A GEOPHYSICAL REVIEW OF SELECTED
GEOTHERMAL AREAS IN SOUTHERN IDAHO

by
Paul R. Donaldson
and
James K. Applegate

GeoTechniques, Inc.
Boise, Idaho
INTRODUCTION

There are numerous areas within the state of Idaho where occurrences of thermal water have been reported. Fourteen such areas (Figure 1) were outlined for which a search to find all available published and unpublished geophysical work was made. The information accumulated through this search is interpreted and/or summarized in an effort to define geologic structures which may affect thermal water occurrences. A bibliography of all geophysical works found through the literature search is also provided.

While many references to geophysical work were found, very few related directly to the prescribed areas. Of the pertinent work found, most was of a regional nature while very little was useful on a specific-site scale. The general conclusion is that even reconnaissance level data sets are incomplete for most, if not all, of the prescribed areas. As a consequence, interpretations offered in this report are of necessity somewhat sketchy and often times speculative in nature.
Figure 1. Locations of selected geothermal areas.
COUNCIL-CAMBRIDGE AREA

The Council-Cambridge area geology is dominantly Miocene basalt flows in contact with intrusives of the Idaho Batholith. The area is quite strongly faulted with basically N-S and NW-SE trends.

Geophysics and Tectonics

The preliminary gravity map (Figure 2) of southern Idaho shows this area being dominated by a distinct gravity high with a residual magnitude of nearly 40 mgal near Council (Figure 3). The gradient of the anomaly is enhanced to the east where the dense basalts lie adjacent to relatively low density intrusives. This steep gradient indicates a sharp contact between basalt and batholith rocks and a faulted contact is certainly possible. The gravity profile as a whole indicates that these plateau basalts are considerably thickened in this area. The anomaly may represent a local embayment on the plateau-basalt depositional surface or perhaps subsidence and filling during the volcanic activity.

Bond (1975) shows many faults in this area and Witkind (1975) classifies several of them as active (Figure 17). The faulting patterns (Bond, 1978) suggest that alluvial-filled river cut valleys in this area may be fault controlled. Unfortunately, the gravity data are very sparse and do not define the valley margins or allow any estimation of their depths or structural controls.
Figure 2. Gravity, Council-Cambridge area
(Mabey, Peterson, and Wilson, 1974).
Figure 3. Gravity profile near Council.
Discussion

Additional gravity data in this area should be of value in further clarifying local structural controls. Some specific questions that might be answered include whether or not the alluvial-filled valleys are structurally controlled and, if so, are they deep enough to expect significant heat accumulation beneath sediments (Applegate and Donaldson, 1977).

The source or cause of the broad positive gravity anomaly (Figure 2) in this area may be of particular significance. Short of deep drilling, the best source of sub-surface information for resolving this is certainly seismic reflection work. While there are reported successes (Applegate and Donaldson, 1978), there is always some question about the likelihood of being able to record useable seismic data in complex volcanic areas such as this.
SNAKE RIVER PLAIN

General

Gravity work in Idaho, beginning with a reconnaissance program by Princeton University in 1955 (Bonini and Lavin, 1957), has shown a prominent gravity high associated with the Snake River Plain. Subsequent work by Dr. Bonini, his associates at Princeton, and other groups including the USGS, has led to a number of publications concerning the nature of this geographically and geologically significant region.

There is general agreement among workers, observers and interested critics that a genuine difference exists in structural style between the eastern and western portions of the Snake River Plain. An approximate division can be made by a N-S line along 114°30' west longitude (La Fehr and Pakiser, 1962) where the axis of the Plain changes direction quite abruptly.

An early hypothesis, attributing the Snake River Plain to downwarping (Kirkham, 1931), has largely been ruled out or modified for the western plain by new data. Malde (1959) described a fault zone along the northern boundary of the western Snake River Plain and estimated an average throw of at least 9000 ft. Gravity studies have led to an interpreted graben filled with sedimentary rocks and interbedded basalt flows for the western plain (Hill, Baldwin and Pakiser, 1961). Kirkham's (1931) hypothesis may, however, still be valid for the eastern plain where abrupt bounding faults have not been interpreted.

