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A section for teachers

Geothermal resources in New Mexico

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Introduction

Temperatures normally increase with depth in the earth. This results largely because of the initial heat of accretion (gravitational collapse) when the earth was formed some 4 to 5 billion years ago, and the normal decay of radioactive elements in the earth's interior. In areas where there has been no geological activity in the past few tens of millions of years (activity such as mountain building, magmatism, and volcanism) temperatures increase with depth generally at about 1°F/100 ft (1.8°C/100 m). In areas of relatively recent geologic activity, say in the past 10 million years or less, temperatures typically increase with depth much more rapidly, perhaps 2°F/100 ft. In locales where geothermal resources of some kind are potentially present, temperatures will increase with depth at 5–10°F/100 ft and more. It is the earth's heat associated with these elevated temperatures at depth that is the ultimate geothermal energy source.

New Mexico is a state of great geologic diversity with four major physiographic provinces which incorporate a half-dozen different geologic regions (Fig. 1). Subsurface temperature and heat flow studies, and the locations of thermal springs and young volcanism, indicate that the southern Basin and Range province and the southern Rocky Mountains province have the greatest potential for geothermal energy resources in New Mexico.

Resource description

Geothermal resources may be classified by the mechanism of heat transport as well as the temperature of the resource. Table 1 summarizes possible geothermal systems; we will discuss those important to New Mexico in some detail.

Forced convection systems (typically low temperatures, 95–195°F). At the present time only the forced convection type geothermal system is being utilized as a practical energy resource in New Mexico. Future geothermal resource development may be expected to concentrate on this type of convection hydrothermal resource. These systems involve the deep circulation of ground water under approximately normal subsurface temperature conditions for the region. After the ground water has been heated to relatively high temperatures at great depths, hydrogeologic conditions force the ground water to flow upward toward the surface. Therefore, warm water is obtainable at shallower depths than otherwise expected.

Two different geologic models can explain the forced convection geothermal systems (Fig. 2). Ground-water flow in both cases is driven by differences in water table elevation. First, in the constriction model, subsurface bedrock barriers force ground water to flow upward in the basin-fill aquifer (Fig. 2 top). Second, in the hydrogeologic window model, shallow low-permeability units confine ground water at depth (Fig. 2 bottom). Ground water rises to the surface at low elevation sites where the low-permeability material is missing and the aquifer crops out at the surface.

Fig. 3 shows locations of current geothermal energy use in New Mexico (sites 1–7). Table 2 presents information about these sites; sites 1–7 are low-temperature (95–195°F) forced convection sites as discussed in the preceding paragraph. These geothermal resources provide energy for direct heating applications to greenhouses and spas and for space heating. New Mexico is presently the nation's leader in geothermally heated greenhouse acreage with five commercial operations. The two largest geothermally heated greenhouses in the nation are operated by Burgett Flormat near Animas (20 acres) and by Masson S.W. Inc. at Radium Springs (8.5 acres; Fig. 3). Considerable economic growth potential exists for the geothermal greenhouse industry in New Mexico because of the large low-temperature (95–195°F) resource base, reasonable land prices, abundant sunshine, and an existing agricultural economy. Growth for geothermal space heating is possible for large-scale users who co-locate with a resource; in addition, controlled-environment fish farming and other low-temperature industrial applications also provide a potential for growth.

Electric power has been generated using geothermal energy in a remote location at Gila Hot Springs (site 3, Fig. 3) where abundant low-temperature (165°F or 175°F) geothermal water exists. Intermediate-temperature (195–354°F) hydrothermal convection systems near Animas and Rincon (sites 4 and 8, Fig. 3) have near-term potential for small (1–5 MW) power production using binary-cycle generators.

Free convection and hot dry rock systems (typically hot temperatures exceeding 350°F). New Mexico has a free convection hydrothermal system at the Baca geothermal field (more recently referred to as the Valles geothermal system) west of Redondo Peak, the resurgent volcanic dome in the young Valles caldera (site 9, Fig. 3). The Baca reservoir is underpressured and liquid dominated, with a base temperature exceeding 500°F (260°C). Seven production wells were drilled in the late 1970s and early 1980s; however, these wells produced only half the energy required for the 50 MW power plant proposed by Public Service Company of New Mexico in cooperation with the U.S. Department of Energy Geothermal Demonstration Power Plant Program. In early 1982 the project was terminated because of the lack of proven production with exploration wells. Future plans for the Baca geothermal field are unknown.

