[PS]Interpreting 2D Seismic with the Assistance of FALCON® Airborne Gravity Gradiometer Data in the Canning Basin*

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Abstract

In recent years, airborne gravity gradiometry has gained popularity as a useful tool for all stages of oil and gas exploration. It is able to be acquired rapidly, cost effectively and provide complete coverage of exploration blocks. When combined with seismic, magnetic, well and other geological data, significant advances in the understanding of the geology of a project area can be made. In a variety of geological environments, gravity anomalies resulting from density contrasts contain useful information about the distribution of rocks in the subsurface. Lithologies with atypical densities include carbonate, salt and volcanic rocks. These lithologies are good targets for gravity gradiometry but are often difficult to resolve with seismic meaning gravity gradiometry can complement and add value to new or existing seismic surveys. Transfer faults oblique to seismic lines are often difficult to identify on seismic lines but are obvious on gravity gradient data. Gravity gradiometer surveys are often used to interpolate structures between widely spaced 'vintage' 2D seismic lines and assist in more effective planning of new seismic surveys.

References Cited

Reid, A.B., J.M. Allsop, H. Granser, A.J. Millet, and I.W. Somerton, 1990, Magnetic interpretation in the three dimensions using Euler deconvolution: Geophysics, v. 55, p. 80-91.

Werner, S., 1953, Interpretation of magnetic anomalies of sheet-like bodies: S.G.U. ARSBOK, v. 43, p. 1-130.

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Background

Hydrocarbon exploration in under-explored frontier basins is often challenging due to the sparse coverage of 'vintage' seismic data. The Canning Basin is such an under-explored frontier basin. Partly due to this limitation hydrocarbon exploration has made little progress for many years. For example, the deep structure of the Fitzroy Trough and its margins was largely unknown. This example from the Canning Basin illustrates how FALCON® Airborne Gravity Gradiometer (AGG) data greatly enhances the 2D seismic interpretation, making it a valuable tool in exploring frontier basins.

Introduction

Buru Energy acquired a large FALCON® Airborne Gravity Gradiometer (AGG) survey (38,800 km²) over the south-western margin of the Fitzroy Trough and Gregory Sub-basin, and parts of the Jurgarra Terrace, the Mowla Terrace, Broome Platform, Barbwire Terrace and Crossland Platform (Figure 1). Figure 2 shows the lithostratigraphy of this part of the Canning Basin.
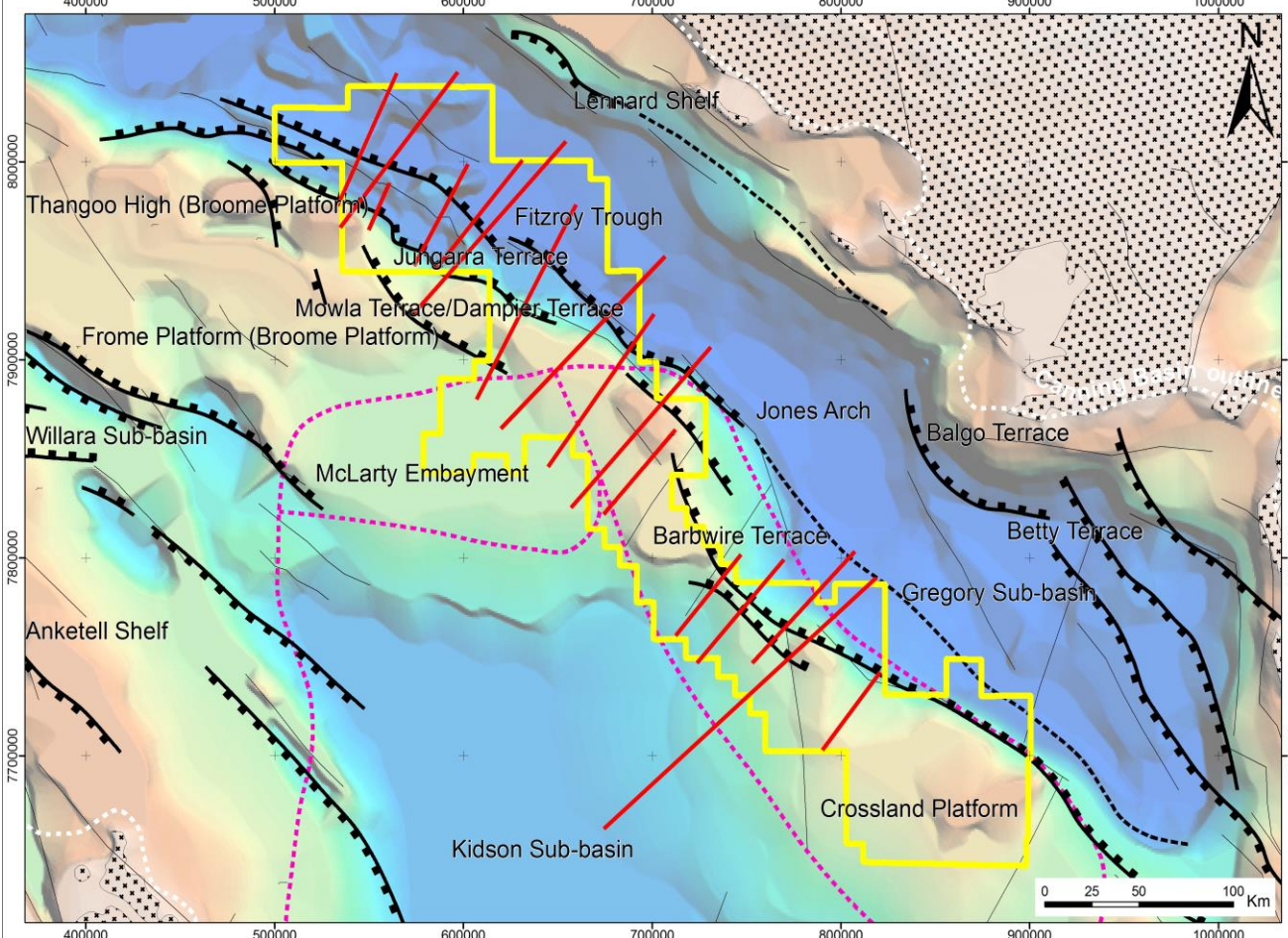