In its eastern portion the Snake River Plain intersects flanking topographic and structural features at high angles while features
bordering the western portion are roughly in line with the axis of the plain (La Fehr, 1962). Malde (1959) reports that a crustal break inferred from gravity aligns with earthquake epicenters along a diagonal from Puget Sound to northern Utah. This implies a possible crustal-scale structural division of the plain and, in conjunction with other differences in structural style, reinforces the logic of dividing the plain into two regions of study.

Gravity presently accounts for a major portion of the data available for interpreting the subsurface in and around the Snake River Plain. Data coverage is quite good in some areas where specific projects have generated interest in its collection. Many areas of interest, however, have very sparse coverage and gathering additional data probably represents one of the most efficient means of increasing knowledge on a selective basis.

Many of the areas prescribed for discussion in the report lie along the margins of the Snake River Plain or its zones of transition into the Idaho Batholith or Basin and Range geology. The Snake River Plain manifests itself as a region of high gravity. Since rocks of the Idaho Batholith are of comparatively low density, extreme regional gradients of gravity exists where the two come together. This greatly complicates local scale interpretation of data in transitional zones between the plain and the batholith, particularly where data are sparse and show little if anything more than the regional gradient. The implication is that the information available from gravity in many areas could be greatly enhanced by locally increasing the data density and carefully removing the regional
gradient. Similar gains should be realizeable in areas where steep gradients along the margins of the plain truncate and obscure the gravity signatures of basin and range structures.
BOISE-CALDWELL-WEISER AREA

This area is on the northern edge of the western portion of the Snake River Plain (Figure 1). The southern part of this area lies in the transition zone between the Snake River Plain and the Idaho Batholith which lies within the Northern Rocky Mountain Province. The northern part of the area lies within the Snake River Plain proper and its transition into the Columbia Plateau. The Plain is commonly included in physiographic definitions of the Columbia Plateau.

Geophysics and Tectonics

Gravity in this region is dominated by anomalously high values in the central plain, steep gradients in the direction of the batholith and moderate gradients in the direction of the undisturbed Columbia Plateau. The highest amplitude gravity anomaly in the Snake River Plain is centered just to the south of the area (Figure 4). Its residual amplitude is in excess of 50 mgal and exhibits gradients as high as 6 to 8 mgal per mile. By comparison, significant Basin and Range faults exhibit gradients on the order of 10 mgal per mile with significantly larger density contrasts than those estimated for the Snake River Plain (0.5 gm/cc contrast in Basin and Range compared with not more than 0.3 gm/cc contrast in the Snake River Plain).

Malde (1959) has speculated, on the basis of the gravity and seismic studies in the area, that a high angle fault with at least 9000 ft of throw displaces the Snake River Plain downward with respect to the Idaho Batholith. He further speculates that the crustal break inferred from gravity may coincide with a long line of earthquake epicenters from
Figure 4. Gravity between Boise and Mountain Home (Mabey, Peterson, and Wilson, 1974).
Puget Sound to northern Utah. Witkind (1975) documents a series of known or suspected active faults along the northern edge of the western Snake River Plain. These faults (Figure 5) extend into the Plain near its axial discontinuity and align with faults across the Plain. In combination, these observations support the logical subdivision of the Plain into eastern and western components, as proposed by La Fehr and Pakiser (1962), and suggest the possibility of a major crustal break. If a structure of this scale exists its location and nature would certainly be pertinent to geothermal investigation within a continuous strip from Weiser, along the northern margin of the western Snake River Plain through Boise, and continuing past Mountain Home and Twin Falls and crossing into northern Utah near the southern Raft River Valley. It is a point of curiosity, if not genuine significance, that within this strip the Snake River abruptly changes direction near Buhl, Idaho, and resumes its previous approximately westerly course near Bliss, Idaho (Figure 5). This shift, suggestive of right-lateral movement cutting across the plain corresponds in location to the change in trend and structural style defining the subdivision of the plain into its eastern and western segments (La Fehr and Pakiser, 1962). The Thousand Springs area occurs within this offsetting segment of the Snake River.

A significant amount of reconnaissance phase investigations have been completed in the Boise area proper to assess the geothermal potential (Applegate, Donaldson, Mink and Nichols, 1977). Geophysical efforts included a few ground magnetometer lines, dipole-bipole resistivity surveys covering about 50 square miles and continuous microseismic monitoring since June of 1975.
Figure 5. Active faults in the western Snake River Plain (Witkind, 1975).
MOUNTAIN HOME-HAMMETT-KINGHILL AREA

Most of the general comments made concerning the Boise-Caldwell-Weiser area are applicable to this area. For study purposes there seems to be no reason for considering this area separately other than the total size if the two were combined.

