# FIRST EXPERIENCES WITH A NEW GRAVIMETRIC FIELD METHOD

BY

H. LINSSER*)

ABSTRACT

The costs of gravity field measurements can be considerably reduced if the drift-control readings at base stations are extended to a full day. A high accuracy is achieved by a computerized adjustment of discrepancies at profile intersections.

Applying this method, an area having difficult access was covered with 12.500 profile kilometres during a period of approximately one year. The paper describes the experiences obtained during this survey.

## 1. INTRODUCTION

The adjustment of airborne magnetometric measurements is relatively simple. Field surveys are planned in such a way that the data are of high accuracy and consequently the misties of the loops are generally so small that the choice of the adjusting method is of minor importance.

The above consideration does not, however, apply to most marine magnetic measurements. These surveys are exclusively programmed for the best seismic results, whilst the magnetometric data are a mere by-product of the seismic survey and usually a magnetometric map is not constructed until the area proves promising for oil or gas production. In the meantime, a considerable number of surveys has been carried out by different companies, and as the preparation of contour maps was not planned the accuracy of the data is inferior to that of airborne data. The methods used by the different geophysical companies involved were varied. Diurnal variation was generally not corrected, normal fields were partly subtracted, etc. The first requirement is to make a common datum for all data, the second step is the elimination of linear drift, and then the adjustment with higher term polynomials is considered.

For the execution of these steps, a computer program has been written which differs from the common adjustment methods. Instead of determining misties of loops, the discrepancies of intersecting profiles (fig. 1) are used as the main input values for the program. The different terms are adjusted individually by an iteration procedure (Linsser 1974), which gradually diminishes most discrepancies; the remaining inconsistencies being removed by interpolation.

Results from areas where the program has been applied have proved that this method is most efficient. It also has been applied to marine gravimetric measurements, which are confronted with basically similar problems and accordingly it was not far-fetched to apply the same principle to gravimetric field measurements on land. Careful planning of the gravity survey allows the difference in reading times between intersection points to be much shorter than the time elapsed between readings at the two base stations. It can be expected that the adjustment based on discrepancies only, i.e. without base stations, results in the same accuracy as the conventional method.

