Comprehensive Treatment of Terrain Corrections with Examples from Sheep Mountain, Wyoming

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SUMMARY

A comprehensive examination of terrain corrections, especially applicable to rugged topography but also relevant to areas of less relief where high precision is required, suggests modifications to the standard methods for treating the problem. Inner-zone corrections may be substantially improved by augmenting normal survey procedures to include selective in-field determination of the actual relief near the station. Both inner and intermediate zones may benefit by examining the slope of the topography (in addition to absolute relief) in its actual relationship to the station. Outer zones, frequently ignored altogether, should be incorporated. In the Sheep Mountain area, terrain corrections are improved by up to 4 mGal, and the reduced Bouguer anomalies are accordingly more reliable.

INTRODUCTION

In rugged topography, terrain corrections are the most important source of error in the reduced Bouguer anomalies; and even in relatively mild terrain, if high precision is required, proper treatment of terrain is mandatory. By considering the problem in terms of inner zones (0-230 m), intermediate zones (230- 8440 m), and outer zones (8440- 166700 m), we can better isolate the limitations of standard reduction techniques and demonstrate the importance of making improvements over standard reduction procedures.

This paper discusses the use of new field procedures and a new calculation algorithm and provides a comparison between standard corrections and those which result from the techniques described herein.

Examples are taken from Sheep Mountain, Wyoming, an area of very rugged topography. Available data include the National Cartographic Information Center (NCIC) fine grid, the NCIC coarse grid, and elevations actually surveyed in the field. Comparisons are made between the surveyed elevations and those interpolated at the same location from the NCIC-supplied fine grid, as well as between the terrain corrections which result from the two independent data sources.

DESCRIPTION OF TERRAIN

Inner-zone relief ranges between -325 and +331 feet for the subject area, the average of which is 31 feet. Figure 1 illustrates the relief for a representative sample of the stations, based on the field surveying.

Intermediate zone relief is shown in Figure 2, which is a plot of elevations for about 40 percent of the data. Because several of the elevations shown in Figure 2 are off line, a "stair-step" appearance results. However, the range of intermediate-zone relief of up to more than two thousand feet is clearly indicated.

Outer zone relief also ranges from zero to several thousand feet. Thus, the contributions from outer zones are significantly dependent on station elevations and cannot be ignored as is often the case in commercial exploration.

TOPOGRAPHIC SURVEYING

Although field surveying of the inner-zone topography can be time consuming and expensive, a strategy has been developed by which it can be justified. For areas like Sheep Mountain, inner-zone surveying cannot be avoided if accuracy is important. Figure 3 shows an idealized approach to determining relief in the field wherein two prism-rod locations are established for each of the four principal directions. The actual locations are adjusted in the field to coincide with changes in topographic slope. The number of prism-rod locations in moderate to rugged topography varied from three to fifteen.

The three coordinates (easting, northing, elevation) of each prism-rod location were stored in a data logger for downloading each evening to a field computer for in-field processing.

COMPARISON WITH NCIC FINE GRID

Elevations at all locations were independently determined from the NCIC fine grid {7 1/2 minute Digital Elevation Model (DEM) at an interval of 30 m} and compared with the surveyed elevations. Representative results are shown in Figure 4. A strong systematic difference at each station result from uncertainties within the NCIC grid, interpolation errors, and errors in absolute position. Because of the rugged terrain, small horizontal offsets produce systematic errors in elevation and relief.

Field surveying provides the most accurate determination of near-station relief, but unless a very expensive survey is contemplated, the DEM provides the best determination of terrain morphology. For most surveys in rugged topography, both are important and should be integrated. Modifications are needed to meet the requirements and available data of specific areas.

CALCULATION OF TERRAIN EFFECTS

The terrain-correction algorithm is the subject of another paper and is an important component toward obtaining more precision in the calculations for all zones from the station to zone O of the Hayford-Bowie system in regions of rugged topography. This can be accomplished by utilizing slope information as well as average compartment elevations. Errors related to the mass excesses and deficiencies of each compartment in comparison to the actual topography typically are not self cancelling but may produce over or under estimates of the effect depending on whether the average slope from the station to the compartment is positive (i.e., in the same direction) or negative (i. e., in the opposite direction) with respect to the slope within the compartment. Now that computer memory and power is relatively inexpensive, this problem can be economically approached providing an adequately fine terrain grid (DEM) is available.

