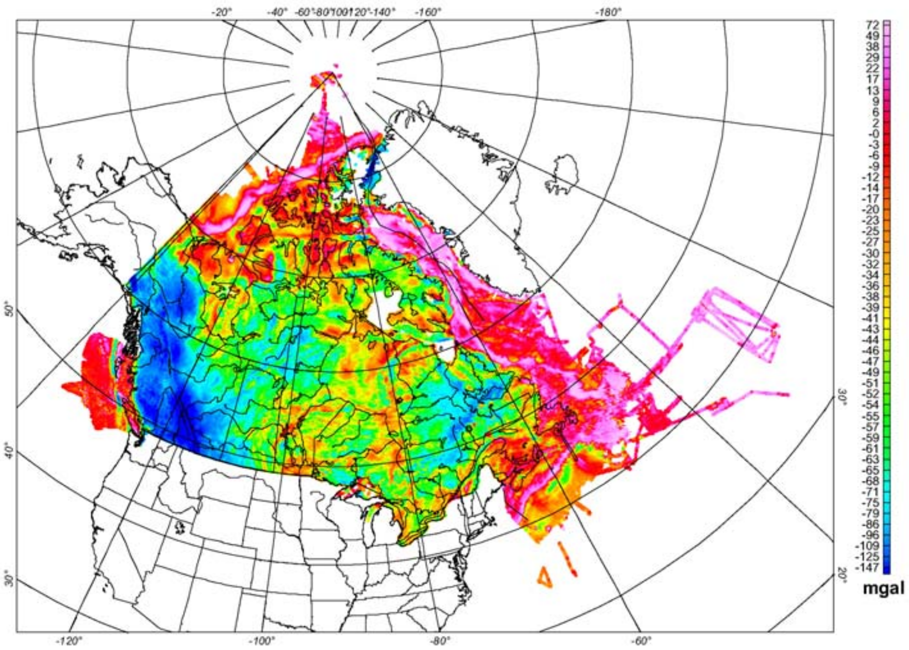
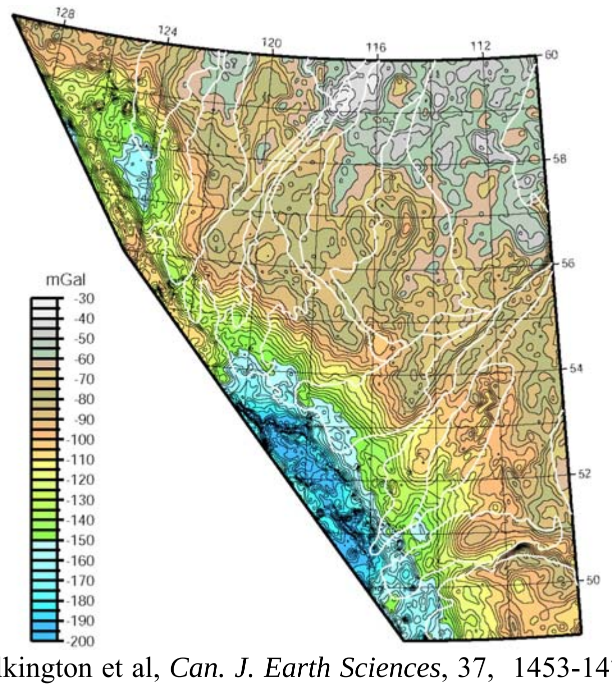
Geophysics 224
B5 : Interpretation of gravity data

B5.1 Bouguer anomaly maps

● Once the Free Air and Bouguer corrections have been made, the Bouguer anomaly should contain information about the subsurface density alone. The effect of latitude and elevation should have been removed. A map of the Bouguer anomaly gives a good impression of subsurface density. **Low (negative) values** of Bouguer anomaly indicate **lower density** beneath the measurement point. **High (positive) values** of Bouguer anomaly indicate **higher density** beneath the measurement point.





From M. Pilkington et al, *Can. J. Earth Sciences*, 37, 1453-1471, 2000. Note decrease in Bouguer gravity anomaly towards the southwest. This is due to (a) thickening of the Alberta Basin and (b) thicker crust beneath Rocky Mountains.

B.5.2 Regional trends and residuals

- Measurements of gravity at the Earth's surface depend on Earth structures ranging from spatial scales of 1m to 10,000 km.

- **Deeper** density structures produce gravity anomalies with a **long** spatial wavelength. For a body such as a sphere, this would be expressed as a large value for the half-width ($x_{½}$) .

