Density Mapping Technology — A New Geophysical Method and Technology for Density Contrast Exploration in the Crust*

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Abstract

Density Mapping Technology (DMT) is new geophysical method that provides new information about the density variations in the Earth's crust. These density variations can be relevant during initial prospecting in regional scale and can also provide useful information in detail (e.g., structures with hydrocarbon reservoir).

The DMT has been used in different areas around the world, and this article is focused on the demonstration of the results related to hydrocarbon exploration. This technology is very well applicable in basin areas. For instance, it may help to find target horizons where DMT may significantly differ from Bouguer anomalies or to identify perspective zones in accordance with seismic profiles. Moreover, the DMT can be easily acquired within a short time and for reasonable costs, even in large unexplored areas. Moreover, this method does not require any physical measurements or personal exploration in the field.

One of the essential elements for the DMT is a numerical value of the constant W_0 (62 636 856.0 m^2/s^2). This global geodetic constant, representing the potential of the Earth, is not dependent on tidal disturbances and/or any other disturbing influences. Such constant can be used for any point on Earth as a supporting parameter. Eventually, this parameter has been internationally accepted and incorporated into the set of fundamental worldwide constants.

The DMT method is based on specifically derived application of the W_0 constant representing geoidal potential. This technology may be used to efficiently discover/reveal even small changes in density (Density Deviations) throughout the Earth's crust. Therefore, the DMT technology should be considered a valuable addition to the geological dataset that provides new information relevant for further geological interpretation and for making more accurate assessments during the prospective phase of any exploration.

Introduction

Density Mapping Technology (DMT) is a new geophysical method that provides new information about the density variations in the Earth's crust. These density variations can be relevant during initial prospecting, and in combination with other techniques they provide useful detailed information about the explored area (e.g., hydrocarbon reservoir structures). The DMT method calculates a new parameter, which we named Density Deviations (DD). Density Deviations are measured in m or m^2s^{-2}.

Calculation of Density Deviations uses the geoid potential W0 (62 636 856.0 m^2/s^2) together with an extensive set of coefficients and additional information (developed during the modeling of a real geophysical shape of Earth's body) in connection with altitude data from the explored area.

North Sea Case Study

The very detailed resolution of DMT allows precise density mapping of the explored areas. Density deviations reflect a wide range of different density features.

This case study shows DMT application in the northern North Sea. The gravity method reflects gross structure of the region. The Viking Graben area is marked by a positive zone in the gravity map, which is the effect of deeper structures of failed rift and high-density intrusive at the lower-to mid-crustal level (Lyngsie et al., 2006). Shallower structure of the region is better reflected in the DMT map, where effects of higher thicknesses of sedimentary sequences in individual sub-basins or elevated basement in horsts are reflected in DD values (Figures 1 and 2).

Density Mapping provides useful information about structural styles of the explored area. Complex structures, such as faults, folds, and their combination, commonly create density contrasts. Distribution of these density contrasts allows one to interpret structures, potential trapping system, role of faults in hydrocarbon migration paths, etc.

Figure 3 shows a DMT map compared to a gravity map in the area of western margin of Viking Graben, where productive hydrocarbon fields, like Statfiord, Gullfaks, Brent, and many others have been discovered. These fields are associated with pre-rift tilted fault blocks covered by younger sedimentary rocks. Clearly, the DMT map (Figure 3b,c,d) has better resolution and shows the N-S to NNE-SSW trend of anomalies and gradients. This is in concert with the strike of major faults and fault blocks, which were delineated by Fossen et al. (2000) (Figure 3c,d). Decrease of DD values in the eastern and southeastern direction reflects deepening of basement and increase of thickness of less dense post-rift sediments. This example shows that DMT allows basic structure mapping in unexplored areas or following continuation of structures known from seismic surveys to the areas without any seismic data.

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Rockall Trough Case Study

Rockall Trough, situated northwest of the British Isles, is another area where DMT has been tested. Figure 4 provides details of channel structures reflected in DMT and confirmed by the existing 2D seismic lines. Density contrast between sedimentary infill and basement results in a continuous trend which enables one to follow the shape and direction of the geological structures located between the 2D seismic lines. Boreholes with hydrocarbon shows (164/28- 1A, 154/01- 1) were located exactly in the zones confirmed by DMT.

