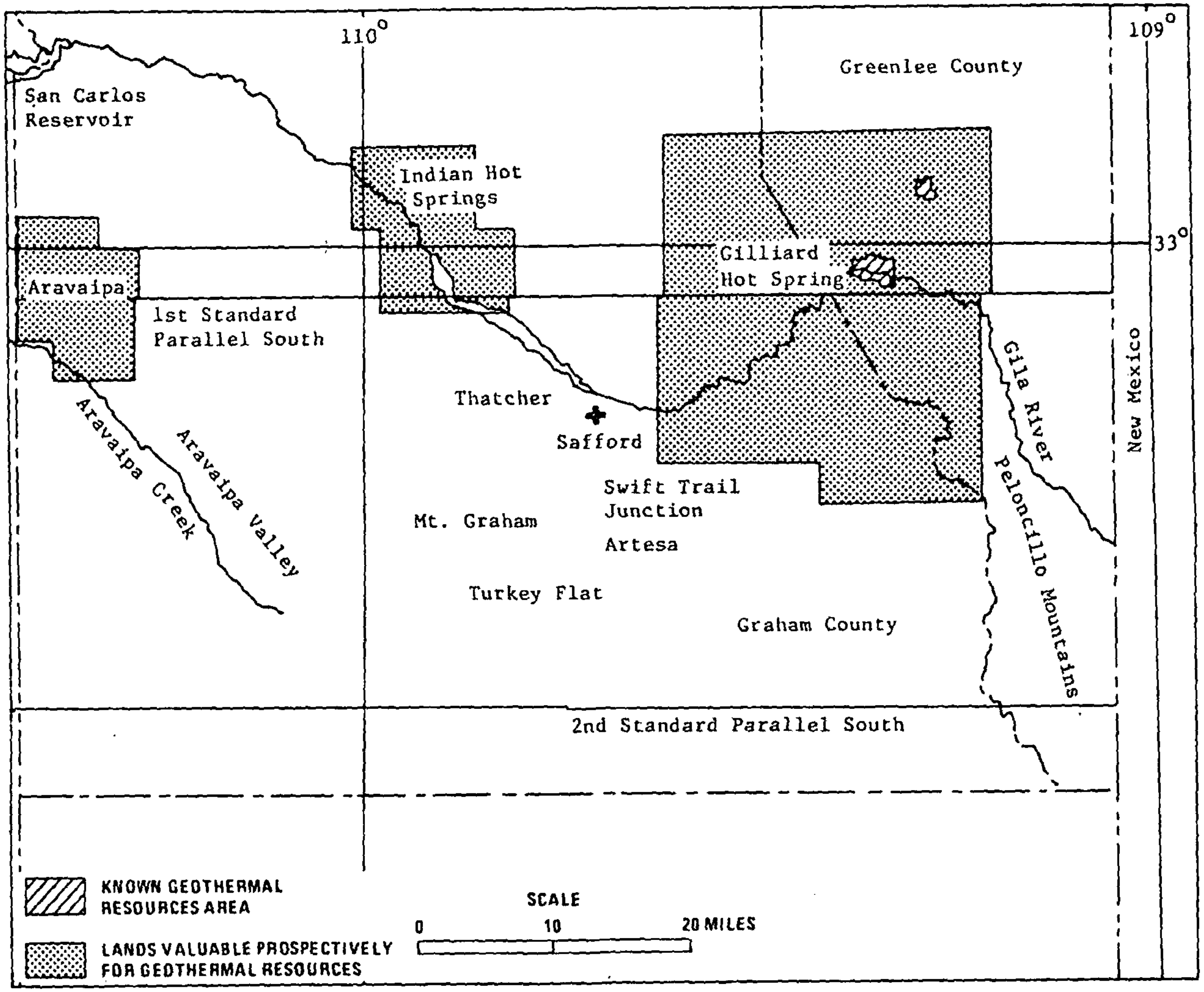
Blackwell, D. D., 1975, Interpretation of geothermal data from Desert Peak 29-1, Churchill County, Nevada. Confidential report for Phillips Petroleum Company, 19 pp.

NEV

- Truckee Meadows, Nev, ~~[illegible]~~ Washoe Co, – heating 32 dwellings + 3 commercial blgs

- (not available) Evaluation of Geothermal Activity in Truckee Meado, Washoe Co, Nev,
  Bateman, R.L and Scheibach, R.B., Univ. Nev., 1975, Reno

- (not available) GeoThermal Exploration and Development in Nevada through 1973
  Garside, L.J., Univ. Nev., Reno, 1974



