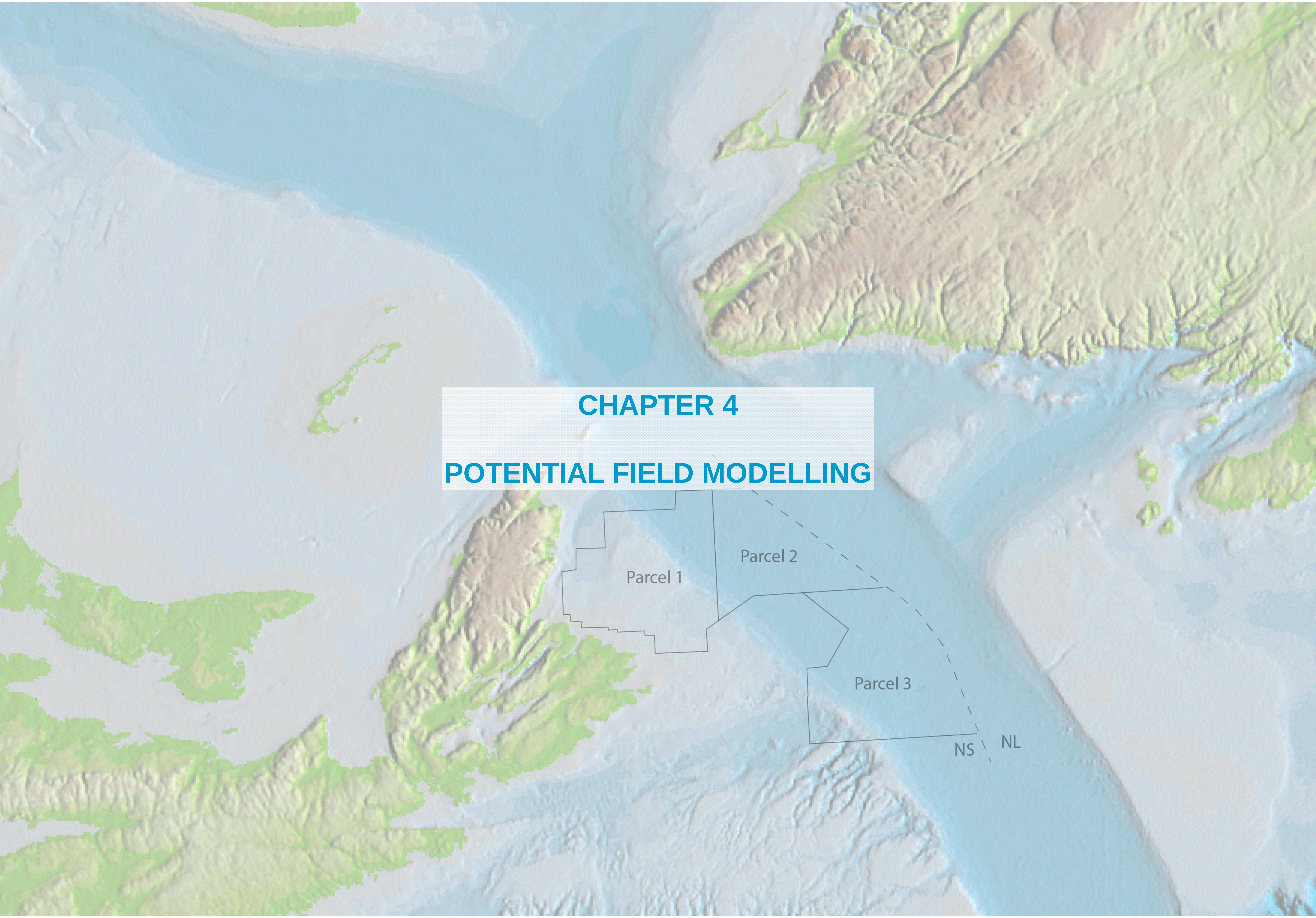
CHAPTER 4

POTENTIAL FIELD MODELLING



POTENTIAL FIELD MODELLING

The reference dataset used for the potential field modelling is the Gravity anomaly map and Magnetic anomaly map of the Atlantic region of Canada (Jobin et al., 2017).

The gravity correction in Bouguer on land and free-air at sea.

Regional magnetic and gravity map patterns, combined with modeling of magnetic and gravity data presented in this Atlas, are used to develop a better understanding of the major tectonic elements in the New England Appalachians region presented in Figure 2.

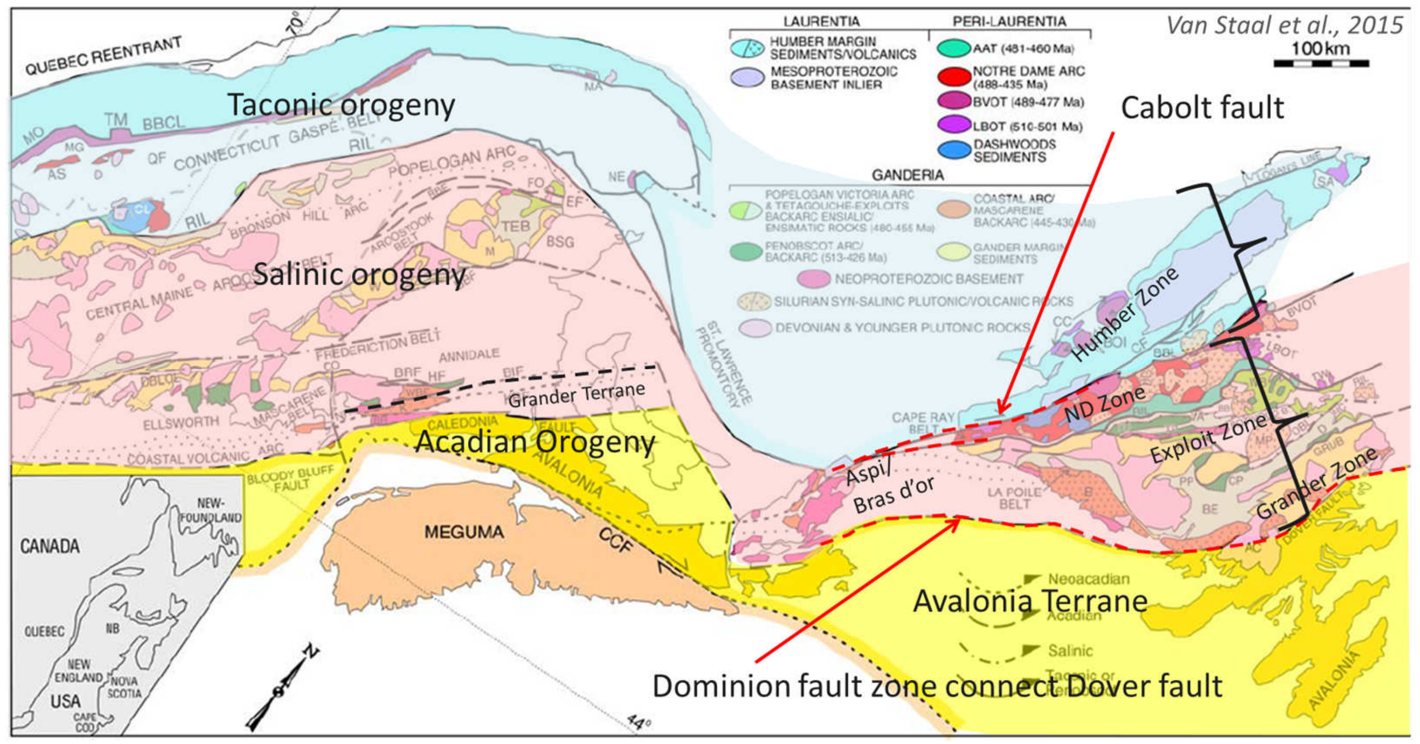
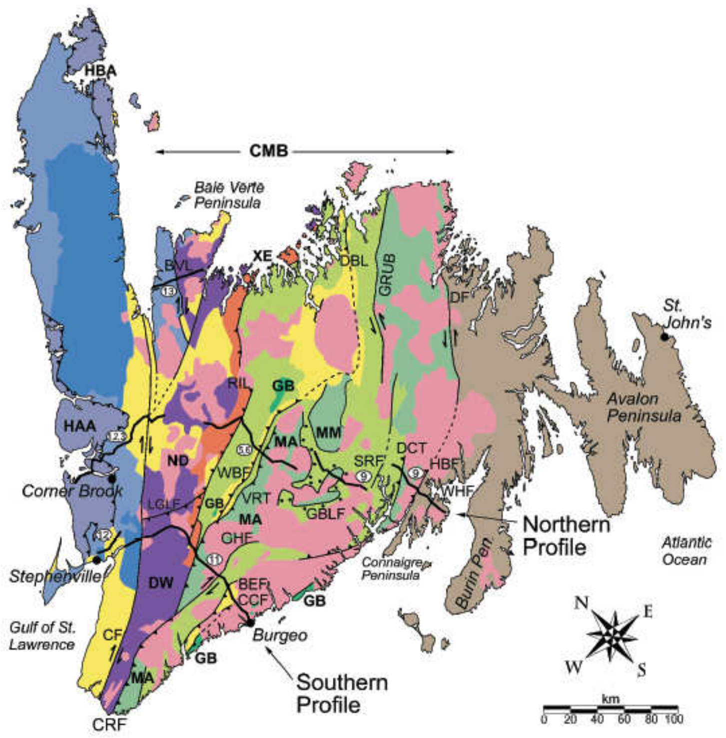