This predetermines the DMT method to be an interesting tool for areas with low-spatial density of seismic data due to its capability to predict tendency of geological structures between the seismic lines, or even better, due to more precise planning of seismic data acquisition in the first stage of hydrocarbon exploration.

Shape and structure of crystalline ridge at the eastern margin of Rockall Trough are precisely reflected in the DMT map (Figure 5). Structure of this ridge was confirmed by 2D seismic lines and 2 wells. Comparison of the DMT map with the gravity map (Figure 6) clearly shows that the DMT method is very precise with better reflection of the geological features discussed above.

Beaufort Basin (Alaska) Case Study

Another region where DMT was tested is Beaufort Basin of Alaska North Slope. Based on the example of three seismic horizons (acoustic basement, Ellsmerian, Pro-delta) (Triezenberg et al., 2016), the DMT method is confirmed as the basin-infill monitoring tool. The DMT method reflects the area with structurally deepest position of the basement. Negative and positive zones in DMT predominantly correspond to the deepened or elevated parts of acoustic basement surface (Figure 7).

Main Applications of DMT

Our study clearly shows that new DMT method is a useful tool for:

- Precise density mapping
- Structural and tectonic mapping (interpretation)
- Increasing success of seismic surveys planning
- Exploration of the basement surfaces
- Monitor of basin infill

The main added value of the DMT Method and Technology is:

- Success increase in seismic surveys planning
- Monitor and supply of information on seismic interpretation
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References Cited

Fossen, H., T. Odinsen, R.B. Færseth, and R.H. Gabrielsen, 2000, Detachments and low-angle faults in the northern North Sea rift system: Journal of the Geological Society of London, v. 167, p. 105-131.

Lyngsie, S.B., H. Thybo, and T.M:Rasmussen, 2006, Regional geological and tectonic structures of the North Sea area from potential field modelling: Tectonophysics, v. 413, p. 147–170.

Triezenberg, P.J., P.E. Hart, and J.R. Childs, 2016, National archive of marine seismic surveys (NAMSS): A USGS data website of marine seismic reflection data within the U.S. Exclusive Economic Zone (EEZ): U.S. Geological Survey Data Release. doi: 10.5066/F7930R7P.