Figure 1. Location of the Airborne Gravity Gradiometer (AGG) survey (boundary shown in yellow) at the south-western margin of the Fitzroy Trough and Gregory Sub-basin. The location of modelled traverses is shown in red.
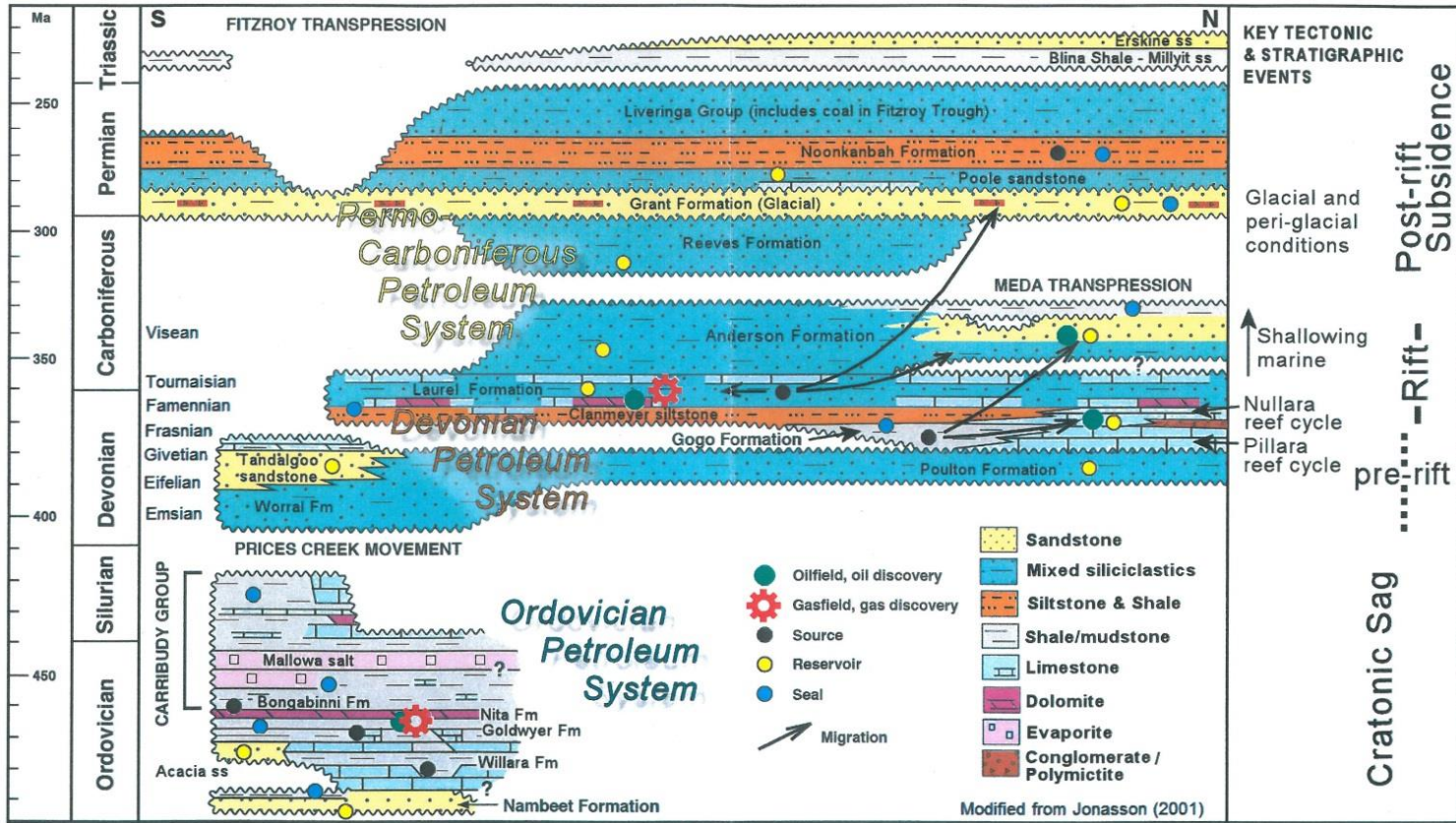
Figure 2. Schematic lithostratigraphy of the Canning Basin, with key tectonic and stratigraphic events and petroleum systems.

Available 'vintage' 2D seismic data was interpreted iteratively with AGG and airborne magnetic data, well, Landsat Geocover and SRTM (Shuttle Radar Topography Mission) data, along with published geological maps and literature.

