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ABSTRACT

A heat-flow survey of the eastern Snake River Plain, Idaho, was initiated to determine the regional tectonic implications and to assess the geothermal potential. High surface heat-flow values, 3 HFU or greater, are observed on the margins of the eastern SRP. Regional considerations suggest that the heat flow should be high throughout the whole eastern SRP; however, in the center of the eastern SRP, the observed surface heat-flow pattern shows negative values in the east (Idaho Falls area) with a gradual increase to about 1.5 HFU at the west (Hagerman-Twin Falls area). The observed heat-flow values are controlled by groundwater flow in the Snake Plain Aquifer. Flow rates in the aquifer are as high as several meters per day. A model of the aquifer is presented to explain the pattern of low surface heat flow while high heat flow is present under the aquifer. Data from intermediate-depth wells (>1 km) and deep wells (>2-3 km) being drilled will soon be available to indicate the nature of heat flow present under the aquifer.

INTRODUCTION

The Snake River Plain (SRP) is one of the major volcanic and tectonic features of the western United States (see Figure 2). It extends in a broad arc across southern Idaho from the Oregon border to Yellowstone National Park. The major tectonic and volcanic activity of the SRP is well-known. For example, in the west, the SRP appears to be a basalt and sediment-filled rift or graben structure (Hill, 1963; Hill and Pakiser, 1966; Mabey, 1976, 1978). The eastern part appears to be a downwarp filled by sediments and volcanics. Armstrong et al. (1976) traced an eastward progressive history of silicic volcanism across the SRP starting about 17 M.Y. ago at the Oregon-Idaho border and continuing essentially to present time in Yellowstone National Park. They postulated an eastward progressive volcanic episode moving at a velocity of 35 mm/yr.

Brott et al. (1976, 1978) discussed an extensive heat-flow study focusing on the western SRP. Based upon this study, they proposed a model which predicts very high heat flow in the eastern SRP. A model was constructed which shows that surface heat-flow profiles in the western SRP could be explained by using Basin-and-Range mantle heat flow, crustal thermal refraction, and the emplacement of a large instantaneous heat source (mafic intrusion) at a depth of 10 km approximately 12.5 M.Y. ago. The age of the thermal source corresponds to the regional silicic volcanism associated with the formation of the SRP. Using this model, coupled with the evidence for progressively younger silicic volcanism to the east, they proposed that the observed eastward increase in average elevation is consistent with an increase of average crustal temperatures. The assumption is that elevation is related to average crustal temperature via thermal expansion. The changes in average crustal density (elevation versus time) shown in Figure 1 were calculated in two ways. The models used to construct these two elevation profiles were an infinite-width moving heat source similar to McKenzie's (1967) oceanic model, and a finite-width moving heat source.

![Figure 1. Elevation and integrated crustal temperature versus the square root of distance and time.](image-url)
To investigate this elevation-versus-crustal temperature hypothesis, an extensive heat-flow study was initiated in the eastern SRP. At the present time, there are about 600 heat-flow data points in southern Idaho, with half of these being in the eastern SRP. Figure 2 shows the locations of these points.

FIGURE 2. Geothermal data location map of southern Idaho. Dashed lines show approximate boundaries of the Snake River Plain.

Heat-flow values of 3 HFU or greater are observed on the far eastern margins of the SRP, while in the eastern SRP low surface heat flow is observed due to the Snake Plain Aquifer. The Snake Plain Aquifer is the most prolific aquifer in Idaho, with a coefficient of transmission of 4-173 million liters per meter per day. The discharge of the aquifer is 185 kiloliters per second, occurring primarily at the thermal springs near Hagerman, Idaho (Mundorff et al., 1964). The aquifer transports heat laterally because of the rapid water flow. To verify the nature of the heat flow under the aquifer, we suggest that the observed temperature increase of about 5°C in the aquifer, from recharge to discharge regions, can be explained by high heat flow under the aquifer. The boundaries and flow lines of the aquifer are shown in Figure 3, along with locations of measured aquifer temperatures.

SNAKE PLAIN AQUIFER MODEL AND TYPICAL TEMPERATURE-DEPTH DATA

In order to model the observed data, we have superimposed transient thermal conditions, as influenced by fluid flow in the Snake Plain Aquifer, on a regional heat-flow model. The constraints of the aquifer model were based on available data on velocities, dimensions, etc. Calculations of the thermal characteristics of the aquifer were made by use of a finite difference program. Given the heat flow from below, the surface temperature, and input flow parameters, this program calculates temperatures within the aquifer, as shown in Figure 4. In the geothermal gradient profile shown above the model, the dashed profile represents the gradient profile excluding the effects of the aquifer.

FIGURE 3. Snake Plain Aquifer.

FIGURE 4. Snake Plain aquifer temperature and heat-flow model.
Typical temperature-depth curves on the margins of the aquifer (Figure 5) show little or no effect from the aquifer, as predicted by the model.

![Figure 5](image)

**FIGURE 5.** Typical temperature-depth plot on the margins of the aquifer.

Temperature-depth curves observed in the recharge areas are shown in Figure 6. Cold water from higher elevation runoff causes negative gradients in the recharge areas of the aquifer. These negative gradients are also predicted by the model.

![Figure 6](image)

**FIGURE 6.** Typical temperature-depth plot in the recharge areas of the aquifer.

Downstream of the recharge areas, the temperature of the water increases due to heat flow from below the aquifer, and the gradients become isothermal. Further downstream, the gradients begin to show a positive character and aquifer temperatures increase. Some examples of these temperature-depth curves are illustrated in Figure 7.

![Figure 7](image)

**FIGURE 7.** Typical temperature-depth plot downstream of the recharge areas in the aquifer.

Thus, the recharge areas of the aquifer are characterized by negative gradients at shallow depths and the aquifer temperature increases systematically with distance downstream from the recharge areas. A one-dimensional model calculation predicts a downstream increase of aquifer temperature of 3-4°C, due to the heat flow from below the aquifer. The measured downstream temperature change in the aquifer is approximately 5°C, which is consistent with the possibility of high heat flow occurring below the aquifer, even though surface heat-flow values are low or negative.

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