GRAVITY MAP SERIES

of the

DOMINION OBSERVATORY

Ottawa

The Gravity Anomaly Field in Western Canada with maps Part I

No. 39—Medicine Hat-Hanna

No. 40—Lethbridge-Banff

No. 41—Red Deer-Edmonton

No. 42—Wainwright-Battleford

No. 43—Saskatoon-Prince Albert

R. J. Buck

CANADA

Department of Energy, Mines and Resources

OBSERVATORIES BRANCH

1967

GRAVITY MAP SERIES

of the

DOMINION OBSERVATORY
Ottawa

THE GRAVITY ANOMALY FIELD

in

WESTERN CANADA

WITH MAPS

PART I

No. 39- Medicine Hat-Hanna
No. 40- Lethbridge-Banff
No. 41- Red Deer-Edmonton
No. 42- Wainwright-Battleford
No. 43- Saskatoon-Prince Albert

R. J. Buck

Canada

Department of Energy, Mines and Resources

Observatories Branch

1967

ROGER DUHAMEL, F.R.S.C.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1967

CONTENTS

THE GRAVITY ANOMALY FIELD IN WESTERN CANADA WITH MAPS

Part I

R.J. Buck

INTRODUCTION

This report and the accompanying maps comprise the fifth issue in the Gravity Map Series of the Dominion Observatory. The five maps presented here as Part I under this title cover an area of 125,000 square miles in southern Alberta and Saskatchewan between latitudes 49° N and 54° N and between longitudes 104°W and 116° W; four additional maps covering 125,000 square miles in southern Saskatchewan and Manitoba are in press and will be issued as Part II under the same title. The discussion which follows applies to both parts.

The data have been drawn from three different sources:

a) the western Canada section of the national control station network,
b) the regional gravity surveys of the Gravity Division, and
c) gravity values submitted by several Canadian oil companies as their contribution to the program of the International Geophysical Year.

The report discusses the methods of reduction used for the data from each of of these sources, and the difficulties encountered in the compilation of the maps. No attempt is made to interpret the resulting anomalies. As the lithology and stratigraphy of the western Canada sedimentary basin is well known, the gravity information could best be used to interpret the structure and lithology of the Precambrian basement. Such an interpretation would involve the collection of large amounts of geological and density data from drill hole cores and logs and a large amount of computing to remove the effect of the sedimentary layers.

CONTROL STATION NETWORK

The gravity control station network in western Canada consists of approximately 400 stations established on the method of looping and connected to form a series of closed circuits (Figure 1). The basic network was established in 1957 using North American and Worden gravimeters, and has since been strengthened by additional control stations and cross connections observed with LaCoste and Romberg

