

Gravity and Magnetic Anomalies in the Soda Springs Region, Southeastern Idaho

GEOLOGICAL SURVEY PROFESSIONAL PAPER 646-E



Gravity and Magnetic Anomalies in the Soda Springs Region, Southeastern Idaho

By DON R. MABEY *and* STEVEN S. ORIEL

G E O P H Y S I C A L F I E L D I N V E S T I G A T I O N S

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*Geophysical data indicate the thickness of
Cenozoic sedimentary rocks and the
distribution, and locally the thickness,
of igneous rocks*



UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1970

UNITED STATES DEPARTMENT OF THE INTERIOR

WALTER J. HICKEL, *Secretary*

GEOLOGICAL SURVEY

William T. Pecora, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

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GEOPHYSICAL FIELD INVESTIGATIONS

GRAVITY AND MAGNETIC ANOMALIES IN THE SODA SPRINGS REGION, SOUTHEASTERN IDAHO

By DON R. MABEY and STEVEN S. ORIEL

ABSTRACT

Two major gravity lows indicate deeply filled troughs in Gem and Bear Lake Valleys in the western, block-faulted part of the Soda Springs region. A third large and compound gravity low at China Hat may record an igneous collapse structure, but the evidence is equivocal. In contrast, the relatively uniform gravity values in the eastern, mainly folded, part of the region indicate little detrital fill in strike valleys in the folded and thrust belt. Gravity data also indicate that variations in regional topography in the surveyed area are isostatically compensated but that the region in general is undercompensated.

All but two of the aeromagnetic anomalies are attributable to surface volcanic features and to structures inferred therefrom. The magnetic anomalies indicate the distribution and thicknesses of basaltic rocks. The largest anomalies, north of Niter, west of Grace, and north-northwest of China Hat, are associated with vents and craters, and these may be guides to concealed related intrusive bodies. The magnetic survey also confirms the presence of extensive areas of inversely magnetized, slightly older basalt east of the Blackfoot River Reservoir. Two positive magnetic anomalies of undetermined origin at Eighteenmile Creek in the Chesterfield Range may reflect dikes or sills of Cenozoic age within Paleozoic sedimentary rocks, lava flows within Pliocene strata, or secondarily iron-enriched Carboniferous beds.

INTRODUCTION

Gravity and aeromagnetic surveys were made in the Soda Springs region as a part of the more extensive geophysical studies undertaken in conjunction with concurrent geologic investigations in the Idaho-Wyoming thrust belt. The gravity measurements are useful in estimating depths of fill in intermontane basins and in delimiting partly concealed bounding faults. Aeromagnetic data are particularly helpful in outlining partly concealed bodies of basalt which are abundant in the region and, indirectly, in locating ancient stream valleys. Because none of the local magnetic anomalies seem to be related to basement rock, the basement must be either nonmagnetic or deeply buried. We have been unable to apply the geophysical data directly to the recognition of thrust-fault relations at depth.

The surveys cover about 1,200 square miles in the Portneuf, Henry, Bancroft, Soda Springs, Lanes Creek, and Slug Creek 15-minute quadrangles, which are all in the northwest quarter of the Preston 1° by 2° sheet.

Major topographic features in the region include, from west to east, a part of the Portneuf Range, Gem Valley, the Chesterfield Range, the north end of the Bear River Range, the Blackfoot lava field, the valley of Bear River near Soda Springs, and small ranges and basins in the upper drainage of the Blackfoot River (fig. 1).

Gravity observations were made by Mabey during several brief periods from 1961 to 1964. The aeromagnetic surveys were flown in 1960 (Meuschke and Long, 1965) and 1963 (Mitchell and others, 1965). Geologic material was assembled by Oriel from published reports

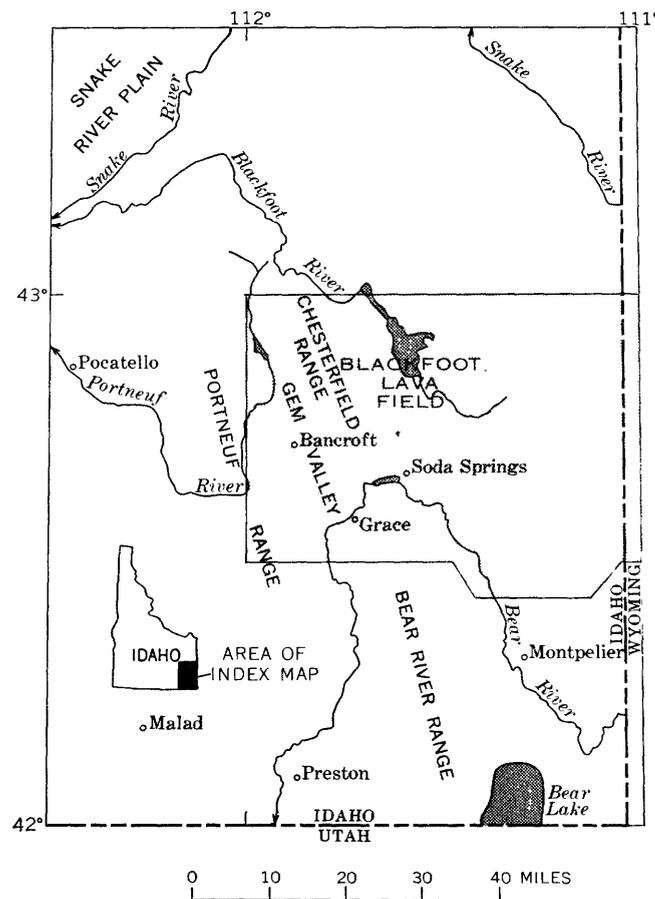


FIGURE 1.—Index map of Soda Springs region, southeastern Idaho, showing area of gravity and magnetic surveys (shaded).

by Mansfield (1927, 1929), unpublished maps of the Soda Springs quadrangle by Frank C. Armstrong (1969) and of the Bancroft quadrangle by Oriel (1968), and observations made during reconnaissance mapping of the Preston 1° by 2° sheet. Although the reconnaissance geologic mapping underway in the Preston 1° by 2° quadrangle has not been synthesized, publication of the geophysical results seems desirable, despite the possibility that the work now in progress may result in future reinterpretations.

We gratefully acknowledge Mr. Armstrong's generosity in making his map available to us before publication. We are also indebted to Mr. Armstrong, H. J. Prostka, L. B. Platt, and M. D. Kleinkopf for their many helpful suggestions during review of this manuscript.

GENERAL GEOLOGY

PHYSIOGRAPHY

The Soda Springs region lies in both the Basin and Range and the Middle Rocky Mountains physiographic provinces. The boundary between the two provinces commonly has been placed along the west edge of the Wasatch and Bear River Ranges (pl. 1) and at various places north of Soda Point. The boundary was first placed along the course of the Blackfoot River (Fenneman, 1917, p. 82), was later shifted to the valley of Meadow Creek (Mansfield, 1927, p. 11), and still later was placed along the east edge of the Blackfoot and Willow Creek lava fields (Fenneman, 1931, footnote 2, p. 170). Although some of the criteria used to recognize the boundary¹ would support placing it along the east side of the Bear Lake and Blackfoot River Reservoir valley (along the west edge of the Aspen Range), no attempt is made here to redefine the boundary.

The western, or Basin and Range, part of the region consists of wide, deeply filled flat basins which separate broken and tilted ranges formed by block faulting. Local relief is moderate, with altitudes ranging from 9,167 feet at Sedgwick Peak in the Portneuf Range to 4,950 feet along Bear River 7 miles to the east.

The eastern, or Rocky Mountain, part of the region consists of numerous narrow subparallel ridges and

¹ The criteria are cited by Fenneman (1931, p. 170) as follows: "The attempt has been made to draw this line in such a manner as to leave on the east the closely crowded mountains whose forms are determined chiefly by close folding, thrust-faulting, and erosion, and on the west what seem to be block mountains due perhaps to normal faulting, more widely spaced and often separated by Quaternary-filled valleys." If the proportion of mountains to detritus-filled basins is stressed (Fenneman, 1917, p. 90-91; 1931; p. 327), then the west edge of the Portneuf Range would be a logical boundary. If the presence of Quaternary-filled basins is the paramount criterion (Fenneman, 1917, p. 82), then the east edges of Bear Lake, Grays Lake, and Star Valleys would be suitable boundaries. If, however, gross geologic structure is emphasized, then the west edge of the Aspen Range marks the boundary between predominantly folded rocks on the east and block-faulted rocks on the west.

thinly filled valleys of the folded and thrust belt. Local relief, which is moderate, decreases northeastward as the altitudes of valley floors increase.