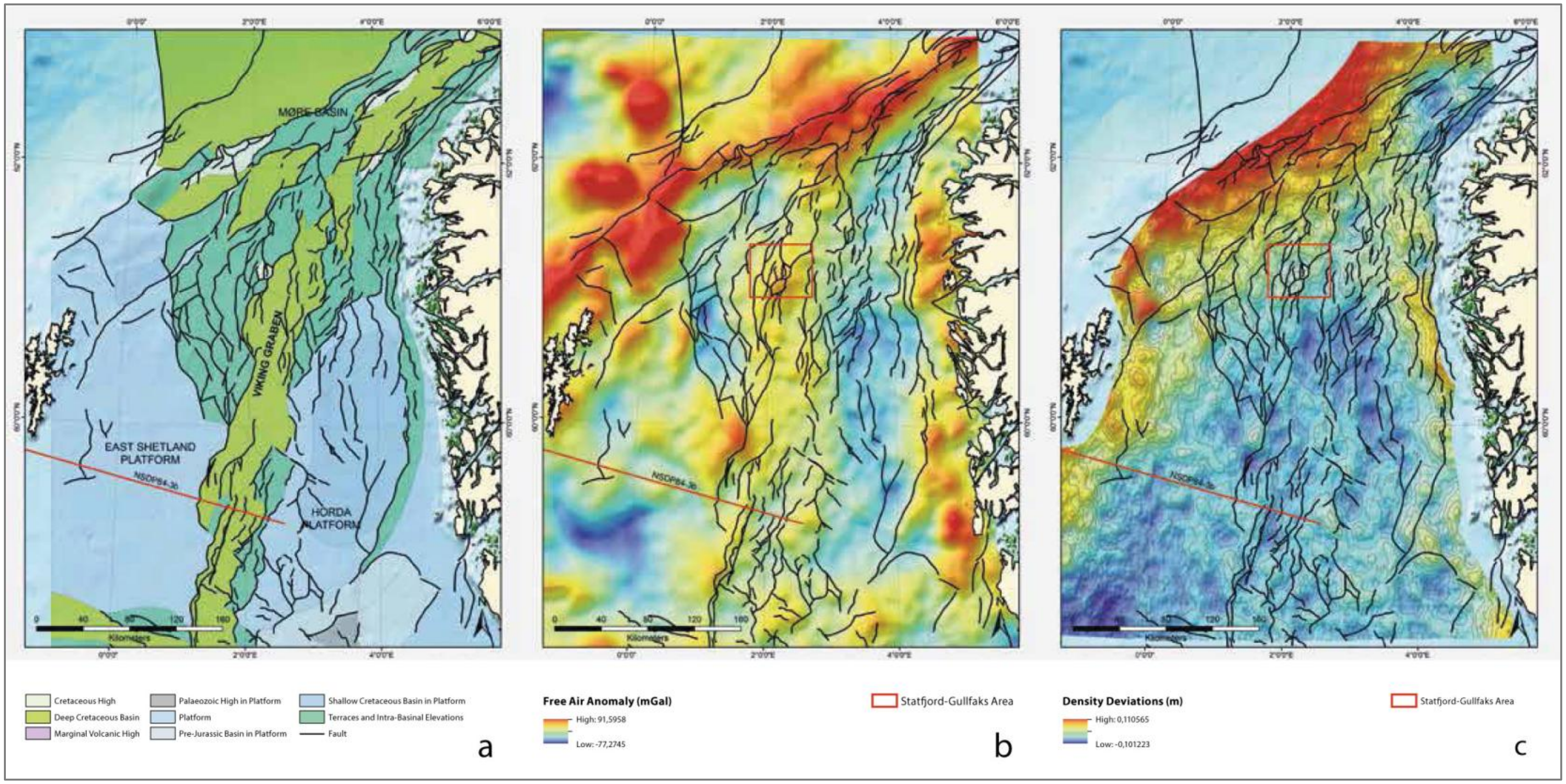

Figure 1. Comparison of a gravity map (b) and a DMT map (c) in the northern part of North Sea. Simplifieded geological structure of the area (a) is taken from The Norwegian Petroleum Directorate.

