



ARIZONA WATER RESOURCES PROJECT INFORMATION

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SUMMARY OF A REPORT

ON

GEOTHERMAL WATER RESOURCES IN ARIZONA: FEASIBILITY STUDY*

The report summarized herein was prepared by:

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INTRODUCTION

Arid lands will undoubtedly experience increased energy stresses in the near future because of increasing internal populations and external energy appetities. Many arid lands are underlain by vast quantities of energy fuels, but geothermal energy is one of the few environmentally acceptable energy alternatives for arid regions based on criteria of water consumption, efficiency of energy production and pollution characteristics. This report summarizes the published findings of the authors' search of existing data related to Arizona geothermal resources and of geological investigations undertaken by them to provide a comprehensive guide for exploration and to suggest further studies.

arid environment not only because of the large quantities of water required, but also because of the pollution they tend to generate. Thus, geothermal water and magma energy resources become important as possible sources of energy to produce electricity without creating pollution on the same scale as the other alternatives and without the drain on Arizona's rather limited water resources.

WHY SEEK GEOTHERMAL WATER RESOURCES IN ARIZONA?

In Arizona, large deposits of fossil and nuclear energy fuels have not been extensively extracted. Exploitation of these deposits has been minimized, even in the recent past, by the scarcity of water needed to mine, refine and convert them to electricity. It is inevitable, however, that Arizona's energy deposits will become focal points of future exploitation because of the abundant resource alternatives they contain. Most of the alternatives, however, pose serious threats to the

NEEDS

Although the geothermal energy potential of Arizona is not well known at this time, considerable activity can be expected in the near future with respect to its exploration and development.

Background information on thermal resources is critical in exploration programs. Natural geothermal reservoirs have rather subtle surface expressions. Remote sensing technology has been utilized on an empirical basis in attempting to describe known thermal systems, but with poor success because interpretation guides for data acquired with this technique are complex or nonexistent for geothermal resources. Consequently, lack of knowledge about Arizona thermal water resources makes exploration a high-risk venture.

Once found, developing geothermal water resources will present several long-term water resource problems. Water use policies and ecologically acceptable development guidelines

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will have to be formulated to guide water management agencies. Unfortunately, the occurrence, distribution and qualities of thermal water resources in Arizona are poorly known, making anticipation of development problems difficult. Electric generating plant equipment obviously must be compatible with the specific energy form contained within the geothermal reservoir. Brine and volatile gas contents of Arizona geothermal resources are presently unknown and may necessitate environmental controls on steam-electric plants and will determine the utility of generating plant effluents.

In view of these limitations, the Water Resources Research Center at the University of Arizona supported a project designed to:

1. Gather fundamental geologic and geochemical data relevant to Arizona thermal water resources;

2. Assemble the data in a form useful to exploration groups, land management and environmental policy researchers, resource inventory analysts and for modeling studies of convective fluid flow in groundwater basins;

3. Examine geologic details of a region thought to have especially high potential for geothermal energy based upon information in the data compilation and then develop heuristic numerical models of the hydrothermal system in the subject region; and

4. Make recommendations for future thermal water research studies and policies in Arizona.

Findings of the study are published as Technical Completion Report, Office of Water Research and Technology, Project A-054-ARIZ., *Geothermal Water Resources in Arizona: Feasibility Study*, Water Resources Research Center, University of Arizona. The report is liberally illustrated and is produced with three large data maps as well as tables giving information on more than 100 wells and springs having geothermal characteristics.

FINDINGS

Approximately half of Arizona lies within the Basin-Range physiographic province of the western United States. The geologic environment here is considered to have relatively high geothermal energy potential, the most promising regions being those in which water-saturated, permeable rocks occur as hosts to a subsurface thermal source and are confined above by an impermeable cap rock. In Arizona, prospective localities commonly occur along the margins of groundwater reservoirs within Basin-Range environments.

Most of Arizona's conventional geothermal water resources appear to occur in the Basin-Range region along an east-west trending belt about 100 miles wide closely aligned with the Gila River (see map).

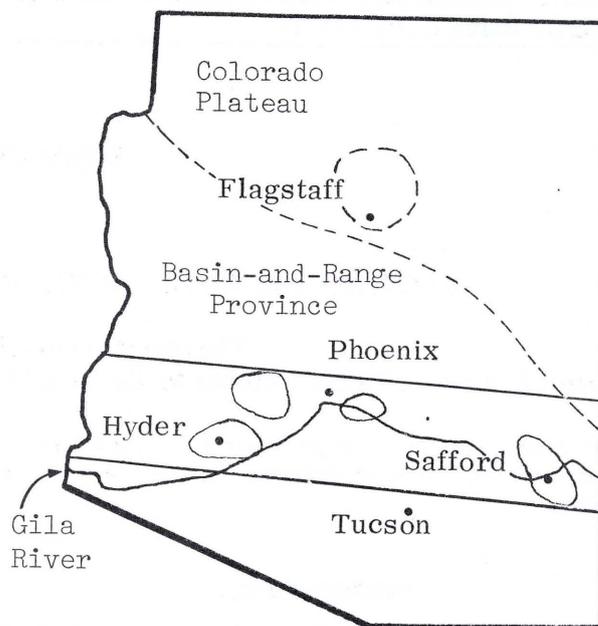
Numerous wells and springs with temperatures greater than 32°C are found within the 100-mile-wide zone. Usually their location is coincident with linear features described by ERTS (Earth Resources Technology Satellite) photographs.