Figure 2: The major tectonic elements in the New England Appalachians, from *Van Staal, et al, 2005*



The structural setting interpreted along the reflection profile to the south of Newfoundland presented in Figure 3 shows how the geometries of the Carboniferous series may be substantially more complex than can be resolved with gravity and magnetic modelling alone.

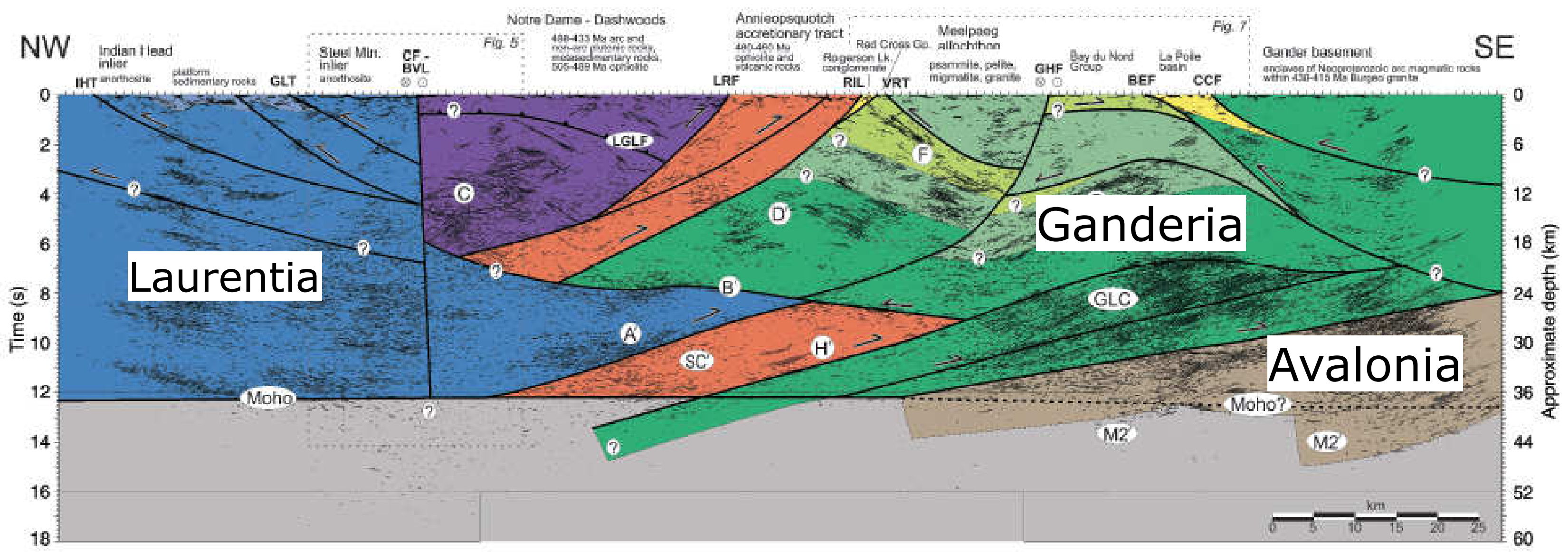


Figure 3: Interpreted migrated seismic reflection data to the south of Newfoundland, from Van der Velden et al, 2004.

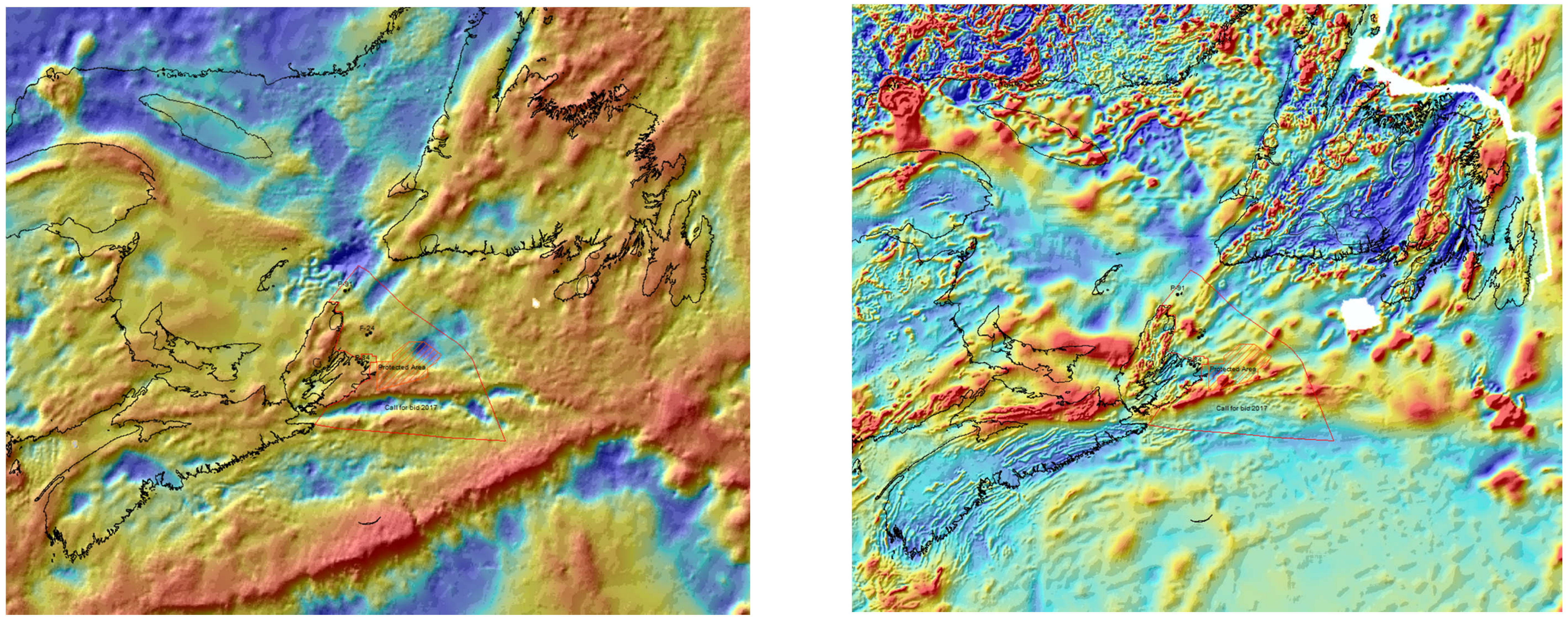
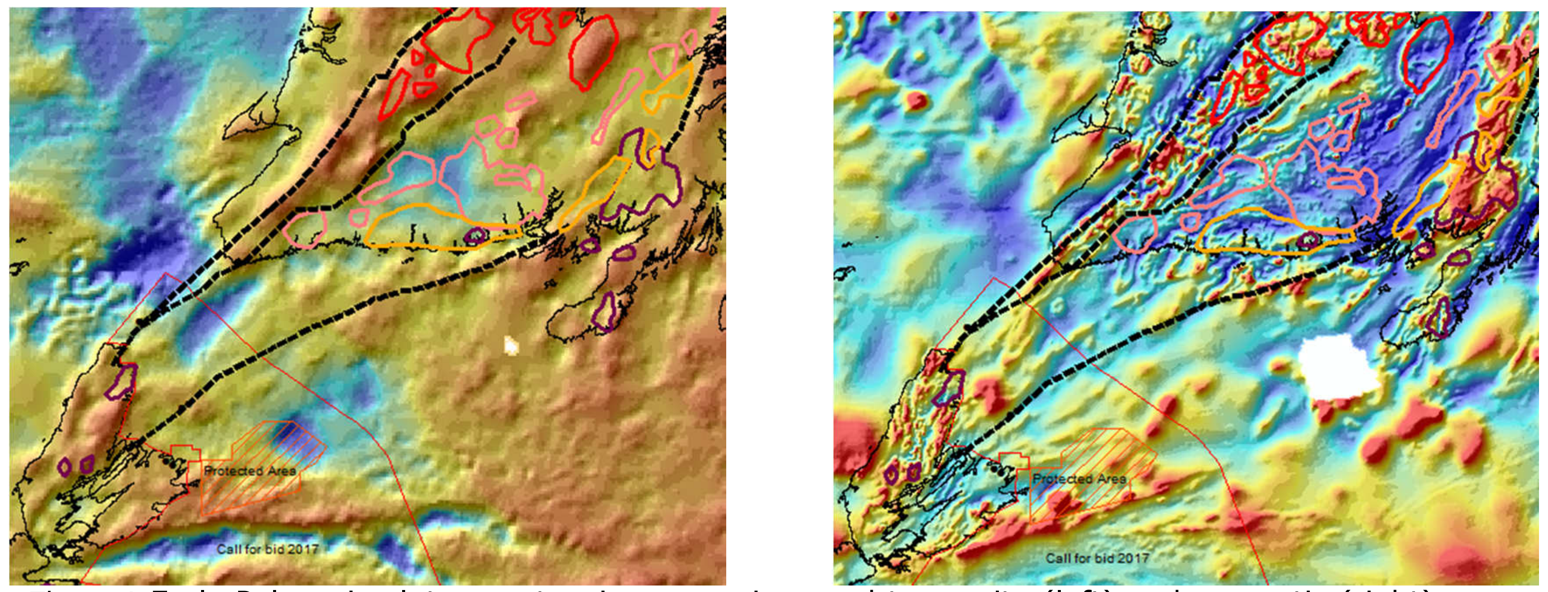


