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REGIONAL GRAVITY AND MAGNETIC SURVEYS IN THE ALBION MOUNTAINS AREA OF SOUTHERN IDAHO

by

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Regional gravity and magnetic surveys in the Albion Mountains area of southern Idaho

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Abstract

Fault-bounded basins containing several thousand feet of sedimentary and volcanic rock of Cenozoic age are indicated by gravity lows in the Oakley area and in Upper Raft River and Raft River Valleys. A gravity low and a magnetic high in the north end of Raft River Valley extends over the Cotterel Mountains and into Marsh Creek valley. These anomalies may reflect a Tertiary caldera. A gravity high and a magnetic high in the Raft River Valley south of Malta suggests a buried intrusive that may be the source of heat for the thermal waters in that area.

Introduction

Regional gravity and aeromagnetic data have been obtained over the Albion Mountains and adjoining areas to the east and west. The area covered is about 50 miles wide and extends south from the Snake River Plain about 35 miles to the Utah-Idaho border (fig. 1). The purpose of the survey was to obtain information on the subsurface geology of the extensive valley areas covered by Cenozoic sedimentary and volcanic rocks and on the structural geology of the older rocks in the ranges.

The Albion Mountains rise from the southern edge of the Snake River Plain and extend south-southwest for about 35 miles (fig. 2). They are the westernmost of the major north-trending ranges of southeastern Idaho, and the highest point--Cache Peak with an elevation of 10,335 feet above sea level--is the highest point in Idaho south of the Snake River Plain. The Albion Mountains are flanked on the northwest by the valley of lower Goose Creek, which is an embayment of the Snake River Plain, and on the southwest by Junction Valley and Middle Mountain. On the east the range is separated from Raft River Valley by a series of moderate size valleys and the Cotterel and Jim Sage Mountains. The Raft River Valley is the westernmost of the major intermontane valleys in southeastern Idaho. The north-trending Black Pine Mountains and Sublett Range lie east of Raft River Valley, and the east-trending Raft River Mountains lie to the south a few miles beyond edge of the map.

The Albion Mountains separate two drainage basins. The northwest part of the range drains west into Goose Creek. Goose Creek heads in Nevada, flows generally northeast through the northwest corner of Utah, enters Idaho and flows north through an embayment of the Snake River Plain toward the Snake River. Raft River, which drains the western and southern part of the Albion Mountains, heads in Utah and flows