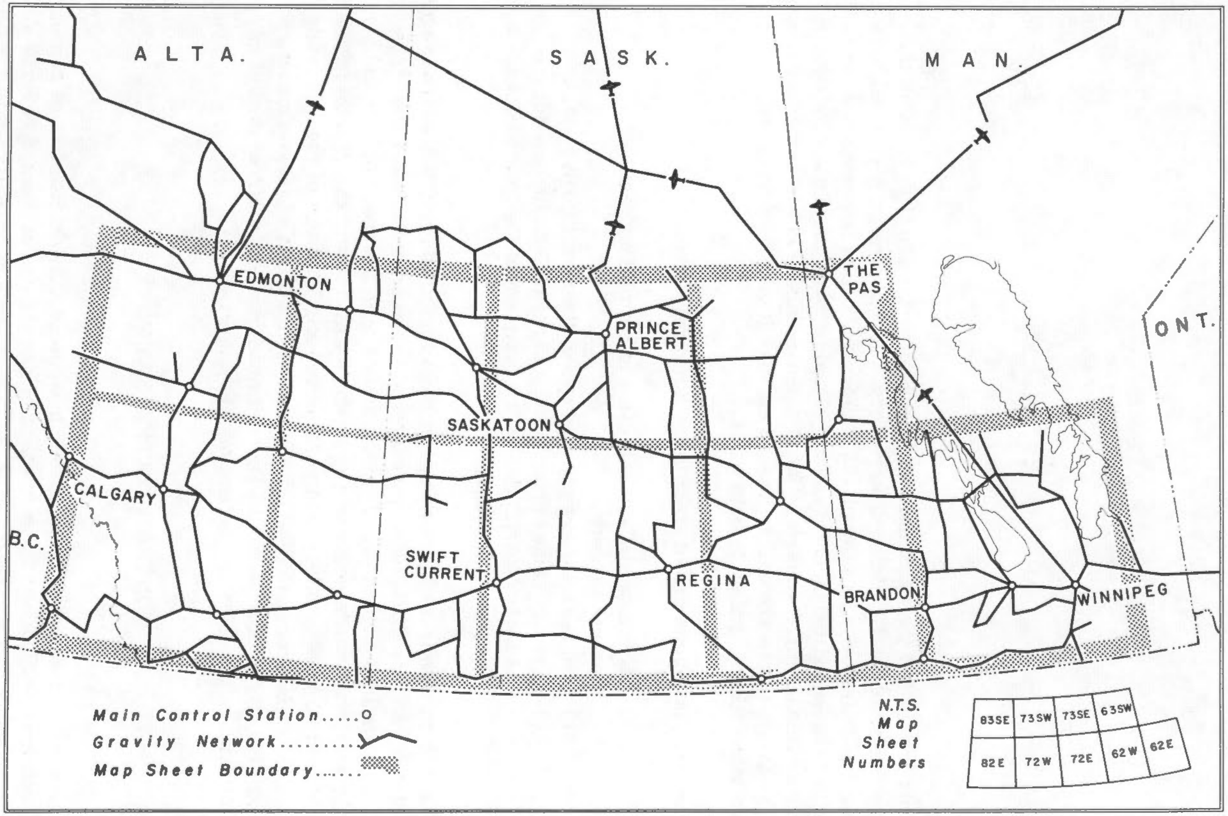

Figure 1. Location map showing the extent of the gravity control network and the map sheet boundaries.

gravimeters. Primary stations have been located at airports in each of the cities and large towns. Secondary stations (excentres) have been observed at railway stations, post offices and universities in these centres, and these have been connected to both the primary and the other excentre stations to form local networks. The primary stations have been linked together by air ties and by lines of looped control stations along the connecting highways. The resulting network provides control stations at intervals of about 30 miles. Descriptions and gravity values for these control stations are available upon request from the Gravity Division.

The network was adjusted in 1962 using the method of least squares programmed for IBM 1620 and 7094 computers; this gave the best value for 50 primary stations. The intermediate control stations along the lines connecting the primary bases were adjusted between the primary values and the results were checked against an earlier adjustment which was done by relaxation (Bancroft, 1960). The standard deviation of the interval between adjacent primary bases is ±0.05 mgal.

TABLE I

OBSERVATORY STATIONS INCLUDING TIES

Year	Area	Observer	Number of Observations	Instrument
1958	Southern and Central Alberta and Saskatchewan	J. V. Gore	674	North American 137
1958	Central Saskatchewan	M. J. S. Innes	170	Worden 44
1959	Manitoba and Eastern Saskatchewan	J. H. Sass	728	North American 137
1960	Northern and Central Saskatchewan and Alberta	R. J. Buck	1116	North American 137
1961	Manitoba and Saskatchewan	R. J. Buck	743	North American 137
1963	Northern Manitoba, Alberta and Saskatchewan	J. B. Boyd	425	Worden 460
1963	Northwestern Alberta	J. P. Charette	477	Worden 460
1963	Central Saskatchewan	R. J. Buck	649	Worden 460
			4982	

REGIONAL GRAVITY SURVEYS

Between 1958 and 1963, approximately 5,000 gravity observations were made in western Canada by field parties from the Gravity Division, using North American and Worden gravimeters (Table I). Two- and four-wheel drive vehicles were used for transportation in the settled area; a helicopter was used in the less accessible areas. Stations were established at 6-mile intervals at easily identifiable points such as road intersections, railway stations and crossings, and shores of lakes. The observations were made by traversing between control stations; the gravimeter and two surveying altimeters were read at each location. Elevation control was provided by known elevations at section corners, railway crossings, benchmarks and lake levels. Readings were taken at gravity control stations every 4 hours and at points of known elevation every hour.

