Gravity survey of Ogden Valley, Weber County, Utah

By

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This report and accompanying maps have not been edited or reviewed for conformity to Geological Survey standards or nomenclature.

U. S. GEOLOGICAL SURVEY

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Contents

Illustrations

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Abstract

Ogden Valley is a northwest trending valley within the Wasatch Mountains of north-central Utah. On the basis of geological evidence Ogden Valley is believed to be structurally controlled by normal faults along both the east and west margins. Gravity measurements in the valley definitely indicate a fault with at least 2000 feet of vertical displacement along the west margin of the valley. A fault with at least 1000 feet of vertical displacement is postulated along the east margin of the valley, together with three smaller, buried faults within the valley. The maximum depth of Quaternary alluvium and Tertiary sediments within the valley is about 6000 feet.

INTRODUCTION

Statement of the Problem

Ogden Valley is located along the eastern margin of the Basin and Range province, about 5 miles east of the Wasatch front. It is one of the largest back valleys within the north-central Wasatch Mountains, and has an area of about 40 square miles. It trends approximately parallel to the Wasatch Mountains.

On the basis of geologic evidence, Ogden Valley is usually referred to as a "structural trough", implying that its present disposition is due primarily to normal faulting along its eastern and western margins, or to faulting along one margin only. However, none of the geologic maps of the area, from Gilbert (1890) to Lofgren (1955), indicate the location or trends of these faults.

The purpose of this investigation is to demonstrate the presence or absence of these faults, and to delineate other major structural trends that may exist in the area. Furthermore, it is hoped that this study will aid in the interpretation of similar Basin and Range type structures, and find application in ground water problems in the valley.

General Setting

Ogden Valley is unique in that it is completely enclosed on all sides except for one narrow drainage outlet--the Ogden River. The tributaries of the Ogden River unite near the head of Ogden Canyon, through which it flows in its journey to the Great Salt Lake. The Ogden River and its tributary system is the chief source of water for the city of Ogden.

The principal settlement in Ogden Valley is the town of Huntsville, with a population of 1,300. It was founded in 1860 by Brigham Young, then president of the Mormon Church. The settlements of Eden (population 250) and Liberty (population 200) were founded later. (See figure 1.) Today the chief industry in the valley is farming and stock raising.

Geologic Setting

The general geology of the Wasatch Mountain region has been reported in many early studies, most notable of which are those of King (1877) and Gilbert (1890). In 1910 Blackwelder first reported the complexities of the thrust structures in the vicinity of Ogden Canyon. Eardley, in 1944, published a comprehensive report on the stratigraphy, structure, and physiography of the north-central Wasatch, with special emphasis on the evolution of the Laramide and later structures. The U. S. Geological Survey, in cooperation with the state of Utah, has made numerous studies of the unconsolidated sediments of Ogden Valley, with emphasis on their hydrologic aspects. A few unpublished theses of the Department of Geology, University of Utah, deal with the stratigraphic and structural features of selected areas within the central Wasatch Mountains. (See Egbert, 1954, and Schick, 1955.)

In addition to these sources of information on the central Wasatch region, there is an extensive literature dealing with the regional features of Laramide and Basin and Range type structures in the western United States. Although the specific characteristics of these structures are not yet agreed upon in every detail, the general characteristics are fairly well known. It is from a synthesis of these two types of sources that a reasonably accurate picture of the geologic evolution of Ogden Valley may be obtained.