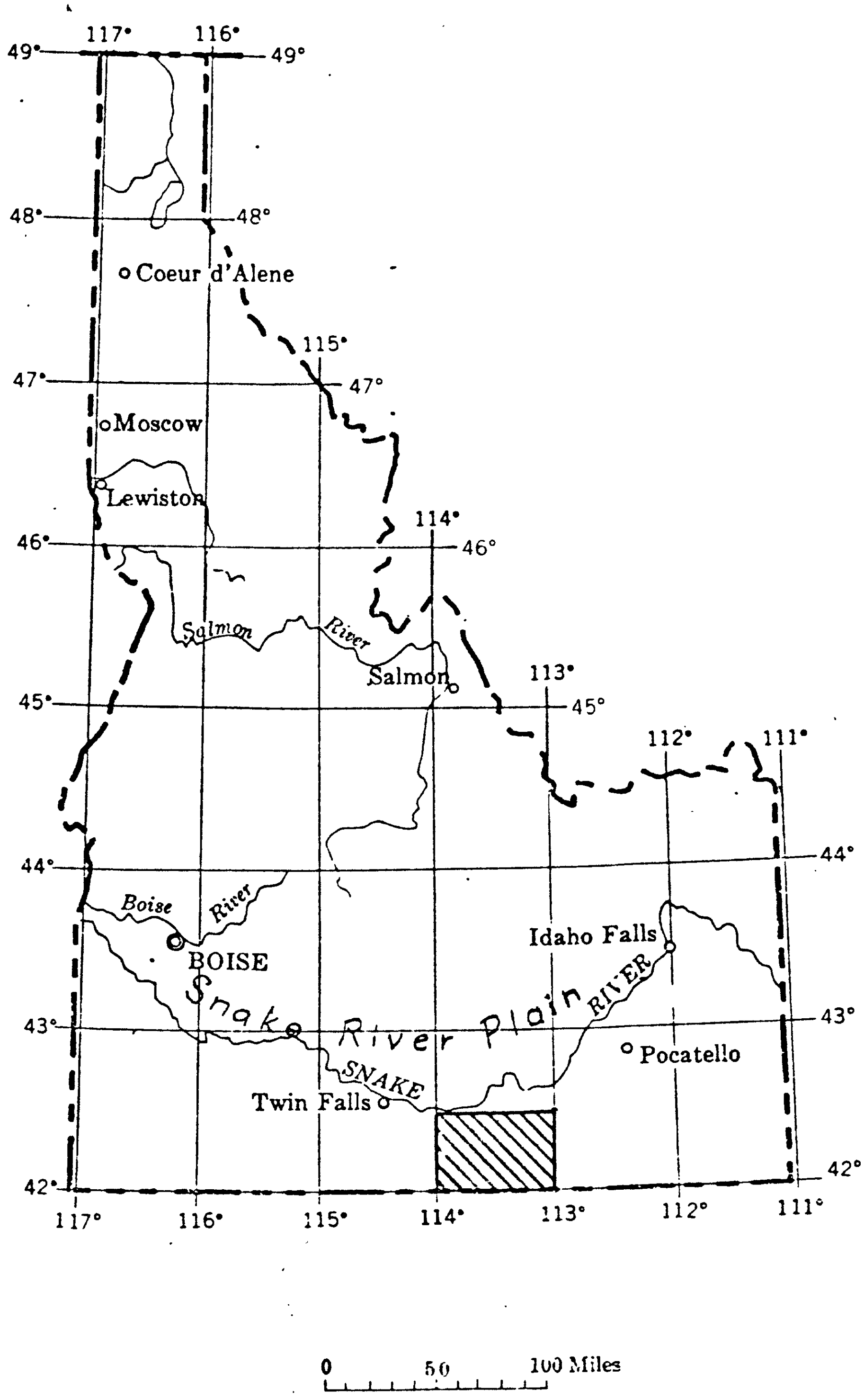

Figure I. Index map showing location of the Albion Mountains area.

north and east through Upper Raft River Valley into Raft River Valley and north to the Snake River.

Geology

The geology of parts of the region is well known and reconnaissance studies have been made of other parts. Anderson (1931) has reported on the geology of the entire area of this survey. Armstrong (1968 and 1970) has studied much of the Albion Mountains in considerable detail, and Mapel and Hail (1959) have mapped the southwest part of the area. The ground-water resources are described by Nace (1961), Crosthwaite (1969), and Walker and others (1970). The generalized geology in figures 2, 3, and 4 and the following geologic summary are based on the above reports.

The pre-Tertiary rocks are exposed in the ranges and comprise a lower series of metamorphic rocks and an upper series of limestone, sandstone, shale and chert. These rocks have been complexly folded and sliced by great low angle overthrusts and normal faults. In Oligocene time they were intruded by granite, which is exposed in the southern part of the Albion Mountains and in Middle Mountain.

Erosion and uplift occurred in Early Tertiary time, and in Miocene and Pliocene time much of the area was covered with lacustrine and fluviatile deposits, volcanic ash, and flows of lava, mainly quartz latites. These alternating beds of sedimentary and volcanic rocks, which have a total exposed thickness of about 2,000 feet, are extensively exposed in the Cotterel and Jim Sage Mountains and in the southwestern part of the area. They are also penetrated in many of the deeper drill holes in the valleys. In the western part of the area these rocks are called Payette(?) Formation, Salt Lake Formation, and Idavada Volcanics; in the east, Salt Lake Formation. In this report they are referred to as Tertiary rocks. Early in the Quaternary period, normal faulting formed the present basin and range topography.

