Regional Gravity and Magnetic Interpretation over East Coast-Pegasus Basin, New Zealand*

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Abstract

The East Coast and Pegasus basins are situated between the North Island of New Zealand and the Hikurangi Trench. DHI's and structural traps are observed on 2D seismic data over the East Coast and Pegasus basins. These observations promote interest in exploration of the basins. However, seismic imaging is complicated by presence of gas clouds and widespread volcanic deposits and intrusions as well as the folding and thrusting in the west. To better understand the geologic framework of the basement and distribution of the volcanics, Schlumberger WesternGeco acquired marine gravity and magnetic data over the basin for a qualitative structural and geologic interpretation. Interpretation of standalone gravity and magnetic data results in non-unique solutions. When combined, the solution becomes less non-unique. In order to correct for bathymetry and Moho effects, the Free Air gravity data was first complete Bouguer corrected at 2.2g/cc, then regionally and residually corrected. The Total Magnetic Intensity data was corrected by Reduction to Pole (RTP). The CRUST2.0 Moho model has been compared with the New Zealand Extended Continental Shelf SEEBASE Moho model. The SEEBASE model has more information in the SE East Coast and Pegasus basins although the overall anomaly pattern of the two residual maps shows good similarity. Radial Average Power Spectrum Analysis of Residual corrected gravity and RTP magnetic data yielded a selection of filter maps and their wavelengths compared to the seismic data. Kinematic analysis for the basement structural interpretation of lineaments from filter maps was conducted taking into account the regional NW-SE compressive stress regime orientation (Beavan et al., 2002) and Scotese (2014) plate motion model. Some major findings are a transpressive pattern of strike-slip fault zones that terminate on the Hikurangi Trench on both sides. The subduction is oblique given the orientation of the trench and the stress regime. The trench itself displays a stepping geometry where the transfers terminate and near the trench, igneous intrusions are observed that intruded into the sedimentary sequence are visible on the seismic data, hence may have had an effect on the thermal history of the sediments. These intrusions manifest as high frequency chaotic magnetic anomaly patterns and gravity highs. Buried seamounts on the subducting plate are also observed in the seismic data and correspond exactly to the gravity and magnetic highs.

Scope

Interpretation of 2D seismic data in the East Coast – Pegasus Basin is complicated by the presence of gas clouds and widespread volcanic deposits and intrusions. These features cause poorer seismic imaging over many parts of the seismic data set at hand. On the positive side, the

presence of structural traps and DHI's stimulates further exploration efforts in the basin. To obtain a clearer picture of the geologic framework of the basement and distribution of the volcanics, a qualitative structural and geologic interpretation has been undertaken using Gravity and Magnetic data over the basin in the regional context.

The East Coast- Pegasus Basin is situated east of the Northern Island of New Zealand and resides on the hanging wall of the Hikurangi Trench subduction zone, where the Oceanic Crust of the Hikurangi Plateau (Pacific Plate) subsides under the Northern Island that is part of Australian Continental Crust (Figure 1).

The marine gravity and magnetic data available for this study have been acquired for Schlumberger and subjected to the Complete Bouguer Gravity Correction (including removal of the Moho effect) and Reduction to Pole respectively. The gravity correction for the Moho effect resulted in a significant impact on the residual gravity map for basement and sedimentary cover. The Reduction to Pole of the TMI magnetic data was needed to place the anomalies over their causative sources.

Regional Gravity Analysis

Gravity data interpretation and modelling is a challenging task, which potentially can provide non-unique solutions. This is because gravity data at each observation point is a measurement of the gravitational effect of the entire density distribution of the Earth according the Newton's law of Gravitation. In fact, a gravity map is the superimposition of effects derived from density anomalies in the subsurface placed at different distances and depths from the station.

Short-wavelength Bouguer Gravity anomalies correspond to the gravitational effect of shallow density geo-structures placed in the sediments and upper Crust, while long-wavelength components derive by deep regional structures, such as the basement and Moho reliefs. In order to minimize this non-uniqueness and isolate the anomalies caused by local density variations, the observed gravity data have been subjected to a processing, which involves a series of corrections resulting in different gravity anomaly maps (e.g. Free-Air, Bouguer, Regional and Residual) that are more reliable for a quantitative and qualitative interpretation.