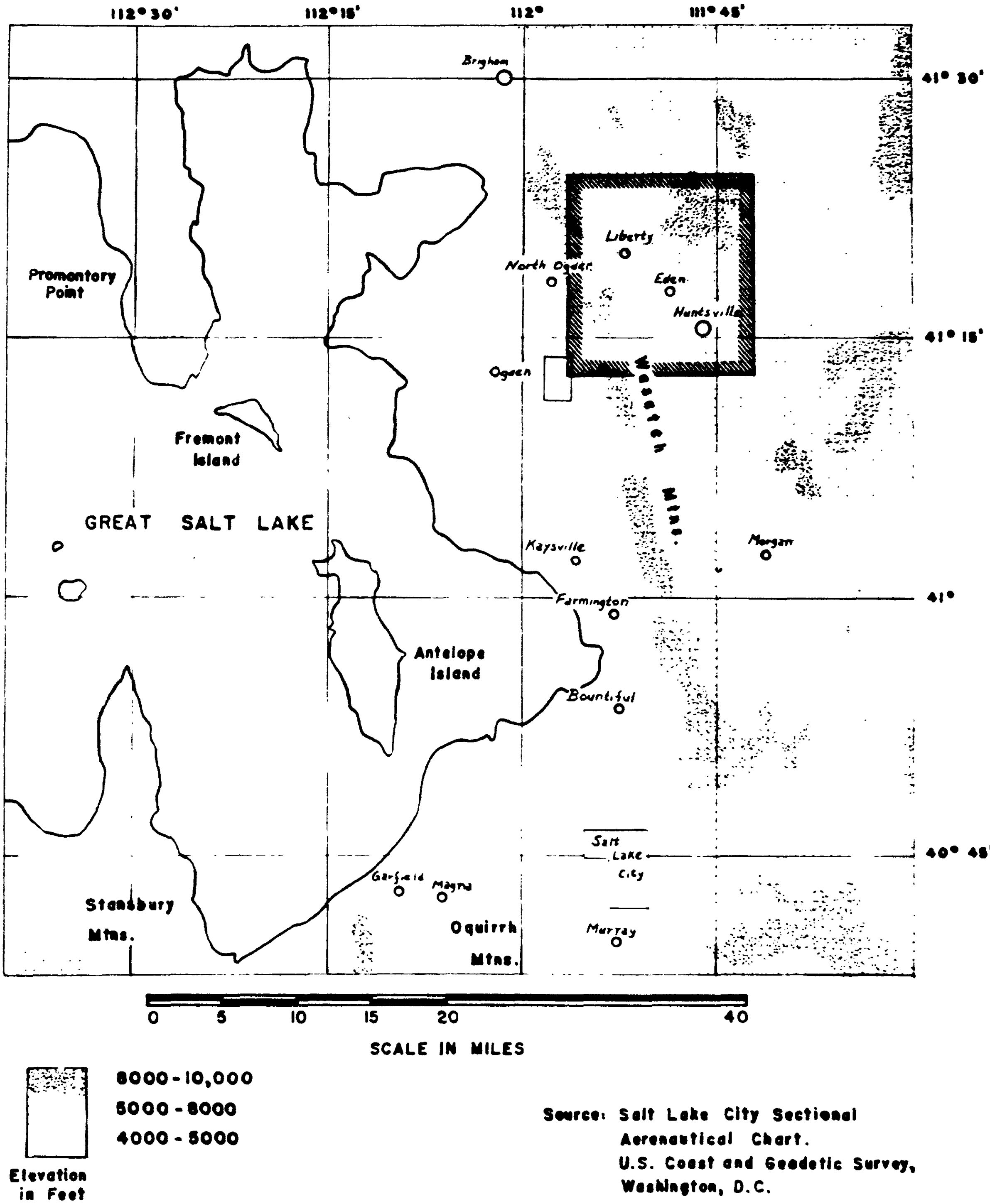

FIGURE 1: INDEX MAP OF NORTH-CENTRAL WASATCH MOUNTAIN REGION

7

Except for a few Paleozoic sediments cropping out along the west margin, Ogden Valley is enclosed on the north, east, and west by the Proterozoic metasediments of the Wasatch Mountains. These mountains rise 4000 feet above the valley floor. Along the south margin of the valley is a low, rolling ridge of Tertiary stratified tuffs and marls which topographically separates Ogden Valley from Morgan Valley to the south.

The present physiographic expression of Ogden Valley, of Morgan Valley to the south, and Cache Valley to the north is due primarily to late Laramide broad folding that trends north-south, and post-Laramide Basin and Range type normal faulting.