The station positions were marked on 3- and 4-mile topographic maps, from which their latitudes and longitudes were scaled. The Dominion Land Survey co-ordinates, that is section, township and range, were also scaled from these maps. The elevation and gravity observations were processed on an IBM 1620 computer using our standard reduction programs (Tanner and Buck, 1964). Plots of the gravity anomaly values were prepared using an automatic electronic data plotter and the computer output cards. These plots were checked for correct station positions and reasonable anomalies, and questionable stations were listed for reobservation during the following field season.

An analysis of the barometric elevation data indicates an average accuracy of ±10 feet. This is the major contributing factor to the estimated uncertainty of ±0.8 mgal in the final Bouguer anomalies.

OIL COMPANY OBSERVATIONS

In 1958 several Canadian oil companies agreed to release gravity data for inclusion in these maps. They submitted one station per township in selected areas, in the form of an observed gravity value quoted to 0.01 mgal relative to some central base, or in the form of a Bouguer anomaly. A spirit level or stadia elevation was given for each station. The station positions were plotted on special maps or given by reference to the DLS coordinate system. Approximately 5,800 stations were submitted by 10 companies, of which 4,760 were located within the area covered by these maps; the remainder were in Alberta north of the map area.

The gravity values submitted by the oil companies had to be tied to the national network and the anomalies had to be calculated using mean sea level as the datum. Because there was no information concerning the instruments, the control stations and the sequence of observation in the original surveys, the data could not be processed using our standard reduction programs. It was decided to use the method of least squares line fitting to obtain a conversion equation of the form