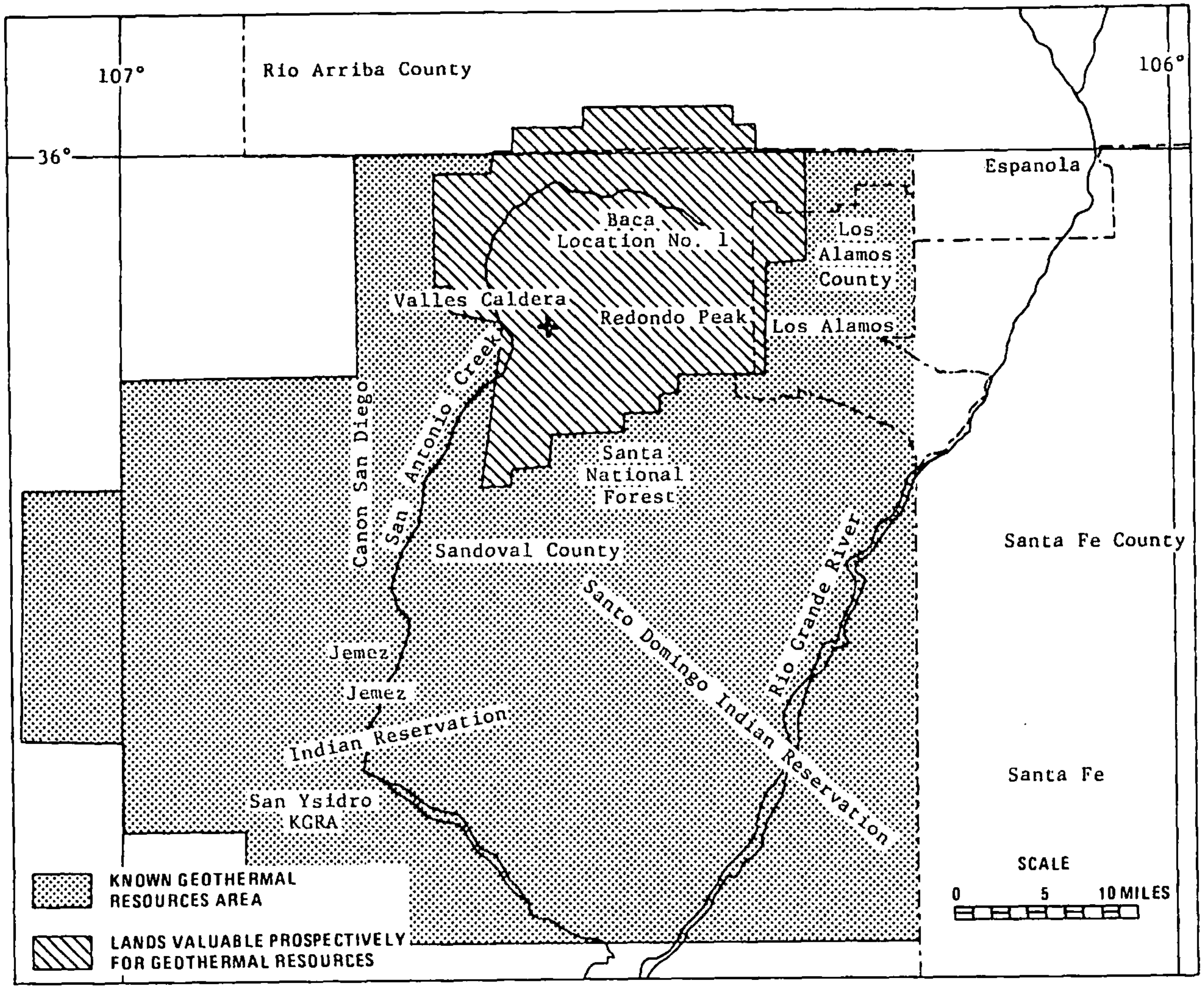
SITE: SAFFORD, AZ

AZ

SITE: SAFFORD, AZ

GEOTHERMAL DEVELOPMENT STATUS

PRESENT DEVELOPMENT STATUS	PROJECTED OR PLANNED DEVELOPMENT
305 m (1,000 feet) mineral exploration wells encountered 100°C.(20) Indian tribes and Sun Oil involved in development. (Sun Oil interested in Springville area).(20)	There is a possibility of direct heat application and electrical potential in Safford-Morenci Copper district. Demo plant needs were not apparent by February 1977.(20) Reservoir assessment is planned for 1977-78. USGS will initiate regional volcanic mapping in 1977. Arizona (ABM) will select sites in 1977 for 1978 work. Market analysis of potential use of heat by copper industry should be initiated in 1977.(20)



SITE: VALLES CALDERA, NM

N. Mex

SITE: VALLES CALDERA, NM

GEOTHERMAL DEVELOPMENT STATUS

PRESENT DEVELOPMENT STATUS	PROJECTED OR PLANNED DEVELOPMENT
The Union Oil Company has drilled 16 wells of which 9 or 10 are producing wells. The wells that Union drilled along Sulfur Creek were not satisfactory. Of the 6 wells that were drilled at Redondo Peak, 3 had flow rates of separated steam >50,000 lbs/hr and 3 wells had flow rates ≤50,000 lbs/hr. Maximum temperatures at the Redondo Peak wells were ∿300°C. Well costs have been as high as $1,000,000 per well.(47) In June 1977, negotiations were underway to sell steam to utility companies.(47) By February 1977, the Los Alamos Scientific Lab (LASL) was conducting a hot dry rock experiment at Fenton Hill to the west of the KGRA.(20) Wells drilled by LASL prior to June 1977 produced no heat or hot dry rock. (47)	Union Oil is planning to construct a 50 MWe generator at Redondo Peak. (It is estimated that 8 to 10 additional producing wells are needed.)(47)

SITE: CHANDLER, AZ (REGION 4)

SUMMARY

TEMPERATURE °C
Surface: Subsurface: 178°C (352°F)(4) 184-200°C(20)

TOTAL DISSOLVED SOLIDS (PPM): 62,000 (possible contamination from salt based drilling mud)(4)
ESTIMATED ELECTRIC ENERGY POTENTIAL (MWe 30 YEARS): 200(20)
TYPE OF OVERLAYING ROCK: Medium to Hard - first 1524 m (5000 feet) soft
ESTIMATED DEPTH TO TOP OF RESERVOIR (METERS):

DESCRIPTION OF KGRA
Total KGRA Acres: No KGRA defined
Total Federal Acres: Total State and Private Acres:
Federal Acres Leased: State and Private Acres Leased:

GEOTHERMAL DEVELOPMENT STATUS: Two deep wells were drilled. Neither was a good producer when completed with liner and downhole pumps. The deepest well was drilled to 3,186 m (10,450 feet).(4) No known drilling taking place in June 1976.(2)

LOCAL AND STATE ATTITUDE TOWARD GEOTHERMAL DEVELOPMENTS: Geothermal development not being pursued (little public interest in it.)(1) The local administration is not against development.(4)

LAND USE AND POPULATION: Grazing and farmland. Williams Air Force Base adjoins site.(4) Rural area outside Phoenix.(4)

COMMENTS AND CRITICAL ISSUES: Water shortage in area. Electric power generated from dams on Salt River.(4) Possible nonelectric geothermal development.(20) Geothermal development at Chandler will depend upon Federal leasing.(47)

AZ

SITE: CHANDLER, AZ

GEOTHERMAL DEVELOPMENT STATUS

PRESENT DEVELOPMENT STATUS	PROJECTED OR PLANNED DEVELOPMENT
Two deep wells by Geothermal Kinetics were drilled by August 1975. Neither hole was a good producer when completed with a slotted or perforated liner and down-hole pumps.(4) The first well which was drilled to 2,806 m (9,207 feet) had a temperature of 163°C and low permeability. (The flow rate was ∿2,000 gal/minute.) The second well was drilled to 3,186 m (10,454 feet) and had less permeability.(47) In June 1976, no known drilling activity was taking place.(2)	Possible nonelectric geothermal development may occur near Phoenix and Tucson.(20)

ARIZ.

ARIZONA OIL AND GAS CONSERVATION COMMISSION
1645 W. Jefferson, Suite 420
Phoenix, Arizona 85007

SUPPLEMENT TO TABLE IV-1, PAGE 39, DRAFT - REGIONAL HYDROTHERMAL DEVELOPMENT PLAN, JUNE 16, 1978

Data abstracted from Thermal Gradient Anomalies in Southern Arizona, Report of Investigation 6, 1978, and Subsurface Temperature Maps, State of Arizona, GT-3, 1977, published by the Oil and Gas Conservation Commission.