Geophysics and Tectonics

The gravity high mentioned in discussions of the Boise-Caldwell-Weiser area (Figure 4) lies partially within the defined boundaries of the Mountain Home-Hammett-Kinghill area. This anomaly has been interpreted by Hill et al. (1961) to be due to large tabular bodies within the Plain. Their favored geologic explanation is a graben bounded by faults with en echelon fissures producing volcanism and the resulting lava flows filling the depression as subsidence proceeded.

In 1962 the U.S.G.S. established a series of reversed seismic refraction profiles to study the crustal structure between the Nevada test site and Boise, Idaho. Interpretations of this data (Hill and Pakiser, 1967) suggest an abrupt thickening of the crust at the boundary between the northern Basin and Range and the western Snake River Plain. Of greater significance to interpretation of the gravity, however, is the further interpretation that a 6.0 km/sec upper crustal layer thins across this boundary and may be absent beneath the Snake River Plain (Figure 11). This thinning of the upper crust and the accompanying thickening of the theoretically denser lower crust should produce a positive gravity effect.
Figure 11. Crustal structure between Eureka, Nevada and Boise, Idaho based on seismic refraction profiles (Hill and Pakiser, 1967).
Mabey (1976) has interpreted a gravity profile across the afore-mentioned gravity anomaly. His interpretation takes into account and is consistent with the seismic refraction results (Hill and Pakiser, 1967). He proposed two crustal models which fit the gravity profile and are reproduced in this report (Figure 12). Mabey (1976) reports that there is no evidence from subsurface or surface geology to indicate the subsidence shown in model A and model B is more consistent with the magnetic data (Figure 12).
Figure 12. Gravity and Magnetic profile across the western Snake River Plain and two-dimensional gravity models (Mabey, 1976).
TWIN FALLS AREA

The Twin Falls area lies on the boundary of the subdivision of the Snake River Plain into its eastern and western components. This may be significant if the division reflects a crustal break as has been suggested by Malde (1959) based on gravity and earthquake epicenters.

Geophysics and Tectonics

In this area, gravity does not suggest any sharp structural features. The regional gradient toward the axis of the plain is dominant with the exception of a broad 5-10 mgal low centered about 14 miles due east of Jerome (Figure 13). A corresponding local magnetic low (Figure 14) enhances the possibility that a structural depression exists. There are no active faults documented by Witkind (1975) in this sub-area but Day (1974) has mapped lineaments from ERTS imagery which approximate the trend of the western plain in direction (Figure 15).

A series of warm wells in the southern portion of this area match quite closely the trends of 3 active faults reported by Witkind (1975).
different stratigraphic levels in the Idaho Group. For instance, the sandstones just north of the BWSWD wells lie directly upon the basaltic tuffs and the Idavada Group, whereas the sandstone that forms the mesa of Table Rock (center of sec. 8, T.3N., R.3E.) overlies about 500 ft of Idaho Group sediments. The Table Rock section has been downfaulted to the south at least 400 feet. Downfaulting has preserved this section of younger rock near the edge of the foothills from erosion.

We are able to map an abrupt lithologic contact of a thick sequence of coarse deltaic sands overlying the lake margin facies of the lower Idaho Group. This contact clearly marks a major regression of the lake system toward the southwest. We call these sands of the regressive phase "the upper Idaho Group" in the Boise foothills. These sands do not occur east of Crane Creek, but they occur at the tops of the hills and overlie much of the area to the west (fig. 2).

We have not been able to identify such a clear break in lithology in the subsurface beneath Boise. The upper 600 feet of the Idaho Group beneath Boise contains sand units that serve as cold water aquifers. The lower part contains up to two sequences of basalt varying in thickness from 10 to 150 feet. These basalts serve as good local marker beds during drilling.

The Idaho Group of the foothills probably has correlative units with the Chalk Hills formation exposed on the south side of the Snake River Plain. The uppermost regressive sand may correlate with the lower part of the Glenns Ferry Formation, but the seismic section from the foothills to Caldwell (fig. 5) indicates that most of the units in the foothills are the lower Idaho Group. The seismic section shows that the units dip about 7 degrees and emerge in the foothills. Sediments in the basin beneath Caldwell appear to thin and pinch out to the east at about Meridian. The 4000-to-5000-ft-thick section beneath Caldwell represents a major depositional center and it is probably the Glenns Ferry Formation (Wood and Anderson, 1981). Criteria for recognizing the formation break between the Glenns Ferry and the Chalk Hills formation is being developed by Swirydczuk and others (1979, 1981) by detailed stratigraphic study of volcanic ash marker beds, but these have not been applied to the Idaho Group on the north side of the plain.