The key to this integrated approach is the interpretation of seismic traverses with the assistance of AGG data, and particularly the validation of the interpreted seismic traverses by 2.5D gravity modelling. The workflow presented here resulted in a geological model and an overall better understanding of the 3D structure and stratigraphic relationships in the frontier basin. Gravity modelled traverses were used for further planning of seismic acquisition and input for 3D modelling.

Method

The integrated interpretation and modelling method involves the following stages:

(1) By integration of AGG and seismic data with all available datasets, structural interpretation maps of the intra-sedimentary fault structure (Figure 3a) and basement fault structure were produced. Intra-sedimentary features, including faults, were mapped at intermediate and shallow levels, and the distribution of the various gravity sources was mapped at an intermediate structural level (Figure 3b). AGG data were used to map structure between the seismic lines and in areas where seismic data was of low quality.
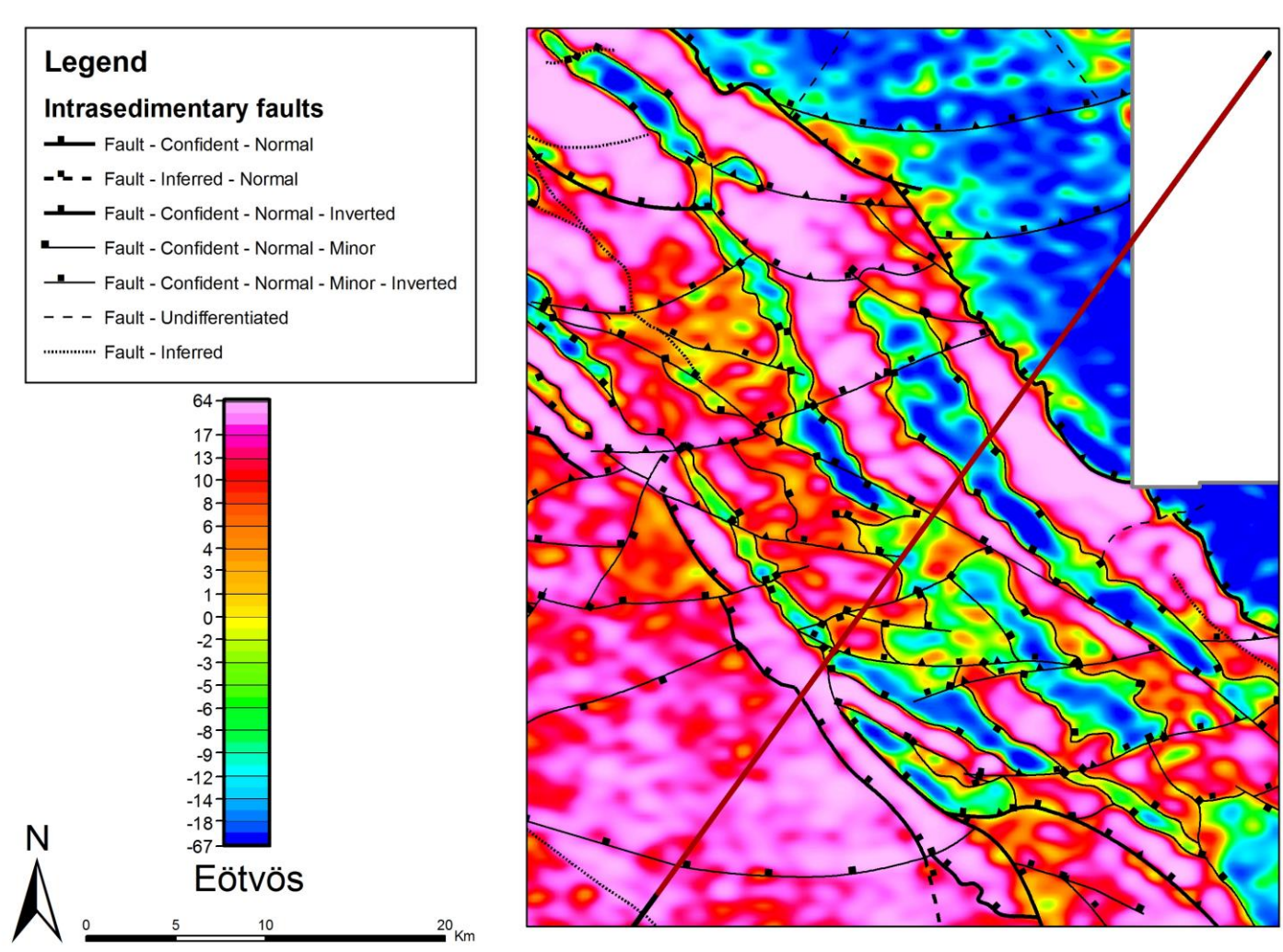