Application of geochemical geothermometers to these waters during this study yields predicted reservoir temperatures up to a maximum of 130°C.

Thermal waters and waters with chemical characteristics indicating anomalously high reservoir temperatures are found throughout the Gila River Basin. These waters are commonly

associated with lineaments within Quaternary alluvium forming basin fill deposit surfaces in the Basin-Range area. Recent igneous flows, in the geologic sense, are characteristically present nearby and probably represent surface manifestations of igneous thermal sources at depth.

ARIZONA GEOTHERMAL ENERGY RESOURCE POTENTIAL



○ Area of concentration of reported hot springs and wells ($T > 32^{\circ}\text{C}$)

— Corridor of possible geothermal locations

Well logs, core and outcroppings of basin fill deposits in the Safford Basin suggest that thermal waters are contained in coarse sand and conglomeratic basin fill reservoirs and possibly in lava flows and tuff deposits under the sediments which fill the basin. Shallow lacustrine deposits of evaporites and clays probably function as cap rocks in this area, preventing mixing of warm, deeper waters with cooler, surface waters.

Lithologic and hydrologic characteristics of sediments within the basins are not well known. But it appears that water-saturated, coarse, alluvial sediments and volcanic tuffs and flows of at least 3,000 feet (1 km) are potential reservoir rocks under many basins. Lacustrine clays and evaporites 300m or more thick are apparently common at moderate depths and could constitute reasonably good cap rocks.

Hot, dry rock and magma-tap geothermal energy also may occur within the 100-mile-wide belt and elsewhere, for instance, in the Flagstaff region. All geothermal energy sources are reasonably close to Arizona's major population centers.

Geophysical characteristics along the Gila River in Yuma County and western Maricopa County are consistent with the

occurrence of geothermal energy resources. Basement rock heat-flow measurements are high, crustal rock magnetic features are weak and negative Bouguer anomalies occur.

Similar geophysical characteristics exist along the eastern portion of the Gila River in the Safford Basin. But the heat-flow values tend to be lower and distinctive magnetic signatures of crustal rocks persist in spite of the occurrence of thermal waters. Exothermic hydration of anhydrite in basin evaporite facies could be the thermal energy source of hot waters in the area.

RECOMMENDATIONS

Based on the study, the authors make the following recommendations.

1. Geothermal energy deposits are a realistic possibility in the areas described in the report. Arizona should take action through appropriate agencies to insure wise geothermal energy exploration and development. Agencies should consider associated problems including land management, environmental policy and multiple-use concepts.

2. Within the regions of high potential, the state should support studies which would define subsurface geological characteristics. Lithologic and hydrologic characteristics of potential cap rock and reservoir rock strata in basin fill sediments should be defined either from existing drill-hole data or from new drilling. The studies' purposes would be to determine if reservoirs of significance occur within the basement rock under basin fill deposits, to establish scale and frequency of recent igneous intrusions into these deposits, and to estimate extent of convecting hydrothermal systems associated with igneous intrusions by mapping the alteration mineralogy of host rocks.

3. Recent flows and dikes in potential geothermal regions should be subject to surface geologic mapping to determine a

relative chronology based on geomorphologic, structural and petrochemical features. Absolute age-dating methods should be then employed to calibrate the chronology. Such a study should indicate absence or presence of adequately young igneous heat sources in areas of potentiality. Estimates of igneous rock volumes of a given age likely to be under a basin also could be made in such a study. These data could be used then to model potential deposits and total energy content.

4. Water sampling and chemical analysis studies within regions of high geothermal potential should be supported. Reservoir temperature maps could be developed using geochemical geothermometers. *Complete chemical analyses including field measurements of temperature and pH should be made* so that activity diagrams could be used to relate water chemistry to reservoir mineralogy and hence to stratigraphy. Whether or not, and to what extent, hydration of anhydrite produces much of Arizona's thermal waters could be determined using data gathered through these studies. Knowledge of Arizona's thermal waters chemistry also will be valuable in developmental and environmental policy formulation. Effluent chemistry and its effects on surface waters, the possible need to reinject fluid, production of commercial by-products from spent thermal waters and equipment-working fluid compatibility are all areas requiring prior knowledge of the involved brines' chemistry.

5. Heat-flow geophysical surveys should be made in regions of geothermal energy potential to further substantiate evidence presented in this report and to increase subsurface geologic knowledge. The most useful data in need of collection are gravity, seismic, and resistivity.

6. Syntheses and analyses of data collected through efforts outlined in paragraphs one through five should be undertaken.

7. Mechanisms to obtain subsurface properties information on basin and bedrock areas and to preserve the information in the public domain need to be established.



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