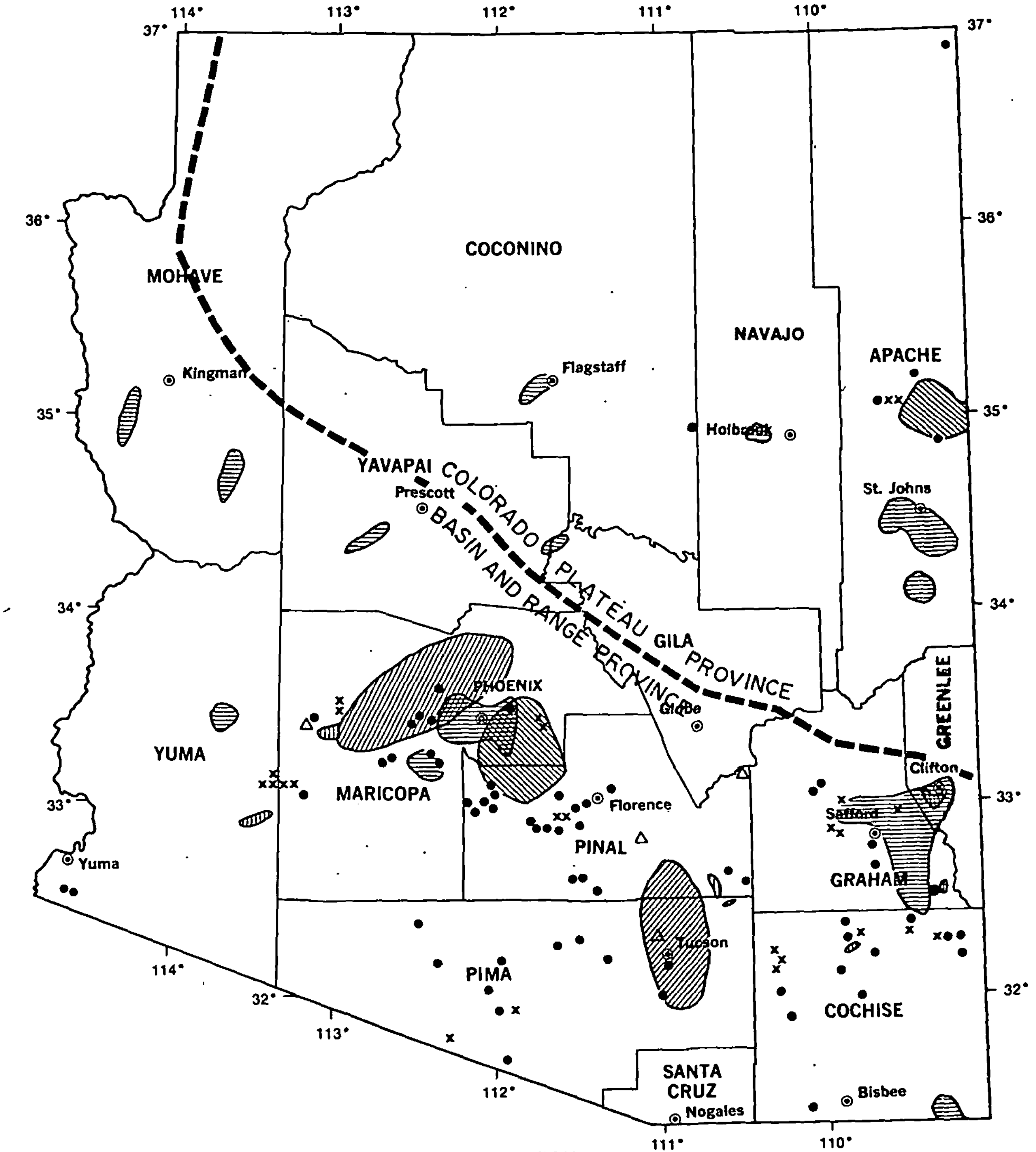
Type of temperature measurement: D = drill stem test data; G = bottom-hole temperature recorded on geophysical log; T = temperature log

Type of hole: P = petroleum test; S = stratigraphic; G = geothermal

RI 6 NO.	O&GCC ID NO.	LOCATION	TEMP. °C		DEPTH AND GEOLOGIC AGE (m)		THERMAL GRADIENT °C/km	TYPE HOLE
COLORADO PLATEAU PROVINCE								
		Apache County						
159	60	40N-25E-11 NE SE	68.9	D	1985	Precambrian? metamorphics	30	P
160	95	40N-26E-20 SE SE	70.0	D	1871	Devonian	32	P
165	179	40N-28E- 6 NW SW	77.2	D	2178	Mississippian	30	P
191	245	41N-25E-20 NE NE	62.2	D	1993	Devonian	26	P
222	44	41N-30E-10 NW SW	61.7	G	1928	Mississippian	25	P
226	46	-16 SW SW	71.7	G	2070	Cambrian?	28	P
		Coconino County						
8	474	29N-14E-11 NW NW	60.0	D	2118	Precambrian granite	23	P
10	3-6	37N-14E-28 N½ NE	61.1	G	2198	Cambrian	22	P
BASIN AND RANGE PROVINCE								
		Cochise County						
35	2-3	13S-24E-23 SW SE	86.7	T	2028	Cretaceous?	35	P
65	2-5	13S-30E-27 SE NE	134.4		1952 ?	?	61	P
		Pima County						
68	597	16S-15E- 5 NE SW	146.7	G	3834	Precambrian?	33	S
		Pinal County						
321	622	7S- 8E- 8 SE SW	82.2	G	1782	Tertiary (quartzite, schist, altered feldspar)	34	G
406	583	8S- 8E- 2 NW SE	110.0	G	3101	Precambrian	21	S
		Maricopa County						
530	605	2S- 6E- 1 NE SE	117.8	G	2768	Igneous rock	35	G
529	611	- 1 SE NE	120.0	G	2783	Tertiary volcanics	36	G
		Yuma County						
253	604	11S-24W- 8 SW NE	137.8	G	3219	Miocene	36	S

ARIZ

Thermal Gradient Anomalies – Southern Arizona
Giardina and Conley
Ariz. Oil & Gas Conservation Comm., Tucson, 1978



EXPLANATION

NEW MEXICO ENERGY INSTITUTE REPORT NO. 006	ARIZONA OIL AND GAS CONSERVATION COMMISSION
ANOMALOUS GEOTHERMAL REGIONS	GEOTHERMAL ANOMALIES – GRADIENTS > 60° C/Km

- ▤ High chemical geothermometers
- ▨ High heat flow (> 2.5 HFU)
- ▥ High geothermal gradients (> 150° C/Km)
- ▧ Moderate geothermal gradients (> 36° C/Km)
- △ Single point anomalies

- x Multi-well control within a minimum radius of 2½ miles
- ● Single well control

FIG. 9. — Map showing location of geothermal anomalies of this report with respect to anomalous geothermal regions of Swanberg and others (1977).

ARIZ

Arizona Energy - A framework for Decision
M. Ellen Hale, ed., U. of Ar. Press, Tucson 1976

