

Turner Valley, Canada - A Case History in Contemporary Airborne Gravity

J. W. PEIRCE, S. SANDER, R. A. CHARTERS, AND V. LAVOIE

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Abstract

In the summer of 2001, GEDCO and Sander Geophysics (SGL) carried out an airborne gravity survey using Sander's AIRGrav system in the overthrust belt in the Turner Valley area near Calgary, Alberta. The final results image all of the structures known from older ground surveys and reveal more complex details. This comparison demonstrates the exploration value of high quality airborne gravity surveys flown in severe foothills environments.

Geological Setting

The Turner Valley region is a well-established area for oil and gas production and was the site of the first Alberta oil boom in the 1920's. New discoveries are still being drilled in the structure and in sub-thrust plays where accurate depth mapping from seismic data is a challenge. The principal producing zones are from porous Mississippian aged carbonate rocks carried in overthrust structures. Figure 1 shows the location of the survey and a seismic section across the Highwood and Turner Valley structures (MacKay, 1996). The average density of clastic rocks above the carbonates is about 2.5 g/cc, whereas the average density of the carbonates is about 2.7 g/cc. This contrast of about 0.2 g/cc provides sufficient signal to map the thrust structures provided that they are not too deep relative to the size and complexity of the structures. In the Turner Valley area, the top of the primary producing reservoirs is about 1500 m in depth, but the structural culmination continues to the surface.

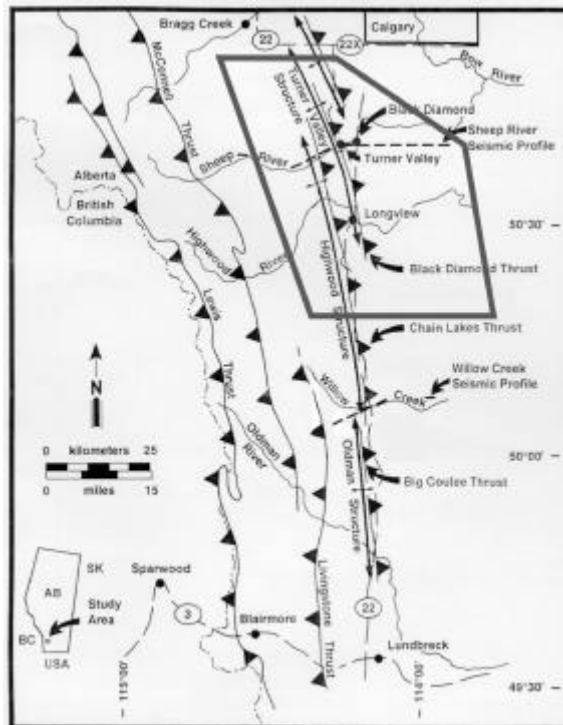


Figure 1a - Index Map showing polygonal area of airborne gravity survey. The Sheep River seismic profile is the seismic line in Figure 1b. (after MacKay, 1996).