Tenmile gravels, Boise River terrace deposits, and intercanyon basalt flows

A blanket of fluvial gravel and sand was deposited upon the Idaho Group over much of the plain in the Boise area. The deposit heads in the foothills just south of Lucky Peak Dam, about 5 miles east of Boise, where it is as much as 500 ft thick. The deposit extends to the Oregon border. Remnants are found over much of the area to the west of Boise where the gravels are 10 to 50 feet thick. These gravels were called the Tenmile Gravels by Savage (1958), but Wood and Anderson, 1981) have restricted usage of the name to gravels clearly derived from the Boise River Drainage, and excluded similar gravel deposits derived from the Payette or the upper Snake River drainages. The Tenmile Gravels are downfaulted to the north, and this faulting may have produced the graben like valley in which the present Boise River is confined (fig. 2). During the Quaternary the river has occupied at least 6 successively lower flood plain levels now preserved as the broad terraces.
Figure 15. Linears mapped from band 5, MMS-ERTS (Modified from Day, 1974).
BLUE GULCH AREA

Geophysics and Tectonics

The northern portion of the Blue Gulch area abuts against one of the large amplitude gravity highs in the axial zone of the western Snake River Plain. These maximums have been interpreted by Mabey (1976) to represent a thinning of the upper crust. This interpretive model is consistent with an interpretation of a seismic refraction profile that crosses the Snake River Plain (Hill and Pakiser, 1966).

A small gravity low is situated north of Buhl and south of the axial high (Figure 13). Mabey (1976) has interpreted a similar situation elsewhere in the region as possibly indicating a gap in a subsurface high density unit such as a basalt flow. If such is the case here, this small gravity low would be of geothermal interest. It is also noteworthy that the small gravity low coincides with an abrupt change in direction of the Snake River which implies the possibility of fault control. The presence of many springs in the Thousand Springs area, nearby adds to the credence of fault or fracture control.
OAKLEY AREA

Geophysics and Tectonics

A gravity map compiled by the USGS (Mabey, Peterson and Wilson, 1974) reveals an anomaly in the vicinity of Oakley, Idaho. The anomaly is a relatively small amplitude low which trends basically NS, broadens near the Utah-Idaho Border and narrows and shifts eastward north of Trapper Creek (Figure 13). A SE trending gravity profile was taken from map values (Figure 16). Computations based on a 21 mgal anomaly and a density contrast of 0.4 g/cc results in a basin depth estimate of about 4100 ft near Oakley. The profile indicates a regional gradient with gravity increasing toward the Snake River Plain and decreasing toward a neighboring gravity low SE of Almo, Idaho.

The Oakley anomaly is not strongly definitive of structure and Witkind (1975) does not document known or suspected active faults which would control the nose of the anomaly to the NE. He does identify a fault suspected of being active since mid-Miocene which lies about 7 miles west of Oakley, trends NW and appears to control a rather linear topographic break. The position of this fault does correlate very well with a coherent distortion of gravity contours as expected for movement downward toward the basin.

While faults are not documented to define the gravity suggested structure, Day (1974) has mapped lineaments from ERTS imagery which correspond very well to the location, shape and trend of the gravity anomaly (Figure 15).
Figure 16. Gravity profile near Oakley.
Discussion

The basin depth estimate of about 4100 ft near Oakley is a very conservative estimate based on calculations using a Bouguer approximation. This approximation is generally quite accurate where basin width is several times the basin depth and results in increasingly conservative estimates as the width to depth ratio decreases.