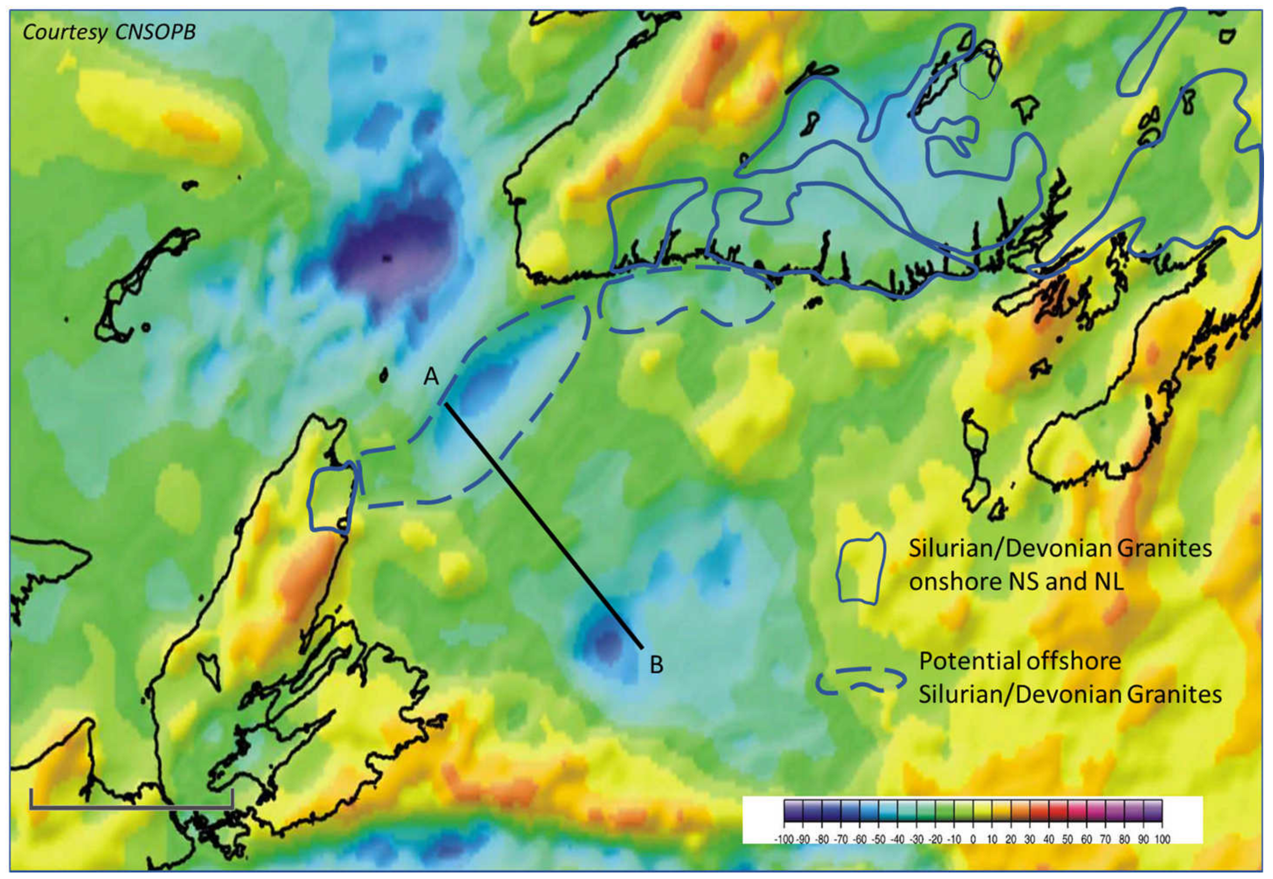
Figure 1: Gravity anomaly map (left) and Magnetic anomaly map (right) of the Atlantic region of Canada.



Silurian syn to post orogenic Salinic pluton
Upper Silurian/Lower Devonian syn-orogenic Acadian pluton
Silurian coastal arc/ Mascarene back/arc pluton
Middle Devonian to Lower Carboniferous Pluton

Figure 4: Early Paleozoic plutons extensions superimposed to gravity (left) and magnetic (right) anomaly maps.

The Bouguer anomaly and the magnetic anomaly maps may indicate negative or positive values which are reflective of basement structures and are not relatable to the structure of overlying basin sediments, either in terms of thickness or facies variations. Lower Carboniferous and earlier plutons, as displayed in Figure 4, have density and magnetic susceptibilities that are lower than the same properties in sediments (cf. bulk densities presented in Table 4.1 of Creaser, 1996 publication).



For instance, a Silurian/Devonian granite occurrence may be the source of the low gravity observed near point A on Figure 5. On a seismic profile, a basement high is interpreted in the location of this gravity low and deep seated seismic reflections are related to peg leg multiples.