The region lies in the Columbia River and Great Basin drainage systems. The northern and westernmost parts of the region are drained by the Blackfoot and Portneuf Rivers, which flow into the Snake River, whereas the southern part is drained by the Bear River, which flows into Great Salt Lake. Drainage divides in Gem Valley and on the Blackfoot lava field are low and barely perceptible.

Anomalous features characterize all three of the major rivers in the western part of the region and are products of considerable late Cenozoic deposition, volcanism, and recurrent block faulting. The Portneuf River heads near the Blackfoot River, flows southward through Gem Valley, leaves the valley through a canyon on the west, flows south and west before turning north to enter American Falls Reservoir 13 miles from the mouth of the Blackfoot River. The Bear River heads in the Uinta Mountains and flows generally northward for about 150 miles before turning sharply, at the bend near Soda Springs, to flow southward toward Great Salt Lake. The Blackfoot River flows west-southwest before turning to the northwest in channels cut in basalt flows. The divide between the Blackfoot and the Bear Rivers is about 3 miles south of, and less than 100 feet higher than, the Blackfoot River at the bend. The divide between the Portneuf and Bear Rivers in Gem Valley is within 1 mile of, and about 100 feet higher than, the Bear River but is less than 50 feet higher than the top of the channel cut by the river in the basalt flows. Quaternary basalt flows are thick enough to have diverted any of the three major rivers from their pre-basalt courses.

Drainage in the eastern part of the region is much more regular; a few of the main streams cut across strike ridges, but almost all the tributaries occupy strike valleys which parallel fold axes and faults. Erosion of old strata predominates over recent deposition. A few anomalous, wide, continuous valleys, such as Dry Valley, are undoubtedly related to stream capture.

STRATIGRAPHY

Stratigraphic units recognized in southeastern Idaho are summarized in the explanation on plate 1. Thicknesses and facies of all Paleozoic and Mesozoic rock units in the region (Mansfield, 1927; Armstrong, 1953; Armstrong and Oriel, 1965) indicate that the rocks formed within the Cordilleran miogeosyncline.

Both the oldest and the youngest rocks of the region are extensively exposed in the Basin and Range part of the region; rocks of intermediate age are exposed only

sparsely but may be more abundant at depth. The Cambrian and Precambrian Brigham Quartzite and overlying Cambrian units are abundantly exposed in the Bear River Range and are predominant in the Portneuf Range and the several ranges to the west. Underlying Precambrian metamorphic rocks are exposed no closer than the Ogden, Utah, area, 60 miles to the south. Ordovician through Triassic sedimentary rocks, mainly carbonates, underlie the mountain ranges. Upper Tertiary sediments assigned to the Salt Lake Formation bury parts of the ranges and are thousands of feet thick in the intervening basins. Upper Cenozoic volcanic rocks are especially extensive in the basins and join northward with similar rocks of the Snake River Plain. Most of the volcanic rocks are of Pleistocene age, although some are as old as Pliocene, and others, as young as Holocene. Basalt predominates overwhelmingly, but rhyolite is also present, primarily in the cones in and south of the Blackfoot River Reservoir. Water wells indicate that the basalt is, in places, at least several hundred feet thick.

Upper Paleozoic and Mesozoic rock units underlie most of the Middle Rocky Mountains province; the province has no exposed rocks older than the Devonian in the region discussed, although some are present farther east. The units present extend from the Devonian Jefferson Dolomite to the Jurassic Twin Creek Limestone. The most extensively exposed units, however, are of Pennsylvanian, Permian, and Triassic age. The province includes comparatively little upper Tertiary Salt Lake Formation and Quaternary basalt.

No Cretaceous or lower or middle Tertiary rocks are in the region, except for Lower Cretaceous strata that crop out in the Caribou Range, in the northeast corner of the mapped area. Strata in the southeastern part of the region, formerly assigned to the Wasatch Formation (Mansfield, 1927, pl. 6), are regarded on the basis of recent observations as considerably younger.

STRUCTURE

The western part of the Soda Springs region is characterized mainly by homoclinal strata cut by several sets of block faults of late Cenozoic age. Although broad broken folds are also present, pre-Mesozoic strata in most ranges dip 20°–30° east-northeastward. Only one thrust fault, the Paris fault of the Bannock zone (Armstrong and Cressman, 1963, p. J8), is present and well documented in this part of the region. The fault accounts for the juxtaposition of the Brigham Quartzite and the Thaynes Limestone near Cavanaugh Siding (plate 1, southern part), but its trace is covered northward. Several generations of steeply dipping faults strike north-northwestward, northward, and northeast-

ward. Many cut the Salt Lake Formation. Young range-front faults strike north-northwestward and northward. They clearly cut the Salt Lake Formation, and a few offset post-Pliocene basalt flows. Fairly recent recurrent movement apparently has occurred along some faults, but data are insufficient to date all the times of movement along the various faults. A better understanding of the stratigraphy and structure of the Salt Lake Formation would help date many events, for the strata of the Salt Lake Formation are involved in at least some of the deformation.

The eastern part of the Soda Springs region is characterized by thrust faults (Rubey and Hubbert, 1958, p. 186–200) and tight asymmetrical folds. Block faults are also present, but they are not so dominant as they are farther west. The major thrust of this region is the Meade fault (Armstrong and Cressman, 1963, p. J8; Cressman, 1964, p. 68–80), which places Mississippian limestone and, locally, Devonian dolomite over Upper Jurassic and Lower Cretaceous strata. This fault, which is a single surface in its westernmost exposures, splays into a thrust zone of several slices eastward along Crow Creek valley, Sage Valley, and Stump Creek valley. Folds above and below the fault are asymmetrical and have axial planes that dip moderately to steeply west. The folds and the Meade fault were formed at about the same time. Movement along the Meade fault probably occurred late in Early Cretaceous time, somewhat later than the first major movement along the Paris fault, which occurred in latest Jurassic and earliest Cretaceous time (Armstrong and Cressman, 1963, p. J14–J15; Oriol and Armstrong, 1966). Block faults and some transverse faults cut the Meade fault and, therefore, are considerably younger, although some of these faults were formerly mistaken for the Bannock fault (Mansfield, 1927). The block faults are mainly normal faults, downthrown to the west, and strike mainly north-northwestward. Some of them cut Salt Lake strata and are clearly post-Pliocene, but others cannot be dated more closely than postthrust. The transverse faults strike due east and apparently are strike-slip faults. They offset minor thrust slices and adjoining strata. Their ages are not established, but the offset would suggest that they may be either tear faults formed in a late stage of thrusting or strike-slip faults formed later.

PERTINENT ROCK PHYSICAL PROPERTIES

DENSITY

Densities measured on several hundred samples of major rock units are summarized in figure 2. The densities of the Quaternary and Tertiary sediments are estimates based on measurements of a few samples of Salt Lake Formation and on measurements made on

similar sediments in other areas. The composition of the Salt Lake varies so markedly that an estimate is necessary. Because no crystalline basement is exposed in the area, the density of the basement is assumed to be similar to that of the Farmington Canyon Complex of Eardley (1939) in Utah.

Density, in general, increases with increase in age of the strata down to Middle Cambrian carbonate rocks. Lower Cambrian and upper Precambrian quartzites, however, are less dense than the overlying carbonate rocks. The largest density contrast is between Cenozoic detrital strata and the Paleozoic carbonate rocks. In the analysis of the gravity lows produced by Cenozoic basin fill, a density contrast of 0.45 g per cm³ (gram per cubic centimeter) between the fill and the enclosing rock is assumed. If all Cenozoic material in a basin were unconsolidated sediments, the density contrast could be as great as 0.6 g per cm³, and the actual thickness would be about 75 percent of that computed with an assumed

density contrast of 0.45 g per cm³. A density contrast of less than 0.45 g per cm³ is possible in a basin filled with dense volcanic units or well-indurated sediments. Under these conditions the actual depth of fill could be several times the computed depth. Thick accumulations of Mesozoic strata, and perhaps thick sequences of Cambrian and Precambrian quartzite, could also produce gravity anomalies of sufficient amplitude and extent to be apparent in the gravity survey reported here.