To the north is the 400 mile long, 50-to-75 mile wide, arcuate Snake River Plain, and the northern ends of the Albion and Cotterel Mountains and Sublett Range are downwarped into the plain. The Snake River Plain is a depression that is partly filled with massive flows of Cenozoic olivine basalt. These basalt flows also overlap the downwarped ends of the ranges and spread southward into the northern part of the basins. The thickness of individual flows ranges from a few feet to several tens of feet, and the lava beds are intercalated with lake and stream deposits.

In Raft River Valley a Pleistocene lake formed when basalt flows blocked the northward drainage. Sediments of the Raft Formation deposited in this lake are as much as 1,000 feet thick. Spread over the broad basin floors and scattered on the mountain slopes are Pleistocene fan deposits, slope wash, glacial and loess deposits, and landslide material.

Large areas of the lowlands have been developed for agricultural purposes through the use of surface and ground water for irrigation. The Cenozoic volcanic and sedimentary rocks are the important aquifers. Most of the Raft River and lower part of the Goose Creek drainage basins are in the survey area, and important ground-water resources occur in both basins. The extensive use of ground water, however, has caused water levels in the wells to decline, and the development of new wells has been restricted by the State of Idaho.

Thermal springs and wells occur in several areas and may reflect geothermal systems that are potential resources for the generation of electricity. Two wells in the southwest part of Raft River Valley produce boiling water and steam at a depth of only 400 feet. The water from one of these wells presently is used for heating a large greenhouse. Sylvia H. Ross, who studied the geothermal potential of Idaho, reports, "South Raft River Valley seems to be one of the most likely places to drill for steam in the entire State of Idaho." (Ross, 1971).

Mineral deposits occur in the area but have not been developed on a large commercial scale (Anderson, 1931). Deposits of lead-silver ores, zinc-silver ores, and ores of other metals have been found in the Albion and Black Pine Mountains. Lignite, bentonite and low-grade uranium deposits have been found in the Tertiary rocks but are not of commercial value. Building stone includes mainly the Tertiary tuffs and lavas and to a limited extent quartzite, basalt, and marble.

Physical properties

No attempt has been made to measure the density and magnetic properties of all the major rock units in the area. The density of a few rocks was measured and information available on the properties of similar rocks in the region provides the necessary background for an interpretation of the gravity data.

Measured dry densities of nine samples of pre-Tertiary rocks of the area range from 2.67 g per cm^3 for samples of limestone and quartzite to 3.08 g per cm^3 for Precambrian amphibolite. Most of the pre-Tertiary rocks have densities of about 2.7 g per cm^3, but significant gravity anomalies may be associated with the more dense Precambrian units. The Oligocene granite at the City of Rocks has a density of about 2.6 g per cm^3.

The densities of the Cenozoic sedimentary and volcanic rocks cover a considerable range. Saturated densities as low as 2.07 g per cm^3 have been determined for Tertiary sedimentary rocks in the Cotterel and Jim Sage Mountains, and units with lower densities may exist. Densities as high as 2.55 g per cm^3 have been measured for Tertiary sedimentary rocks east of study area. The average density of saturated Tertiary sedimentary rocks in the study area is estimated to be about 2.25 g per cm^3. Measured dry densities of six samples of Tertiary volcanic rocks in the area ranged from 2.21 to 2.48 g per cm^3, and the average density of these rocks is estimated to be about 2.45 g per cm^3.

The basalt flows and associated rubble of the Snake River Plain have a wide range in density. The average is estimated to be about 2.65 g per cm^3. No densities of Quaternary sediments in the region have been measured, but an average density of about 2.1 g per cm^3 is suggested by published descriptions.

Thus, the rocks in the area fall into three major density groupings. The most dense rocks are pre-Tertiary rocks, Tertiary intrusive rocks, and the Quaternary basalt. Tertiary silicic volcanic rocks have an intermediate density, and Cenozoic sedimentary rocks have the lowest density. Gravity lows relative to areas of pre-Tertiary rocks would be produced by, (1) Cenozoic sedimentary rocks, (2) Tertiary silicic volcanic rock, (3) interbedded volcanic rock and sedimentary rocks, and (4) Tertiary intrusive rock. Gravity highs could be produced within the pre-Tertiary rocks by dense Precambrian units and within Cenozoic rocks, by igneous intrusives or by a thick sequence of volcanic rocks enclosed in Cenozoic sedimentary rocks.