Figure 3a. Integrated structural interpretation of the AGG data in the vicinity of the traverse (red line) shown in figures 4 to 6. The mapped faults are overlain on the image of G_{DD}.
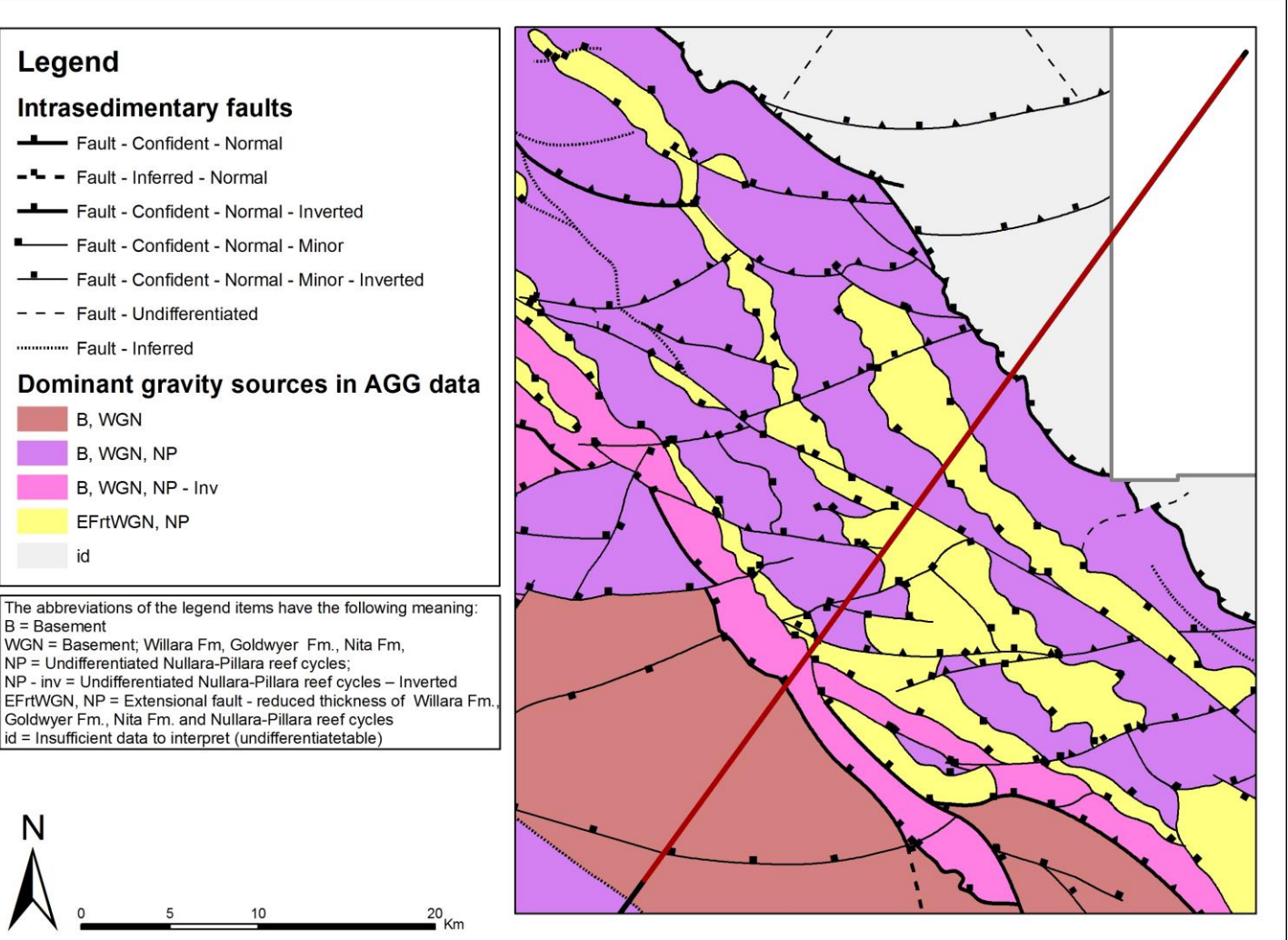
Figure 3b. Interpretation of the distribution of gravity sources identified by the integration of seismic and AGG data.

(2) Werner (Werner, 1953) and Euler (Reid et al., 1990) methods in line magnetic data were used to produce a depth to magnetic basement map.

(3) Before the potential field data interpretation project started, a seismic interpretation was performed by Buru Energy. Figure 4 illustrates limitations of some of the 'vintage' seismic data along one of the modelled traverses. It shows that the interpretation of some of the seismic lines is limited by data quality and further interpretation was only possible through integration with other data.
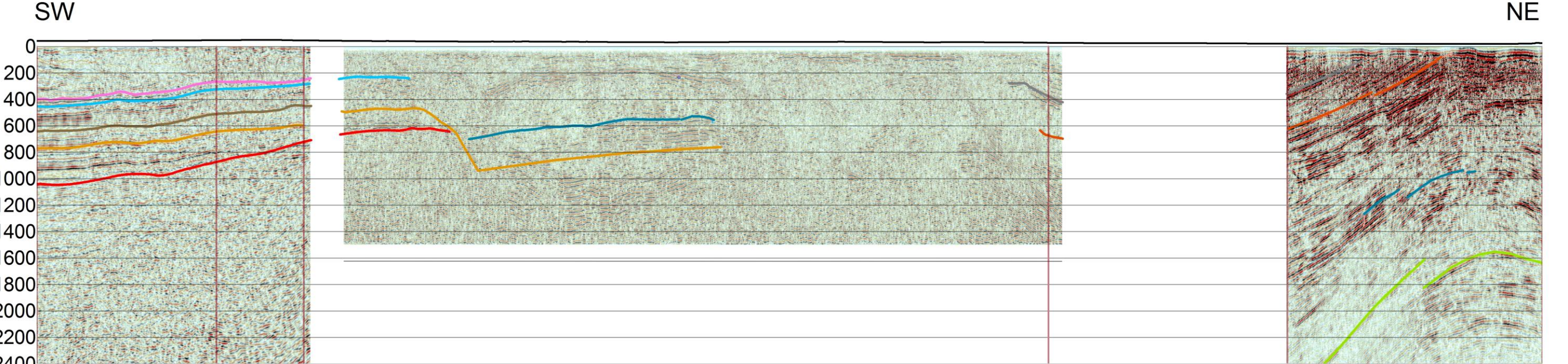

Figure 4. Seismic data along the modelled traverse shown in figures 4 and 5. Note the very different quality of the each of the seismic lines along this part of the traverse. The original seismic interpretation of this 'vintage' seismic data is shown on this figure.