The average density of dry samples of basalt in the region is slightly less than that for dry samples of Paleozoic rocks in the region. If the rocks are saturated with water, the density of the basalt is equal to, or slightly greater than, that of Paleozoic rocks. However, scoria, abundant unfilled joints, and inclusions of Cenozoic sediments reduce the average density of volcanic-rock sequences to below that of Paleozoic rock. Thick sequences of volcanic material are positive mass anomalies relative to Cenozoic sediments, but are negative, relative to Paleozoic rocks.

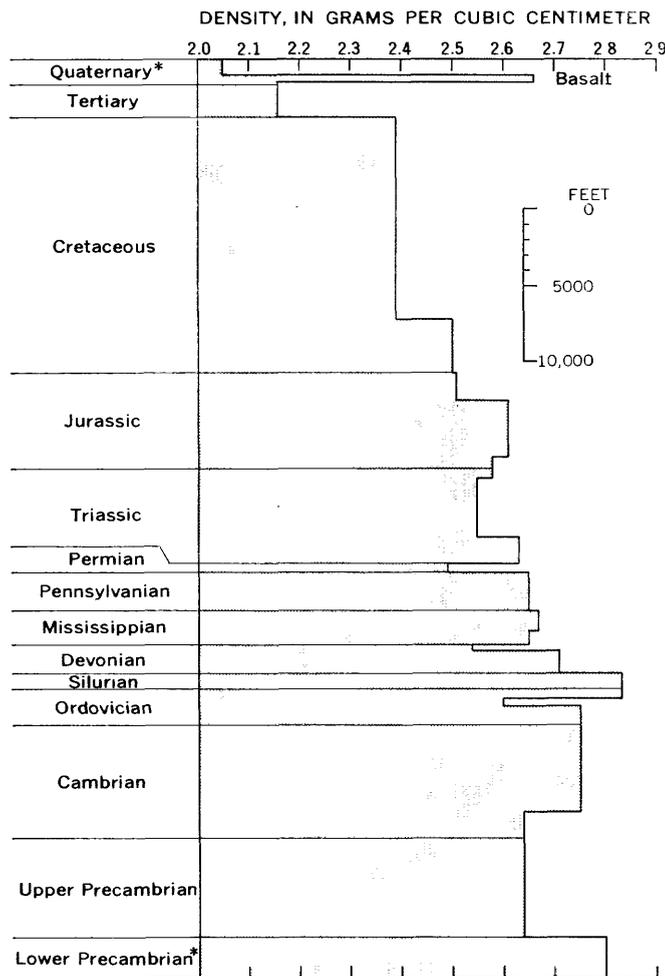


FIGURE 2.—Density of major rock units in the Soda Springs region. Thickness of units based mostly on data from Mansfield (1927). Asterisk (*) indicates estimated density.

MAGNETISM

Magnetic properties were not measured systematically for various rocks in the region, but they were measured on six oriented samples of basalt from four localities in Wooley Valley. The total in-situ magnetization of these magnetized rock samples is about 5×10^{-3} emu per cm³ (electromagnetic unit per cubic centimeter) in a direction approximately opposite to that of the earth's present magnetic field (reversely magnetized). A magnetic anomaly produced by a known thickness of normally magnetized basalt in Gem Valley suggests a total magnetization of about 5.7×10^{-3} emu per cm³. Quantitative analyses of the magnetic anomalies produced by the basalt were attempted only where all the basalt appears to be magnetized in the direction of the earth's magnetic field, and a total magnetization (induced and remanent) of 5.7×10^{-3} emu per cm³ was assumed.

GEOPHYSICAL SURVEYS

GRAVITY SURVEY AND MAP

Most gravity observations were made where the altitude could be obtained directly from bench marks or spot elevations shown on U.S. Geological Survey quadrangle maps. Altitudes of additional stations in areas of low relief were determined by altimeter surveys. The maximum error in altitude of the gravity stations is estimated to be about 20 feet, and the altitudes of most stations are known to within 5 feet. Although most stations are in the valleys, enough observations were made in the ranges to define the larger regional variations.

Observed gravity values were referenced to base station WU29 in Salt Lake City, Utah (Behrendt and Woollard, 1961). Theoretical gravity was computed from the International Formula. Bouguer anomaly values were computed by using an assumed density of 2.67 g per cm³ for material above sea level. Terrain corrections in excess of 1 mgal (milligal) through Hayford zone O have been applied (Swick, 1942). Terrain corrections range from less than 1 mgal in the larger valleys to 24 mgal for a station on Sedgwick Peak.

Bouguer anomaly values (pl. 1) range from -164 mgal for stations in the Portneuf Range to -210 mgal for a station in Bear River valley. The largest local gravity anomalies are in Gem Valley, over the Blackfoot lava field south of Henry, and in Bear River valley southeast of Soda Springs. These anomalies occur at exposures of Cenozoic sedimentary and volcanic rocks and presumably reflect depressions filled with these low-density rocks. Small, but significant, local gravity variations occur over pre-Tertiary rocks in several of the mountain ranges. The local anomalies are superimposed on a regional southeastward decrease in gravity values.

AEROMAGNETIC SURVEY AND MAP

The aeromagnetic survey was flown in two parts. The first was a survey of a small area east of Henry (Meuschke and Long, 1965). Flight lines were approximately N. 45° E., half a mile apart and 7,000 feet above sea level. The data were obtained with a modified ASQ-3 fluxgate magnetometer towed from a DC-3 aircraft. Data for the more extensive survey (Mitchell and others, 1965) were obtained with an ASQ-8 fluxgate magnetometer in the tail boom of a Convair aircraft flown along east-west flight lines 1 mile apart and 9,000 feet above sea level. On both surveys, flight path of the aircraft was recorded by a gyro-stabilized continuous-strip-film camera; magnetic data were compiled relative to an arbitrary, but approximately common, datum.

Magnetic contours are shown on plate 2 as an overlay for plate 1. Because the flight lines are at different altitudes and have different spacing and orientation, magnetic contours do not exactly match across the boundary between the surveys. Although the magnetic field is complex within the region it is, in general, adequately defined at the flight altitudes.

Complex magnetic anomalies prevail in the central and northeastern parts of the mapped area. These anomalies reflect Cenozoic volcanic rocks that are extensively exposed in the basins and, locally, in the ranges. The dominant magnetic anomalies are highs flanked on the east or northeast by correlative lows. However, in the northeastern part of the mapped area

several discrete magnetic lows are apparent. Magnetic relief is low where Cenozoic volcanic rocks are absent; notable exceptions are a pair of north-trending highs in the Chesterfield Range.

INTERPRETATION OF LOCAL GEOPHYSICAL ANOMALIES

GEM VALLEY

More gravity observations were made in Gem Valley² than in any other area included in the survey. Preliminary results of the gravity survey and seven low-level aeromagnetic profiles were described earlier by Mabey and Armstrong (1962). Additional gravity observations made in the valley since preparation of the preliminary report do not substantially change the earlier map. The 35-mgal gravity low in Gem Valley, which is larger than any other measured in this survey, is comparable in magnitude to the larger anomalies associated with other intermontane basins in the Western United States.

The residual amplitude of the gravity low in Gem Valley is largest in the northern part of the valley, decreases over a gravity saddle northwest of Grace, and increases again toward the south end of the valley. In the north end of the valley, the lowest gravity values are east of the center of the valley; in the southern part, the lowest values are near the center of the valley.

The gravity anomaly in Gem Valley indicates a deep trough of low-density material bounded by steep sides (pl. 1, section A-A'). An earlier interpretation (Mabey, 1964) that the trough may have formed as a pull-apart gap at the rear of a major overthrust sheet (Rubey and Hubbert, 1959, p. 194) is now regarded as improbable, on the basis of stratigraphic data from bounding ranges (Oriel and others, 1965). The trough is probably a sediment-filled graben. If all the gravity anomaly in Gem Valley is interpreted to reflect low-density sediments, the sediments are thickest north of Bancroft, thinner near the old settlement of Central, and thicker southward. The trough narrows at the north end, but its floor apparently remains relatively flat as far north as the north end of the Portneuf Reservoir, where it rises abruptly.

Because no deep holes have been drilled in the valley, the nature of the low-density material producing the large gravity low is not known. The gravity low may reflect poorly indurated detrital strata of three possible ages: Quaternary, Tertiary, and Mesozoic. Quaternary sediments and lavas cover the area of the gravity low everywhere except on the southwest side of the Portneuf Reservoir, where an exposure mapped as Salt Lake Formation (Mansfield, 1929, pl. 1) extends to the

² Gem Valley, as used in this report, includes Portneuf Valley and the north end of Gentile Valley.

center of the low. If the indicated exposure is, indeed, Salt Lake, the gravity anomaly must be produced largely by low-density rocks of Salt Lake age or older. Moreover, post-Salt Lake sediments are probably too thin in the region to account for an anomaly of this magnitude.