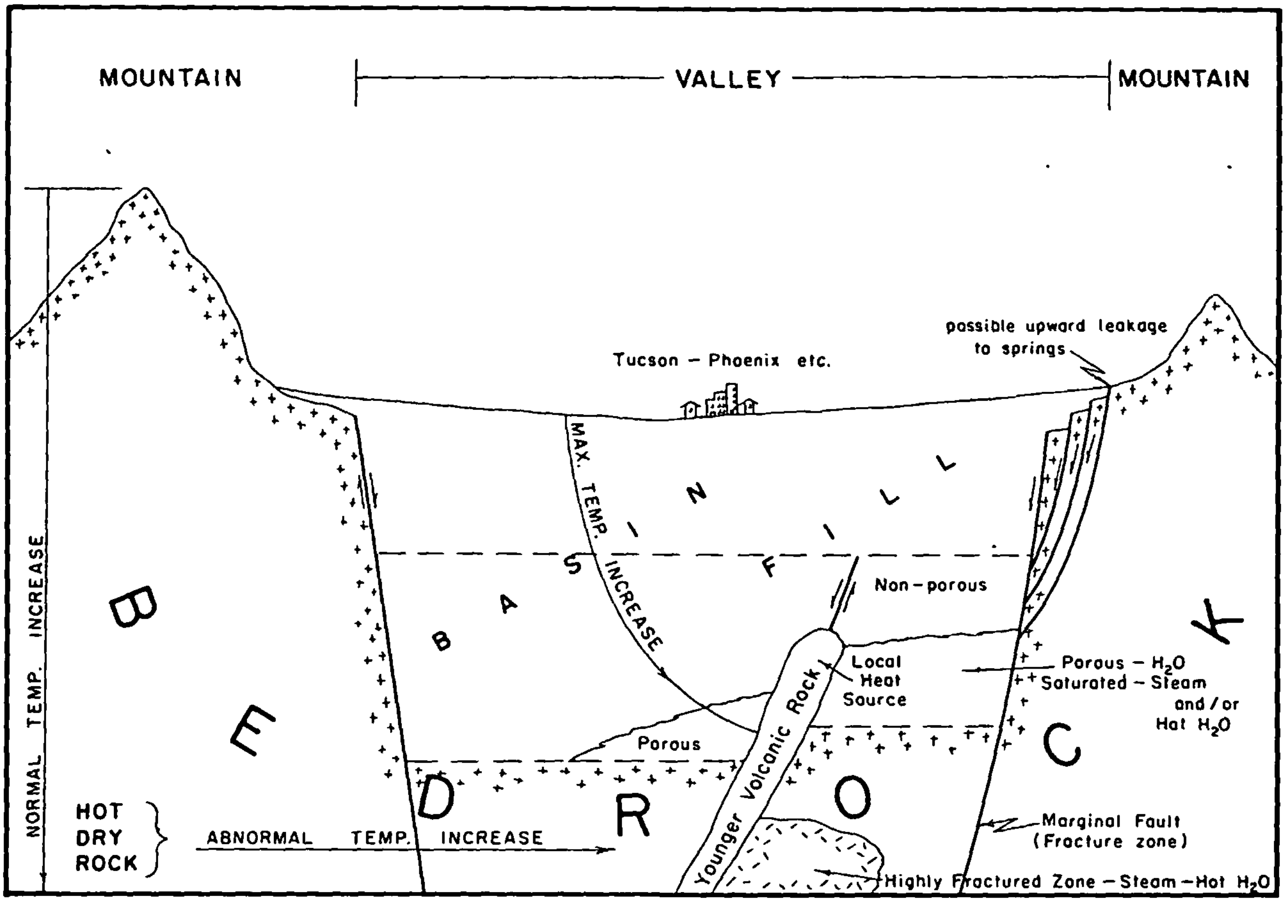


Fig. 3.5. Possible Geothermal Energy Sources in the Basin and Range Province of Southern Arizona.

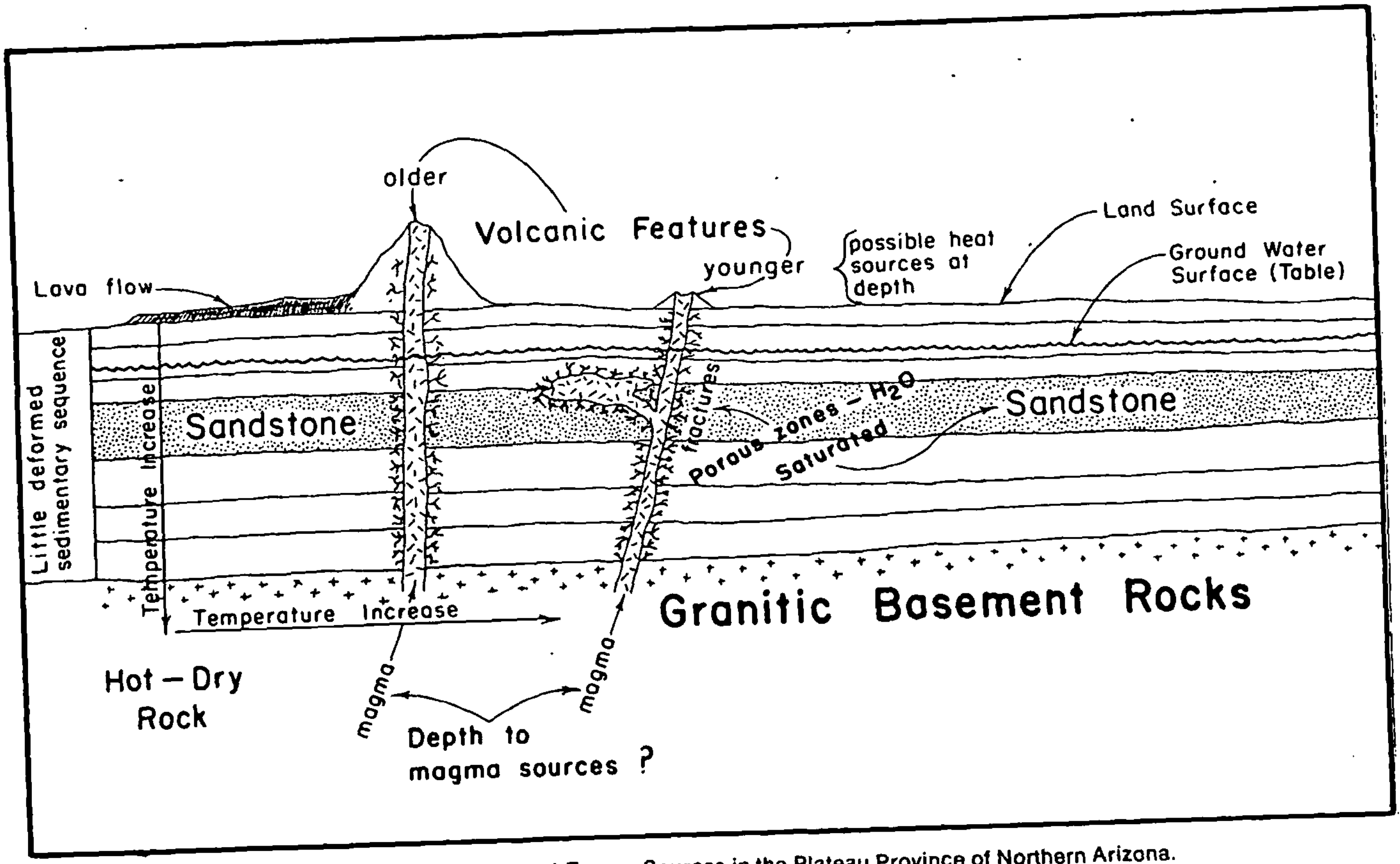


Fig. 3.6. Possible Geothermal Energy Sources in the Plateau Province of Northern Arizona.