*) Intergeo-Canada Ltd., Calgary

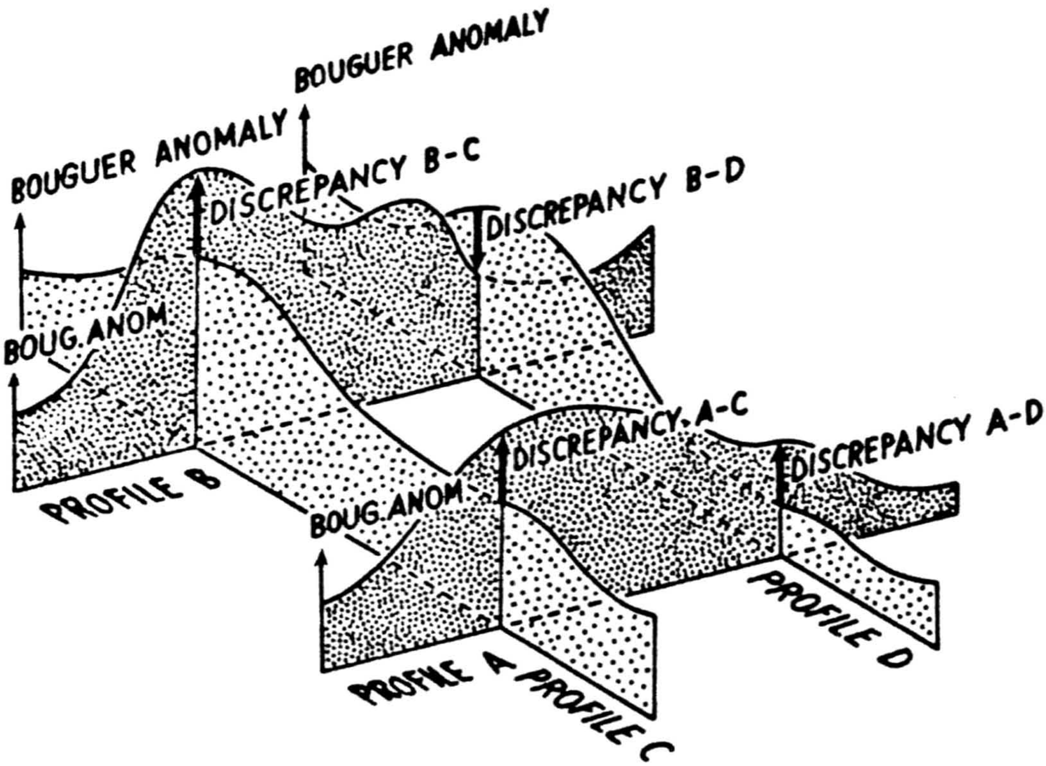


Fig. 1 Discrepancies at intersection points

This type of adjustment program can only be applied after completion of the survey. However, if the gravity meter is read in the morning and the evening at the base stations, the drift of the meter can be linearly adjusted and preliminary Bouguer maps can be prepared. The resulting preliminary values are accurate enough for selecting interesting areas that should be covered by a more detailed survey. The final adjustment of the discrepancies at intersection points is done after completion of the survey in order to increase the accuracy of the Bouguer map. In this case the constant and linear term of the adjusting functions have to be deleted. The applied higher terms have to equal zero at both ends of the profile in order to maintain the values at the base stations, then the following adjustment can be carried out in steps for each individual term if the adjusting functions are orthogonal. A set of functions which fulfils these requirements has been developed by Linsser (1976).

Besides elaboration of the computer program, the new field procedure requires special crew training. Pakistani Texasgulf Inc. employed a PRAKLA-SEISMOS gravity party during 1975/76, which applied the above described method under the supervision of the author. High production combined with sufficient accuracy showed that this method is superior to the conventional field procedure. This paper describes the execution of the field work of this survey.

## 2. THE FIELD CONDITIONS

The concessions of Texasgulf Inc. comprise an area of about 25,000 square kilometres, the structural conditions of which had to be evaluated within a relatively short period. It was planned to initiate exploration combining gravimetric and magnetometric surveys. The client expected that within a few months sufficient promising anomalies could be found to guide a seismic program in selected areas.

The permits consisted of three areas each with different field conditions. The bed of the Indus River, which follows the main part of the concessions, is about 15 to 20 kilometres wide during the high water season. This area is bordered by dykes. It can be surveyed only in the dry season, during which time the river, then relatively small, generally ramifies forming several partially dead arms. The courses of these small river beds change every year after the flood and were therefore unknown prior to the survey. The vast area remaining between the dykes is partly covered by sand dunes, dense scrubs and in places, during low water season, by cultivated land. The use of vehicles is impossible in most parts; cars can descend from the main dykes at only a few places and dead river arms cannot be traversed by cars at all. Therefore, the transportation of the survey personnel was restricted to the river, using rubber boats with outboard motors. All other moves could only be done on foot.

The permit areas were bordered by a wide belt of desert in which the sand dunes have a very gentle gradient to the south as a result of the constant wind blowing from the south. The flanks have an irregular cover of bushes and small trees, whilst the northern flank of the dunes is very steep and consists of loose sand. Whereas vehicles can cross the gently inclined southern flank in an E–W direction, the steep northern flanks cannot be generally crossed by cars. Here, transportation by vehicles was widely restricted. Although cars could bring the survey personnel part of the way from a fly camp to the beginning of the day's working area and pick them up in the evening, most of the locomotion, however, had to be done on foot or by riding camels. Camels also carried water, food, pickets for marking stations, etc.

The area between the main dykes and the desert is intensively cultivated and is crossed by numerous canals with each field being irrigated by ditches. Although they can be crossed by vehicles, they represent a considerable obstacle and therefore it was much more convenient to cross the fields by walking than with the aid of cars.