DIFFERENCES IN INNER-ZONE TERRAIN CORRECTIONS

Figure 5 shows the near part of the inner-zone terrain correction calculations based both on the fine grid and the surveyed elevations. These do not include the outer part of the inner zones which are solely based on the fine grid. Both calculations incorporate topographic slope information. As seen in the figure, differences from this source *alone* can be several tenths of a milligal.

This study indicates three important considerations when making inner-zone terrain corrections in rugged topography: 1) acquiring additional information while in the field, 2) improve, by field calibration, the qualitative observer's field notes, and 3) incorporation of slope in the calculation.

INTERMEDIATE-ZONE TERRAIN CORRECTIONS

The NCIC fine grid was also employed for the intermediate zones. For a large number of stations, critical attention to the intermediate zones is important because of the large relief at a relatively close proximity to the station, as noted in Figure 2. Differences for all zones between the standard Hayford-Bowie (using the Krohn computer method) and the slope method employed at Sheep Mountain vary substantially and range up to four mGal. Although the larger differences correlate with the more severe cases of inner-zone relief discussed above, they always correlate with significant intermediate zone relief. The Sheep Mountain terrain data indicate improvements in the intermediate zones alone of up to three mGal. This study- utilizing the resulting fully reduced Bouguer anomalies- demonstrates the importance of incorporating slope as well as relief in the corrections.

OUTER-ZONE TERRAIN CORRECTIONS

Figure 6 shows the gravitational influence of the three outer zones of the Hayford-Bowie system as a function of elevation for stations in the Sheep Mountain area. Although fortunately a rare occurence, we do occasionally see terrain corrections for which earth curvature as applied to compartments has been neglected (e. g., Krohn, 1976). The principal reason for this neglect is itself, unfortunately, a strong negative, particularly in an area like Sheep Mountain: that curvature effects are not significant near the station where all too frequently terrain corrections are arbitrarily truncated. Figure 6 shows both the importance of including the outer zones and making sure that earth curvature is accounted for. The elevations shown on the horizontal axis cover the range of elevations in Sheep Mountain.

BULLARD B EARTH CURVATURE EFFECTS

Another frequently ignored correction is the Bullard B (Swick, 1942). Unlike the earth curvature effects discussed above, Bullard B is a function of station elevation alone (i. e., independent of the ruggedness of topography, except to the extent that steep horizontal terrain gradients create large differences in the B correction between adjacent stations). This correction is an adjustment to the simple Bouguer slab formula out to a distance of 166,700 m and recognizes that the earth is curved rather than flat. For elevations in the Sheep Mountain area, the differences in Bullard B corrections are generally a few tenths of a mGal.

REFERENCES

Krohn, D. H., 1976, Gravity terrain corrections using multiquadric equations: Geophysics, 41, 266-286.

Swick, C. H., 1942, Pendulum gravity measurements and isostatic reductions: Special Publication No. 232, U. S. Department of Commerce, Coast and Geodetic Survey.

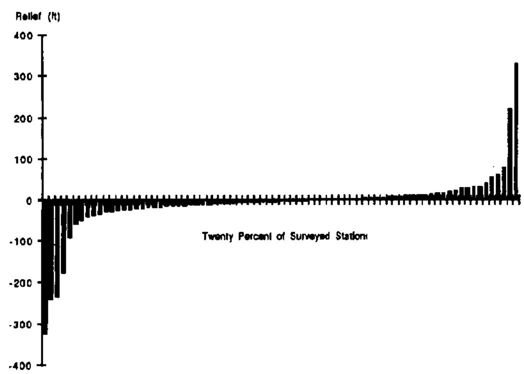

FIG. 1. Representative sample of topographic relief, Sheep Mountain.