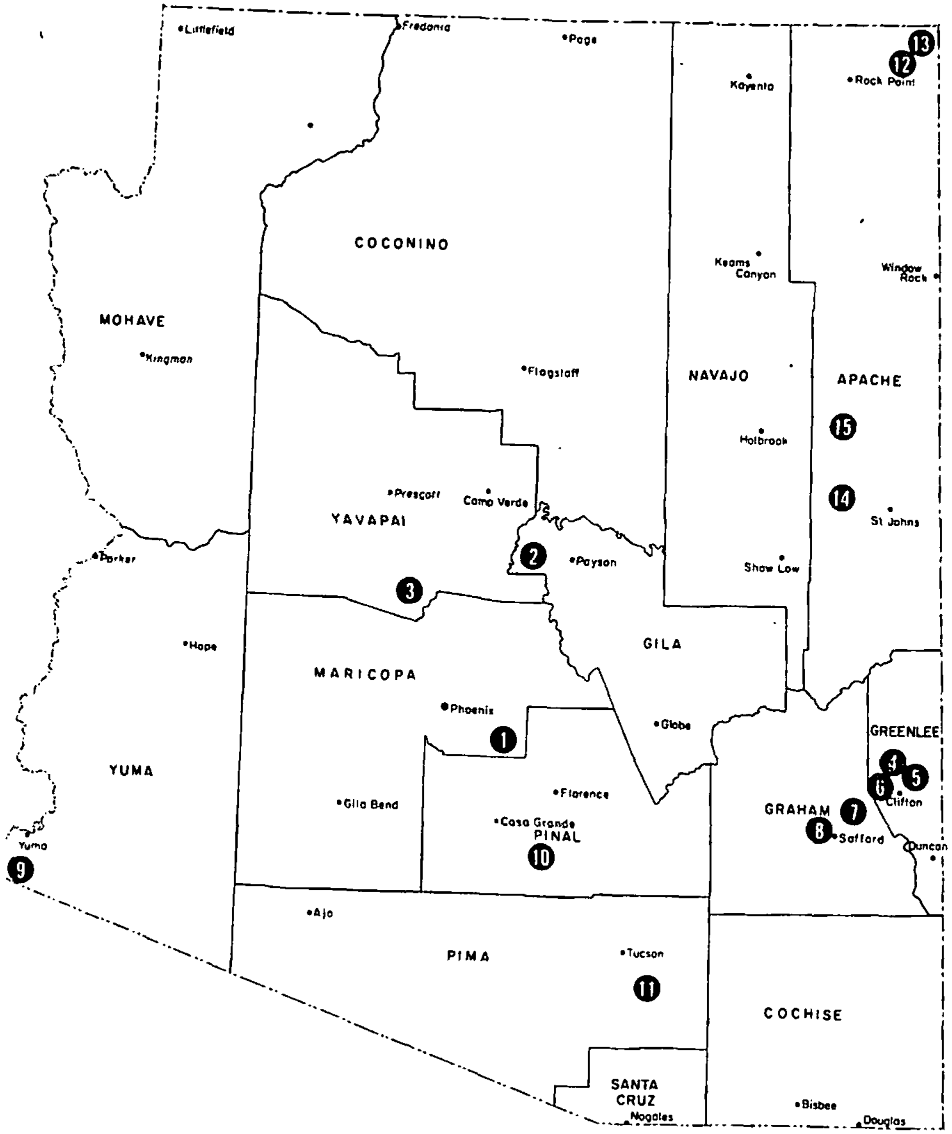


Fig. 3.4. Geothermal Hot-Water Sites In Arizona.

ARIZ

TABLE 3.5

Bottom Hole Temperatures of Some Deep Arizona Basin and Range Drill Holes

	Location			Temperature	Depth
Code*	Sec.	Township	Range	(°C)	(Feet)
9.	8	11S	24W	138 (280°F)	10,596
10.	2	8S	8E	110 (230°F)	10,179
11.	5	16S	15E	146 (296°F)	12,556

* Code: 9. Exxon Yuma — Fed. No. 1 — Yuma County — Bottom hole in basalt
10. Exxon State (74)-1 — Pinal County — Bottom hole in gneiss
11. Exxon State (32)-1 — Pima County — Bottom hole in granite

TABLE 3.6

Bottom Hole Temperatures of Some Plateau Drill Holes

	Location			Temperature	Depth
Code	Sec.	Township	Range	(°C)	(Feet)
12.	1	39N	29E	46 (114°F)	8,461
13.	2	40N	30E	57 (135°F)	7,230
14.	12	13N	25E	34 (94°F)	3,680
15.	23	18N	25E	69 (157°F)	3,456

The average heat flow in the Basin and Range geologic province is significantly higher than it is in the Plateau geologic province. Much of the Basin and Range in Arizona is underlain by rocks within 10,000 feet of the surface, or less than two miles, with temperatures higher than needed to boil pure water at the surface. This is a vast amount of stored heat energy and represents a potential resource (Figure 3.5) in Arizona that must be studied from the point of view of recovering and using naturally existing hot water as well as introducing water to the heater and recovering it as flashed steam and/or hot water. Arizona does have potentially useful geothermal energy (Figures 3.5 and 3.6) and only increased geologic, economic and technologic research will determine if any of the known geothermal resources can be relabeled reserves.

Energy Storage

Arizona's geologic environment provides an option for the storage of vast amounts of energy materials — natural gas, butane, propane and even liquefied natural gas (LNG) and petroleum. While not strictly an energy source, storage capacity is an important factor in planning not citable Ariz

Other indications of geothermal resources include a large number of anomalously warm wells and springs, mainly in the Basin and Range portion of the state. There are also several areas of unusually high heat flow, and many areas contain anomalous geochemical thermometers.

1.2 High-Temperature Resources (see Figure IV-2)

1.2.1 Confirmed Reservoirs: None.

1.2.2 Prospects: Little drilling has been done for geothermal resources in Arizona, and only one deep geothermal hole has been attempted. The following table shows the temperature and depth of water found in a number of oil and gas test wells:

TABLE IV-1

WATER IN ARIZONA PETROLEUM WELLS

Name	Location	Temperature (°C)	Depth (m)
Chandler	T2S R6E	120	2781
La Planta	T7S R8E	120	3186
Picacho	T8S R8E	113	2440
Tucson South	T16S R5E	147	3830
San Simon	T13S R30E	134 (?)	1951

Other oil and gas test wells and one geothermal test well (between Coolidge and Eloy) have encountered water at elevated temperatures less than 100°C. These wells have all been drilled in the valley areas, and no systematic geothermal prospecting has yet been done in any of the areas of recent volcanism.

1.2.3 Potential for Discovery. There are relatively few petroleum test wells in Arizona. Petroleum Information Corp. lists only 850 wells in its computer files, whereas about 106,000 wells have been drilled just in the Permian Basin of western Texas and eastern New Mexico. Researchers know of a number of areas with unusual geothermal gradients