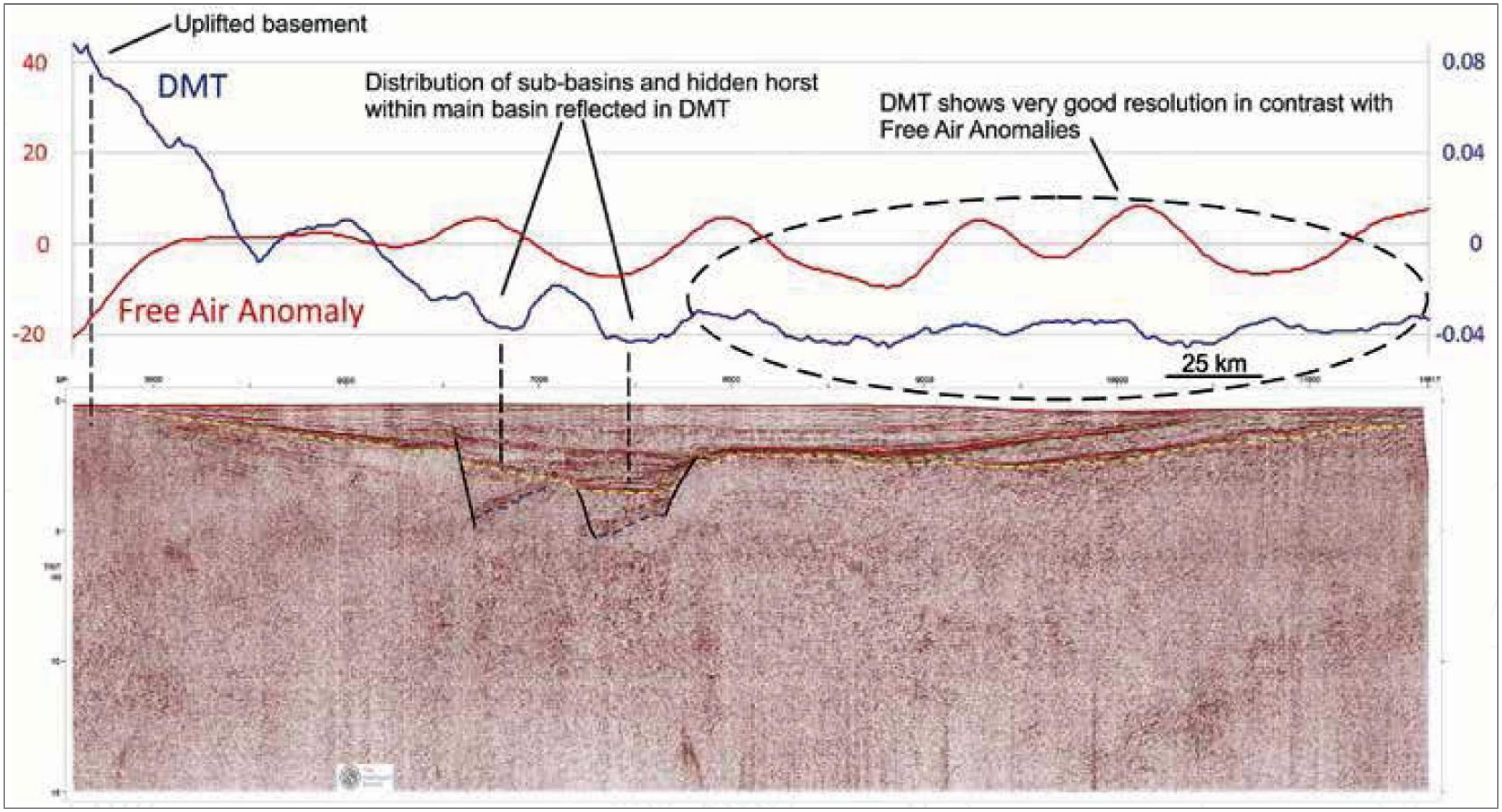

Figure 2. Gravity (free-air anomaly) and DMT curves above eastern part of deep regional seismic profile NSDP84-3 (BIRPS survey; taken from VSA seismic atlas).

