Gravity determination of basement configuration southern Deer Lodge Valley Montana

Edward A. Cremer

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GRAVITY DETERMINATION OF BASEMENT CONFIGURATION, 
SOUTHERN DEER LODGE VALLEY, MONTANA

By

Edward A. Cremer III

B. A. Franklin and Marshall College, 1954

Presented in partial fulfillment of the requirements for the degree of 
Master of Science
UNIVERSITY OF MONTANA
1966

Approved by:

Robert M. Woodward
Chairman, Board of Examiners

JUNE 15, 1966
Date
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ABSTRACT

Relative gravity values were established for 308 stations in the southern part of the Deer Lodge Valley, Montana. Three east-west cross-sections were calculated using a graticule to convert corrected gravity profiles to depth of valley fill, and a residual gravity map, showing the valley fill anomaly, was constructed for part of the area.

The results indicate minimum depths of fill of more than 5500 feet in the deepest, southern part of the valley, decreasing to the north to approximately 2300 feet near the town of Deer Lodge.

There is a major north-south striking fault along the foot of the mountains on the east side of the valley. A smaller fault along the western side of the valley, south of the known Powell Fault is also indicated.
INTRODUCTION

Purpose and Scope of Present Study

The purpose of the present study was to determine by gravitational methods the approximate depths of valley fill and if possible to locate subsurface faults in the southern part of the Deer Lodge Valley of Montana.

In the fall of 1960, relative gravity values were observed for 308 stations in the southern part of the valley.

A residual gravity map showing the valley fill anomaly was constructed for the part of the valley having a sufficient station density (see Plate 1), and three east-west cross-sections were calculated showing depths in feet to basement (see Plate 2).

Location and Accessibility

The Deer Lodge Valley heads on the western slope of the Continental Divide near Butte, Montana, latitude 46°00' North, longitude 112°30' West. The valley trends to the north to Garrison, Montana.

Highway U.S. 10S runs through the valley and there is an excellent system of secondary roads. Except for the extremities of line B-B', which lie in the hills above the valley, all of the stations are accessible throughout the year.

Previous Work

Pardee (1950, 1951) and Alden (1953) discuss the physiography
Figure 1. Location of map area and cross-sections
and geologic history of Western Montana. Konizeski (1957, 1961, 1962) has mapped the surface geology in the area with which this study is concerned.

Previous geophysical work in the valley has been limited to regional studies with particular emphasis on interpretation of the intrusive bodies of the area (Biehler and Bonini, in press; Renic, 1965).

Acknowledgements

The writer is grateful to the University of Montana and to the United States Geological Survey for financial support and cooperation. Special thanks are due Dr. John Hower, who proposed the study and contributed invaluable assistance and advice during its earlier stages and also to Dr. Robert M. Weidman for his advice, assistance and encouragement.

The writer is also particularly indebted to Dr. Richard L. Konizeski for many pleasant hours in the field and for the use of his work in the Deer Lodge Valley as geological background for this study.
Figure 2. View westward along A-A'
METHODS OF INVESTIGATION

Instrumentation

A total of 537 readings was made between October 11 and 23, 1960 with World Wide Instruments gravimeter number 34. This was a portable, temperature compensated gravity meter with a constant of 0.09608 milligals per scale division.

Additional ties (24 readings) were made on June 13 and 15, 1961 with Worden meter number 424, a meter similar to the World Wide instrument. Constant of the Worden meter was 0.0826(7) milligals per scale division.

The elevations necessary to correct the gravity readings to usable values were established with an engineer's level for those stations prefixed by G by Mr. Gale McMurtrey of the United States Geological Survey. The remainder were obtained by the author with transit using stadia distances and vertical angles. In no place did the vertical closure exceed three feet, and the elevations are believed to be generally accurate to the nearest foot.

Procedure

Meter drift and tidal corrections were made for all stations by rereading a previously read station at intervals of approximately one hour and applying the correction interpolatively to the intervening stations.
Figure 3. View westward along B-B'.
The observed gravity values were reduced to a base level of 4391.29 feet.\textsuperscript{1} Latitude corrections were applied to reduce all values to a base of 46° N. Latitude. The corrections were made as described by Nettleton (1940, p. 41-58). An arbitrarily assumed density of 2.5 g per cm\(^3\) was used in computing terrain and Bouguer corrections.

Terrain corrections were calculated using tables published by Hammer (1939) for twenty eight stations throughout the area and interpolated values were applied to all other stations.

The regional gravitational gradient, as determined by gravity differences of stations on bedrock, was found to be representable as a smooth surface sloping to the southwest. This surface was contoured between the maximum and minimum bedrock readings and superimposed on the overall gravity map. The appropriate value was then subtracted from each station with a value above the minimum, thus reducing all bedrock stations to a common, minimum value and leaving a residual gravity map showing only the anomaly caused by varying depths of valley fill. The resulting contours were compared to a regional map prepared by Biehler and Bonini (in press) and found to be in harmony with it.

The maximum regional correction for the entire area was 29.9 milligals; however, the maximum correction for the area covered by the map (Plate 1) was only 13.7 milligals. This correction is the limiting

\textsuperscript{1}This is the elevation of a station located in the northern part of the valley near Garrison. It was chosen for base level because it was at the lowest elevation of any station observed in connection with this study. This station and thirty others in the same area were omitted from the present study because of complications introduced by large extrusions of andesite.
Figure 4. View westward along C-C'
one for the precision of the final values, and is believed to be sufficiently accurate to justify the one milligal contour interval.

A residual gravity map with a contour interval of one milligal was prepared for that portion of the study area with a station density sufficient to justify the contour interval (see Plate 1).