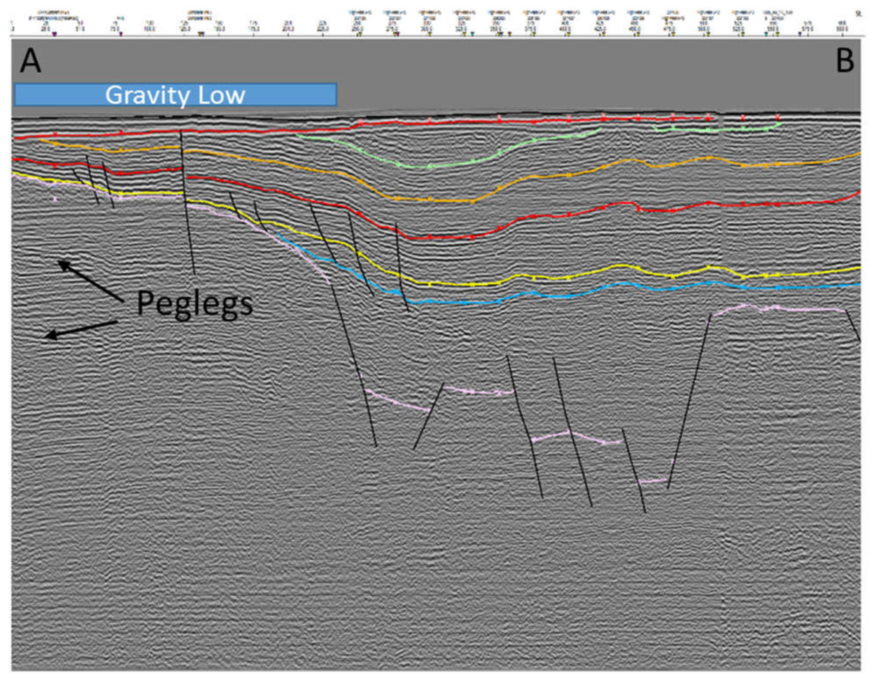


Figure 5: Silurian/Devonian granites occurrence as the source of low gravity

POTENTIAL FIELD MODELLING

The Sydney Basin is part of the Newfoundland Appalachians, one of the world's classic Paleozoic accretionary – collisional orogenies. Van Staal et al (2015) have demonstrated that the relationships between deformation, metamorphism and magmatism are highly complex. The understanding of these relationships requires a determination of the age and nature of basement plutons. Figure 6 shows the distribution of Silurian – Early Carboniferous plutonism. Nonetheless these plutons do not have a constant gravity signature. Indeed, they can be related to either a low gravity (black arrows on Figure 7), an average gravity (green arrows on figure 2) or high gravity (red arrows on Figure 7). The same behavior has been observed on magnetic data. Therefore, the identification and delimitation of plutons in the study area cannot then only be based on potential data.

The complexity of the area prevents a simple interpretation of the gravity map as having a one to one correspondence with the topography of the basement-basin interface; i.e., gravity anomalies cannot be used as simple proxies for depocenters and basement highs.

Nevertheless, a detailed spectral analysis helped to identify the major sources that contribute to the gravity signal in the full study area, in the North Cabot area, Sydney area, SW Sydney area and NE Sydney area (see Figure 8 for location and results). Over the study area, five different sources of density anomalies have been identified at 26km, 12km, 7km, 5km and 4km deep.

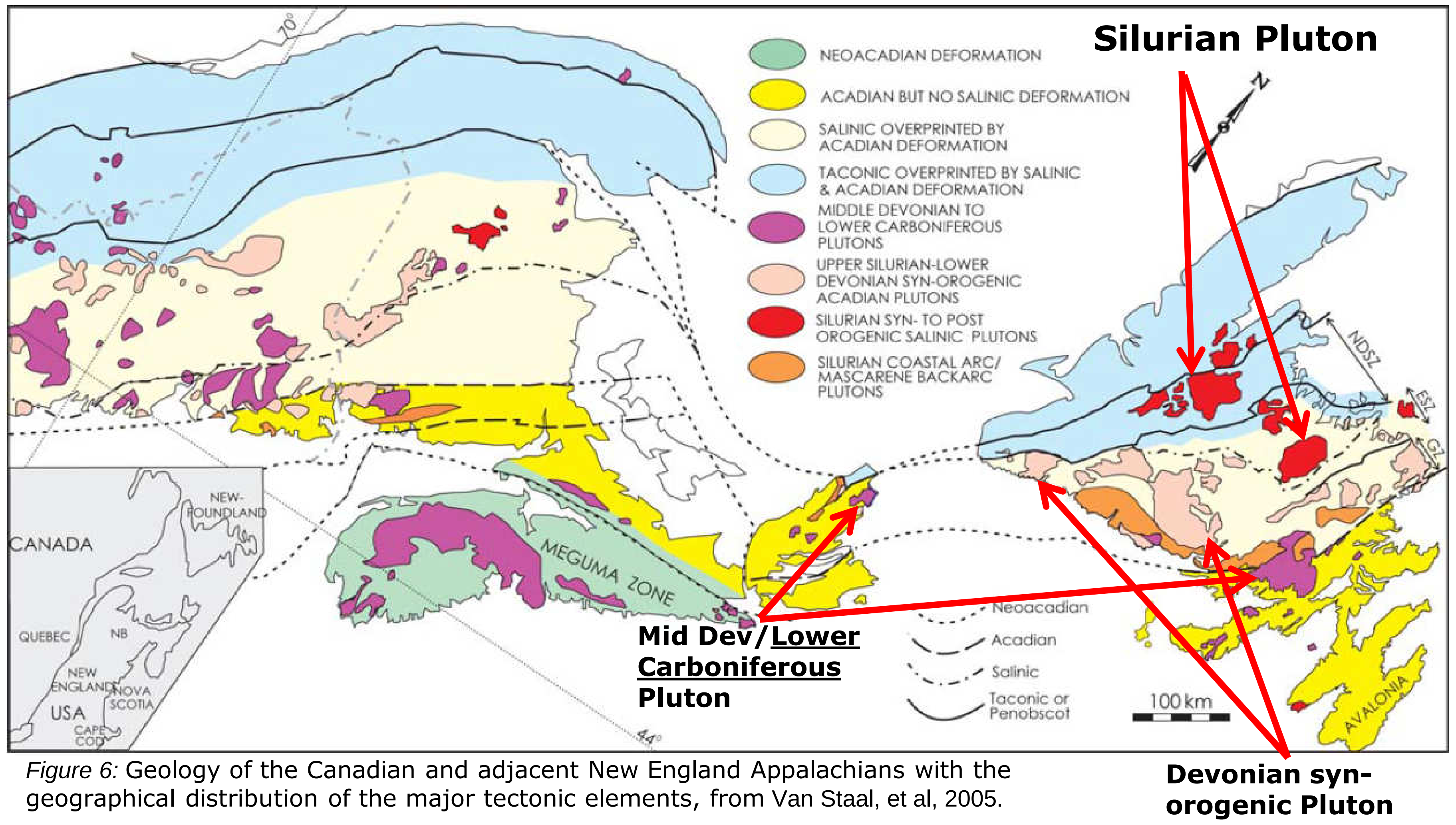


Figure 6: Geology of the Canadian and adjacent New England Appalachians with the geographical distribution of the major tectonic elements, from Van Staal, et al, 2005.

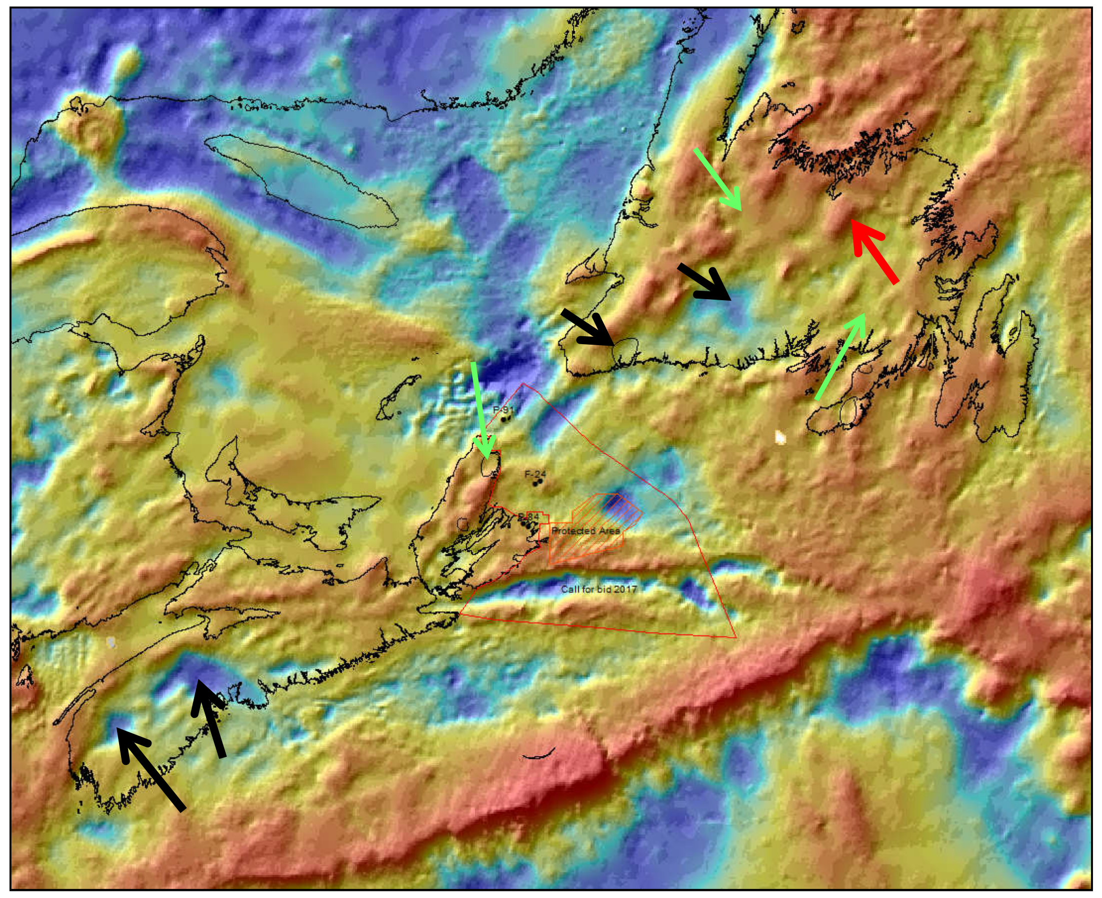


Figure 7: Regional gravity map. Arrows show the location of plutons associated to low gravity (black arrows on Figure 2), average gravity (green arrows on Figure 2) or high gravity (red arrows).