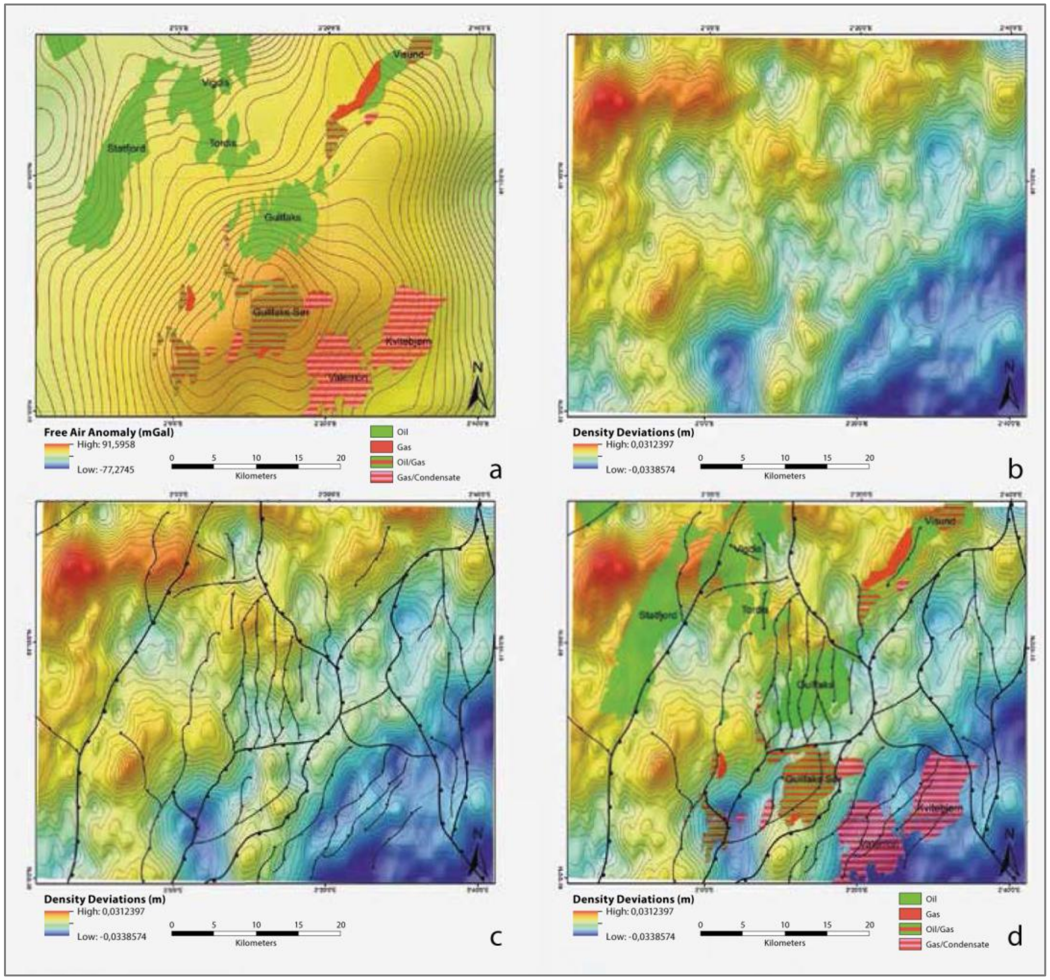

Figure 3. Detailed structure of Statfjord-Gullfaks area and its reflection in a DMT (b, c, d) map compared to a gravity map (a). Position of hydrocarbon fields (a, d) is taken from the Norwegian Petroleum Directorate.

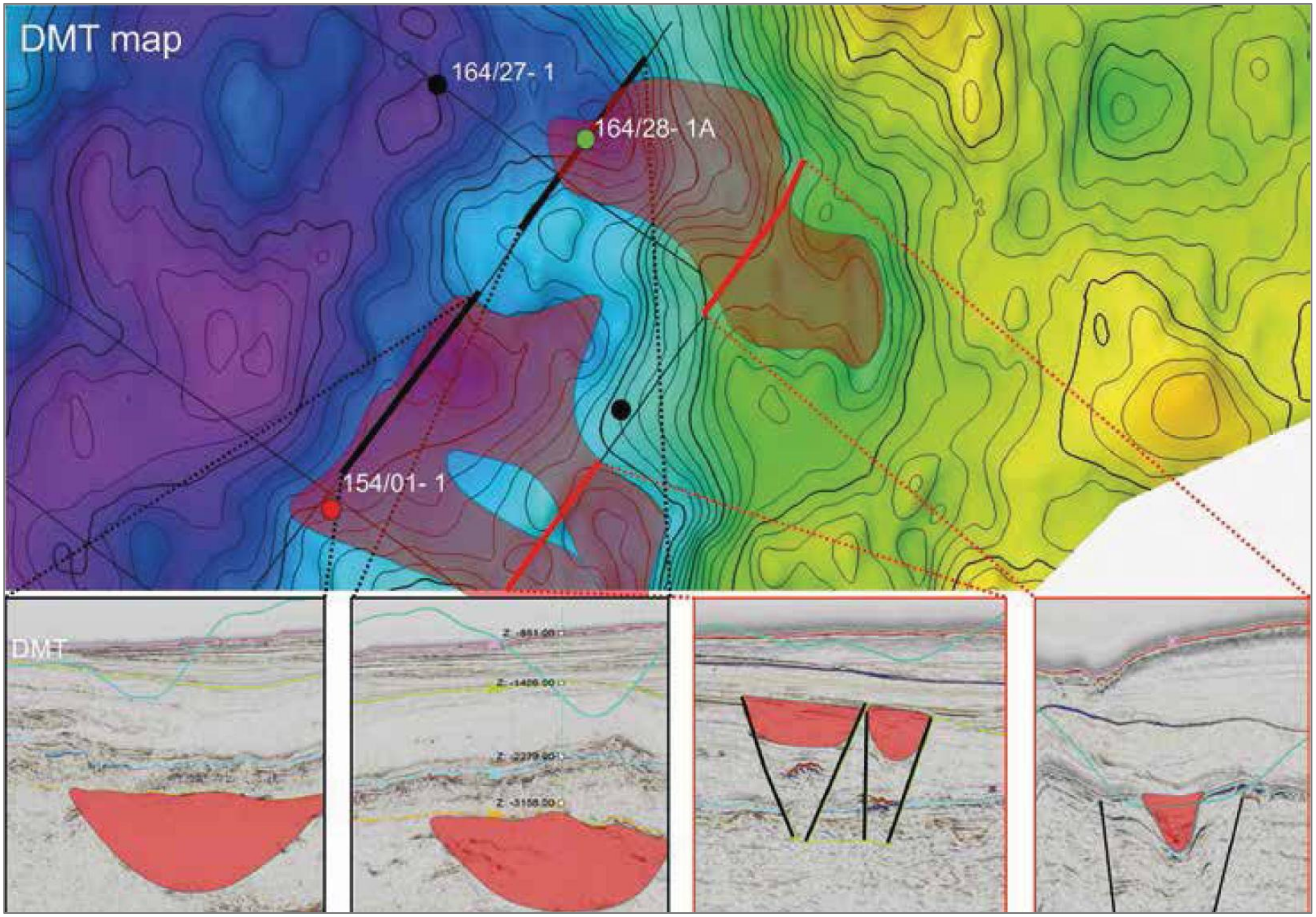

Figure 4. DMT map reflects channel structures confirmed by the existing boreholes and 2D seismic lines.