Assuming a 4100 ft deep basin structure with a basement rock thermal conductivity of 6.0 mcal/cm-5°C, a basin fill thermal conductivity of 3.0 mcal/cm-5°C, and a heat flow of 3.0 HFU (see Brott et al., 1976), one can calculate a predicted temperature of about 90°C at maximum depth (Diment, et al., 1975). This maximum temperature estimate is conservative in the same sense that the depth estimate is considered conservative.
POCATELLO AREA

Geophysics and Tectonics

The Pocatello area is characterized by a small amplitude gravity high with flanking lows to the NE and SW, and a positive gradient toward the Snake River Plain to the NW. Of particular significance is a negative gradient to the east which appears to reflect a fault on the east flank of Camelback Mountain. This fault which has been documented by Witkind (1975) has reportedly experienced movement since Pliocene time. This fault trends toward and perhaps merges with a major fault which probably continues uninterrupted from the Cache Valley until its trace disappears into the Snake River Plain near Blackfoot (Figure 17). The Portneuf Range is bounded on the west by this major fault.

A gravity anomaly of significant magnitude and proportions is found about 25 miles east of Pocatello. The anomaly reflects the Portneuf Valley, bounded on the west by the Portneuf Range and on the East by the Chesterfield Range, and extends SSE into Gem Valley and Gentile Valley (Figure 17). Witkind (1975) documents faults on the margins of this series of valleys with most recent movement apparently in the late Cenozoic. However, a Richter Magnitude 4.3 earthquake which occurred in October, 1978 was located west of Niter, Idaho and may have originated in the West Gem Valley Fault.

Mabey and Armstrong (1962) have interpreted the Portneuf and Gem Valleys anomaly. Their modeling indicates a maximum basin depth of about 9000 ft.
Discussion

The expected containment of heat at the base of thermally insulating material is considered a realistic source of energy for geothermal systems in high heat flow areas (Keller, 1975, Diment, et al., 1975, Applegate and Donaldson, 1977). Assuming the 9000 ft deep basin or trough interpreted by Mabey and Armstrong (1962), maximum expected temperature at depth in the Gem Valley would be about 160°C for basement and basin fill thermal conductivities of 6.0 and 3.0 mcal/cm S-°C, respectively and 3.0 HFU.
BLACKFOOT-GAY MINE AREA

Gravity and Tectonics

The preliminary Gravity Map of southern Idaho (Mabey, Peterson and Wilson, 1974) defines a prominent low about 12 miles south of Blackfoot (Figure 18). An E-NE profile through this anomaly (Figure 19) defines a 22.5 mgal low which, assuming a 0.4 gm/cm³ density contrast, results in calculations estimating a basin depth of about 4400 ft. A steep gravity gradient on the east side of the anomaly is very suggestive of a fault but the equidimensional nature of the main part of the anomaly does not suggest a preferred direction of valley strike. Witkind (1975) defines a 65-mile long active fault which is terminated in the vicinity of the east flank of the gravity anomaly (Figure 17). This fault has been recurrently active since middle Miocene time. East of this anomaly gravity is quite featureless and exhibits only a regional gradient of about -1.4 mgal/mile eastward. Day (1974) has mapped a lineament from ERTS imagery (Figure 15) which approximates a portion of the Witkind fault but terminates before reaching the gravity anomaly. In the vicinity of the gravity anomaly, Day has mapped several NE-trending linears which parallel the trend of the Eastern Snake River Plain, only a short distance northward (Figure 15). It is probably significant that gravity contours enclosing the main portion of the previously mentioned anomaly are distorted toward the NE (Figure 18). Gravity, mapped lineaments and a prominent fault interruption all indicate effects of the force or forces responsible for the presence of the Eastern Snake River Plain and the complexity expected in the transition into this dominating structural feature."
Figure 18. Gravity lows south of Blackfoot (lower right) and Swan Valley (upper left) (Mabey, Peterson and Wilson, 1974).
Figure 19. Gravity profile near Blackfoot.
To the east of the anomaly, gravity is quite featureless and exhibits only a regional gradient of about -1.4 mgal/mi eastward.

Discussion

Calculations described by Diment et al. (1975) estimate maximum temperatures of 92°C at the base of a 4400 ft thick insulating blanket of sediments. If previously described assumptions about heat flow and thermal conductivity contrasts are reasonable, this temperature estimate would have to be considered conservative since the basin depth estimate, arrived at by Bouguer approximation calculations, is certainly conservative.
PRESTON AREA

Geophysics and Tectonics

A great deal of geophysical work has been completed in the Cache Valley area, Utah and Idaho (Stanley, 1972 and Peterson and Oriel, 1970) and quite detailed interpretations have been published. In the Preston area, gravity (Figure 20) indicates a complex graben structure with a local high about midway between the interpreted bounding faults on the east and west margin of the overall structure (Figure 21). The intra-graben gravity high has been interpreted to result from a subsurface extension of the Clifton Hill, exposed to the north (Peterson and Oriel, 1970). A fault has been interpreted as bounding the east flank of the intra-graben high. Witkind (1975) indicates faults on both the east end and west of Clifton Hill but questions which direction of movement has taken place on the western Clifton Hill fault. He also documents known or suspected active faults which clearly define the margins of Cache Valley and extend well into Idaho, beyond Pocatello and terminating about 12 miles SSE of Blackfoot (Figure 17).