SPECTRAL ANALYSIS METHODOLOGY:

The spectral approach is based on the assumption that interfaces of density and/or magnetic property contrasts are essentially horizontal with some small relief. The potential field variations of this subsurface topography can be described in the frequency domain. Power spectrum analysis (Dimri 1992; Blakely 1995) estimates the mean depth of the interfaces considering the log of power of the potential field spectrum as a function of wave number assuming uncorrelated distribution of sources (Spector & Grant 1970) or scaling nature of sources (Pilkington et al. 1994; Maus & Dimri 1994; 1995; 1996). The spectrum of potential field anomaly due to layered source is separated into multiple segments in the wavenumber domain that can be interpreted in terms of mean depth of the interface. The half of the slope of the segments gives the mean depth of the interfaces. On the Depth vs. Wavenumber plot (Figure 3b and 3c), each peak corresponds to one interface and indicates its mean depth. Spectral analysis applied to Bouguer anomaly maps provides with average depths of main density contrasts.

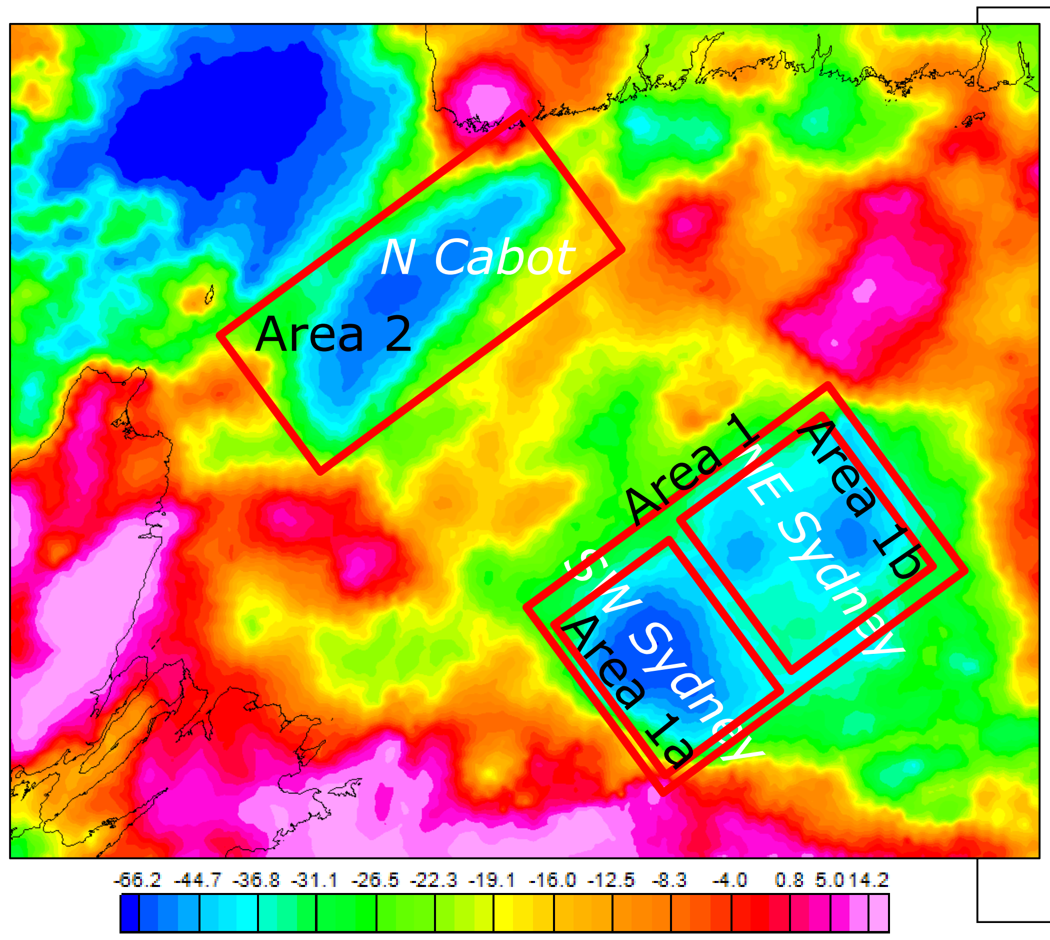
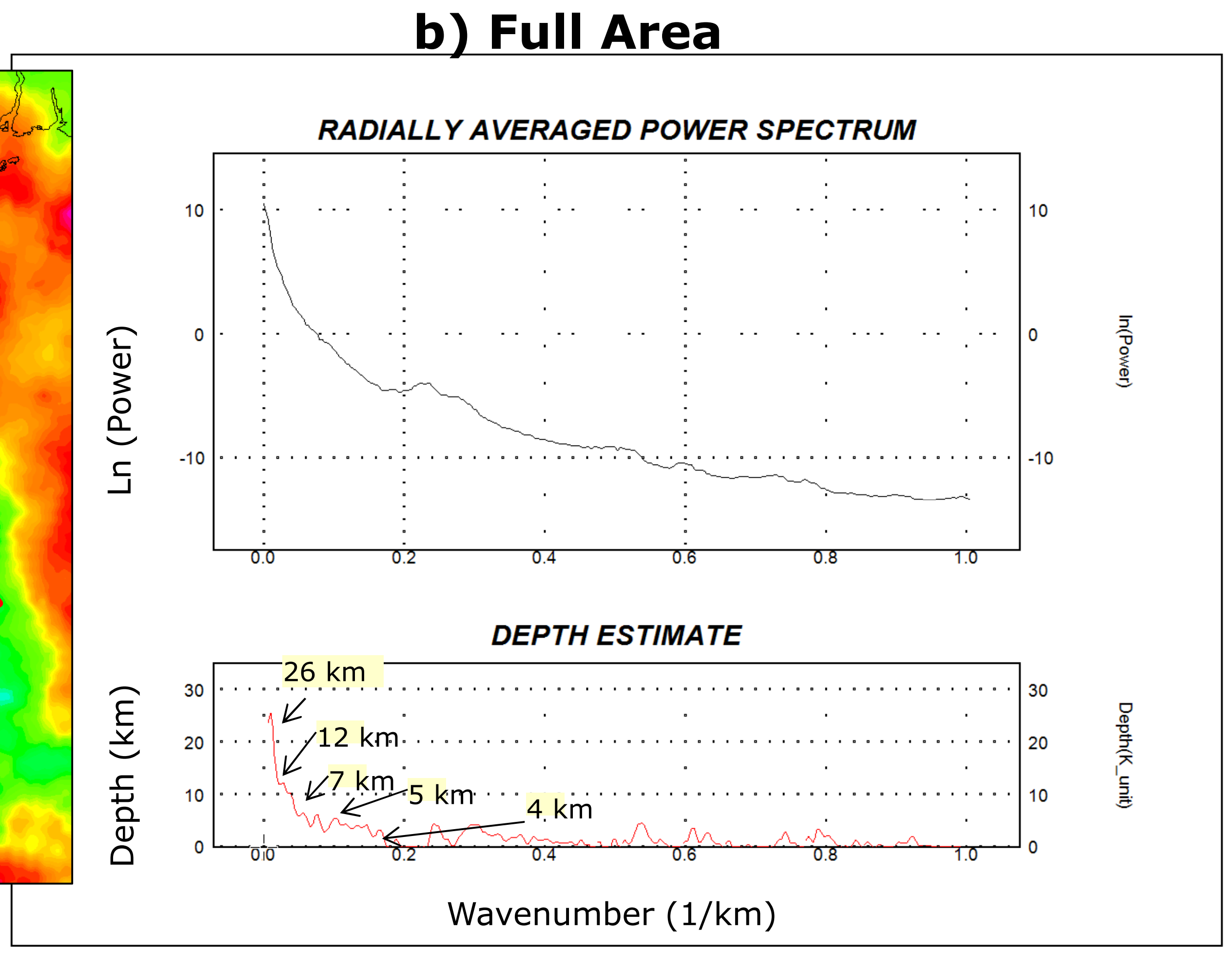


