

## An Optimized Gravity Terrain Correction Algorithm and Test Results from the Rio Tinto Valley, Spain

Ting-Fan Dai<sup>1</sup> and Greg M. Hollyer<sup>2</sup>

### Problem and Approach

The computer calculation of gravity terrain corrections from digital elevation models (DEMs) is a relatively routine task. The conventional approach has been to calculate the gravitational attraction at an observed location by summing the contribution from all DEM nodes. However, even with current high-powered computers, this task can be very time consuming, to the point where very accurate corrections are often not practical. To address this problem, currently available terrain correction algorithms use some sort of optimization strategy at the cost of accuracy.

This paper discusses an optimization method that provides a maximum of accuracy and performance for even very large data sets. The approach combines gravity terrain correction methods described by Kane (1962), Nagy (1966), with new grid-mesh interpolation, zoning and de-sampling techniques. Test results from an area of the Rio Tinto valley in Spain are used to illustrate accuracy and performance against a standard terrain correction algorithm from Geosoft.

### Terrain Correction Algorithm

The terrain correction algorithm described here can be run as either a one-step or two-step process. The choice of process depends on the accuracy required, data volume and operational efficiency (specifically, the need to add more stations and dynamically calculate terrain corrections as a survey progresses). Generally, the one-step process can be used to generate highly accurate results with high performance whereas the two-step process is optimized for large regional gravity surveys (for example, 100,000 or more stations) or ongoing surveys.

With the one-step process, the algorithm generates the terrain (regional plus local) corrections based on a usersupplied correction distance. With the two-step method (default), the process consists of calculating a one-time regional correction grid, and then calculating local corrections at each station with the same local correction distance and summing the regional and local correction at each station to obtain a total correction. Because the regional correction grid is only calculated once, this method is designed to save significant computational time for large data sets or surveys in which stations are being added dynamically.

<sup>1</sup> Geosoft Inc.

<sup>2</sup> GEM Systems Inc.

The calculation of the regional correction (beyond 1000 m) is historically very computationally expensive. We address this by calculating the regional terrain correction from a coarse regional Digital Elevation Model (DEM) over a more finely sampled local DEM model that covers a survey area. This produces a “regional correction grid” that represents terrain corrections beyond a local correction distance. Corrections at each station are obtained by extracting an interpolated milligal value from the regional correction grid and adding the local correction calculated from a local, more highly sampled DEM grid. The local correction distance is the same as the one used to calculating the regional correction grid beyond that distance.

To calculate local corrections, the local DEM data is “sampled” to a grid mesh centred on the station to be calculated. The correction is calculated based on near zone, intermediate zone and far zone contributions (Figures 1, 2 and 3). For more processing efficiency, the far zone calculation can be optimized by de-sampling the outer zone to a coarser averaged grid (i.e. by enlarging the size of each ring segment to 2x2 cells beyond 8 cells, and to 4x4 cells beyond 16 cells, and so on).

## Test Results, Rio Tinto River Valley, Spain

Data were obtained from a area of prospective exploration of the Pyrite Belt in southwestern Spain. In comparison with a variety of geophysical methods, the gravity method has proved to be the most effective in the Pyrite Belt, and has a very good record of discovery (McIntosh et al, 1999). Results from a study of 13 massive sulphides show a mean gravity anomaly (Complete Bouguer) of 1.20 milligals.

The dataset used in this study covers a portion of the Rio Tinto River, which lies approximately 40 km to the NW of the Las Cruces base metal deposit. This dataset was chosen as it represents fairly normal topographic conditions and typical geology within the Spanish section of the Pyrite Belt. Data included regional and local DTMs.

Three tests were performed to evaluate the optimized algorithm’s speed and computational accuracy. The first test used the two-step method with local correction distance = 90 m and outer distance = 2000 m. The second test used a one-step method with local correction distance = 2000 m and no regional correction grid generated. The third test used Geosoft’s Terrain correction programme (1996) — recognized in the industry as a standard benchmark for terrain correction accuracy and speed.

In the first test, we initially generated a regional terrain correction grid using the regional DEM grid of 45 m cell size as topographic data and the more highly sampled local DEM grid of 5 m cell size as station elevation data (as shown in Figure 4). The inner correction distance was 90 m (2x regional DEM cell size). The resulting regional terrain correction grid has the same regional coverage and 5 m grid cell size as the local DEM as shown in Figure 5. This calculation takes about 13 hours (for the total  $2400 \times 3000 = 7200000$  points in the grid calculated) on a Pentium 2-500 personal computer.

