Coordinated by John Peirce

Advantages of close line spacing in airborne gravimetric surveys

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Line spacing for airborne gravity surveys is one of the factors that can influence the accuracy and resolution of the resultant gravity grids. Sander Geophysics has flown several recent surveys with close line spacing to increase the accuracy and resolution of gravity data. Close line spacing improves the data in several ways. Filtering between adjacent lines reduces data acquisition noise on the grid data. Closer line spacing allows using the flight data to compute a better digital elevation model; this can, in turn, be used to improve the gravity terrain corrections. Closely spaced adjacent lines can also be used for quality control and to aid in data processing.

Airborne gravity surveys have, in the past, been flown for regional mapping of the gravitational field, with survey line spacing of 3 km or more, because of the resolution limitations of most airborne gravity systems. Sander Geophysics has found that surveys flown with significantly closer line spacing (from 50 m to 1 km, depending on the survey objectives) can significantly improve the accuracy and resolution of the gravity data. We recently undertook a detailed study to investigate the quantitative improvement that can be realized by using such close line spacing. The results from this study make a compelling argument for closer line spacing in airborne gravity surveys.

In order to demonstrate the advantages of closer line spacing surveys we have evaluated some data flown with Sander Geophysics' AIRGrav system in 2001. The survey described here was a large AIRGrav survey flown in Western Canada over the Turner Valley area, a well known oil and gas producing region south of Calgary, Alberta (Figure 1). The survey area covers the foothills of the Rocky Mountains, and the general trend of the geology in the area is north-northwest/south-southeast. A total of 12 500 line-km of combined AIRGrav and magnetometer data were flown, using a fixed-wing aircraft, in less than five weeks, over very mountainous terrain. The AIRGrav system is relatively unaffected by turbulence, so surveying could continue under normal survey flying conditions. The survey flight lines had a line spacing of 250 m for the east-west lines and 1000 m for the north-south lines. To simulate the effect of wider line spacing, subsets of the data were processed with 500 × 2000 m line spacing, 1000 × 4000 m line spacing, and 3000 × 12 000 m line spacing (Figure 2).

Example data. Figure 2a, the Bouguer gravity calculated using 250 m line spacing, represents a good estimation of the gravity in the area. The linear anomalies over Turner Valley Field, and to the west, are 1-2 mGal in amplitude, and represent thrusted carbonate units in the sedimentary section. Figure 2b is the same area with 500 m line spacing data, Figure 2c is calculated with 1000 m line spacing and Figure 2d uses 3000 m line spacing data. In each case, as the line spacing increases, there is a corresponding increase in the noise level of the data, and a decrease in the resolution of the resultant maps, which tend to obscure the geologic signal in Figure 2a. Note that we have kept the same filter length for the different line spacing examples. This shows the increase in the noise level for the increasing line spacing. In Figure 3, a longer filter was used on the 3000 m line spacing data to show the data set with a more reasonable noise level. The resolution has been noticeably decreased. This means that in comparison to the 250 m line spacing data, some geologically significant features, like the Turner Valley oil and gas field shown on the map, are filtered out on the wider line spacing data.

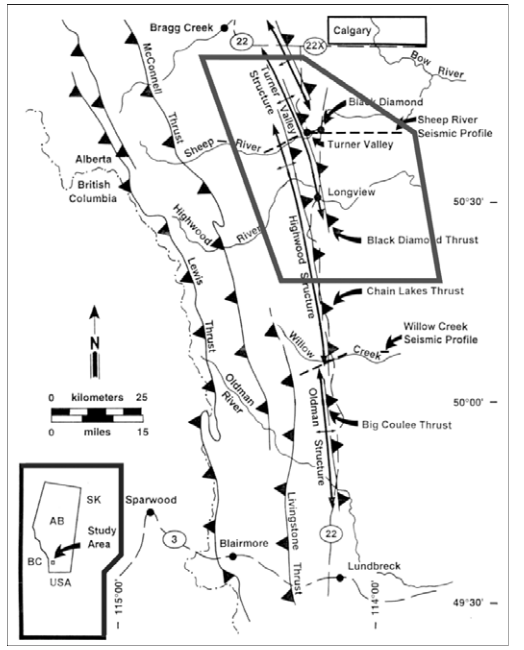

Figure 1. Map of the survey area (outlined in gray) south of Calgary, Canada. The Turner Valley structure trends NNW-SSE in the northern half of the survey area.

