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THE GEOTHERMAL RESOURCES OF SOUTHERN IDAHO

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ABSTRACT

The geothermal resource of southern Idaho is large--perhaps the largest of any state. However, most of the energy in hydrothermal convection systems is at temperatures below 150°C, and no systems with temperatures above 171°C have been found. Geological, geochemical, and geophysical data indicate several areas that are particularly promising for the occurrence of high-temperature systems. These include the margins of the Snake River Plain, the Weiser area, Island Park, and the Blackfoot lava field.

INTRODUCTION

The assessment of the geothermal resources of the United States completed by the U.S. Geological Survey in 1978 (Muffler, 1979) indicates that the geothermal resource in Idaho is very large. The evaluated igneous systems in Idaho contain 40 percent of the energy in such evaluated systems outside of National Parks. This is more than the second and third states, California and Alaska, combined. The 36 known hydrothermal convection systems in Idaho with reservoir temperatures $\geq$90°C contain 32 percent of the total energy in such systems in the United States outside of National Parks. This is second only to California. The energy estimated for undiscovered hydrothermal convection systems in Idaho is 34 percent of the United States total-the largest of any state. The total estimated energy in discovered and undiscovered hydrothermal convection systems in Idaho, $\geq$90°C, is greater than any other state. The Idaho resource in systems above 150°C is less impressive. Most of the known resource in Idaho is below 150°C and much of it is in one large system,Bruneau-Grand View, with a reservoir temperature of 107°C. In addition to the resource $\geq$90°C, water in the temperature range from 30°C to 90°C underlies large areas of southern Idaho.

Although the geothermal resource in Idaho is large, the only commercial geothermal development has been for space heating, and only one of the systems, Raft River, has been investigated in detail. Considerable uncertainty exists concerning the distribution and size of the resource. In 1977, the U.S. Geological Survey, the Department of Energy, the Idaho Department of Water Resources and the U.S. Forest Service began a coordinated study of the geothermal resources of southern Idaho designed to develop a better understanding of the resource and to stimulate its development of the resource. This program has involved geological, geophysical, hydrological, and geochemical studies supported by drilling. Numerous investigators from the four agencies and from several universities and commercial organizations have been involved in the work. Some of the studies have been completed and others are continuing. This report does not attempt to synthesize the results of all of the studies but rather, presents conclusions as to what the studies indicate about the geothermal resources of southern Idaho at temperatures $\geq$90°C. The Idaho Department of Water Resources has the primary responsibility for the investigation of the low temperature resources (below 90°C).

GEOTHERMAL SYSTEMS

Thermal Gradients--Although considerable uncertainty exists as to what representative deep thermal gradients are for southern Idaho, some conclusions can be drawn from existing data. Thermal gradients of 31 and 47°C/km were measured in holes in granite southwest of the Snake River Plain (Urban and Diment, 1975). Brott and others (1976) report gradients of 40 to 100°C/km in numerous areas of southern Idaho but their highest values probably reflect near surface rocks with low thermal conductivity and the presence of hydrothermal convection systems. The normal gradients over most of southern Idaho probably fall in the 25 to 50°C/km range. Support for this conclusion is provided by the Curie isotherm depths suggested by the magnetic anomalies that indicates that a temperature of about 550° occurs at 10 to 23 km below the surface over most of southern Idaho.

Resource Grade--Although the geothermal resource of southern Idaho is large, most of energy in hydrothermal convection systems is in the 90°C to 150°C temperature range with no known system above 171°C. Most of the temperatures are based on geochemical thermometry using water from springs and shallow wells. The computed temperatures do not assume that the thermal waters sampled were mixed with cold water unless mixing could be proved and quantitatively evaluated. This was rarely possible with data available (Brook and others, 1979). The precipitation in Idaho is relatively high--over twice that of Nevada and western Utah. As a result of the high precipitation, in many of the geothermal areas of Idaho there is an abundant flow of shallow ground water that is probably mixing with the thermal water leaking from the underlying geothermal reservoirs. Geochemical temperatures determined for these mixed waters will generally be lower than the actual reservoir temperatures. Additional work will likely result in an upgrading of the reservoir temperatures of some of the Idaho systems.

GEOTHERMAL AREAS

The geology of Idaho is varied and complex. Geothermal systems occur throughout the southern part of the state and the characteristics of the systems are determined by the local and regional geology. Southern Idaho is here divided into nine areas on the basis of the regional geology and the character of the geothermal system.

Weiser Area--Five geothermal systems with indicated reservoir temperatures of over 130°C are in one area north and northwest of Boise, here called the Weiser area. No common element is apparent in the geology of the five systems. Three are in the area of Miocene sediments and basalt and two in rocks of the Idaho batholith. The largest and hottest system is Crane Creek-Cove Creek. This system is expressed at the surface by springs on Crane and Cove Creeks about 11 km apart. The similarity of water chemistry, the continuity of geophysical anomalies and extensive alteration leads to the conclusion that one large system underlies the area. At 171°C indicated reservoir temperature, this is the hottest discovered system in Idaho.