The second step was to obtain full terrain corrections at each station by extracting an interpolated value from the regional correction grid and adding the local correction calculated from a more highly sampled local DEM grid of 5 m cell size with the same local correction distance of 90 m.

The alternative the two-step full correction approach is to apply the one-step terrain correction using a local correction distance of 2000 m. The algorithm generates the full correction in one process without generating a regional correction grid.

## Results and Summary

As shown in Table 1, the results indicate that the one-step and two-step methods both produce results that compare well with the Geosoft Terrain (standard) result. More importantly, departures from this standard are well within the mean gravity anomaly (1.20 milligals) for massive sulphide deposits in this area — indicating that the target is detectable with either method.

Method	Mean value (mgal)	Std. Deviation (mgal)	% Change from Standard	Time (minutes)
Two-step (local correction distance = 90 m, outer distance = 2000 m)	0.7391	0.6790	3.8%	3 **
One-step (local correction distance = 2000 m with no regional correction)	0.7606	0.7035	0.8%	4
Standard. Terrain programme, 1996. (local correction distance = 90 m, outer distance = 2000 m)	0.7669	0.7153	N/A	106

**Table 1:**

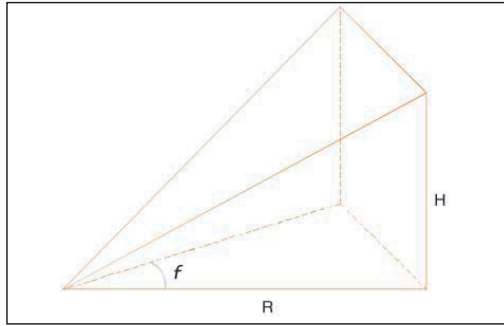
COMPARISON OF ACCURACY AND PERFORMANCE FOR TERRAIN CORRECTIONS FROM THREE METHODS. CORRECTIONS WERE DERIVED ON THE BASIS OF 2065 GRAVITY STATIONS AND A CORRECTION DISTANCE OF 2000 M. THE \*\* ANNOTATION INDICATES THAT AN ADDITIONAL COMPUTATIONAL STEP (I.E. ONE-TIME CALCULATION OF A REGIONAL CORRECTION GRID) WAS ALSO REQUIRED (13 HOURS).

Differences between the two-step and one-step method occur because the stations and local DEM points are not coincidental. In the two-step method, the regional correction value at each station is obtained by interpolation from the regional correction grid — based on the local DEM points. In the one-step method, exact locations are used.

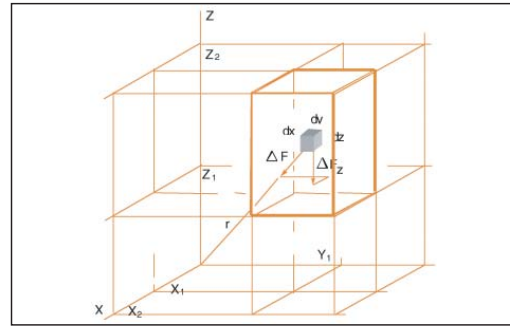
In summary, the test results on the optimized gravity terrain correction algorithm show that the method produces accurate and fast results as compared with Geosoft's benchmark Terrain programme (1996). Accuracy varies within 0.8 to 3.8 percent of results from this system and are well within the accuracy envelope for detecting the numerous known massive sulphides within the Iberian Pyrite Belt.

Performance from the one-step and two-step methods (for individual terrain corrections) is improved by at least 300 per cent over the standard programme and other terrain correction methods in both the speed of calculation and accuracy.