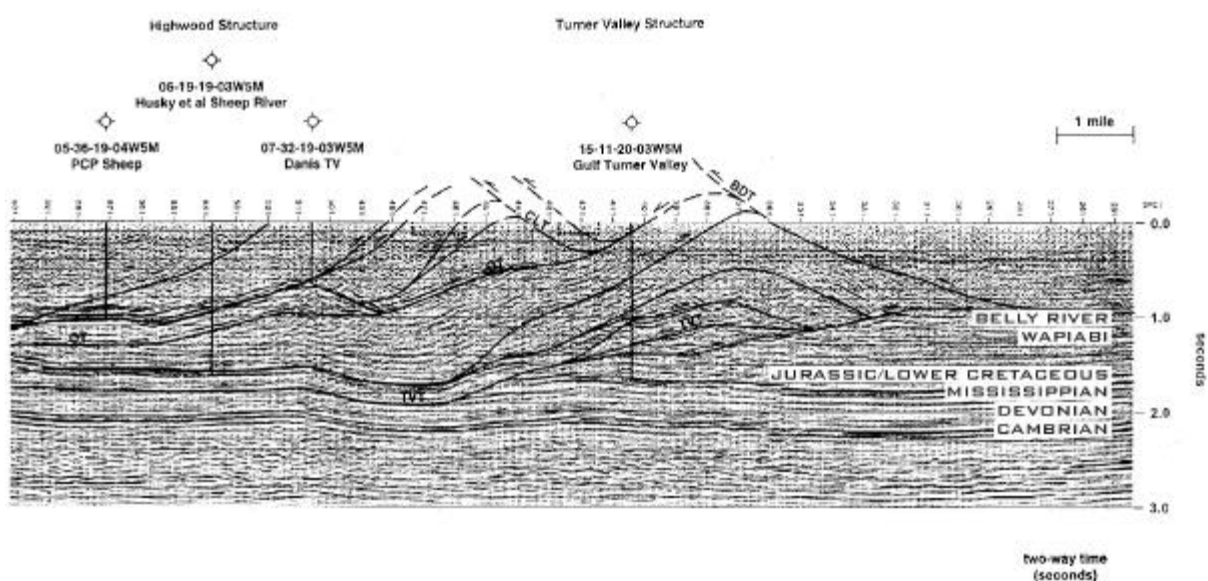


Figure 1b - Sheep River seismic profile. West is to the left. TVT is the blind Turner Valley thrust, carrying Miss. Limestone, which is the reservoir. BDT is the Black Diamond Thrust forming the upper surface of the triangle zone. OT is the blind Outwest thrust that merges with the Chain Lakes Thrust (CLT) (after MacKay, 1996).

Gravity System and Survey Parameters

Sander's AIRGrav system is a new instrument designed and built for airborne gravity acquisition. The sensor is mounted on a gyro-stabilized platform and measures the gravity at 128 Hz – resampled down to 2 Hz for processing. State of the art differential GPS processing, which measures the instantaneous accelerations of the airplane, is an essential part of data processing. The final data quality is dependent on the quality of the digital elevation model (DEM) used for terrain corrections. In this case we used the high-density, 50 m resolution DEM from the Alberta Government for gravity reduction to complete Bouguer values, including Fourier based outer zone terrain corrections. The Turner Valley survey was flown with E/W traverse line spacing of 250 m and N/S control line spacing of 1000 m on a drape surface. Ground clearance over the Turner Valley Field was about 500 m. The tight line spacing is essential for good leveling and repeated sampling of the gravity field at the frequencies of interest.

Processing the data to Bouguer values briefly consists of the following:

- The accelerations of the aircraft measured by GPS, are subtracted from accelerations measured by the gravity instrument to remove the effects of aircraft motion from the gravity signal. The remaining noise at two Hz is about 8000 mgals, is still large compared to a total geological signal of about 200 mgals and target anomalies of about 1 - 5 mgals.

- Eotvos, free-air, Bouguer, earth curvature, and outer terrain corrections are applied to reduce the gravity to complete Bouguer values.
- The next step is to apply a 28 sec filter to mostly eliminate remaining noise spikes.
- The line-filtered data are then leveled and gridded.
- Spatial filter tests are performed and appropriate low pass filters are chosen to emphasize geological structures of interest. For the Turner Valley survey, we chose low pass filters of 4300 m, 5300 m and 6700 m.

Comparison of Airborne Gravity Survey to Older Ground Gravity Surveys

Figure 2 shows a side-by-side comparison of the complete Bouguer airborne gravity after upward continuation of 500 m and a low pass filter of 5300 m. This approach yields a direct comparison between the ground and air data. Note the high degree of similarity between the older ground data (1950-1975 vintage) and the new airborne gravity survey. Total correlation is not to be expected as the ground data are relatively sparse and not evenly distributed, and there are differences in some of the data reduction values which we cannot recompute for the ground data because many of the principal facts are no longer available. The airborne data are much more densely sampled, with even coverage over the whole area.