Quantitative interpretations were made along three profiles (fig. 5). Regional gravity variations were computed from the regional topography (Mabey, 1966) and the residual gravity lows were attributed to Cenozoic rocks with a density of 0.4 g per cm^3 lower than the enclosing older rocks. The interpretation shown on the profiles assumes a two-dimensional model for the basin fill.

No quantitative measurements of the magnetic properties were made as part of this survey, but generalizations can be made from an inspection of the rocks and studies in other areas. The most magnetic abundant rock in the region is the Quaternary basalt. The basalt has a strong remanent magnetization and can produce magnetic highs or lows depending on the direction of magnetization. The silicic volcanic rocks range from weakly magnetic to moderately magnetic and some of these rocks possess a strong remanent magnetization; thus, magnetic highs or lows might be produced by silicic volcanic rocks. None of the sedimentary, metamorphic, or Tertiary intrusive rocks examined appeared to be magnetic, but some metamorphic and intrusive units that are magnetic may exist in the area.

Gravity survey

Gravity observations were made at 416 stations, and 13 stations previously established by D. L. Peterson were incorporated into the survey. The observed gravity was referenced to a value of 980031.1 milligals at U.S.C. & G.S. Bench Mark S-30 in Minidoka, Idaho. Observed gravity values are believed accurate to 0.2 milligals relative to the Minidoka base. Elevation control for the gravity stations was obtained from 1:62,500 and 1:24,000 scale topographic maps published by the U. S. Geological Survey. The maximum error in elevation should not exceed 5 feet. Terrain corrections computed through Hayford-Bowie zone L (approximately 18 miles) range from less than 0.2 milligals in the centers of the large valleys to 26 milligals for a station on the crest of the Albion Mountains. Most of the gravity stations and the local anomalies defined by the survey are in the valley areas where terrain corrections are small relative to the 5-milligal contour interval of the gravity map (fig. 2). However, the larger corrections in the mountains are significant to the gravity map; therefore, terrain corrections were computed for all stations with corrections larger than 2 milligals, and the correction in excess of 2 milligals is included in the anomaly values used to prepare figure 2. The terrain effect beyond zone L is important only for a few stations high in the Albion Mountains.

Although most of the gravity stations are in the valleys where the anomalies of greatest interest occur, enough stations were established in the ranges to define the larger variations. Regional elevation is decreasing and the regional Bouguer gravity values are rising toward the topographic lows of the Snake River Plain in the northern part of the survey area and the Great Salt Lake Basin southeast of the survey area. In the north the regional gravity variation is particularly large, and the local anomalies are somewhat obscured by the broader feature on which they are superimposed. The larger local anomalies are lows over Cenozoic rocks reflecting the density contrast between the Cenozoic rock and the more dense older rocks.

Aeromagnetic survey

The aeromagnetic data were obtained in two surveys. The first survey was made in 1970 with east-west flight lines 5 minutes apart and 12,000 feet above sea level (U.S.G.S., 1972). To obtain better definition of an anomaly southwest of Malta, a few north-south lines were flown at the same elevation in 1972. A residual map (fig. 3) based on both surveys was prepared by removing the IGRF field 1965 (Fabiano and Peddie, 1969). In using the magnetic map consideration must be given to the fact the flight lines are widely spaced relative to the distance between the flight elevation and the ground surface. The survey did not define anomalies of small areal extent and may have completely missed some anomalies between flight lines. The map does, however, illustrate the more extensive variations in the magnetic field.

A residual magnetic relief of about 400 gamma occurs over the area at the survey level and has the highest and lowest intensities over Quaternary basalt along the south edge of the Snake River Plain. A magnetic high extends over most of the highland in the central part of the survey area and into north and south parts of Raft River Valley. This high extends over all of the major rock types of the region and does not correlate well with surface geology.