Hot dry rock systems are geothermal sites in which temperatures are high but fluids are practically absent. Although this resource may be potentially huge, economic and technical difficulties lay ahead. In New Mexico, an important hot dry rock resource has been defined on the Jemez Plateau just a few miles west of the Baca location (site 9, Fig. 3). The Fenton Hill hot dry rock site is heated by a shallow, cooling magma body, which is probably also the heat source for the Baca geothermal field. Temperature gradients at the Fenton Hill site are about 4.3°F/100 ft (78°C/km). In the early 1970s Los Alamos National Laboratory began research to develop an economic method of utilizing hot dry rock for electrical generation. The hot dry rock geothermal system utilizes a heat extraction loop between two wells connected by a system of hydraulically induced fractures. In the most recent experiments, beginning in the 1980s, two 13,000-ft holes were drilled into low-permeability rock with temperatures greater than about 500°F. Nearsurface cool water is injected into one well and pumped through the hydraulically induced fracture system to the second well where hot water returns to the surface at about 375°F. After heat extraction at the surface, water is recirculated back to the first well to form a closed loop with moderate water loss. Tests in the 1970s and 1980s show the potential of hot dry rock geothermal resources for electrical power generation.

Other possible geothermal resources. Geopressured geothermal resources are not known in New Mexico although in some of the deeper basins they may be present. Conduction hydrothermal resources (deep confined aquifers) may be extensive in the San Juan Basin (the Colorado Plateau of northwestern New Mexico), southeast New Mexico, and in the Tertiary basins of the southern Basin and Range province. At present, however, this resource is subeconomical because of the high costs of drilling coupled with moderate-temperature reservoirs. Small, shallow (8,000–13,000 ft deep) magma systems have been proposed at several locales in the Rio Grande rift valley, which runs N–S through central New Mexico. More work needs to be done to confirm the existence and establish the extent of these proposed bodies before energy potential can be assessed.

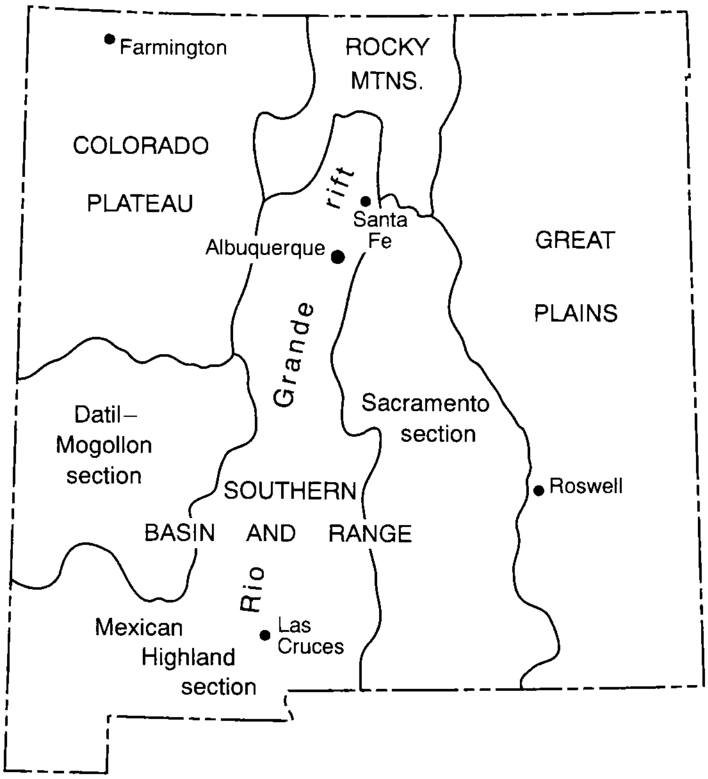

FIGURE 1—Physiographic provinces and subsections in New Mexico.