The Complete Bouguer Gravity Anomaly map (corrected for a background density of 2.2 g/cm^3) over the Pegasus Basin shows evident anti-correlation with respect to the bathymetry, indicating the effect of regional structures present in the gravity data (Figure 2). A regional analysis has been performed to remove the effect produced by the Moho while making the effect of shallow density anomalies more visible in the gravity data. Numerical (band-pass) and physical (isostatic correction using the Airy model and Crustal Global Model) approaches have been applied and the results compared.

In particular, Moho discontinuity has been extracted both from CRUST 2.0 (2 by 2) Global Model and from the NZ ESC SEEBASETM model (New Zealand Extended Continental Shelf model at a regional scale of 1:3 is a depth-to-basement model based on the systematic integration and interpretation of both non-seismic and seismic datasets) and the lower Crust / upper Mantle density contrast taken from the CRUST 2.0 Global Model. The corresponding regional effects have been calculated to obtain the residual gravity maps (Figure 3 and Figure 4).

The validation of the obtained gravity residual maps passes through a qualitative comparison with KPSTM (Kirchhoff Pre-Stack Time Migration) stacks. At this level, the correspondence between the lateral position of the gravity anomalies and the structures at sediment/basement level on the stacks is ranked. This is an indication that the effects of non-sedimentary features at the basement level are visible on the residual gravity map. Shortest-wavelength features lying immediately below the water bottom cannot always be distinguished. Possibly this is a limitation of the sensitivity of the data. One exception to this observation is evident. In the eastern portion of the survey, we observe the effect of very shallow, high-density bodies, suggesting possible volcanic intrusions, the presence of which can be verified using the magnetic signature data.

For the next interpretative step, gravity residual map from SEEBASETM Moho was preferred with respect to CRUST 2.0: the main structures and the wavelength content overlaid on the two gravity residual maps show a good similarity. The main structural differences can be observed in the SE corner of the survey where in fact the CRUST 2.0 model has poorer information than SEEBASETM Moho model, which has a better resolution there.

Pegasus Basin Gravity and Magnetic Interpretation

The qualitative interpretation of gravity and magnetic data has yielded a structural and geological map with delineation of oceanic, transitional and continental crust provinces in the region. The Alpine Fault, a dextral strike-slip fault system that connects the Hikurangi Trench to the Puysegur Trench SW of the Southern Island of New Zealand (Figure 1), accommodates the relative eastward movement of the Northern Island with respect to the Southern Island (Litchfield et al., 2013; Scotese, 2014). The Lord Howe Rise to the West roughly marks the boundary between oceanic crust to the South and continental-transitional crust to the North whereas the Chatham Rise in the East marks the boundary between oceanic crust to the North and continental-transitional crust to the South. Magnetic data clearly shows the seafloor spreading anomalies typical for oceanic crust, as well as the numerous intrusions in the continental-transitional crust. Because of this tectonic plate configuration, the Australian oceanic plate subsides under the Southern Island continental crust. The transfer – strike-slip fault zones along the rises also accommodate the differential plate velocities (Litchfield et al., 2013).

Sedimentation on the Hikurangi Plateau has been interrupted for several long periods, manifested in the regional unconformities in its carbonate-dominated sequence. The sedimentary wedge of the Pegasus and East Coast Basin to the West on the contrary, is majorly composed of turbiditic sequences alternated by widespread sills or basalt flows. Near the Hikurangi Trench numerous igneous intrusions have been observed on the magnetic (high-frequency chaotic anomaly patterns) and gravity enhancements, that intruded well into the sedimentary sequence. These intrusions may have had an effect on the thermal history of the sediments to some extent. Examples observed on the 2D seismic data are intrusions or fossil seamounts that reside on the subducting plate (Figure 5 and Figure 6).

Structural interpretation carried out on the filter maps of the Complete Bouguer Gravity Correction (including Moho effect) and Reduced to Pole Magnetic grids, following a kinematic analysis on lineaments derived from Horizontal gradient and Tilt Angle filter maps, demonstrates a transpressional pattern of strike-slip fault zones that terminate on the Hikurangi Trench. The subduction is slightly oblique and is manifested by angles of termination against the trench line. In addition, the trench line itself displays a stepping geometry where the strike-slip faults terminate.

Conclusions

The computation of Residual Gravity from the SEEBASETM Model provided a very useful map for further geological interpretation. A transpressive pattern of strike-slip fault zones terminates on the Hikurangi Trench on both sides. The subduction is oblique given the orientation of the trench and the stress regime. The trench itself displays a stepping geometry where the transfers terminate and near the trench, igneous intrusions are observed that intruded into the sedimentary sequence are visible on the seismic data, hence may have had an effect on the thermal history of the sediments. These intrusions manifest as high frequency chaotic magnetic anomaly patterns and gravity highs. Buried seamounts on the subducting plate are also observed in the seismic data and correspond exactly to the gravity and magnetic highs.