Basin anomalies

The gravity low in the Oakley area is interpreted as indicating a basin filled with Cenozoic rocks, which is here called the Oakley basin (fig. 4). No deep drill hole exists in the area of this low to provide control for the interpretation; however, Tertiary rocks crop out over part of the area of lowest gravity values, and these rocks are assumed to be the major unit filling the basin. The relative steep gravity gradient along the southeast edge of the low suggests that a fault or fault zone separates the basin from the Albion Mountains to the southeast and Middle Mountain to the south. The axis of the basin lies near this fault zone.

The gravity values over the Oakley basin are strongly influenced by the northward increase in regional gravity into the Snake River Plain. Because of this gradient the structure and depths along the northwest side of the basin cannot be inferred with confidence. One fault has been inferred on the west side of the basin, but others may exist. Over most of the basin the Cenozoic fill appears to be about 4,000 feet thick (section AA', fig. 5). East of Oakley the gravity anomaly is complex and suggests a local thickening of the low density rocks to about 6,000 feet. This inferred intrabasin depression partly underlies a north-trending low ridge of Tertiary rock apparently bounded on the west by a fault. The gravity data do not reflect this fault which indicates that it does not produce a large offset of the surface of the pre-Tertiary rock. The gravity data suggest the basement surface may be elevated on the southeast by a northeast-trending fault that crosses the ridge of Tertiary rock but is not expressed at the surface. The Oakley basin extends to the northeast and southwest beyond the area of this study.

Near the northwest corner of the map is a large magnetic low (fig. 3). The low is partly over basalt flows and partly over alluvial sediments. The magnetic anomaly indicates that the basalt flows are inversely magnetized and extend several miles to southwest under the sediments. Because the last major period when the earth's magnetic field was reversed ended about 700,000 years ago, the inversely magnetized basalt is at least that old. A magnetic high over a basalt dome about 13 miles northeast of Oakley indicates that this basalt is normally magnetized.

A small gravity low occurs in the northern part of Junction Valley and extends south beyond the area of the survey (fig. 2). At the south edge of the map the Cenozoic rocks underlying the valley appear to be about 2,000 feet thick. The steep gravity gradient on the east side of the low suggests that a fault is present on this side of the valley.

The gravity low in Upper Raft River Valley is approximately equidimensional and coextensive with the valley. The low is interpreted as indicating a basin--here called the Upper Raft River basin--

containing about 4,000 feet of Cenozoic fill. As in the Oakley basin, because the lowest gravity values are in an area where Tertiary rocks are exposed, a major part of the anomaly must be produced by Tertiary rocks. Moderately steep gravity gradients occur along the west side of the Upper Raft River basin and an appended depression extending north to Elba suggest that a fault forms the western boundary of the basin. On the southeast side of the basin a fault boundary is also suggested. The gravity data along the northeast side of the Upper Raft River basin do not define the gradients, and the evidence for the faults shown on figure 4 is weak.

No major magnetic expression of the Upper Raft River basin is apparent. A magnetic high over the valley south of Elba and extending onto the Jim Sage Mountains (fig. 3) has a near surface source, probably within the Tertiary rocks. The anomaly is similar and partly continuous with an anomaly on the west side of Raft River Valley.

Over Raft River Valley the Bouguer anomaly is relatively complex. Within the valley three low and two high closures have been defined suggesting considerable variations in the thickness of the Cenozoic fill (fig. 2). At the north end of the valley the gravity low extends west over the northern part of the Cotterel Mountains and Marsh Creek valley. The Bouguer correction applied to the gravity data is based on a density of 2.67 g per cm^3; therefore, the anomaly values will reflect the thickness of low density rocks relative to the surface. Through most of the length of the Cotterel and Jim Sage Mountains the gravity data suggest that the thickness of low density rocks underlying gravity stations on the range is not greatly different from that underlying the immediately adjoining parts of Raft River Valley to the east.