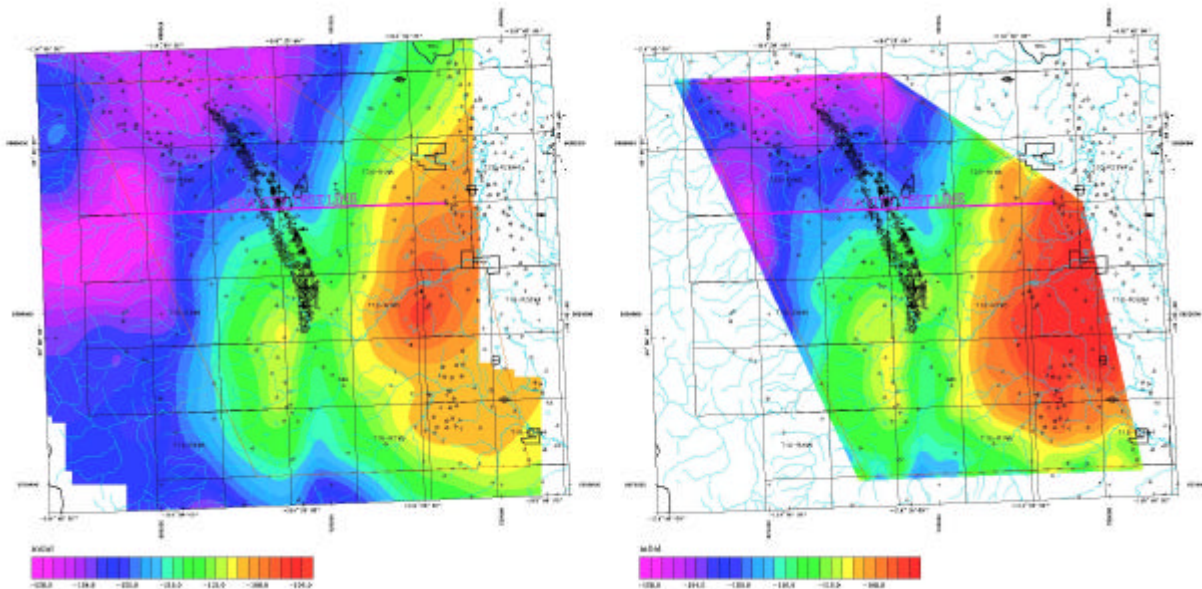


Figure 2 - Complete Bouguer Gravity. The left image is based on older ground gravity data. The data have been upward continued 500 m and filtered with a 5300 low pass filter to match the airborne parameters as closely as possible. The right image is the complete Bouguer gravity field from the airborne survey. The regional slope of the field reflects the isostatic effect of the Rocky Mountains, just west of the survey area. Well control is shown. The rectangular grid shows townships, which are 10 km x 10 km in size. Drainage is in blue.