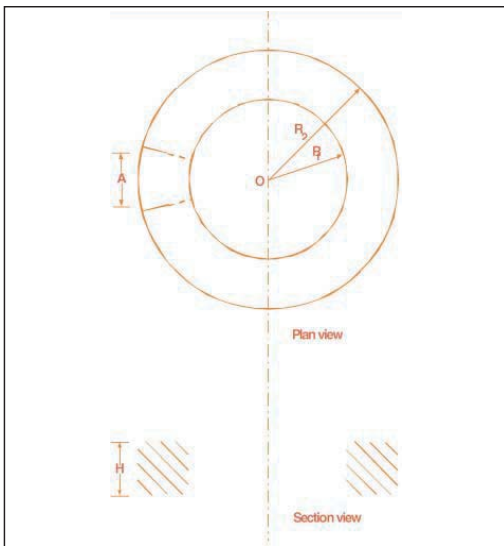
Depending on the data volume, survey requirements and accuracy needs, the optimized algorithm represents a new approach that overcomes a traditional limitation — balancing accuracy with high performance.



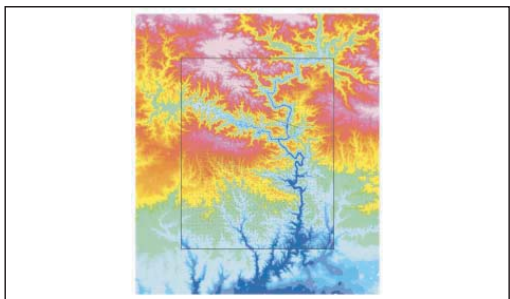
**Figure 1:**  
 IN THE NEAR ZONE (0 TO 1 CELLS FROM THE STATION), THE ALGORITHM SUMS THE EFFECTS OF FOUR SLOPING TRIANGULAR SECTIONS, WHICH DESCRIBE A SURFACE BETWEEN THE GRAVITY STATION AND THE ELEVATION AT EACH DIAGONAL CORNER.



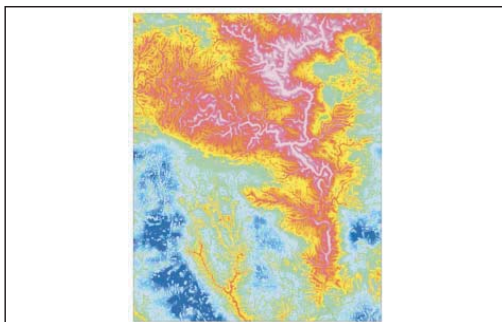
**Figure 2:**  
 IN THE INTERMEDIATE ZONE (1 TO 8 CELLS), THE TERRAIN EFFECT IS CALCULATED FOR EACH POINT USING THE FLAT TOPPED SQUARE PRISM APPROACH OF NAGY (1966).



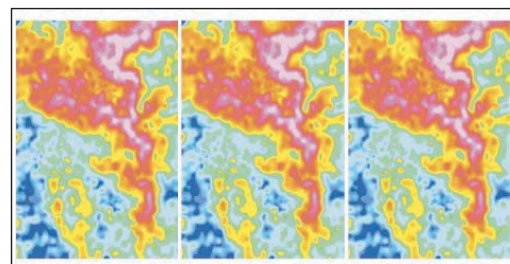
**Figure 3:**  
 IN THE FAR ZONE, (GREATER THAN 8 CELLS), THE TERRAIN EFFECT IS DERIVED BASED ON THE ANNULAR RING SEGMENT APPROXIMATION TO A SQUARE PRISM AS DESCRIBED BY KANE 1962).



**Figure 4.**  
 REGIONAL TERRAIN CORRECTION GRID (45 M CELL SIZE, AND DIMENSIONS 19 X 22 KM) WITH INSERT LOCAL DEM GRID (5M CELL SIZE, AND DIMENSIONS 12 X 15 KM). STATION LOCATIONS ARE SHOWN AS CIRCLES INSIDE THE LOCAL DEM GRID.



**Figure 5.**  
 REGIONAL TERRAIN CORRECTION GRID (5 M CELL SIZE AND DIMENSIONS 12 X 15 KM).



**Figure 6.**  
 TERRAIN CORRECTION GRIDS FROM TWO-STEP METHOD, ONE-STEP METHOD AND GEOSOFTE TERRAIN PROGRAMME. ALL GRIDS HAVE CELL SIZES 68 M AND DIMENSIONS 11 X 14 KM. RESULTS ARE VIRTUALLY IDENTICAL.

## References

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## Acknowledgements

The authors would like to sincerely thank Stephen McIntosh of Rio Tinto Exploration PTY and Ian McLeod of Geosoft Inc. for their support of this paper and review of results.