- Similarly **shallow** density structures produce gravity anomalies with **short** spatial wavelengths or small half-widths.

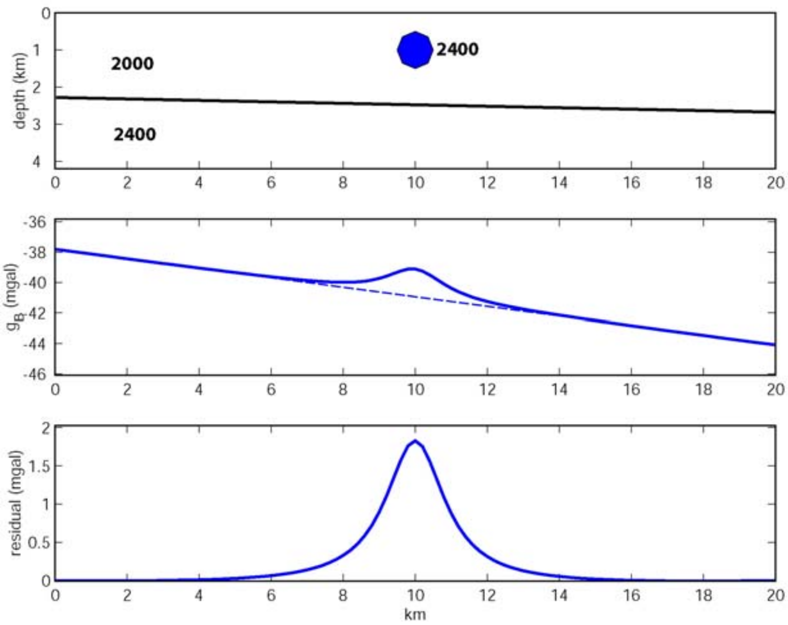
- Often the longer wavelength effects are called **regional trends**, while the shorter wavelength features are called **residuals** or **anomalies**. The distinction between the two is somewhat arbitrary.

- In shallow gravity exploration, we are generally interested in the short wavelength gravity anomalies. The long wavelength regional trends can make it difficult to analyse the short wavelength residuals. Thus we need to find a way to remove the regional trends and emphasize the anomaly more clearly. In other studies the regional trend could be what we wish to study (one person's noise is another persons signal!)

- To emphasize shallow structure, the regional trend can be computed and then subtracted from the measured Bouguer anomaly data. However care is needed not to eliminate useful data during this process.

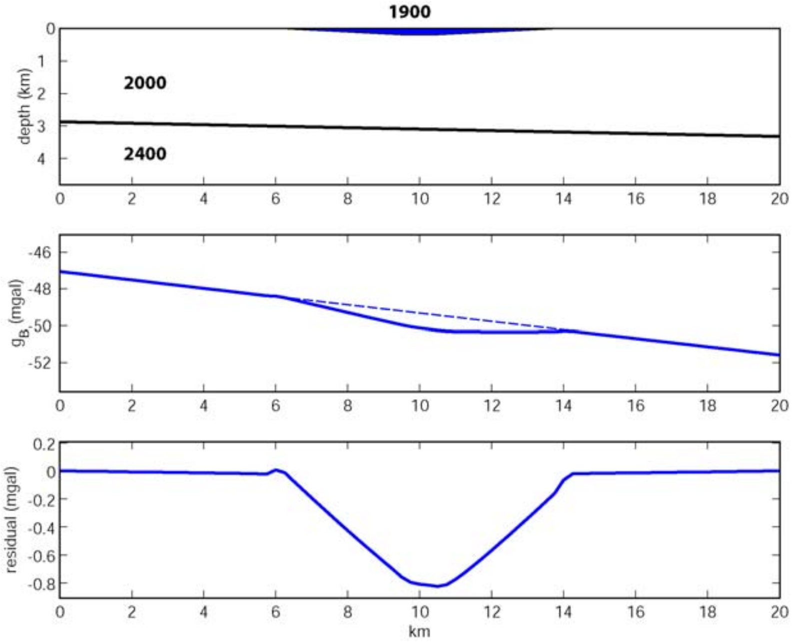
- Sometimes the regional trend can be approximated by a **straight line**. In other case it should be approximated with a **more complex** mathematical form.

- **Example 1** : This shows two density structures (a) higher density bedrock that dips to the right and which produces a slow decrease in g_B from left to right. (b) a shallow buried cylinder. It is difficult to determine the half-width of the anomaly due to the cylinder in the presence of the linear regional trend.