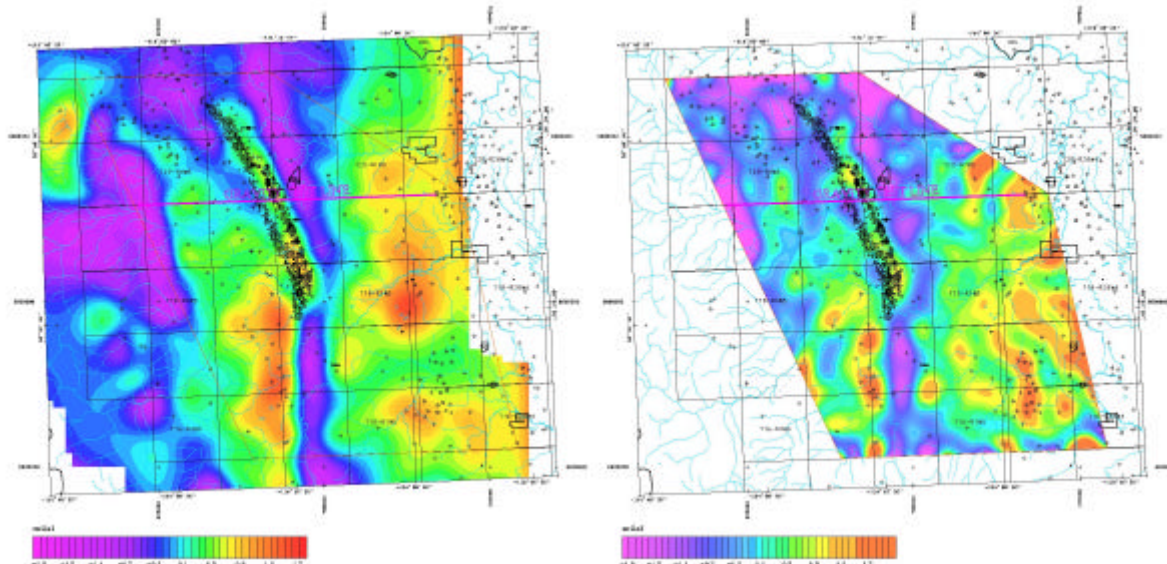


Figure 3 - First Vertical Derivative (1VD) of complete Bouguer Gravity. The left image is the 1VD of the ground gravity data in Fig. 2. The right image is the 1VD of the airborne gravity in Fig. 2. Most of the differences in these maps reflect the additional detail derived from the uniform sampling of the airborne gravity survey.

Figure 3 shows the first vertical derivatives of the ground and airborne data. The first vertical derivative tends to highlight zones of strong density contrasts and also amplifies the higher frequency components of the signal. The strong positive anomaly oriented NW/SE across the northern center of the map is coincident with established oil and gas production. If one “snaps” the airborne data to the ground station locations and uses only those points for gridding, the apparent correlation between the data sets is much higher. Thus most differences between these images are the result of the more complete sampling of the gravity field in the airborne survey as compared to the uneven distribution of the ground data. Some of the finer structures in the first vertical derivative airborne map correspond to density contrasts in the clastic section in the near surface, such as the contrast between the relatively dense Belly River sandstone and less dense surrounding shales.

Conclusions

The Turner Valley survey demonstrates that airborne gravity can be acquired in a severe foothills environment and obtain complete Bouguer data that contains interpretable signal at half-wavelength resolution of 2500 m and longer. This resolution is adequate for many exploration objectives in foothills and other settings around the world. The high-resolution aeromagnetic data collected simultaneously with the gravity data show many high frequency features that correlate with mapped surface structures. In poorly mapped areas, the magnetic data can sometimes provide detailed control for geological mapping. Transitions from one structural culmination to another, such as the transition from the Turner Valley structure to the Highwood structure shown above, are particularly well suited to being mapped with airborne techniques.

The airborne gravity technique provides the opportunity for more integrated approach to exploration. For example, airborne gravity and magnetic maps can be used together to post land for bidding or to plan new seismic programmes. Simultaneous modeling of existing seismic lines, well control (if any) and the potential field data, using profiles extracted from the map grids, can constrain a seismic interpretation and more accurately identify the leading edge of the carbonates in a thrust sheet. The geophysical map view provided by airborne data frequently can identify faulting that cuts across structures and breaks up the continuity of reservoirs.

References

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Bio information:

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Dr. John W. Peirce, jpeirce@gedco.com,
GEDCO - Geophysical Exploration & Development Corporation; (403) 262-5835;
1200, 815 – 8th Avenue SW, Calgary, AB, T2P 3P2

Mr. Stephan Sander, stephans@sgl.com
Sander Geophysics Limited; (613) 521-9626;
260 Hunt Club Road, Ottawa, ON, K1V 1C1

Mr. Robert A. Charters, charters@gedco.com,
GEDCO - Geophysical Exploration & Development Corporation; (403) 303-8679;
1200, 815 – 8th Avenue SW, Calgary, AB, T2P 3P2

Ms. Veronique Lavoie, vlavoie@sgl.com
Sander Geophysics Limited; (613) 521-9626;
260 Hunt Club Road, Ottawa, ON, K1V 1C1