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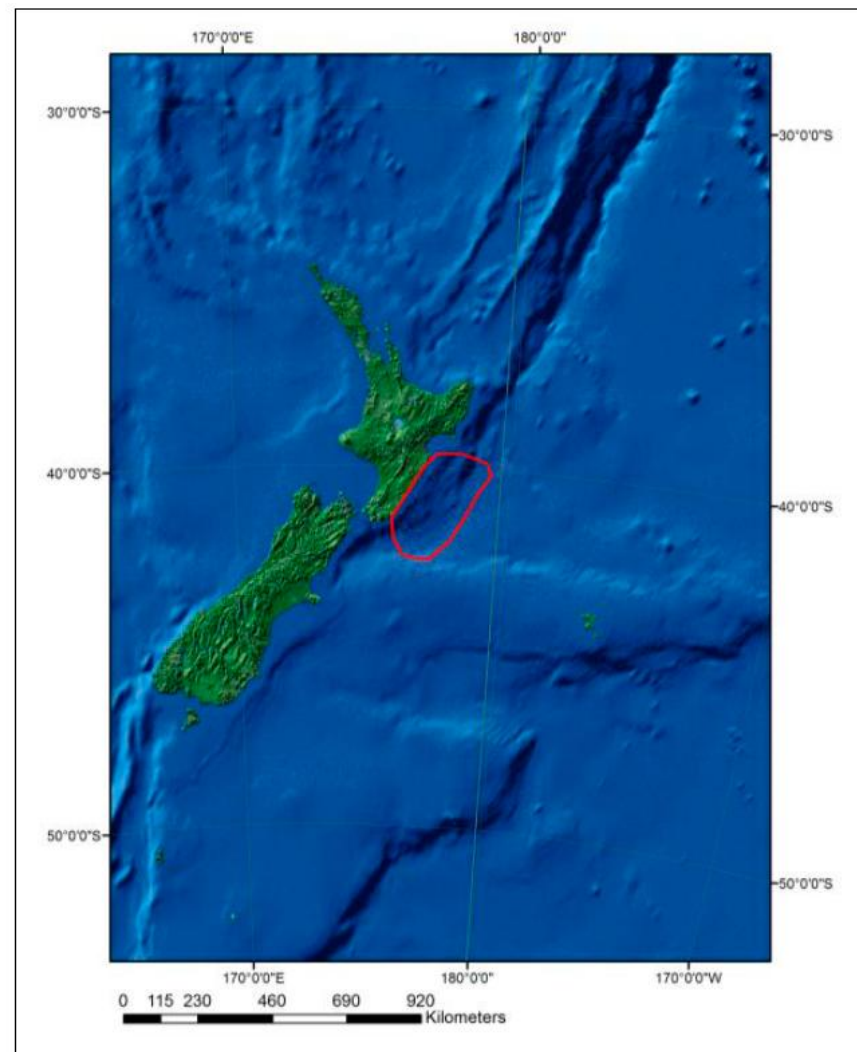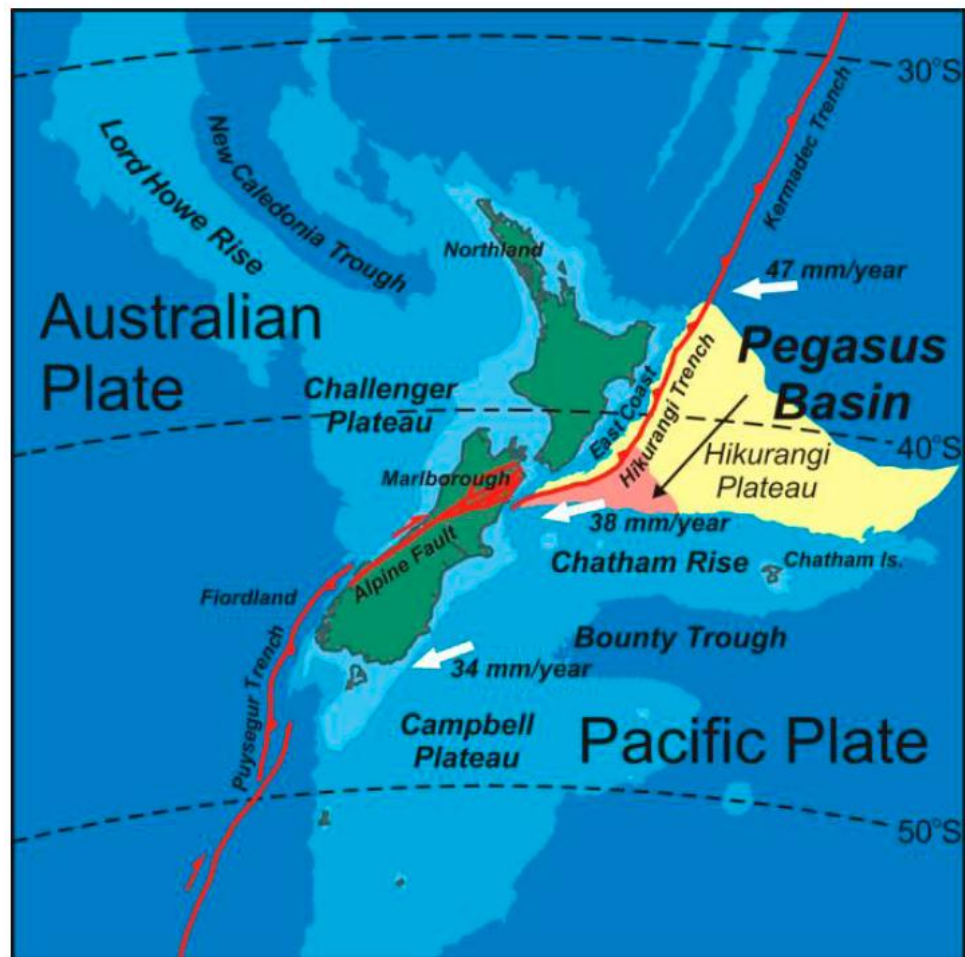