Schick (1955) has demonstrated the existence of post early Oligocene normal faults along the east side of Morgan Valley. Adamson, Hardy and Williams (1955) state that in Cache Valley "Post Salt Lake group high-angle faults seem to parallel the mountain fronts, . . .". The Salt Lake group is given a Pliocene age.

In Ogden Valley, Lofgren (1955) summarizes the evidence for normal faulting as follows: "Whereas the principal structure of Ogden Valley is due to folding, faulting, and general downwarping, which are known to have taken place mainly in Tertiary time, . . . fault scarps showing recent displacement are recognized in the valley. Along the west margin of the valley and paralleling the general trend of the structural trough, a scarp having several tens of feet of displacement is clearly defined. Although this scarp is somewhat modified by erosion, it is recent enough to be traceable in relief for several miles, and is evident along the base of the mountain front west of Liberty. Along this fault line arise several springs, which in the area west of Liberty yield sizable quantities of cold water of good quality. South and east of the large Liberty springs, a series of small springs follows the base of the fault scarp, . . .".

Thomas (1945) fcund evidence of displacements within the late Tertiary and Quaternary sediments of Ogden Valley. Lofgren (1955) states that this displacement may be as much as 25 feet, and is along the west margin of the valley. The writer could find no evidence in the literature of faulting along the east margin of Ogden Valley.

Although the normal faulting throughout the north-central Wasatch is believed to vary in age from late Eocene to Recent, it nevertheless appears that it is all related to some singular sub-crustal force or forces active to the present time.

THE GRAVITY SURVEY

Field Methods

In the Ogden Valley survey a Worden gravimeter with a small dial calibration constant of 0.9951 milligal per scale division, and a large dial calibration constant of 36.920 milligals per scale division, was used. The large dial was used on only one loop of the survey, since it was found that it introduces irregular variations in the drift characteristics of the instrument, and a resultant loss in the precision of the readings of the order of 0.2 milligal. When only the small dial is used, repeat readings at stations already established indicate that the precision of reading the gravimeter is 0.02 milligal.

A total of 113 gravity stations were established, of which all but 13 are in Ogden Valley. The remainder are in Morgan Valley. Those stations in Morgan Valley were taken with the intention of establishing more stations on the low-lying ridge between the two valleys. Because of weather conditions and road conditions at the time of the survey, as well as poor vertical control, it was not possible to establish any stations along this ridge.

Elevation control was primarily by means of bench marks, which are accurate to at least 0.1 foot, and "spot elevations" (see Appendix I) on the topographic maps, which are usually accurate to within 4 feet. Thirteen elevations were interpolated from the contour lines on the topographic maps, and are believed accurate to within 4 feet in the flat areas of the valley, and within 10 feet in the more rugged mountainous areas. For this reason the values of the gravity listed on the gravity map (Plate 1) for those stations established in Ogden and North Ogden Canyons are given only to the nearest milligal.

A plane table and alidade was used to obtain elevations along the east margin of the valley. These elevations are believed accurate to within one foot.

Reduction of Data

Readings of observed gravity were corrected for drift of the gravimeter, for the latitude and elevation of each station, and for topographic effects. An elevation correction of 0.06 milligal/foot was used, corresponding to an average rock density of 2.67 gm/cm^3. Topographic corrections were carried out to zone I on the U. S. Coast and Geodetic Survey charts, a radial distance of 5.2 miles. While more accuracy could have been obtained for the topographic correction by carrying it out to a greater radial distance from each station, it was thought unnecessary for the requirements of this survey. These more distant topographic effects, when combined with the true regional gradient in any region, are merely manifested as an apparent regional gradient on the closely spaced stations.

The survey was tied to the U. S. Coast and Geodetic Survey pendulum station number 49 in Salt Lake City. The Bouguer anomalies, corrected for topography to a radial distance of 5.2 miles, are plotted on the gravity contour map, Plate 1, with a contour interval of one milligal. By subtracting 1000 milligals from the values on the contour map, these Bouguer anomalies may be obtained. Since pendulum stations may be in error by as much as 5 milligals, the absolute Bouguer anomaly value at any station is no more accurate than this amount. The final results of the relative gravity at each station, however, are believed accurate to 0.3 milligal.