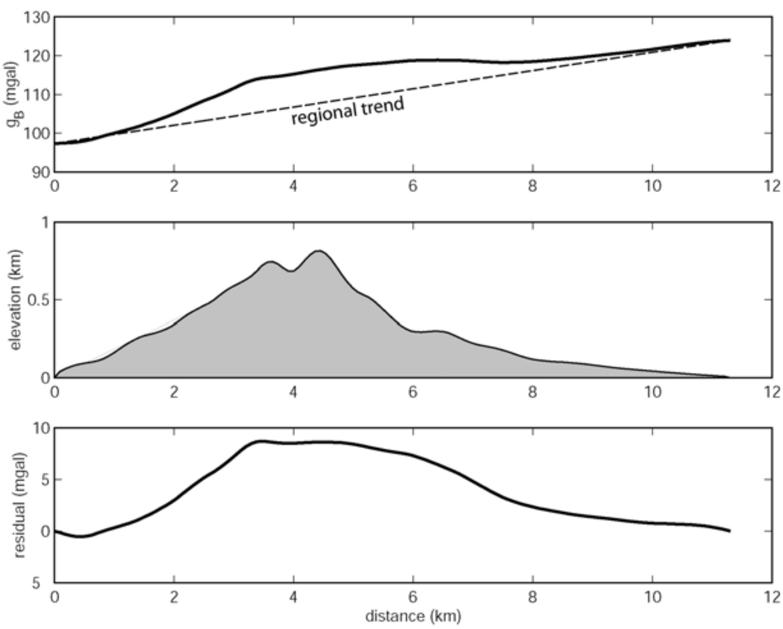


The dotted line denotes the **regional trend**, and is obtained by finding the best-fitting straight line to the data. When the regional trend is subtracted from g_B the anomaly of the cylinder is much easier to interpret.

● **Example 2**: This features the same dipping bedrock layer and a shallow, low density river channel. Again, removal of the regional trend makes the effect of the river channel much clearer.



● **Example 3**: Real gravity data collected in a geothermal exploration project in the Philippines (courtesy of PNOC). These gravity data were analysed in Lab 1 after the regional trend was removed.



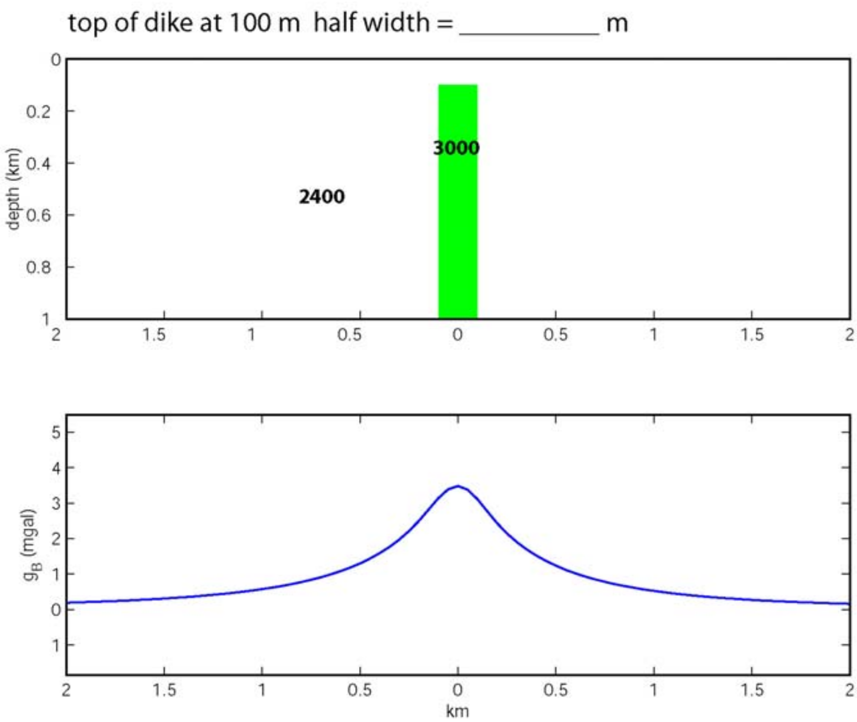
● The above examples are for a single profile. However, regional trends are often removed from Bouguer anomaly data defined on a grid (i.e. a Bouguer anomaly map).