Figure 8a: Bouguer anomaly map



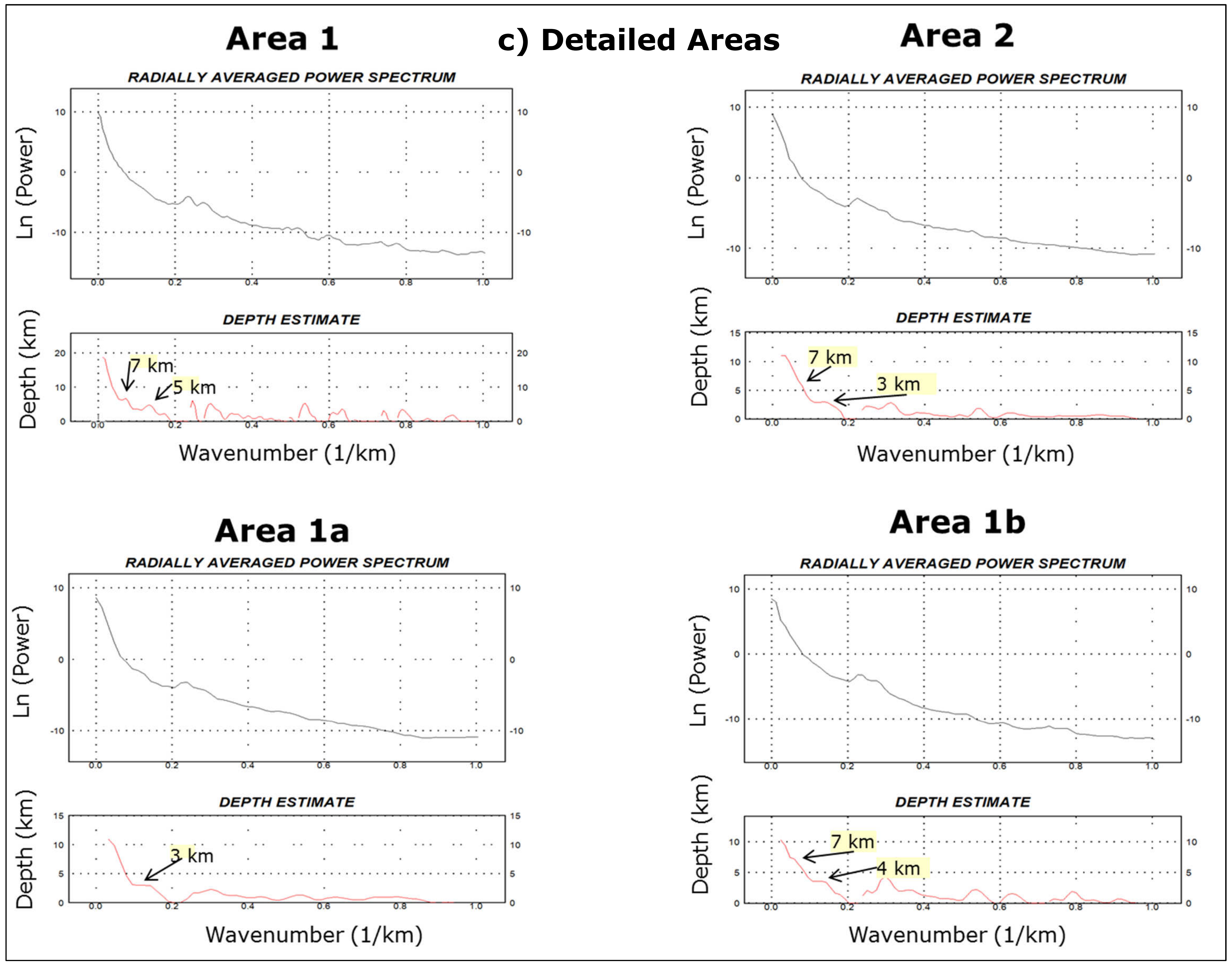


Figure 8b, c: Radial spectrum (top) and depth (bottom) of gravity sources as a function of the wavenumber for the full area (b) and detailed areas (c) (Area 1: Sydney Basin, Area 1a: SW Sydney, Area 1b: NE Sydney, Area 2: North Cabot).

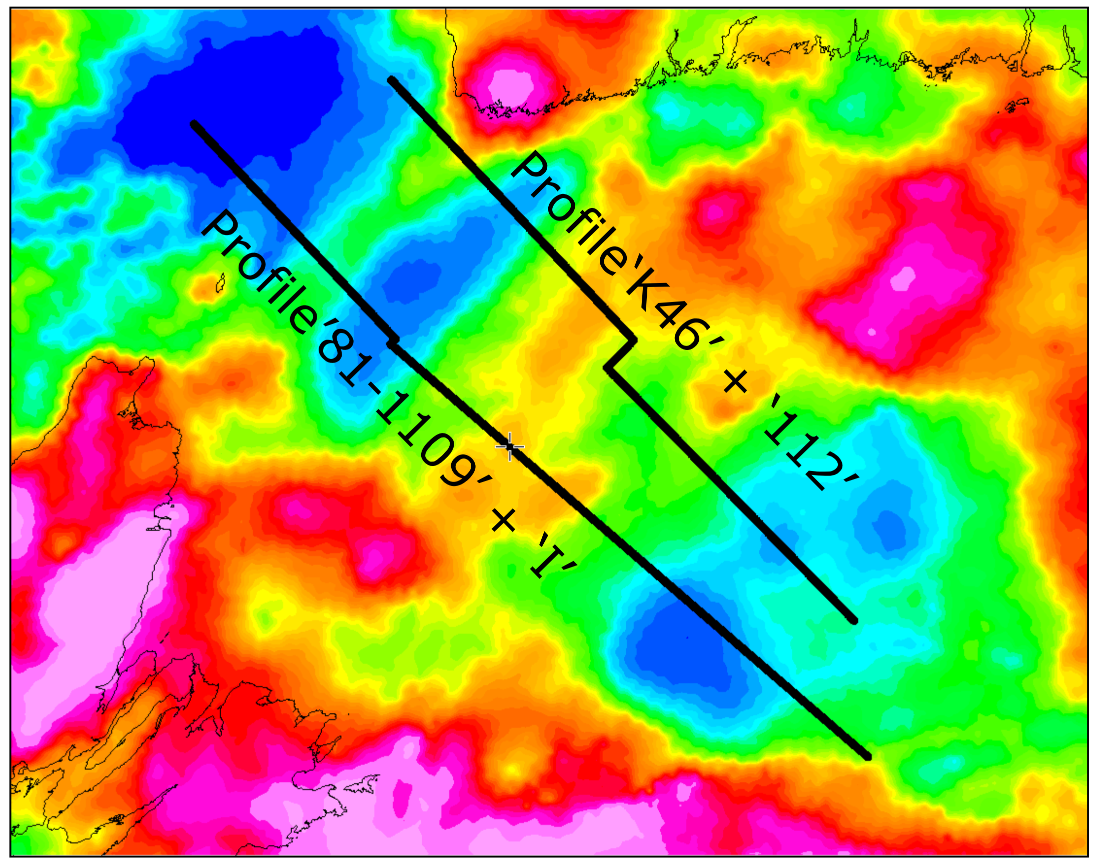


Figure 9: Location of the two modeled profiles on the Bouguer anomaly.