Western US

Utilization of U.S. Geothermal Resources
by John Reitzel, TRW, Inc., 1976

Table 3-1

MAJOR KNOWN HYDROTHERMAL SYSTEMS OF THE WESTERN UNITED STATES

		USGS DATA				
NO.	SYSTEM	RESERVOIR TEMP°C	AREA km^2	VOLUME km^3	HEAT CONTENT 10^{18} cal	CAPACITY MWe x 30 yr.
1*	Yellowstone, Wyo.	250	375	940	133	15,760
2	Bruneau-Grandview, Ida.	145	2,250	3,375	263	13,060
3*	Long Valley, Calif.	220	225	450	55	5,740
4*	Coso H.S., Calif.	220	168	336	41	4,280
5*	Salton Sea, Calif.	340	54	108	21	3,750
6*	Valles Caldera, N.M.	240	65	130	18	2,030
7*	Surprise Valley, Calif.	175	125	250	24	1,940
8*	Geysers, Calif.	240	70	140	19	1,590
9	Klamath Falls, Ore.	120	240	480	30	---
10	Heber, Calif.	190	50	100	11	990
11	Beowawe, Nev.	240	21	42	5.7	640
12	Vale H.S., Ore.	160	50	100	8.7	600
13*	Mt. Lassen, Calif.	240	47	47	6.3	530
14	Crane Creek, Ida.	180	30	60	5.9	500
15	East Mesa, Calif.	180	28	56	5.5	470
16	Weiser, Ida.	160	35	70	6.1	420
17	Brady H.S., Nev.	214	12	30	3.6	370
18	Brawley, Calif.	200	27	27	3.0	290
19*	Cove Fort, Utah	200	15	22	2.5	240
20*	Steamboat Spgs., Nev.	210	6	16	1.9	190
21	Gerlach, Nev.	170	10	25	2.3	180
22	Stillwater, Nev.	160	10	25	2.3	150
23	Mickey H.S., Ore.	210	6	12	1.4	140
24*	Morgan Spgs., Calif.	210	5	10	1.2	120
25*	Roosevelt, Utah	230	4	8	1.0	110
26	Hot Lake, Ore.	180	6	12	1.2	100
27	Sulphur H.S., Nev.	190	4	10	1.1	100
28	Lakeview, Ore.	160	8	16	1.4	100
29	Soda Lake, Nev.	165	5	12	1.1	80
30	Leach H.S., Nev.	170	4	10	0.9	70
31	Crumps Spring, Ore.	180	4	8	0.8	70
32	Calistoga, Calif.	160	5	9	0.8	60
33	Pinto H.S., Nev.	165	5	8	0.7	50
34	Alvord H.S., Ore.	200	3	5	0.5	50
	19 others hotter than 140°C	>140		150		700
	Total					55,470

*Associated with young volcanic system listed by Smith & Shaw (3-1).

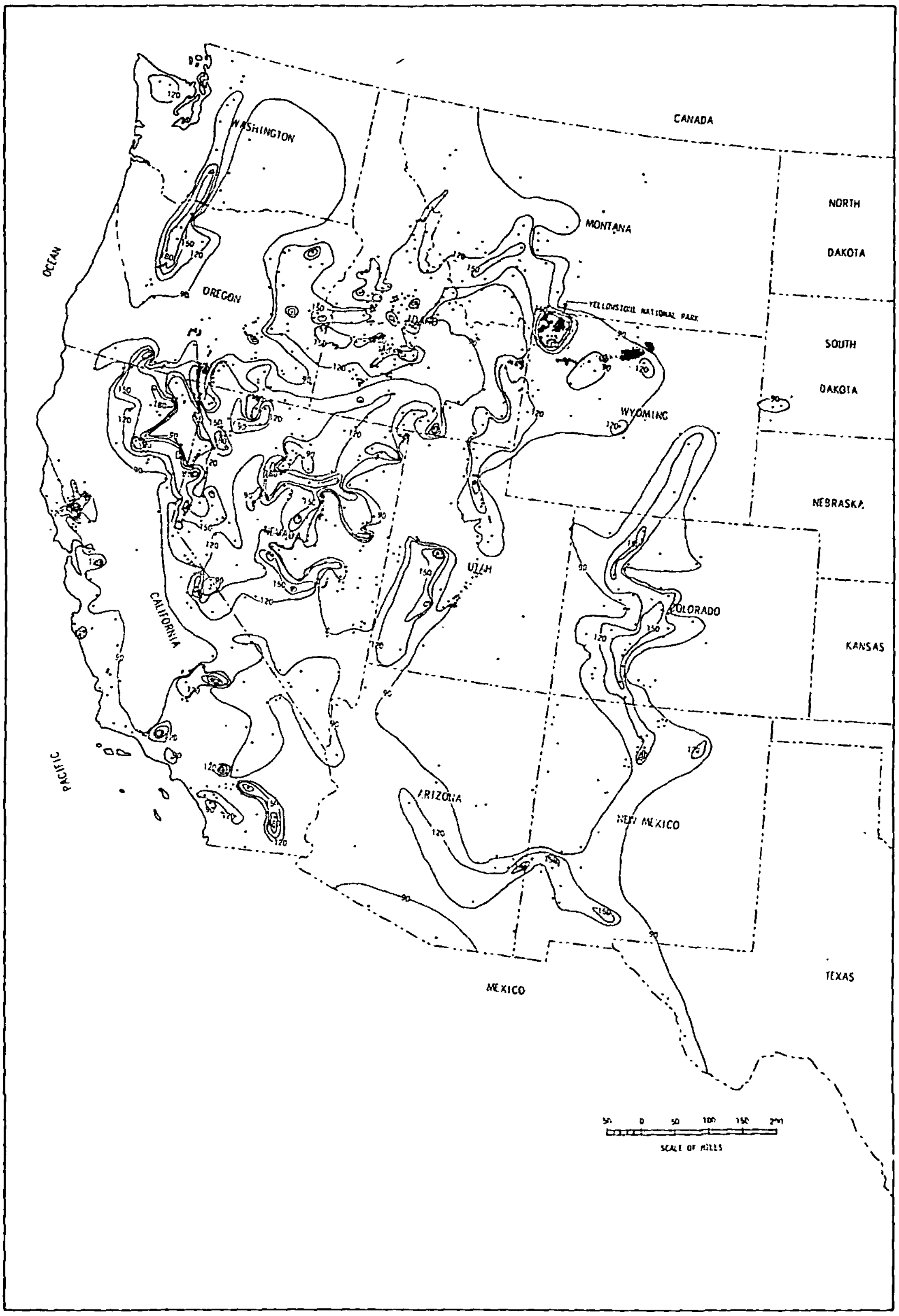


Figure 3-5. Hot Springs of the Western United States, with Contours of Surface Temperature [Sources: Waring (3-2), Choate (3-4)]

Table 5-1A. Geothermal Technological Developments (Electric Energy Production)