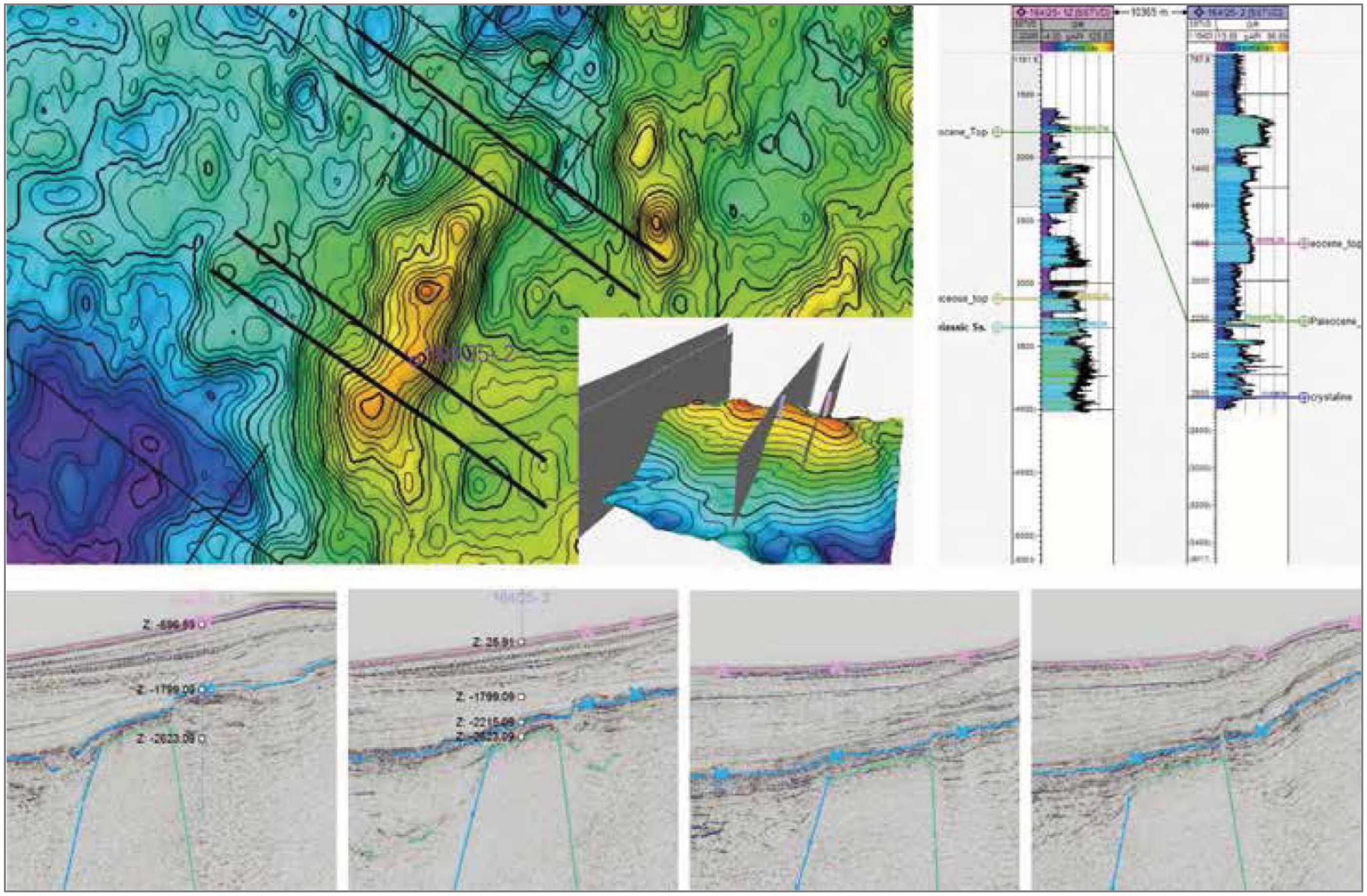

Figure 5. Elevated ridge of crystalline basement buried below sedimentary sequences and lava flows.