Figure 1. Location of the East Coast-Pegasus Basin (red polygon), offshore New Zealand.
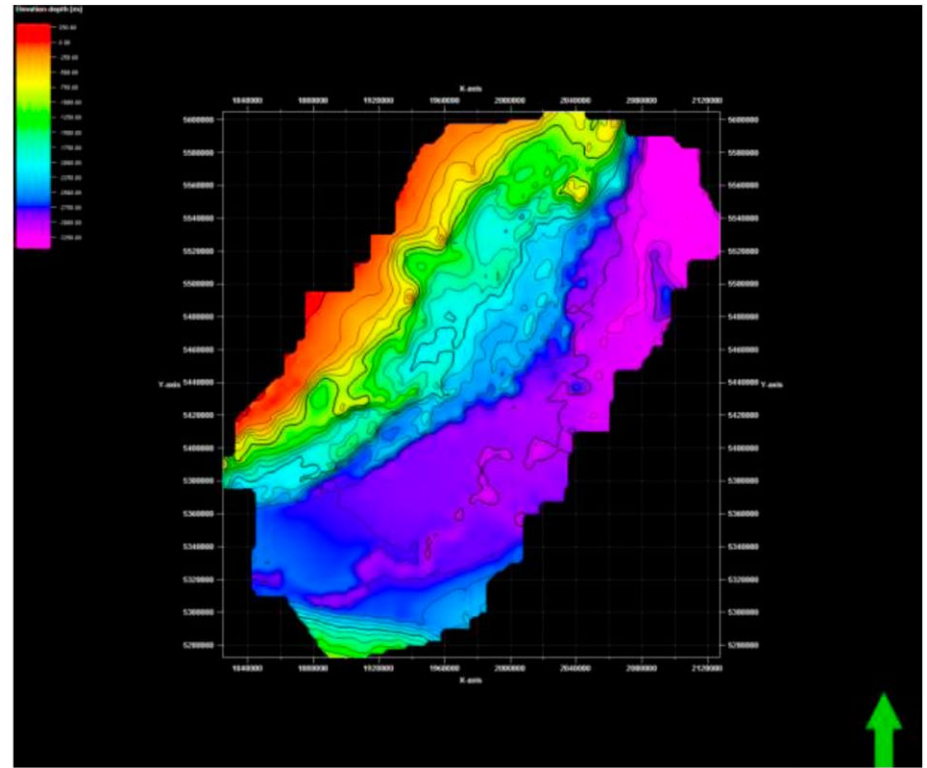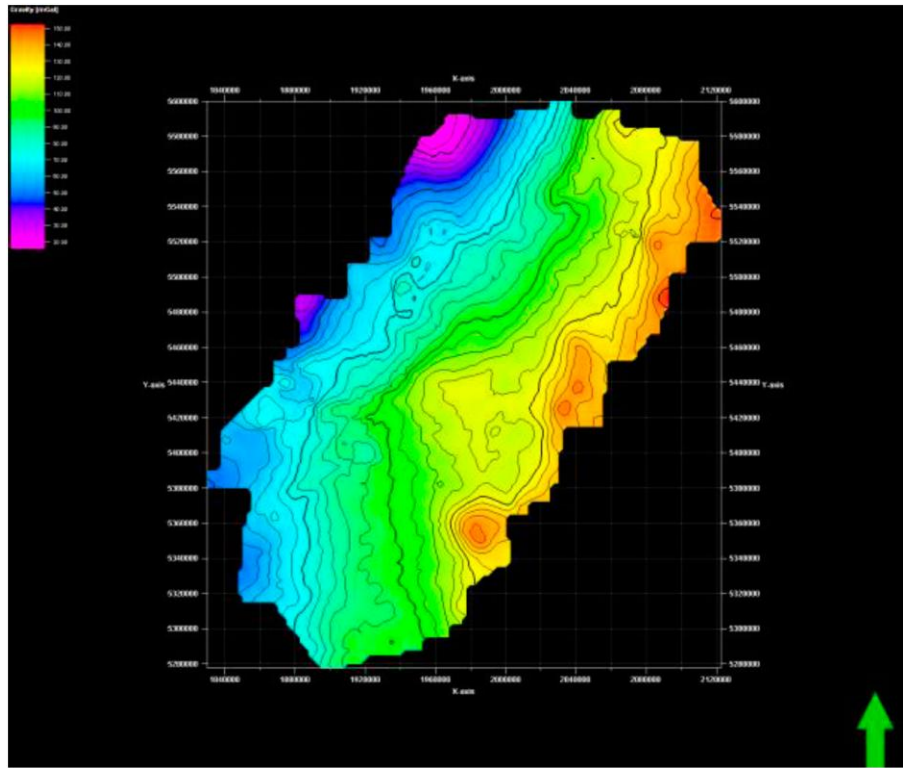