	Profile 'I' + '81-1109'	Profile'212' + 'K46'
Sediments	2,5	2,5
Upper Crust	2,6 to 2,73	2,6 to 2,78
Lower Crust	2,8	2.68 to 2,9
Upper Mantle	3,0	3,1

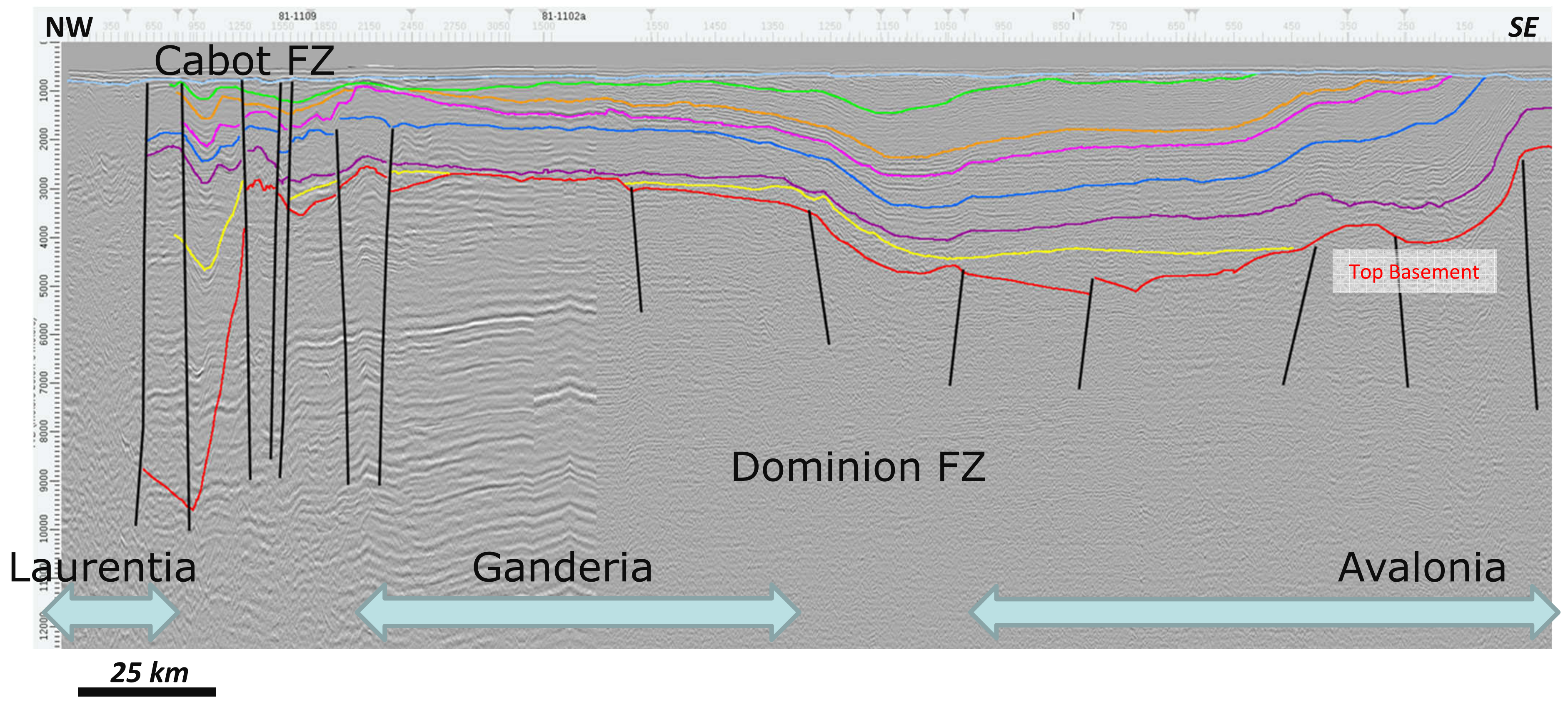
Table 1: Modeled densities in g/cm3

2D gravity modelling was undertaken along 2 seismic transects, both oriented NW-SE (see Figure 9 for location). This work aimed at modelling top basement depth and relative basement density variations in the Cabot and Dominion suture zones. The two models were subdivided in four layers: Sediments, Upper Crust, Lower Crust and Upper Mantle. The general shape of the sediments/Pre-rift interface was given by the 2D seismic interpretation. Gravity undulations were adjusted with density variations in the Pre-rift / Upper Crust layer and topography of Moho and Upper Crust /Lower Crust interface. The density used for each profile are summarized in Table 1. Note that gravity modelling is sensitive to density contrasts rather than absolute values of density.

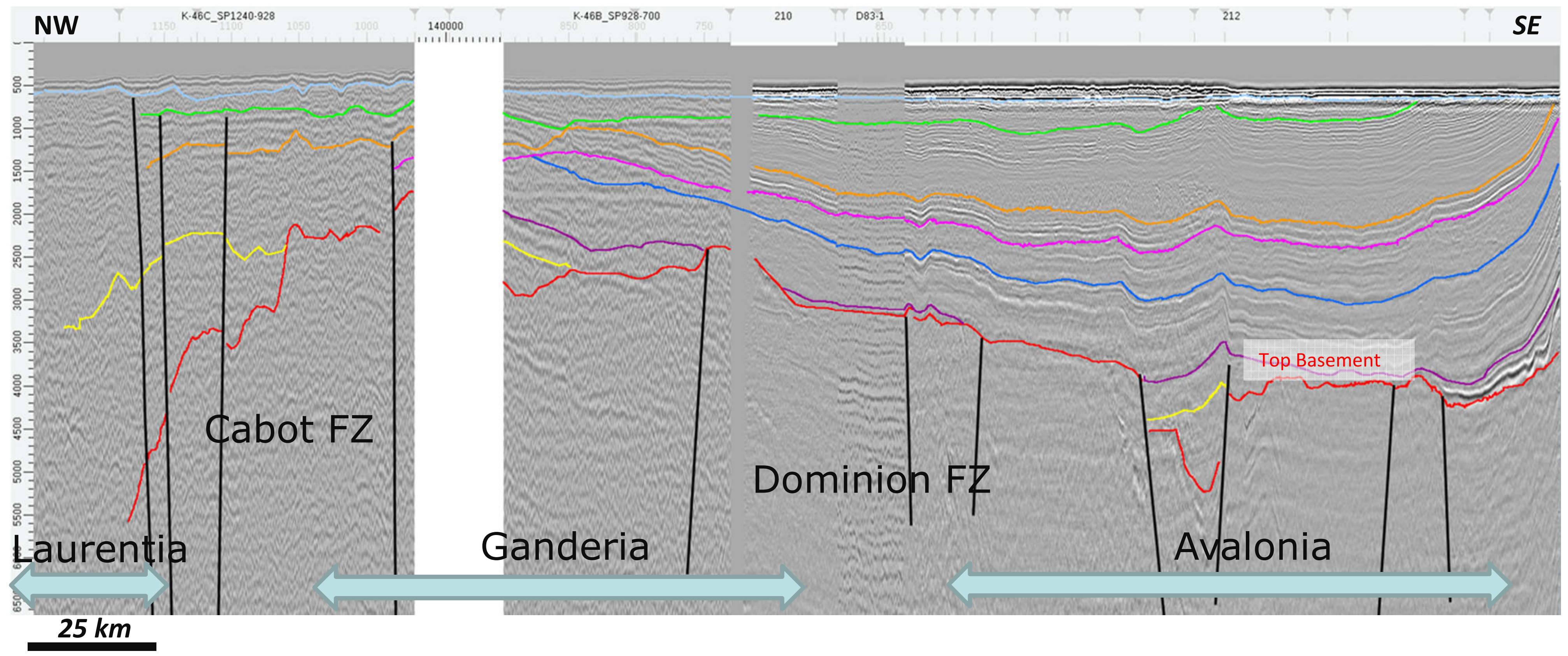
The difference between observed and computed gravity data is very low for both profiles. The gravity modelling shows that the pre-rift / Upper Crust interval is the major source of anomalies and the Upper Mantle is the second source of anomalies.