Two dimensional modeling of the gravity data indicate a thickness of up to about 5500 feet of Cenozoic fill (Peterson and Oriel, 1970). Electrical resistivity surveys conducted by Stanley (1972) to investigate the first few hundred feet of valley fill were shown to be in good agreement with drilling logs from the area.

Lineament mapping by Day (1974) does not clearly correlate with the overall trend and pattern of the gravity anomaly or all of the documented faults but does so to a reasonable degree (Figure 15). It is likely that
Figure 20. Gravity lows from Gem Valley (upper left), near Preston in Cache Valley (lower left), and near Bear Lake (lower right) (Mabey, Peterson and Wilson, 1974).
Figure 21. Gravity profile near Preston and two-dimensional interpretation (Peterson and Oriel, 1970).
specific attention to lineament mapping in this area would increase the degree of correlation and possibly help to extrapolate existing interpretations.

Discussion

Assuming no source of heat other than an abnormally high regional heat flow, estimates of maximum temperatures at depth can be made after making certain assumptions concerning thermal conductivities. Using the assumptions described previously, an estimate for 5500 ft of thermal insulating cover would be about 110°C.
BEAR LAKE-MONTPELIER AREA

Gravity and Tectonics

Gravity mapping (Mabey, Peterson and Wilson, 1974) in the Bear Lake-Montpelier area of southeastern Idaho reveals steep east-west gradients suggesting a north-south striking Basin and Range type graben valley (Figure 20). An E-W profile taken from the aforementioned map along the Idaho Standard Parallel South through the Bear Lake anomaly (Figure 22) defines a 21 mgal residual low. Calculations made assuming a 0.4 gm/cm³ density contrast between valley fill and flanking bed rock result in an estimated basin depth of about 4100ft. Witkind (1975) defines faults along both margins of the gravity-inferred graben (Figure 17) which are presumed active with late Quaternary beds broken. Day (1974) has mapped linears from band 5, MSS-ERTS imagery which also coincide very well with the gravity inferred graben (Figure 15).

Discussion

The basin depth estimate must be considered very conservative. A similar depth estimate was calculated in the Oakley area where a maximum temperature-at-depth of about 90°C was calculated. Given similar assumption, similar temperature estimates would be appropriate for this area.
Figure 22. Gravity profile near Bear Lake
PALISADES RESERVOIR-SWAN VALLEY AREA

Gravity and Tectonics

Swan Valley and its extensions to the NW and SE are reflected quite prominently by a NW distortion of NE trending gravity contours (Figure 18). A NE profile of gravity values taken from the Preliminary Gravity Map of Southern Idaho (Mabey, Peterson and Wilson, 1974) across this feature (Figure 23) shows a 15 mgal residual low near the Pine Creek-Snake River confluence. Computations made, assuming a 0.4 gm/cm$^3$ density contrast, suggest a structural valley or basin about 2900 ft deep. Similar depth estimates would be expected for other profiles across the valley.

Witkind (1975) has shown two active faults, the Grand Valley and Snake River faults or the Swan Valley faults (Figure 17) which define the long slender graben valley reflected in the gravity map. He has indicated probable movement along these faults during the last 20 million years (since mid Miocene time) but also of significance are several intra-graben faults approximately paralleling the valley-defining faults with late Quaternary (Wisconsin time in the Pleistocene) movements indicated. Lineaments mapped by Day (1974) generally define the same features plus many short features at roughly right angles to the valley strike which may or may not be tectonically significant (Figure 15).