Figure 2. Left: Complete Bouguer anomaly map in mGal (reduction density 2.2 g/ cm^3); right: bathymetry in m.
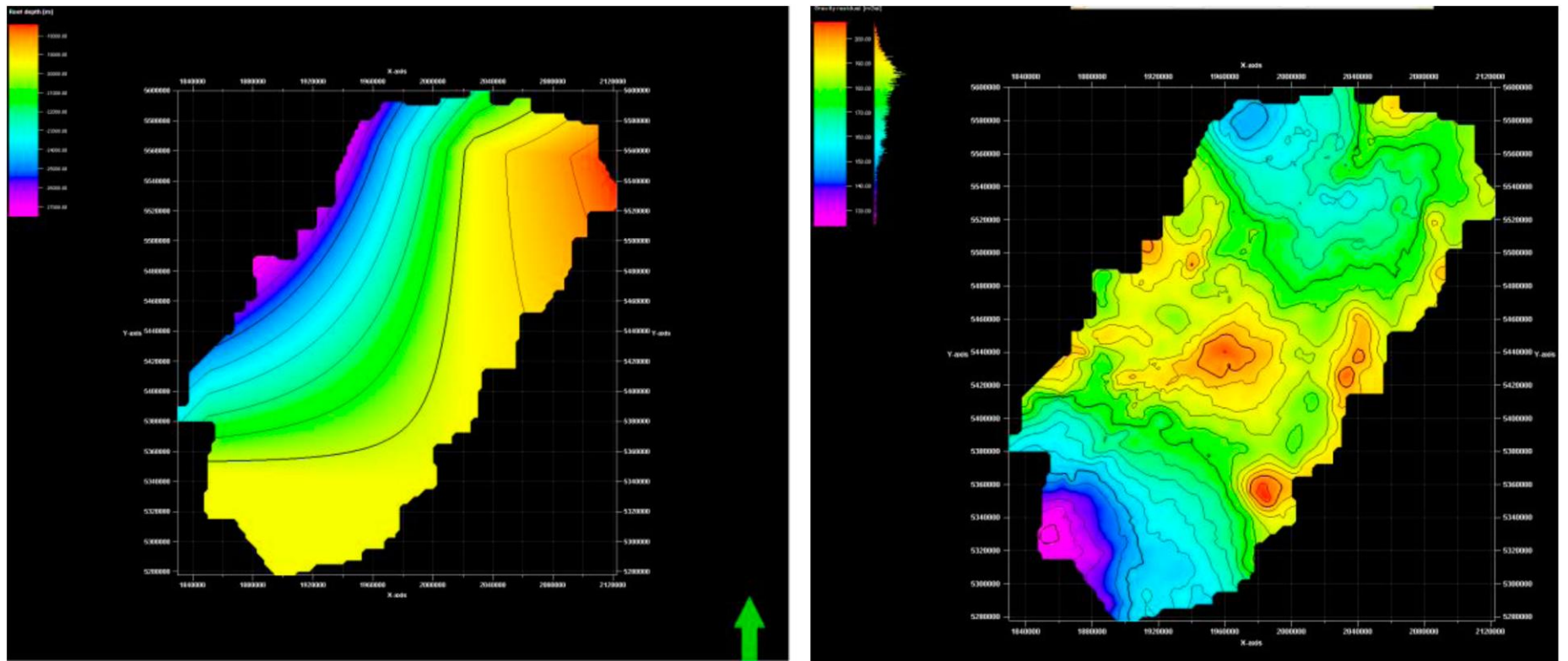