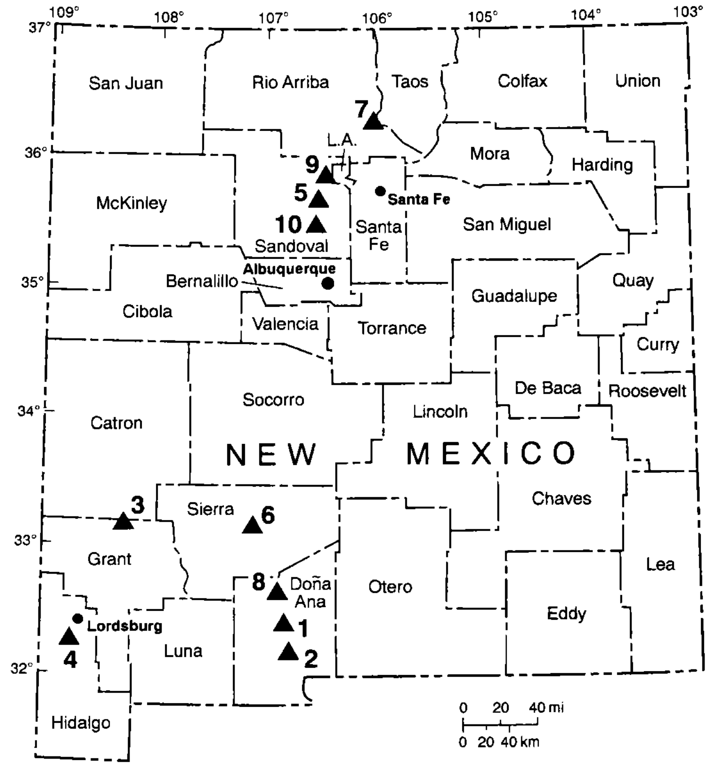

FIGURE 3—Geothermal utilization in New Mexico (see Table 2 for site description).

TABLE 1—Classification of geothermal resource systems.

I. Convection resources—heat transport dominated by fluid flow
   A. Magma systems—magma transports heat
   B. Free convection systems—temperature-induced buoyancy flow
   C. Forced convection systems—regional hydraulic-head-induced flow
II. Conduction resources—very little heat transport by fluid flow
   A. Hot dry rock—almost no natural fluid present
   B. Geopressured—deep, high-pressured, methane-bearing brine
   C. Conduction hydrothermal—deep confined aquifer

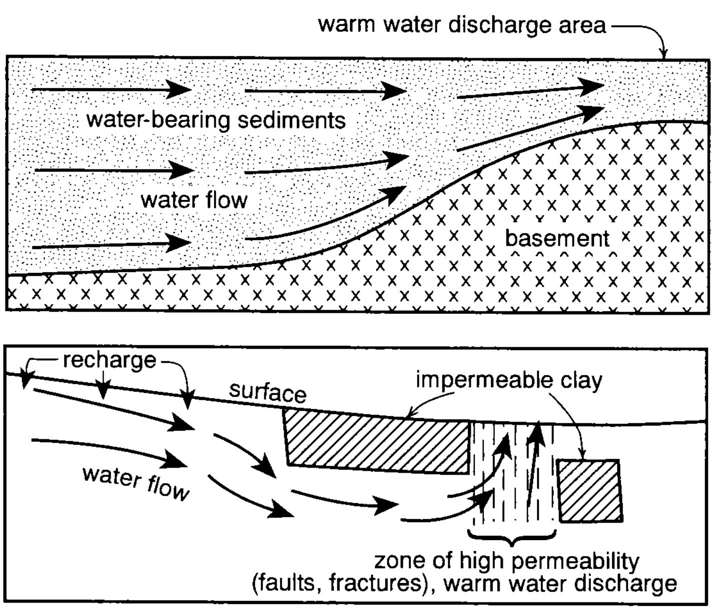

FIGURE 2—Geologic models of forced convection geothermal systems. Top is constriction model; bottom is hydrogeologic window model.

TABLE 2—Geothermal use and potential in New Mexico.

Location	Use	Temp (°F)	Well depth (ft)
Current use			
1. Radium Springs	A. Greenhouses (8.5 acres)	158–167	<500
	B. Mineral bath/ resort	140–158	<50
2. Tortugas Mountain	A. Space-heating NMSU campus	140–149	<1000
	B. Greenhouses (1 acre)	140–149	<1000
3. Gila Hot Spring	A. Space heating	140–165	<300
	B. Greenhouse (<1 acre)	140–165	<300
	C. Electrical generation (formerly 10 KW)	165	<300
4. Animas–Lightning Dock	Greenhouses (20 acres) (see also Rincon)	192–225	<500
5. Jemez Springs	A. Space heating	149–154	<500
	B. Mineral bath/resort	140–167	springs
6. Truth or Consequences	A. Mineral baths/ resorts	104–109	<300
	B. Space heating	104–109	<300
7. Ojo Caliente	Mineral bath/resort	122–131	springs
Near-term potential			
8. Rincon	Small power production, binary-cycle generator (1–5 MW)	>212	<2000
9. Baca field/ Fenton Hill	A. Electric power (20–240 MW)	>392	5,000–9,000
	B. HDR	>392	13,000
10. Jemez Pueblo	Greenhouse	136	<300

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An extensive list of references on the present subject may be found in Witcher, J. C., 1987, Geothermal resources in New Mexico: geologic setting and development update: The Interstate Oil and Gas Compact and Committee Bulletin, v. 1, pp. 49–60. A few other references used in the present report, published since 1987, include:

Barroll, M. C., and Reiter, M., 1990, Analysis of the Socorro hydrogeothermal system, central New Mexico: Journal of Geophysical Research, v. 95, pp. 21,949–21,963.