Presentation of Data

The gravity contour map (Plate 1) has been prepared to show the gravity anomaly in relation to the generalized surface geology. For the purposes of this survey it is permissible to map the geology simply as Quaternary alluvium, Tertiary tuffs and conglomerates, and Paleozoic and Precambrian bedrock. Regional gravity effects, to be discussed later, are not removed from this map.

Two gravity profiles, whose positions are shown on Plate 1, are presented in Plates 2 and 3. These gravity profiles are corrected for regional effects, and then quantitatively examined to determine the most reasonable bedrock-alluvium interface which could account for the residual anomaly. A Skeels graticule, (Dobrin, 1952), modified for the purpose of this survey, was used in the analysis. Because the inferred geologic profile is not infinitely long in the dimension perpendicular to the plane of the profile, it was necessary to apply an end correction factor (Nettleton, 1940) to all the points along the profile where the gravity effect was to be determined.

In choosing a suitable density contrast between the bedrock and the valley fill, it was necessary to consider the densities of the bedrock, of the alluvium, and of the Tertiary tuffs and marls, as well as the compaction of the unconsolidated valley sediments with depth. Lists of densities for the common rock types are plentiful in the literature. For the Precambrian metasediments that constitute the main part of the bedrock, an average density of 2.70 gm/cm^3, based on data in Heiland (1946), is assumed. Similarly, a density of the order of 2.20 gm/cm^3 is assumed for the alluvium and valley fill. This figure takes into account the compaction of the sediments to a depth of 4000-5000 feet, and the fact that they are, for the most part, water saturated. (See Dobrin, 1952.)

In determining an average density for the Tertiary tuffs and marls, no reliable data were found in the literature. As an alternative, a few specimens of the tuff were collected from three outcrops south of Ogden Valley, and density determinations made upon these specimens. The water saturated densities of the tuff were found to vary from 1.39 to 2.25 gm/cm^3, with an average of about 2.10. The densities of these tuffs and marls will certainly increase with depth, due to compaction.

Because of the similar densities of the unconsolidated sediments and the Tertiary tuffs and marls the writer feels secure in combining these two rock types for the purpose of analyzing the gravity data. These combined rock types are provisionally assigned an average density of 2.20 gm/cm^3. The density contrast between the bedrock and the "fill" is therefore of the order of 0.5 gm/cm^3, and this is the figure used in the graticule analysis.

These profiles will be discussed in the next chapter.

Appendix I is a list of the location of all gravity stations established in the survey, and the value of the Bouguer gravity at each station as shown on Plate 1. The data for Morgan Valley are included at the end of this appendix, although they are not shown on Plate 1. These are included for use in any future gravity survey in Morgan Valley. These data will not be further discussed in this report.

INTERPRETATION OF THE DATA

Introduction

The interpretation of gravity data is in a separate and distinct category from the collection and routine reduction of such data. The collection of data includes all the steps up until the time that the areal map is ready for contouring.[1] The act of contouring an areal gravity map is subject to human choice and the interpreter may, within the limits imposed by his data, produce a contour map which he believes is a reasonable representation of the conditions he is attempting to portray.

It is probable that no two interpreters will contour a map exactly alike. For this reason the areal gravity map itself (Plate 1) constitutes a major amount of the interpretative data in this report. It is contoured according to the author's interpretation of the gravity values at the finite number of gravity stations, and according to the known geologic structure of the area.

In order to detect faults by the gravity method it is necessary that the rocks in fault contact exhibit unlike densities. Any fault movements that displace rocks of similar densities against each other, such as bedrock against bedrock, cannot be detected, even though sizeable horizontal or vertical displacements may have occurred.