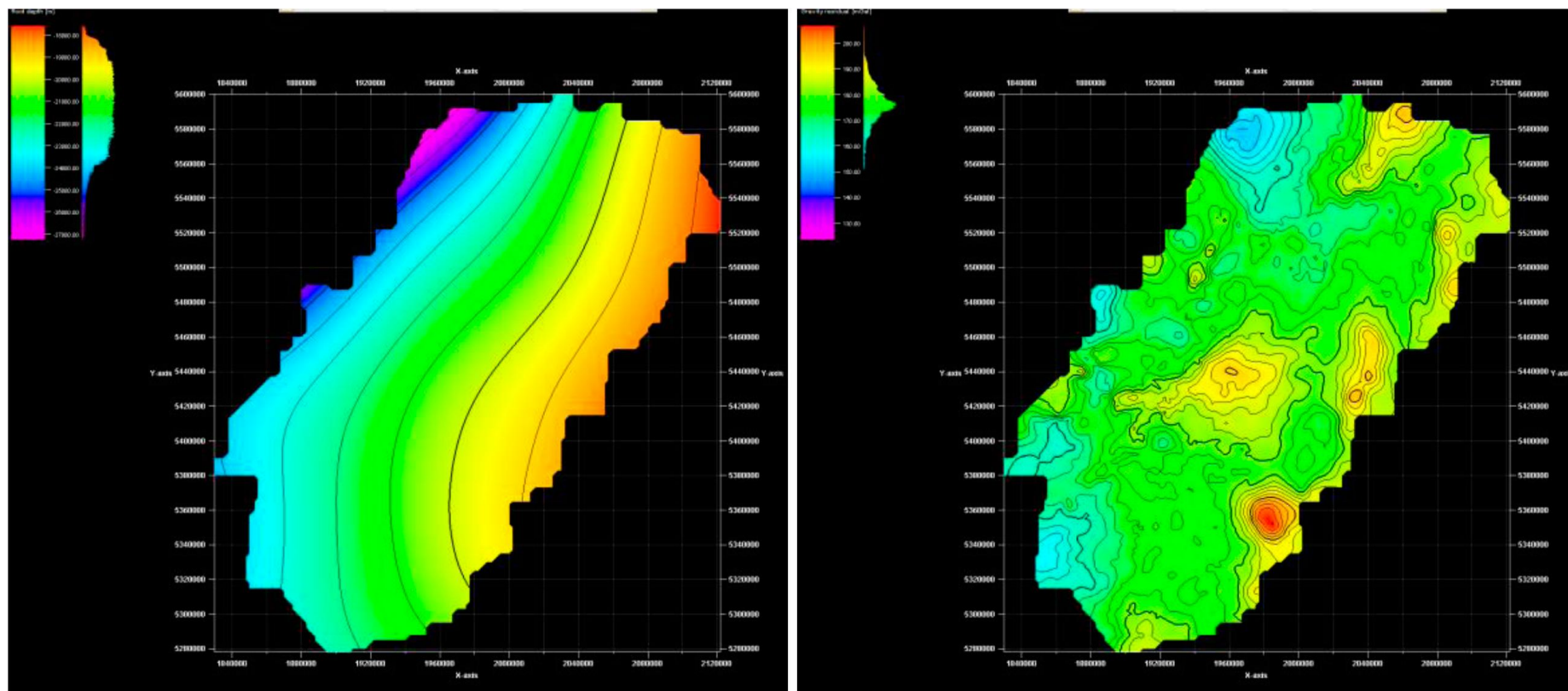Figure 3. Left: Moho depth from CRUST 2.0 in m; right: residual gravity map in mGal.