Triassic rocks, such as those exposed in the northern part of the Chesterfield Range, and other Mesozoic rocks could be preserved under Tertiary rocks in Gem Valley. However, the density contrast between Mesozoic and Paleozoic rocks is only about 0.15 g per cm³; a trough 5 miles wide containing 20,000 feet of lower Mesozoic rocks (their maximum probable thickness) would produce only about 25 mgal of the 35-mgal anomaly. Although Mesozoic rocks may be preserved under Gem Valley, they cannot account for the entire gravity

anomaly, unless they are unusually thick, or unless a thick prism of low-density Cretaceous detritus (unknown this far west) is present. The latter possibility is unlikely.

Basalt flows in Gem Valley do not seem to affect the gravity anomaly significantly. An exception may be north of Grace; there, the amplitude of the gravity low is reduced where magnetic data indicate a thickening of the basalt along the east side of the valley (fig. 3).

Steep gravity gradients along or near the margins of Gem Valley are interpreted as indicating high-angle faults. Places where these inferred faults coincide with the range front are as follows: 2 miles northwest of Bancroft; an area several miles long north of Monroe Canyon; at Buckskin Mountain; and in the north end

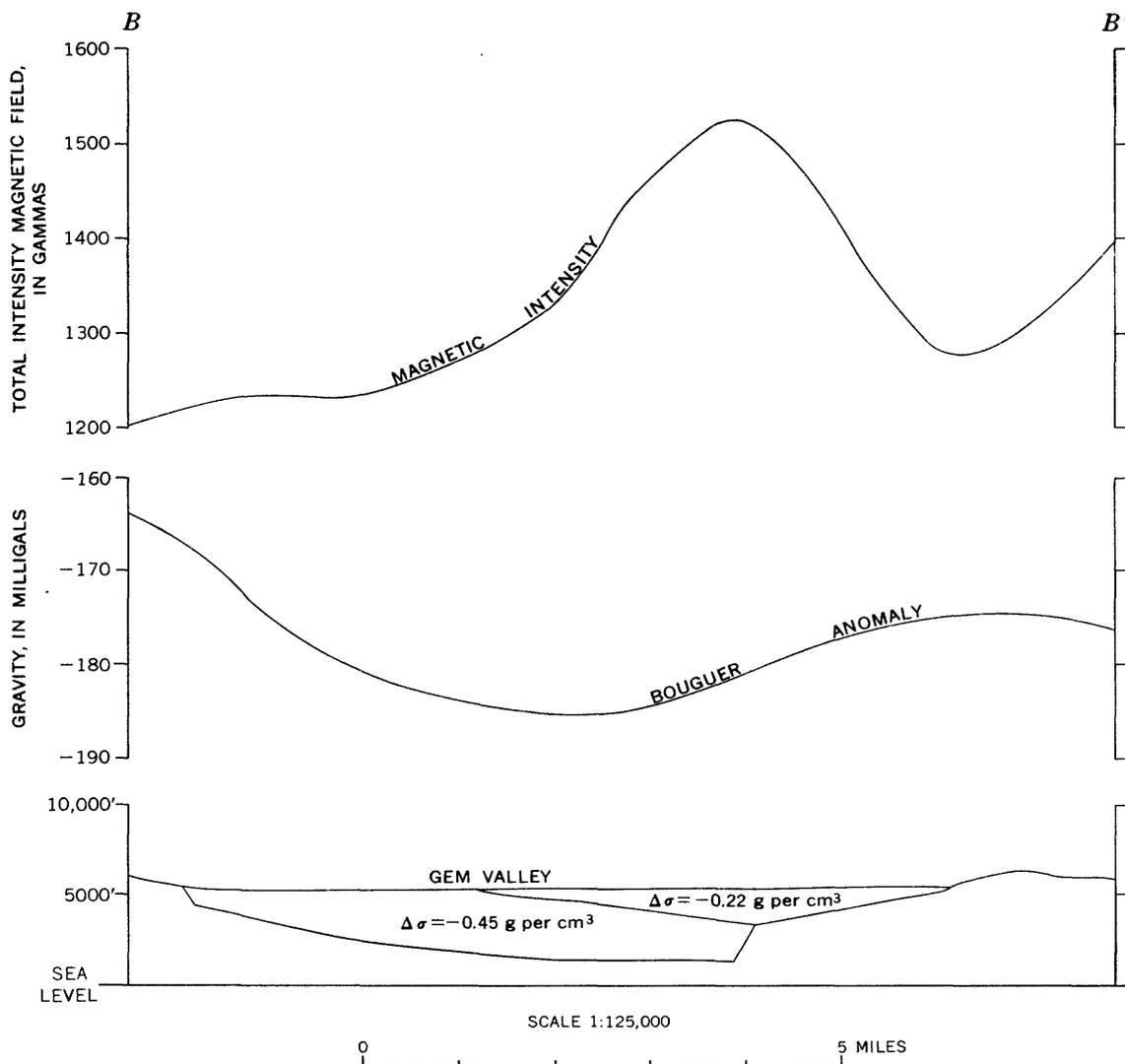


FIGURE 3.—Gravity, aeromagnetic, and interpreted geologic section across southern Gem Valley. Line of section shown on plate 1. $\Delta\sigma$, assumed density contrast.

of Gem Valley. Elsewhere, the major inferred faults lie within the valley and separate a belt of fill of intermediate thickness adjacent to the range front from a thick prism of fill along the axis of the valley. An area of several square miles located about 5 miles northwest of Bancroft and west of the inferred fault along the west side of the valley probably is underlain by Paleozoic rock at relatively shallow depths.

Major features of the gravity anomaly in Gem Valley parallel the axis of the valley; however, the linearity of some of these features is locally disrupted. These disruptions reflect variations in the thickness of fill which are controlled either by structures transverse to the valley or by a buried erosion surface on the older rocks. About 1 mile southeast of Bancroft, the gravity relief decreases along a probable transverse fault, such as the fault east of Gem Valley, 2 miles south of Tenmile Pass, where it strikes east-northeast, and the faults west of Gem Valley just south of Red House Canyon, where they are about 1 mile south of the locus suggested by the gravity data. The relation of these faults to those mapped on the east side of Gem Valley, just north of Upper Valley, is undetermined. The gravity data suggest that the embayment in the range front at Lund may be bounded by faults which parallel probably related faults mapped in bedrock on the north, west, and south sides of the embayment. Faults mapped in the bedrock west of Turner can be inferred from the gravity data to continue into the valley. South of Turner the gravity data suggest either complex structure along the range front or an intricate buried topographic surface.

The magnetic survey, which was flown 3,500–4,000 feet above the land surface, shows extensive anomalies that indicate the thickness and distribution of basalt flows and related intrusive masses. Craters near Niter and Grace coincide with large-amplitude magnetic highs (fig. 3). The coincidence suggests that these anomalies are partly produced by basalt necks and dikes that fed the basalt flows. The magnetic highs near Grace and Niter are probably composite features produced by both intrusive units and local, thick sequences of flows. In areas away from the basalt sources, the magnetic anomalies probably reflect the relative thickness of flow sequences and the proportion of interbedded sediments.

Little is known about the relief on the prebasalt floor of Gem Valley. Undoubtedly, there was some relief related to the ancestral major drainage systems of the Portneuf and Bear Rivers (Bright, 1963), but the absence of any older rocks protruding through the basalt suggests either deep burial or shallow relief. The basalt came from vents in the Grace-Niter area and from vents in the Blackfoot lava field via Tenmile Pass and

perhaps the gap at Soda Point. The thickest accumulations of basalt are probably in prebasalt topographic lows, such as river channels, and near-source areas. Conversely, the basalt is thinner over prebasalt topographic highs and where waterborne sediments were deposited in the valley during volcanism.