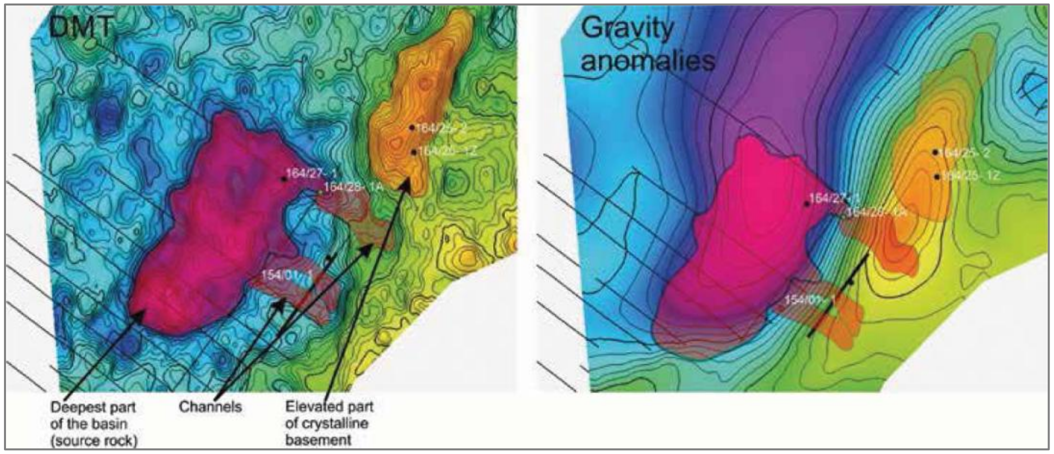

Figure 6. Difference between gravity anomalies (right) and the DMT method (left). Marked geological structures show the deepest part of the basin, channels, and elevated crystalline basement.

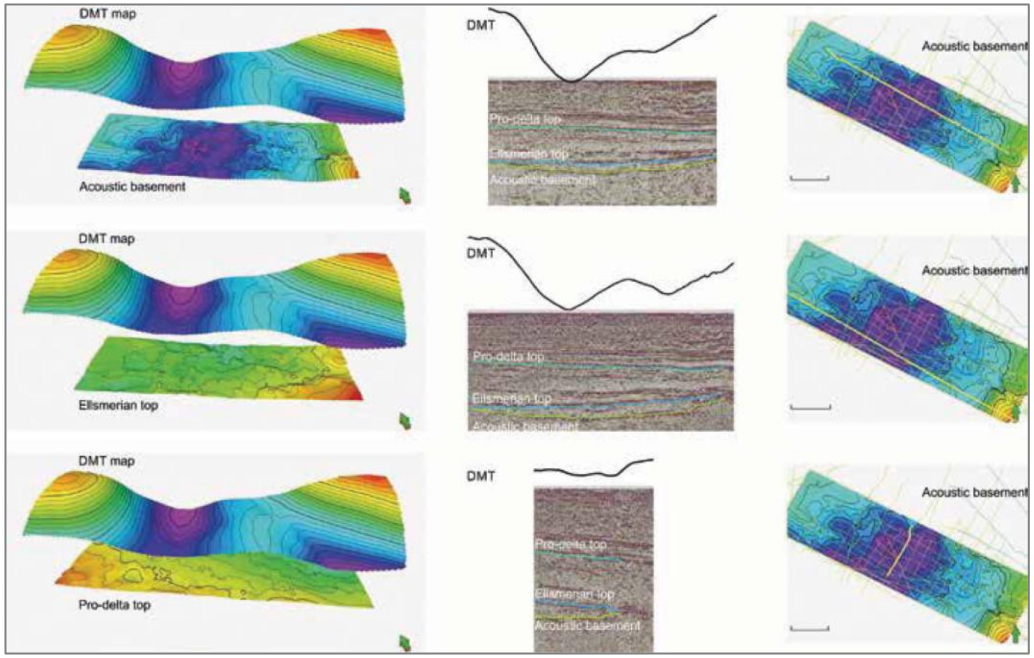

Figure 7. Role of different surfaces in the Beaufort Basin in DMT.