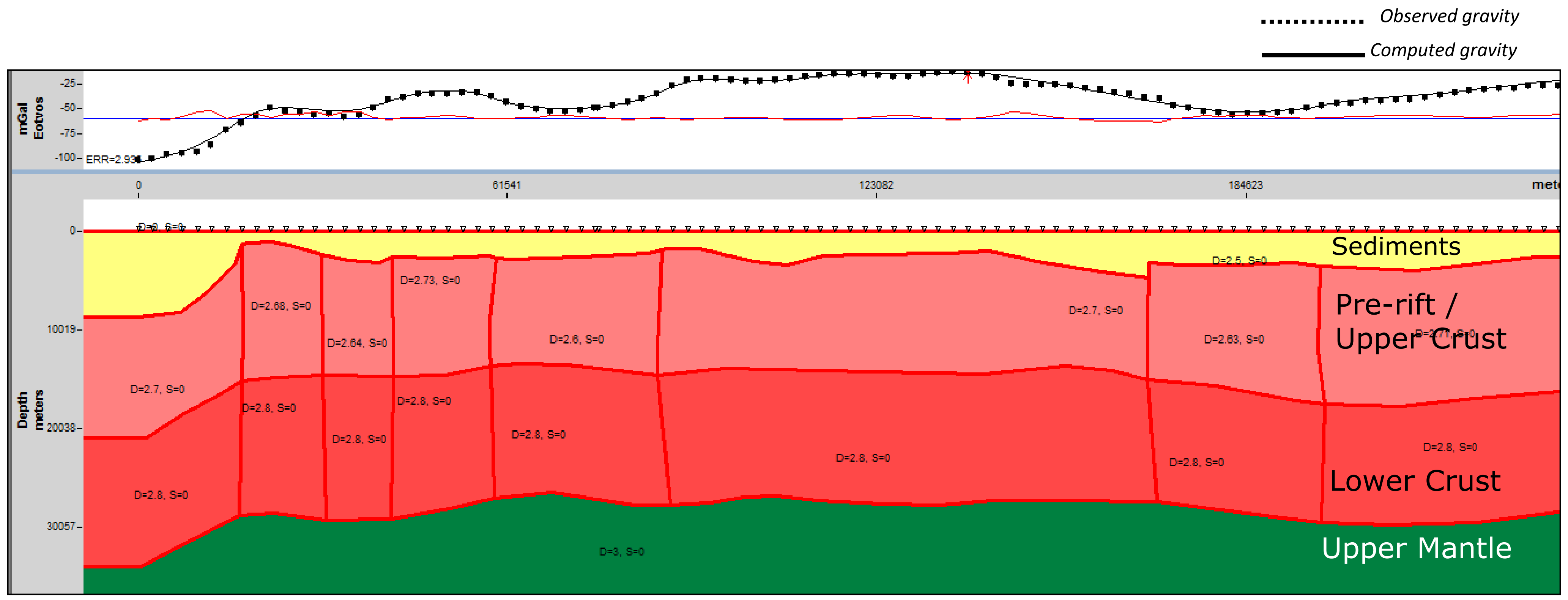
Moreover, strong density variations are evidenced in the fault zones (more in the Cabot fault zone than in the Dominion fault zone). To accurately model the gravity signal, however, the geometries to explain these density variations are beyond the scope of what gravity data can image.

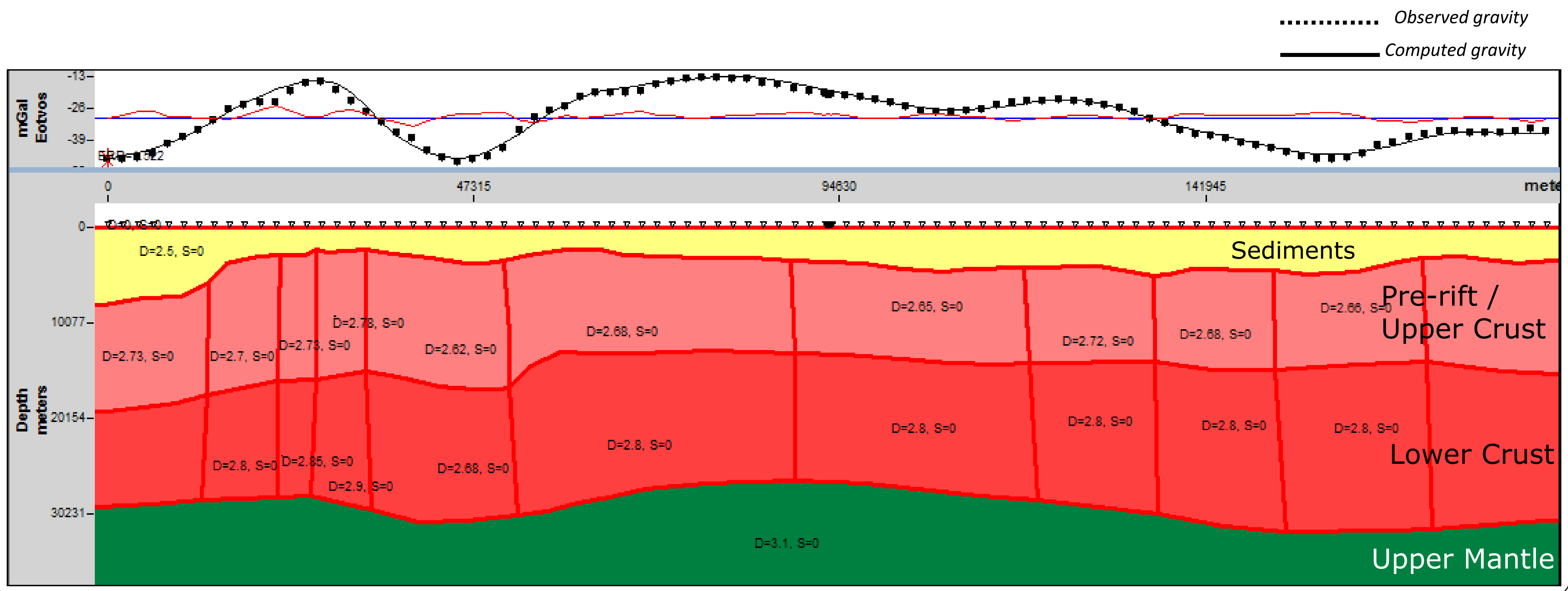
Profile'81-1109' + 'I'



Profile'K46' + '212'







REFERENCES

REFERENCES

Benn, K., Roest, W.R., Rochette, P., Evans, G., Pignottza, G.S., 1999. Geophysical and structural signatures of syntectonic batholith construction: the South Mountain Batholith, Meguma Terrane, Nova Scotia

Blakeley, R.J.,1995. Potential theory in gravity and magnetic applications. United States Geological Survey, California.

Creaser (1996). Table 4.1. Thesis excerpt with measured densities from South Mountain Batholith, Nova Scotia.

Table 4.1 of Dimri, V. (1992). Deconvolution and inverse theory application to geophysical problems: Elsevier Sci. Publ. BV, Amsterdam.

Jobin, D.M., Véronneau, M., Miles, W., 2017. Gravity anomaly map, Canada / Carte des anomalies gravimétriques, Canada, Geological Survey of Canada, Open File 8081, 2017; 1 sheet, https://doi.org/10.4095/299561

King, M.S., Barr, S.M., 2004. Magnetic and gravity models across terrane boundaries in southern New Brunswick, Canada. Can. J. Earth Sci. 41: 1027–1047. Published on the NRC Research Press Web site at http://cjes.nrc.ca

Maus, S., Dimri, V. P., 1994. Scaling properties of potential fields due to scaling sources. Geophys. Res. Lett, 21, 891-894.

Maus, S., Dimri, V., 1995. Potential field power spectrum inversion for scaling geology. Journal of Geophysical Research: Solid Earth, 100(B7), 12605-12616.

Maus, S., Dimri, V., 1996. Depth estimation from the scaling power spectrum of potential fields? Geophysical Journal International, 124(1), 113-120.

Miller H.G., Thakwalakwa , S.A.M., 1992. A geophysical and geochemical interpretation of the configuration of the Mount Peyton complex, central Newfoundland. Atlantic Geology 28, 221-231.

Pilkington, M., Hildebrand, A. R., Ortiz-Aleman, C., 1994. Gravity and magnetic field modelling and structure of the Chicxulub crater, Mexico. Journal of Geophysical Research: Planets, 99(E6), 13147-13162.

Spector, A., Grant, F.S., 1970. Statistical models for interpreting aeromagnetic data. Geophysics, 35(2), 293-302.

van Staal, C.R., Whalen, J.B., Valverde-Vaquero, P., Zagorevski, A., Rogers, N., 2009. Pre-Carboniferous, episodic accretion-related, orogenesis along the Laurentian margin of the northern Appalachians. Geological Society, London, Special Publications, 327(1), 271-316.

van der Velden, A.J., van Staal, C.R., Cook, F.A., 2004. Crustal structure, fossil subduction, and the tectonic evolution of the Newfoundland Appalachians: Evidence from a reprocessed seismic reflection survey. GSA Bulletin; v. 116; no. 11/12.

Wiseman R.E., 1994. Potential field modelling and interpretation along Lithoprobe East onshore seismic reflection transects across the Newfoundland Appalachians, Thesis submitted to the School of Graduates Studies, Department of Earth Sciences, Memorial University of Newfoundland