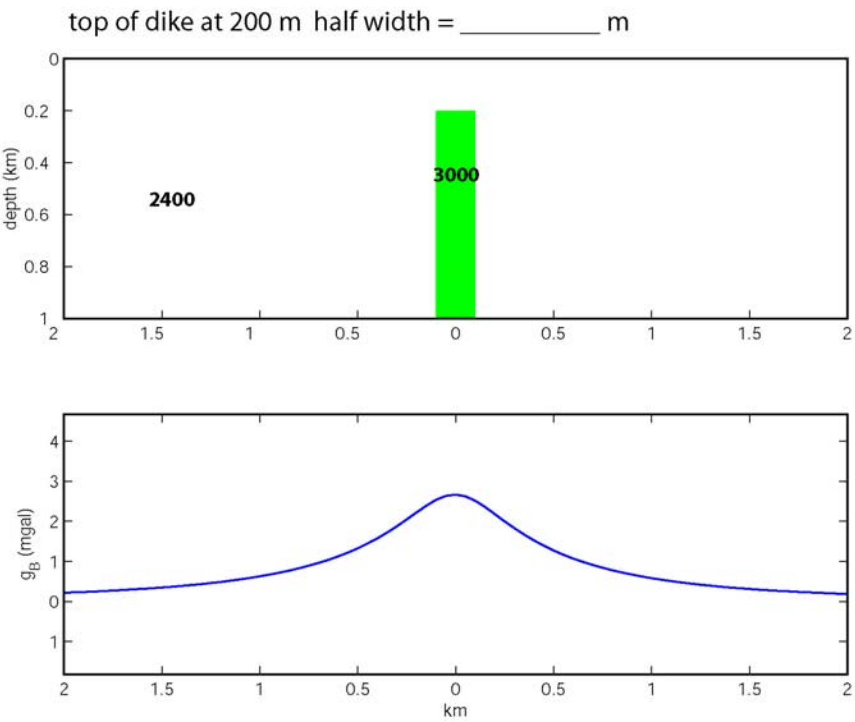
● Must be careful not to remove useful data when removing regional trends from the data.

B.5.3 Half width techniques

- For a number of shapes the width of the anomaly can give an approximate depth to the density anomaly. *e.g.* sphere : depth of centre = half-width
  cylinder : depth of centre = 1.304 *x* half-width

- However in some cases this approach can be very wrong!
  Dike model with MATLAB program, Anticline (*Geophysics*, **12**, 43, 1947)





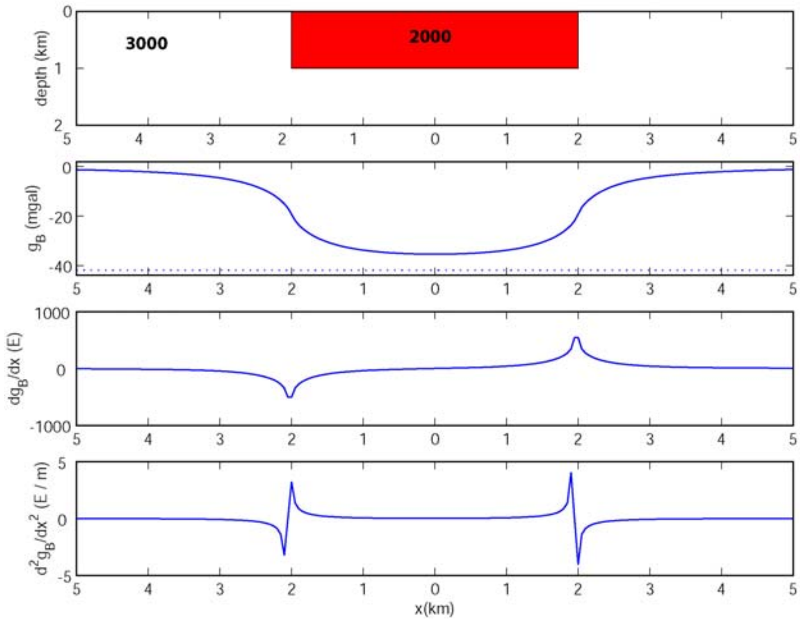
B.5.4 Two-dimensional computer modelling

● This allows the user to handle a more realistic density model. The data is usually fit with a trial and error approach. This is illustrated with the simple MATLAB program used in Laboratory 2 to model a couple of real datasets.