Stations used in the calculations of the cross-sections were established at roughly quarter-mile intervals. These lines were located to afford accessibility and avoid complicating terrain features (see Figs. 2, 3, 4).

The cross-sections were calculated with a graticule, as described by Nettleton (1940, p. 115) to convert corrected gravity readings to depth (in feet) to basement (see Plate 2). For this purpose a density contrast of 0.6 g per cm$^3$ between the valley fill and the more dense basement rock was assumed. This value is higher than 0.4 g per cm$^3$ which was used in recent studies of nearby, presumably similar valleys (Kinoshita, et al., 1964, p. 2, 3; 1965, p. 2, 3; Davis et al. 1963, p. 2, 3; 1965, p. 2, 3; 1965, p. 2, 3). The contrast used in this study is, therefore, probably a maximum value and the calculated depths of valley fill may be regarded as minimum values.
**GEOLOGY**

**Geologic Setting**

The Deer Lodge Valley is bounded on the east by the western slope of the Continental Divide. The rugged Flint Creek Range bounds the valley on the west. The valley is about ten miles wide and nearly thirty-two miles long.

The highest point in the mountains to the east is 8592 feet, while in the Flint Creek Range the maximum altitude is 10,171 feet.

Valley floor altitudes decrease from about 5100 feet at Gregson Hot Springs at the southern end of the valley to about 4300 feet at Garrison near the northern mouth.

There are extensive flows of andesite at both ends and along the eastern side of the valley.

The valley topography is dominated by two terrace levels. Somewhat dissected, high terraces dip toward the river more gently than the slopes in the mountains and end in abrupt scarps above the lower terraces which slope gently toward the Clark Fork, (Konizeski, 1962, p. 7, 8; Robertson, 1953, p. 5).

**Geologic History**

The age of the intrusions forming the fringing mountains is post-middle Late Cretaceous and pre-early Oligocene, (Chapman, et al. 1955, p. 607).
Because the age of the bathyliths surrounding the valley is obscure the origin of the basin is likewise uncertain.

It is, however, a reasonable assumption that the valley originated as a shallow topographic low genetically related to bathylithic intrusion and doming of the regional Precambrian and Mesozoic country rocks (Konizeski, 1965, p. 14).

A summary of the Cenozoic history according to Konizeski (1962, p. 11) is as follows:

1. Eocene and Oligocene: Tectonic origin of valley, probably accomplished mostly by block faulting accompanied and followed by extrusion of local lavas and deposition of gravel, sand, silt and clay; maximum cross-valley relief.

2. Miocene: Gradual reduction of relief; accumulation of fine grain deposits and, finally, re-emphasis of tectonic activity.

3. Pliocene: Increased relief accomplished by block faulting.

4. Pleistocene and Recent: Entrenchment of drainage system; glaciation of Flint Creek Range; development of modern topography.
DISCUSSION OF RESULTS

Plate 1 shows a rapid gravity decrease along the sides and southern end of the valley. The values in the central part of the valley are comparatively constant. Low contour values in the vicinity of the bedrock contact near the southwest corner of T 5 N, R 10 W are explained by the presence of low density volcanic tuffs (R. L. Konizeski, personal communication).

The most outstanding feature common to all three sections (see Plate 2) is a sudden, large break in slope at the eastern end. This is almost certainly a major fault running along the foot of the mountains to the east. This fault is probably a continuation of, and is verified by, a large fault which is known to exist along the east side of Deer Lodge Pass south of Silver Bow, (Pardee, 1950, p. 388).

There is also definite indication of a smaller fault on the western end of Section A-A', which is confirmed, if not as strikingly, by Section B-B' to the north. The magnitude of the break probably precludes the possibility of a terrace in the case of the southern section. In addition, the sharpness of the subsurface features and the depth to basement would seem to indicate that filling must have proceeded at a sufficiently rapid rate to prevent the formation of such an erosional feature.

The Powell Fault (Mutch, 1961) is known to run into the valley between lines B-B' and C-C' and bend northward along the foot of the
Flint Creek Mountains to the west (Konizeski, personal communication). Unfortunately the northern line was terminated before crossing it.

It has been asserted that the Deer Lodge Valley is one of the few valleys of western Montana which was formed primarily by warping rather than faulting (Pardee, 1950, p. 402). In the opinion of the present author, this is not the case.

A more ambiguous feature of the three sections is the humping in the middle of the valley. This may be attributed to faulting of the valley floor or to erosion. However, in the opinion of the author, this feature is much more likely caused by lava flows along the center of the valley. A flow of lava, or a series of interbedded flows, of lesser magnitude than the indicated humping, but closer to the surface, could result in a calculated valley floor exactly as shown by the sections. The presence of andesite flows both to the north and to the south of the valley indicates the likelihood of this explanation. The tight contours in the vicinity of section 21, T 4 N, R 10 W are caused by the nose of such a flow.

The depths of valley fill shown by lines B-B' and C-C' are confirmed at least in part by Montana Power Company test well (State 1-1-22). This well, located in Sec. 22, T 7 N, R 9 W, is approximately 4.25 miles due north of station 13 in line B-B' and 3 miles south of an extension of line C-C'. The well bottomed in tuff (?) without reaching basement at 2,536 feet (Konizeski, 1965, p. 12).
SUMMARY

There is a major fault along the eastern side of the valley and, probably, a smaller one along the western side. These faults indicate a tectonic origin of the Deer Lodge Valley similar to that of most other intermountain valleys in western Montana. The maximum depth of fill is in excess of 5500 feet and occurs to the east of Anaconda. The depth of fill decreases to the north.
REFERENCES CITED


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USCGS

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aAll values arbitrarily reduced by 800 milligals.

bUnderlines denote stations for which terrain corrections were actually calculated. All other values are interpolated.
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For
Oversized
Images