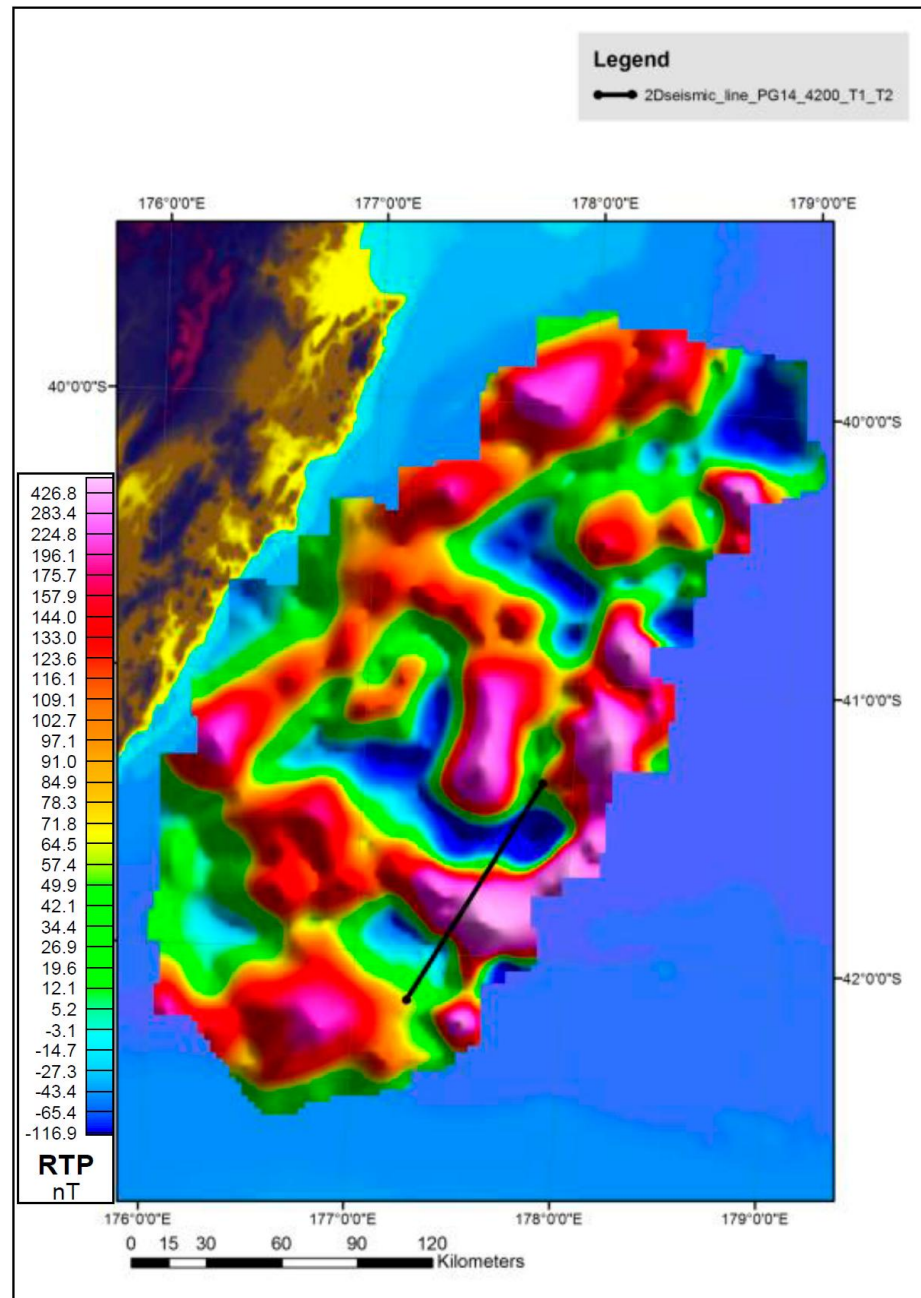Figure 4. Left: Moho depth from NZ ECS SEEBASETM in m; right: residual gravity map in mGal.