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[1]Some may argue that the necessity of choosing an average rock density for the Bouguer and terrain corrections constitutes an interpretation on the part of the computer. However, since the value of 2.67 gm/cm^3 is so often used as an average rock density in the Basin and Range province for the reduction of gravity data, and has no major effect upon the subsequent interpretation of the data, the writer believes that the Bouguer and terrain corrections may be classed as routine reduction.

In this report a density contrast of 0.5 gm/cm^3 has been assumed to exist between the Precambrian and Paleozoic bedrock and those sediments here grouped together as Quaternary alluvium and Tertiary sediments. The oldest of these latter sediments is the Norwood tuff, of lower Oligocene age, which constitutes the major part of the Tertiary sediments on Plate 1. Therefore, the fault movements discussed in this report, and illustrated in Plates 2 and 3, include only those vertical components of displacement that have occurred contemporaneous with, or after deposition of, the lower Oligocene tuffs. That is, the fault movements are of Basin and Range age or younger.

The Gravity Map

The gravity anomaly comprises a closed gravity low centering over the less dense sediments of the valley, with rapidly increasing gravity values along the bedrock margins of the eastern and western parts of the valley. In a qualitative sense these steep gravity gradients indicate the existence of steep bedrock-alluvium interfaces beneath the valley fill.

The northern and southern margins of the valley are characterized by slowly increasing gravity gradients. These indicate a slow rise of the bedrock surface beneath the valley fill to the places where it crops out. There is no evidence for the existence of faults or other steep bedrock slopes along the northern and southern margins of the valley.

The existence of a regional gravity gradient on which the Ogden Valley anomaly is superposed is indicated by the values of the gravity on the bedrock along the east and west margins of the valley. The values of the gravity along the west side of the valley are about 15 milligals higher than those along the east side of the valley. This gradient is too large to be due entirely to distant topographic effects, and must have a more profound cause. It is indicated more clearly in the profiles on Plates 2 and 3, where it decreases to the east or northeast at a rate of about 1.3 milligals per mile.

The presence of this regional gradient in the Ogden Valley survey may have great implications in the regional structure of the Wasatch Mountains and the areas to the east and west. It is possible that this decreasing gradient in the portion of the mountains surveyed indicates a thickening of the lighter density crustal material underlying the mountainous regions of north-central and east-central Utah. It could also indicate horizontal or vertical density variations in the basement rock. Although no definite conclusions can be reached merely on the basis of this local survey, the writer prefers the first interpretation.

The Gravity Profiles

The positions of profiles A-A' and B-B' (Plates 2 and 3 respectively) were chosen for the quantitative graticule analysis in the hopes that they would give the most meaningful interpretation of the subsurface topography. Because of the very few stations established on bedrock along the east margin of the valley, it was necessary to take the profiles virtually next to each other in this region, and then to "skew" them apart in the southwest part of the valley. Profile B-B' is therefore not quite perpendicular to the gravity contours, but this should not have a major effect upon the interpretation.

Profile A-A' was interpreted by placing two faults along the west side of the valley and one fault along the east. A possible fault, indicated by a question mark, is indicated slightly west of the deepest portion of the valley fill.

The westernmost fault in profile A-A' is exposed at the surface, so there is no doubt of its existence. The buried faults in both profiles are postulated on the basis of the gravity data.

Profile B-B' gives a similar interpretation. The westernmost fault exposed along profile A-A' is not, however, definitely indicated by the gravity data along profile B-B'. While the gravity data are admittedly sparse along this latter profile, the writer believes that if a Basin and Range fault of major proportions does exist nearly perpendicular to the plane of this profile it would be manifested in the gravity profile because of the presence of the Norwood tuff.

If the westernmost fault in profile A-A' continues southward to profile B-B', its vertical displacement in the region of this latter profile must be small--probably less than 500 feet. It is tentatively concluded that this marginal fault begins to die out from profile A-A' to profile B-B'. Because the existence of this fault in the latter profile is only inferred--and neither proven nor disproven by the gravity data--it is indicated with a question mark on Plates 1 and 3.