(4) Seismic traverses crosscutting the survey area were reinterpreted using the integrated structural interpretation as a constraint (Figure 4). All selected traverses are NE-SW (Figure 1), each of them consisting of up to three seismic lines, occasionally with gaps in between (Figure 4). Images of the AGG data, AGG profile data (G_{DD} and g_D) and the structure maps were used together with the seismic data to constrain fault locations and depths as well as thickness distributions of geological units. Gradually an improved understanding of the tectono-sedimentary evolution of the basin was obtained, allowing for a better understanding of the deep structure.
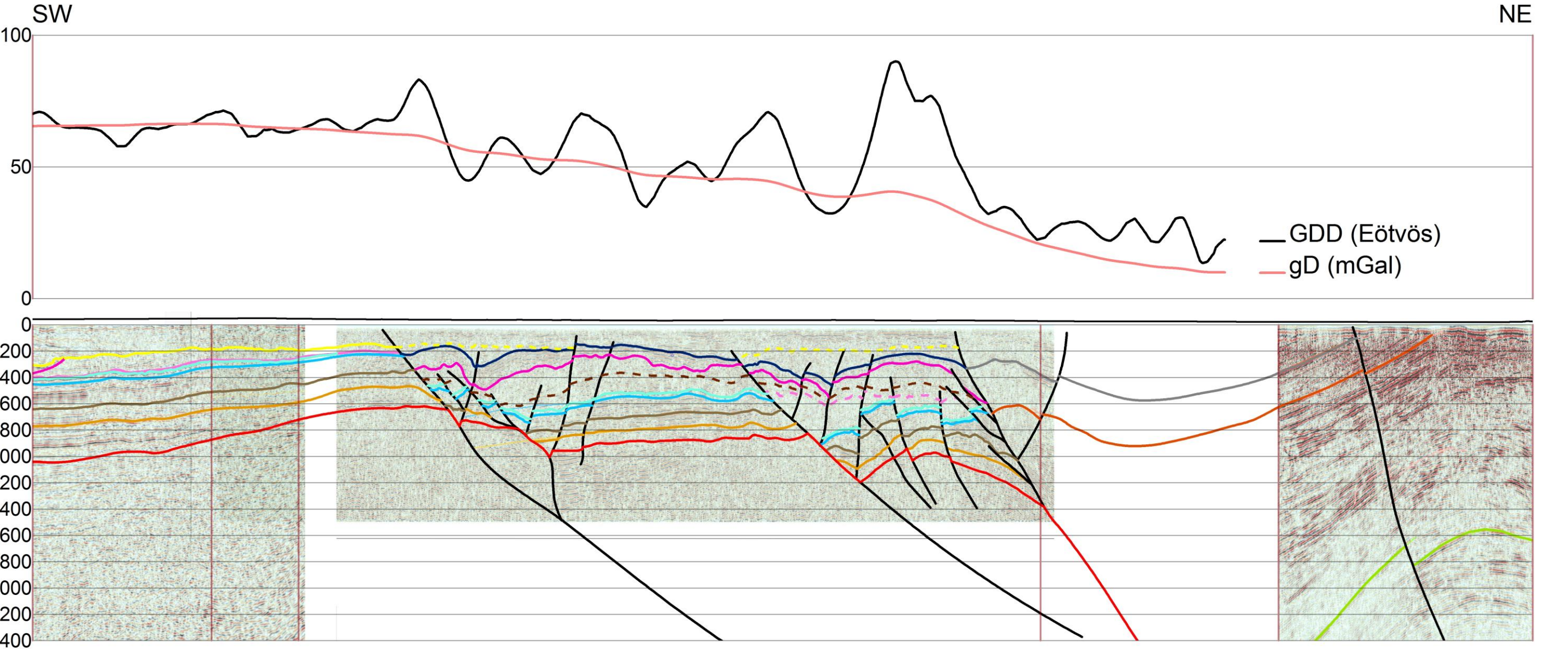

Figure 5. Final interpretation of the seismic traverse. This interpretation was produced using the conceptual geological model developed by the interpretation of the AGG data with the other available datasets. Profiles of the G_{DD} and g_D used to construct the position of faults and gravitational features on this traverse, are shown above. The vertical scale for the AGG data applies for the G_{DD} and g_D.

(5) Time-to-depth conversion of the interpreted traverses was completed using CGG's proprietary software LCT. Using velocity data from scattered wells in the area, the digitised interpreted seismic traverses were converted from the time domain to the depth domain.

(6) The interpretation of the seismic traverses was then validated by 2.5D gravity modelling. To account for excess or absent mass, modifications were made to the interpretation. In some cases multiple models were tested to assess the plausibility of alternative geological assumptions. Figure 6 shows an end result of the gravity modelling of the seismic traverse.