SUBSYSTEM	CURRENT R&D	$ X 1000 FY 75	$ X 1000 FY 76	CRITICALITY % TOTAL SYSTEM COST (BNWL - 1989) 300°F	400°F	500°F	FUTURE TECHNOLOGICAL DEVELOPMENTS COMPONENT OR TECHNIQUE	R&D EFFECT ON FUTURE COSTS	SCENARIO	TIMETABLE 80 85 90 95
ENERGY SUPPLY • WELLS • PUMPS • PIPING • REINJECTION	ERDA (76-53) 6 DRILL TECHNOLOGY 1 WELL PUMP 2 DRILL/PUMP INSTRUMENTATION 1 WELL STIMULATION ERDA PENDING 2 WELL PUMP 1 WELL STIMULATION INDUSTRY 2 IN-HOUSE PUMP (+) TOTALS	904 - 67 - 971	2,000 650 370 30 3,050	57%	BNWL HOLT 38%	30%	WELL COMPLETION	INCREASE FLOW - TOTAL COST DECREASE OF 4 TO 8% WITH 10% FLOW INCREASE	WELL STIMULATION R&D (PRODUCTION & INJECTION)	AS USUAL ACCELERATED
							SELF-PUMP WELL COMPLETIONS	SAME AS ABOVE	DEVELOP AND DEMONSTRATE STAGGERED BORE CONFIGURATION	AS USUAL ACCELERATED
							DOWN-HOLE PUMPS	SAME AS ABOVE	CONTINUE THE 3 ERDA DEVELOPMENTS	AS USUAL ACCELERATED
								INCREASE PUMP/MTR EFFICIENCY	R&D TO OPTIMIZE WELL BORE SIZE & PUMP/MTR CONFIGURATION & EFFICIENCY	AS USUAL
								10% EFFICIENCY INCREASE RESULTS IN 5% TOTAL COST DECREASE		ACCELERATED
							HIGH TEMP/HARD ROCK DRILLING	REDUCE RIG TIME & SUPPORT SERVICES 20 TO 50% PER WELL	R&D TO IMPROVE DRILL BIT LIFE & SERVICES	AS USUAL ACCELERATED
							EXTEND WELL LIFE	INCREASED WELL LIFE FROM 10 TO 20 YEARS - RESULT 10% REDUCTION IN COST OF POWER	R&D TO IMPROVE WELL CASING & COMPLETION TO INCREASE LIFE	AS USUAL ACCELERATED
HEAT REJECTION • WET TOWERS • DRY TOWERS • WET/DRY TOWERS	ERDA (76-53) NONE IDENTIFIED EPRI WASTE HEAT REJECTION STUDY	- -	 50	3% WET 10%	6% WET TO DRY	6% WET 20%	DRY OR WET/DRY COOLING TOWERS	NEED IN AREAS WHERE MAKE-UP WATER CRITICAL OR NOT AVAILABLE	CONTINUE EPRI STUDIES	AS USUAL
								EPRI (HOLT) STUDY - WET 105°F CONDENSING vs DRY 130°F RESULTS IN 50% INCREASE IN UNIT COST/KWH	R&D ON DRY & WET/DRY COOLING TOWERS	ACCELERATED
								ERDA (BNW/TRW) STUDIES - WET 110°F CONDENSING 8% AND DRY 125°F CONDENSING 22% OF PLANT COSTS		

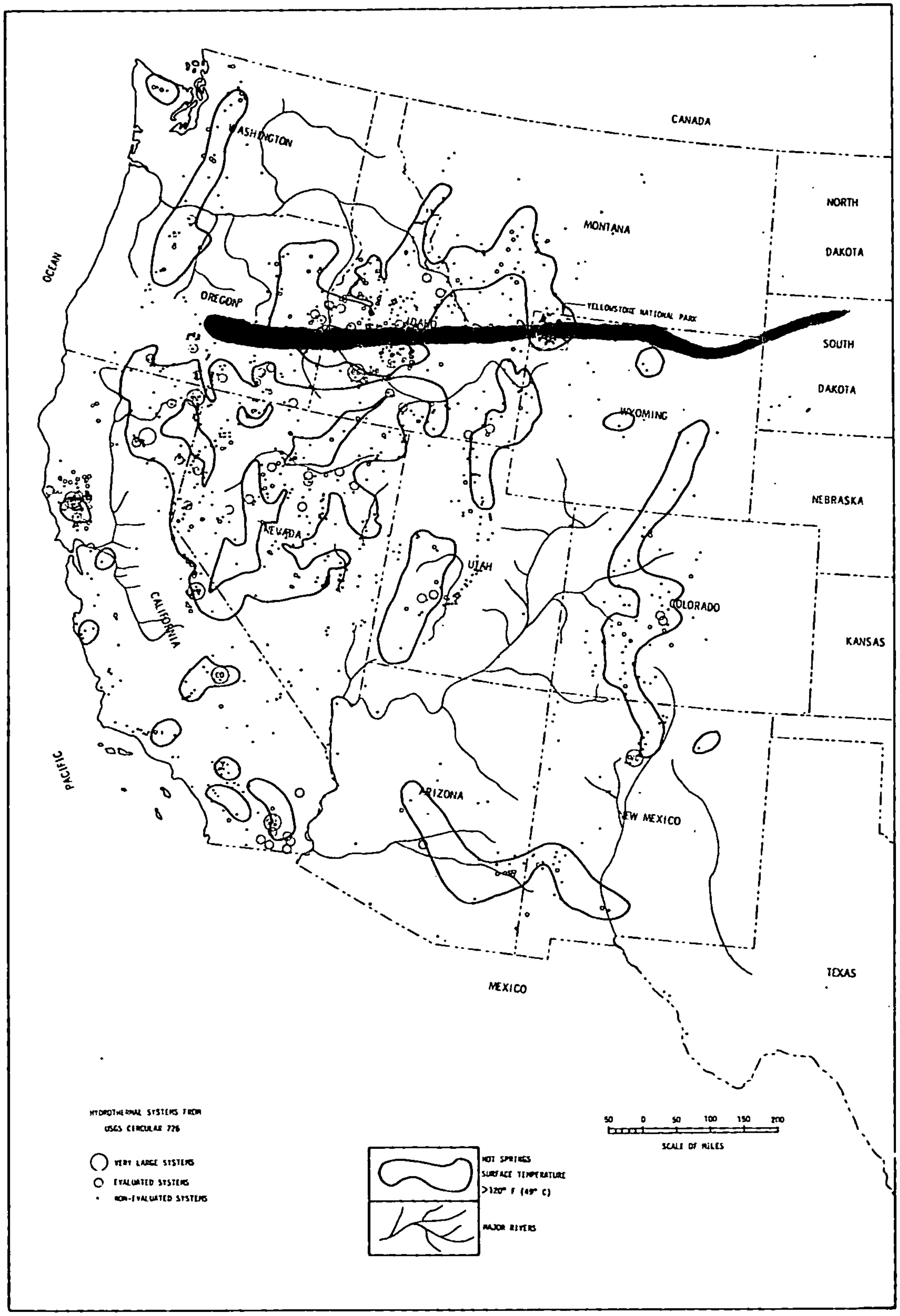


Figure 3-6. Hydrothermal Systems and Hot Springs, with 120°F Hot Spring Contour

Table 5-1B. Geothermal Technological Developments (Electrical Energy Production) (Continued)

SYSTEM OR SUB-SYSTEM	CURRENT R&D			CRITICALITY % TOTAL SYSTEM COST (BNWL - 1989)			FUTURE TECHNOLOGICAL DEVELOPMENTS			
		$ X 1000					COMPONENT OR TECHNIQUE	R&D EFFECT ON FUTURE COSTS	SCENARIO	TIMETABLE
		FY 75	FY 76	300°F	400°F	500°F				80 85 90 95
HEAT EXTRACTION • HEAT EXCHANGER • FLASHER (STEAM) SEPARATOR) • SCALE CONTROL • CORROSION CONTROL	ERDA (76-53) 7 HEAT EXCHANGER 5 SCALING CONTROL 6 CORROSION CONTROL EPRI BRINE CHEMISTRY BRINE TREATMENT (+) TOTAL	 1,116 974 1,138 -- -- 3,228	 637 1,332 915 350 21 3,255	 9% HX 1%	EQUIPMENT 14% HX SCALE MAINTENANCE 1%	 3% FLASHER 1%	DIRECT CONTACT HX	ELIMINATES SURFACES NO SCALING IMPACT POTENTIAL SYSTEM COST REDUCTION 1 TO 2%	CONTINUE 4 CURRENT ERDA CONTRACTS	AS USUAL ACCELERATED
							FLUIDIZED BED HX	BED PROVIDES MINIMUM PRECIPITATION SITES, MINIMUM SCALING IMPACT POTENTIAL SYSTEM COST REDUCTION 1/2 TO 1-1/2%	CONTINUE 3 CURRENT ERDA CONTRACTS	AS USUAL ACCELERATED
							SCALE CONTROL	ELIMINATES COST OF REDUNDANT HX & MINIMIZE MAINTENANCE POTENTIAL SYSTEM COST REDUCTION 1 TO 2%	R&D ON METHODS • BRINE TREATMENT (PH ADJUSTMENT) • NON-STICK COATINGS • CHEMICAL PRECIPITATION	AS USUAL ACCELERATED
							CORROSION CONTROL	MATERIAL COST MINIMUM POTENTIAL SYSTEM COST REDUCTION 1/2 to 1-1/2%	R&D • LININGS • MATERIALS (CR-40 vs TITANIUM	AS USUAL ACCELERATED
							FLASHER (SEPARATORS)	TECHNOLOGY HERE NOW MINIMUM IMPACT ON TOTAL SYSTEM COST	IMPROVE DESIGNS TO FACILITATE MAINTENANCE	AS USUAL