The positions and displacements of the remaining faults in profile B-B' correlate well with those in A-A'. The vertical projections to the surface of the traces of the faults are indicated by X's along profiles A-A' and B-B' in Plate 1.

A fault is postulated slightly west of the deepest portion of the valley in both profiles because a rapid change of the bedrock topography at this point is indicated by the quantitative interpretation of the profiles. This feature is perhaps due not entirely to faulting, but to erosional processes occurring before deposition of the valley fill; to the broad north-south folding known to have occurred in this region in early Tertiary time; or to a combination of all three processes. In any case, the mutual support of one profile by the other lends additional support to the entire interpretation.

With the assumptions made in the analysis of the profiles it would be difficult to arrive at any other reasonable interpretation differing greatly from that already presented. A possible modification, however, would be to substitute a series of step faults of small individual displacements in place of the large normal faults of thousands of feet of displacement postulated along both margins of the valley. The writer feels it would be misleading and unrealistic to attempt to "force" such an interpretation upon the data when it is not definitely warranted by the geophysical or geological evidence available.

SUMMARY AND CONCLUSIONS

The gravity survey has shown Ogden Valley to be structurally controlled by normal faults along the east and west margins. With the assumptions made in the quantitative interpretation of the data, one fault is postulated along the east margin of the valley. This fault is buried beneath approximately 1800 feet of valley fill, and has a total vertical displacement varying from 2000 to 3000 feet.

Two faults are postulated along the west margin of the valley. The gravity data indicate that the westernmost fault, which has been mapped in the vicinity of profile A-A' by Lofgren (1955), has a total vertical displacement of about 2000 feet. In the region of profile B-B' the same fault probably has a displacement of 500 feet or less. It is suggested that this fault begins to die out beneath the Norwood tuff south of profile B-B'. Although the Norwood tuff is soft and easily eroded, more detailed geologic mapping in this area might show one or more small fault scarps existing within it.

Along profile A-A' a fault buried beneath 2000 feet of valley fill, and having a maximum vertical displacement of about 1800 feet, is postulated about 2000 feet east of the westernmost marginal fault. This fault also manifests itself across profile B-B', and there is no gravity evidence to indicate that it begins to die out south of this profile.

The combined vertical displacements along the two western faults in the vicinity of profile A-A' is about 3800 feet. The maximum depth of valley fill, including the lower Oligocene tuffs and marls, is about 5500 feet.

The faults buried beneath the valley fill are postulated on the basis of graticule analyses of two gravity profiles. The bedrock surface so depicted represents the most reasonable interpretation consistent with the available geophysical and geological information. It should be realized that horizontal or vertical variations in the density of the valley fill or of the bedrock will affect the resulting gravity anomaly. It is almost impossible to take these into account when computing the theoretical gravity profiles.

A marked regional gradient, decreasing from west to east at the rate of 1.3 milligals per mile, was noted in the area of the survey. It is suggested that it might indicate a thickening of the lighter density crustal material underlying the mountainous region of north-central and east-central Utah, or it might indicate horizontal and vertical density variations within the basement rocks. Further investigation of this regional trend would possibly prove helpful in our understanding of the tectonic setting of this region.