Idaho Batholith--More hydrothermal convection systems are within the Idaho batholith or in areas thought to be underlain by the batholith than any other area of Idaho. None of them are known to be large; Brook and others (1978) assumed each to have the arbitrary minimum reservoir volume (3.3 km^3) assigned to systems when no information to indicate the dimensions of the reservoir is available. An adequate evaluation of the geothermal resource of the Idaho batholith will require detailed studies of representative systems involving hydrological, geological and geophysical surveys supported by drilling. Current information suggests a large but relatively low temperature resource distributed through many small systems in the batholith.

Western Snake River Plain--The western Snake River Plain contains 87 percent of the discovered hydrothermal resources of Idaho, $\geq$90°C, and about one fourth of the nation's geothermal resource in hydrothermal convection systems outside of National Parks. Most of the energy is in the Bruneau-Grand View system and all is in the Mountain Home-Twin Falls area of the plain. Indicated reservoir temperatures for systems range between 103°C and 124°C with the Bruneau-Grand View system at 107°C. Parts of this area have been intensely studied and three deep holes have been drilled, but several fundamental questions relating to the systems remain unanswered.

The Bruneau-Grand View geothermal system is unique in Idaho because of its size. Water at temperatures to 80°C is produced from artesian aquifiers in Cenozoic volcanic rocks in wells ranging up to 1100 m deep. Temperatures of the water increases with depth at a rate of about 65°C per km which is about equal to the thermal gradient measured in heat flow holes in the area (Brott and others, 1976). There is no data to support the possibility that large volumes of water much hotter than that indicated by the geothermometers will be found associated with the Bruneau-Grand View system within 3 km of the surface.

Five smaller systems have been identified in the Mountain Home-Twin Falls area to the east of the main Bruneau-Grand View system. In these systems water is produced from springs or shallow wells with indicated reservoir temperatures ranging from 103-124°C. However, the geothermometers for some of these waters may be unreliable (Brook and others, 1979). Some or all of these systems may be continuous with the Bruneau-Grand View system. Although warm water occurs widely over most of the rest of the western Snake River Plain and may be of considerable value in low-temperature applications, there is no evidence that a high temperature resource exists in these areas.

Owyhee Area--The Owyhee area lies southwest of the Snake River Plain. Cretaceous intrusive rocks similar to those of the Idaho batholith, as well as metamorphic rock, crop out in the Owyhee Mountains but most of the area is overlain by Tertiary silicic volcanic rock. Murphy Hot Springs, with an estimated reservoir temperature of 103°C, is the only geothermal system in this area with an indicated reservoir temperature of over 90°C. No deep holes have been drilled in this area and the deep subsurface geology is not known. Regional heat flow is probably high, and structures favorable to the development of hydrothermal convection systems are likely to exist. Additional geophysical exploration and drilling is needed to evaluate the area.

Camas Prairie--Camas Praire is an east-trending valley lying north of and parallel to the central part of the Snake River Plain. Although separated from the Snake River Plain by a highland, the Bennett Hills, the structure of Camas Prairie is probably closely related to the Snake River Plain. Three geothermal systems, with indicated reservoir temperatures of over 90°C, are known in the area of the prairie. The Magic Reservoir system at the east end of Camas Prairie has an indicated reservoir temperature of 149°C, the third highest in Idaho. The Magic Reservoir geothermal water is high in dissolved solids and more like the systems in eastern Idaho than those of western Idaho.

Eastern Snake River Plain--The size of the geothermal resource that underlies the eastern Snake River Plain is uncertain. Abundant recent volcanic activity, including large rhyolite domes as young as 300,000 years old, and the proximity and possible relationship to the huge geothermal systems in Yellowstone National Park, suggest that a large resource might underlie this segment of the plain. However, only two hydrothermal convection systems with indicated reservoir temperatures of over 90°C have been found in the area of the eastern Snake River Plain and they are along the edge of the plain and have indicated reservoir temperatures of only 93°C and 100°C. Measurements of the regional heat flow in the eastern Snake River Plain are hampered by the effect of the Snake River Plain aquifer flowing southwest through the basalts that underlie most of this part of the plain (Brott and Blackwell, 1979). One 3 km-deep well and two shallower wells are believed to have been drilled deep enough to permit measurement of thermal gradients below the effect of the aquifer and in these holes the gradients ranged from 40-60°C/km. Numerous high heat flow values have been obtained in measurements in shallow wells near the margins of the eastern Snake River Plain.