Table 5-1C. Geothermal Technological Developments (Electrical Energy Production) (Continued)

SYSTEM OR SUB-SYSTEM	CURRENT R&D			CRITICALITY % TOTAL SYSTEM COST (BNWL - 1989)		
		$ X 1000				
		FY 75	FY 76	300°F	400°F	500°F
ENERGY CONVERSION • ENERGY CONVERTERS (TURBINES/ EXPANDERS) • WORKING FLUIDS/ CYCLES	ERDA (76-53)					
	2 TOTAL FLOW	1,806	2,052	TURBO-GENERATOR		
	HELICAL SCREW	713	--			
	SMALL GENERATOR	22	130	BINARY	BINARY	STEAM
	WORKING FLUIDS	85	141	6%	9%	23%
	CONCEPT DESIGNS	269	1			
	THERMAL LOOP	--	2,800			
	RAFT RIVER	2,744	2,620			
	INDUSTRY					
	IN-HOUSE (ELIOT, GE MITSUBISHI)					
	EPRI					
	LS DEMO FEASIBILITY	88	675			
	TURBINE DESIGN STUDY	--	50			
	(+) TOTALS	5,727	8,469			

FUTURE TECHNOLOGICAL DEVELOPMENTS			
COMPONENT OR TECHNIQUE	R&D EFFECT ON FUTURE COSTS	SCENARIO	TIMETABLE 80 85 90 95
TURBINE EXPANDER (BINARY)	TECHNOLOGY HERE NOW NEED SYSTEM DEMONSTRATION MODULE SIZE OPTIMIZATIONS NEEDED TO INPUT PLANT SIZE DECISION MAKING MINIMUM IMPACT ON SYSTEM COSTS	OPTIMIZE MODULE SIZE OF AXIAL AND RADIAL FLOW EXPANDERS	AS USUAL ACCELERATED
STEAM TURBINE	STATE-OF-ART SMALL TURBINE R&D TO IMPROVE AVAILABILITY AND REDUCE COST	DEVELOP SMALL SIZE TURBINES (5 TO 20MW)	AS USUAL ACCELERATED
WORKING FLUIDS	PURE FLUIDS HERE NOW MIXTURES TO INCREASE NET CYCLE WORK POTENTIAL SYSTEM COST REDUCTION 1/2 TO 1%	DEVELOP OPTIMIZED MIXTURE CRITERIA FOR LT & MT HYDROTHERMAL RESOURCES	AS USUAL ACCELERATED
WELLHEAD GENERATORS	R&D NEEDED TO IMPROVE SMALL SYSTEM (5TO 10MW) SYSTEM COSTS FOR REMOTE APPLICATIONS	HELICAL SCREW AND FREON EXPANDER R&D	AS USUAL ACCELERATED

Table 5-1D. Geothermal Technological Developments (Electrical Energy Production (Continued)

SYSTEM OR SUB-SYSTEM	CURRENT R&D			CRITICALITY % TOTAL SYSTEM COST (BNWL - 1989)			FUTURE TECHNOLOGICAL DEVELOPMENTS			
		$ X 1000					COMPONENT OR TECHNIQUE	R&D EFFECT ON FUTURE COSTS	SCENARIO	TIMETABLE
		FY 75	FY 76	300°F	400°F	500°F				80 85 90 95
<u>RESOURCE EXPLORATION AND ASSESSMENT</u> • EXPLORATION TECHNOLOGY • RESOURCE ASSESSMENT • RESERVOIR CONFIGURATION	<u>ERDA (76-53)</u> 4 EXPLORATION TECHNOLOGY 13 RESOURCE ASSESSMENT <u>USGS (CIRC. 726)</u> <u>EPRI</u> MOBILE LAB (+) TOTALS	 1,334 2,610 -- 3,944	 540 2,464 200 3,204	1%	EXPLORATION 3%	4%	EXPLORATION TECHNOLOGY • INSTRUMENTS • WELL LOG	MAXIMUM EFFECT ON HIGH TEMPERATURE RESERVOIR COSTS POTENTIAL 1% TOTAL REDUCTION	• DEVELOP SENSING TECHNOLOGY FOR HI TEMPERATURE BORE HOLES • R&D SURFACE AND AERIAL TECHNOLOGY	AS USUAL ACCELERATED
							RESERVOIR DEFINITION	MAXIMUM EFFECT ON LOW TEMPERATURE RESERVOIR COSTS MAXIMIZE PRODUCTIVE WELLS POTENTIAL 1 TO 2% COST REDUCTION	• REFINE MODELS • R & D LOW COST SLIM HOLE DRILLING	AS USUAL ACCELERATED
							RESOURCE ASSESSMENT	NEED INPUTS TO LONG RANGE PLANNING & DEVELOPMENT FUNDING	• REFINE MODEL TECHNIQUES • REFINE BRINE SAMPLING TECHNOLOGY	AS USUAL ACCELERATED
<u>NON-CONDENSIBLE GAS CONTROL</u> • H_2S ABATEMENT • EXTRACT NON-CONDENSIBLES	<u>ERDA</u> 1 GAS ANALYSES	325	12	BINARY N/A	BINARY N/A	UP TO 5%	H_2S ABATEMENT	MINIMUM COST IMPACT	IMPROVE TECHNOLOGY TO MINIMIZE ENVIRONMENTAL IMPACT	AS USUAL
							NON-CONDENSIBLE GAS EXTRACTION	STATE-OF-ART STEAM CYCLES ONLY-STEAM JET EJECTOR		AS USUAL
<u>WASTE HEAT UTILIZATION</u> • NON-ELECTRIC	<u>ERDA (76-53)</u> 2 NON-ELECTRIC <u>ERDA (PENDING)</u> FY 77 - $2M 16 TO 19 CONTRACTS	300	800	--	-- SITE PECULIAR	--	NON-ELECTRIC USE OF LOW TEMPERATURE BRINES OR RESIDUAL HEAT	COULD SIGNIFICANTLY IMPROVE OVERALL TOTAL COST EFFECTIVENESS MOST IMPACT ON LT-MT RESERVOIRS	R&D ON RESERVOIR SITE SPECIFIC PROCESSES	AS USUAL ACCELERATED