Clarkson, G., and Reiter, M., 1988, An overview of geothermal studies in the San Juan Basin, New Mexico and Colorado; *in* Coal-bed methane, San Juan Basin: Rocky Mountain Association of Geologists, pp. 285–291.

Duchane, D., 1991, Hot dry rock geothermal energy development program: Los Alamos National Laboratory, Annual Report F.Y. 1990.

Witcher, J. C., 1988, Geothermal resources of southwestern New Mexico and southeastern Arizona: New Mexico Geological Society, Guidebook to 39th Field Conference, p. 191–197. □

Summary of charges for natural resources other than oil and gas on New Mexico State Lands as of January 1, 1992

compiled by
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Type of lease	Length of lease	Filing fees	Annual rental	Royalty rate	Advance royalty	Acquisition method	Minimum bond
General mining	Primary—3 yr Secondary—2 yr Tertiary—5 yr Quaternary—5 yr Lease may be extended by production	$30.00	Primary (1–3 yr) @$0.25/acre Secondary (4–5 yr) @$2.50/acre Tertiary (6–10 yr) @$3.00/acre Quaternary (11–15 yr) @$10.00/acre Rental fixed at production	2% of gross sales price of materials; 5% on other minerals	0–10 yr—no advance royalty; Quaternary yrs.: 11th yr @ $10/acre 12th yr @ $20/acre 13th yr @ $30/acre 14th yr @ $40/acre 15th yr @ $50/acre Advance royalty of two years credited to production royalty	Competitive bid only, sealed or oral (Moratorium on over-the-counter leasing)	Performance bond—$2,000; at time mining commences—additional $5,000/lease
Potash	Primary—10 yr Five years in special cases Lease may be extended by production	$30.00	Negotiable, $100 minimum	Sliding-scale royalty depends on ore grade, ranges from 2–5% of gross sales price	None on older leases; negotiable	Application for lands shown to be open on the tract books	Performance bond for nonproducing—$5,000/lease Performance bond for producing—$10,000/lease (or $20,000 for multiple leases)
Salt	Primary—10 yr Lease may be extended by production	$30.00	$40 for each 40-acre legal subdivision	Not less than 10% of gross sales price at place of extraction	None	Application for lands shown to be open on the tract books	Performance bond—$500/lease (or $1,000 for multiple leases)
Coal	Primary—5 yr Secondary—5 yr Lease may be extended by production	$100.00	$5.00/acre or $500 minimum	12.5% of gross value at point of sale; 12.5% of market value in the area	1% of recoverable reserves	Competitive bid only, sealed or oral	Performance bond $15/acre Damage bond $20,000/lease $50,000 multiple leases (EMNRD bond filed may satisfy requirements)
Geothermal	Primary—5 yr Secondary—5 yr Lease may be extended by production	$30.00	1st–5th yr @ $1.00/acre 5th–10th yr @ $5.00/acre	See statutes* 10% gross value Byproduct: 5% gross value Power plant: 8% net revenue Recreation: 2–10% gross value Space heating: 2–10% gross value Health: 2–10% gross value	None	Competitive bid only, sealed or oral	Performance bond for nonproducing—$2,000/lease Performance bond for producing—$5,000/lease
Sand & gravel	Primary—1–5 yr (subject to change)	$30.00 (subject to change)	$40 for each 40-acre legal subdivision or any fraction thereof	See schedule in Rule 5* Range: $0.55–$1.45/yd^3	Negotiable	Application for lands shown to be open on tract books; 40-acre restriction	Damage bond—$5,000 Performance bond—$2,000 (except on purchase contract or patent)
Caliche	15-day permit	$30.00	None	See schedule in Rule 5* Range: $0.55–$1.45/yd^3	None	Application for lands shown to be open on tract books; 40-acre restriction	Damage bond—$5,000 Performance bond—$2,000 (except on purchase contract or patent) May tender advance royalty in lieu of performance bond

Data source: State Land Office, Mineral Division. *For information, contact the State Land Office, Mineral Division.