The gravity low at the north end of Raft River Valley is interpreted as reflecting a basin, which is here called the Idahome basin. Steep gravity gradients occur around most of the perimeter of the gravity low suggesting bounding faults. Over the north end of the valley and the Cotterel Mountains is a magnetic high with approximately the same extent as the gravity low suggesting that the two anomalies are related. Horse Butte at the north edge of the study area is a Quaternary basalt dome. The magnetic high is centered over Horse Butte, but the anomaly extends over older rocks in the Cotterel Mountains so that the basalt flows at Horse Butte cannot be the major cause of the anomaly. The gravity and magnetic anomaly suggests that the Idahome basin may be a major caldera filled with low density sedimentary and volcanic rocks (section BB', fig. 5). The basin is older than Raft River Valley and is presumed to be Tertiary. Sedimentary and volcanic rocks within the depression could account for the gravity anomaly, but the magnetic anomaly probably has more than one cause. Basalt associated with the eruptions at Horse Butte are probably part of the source of the magnetic anomaly. Silicic volcanic rock within the depression may also contribute to the magnetic anomaly but an underlying mass of intrusive rock may exist and contribute to both the gravity and the magnetic anomaly.

Superimposed upon the Idahome basin are structures associated with the younger Raft River Valley. The lowest gravity values in the valley are generally within about 2 miles of the Raft River and are probably in the area of the greatest thickness of the Quaternary Raft Formation, which consists of sediments that are presumed to be less dense than the Tertiary sedimentary and volcanic rocks. Faulting that is assumed to have resulted in the uplift of the Cotterel Mountains relative to Raft River Valley does not appear to be related to the older structure. Because no major gravity anomaly occurs at the front of the Cotterel Mountains, the Raft Formation is probably absent or relatively thin near the range front and thickens eastward toward the center of the valley where a thickness of about 1,000 feet has been reported (Walker and others, 1970) in the area of the lowest gravity values.

In the northeastern part of Raft River Valley is an area of high gravity that is interpreted as reflecting a largely buried ridge of pre-Tertiary rock, which is here named the Chapin ridge. This ridge extends southwest and south into the valley for about 16 miles (fig. 4). Gravity gradients along the flanks of this ridge are locally high suggesting faulting; however, linear zones of high gradient are not apparent. Perhaps the ridge was uplifted along faults, but the topography was considerably modified by erosion before the ridge was buried. The magnetic low over the ridge (section CC', fig. 5) suggests that the rock in the ridge is nonmagnetic.

East of the Chapin ridge is the partly closed Sublett basin (fig. 4 and section CC', fig. 5) with about 5,000 feet of fill indicated by the gravity anomaly. Steep gravity gradients suggest that the basin is partly bounded by faults. A low amplitude magnetic high over the basin suggest that part of the material filling the basin is volcanic.

In the southern part of the Raft River Valley is another extensive gravity low. The low is interpreted as reflecting a basin, here called the Bridge basin, filled with low density Cenozoic rocks (fig. 4). The low is partly open to the southwest toward the Upper Raft River basin and north toward the Idahome basin. On the northwest, east, and south the basin is bounded by steep gravity gradients, which are interpreted as indicating faults. The fill in Bridge basin is about 6,000 feet thick with the greatest thickness east of the topographic low area of the valley (section AA', fig. 5). The magnetic data do not suggest any magnetic material underlying the main part of the Bridge basin.

West of the Bridge basin but within Raft River Valley are approximately coincident gravity and magnetic highs, which are here called the Bridge anomalies. No similar coincident anomalies were mapped in the area, and no evidence at the surface suggests a cause of the anomalies. Quantitative interpretation of the anomalies is uncertain because the magnetic anomaly merges with an extensive high to the northwest and the gravity anomaly is effected by the Bridge basin to the east. The magnetic anomaly can be modeled by a body of moderately magnetic material (susceptibility about 1×10^{-3} cgs units), striking northeast, about 2 miles wide and 6 miles long and with considerable depth extent. The gradients associated with the magnetic anomaly indicate the top of the magnetic body is within 4,000 feet of the surface and may be within 1,000 feet. The gravity anomaly suggests a source at the same location but perhaps nearer the surface and could be produced by a 1,000 foot thinning of the low density Cenozoic rocks. A small magnetic closure north of the Bridge anomalies has a near surface source.