Figure 5. RTP Magnetic Anomaly map over the East Coast-Pegasus Basin with location of 2D Seismic line PG14-4200_T1_T2 (shown in Figure 6).
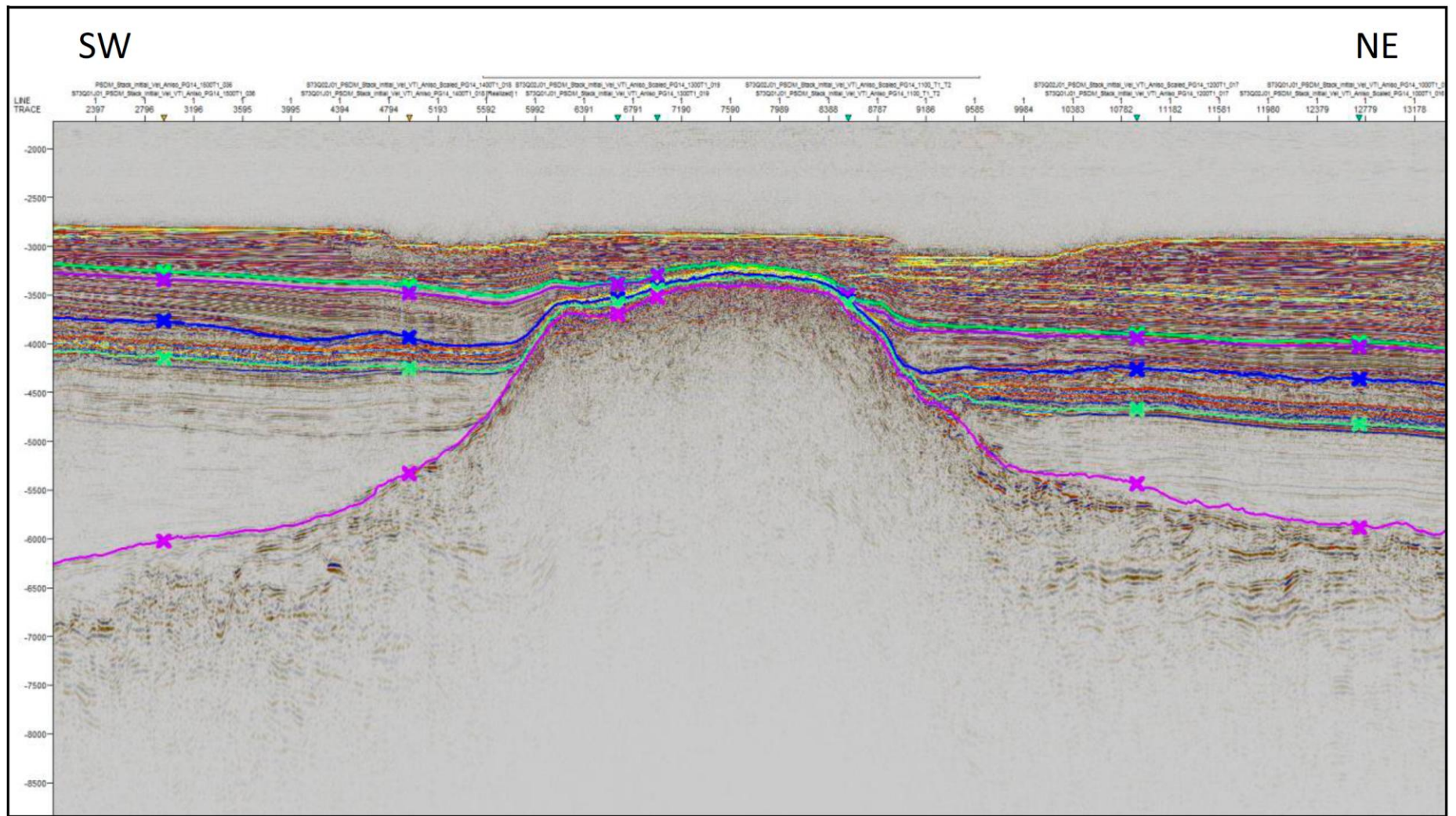
Figure 6. 2D Seismic line PG14-4200_T1_T2 illustrating the intrusive complex, which is clearly visible on the RTP Magnetic data. Location of the line is presented in Figure 5.