The magnetic high in the north end of Gem Valley is along the west edge of a deep trough indicated by the gravity data. The location suggests that this magnetic belt reflects a prebasalt topographic low that now contains a greater thickness of basalt flows than do the adjoining areas. If an intensity of magnetization of 5.7×10^{-3} emu per cm^3 is assumed for the basalt sequence, the base of the thickest accumulation of basalt is about 5,000 feet above sea level. Northward, in the Chesterfield Reservoir area, where basalt is absent both on the surface and in shallow wells, the magnetic data do not indicate that basalt is present at depth, either. Although basalt seems to be thin over much of the area of relatively shallow fill northwest of Bancroft, local thickenings are indicated by magnetic highs extending westward into the canyon of the Portneuf River, and also along the northeast front of the Fish Creek Range. These elongate magnetic anomalies suggest ancient river channels filled with basalt. The magnetic anomaly at the head of the canyon of the Portneuf River is parallel to the flight lines of the magnetic survey; hence, it is not well defined, but the indicated amplitude of this anomaly suggests that the basalt is about 300 feet thick. A detailed gravity profile across the head of the canyon did not reveal a gravity low, such as would be expected if several hundred feet of sediments underlay the basalt. A magnetic low at Hatch suggests that the basalt is relatively thin over an area of several square miles. Abundant prebasalt travertine now exposed in this area may be the reason. The magnetic high in, and west of, Tenmile Pass reflects both higher elevation and greater thickness of basalt than in adjoining areas, for lava entered Gem Valley from the Blackfoot field via the pass.

The zone of relatively low magnetic intensity north of Talmage Siding coincides with a slight topographic low; this probably reflects an area of basalt thinner than that in the areas to the north and south, which were near the sources of flows. A drill hole 295 feet deep in this area about 1 mile from the east edge of the valley penetrated only 75 feet of volcanic material, and this, within 90 feet of the surface. The northwest-trending zone of higher magnetic intensity northeast of Talmage Siding may reflect a local prism of more abundant basalt.

Along the west side of the valley near Bancroft, an elongate magnetic high, which is continuous with the

high to the north, can be explained best as a local basalt-filled channel largely concealed by Holocene sediments. Basalt and interbedded sediments to depths of 270 and 283 feet were found in two water wells along the axis of the high about 1–2 miles south of Bancroft, where the surface elevation is about 5,450 feet above sea level. The measured magnetic anomaly in the area of these wells could be produced by a prism of basalts and sediments 300 feet thick and 3,000 feet wide and with an average intensity of magnetization of 4×10^{-3} emu per cm^3 .³ Basalt must be absent west of the prism and thinner east of the prism. The former was confirmed by drilling, but no test drilling has been done to verify the latter.

The large magnetic high in the south end of Gem Valley could be caused almost entirely by a thick accumulation of basalt flows or by a combination of basalt flows and intrusive bodies related to the cones and craters. About 1,500 feet of basalt with an intensity of magnetization of 5.7×10^{-3} emu per cm^3 would produce the observed anomaly. However, the very close coincidence of the crest of the magnetic anomalies with large craters suggests that at least part of the anomaly is related to basaltic intrusive bodies.

Along the west side of the valley from Lund southward, the magnetic pattern is relatively complex. The magnetic nose west of Niter coincides with several craters and with the west edge of the basalt flows. The magnetic high east of Buckskin Mountain, along North Extension Canal, coincides with extensive exposures of basalt, whereas the low to the north coincides with moderately thick deposits of silt southwest of Central. The magnetic anomalies probably also reflect the proportion of Quaternary lacustrine sediment that intertongues eastward with basalt flows. These intertonguing relations are well displayed for the higher flows in the valley of Bear River a few miles to the south. The closed high northeast of Lund appears to be produced by a widening of the inferred basalt prism which is to the north.

Alexander Crater and adjacent craters to the south lie along a zone of moderately steep gravity gradients on the east side of Gem Valley. If allowance is made for the gravity effect of thick flows or of intrusive units in this area, a fault zone inferred from the gravity could control crater locations (fig. 3). However, the craters north and northwest of Niter are not along this inferred fault but are near local, irregular gravity anomalies along the west side of the valley. These latter craters, which lie along the projected trace of a minor eastward-trending fault mapped in Ordovician rocks

³The drill holes indicate that about 70 percent of the material is basalt. Therefore, the indicated intensity of magnetization of the basalt is 5.7×10^{-3} emu per cm^3 .

in the east end of Beaver Basin, may well indicate local structure transverse to Gem Valley.

In summary, the gravity and magnetic data for Gem Valley provide several clues to the geologic history of the valley. The data suggest that subsidence of the central trough, at least in the northern part of the valley, occurred during deposition of the Pliocene Salt Lake Formation. Although Quaternary sediments and basalt are exposed in most of the valley, the major part of the low-density material, estimated to be about 10,000 feet thick, is Tertiary. Mesozoic strata may be preserved under the Tertiary fill, but this possibility is unlikely.

The magnetic data in Gem Valley suggest a subbasalt surface of moderate relief. In the northern part of the valley, the basalt does not appear to extend below an altitude of about 5,100 feet and is locally thin or absent. A belt of thin basalt is indicated between the area of the Tenmile Pass flows, at the north end of the valley, and the area of locally derived flows to the south. This inferred deficiency of basalt may reflect either a subbasalt topographic high, possibly breached by a channel north of Talmage Siding, or more abundant sediments interlayered with the basalt. Over the southern part of the valley, the magnetic anomalies are complex because of the effects of numerous source areas. The basalt in the Grace-Niter area, indicated by magnetic data to be much thicker than anywhere else in the valley, probably was ponded in a depression related to the eruption of the basalt. The magnetic data suggest two basalt-filled channels: one that extends east from the head of the canyon of the Portneuf River, and another, along the front of the Fish Creek Range near Bancroft. A third, not as well defined, may be north of Talmage Siding. These basalt-filled channels, presumed to be the courses of the major streams prior to diversion by the basalt flows, should be excellent sources of ground water.

BLACKFOOT LAVA FIELD

The Blackfoot lava field (Mansfield, 1927, p. 36) is the area of basalt that extends from a few miles southeast of Soda Springs northward to a few miles beyond the north border of the mapped area (pl. 1). The surface of the lava field ranges in altitude from about 6,700 feet east of the Blackfoot River Reservoir to about 5,800 feet south of Soda Springs. Numerous cliffs, collapse depressions, and fissures make the surface very irregular. Several basalt and cinder cones and craters and three large and two small hills of rhyolite rise above the lava field. Quaternary alluvium covers the basalt in most of the valley of Corral Creek and in several smaller areas along the mountain front, adjacent to the lava field.

A large gravity low southeast of Soda Springs centers over the valley that is the northern extension of Bear Lake Valley. This anomaly, which includes the exposures of the Salt Lake Formation in the Bear River Range, could be produced by 5,000 feet of material that is 0.45 g per cm^3 less dense than the enclosing rock. The gravity data indicate a high-angle fault along the front of the Aspen Range; normal faults with the down-dropped Salt Lake Formation to the southwest have been mapped in reconnaissance along the range front. The gravity data suggest a fault along the east margin of the Bear River Range, where several mapped north-westerly trending faults cut the Salt Lake at the surface. West of these faults the low-density material appears to gradually thin over several miles. Cambrian rocks are exposed 3 miles south of Soda Springs in an area where gravity data suggest about 1,000 feet of low-density material; these Cambrian rocks may be large slide blocks mixed with the Salt Lake Formation, or they may be parts of a narrow horst of bedrock bounded by a Salt Lake-filled graben. The gravity data are too sparse to distinguish between the alternatives.

The gravity low in Bear River valley probably reflects a thick prism of Tertiary sediments. A 3,520-foot-deep hole drilled near the axis of the anomaly penetrated more than 2,500 feet of Salt Lake Formation and may have bottomed in Triassic strata that are unconformably below the Salt Lake. Triassic rocks exposed in Bear River valley at the south edge of the mapped area and at Threemile Knoll, north of Soda Springs, may be part of a continuous sheet beneath the intervening Cenozoic cover. However, a gravity profile across the valley 2 miles south of the mapped area did not indicate a negative anomaly where Triassic rocks are exposed; hence they may not be a major cause of the gravity low southeast of Soda Springs, although Triassic rocks underlie part of the valley.

A magnetic high, which occurs along Bear River valley from Soda Point to about 5 miles southeast of Soda Springs, coincides with extensively exposed and partly covered basalt. This magnetic anomaly could be produced by 750 feet of basalt. If concealed basalt feeders contribute to the anomaly, the flows may be thinner than 750 feet.

The Bear River valley gravity low ends abruptly near Soda Springs. Gravity data indicate that the depth to pre-Tertiary rock is less than 1,000 feet at the west side of Rabbit Mountain. Sedimentary fill is probably thin or absent at the Soda Point Reservoir. Threemile Knoll consists of Triassic rocks surrounded by basalt flows, and the absence of gravity lows adjoining the knoll suggests that the basalt is not underlain by thick Cenozoic sediments.