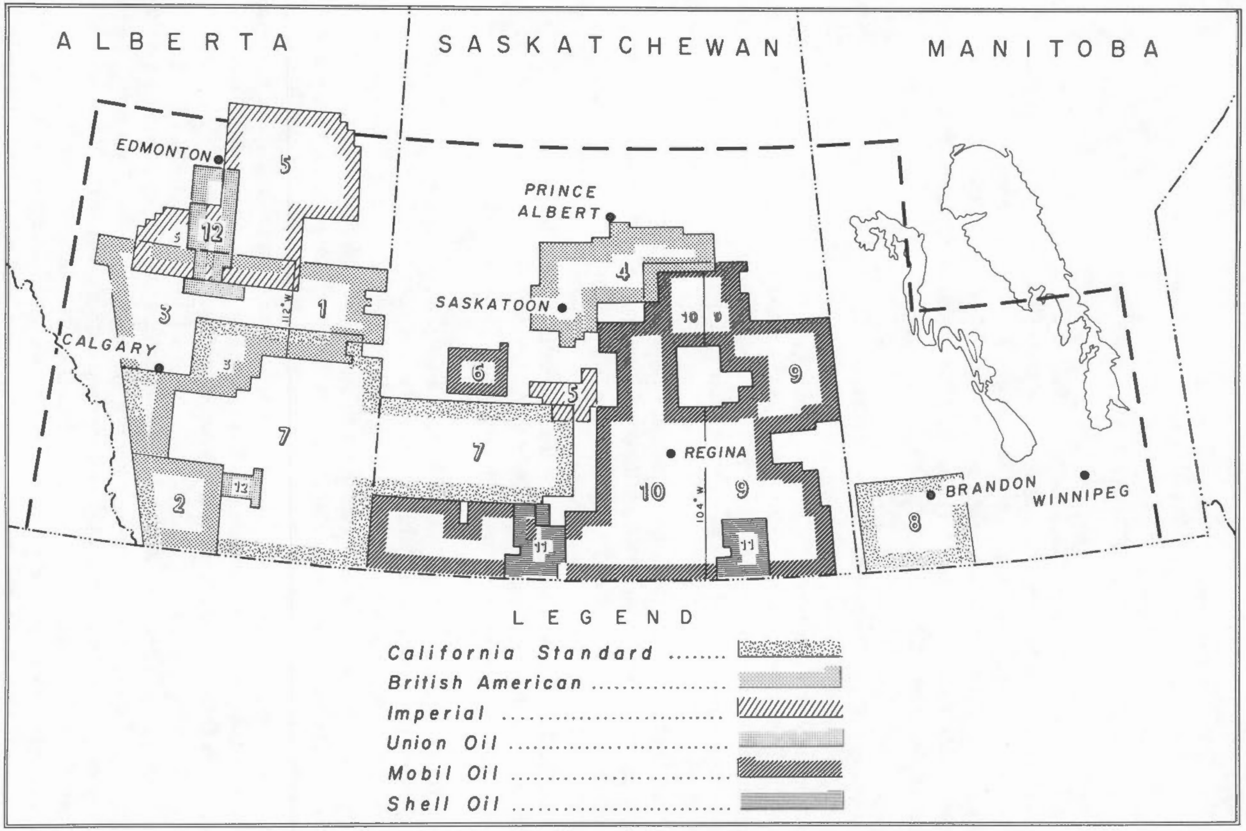

Figure 2. **Contributions of gravity data by the petroleum exploration industry. The numbers 1 to 12 correlate with the areas shown in Table II.**

$$G_d = A + B \cdot G_r$$

where G_d = the value of observed gravity for the station on the national standard,
A = the absolute term or gravity datum shift,
B = the scaling factor, and
G_r = the relative value of gravity submitted by the oil company.

All the oil company stations were plotted on 3- and 4-mile topographic maps, using the submitted station position maps or the listed DLS coordinates. The latitudes and longitudes were scaled to the nearest 0.1 minute and the DLS coordinates were converted mathematically to latitude and longitude and checked against the scaled values. Sequential station numbers were assigned and the data were punched on computer input cards and listed.

During the summer field seasons between 1958 and 1961, approximately 10 per cent of the stations of each company were reoccupied, and independent elevation and gravity readings were taken. These stations were chosen to cover a wide range of latitude, elevation and gravity value. More than usual care was taken to provide good elevation, gravity and position control. These observations were punched and processed using our standard computer programs.

The reobserved stations and those of each oil company were correlated using a computed program which selected stations with the same latitude and longitude, within narrow limits, from the files of Observatory and oil company observations. The resulting pairs of stations were checked for similarity in elevation and DLS coordinates, and also against the known ties recorded in the field books. When a disagreement was found, it was thoroughly investigated and, if not resolved, the station was listed for reobservation in the following field season.

A least squares line-fitting program was used to compute the values of A and B in the conversion equation, as well as the standard deviation of the solution and the residual for each tie. Stations showing residuals of greater than 0.3 mgal were investigated, and if the difference could not be resolved, the pair of stations was removed from the input card deck and the solution was recomputed. Where submissions of the oil companies suggested that their work had been divided into blocks within the major area of coverage, the tie stations within each block were processed separately and the resulting equations and residuals were checked aginst that for the major area. In this way, the best conversion equations were chosen.

Finally, each block or area of oil company stations were processed using its conversion equation, and the Bouguer and free air anomalies were computed. The oil company output cards were sorted and merged with those for the Observatory stations and the resulting file was processed using a computer program which detected and listed those stations which would overprint on the final map plots. Since most of the overprints were caused by the reobservation of oil company stations, this program provided another check on the consistency of the two sets of data. Each set of overprinting stations was inspected for similar anomaly values and any discrepancies were thoroughly checked. If the difference of anomaly was caused by a difference in elevation, the oil company elevation was assumed to be more accurate and the Observatory station traverse was corrected and reprocessed. If the difference of anomaly was caused by a difference in observed gravity value, the Observatory station was assumed to be more accurate and the oil company station was discarded. In the case of overprints with similar anomaly values, only the Observatory station is shown on the final map.

In the above description, it was assumed that the values of observed gravity were directly available from the original oil company submissions. However, several companies sent Bouguer anomaly values rather than observed gravity values. Where the density factor and elevation datum used in the computations were specified, the anomalies were converted to values of observed gravity and processed as previously described.