Figure 4 is a graph of the increase in noise level with increased line spacing, using the 250 m line spacing data as a standard. The x-axis is the filter length used on the grid data. The y-axis is the standard deviation of the difference between the wider line spacing grid and the 250 m line spacing grid. The lower (black) line is from the 500 m data, the middle (red) line is from the 1000 m data, and the upper (green) line is from the 3000 m data. Using a 2.2 km half wavelength filter, the rms noise level in the 500 m data is 0.5 mGal higher than for the 250 m data. The 1000 m data is 0.7 mGal higher and the 3000 m data is 1.55 mGal higher. As an example, an rms noise level of 1.55 mGal could result in peak-to-peak noise of over 4 mGal on the grid data, more than would be acceptable for many geologic applications. The noise level can be reduced by increasing filter lengths; however, this will result in the

Editor's note: The Meter Reader is a regular column in TLE, *coordinated by John Peirce, that seeks to highlight new ideas in geophysical fields besides seismic—particularly gravity, magnetics, and electromagnetics. If you have a short contribution on these topics that is written in the relatively informal but informative style of* TLE, *please submit it to Dean Clark, editor of* TLE *in Tulsa, or to John Peirce, at GEDCO in Calgary. This month's article is a discussion of some new ideas on the most effective way to design airborne gravity surveys, which is a logical sequel to several earlier articles on different airborne gravity systems and the resolution each can achieve. The ideas expressed in this paper are not yet widely accepted, so alternate opinions on this topic are most welcome!*

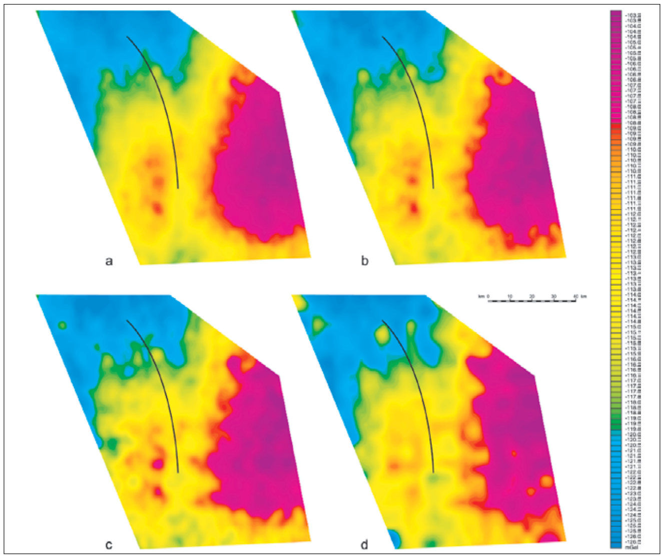

Figure 2. *Plots of terrain corrected Bouguer gravity grids calculated using various line spacing, with the Turner Valley structure indicated by the curved black line. All four grids have a 1.7 km half wavelength low-pass filter applied. (a) The original 250 × 1000 m line spacing; (b) 500 × 2000 m line spacing; (c) 1000 × 4000 m line spacing; and (d) 3000 × 12 000 m line spacing.*

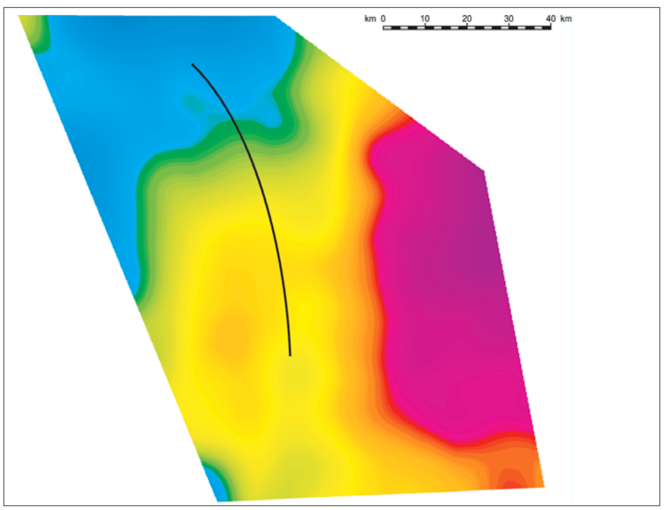

Figure 3. *The 3000 × 12 000 m line spacing data filtered with a 2.8 km half wavelength low-pass filter to reduce the noise level. Color bar is the same as used in Figure 2.*

attenuation, and even elimination of some of the geologic signal of interest.