Gravity relief over the Blackfoot lava field, north of Threemile Knoll, is relatively complex. The largest feature is a compound low, which has two areas of closure. Cenozoic basalt is extensively exposed in this region, three rhyolite hills rise above the basalt, and Quaternary travertine and detrital sediments occupy several square miles adjacent to mountain fronts. North of Conda, the gravity low extends over Tertiary and Quaternary sediments that are older than the youngest basalt; no other Cenozoic material beneath the basalt is exposed. The gravity anomalies could be produced by about 5,000 feet of material that is 0.45 g per cm^3 less dense than the enclosing pre-Tertiary rocks (pl. 1, section A-A').

Westward projection of the Blackfoot fault (Mansfield, 1927) extends through Middle Cone and is between the two areas of closure in the compound negative anomaly. The apparent strike-slip movement along the fault is left lateral. The relation of the anomaly to the fault is not understood. Rocks responsible for the anomaly probably postdate fault movement, and the anomaly may bear only an indirect relation to the fault.

The gravity low is bounded on the southwest by a steep gravity gradient, indicating a north-northwest-trending high-angle fault. Elsewhere along the margins of the anomaly, the gradients suggest (but do not require) high-angle faults, such as those mapped along the Aspen Range front to the east. Southwest of the anomaly, gravity data suggest local relief on the surface of the pre-Tertiary rock at shallow depths.

The magnetic field over the main part of the Blackfoot lava field is complex. Southwest of North Cone and west of the Blackfoot River Reservoir, high-amplitude positive anomalies occur, whereas east of the reservoir, smaller amplitude negative anomalies predominate. East of Meadow Creek a high-amplitude magnetic low coincides with exposed basalt. Most of the basalt craters and cones are near the crests of magnetic highs or are on magnetic noses. Exceptions are the cones along the east front of Reservoir Mountain and the small cone 1 mile north of Broken Crater. These occur midway between flight lines; hence, small anomalies may not have been detected.

Magnetic highs, which reflect basalt flows, flank Threemile Knoll on the west and the east. The high on the west is part of an elongate northwest-trending anomaly. Amplitudes northwest and south of Threemile Knoll are 300γ (gamma) and 200γ ; however, the amplitude southwest of the Knoll is 140γ , the smallest amplitude along the anomaly. Northwest and south of the knoll, about 1,000 feet of basalt would be required to produce the measured anomaly, whereas near the knoll, only about half this thickness would be required. The

lower amplitude of the anomaly at the knoll could also be explained if a basalt prism of uniform thickness were assumed to lie from north to south but to have marked narrowing near the knoll.

Magnetic anomalies north of Threemile Knoll, as in Gem Valley, are believed to reflect both the variations in thickness of basalt flows and the presence of intrusives related to vents. Data along flight lines directly over the rhyolite hills reveal small magnetic highs which seem to reflect topography.

A zone of low magnetic intensity and high gravity, which extends north-northwest across the lava field from Threemile Knoll to a spur of the Chesterfield Range, is interpreted as indicating a bedrock ridge beneath relatively thin basalt. This inferred ridge may be partially breached northwest of Fivemile Meadows. Another magnetic low 3 miles northeast of Tenmile Pass suggests a buried connection between the south spur of the Chesterfield Range and the Ninety Percent Range to the south, both of which are underlain by Devonian and Mississippian carbonate rocks.

Magnetic intensity is very high near China Hat and east of the inferred fault zone, which bounds the gravity low along its southwest side. This magnetic high is interpreted as reflecting thick basalt flows ponded in a depression and intrusive rocks related to known basalt vents.

Magnetic intensity is high east and north of Reservoir Mountain and up the valley of Corral Creek. The magnetic intensity increases eastward toward a maximum at Crater Mountain which suggests that the flows thicken toward a vent in that area. The magnetic data indicate that basalt underlies alluvium at the north end of the valley of Corral Creek for about 2 miles south of the exposed basalt. In the central part of this valley, basalt is either absent or thin. The gravity low in the valley of Corral Creek could be produced by about 1,200 feet of fill.

The negative magnetic anomalies east of the Blackfoot River Reservoir are probably produced by reversely magnetized basalt that is older than the normally magnetized basalt to the southwest. This older basalt, which is at a higher elevation than the normally magnetized flows, presumably was a topographic high when the younger flows were extruded. The reversely magnetized basalt differs from the normal basalt in several ways: it is much lighter gray, more finely crystalline, and more altered. The slightly greater degree of alteration of the reversely magnetized basalt may reflect its somewhat greater age.

Two cycles of volcanism and associated deformation in the central part of the Blackfoot lava field are suggested by the gravity and magnetic data. First, basalt

flows accumulated in a local depression east of the present site of the Blackfoot River Reservoir. Evidence of their former extent is now masked by younger flows. The reverse remanent magnetization of these flows suggests an age greater than 0.7 million years.⁴

During the second phase of volcanism a thick sequence of normally magnetized basalt flows accumulated in depressions south and west of the Blackfoot River Reservoir. Some of these flows extended south into Bear River valley, west into Gem Valley, northwest along the Blackfoot River, and over a surface of considerable relief east of Tenmile Pass.

Several lines of evidence suggest that the large compound negative gravity anomaly may indicate a volcanic collapse structure related to the withdrawal of magma at depth. The anomaly lacks the pronounced elongation that characterizes troughs in this region and in other parts of the Basin and Range province. The general area abounds in craters, cones, and large magnetic anomalies, and the spatial relations between the basalt flows and the gravity depressions suggest that subsidence occurred during, or shortly before, eruption of the basalt. Local magnetic anomalies obviously related to exposed rocks are superimposed on an extensive area of high intensity. The gravity and magnetic anomalies could be produced entirely by exposed basalt flows, pumiceous rhyolite and sediments filling a collapse structure; however, an alternate interpretation is that a part of each anomaly is produced by an underlying granitic intrusive body. Both interpretations are suggested by the rhyolite hills that occur only in this area.

The presence of inversely magnetized basalt in the Blackfoot River Reservoir area precludes calculations of the thickness of the basalt, as in the Bancroft-Soda Springs area. However, adjacent to the Chesterfield Range and the Soda Springs Hills, where there is no evidence of inversely magnetized rock, the magnetic anomaly indicates a prism of basalt, about 1,000 feet thick, extending northwest from the west side of Threemile Knoll to the Tenmile Pass area. Because the narrow gap at Tenmile Pass is between flight lines, the maximum amplitude of the magnetic anomaly is not known. The basalt could be 1,000 feet thick at the pass, but this would require a higher amplitude positive anomaly than was inferred during preparation of the magnetic-contour map. The magnetic anomaly in the Canyon of the Blackfoot River northwest of Corral Creek suggests that the basalt is less than 400 feet thick there.

⁴ The reverse remanent magnetization is interpreted as indicating that the flows cooled through the Curie temperature when the polarity of the earth's magnetic field was the reverse of the present polarity. The most recent major reversed period ended about 0.7 million years ago (Cox and others, 1967).

Magnetic anomalies produced by the basalt west of Threemile Knoll, in range gaps at the head of Portneuf River canyon, and at Soda Point and Tenmile Pass are all consistent with an elevation of about 5,000 feet above sea level for the prebasalt surface. A higher elevation is suggested, however, along the Blackfoot River near the mouth of Corral Creek. Several possible prebasalt drainage systems, involving interconnections of the Portneuf, Bear, and Blackfoot Rivers near Soda Point, Threemile Knoll, and Tenmile Pass, are consistent with the magnetic data. An earlier connection between the Bear River and the present Blackfoot River drainage into the Snake River seems unlikely unless recent regional deformation has raised the northern part of the region several hundred feet relative to the central part.

UPPER BLACKFOOT RIVER DRAINAGE

East of the Blackfoot lava field are several narrow, generally north trending valleys. In Upper Valley a gravity low of about 5 mgal indicates that about 1,000 feet of fill is present. In the other valleys the gravity anomalies are smaller or absent, although some small gravity variations may have been overlooked because of insufficient control.

In the upper Blackfoot River drainage area the magnetic map is dominated by local magnetic anomalies produced by basalt in the valleys. Negative anomalies in Lower, Wooley, and Upper Valleys, the south end of Enoch Valley, and Pelican Slough are produced by reversely magnetized basalt. Reverse magnetization is confirmed by laboratory measurements on samples collected in Wooley Valley. Positive anomalies are produced by normally magnetized basalt flows in the north end of Enoch Valley and along Meadow Creek, northwest of Pelican Slough. The magnetic data indicate that basalt underlies alluvium in the north end of Upper Valley, the north end of Enoch Valley, and along the Blackfoot River south of Fox Ranch.