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APPENDIX I

RESUME OF STATIONS IN OGDEN AND MORGAN VALLEYS

<u>Ogden Valley</u>

Quadrangle	Latitude	Listed Elevation	Gravity Value
Huntsville	41° 17.6'	BM 4933	793.4
"	" 17.6'	Spot 4896	789.7
"	" 17.6'	BM 4934	792.7
"	" 17.6'	UE 4942	795.2
"	" 18.1'	Spot 4951	796.2
"	" 18.3'	UE 4969	798.9
"	" 18.5'	UE 4984	799.7
"	" 19.1'	Spot 5041	800.0
"	" 19.5'	Spot 5067	801.7
"	" 20.0'	Spot 5119	803.2
"	" 17.6'	UE 4984	800.4
"	" 17.6'	UE 5037	805.9
"	" 20.0'	Spot 5110	804.6
"	" 20.5'	Spot 5154	805.7
"	" 20.8'	Spot 5173	806.6
"	" 21.2'	Spot 5207	807.9
"	" 21.6'	UE 5252	813.3
"	" 21.8'	UE 5260	814.6
"	" 22.2'	Spot 5416	816.1
"	" 22.3'	UE 5506	815.9
Ogden 2SW	" 22.0'	Spot 5303	814.3
"	" 22.0'	CE 5335	810.1
"	" 22.4'	Spot 5417	812.6
"	" 20.0'	T 5183	810.2
Huntsville	" 19.2'	T 5290	808.4
"	" 18.8'	SE 5522	812.0
"	" 18.7'	T 5334	808.4
"	" 16.7'	BM 4946[a]	798.8
"	" 16.4'	BM 4942[a]	802.5
"	" 16.1'	BM 4946[a]	808.6
"	" 15.5'	BM 4925[a]	815.6
"	" 17.6'	BM 4908	790.5
"	" 17.3'	BM 4925[a]	794.0
"	" 16.8'	CE 4905	790.9
"	" 16.1'	Spot 4884	787.6

[a]Bench mark is not located on the topographic map. It is described in a pamphlet available from the Bureau of Reclamation.

APPENDIX I (Cont'd)

Quadrangle	Latitude	Listed Elevation	Gravity Value
Huntsville	41° 15.6'	BM 4924[a]	790.2
"	" 15.7'	BM 4922[a]	791.7
"	" 15.9'	BM 4905[a]	794.2
"	" 17.1'	Spot 4941	793.2
Ogden 2SW	" 20.0'	CE 5500	816.2
Huntsville	" 17.0'	Spot 4966[b]	799.5
"	" 16.7'	BM 4955	796.0
"	" 16.4'	Spot 4937[b]	792.8
"	" 16.2'	Spot 4934[b]	791.7
"	" 15.7'	Spot 4920[b]	789.4
"	" 17.3'	CE 4930	792.4
"	" 16.9'	CE 4925	793.0
"	" 16.4'	CE 4880	795.3
Ogden 2SW	" 19.2'	T 6190	816.5
"	" 19.1'	T 5893	819
"	" 19.1'	CE 5000	820
Huntsville	" 15.8'	Spot 4970[b]	799.4
"	" 15.7'	Spot 5005[b]	803.2
"	" 15.6'	BM 5030[b]	803.4
"	" 15.7'	Spot 5071[b]	804.1
"	" 15.7'	Spot 5086[b]	801.9
"	" 15.3'	Spot 5024[b]	803.6
"	" 15.3'	Spot 5005[b]	802.7
"	" 15.3'	Spot 5971[b]	799.0
"	" 15.1'	Spot 4970[b]	798.8
"	" 14.6'	Spot 4973[b]	798.5
"	" 14.6'	Spot 4994[b]	801.9
"	" 14.7'	Spot 5003[b]	802.9
"	" 15.3'	Spot 4961[b]	796.7
"	" 15.3'	Spot 4939[b]	789.7
Ogden 3NE	" 14.8'	Spot 4932[b]	791.1
Huntsville	" 15.3'	Spot 4934	790.4
"	" 15.0'	Spot 4902	792.5
Ogden 3NE	" 14.6'	Spot 4974	794.2
"	" 15.0'	CE 4885	794.2

[b]These elevations are from an old topographic map made by the Bureau of Reclamation of the Huntsville area. They are not found on the newer topographic maps.