(7) Knowledge gained from the 2.5D gravity modelling was fed back into the structural interpretation maps to update the conceptual model. Using this workflow, significantly improved interpretation of 'vintage' seismic data can be achieved. A comparison of the initial seismic interpretation (Figure 4) to the final validated interpretation (Figure 6) clearly shows the value of integrating AGG and other datasets to produce an integrated interpretation that honours all data. Figure 7 shows the result of 6 modelled sections in the northern part of the survey in 3D view.
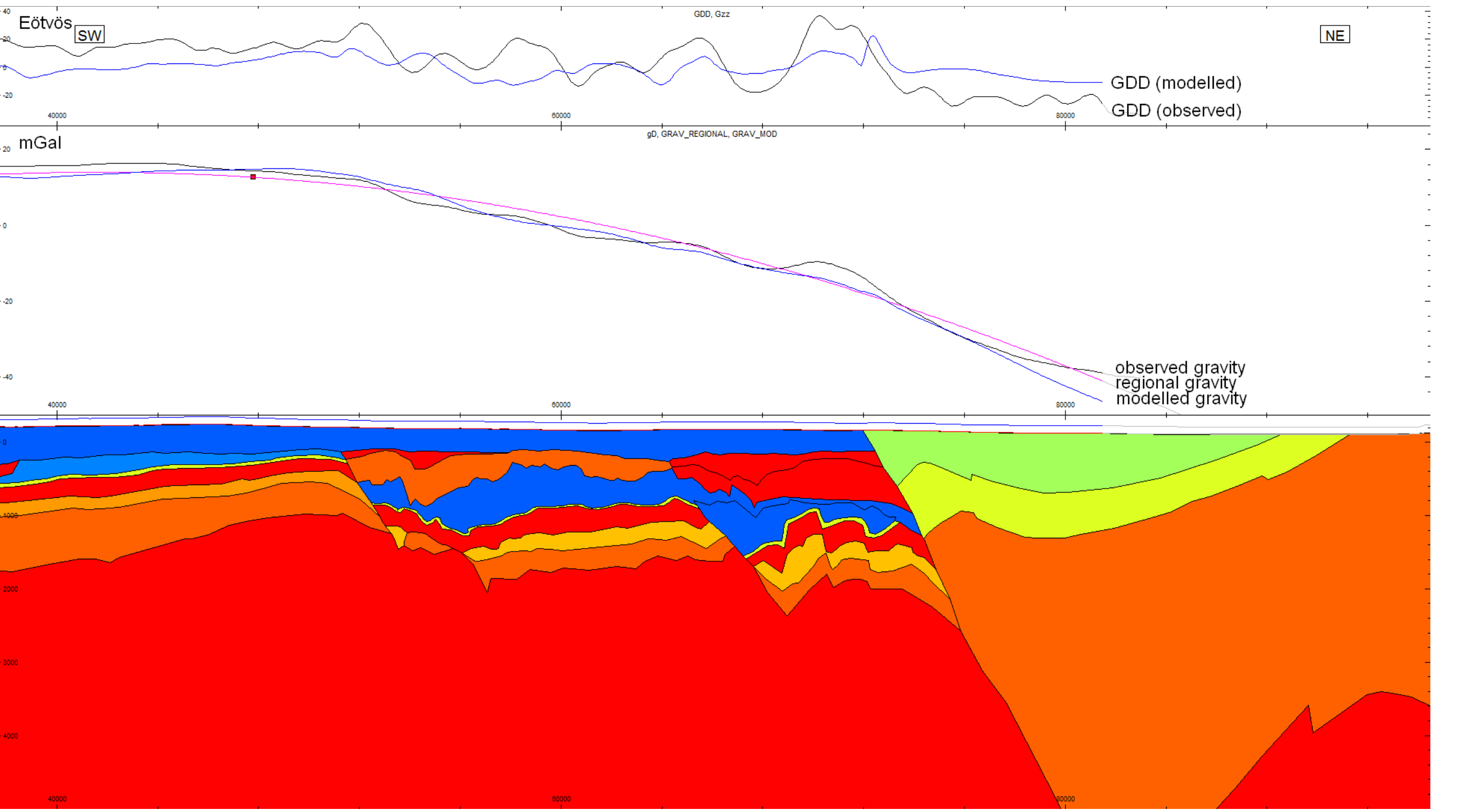