In 1979, the Department of Energy drilled a geothermal test well on the Snake River Plain about 10 km from the northwest border of the plain at the Idaho National Engineering Laboratory. The hole was bottomed at 3155 m in rhyodacite, which may be either a dense welded tuff or a high-level intrusive. The bottom-hole temperature was 138°C, the permeability was very low below 500 m, and little water could be produced. Subsequent to the drilling, Doherty and others (1979) have proposed that the well was drilled in intracaldera fill of a large caldera. Several other large calderas may underlie the eastern Snake River Plain. Extensive geological and geophysical surveys and drilling in recent years have failed to provide any support for the existence of a major high temperature geothermal resource underlying the central part of the eastern Snake River Plain. However, exploration for geothermal energy on the eastern Snake River Plain is difficult and much more work must be done before the resource in this area can be evaluated. Known hot water and high thermal gradients along the margins of the plain suggest that the major resource may occur along the margins of the plain.

Island Park Area--The Island Park area, as used in this report, is the area lying between the northeast end of the Snake River Plain and Yellowstone National Park. Several thermal springs have been identified but none have water temperatures over 25°C or geochemical temperatures of over 90°C. The primary indication that a large geothermal resource might occur in the area is in the geology. Between about 1 and 2 million years ago large volumes of rhyolite were erupted from the Island Park area during three cycles of activity associated with the development of the Island Park caldera system. Smith and Shaw (1978) estimate that the system contains 16,850 x 10^{+18} joules of thermal energy. Of the igneous systems in the United States, this energy content is second only to the Yellowstone caldera system. The geophysical data from the area are inconclusive and there is no evidence in the geophysical, geological, or hydrological data that indicate high temperatures in the near surface. Deep drilling will be required to evaluate the geothermal resources of the Island Park area but the existing data suggest that it is one of the most promising areas in southern Idaho.

Lost River Area--The Lost River area, which lies east of the Idaho batholith and north of the Snake River Plain, contains only one geothermal system with an indicated reservoir temperature, ≥90°C. Although the direct indicators of a geothermal resource are lacking, the area offers sufficient promise to justify additional exploration.

Southeastern Idaho--Southeastern Idaho is defined here as the area lying south of the Snake River Plain. It is an area of Basin and Range structure with Cenozoic fill in the basins as much as 4 km thick. Five geothermal systems with indicated reservoir temperatures ≥90°C, have been identified in this area. The Raft River system is near the western edge of the area and has a measured reservoir temperature of from 146°C to 149°C. Water from this system is being used by Department of Energy in a demonstration project to produce electrical energy from this relatively low temperature water and it is the most intensely studied system in Idaho. The other four systems with indicated reservoir temperature from 93°C to 119°C are along the Bear River within 27 km of Preston.

The primary reservoir of the Raft River system is made up of fractured Tertiary sedimentary rocks overlying a less disturbed pre-Tertiary basement complex. The fracturing of the reservoir has been interpreted as resulting from movement on a low angle detachment fault near the contact between the Tertiary sedimentary rocks and the basement. The four systems near Preston are along normal faults bounding a prism of Cenozoic sediments about 2 km thick underlying northern Cache Valley. Although the area merits more study, there is no suggestion in the available data of a large reservoir or water much above 120°C associated with those four systems.

Quaternary basalt flows occur in several valley areas in a north-trending zone about 35 km wide and about 200 km long extending from near the southeast margin of the Snake River Plain to a few kilometers south of Soda Springs. The age of the youngest basalt flows have not been determined but most of the basalt is probably more than 50,000 years old. Near the center of the zone of basalt flows is the Blackfoot lava field, which appears to have been the source area for much of the basalt. Here, in addition to about 25 basalt cinder cones and vents, are several young rhyolite domes.

Although there are numerous thermal springs in the general area of the Blackfoot lava field and high temperatures may have been encountered in an oil test a few kilometers to the north, none of the waters are above 42°C and indicated reservoir temperatures are generally low. Despite the absence of direct evidence of high temperature in the area of the Blackfoot lava field, the geological and geophysical evidence of a large thermal anomaly in the area suggest that it is one of the most promising areas in southern Idaho for the occurrence of large high temperature geothermal reservoirs. Geothermal gradient surveys in drill holes several hundred meters deep will be required to confirm or refute the existence of a major geothermal anomaly.

CONCLUSIONS

Although the geothermal resource of Idaho is large, most of the known resource is below 150°C. Studies reported to date have failed to confirm the presence of any large high-temperature resource. However, the very large volumes and wide distribution of water with indicated reservoir temperatures ≥90°C and the presence of geologic settings that are believed to be favorable for the development of hydrothermal convection systems, suggest that higher temperature systems exist. Exploration for geothermal energy in Idaho is unusually difficult because of problems of obtaining heat flow and thermal gradient data undisturbed by ground water movement and the extensive cover of young sedimentary and volcanic rocks in many areas of interest. However, recent geological, geophysical, and hydrological studies have provided an improved understanding of the regional geology and several attractive areas for additional exploration have been identified.

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