LOCAL ANOMALIES IN THE RANGES

Local gravity variations in the ranges are small. The lows in the Portneuf Range, near the southwest corner of the mapped area, and in the southeastern part of the Chesterfield Range coincide with Salt Lake Formation exposures and probably reflect local thickenings of the Tertiary sediments. The high in the Monroe Canyon area coincides with exposed Devonian and Silurian dolomites, which are among the densest rocks of the region.

The magnetic field of the ranges is generally featureless, with only minor deviations from a general north-eastward increase related to the primary field. Notable exceptions occur in the Chesterfield, Bear River, and Grays Ranges. Positive anomalies in the northern Ches-

terfield Range and in the Bear River Range are clearly related to exposed volcanic rocks. In the Grays Range the anomaly may be related to concealed igneous rock, for the known distribution of volcanic rock could not produce the anomaly indicated on the contour map. The anomalies along Eighteenmile Creek in the Chesterfield Range do not correlate with known geology.

Along Eighteenmile Creek in the Chesterfield Range two parallel positive magnetic anomalies, about 2 miles apart, trend northward in areas covered mainly by Salt Lake Formation. These anomalies persist, with greatly diminished amplitude, across exposures of upper Paleozoic rock. The anomalies parallel the regional strikes of bedrock units beneath the Salt Lake and, also, the strikes of some previously unmapped block faults. Rocks in the area of maximum intensity were examined, but no explanation of the anomaly was apparent.

Magnetism of basalt adjoining the Chesterfield Range partially masks the configuration of these anomalies; however, enough of their configuration is evident to justify an analysis (fig. 4). North of Eighteenmile Creek the amplitudes of both anomalies are 25 γ or less, but at the creek the amplitude of the eastern one exceeds 50 γ and remains high for about 2 miles south of the creek. The western anomaly terminates between Eighteenmile Creek and Little Flat Canyon. Depth analysis of the eastern anomaly near Eighteenmile Creek suggests the source to be within 500 feet of the bottom of the canyon.

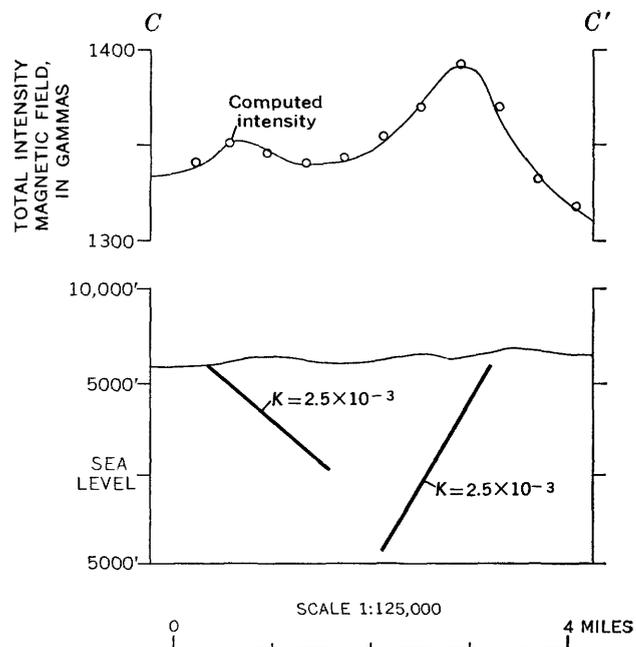


FIGURE 4.—Aeromagnetic profile and interpretive section in the Chesterfield Range. Line of section shown on plate 1. K is magnetic susceptibility, in electromagnetic units.

The eastern anomaly at Eighteenmile Creek suggests a north-trending sheet of magnetic rock dipping steeply toward the west. The anomaly on the west is more difficult to analyze because the amplitude is low, and the west side may be distorted by nearby valley basalt; however, it does not appear to be caused by a westward-dipping sheet. The anomalies could be produced by a tabular mass either folded into a syncline or faulted, with opposing dips (fig. 4). The magnetic data do not yield a minimum thickness for the mass that produces the anomaly; the relative amplitudes of the computed anomalies could result either from eastward thickening of the magnetic mass or from eastward increase in susceptibility.

The available data are insufficient to explain the anomalies along Eighteenmile Creek. However, two suggestions are offered: The anomalies may be produced by Cenozoic lavas, dikes, or sills in the Paleozoic or Tertiary rocks or by iron-enriched strata in the Amsden Formation.

Four miles north of the eastern magnetic anomaly and on the projection of this anomaly, a thin dike of weathered andesitic material found in a prospect in Phosphoria Formation was reported by Mansfield (1929, p. 40) to closely resemble larger bodies of hornblende andesite porphyry exposed at Sugar Loaf Mountain 20 miles to the northeast. However, a test flight over Sugar Loaf Mountain revealed an anomaly of only a few gammas—much smaller than the anomaly at Eighteenmile Creek. If dikes or sills are producing the anomalies at Eighteenmile Creek, they are more likely to be basalt than andesite porphyry. No tabular bodies of basalt are exposed in the Chesterfield Range, but basalt vents are present in the Bear River Range, along strike to the south, and a small remnant of basaltic lava is exposed near the center of the NE $\frac{1}{4}$ sec. 24, T. 8 S., R. 40 E., in the Soda Springs Hills (F. C. Armstrong, written commun., May 10, 1968). These basalts, though possibly somewhat older than the valley basalts, are still presumably of Quaternary (possibly early Pleistocene) age; however, conclusive data on age are lacking. A third alternative for the igneous origin of the magnetic anomalies is suggested by the presence of both basalt and rhyolite in the Salt Lake Formation sequence to the north, as in sec. 8, T. 5 S., R. 39 E. (Mansfield, 1929, p. 41-45, pl. 1). A folded or broken layer of basaltic lava of presumably Pliocene age in the Salt Lake Formation at Eighteenmile Creek could best account for the magnetic anomalies (with the imprecisely known local geology). However, this interpretation does not adequately explain the apparent northward extension of the eastern anomaly across an area near the crest of the range, where the Salt Lake Formation is absent.

No magnetic rocks are known in the Paleozoic sequence within this or adjoining regions. The Amsden Formation is reported to include pisolitic iron oxide farther east in Wyoming in the Bedford quadrangle (Rubey, 1958) and the Little Flat Canyon Formation of the Chesterfield Range contains ferruginous beds (Dutro and Sando, 1963, p. 1970). Although the Amsden Formation has not commonly been recognized and mapped in the Soda Springs region, equivalent rocks may be present near the contact between Mississippian limestones and Pennsylvanian quartzites in the Chesterfield Range. Secondary iron enrichment of Paleozoic units underlying the Salt Lake Formation in the Eighteenmile Creek area may have occurred, but this is not regarded as a likely cause of the magnetic anomalies.

None of the suggestions offered here is sufficiently documented to adequately explain the magnetic anomalies in the Chesterfield Range. More intensive geophysical surveys or shallow drilling is required to resolve the questions.

The accompanying maps do not indicate any local geophysical anomalies of possible economic interest. Small deposits of manganese oxide, and copper, lead, zinc, and iron sulfide minerals, some of which have been mined on a small scale, are present in the Portneuf Range near the southwest corner of the survey area. These deposits are in the area of an extensive magnetic low, but neither the gravity maps nor the magnetic maps show any local features related to them, possibly because of insufficient data.