## 3. THE LAYOUT OF PROFILES

The detailed description of the terrain has been given to show the difficulties which had to be faced by the crew. The main obstacles obstructing the required high production rate was the difficulty in establishing a sufficiently controlled net of base stations. The fly camp, to which the survey personnel had to return every evening, could only be moved into areas with reasonable access and consequently the distance between the fly camp and the work area would become larger during the proceeding survey. Several hours were lost due to unproductive moves and, in addition, the observer's constant transportation to and from the work area was very time-consuming. The use of helicopters was not feasible.

After carefully studying the field conditions prior to the survey, it was decided to apply the above described intersection point method. The required accuracy can be achieved only if a suitable layout of the profiles guarantees establishing a high number of intersection points. The best possible production can be expected only if the ratio of productive to unproductive moves is kept as high as possible.

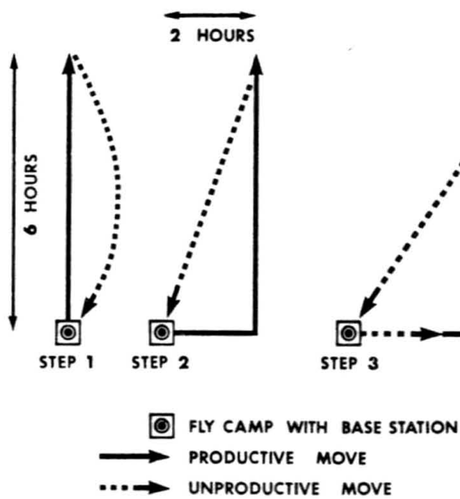


Fig. 2 Execution of measurements with a minimum of unproductive moves

The measurements were to be made according to fig. 2, here, the survey crew makes measurements whenever it crosses an area where gravity stations can be established. The layout of profiles tied to one base station is shown schematically in fig. 3. The area covered, using four base stations, is displayed in fig. 4. An acutal example of profile distribution that was carried out during the survey is depicted in fig. 5, in which

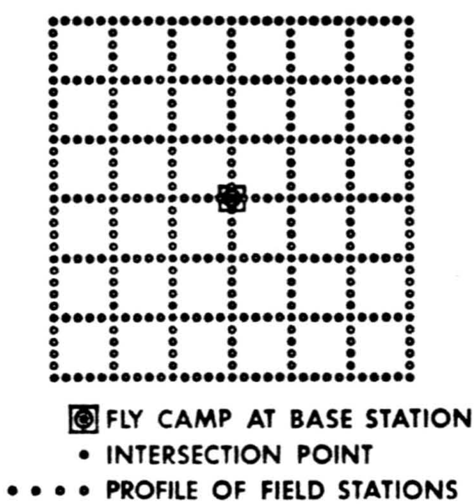


Fig. 3 Layout of profiles belonging to one fly camp

one sees that usually only three to five gravity stations were located between two intersection points. It is obvious that this distribution of profiles guarantees a high data accuracy.

## 4. EXECUTION OF THE FIELD SURVEY

The main modification of the routine field work with respect to usual procedures was the simultaneous execution of the gravity measurements and topographic survey. The normal procedure separates these two basic activities because the gravity observer has to repeatedly return to a base station during the day. The topographic party on the other hand can work consistently. This joint operation, which is possible because the gravity meter operator needs approximately the same time as the surveyor if both are walking, has an important advantage in that of the gravity station marked by the topographer is easily recovered by the operator. In an area where fire-wood is sold by the pound, most of the pegs disappear within 24 hours. Wherever possible, the gravity station is marked not only by a picket, but also with spray paint.

When a profile is surveyed during the initial period of a new subarea, no other profiles can be intersected. The gravity observer, however, knows the approximate locations of planned intersection points. The sites of these gravity stations are chosen, whenever possible, to be at positions which can be indentified by a sketch. Thus, the subsequent crew surveying along the intersection profile can recover the former stations on the basis of the sketch, even if the picket has been removed. Stations marked in this way are identified on the progress map.

In order to reach profiles which are situated far away from the fly camp a considerable time is required before the measurements can start in the morning and before the loop for the linear drift can be closed in the evening. The final adjustment results can be improved if the meter operator reads the instrument at intersecting points located along his route in the morning and the evening.