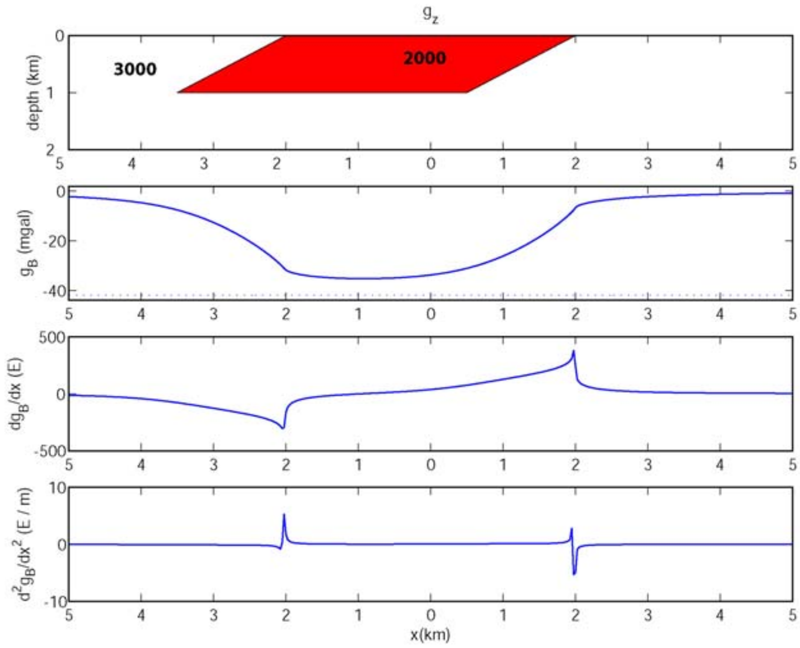
B.5.5 Horizontal derivatives of gravity

●Taking the horizontal derivatives of the Bouguer anomaly emphasizes **changes** in the horizontal gradient. This is effectively another way of removing (or suppressing) the regional trends in the data.

● Consider the application to the basin example shown below. The gradient is very effective at defining the edge of the basin. The unit E is the Eotvos. 1 E = 10^{-9} s^{-2}

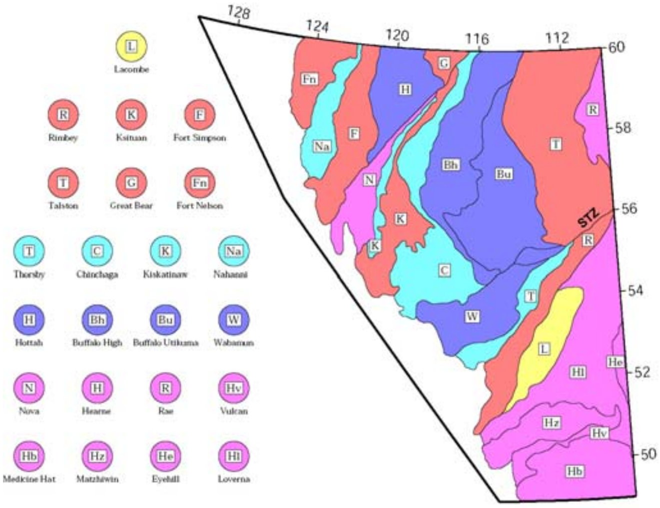


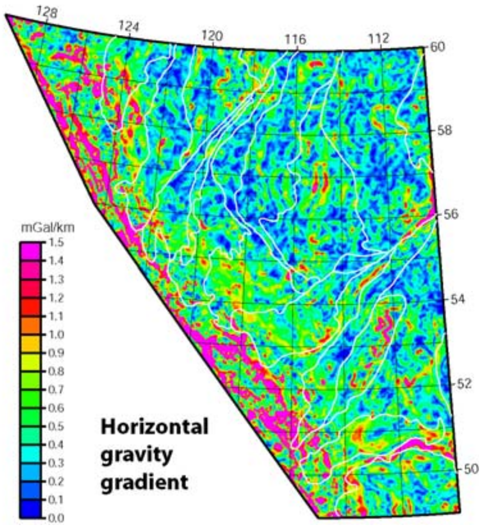
● In the example below, note that the second derivative has a different sign depending on the geometry of the edge of the basin..



Gravity gradients : Alberta basement

The primary domains of basement geology in Alberta are shown on the left. Note that the several domain boundaries are coincident with high values of the horizontal gravity gradient (e.g. Vulcan structure in Southern Alberta and Snowbird Tectonic Zone). These variations are clearer than in the Bouguer anomaly map shown earlier in this handout.





Gravity gradients : Chicxulub Impact Crater, Mexico

The horizontal gradients of the Bouguer gravity anomaly data from the Chicxulub impact structure defines the edges of the structure very clearly. Data from Alan Hildebrand, University of Calgary. Noise in field data can make this procedure unstable, so smoothing may be needed.