One company submitted its observations as positions on a DLS base map accompanied by elevation and Bouguer anomaly values, but with no station identification number and no information on the anomaly computation procedure. All attempts at correlating these data proved futile and at our request, the company agreed to open its files to our personnel so that the observed gravity values could be obtained for these stations. For half of the area of coverage, a good conversion equation was computed using these values; however, no such equation could be computed for the other half. For this half of the area, a computer program was written to check the internal consistency of the data by comparing the anomalies computed from the new observed gravity values with those originally submitted. There seemed to be little internal consistency in the data. It is probable that during the transcription of the gravity values, errors were made in equating the station positions as shown on the base map with the DLS coordinates listed in the files. As a result, the oil company data for this half of the area was discarded and the area was resurveyed by Observatory field parties.

Of the 4,760 oil company stations located within the map area, 3,630 were used in the compilation of these maps. The remaining 1,130 stations were discarded for various reasons (Table II). Uncertainties in the conversion equations contribute the major part of the uncertainty of ±1.0 mgal in the final Bouguer anomalies.

TABLE II

OIL COMPANY DATA

Company	Area (Fig. 2)	No. of Stations	No. of Ties	A	B (Mgal)	S.D. (Mgal)
British American	1	149	19	1.00853	980,819.04	0.18
British American	2	49	6	1.01869	980,817.70	0.24
British American	3	578	52	1.01609	980,817.93	0.20
British American	4	243	74	1.00477	980,809.33	0.16
Imperial	5	429	103	1.00124	980,498.28	0.04
Imperial	6	56	19	0.99127	980,504.26	0.22
California Standard	7	1381	105	1.00711	980,806.53	0.24
California Standard	8	202	42	0.99748	980,030.24	0.39
Mobil	9	542	61	0.98791	980,011.93	0.20
Mobil	10	788	Within the map area but not used in the compilation			
Shell	11	143	Within the map area but not used in the compilation			
Union	12	200	Within the map area but not used in the compilation			
Triad		427	In Alberta north of the map area			
French Petroleum		273	In Alberta north of the map area			
Seaboard		111	In Alberta north of the map area			
Colorado		9	In Alberta north of the map area			
Richfield		17	In Alberta north of the map area			

SUMMARY

Many difficulties were encountered in the preparation of these maps. First, this project was undertaken at a time when the Gravity Division was converting to the use of electronic computing systems for routine data processing. The required computer programs were either in a state of development or had to be specially written and tested. Second, the facilities for repeated plotting and checking of large amounts of data were not available until the automatic data plotter was acquired in 1964. Errors found at this time necessitated the reprocessing of some of the data. Third, this project provided us with our first experience in the compilation and conversion of large amounts of data from external sources. We experienced difficulty in converting the oil company data and were unwilling to discard large blocks of it when the problems were first encountered. From our experience we suggest that in the future all data submitted for incorporation in the Gravity Map Series should be in original traverse form. Furthermore, if an outside agency is planning such a gravity survey, the Observatory will provide the advice and assistance that is necessary for the conduct of the survey and the processing of the observations. In conjunction with a more advanced computing system now being developed, this will increase the speed with which the data are published and will ensure conformity with the national gravity standard.

ACKNOWLEDGMENTS

The writer wishes to thank Dr. M. J. S. Innes and J. G. Tanner of the Dominion Observatory for their many helpful suggestions during the preparation of the maps, and to the former for his review of the manuscript. N. Babey of the Dominion Observatory designed and prepared the illustrations. Finally, the author wishes to express his gratitude to the oil companies who supplied gravity data for use in this report.

REFERENCES

Bancroft, A. M.
1960: The establishment of gravity bases at airports across Canada. Pub. Dom. Obs. Vol. XXIV, No. 2.

Tanner, J. G. and Buck, R. J.
1964: A computer oriented system for the reduction of gravity data. Pub. Dom. Obs. Vol. XXXI, No. 3.

1867 Centennial of Canadian Confederation 1967
Le Centenaire de la Confédération Canadienne