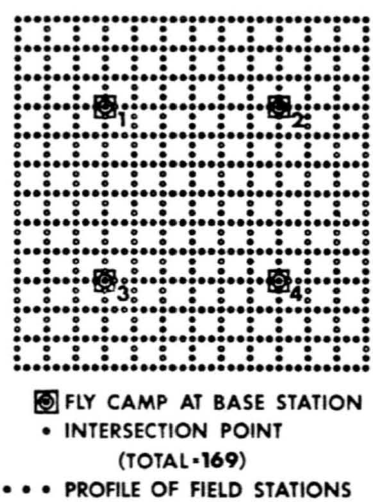


Fig. 4 Composition of four blocks belonging to four fly camps (Intersection point method)

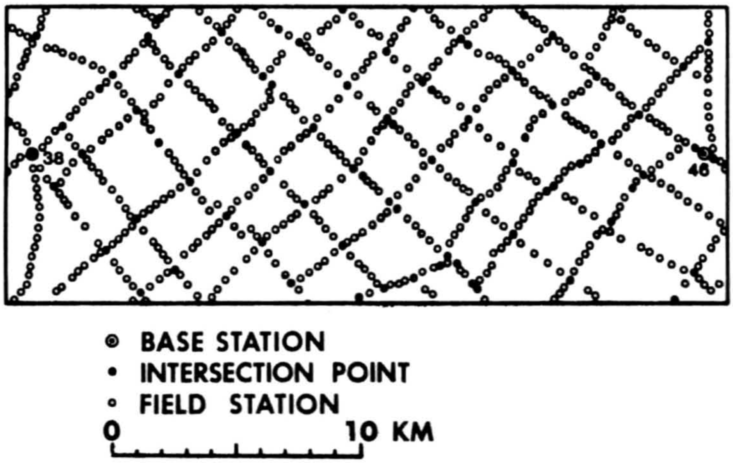


Fig. 5 Actual example of profile distribution

5. ADJUSTMENT OF THE DATA

The conventional method determines the absolute gravity for each gravity station, that is to say the measured gravity corrected for the drift only and tied to the base net. Discrepancies at intersection points can be adjusted in the same way if these points can be completely recovered. However, a small horizontal shift of the gravity station can result in a considerable elevation difference. The absolute gravity, therefore, can differ by several milligal whenever the picket cannot be found. Since the Bouguer anomaly is generally much smoother than the topography, a mislocation of the gravity station affects the Bouguer anomaly much less than the absolute gravity and, therefore, the Bouguer anomaly at the intersection points has been adjusted instead of the absolute gravity. At one time a profile crossed a former line which was not then recognized by the survey party, and it was not until after plotting the gravity stations on a map that the intersection of the profiles was identified. In such cases the mapping provided so-called "fictitious intersection points". For these points, the fictitious Bouguer values and reading times are obtained by interpolation and inserted in chronological order into the input data for the later adjustment.

The crew determined provisional Bouguer values and prepared provisional contour maps, and they also prepared a list of the data required for adjustment. This list comprised all measurements except those needed for the establishement of the base station, and contained the profile number, station number, time of measurement and provisional Bouguer anomaly. Whenever a gravity station was reoccupied, the previous profile and station number were noted. This listing was the input for the computer program.

The first step of the computer program is the completion of information. When a station has been reoccupied, the topographer notes in the field sheet the profile number and station number of one previous reading at this point. This annotation does not give information about subsequent readings at the same station. Whenever an intersection point is repeated more than once, each adjustment has to compare the reading to be adjusted with the mean value of all other readings. Therefore, the list of computer input values has to contain the profile and station number of all intersecting profiles for each intersection point. This updating of the data is included in the computer program. The program does not require that each repetition identifies the profile and station number of the first reading. Any other simple identification enables the computer to complete the listing. Only the following combination has to be avoided: a multiple intersection point consists of the readings A, B, C und D. If the topographer indicates that A is identical to B and C is identical to D, the computer does not identify the pair A–B with the pair C–D. Thus, if different survey parties operate in the same area, the field notes have to be checked carefully to avoid the splitting of one intersection point into two different units.