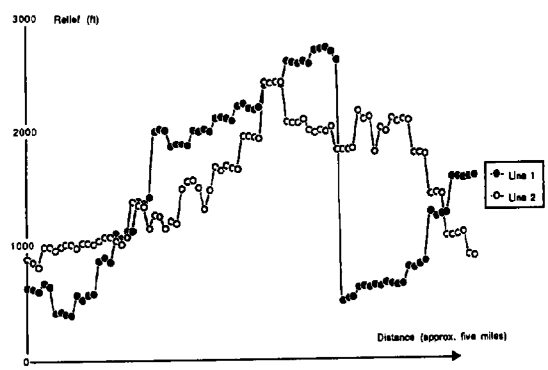

FIG. 2. Overall relief of intermediate zones, Sheep Mountains.

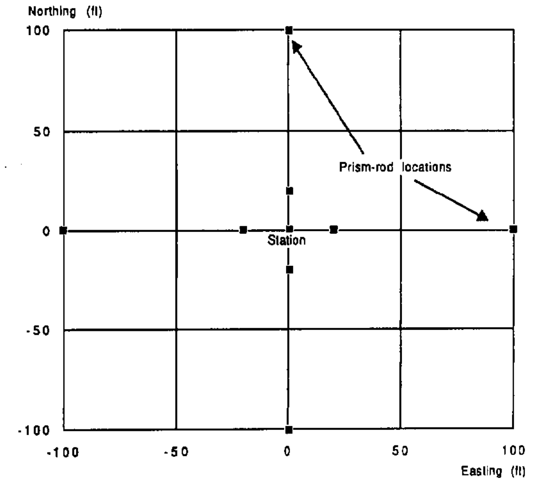

FIG. 3. Idealized plan for field determined relief.

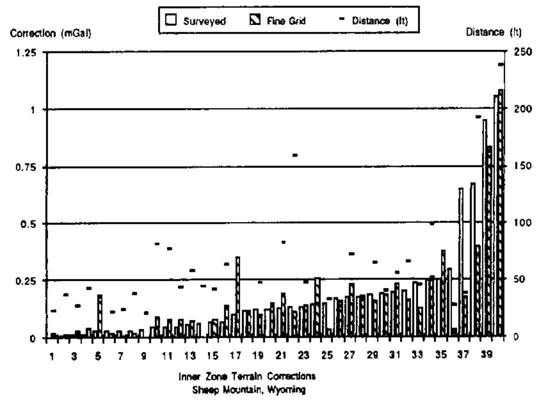

FIG. 5. Inner-zone terrain correction comparisons, Sheep Mountain.

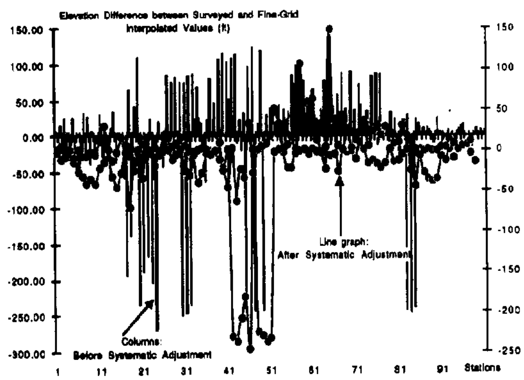

FIG. 4. Elevation differences, Sheep Mountain.

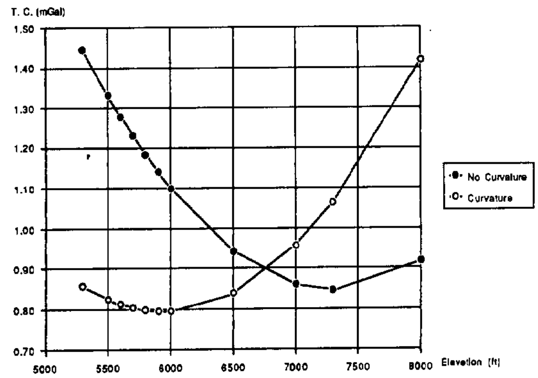

FIG. 6. Elevation dependence of zones M, N, and O.