Two possible explanations are proposed for the Bridge anomalies: (1) a local accumulation of basalt, or (2) a concealed intrusive possible combined with relief on the base of the low density Tertiary rocks. Basalt is more dense and more magnetic than the rocks exposed in the Jim Sage Mountains to the west, but a very local accumulation of the several thousand feet of basalt required to produce the anomalies does not appear geologically reasonable. An intrusive mass could produce the magnetic anomaly but an intrusive of the size required would not be expected to be much more dense than the pre-Tertiary rock. The Tertiary granite in the south end of the Albion Mountains has a lower density than the average for pre-Tertiary rock in the region and is not expressed in the magnetic data. The gravity anomaly can be produced by a thinning of the low density Tertiary rocks (section AA', fig. 5), but the resulting ridge of higher density rocks would not produce the magnetic anomaly. A tentative interpretation of the anomaly is that an intrusive body that is moderately magnetic (section AA', fig. 5) underlies the area, and this mass is either more dense than the normal pre-Tertiary rock or is part of or underlies a buried ridge that is enclosed by low density Tertiary rocks.

Geothermal resources

Thermal waters occur in several springs and wells in the survey area and are a potential resource. The hottest water reported comes from two wells in the southwest part of Raft River Valley on the west side of the Bridge basin (figs. 2 and 3) and this area has been classified as a "known Geothermal Resource Area" (Goodwin and others, 1971). The wells are south of the Bridge anomalies and are adjacent to the steep magnetic and gravity gradients on the south side of these anomalies. Also in the area is a low amplitude gravity trough and ridge within the basin. Because the thermal waters tapped by the wells could have migrated horizontally for substantial distances, the heat source need not underlie the wells. The most anomalous features in the area are the Bridge gravity and magnetic anomalies. Perhaps the Bridge anomalies reflect a relatively young intrusive that is still cooling and providing heat to ground water that is circulating in normal faults that bound the Bridge basin. If this interpretation is correct, a rather large area lying generally north of the two wells might be underlain by significant amounts of hot water or steam.

All of the known hot wells or springs lie within or along the margins of the extensive area of high magnetic intensity in the central part of the survey area. Hot waters are known to occur in the vicinity of several inferred faults. If we assume that the combination of a near surface mass of intrusive igneous rock and high angle faults provide a favorable environment for the development of geothermal systems, the gravity and magnetic data suggest two general areas for more intensive examination: the vicinity of faults around and within the Idahome basin, and the area of high magnetic relief adjacent to the Cotterel Mountains south of the Idahome basin.

Ranges

Over the Albion Mountains the gravity values increase northward toward the Snake River Plain. Most of this increase correlates with the decrease in regional elevation and no relation of this broad feature to the geology in the upper crust would be expected.

South from Marsh Creek valley is a northeast-trending chain of four mantled gneiss domes described by Armstrong (1968). The southern two domes are west of Almo and have cores of Tertiary granite. The gravity anomaly values over this granite are relatively low and presumably reflect the small density contrast between the granite and the enclosing pre-Tertiary rocks. No similar anomaly is apparent over the northern two domes. North and east of the chain of domes the anomaly values on or near pre-Tertiary rock increase more abruptly than the normal regional increase suggesting that the area north of the domes is underlain by higher density rocks at depth or that the overlapping sedimentary and metasedimentary rocks are more dense than the gneiss in the dome. At the southwest edge of the Black Pine Mountains the Bouguer anomaly values are high. Part of this increase reflects the decrease in regional elevation south toward the Bonneville basin of Utah, but a part may reflect a mass anomaly in the upper crust.

The magnetic anomalies over the Albion Mountains do not correlate with the exposed geology. The magnetic high that crosses the southern part of the range is partly underlain by Tertiary granite but the anomaly could not be produced by a body with the lateral dimension indicated by the distribution of the granite at the surface. The anomaly appears to be produced by a buried mass that is not reflected in the surface geology. No explanation is apparent for the ridge of high magnetic intensity that trends across the range south of Mount Harrison although this feature appears to have a shallow source.

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