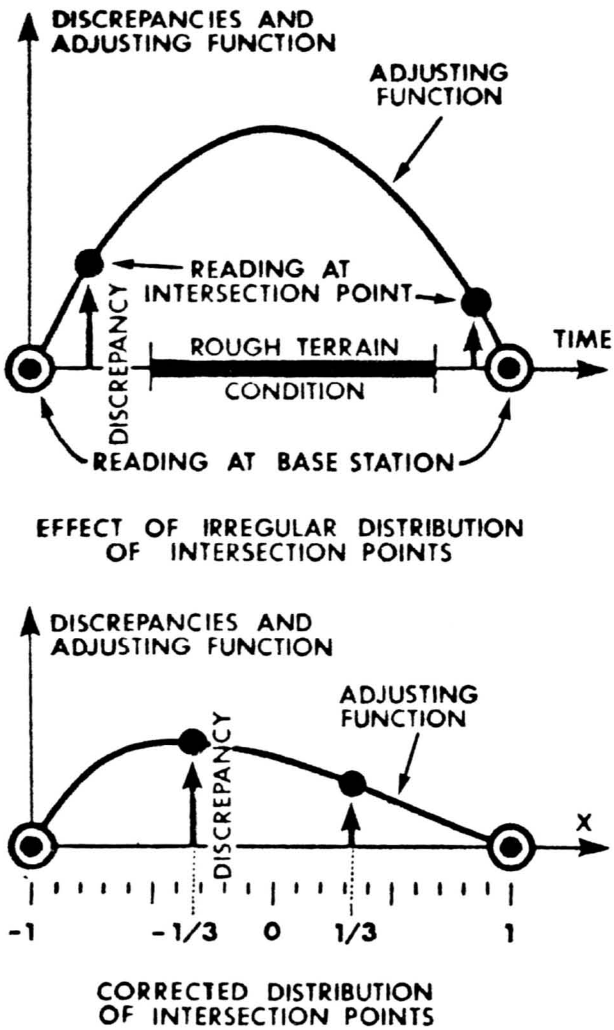


Fig. 6 Adjustment of measurements with extremely irregular distribution of intersection points

When the crew is returning to the fly camp, gravity readings of the same loop can be repeated. These points can then be processed like intersection points.

After updating the list of input data, it is recommended to define a file containing only the intersection points. These values are corrected iteratively by polynomials. The coefficients for each profile and for each polynomial term are accumulated and, after finishing the adjustment, these accumulated coefficients are applied to the original complete field data file. The last step is the final interpolation of residual discrepancies.

Gravity and magnetics were measured simultaneously and it was intended to adjust both sets of values likewise. However, the combined adjustment was not possible because a few intersection points were missing in the set of magnetometric data.

The drift of the gravity meter is a function of time. Therefore, the time is the x-coordinate for the adjustment, not the horizontal distance. If, due to delay during the measurements, the time intervals between intersection points are very irregular (fig. 6), it is recommended to divide the intervals between readings at intersection points into equidistant portions.

## 6. PRODUCTION AND ACCURACY

The crew operated in 2 to 4 parties with one gravity observer and one topographer each. A total number of 25,000 gravity stations was measured at 500 m spacings. The time required was 12.5 months, including time for establishing the base stations. The production of 1,000 profile kilometers per month in this area of generally difficult access is at least twice the production which could have been achieved for the same costs by the conventional method.

In the desert area, the loose sand impaired the levelling and consequently the accuracy of the measured values. In all other parts of the permits, very smooth contour lines at 0.2 mgal spacings indicate that the accuracy is at least as high as the results of measurements with the conventional strict drift control.

The computer costs for the adjustment are minimal compared to the costs of the field work. A minicomputer with 32 k, 16 bit words and with disk is sufficient for the execution of the program. If such a minicomputer is available in the survey area the Bouguer map can be continually updated during the survey.

## REFERENCES

Linsser, H., 1974, Adjustment of measurements affected by drift, Paper presented at the 44th Annual International Meeting of the S.E.G. in Dallas, Texas.

–, 1976, Definition of Functions to adjust gravimetric data, Paper presented at the 46th Annual International Meeting of the S.E.G. in Houston, Texas