Advantages of close line spacing. The advantages of closer line spacing are described below. Points 1 and 2 are the main advantages, while points 3 and 4 are additional benefits.

1) Lower noise levels on the gravity data. The gravity grids are filtered to average the noise on adjacent lines, in a manner analogous to stacking of seismic data. Closer line spacing results in more data per unit area, and it is possible to take advantage of the averaging effect to reduce noise. The noise level increases significantly for wider line spacing: for line spacing of 1 km the noise would be twice the noise of 250 m line spacing data.

2) Better terrain corrections. Available digital elevation models (DEMs) in most areas are not sufficiently accurate for gravity terrain corrections. Terrain models are calculated by subtracting the aircraft radar altimeter data from the aircraft GPS heights. At wider line spacing, significant terrain features could be missed. A 50 m error in the DEM will cause a 5 mGal

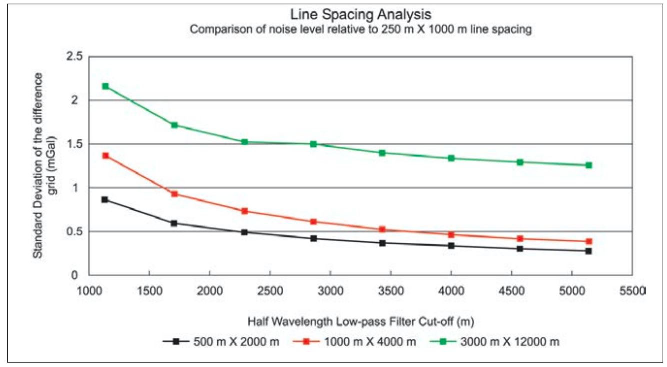

Figure 4. *Graph of noise versus filter length for the various line spacing choices, using the 250 m line spacing data as a standard. Lower (black) line is for 500 × 2000 m line spacing; middle (red) line is for 1000 × 4000 m; and upper (green) line is for 3000 × 12 000 m.*

error in the final gravity data, which would significantly distort the gravity data. The exact effect is dependent on the terrain, but a 100 m (10 mGal) error is possible if the line spacing is too wide. The more mountainous the area, and the smaller the geologic gravity signal, the more significant the terrain correction effect.

3) Better data interpretation. For a survey flown with wider line spacing a much longer filter on the data would be required, leaving the data with significantly lower resolution. In addition, much of the interpretation of the data is based on examining the shape of anomalies, which is impossible if the shape of an anomaly has been altered by heavy filtering, or by excessive noise levels. This would make the interpretation process much more subjective and qualitative.

4) Better quality control and better identification of problems during data processing. The processing stream used by Sander Geophysics relies on the comparison of adjacent lines to determine what is real and what is noise. This comparison is used for quality control, to indicate which lines require additional processing, and to indicate when a line has been improved.

Conclusions. In summary, closer line spacing results in better quality airborne gravity data, because: (1) the data are averaged in a manner similar to weighted average stacking of seismic data and closer lines provide more data to average, which results in less noise; and (2) the terrain corrections are more accurate because the survey system is able to measure the terrain with a higher resolution. The end result of closer line spacing is data with lower noise levels and higher resolution, which can be more accurately modeled and interpreted. In addition, there is increased opportunity for quality control and for more sophisticated data processing. The additional kilometers required to reduce the line spacing can be acquired economically by utilizing a robust gravimeter that can be flown efficiently.

Suggested reading. "Measurement of noise in airborne gravity data using even and odd grids" by Sander et al. (*First Break*, 2002). "Experiences with AIRGrav: Results from a New Airborne Gravimeter" by Ferguson and Hammada (GGG, 2000). "AIRGrav results: a comparison of airborne gravity data with GSC test site data" by Argyle et al. (*TLE*, 2000). "Turner Valley, Canada—A case history in contemporary airborne gravity" by Peirce et al. (EAGE 2002 Meeting). TLE

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