REGIONAL GRAVITY ANOMALIES

Bouguer anomaly values unaffected by local valley anomalies decrease eastward and southeastward from about -165 mgal over lower Paleozoic sedimentary rocks on the west side of Gem Valley to less than -200 mgal over upper Paleozoic rocks in the ranges at the east edge of the mapped region (fig. 5). The region lies between the topographically low Snake River Plain on the northwest and the Lake Bonneville basin on the south, and the rugged Wyoming and Salt River Ranges to the east. Although elevations of the range crests generally do not increase eastward, the elevations of the valleys increase eastward by about 1,000 feet to 6,500 feet above sea level in Upper Valley. In the east the ranges occupy a greater percentage of the area, and this, combined with higher valleys, produces an eastward rise in regional elevation. Quantifications of average rise in regional elevation depends on the method used in measuring regional elevation. Regional elevations were computed here by averaging elevations in circular areas around the gravity station. Averaged over areas 32 and 64 kilometers in radius, the increase in elevation in this

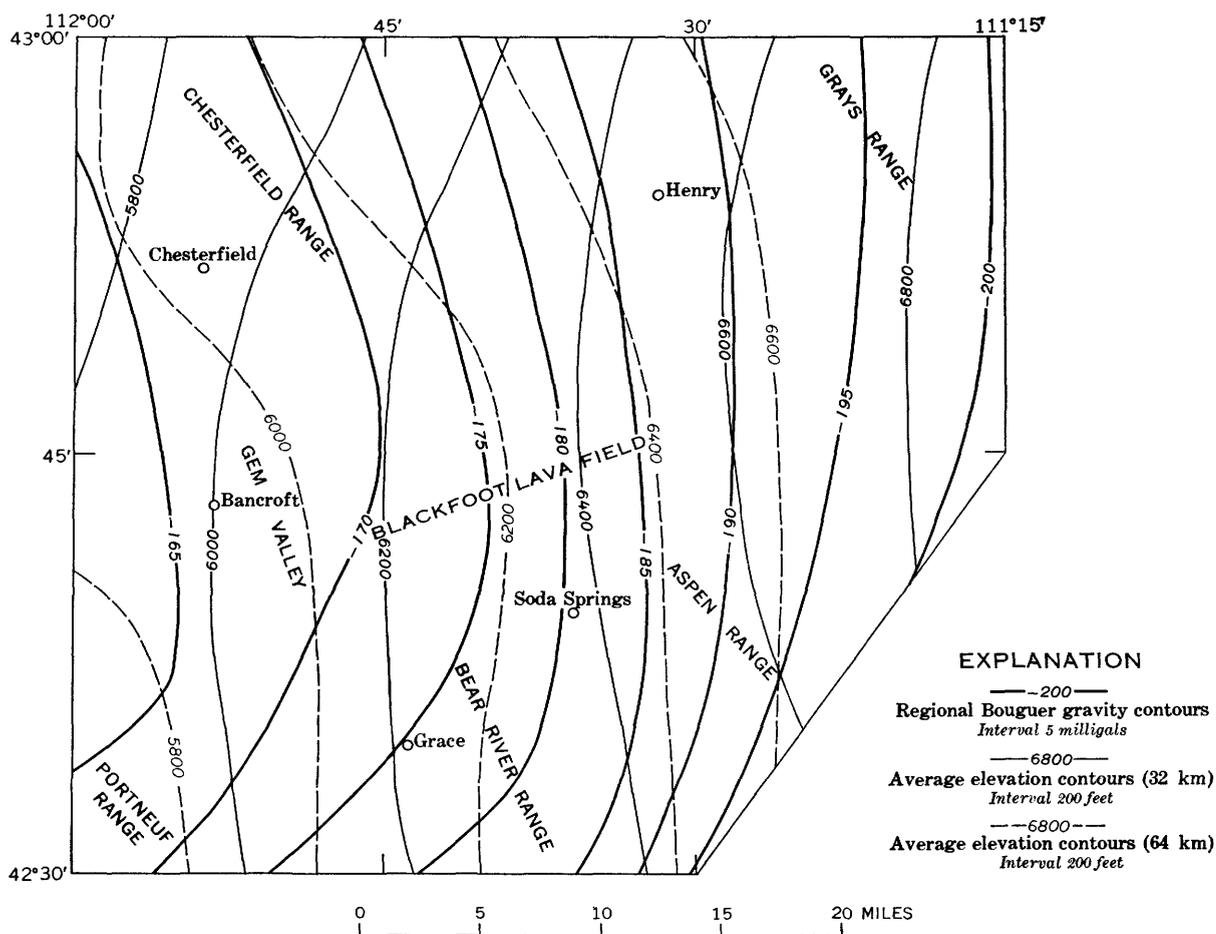


FIGURE 5.—Regional gravity and topographic contours. Gravity contours are based on stations on pre-Tertiary rock. Topographic contours are elevations averaged over circular areas with radii of 32 and 64 kilometers.

region is about 1,000 feet (fig. 5). The accompanying decrease in Bouguer anomaly values of about 35 mgal is about that expected if the higher topography is isostatically compensated (Mabey, 1966).

Isostatic anomalies have been computed at the seven U.S. Coast and Geodetic Survey pendulum stations in and adjoining the Soda Springs region (Duerksen, 1949). Pratt-Hayford isostatic anomalies at all these stations are positive, ranging from +13 to +31 mgal.⁵ The average isostatic anomalies at the seven stations for different depths of compensation are: +26.1 mgal (56.9 km), +19.5 mgal (96 km), +17.0 mgal (113.7 km), +24.7 mgal (96 km, corrected for indirect effect).

Free-air anomalies for the stations occupied in this survey ranged from -22 mgal for a station in Gentile Valley, where both elevation and Bouguer anomaly value are low, to a high of +119 for the station at the highest elevation. The average free-air anomaly for all

stations is about +14 mgal. However, this average is heavily weighted toward the valleys, where stations are more abundant and the free-air anomaly is relatively low because of local negative anomalies and low elevations. The average free-air anomaly for the entire region is more positive, probably about +35 mgal.

The positive free-air and isostatic anomalies and the correlation between Bouguer anomaly values and regional elevation indicate that variations in regional topography are approximately compensated but that the entire region is undercompensated. Gravity data from surrounding regions indicate that the zone of positive free-air and isostatic anomalies extends to the north and east, but not southwestward into the main part of the Basin and Range province.

Although eastward decrease in Bouguer anomaly values across the Soda Springs region clearly correlates with increase in regional elevations and does not require any mass anomalies in the upper crust, the southward component observed in the southern part of the mapped

⁵ The isostatic anomaly values were adjusted for differences between original pendulum gravity observations and data obtained in the more accurate gravity-meter survey reported here.

area does not have an obvious correlation with regional topography. North of Fish Creek Basin, between the Portneuf and Fish Creek Ranges, anomaly values of -162 to -165 are indicated for exposed Paleozoic rock. Between Fish Creek Basin and the south edge of the mapped area, the values decrease about 10 mgal in a distance of 6 miles. Along the Chesterfield Range, the anomaly values on or near Paleozoic rock have a variation of about 3 mgal; the values decrease slightly over the Soda Springs Hills and then more rapidly over the Bear River Range. A similar southward decrease is evident in the Aspen Range near Sulphur Canyon, and a similar, but smaller, decrease is suggested in the ranges to the east.

The cause of the southward decrease in Bouguer anomaly values observed in the eastern part of the Portneuf Range and in the Bear River and Aspen Ranges is not obvious. Southward along the Chesterfield Range-Soda Springs Hill-Bear River Range chain, progressively older rocks are exposed, suggesting that the basement surface may rise as the gravity values decrease. Although the nature of the basement rock in the region is unknown, the density of the basement is not likely to be less than the upper Paleozoic rocks, and, therefore, a basement high should not produce a gravity low. A southeastward thickening of the Cambrian and Precambrian quartzites would be consistent with the gravity data, but geologic evidence does not support this possibility. Structural thickening of the quartzites is a possibility, but this cannot be evaluated without additional geologic mapping.

Bouguer values on the east side of the north end of Gem Valley are not much lower than those on the west side. If a linear eastward decrease in regional gravity is assumed across the mapped area, data in the Chesterfield Range suggest a residual gravity high relative to other ranges. Such an anomaly would be expected if basement were relatively high beneath the range. East of the Chesterfield Range, in the vicinity of the Black-foot lava field, the Bouguer anomaly values unaffected by low-density basin fill decrease eastward more abruptly than in areas to the east and west. A similar abrupt decrease occurs across the valley of the Bear River south of Soda Springs. East of this zone of abrupt decrease in regional Bouguer anomaly values, no rocks older than Mississippian are exposed; west of this zone, older rocks are abundant. The gravity data suggest a greater thickness of younger Paleozoic rocks east of this zone.

Although gravity and magnetic surveys provide much information for the interpretation of subsurface structure in areas underlain by Cenozoic sediments and lavas, they fail to yield unequivocal clues to structures within pre-Tertiary rock. Only in the Chesterfield Range are magnetic anomalies possibly related to pre-Cenozoic rock, and even here these anomalies could be caused by Cenozoic igneous rock. The relatively high gravity values in the Chesterfield Range and the southward decrease of gravity values probably reflect mass anomalies in the upper crust. Geological interpretations involving the upper few kilometers of the crust should explain these anomalies.

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