Figure 6. Final result of gravity modelling of the traverse shown in the figures 3 to 5. The vertical and horizontal scales of the section are in meters. Each colour shown in the modelled section represents a different density applied in the final model (in order of decreasing densities: red = 2.7 g/cm³, orange = 2.65 g/cm³, light orange = 2.6 g/cm³, yellow = 2.55 g/cm³, light green = 2.52 g/cm³, light blue = 2.37 g/cm³ and dark blue = 2.35 g/cm³).
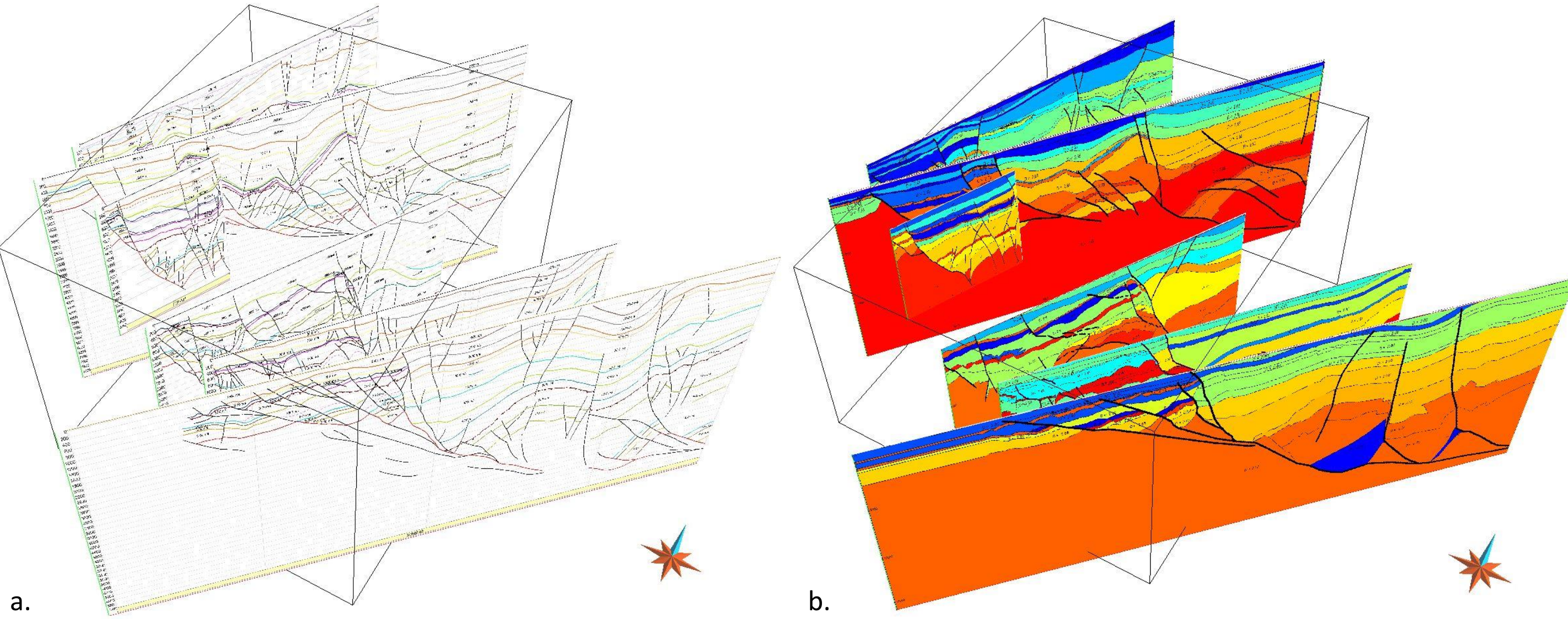

Figure 7. Final result of gravity modelling of the 6 traverses in the northern part of the survey area shown in a 3D view. The left image (a) shows the validated cross sections in time. These sections show all interpreted horizons and faults. The image on the right (b) shows the same sections in depth (vertical exaggeration 6x). The colours on these sections represent different densities, however the colours do not match between the cross sections. View from the SE.

(8) 3D geological modelling was performed in SKUA® GOCAD® after the completion of the 2.5D gravity modelling (Figure 8). The completed 2.5D modelled traverses (Figure 7) were used as input. The model was validated by forward modelling and inversion, using VPmg. Figure 9 shows the final result; a 3D voxel model.
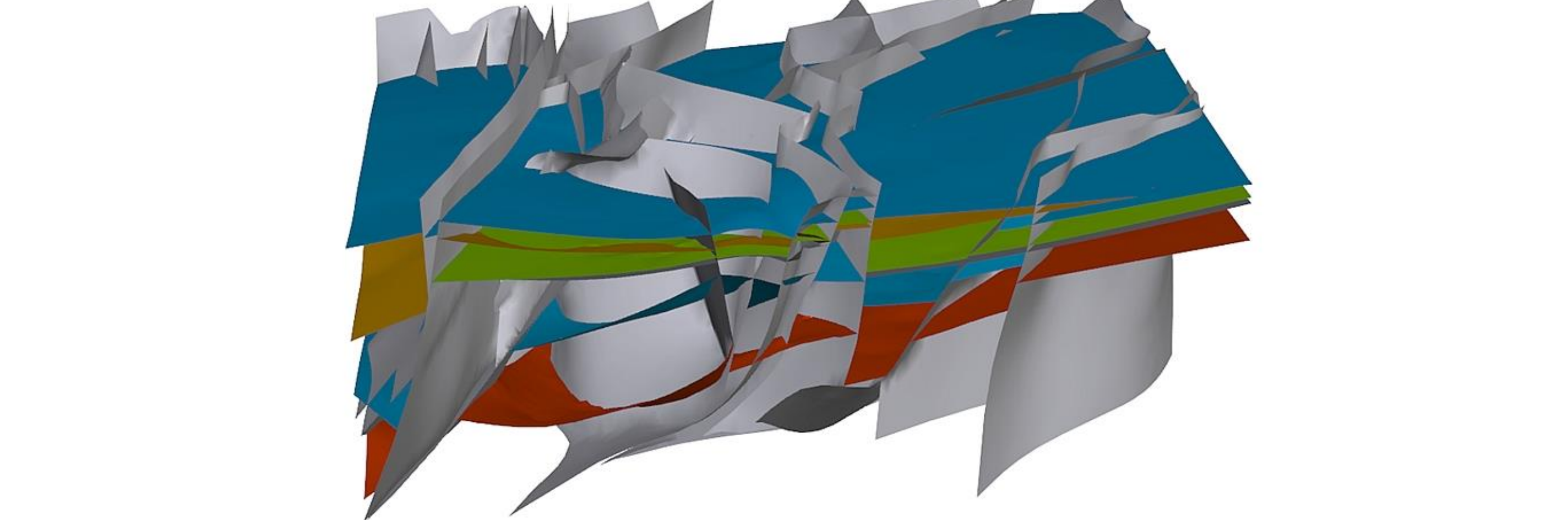