Discussion

Maximum temperature-at-depth estimates from previously described calculations are about 70° C for the 2900 ft depth conservatively calculated for this area from the gravity profile data.
Figure 23. Gravity profile near Swan Valley.
THE IDAHO BATHOLITH

General

Swanberg (1972) has related heat generated by radioactive decay within the Idaho Batholith to depth of emplacement. He demonstrates that heat generation decreases exponentially with increased depth of emplacement. Building upon his data and conclusions one might speculate that areas of anomalously high heat flow in the Batholith should correspond to those regions of original shallow emplacement that have not been removed by erosion. Conversely low heat flow areas should correspond to those regions where the shallow-emplacement fractions have been largely eroded away. Estimating approximate emplacement depths petrologically would probably be a more efficient means of distinguishing than direct heat flow measurements.

Thermal water occurrences within the Idaho Batholith seem to coincide with stream drainage patterns to a remarkable degree. It is reasonable that drainage pattern development will be controlled largely by joint and fracture development. It is also reasonable that thermal water occurrences would coincide with dominant joints and fractures which would provide avenues for deep circulation and the return to the surface of water heated during such intrabatholith circulation. Accepting these premises, it is not surprising that thermal water manifestation coincide with stream drainage patterns.
WARM LAKE AREA

Geophysics and Tectonics

The Preliminary Gravity Map of Southern Idaho (Mabey, Peterson and Wilson, 1974) indicates nothing of local significance in the Warm Lake area. This area lies within the central part of the Idaho Batholith which is characterized by a broad regional gravity low as would be expected for isostatic mass compensation at depth.

A broad small amplitude local gravity low is shown several miles north of Warm Lake. It is not interpreted as being indicative of local scale structures. Gravity data are sparse in this area as they are throughout most of the Batholith area. Additional data may provide some insight into local structural conditions.

Vulcan Hot Springs are found within this area about six miles south of Warm Lake. They constitute one of the most prominent surface thermal manifestation in Idaho and are probably controlled by deep fracturing in the Batholith. Witkind (1975) does not document any known or suspected active faults strictly within this area but this is certainly not viewed as being final and conclusive. He does, for example, document a fault nearby to the southeast with late Quaternary movement and Day (1974) has mapped lineaments which may reflect significant structures (Figures 17 and 15).
GARDEN VALLEY AREA

Geophysics and Tectonics

The Garden Valley area lies within the Idaho Batholith near its western contact with the Snake River Plain. Gravity data are quite sparse in this area and are completely dominated by the strong regional gradient between the highs within the Plain and the lows over the heart of the Batholith. More detailed gravity work accompanied by a careful removal of the regional gradient might reveal some indications of local structures.

Witkind's (1975) study of known and suspected active faults in Idaho reports a N-S feature of major proportions which passes through this region and merges with a complex system of faults in the vicinity of and northward from Cascade (Figure 17). The fault shown passing through the Garden Valley area is 40 miles long with last movements suspected to be late Cenozoic. It is commonly known as the Boise Ridge Fault and features sympathetic to it may be responsible for the series of hot springs paralleling the Middle Fork of the Payette River north of Garden Valley.

Day's (1974) lineament mapping of Idaho from ERTS imagery shows a strong linear following the general course of the Middle Fork of the Payette and a few short features with high angle intersections (Figure 15).

The Aeromagnetic Map of Southwestern Idaho (U.S.G.S., 1971) terminates near the Garden Valley area and is not helpful in attempting a more thorough local interpretation.
KETCHUM-HAILEY AREA

Geophysics and Tectonics

Gravity in the Ketchum-Hailey area is dominated by a strong regional gradient controlled by the transition from the Snake River Plain gravity high to the gravity low over the Idaho Batholith. Any detailed interpretation from gravity in this area would necessarily involve increasing the amount of data and carefully removing the strong regional gradient.

Witkind (1975) has identified an active fault in the lower Wood River valley which is terminated about 4 miles north of Hailey. Distortions in the regional gradient contours are, however, suggestive of faulting further up the valley and faults are indicated on the Idaho State Geologic Map (Bond, 1978).

A relatively small-amplitude, low-frequency magnetic high roughly centered over Bald Mountain and an associated low to the north may be indicative of a buried igneous unit. A strong elongate high and associated low centered about 15 miles NE of Sun Valley appears to be a near surface phenomena (Figure 24).
Figure 24. Magnetic anomalies near Bald Mountain (right of center) and NE of Sun Valley (upper right) (U.S. Geological Survey, 1971).


Witkind, I.J., 1975, Preliminary map showing known and suspected active faults in Idaho: U.S. Geol. Survey open file report no. 75-278.