APPENDIX I (Cont'd)

Quadrangle	Latitude	Listed Elevation	Gravity Value
Ogden 3NE	41° 14.7'	T 5042	804.4
"	" 14.2'	T 5665	810.2
"	" 13.5'	T 5950	819.6
Ogden	" 14.2'	BM 4425	823
"	" 14.3'	CE 4550	819
Ogden 2SW	" 15.1'	CE 4711	819
Huntsville	" 16.5'	CE 4885	788.0
"	" 18.0'	Spot 4946[b]	793.8
"	" 18.3'	Spot 4955[b]	796.2
"	" 18.3'	Spot 4949[b]	795.5
"	" 18.0'	Spot 4932[b]	792.4
"	" 18.7'	Spot 4994[b]	799.6
"	" 19.0'	Spot 5036[b]	801.4
Ogden 2SW	" 19.6'	Spot 5142[b]	809.0
Huntsville	" 19.1'	Spot 5162[b]	803.4
"	" 18.8'	BM 4987	800.2
"	" 19.3'	Spot 5017[b]	800.5
"	" 20.2'	Spot 5090[b]	807.5
"	" 20.0'	Spot 5076	804.4
"	" 19.9'	Spot 5069	804.6
"	" 17.7'	SE 5070	807.0
"	" 17.8'	SE 5150	807.4
"	" 17.9'	SE 5217	807.8
"	" 18.0'	SE 5240	807.8
"	" 18.1'	SE 5264	807.4
"	" 17.8'	SE 5169	807.8
"	" 20.2'	SE 5202	808.6
"	" 20.2'	SE 5231	808.7
"	" 20.2'	SE 5357	808.4
"	" 20.4'	SE 5457	810.0

<u>Morgan Valley</u>

Quadrangle	Latitude	Listed Elevation	Gravity Value
Ogden	41° 7.9'	CE 4590	829.4
Ogden 3NE	" 8.6'	Spot 4844	801.8
"	" 8.6'	Spot 4866	794.5
"	" 8.4'	Spot 4898	789.3
"	" 8.4'	T 4814	807.0

APPENDIX I (Cont'd)

Quadrangle	Latitude		Listed Elevation	Gravity Value
Ogden 3NE	41°	8.4'	CE 4810	817.0
"	"	8.0'	Spot 4910	786.1
"	"	8.6'	Spot 4919	786.8
"	"	9.3'	Spot 5038	785.9
"	"	9.5'	Spot 5078	786.7
"	"	9.7'	Spot 5146	790.4
"	"	9.0'	Spot 4977	786.4
"	"	8.9'	Spot 4924	794.6

EXPLANATION OF PREFIXES TO THE LISTED ELEVATIONS

BM: Elevations with this prefix indicate that the gravity station was established directly over or within a few feet of a recognized bench mark. These elevations are available to the nearest 0.001 foot, but are given above to the nearest foot.

UE: Elevations with this prefix indicate that the gravity station was established within a few feet of a recognized semi-permanent marker established during the leveling survey. These elevations are sometimes not shown on the topographic maps, but descriptions of the markers are found in pamphlets available from the U. S. Geological Survey. These elevations are available to the nearest 0.1 foot.

Spot: Elevations with this prefix indicate that the gravity station was established on the basis of elevations shown at road intersections or other such locations on the topographic map. In some instances it was found that these "spot elevations" coincided with the unadjusted elevations (UE) found in the bench mark description pamphlets. Where this was known to occur the elevation is prefixed by UE and not Spot. These elevations are given to the nearest foot, but on the topographic maps of the U. S. Geological Survey they are regarded as accurate only within one-tenth of the contour interval. Thus in this survey they are accurate within four feet.

T: Elevations with this prefix indicate that the gravity station was established on the basis of elevations shown on the topographic map and followed by a T. This indicates that the elevation so assigned is only a temporary one, and may be readjusted by a few feet when field completion surveys are conducted. These elevations are usually accurate to about 5 feet.

SE: Elevations with this prefix indicate that the gravity station was established at points where elevations were determined by plane table and alidade by the gravity crew. These elevations are therefore not shown on any topographic maps and are usually not recoverable. These elevations are accurate to one foot or better.

CE: Elevations with this prefix indicate that the gravity station was established at a convenient point on the topographic map, and the elevation of the point was determined by interpolation of the topographic contours. These elevations may be accurate to within one-tenth of the contour interval, or about four feet, in the Ogden Valley survey.