Figure 8. 3D Fault network (in grey) and horizons, produced in SKUA® GOCAD® for part of the survey area. The following horizons are shown: Top metamorphic basement (red), top Nita Formation (blue), Base Nullara-Pillara carbonates (dark grey), top carbonates of the Nullara and Pillara Fms. (light green), top Laurel Formation (brown) and PooleFM. ~/top Grant Formation (light blue). View is toward the east. The model shows an area of 83 km (N-S) x 71 km (E-W) and reaches a depth of 6.5 km.
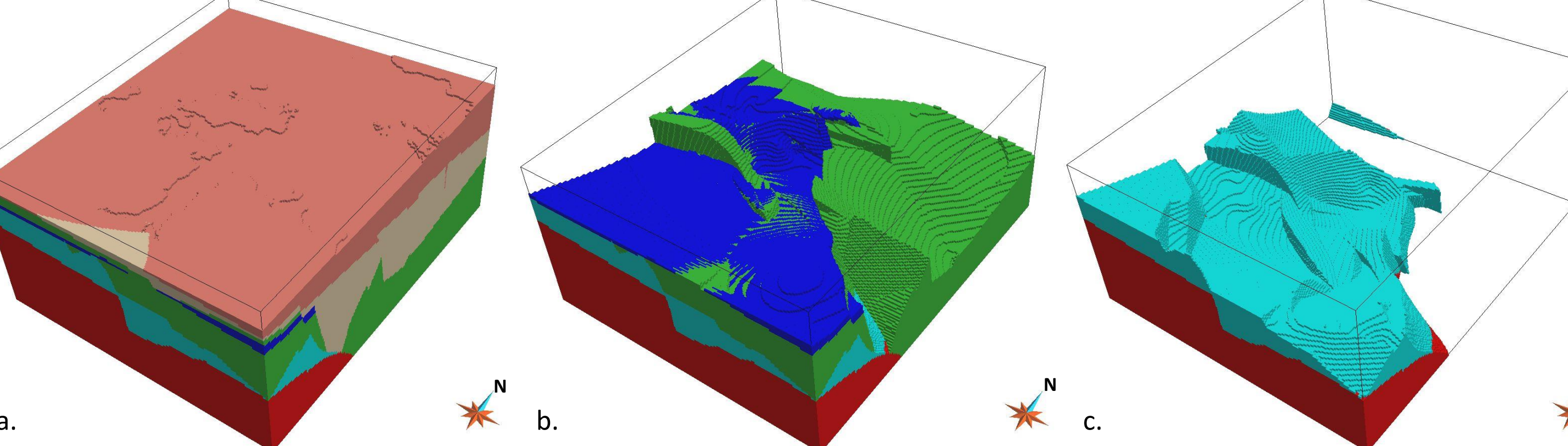

Figure 9. a. 3D voxel model of part of the survey area. Vertical exaggeration 5x. The geological intervals shown are: Metamorphic basement (red), top Nita Fm. to top metamorphic basement (light blue), top Laurel Fm. to top Nita Fm. (green), Nullara and Pilara Fms. (dark blue), Poole Fm./top Grant Fm. to top Laurel Fm. (beige) and surface to Poole Fm./top Grant Fm. (pink). b. The same model showing the distribution of the carbonates of the Nullara and Pilara Fms. (dark blue). c. A view of the structure at the stratigraphical level of the top Nita Fm.

Result

The result of this interpretation and modelling is an improved understanding of the 3D structure, stratigraphy and tectono-sedimentary evolution of the basin. The seismic data that was used to constrain the modelling could be interpreted with increased confidence to deeper levels, as the cross sections were validated by 2.5D gravity modelling. The detail of the interpretation, construction and modelling allowed the identification of potentially prospective stratigraphic units, structural trends, and prospective structures. The selection of areas for future exploration and seismic acquisition has been facilitated.

Conclusions

In underexplored frontier basins, like the Canning Basin, integrated interpretation of 'vintage' quality seismic data in conjunction with AGG data and the value of 2.5D gravity modelling of geological cross sections along seismic lines has proven to be valuable. Although there could be multiple solutions the guided interpretation of the vintage seismic data provides key geological insights to constrain the final inversions of the gravity data. By gravity modelling multiple seismic traverses the 3D understanding of the structure, stratigraphy and tectono-sedimentary evolution of the basin can be better understood. This ultimately leads to more informed exploration decisions, such as targeted seismic surveys and drilling locations.

REFERENCES
Reid, A.B., Allsop, J.M., Granser, H., Millet, A.J. and Somerton, I.W., 1990, Magnetic interpretation in three dimensions using Euler deconvolution: Geophysics, 55, 80-91.
Werner, S., 1953, Interpretation of magnetic anomalies of sheet-like bodies: S.G.U. ARSBOK, 43, 1-130.

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