Application of Marine Magnetic and Gravity Data in Mapping Basement and Sedimentary Horizons in the Rovuma Basin, Mozambique*

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Abstract

Marine magnetic and gravity data, acquired in 2010 during seismic data acquisition over part of the Rovuma Basin, Mozambique, was used to map basement and two intra-sedimentary horizons. Depth estimates to these three horizons were derived from the interpretation of energy density spectra of magnetic and gravity data. Magnetic lineaments corresponding to fault patterns were interpreted from the magnetic data using the ACM (Automatic Curve Matching) method (Shi, 1993).

The new spectral technique named Multi-Window-Test (MWT) was used in this project to detect magnetic susceptibility and density contrasts within the sediments at stations located on a regular mesh which covers the whole project area. The lateral correlation between stations allowed the identification of multiple horizons. The results derived from potential field data show a good correlation with seismic and well intersections.

Introduction

A study of potential field data covering the offshore Rovuma Basin in Mozambique was conducted to map the crystalline basement and two intra-sedimentary horizons of Cretaceous and Jurassic age, as well as to determine the major fault structures within the basement.

The magnetic and gravity data were acquired at the same time as marine seismic and the survey had a shiptrack spacing of 2.5 km. in the northwest and 5 km, elsewhere. Data was acquired in both north-south and east-west directions. It was gridded at 500x500 m where the shiptrack spacing was 2.5 km. and at 1x1 km. for the whole area (Figure 1).

The horizon mapping was undertaken using the Energy Spectral Analysis method in two stages; (1) The MWT spectral technique was applied to gridded magnetic and gravity data to identify the horizons. (2) The ESA-MW technique was used to conduct detailed mapping of basement and the two sedimentary horizons that were identified. These two steps of analysis were repeated for each horizon that was interpreted.

The ACM method was applied to located magnetic data along profiles extracted from the TMI grid, to define major faults and magnetic lineaments indicating the structural grain of the region.

Methodology

Energy Spectral Analysis (ESA) is a well established technique for estimating the depth to a magnetic/gravity horizon, originally based on the work of Bhattacharyya (1966). Following Spector and Grant (1970), a magnetic/gravity interface is modeled by a statistical layer of magnetized multi-prisms. The logarithm of the radially averaged spectrum plotted vs. radial frequency produces a function where slopes tangent to the decay of the function are proportional to the depth to source(s). In order to obtain an estimate of depth in a localized area, ESA is applied to a windowed sub-region of the potential field data. By performing the ESA-Moving Window (ESA-MW) procedure at multiple locations, a depth map of the interface can be produced (Kivior et al., 1996).

ESA-Multi Window Test (ESA-MWT)

The MWT procedure consists of calculating energy spectra over a series of increasingly larger windows (Figure 2), all centered over a point of interest. Ranges of window sizes where the derived depth value is nearly constant, "Depth-Plateaus", indicate both a suitable window size for performing ESA-MW in the neighbourhood and the approximate depth to a magnetic/gravity interface.

Coupled with fast, automatic spectral decay estimation, the MWT can be applied along a profile or over a whole survey area on a regular mesh, to quickly map both depth estimates and stable window sizes for ESA-MW. Each station can have multiple depth-plateaus, and these can often be successfully identified with distinct magnetic susceptibility or density interfaces. At any station, the MWT may identify, from the depth-plateau, the approximate depth to the mapped horizon and estimate the corresponding optimal window size. Plotting all depth-plateaus along a profile can simultaneously image multiple horizons. Depth-plateaus identified as the same interface, form a coarse image of the detected horizon, called a *'horizon skeleton map'*.

Geological Setting

The formation of the Rovuma Basin is related to the break-up of Gondwanaland. N-S, NE-SW and NW-SE trending faults evolved as a consequence of the opening of the Madagascar Strait (Salman and Abdula, 1994) (Figure 3).

The region has undergone two main tectonic phases. Firstly; rifting occurred in the Triassic as Gondwana started to break up. This resulted in the formation of N-S to NW-SE trending faults and the formation of a horst/graben system. Rifting ceased in the Jurassic and active sea floor spreading took place to the north and to the south of Madagascar. This resulted in transform faults forming along the N-S fault system developed in the Triassic. During this time a number of E-W extensional fault structures formed within the basin. As a result of this tectonic activity, the offshore Rovuma Basin is structurally dominated by a horst/graben system along with tilted block/half grabens.

Horizon Mapping in the Rovuma Basin

One of the objectives of the study was to detect and map basement and other intra-sedimentary horizons using ESA-MWT. MWT conducted at the stations located on a 10x10 km + 5th point mesh, was used to estimate spectral decay, in order to detect depth-plateaus to obtain an average estimate of depth to the targeted horizons and to identify optimal window sizes for more detailed horizon mapping (ESA-MW). This was undertaken every 2.5x2.5 km plus 5th point in area-1 and 5x5 km in area-2. Each depth plateau corresponds to various magnetic or density (in gravity data) interfaces. These depth plateaus are related to the following horizons, Basement (Horizon 1), Jurassic (Horizon 2), Cretaceous (Horizon 3). In the first stage, depth plateaus were detected and approximate, average depths from plateaus were used to create a skeleton map for the horizons mentioned above. In the next stage, the optimal window size was determined from the depth plateaus and used to conduct detailed horizon mapping.

The detailed mapping interpretation was performed using the ESA-MW technique. For both data sets, spectra of different window sizes were computed on a very dense mesh of 2.5x2.5 km. Basement and Jurassic (Horizon 2) were mapped using spectra computed from gravity and magnetic data and the shallower intra-sedimentary interface (Horizon 3) of Cretaceous age was mapped only from gravity data. As the magnetic and gravity data are derived from sources with different rock properties, the same horizons may not necessarily be mappable using both data sets.

Detailed Mapping highlights many small features and structures which could be of great importance and add value to the exploration programme.

Comparison with Seismic Data

The results of the magnetic and gravity data interpretation were plotted against available seismic profiles. The comparison shows a very good agreement in configuration of the basement geometry (Figure 4).

Magnetic Lineaments

The ACM method is the main tool used by Archimedes to interpret magnetic lineaments and faults. The main purpose of the ACM interpretation work undertaken as part of the project was to assist in the understanding of the structural fabric of the study area.

The output of ACM processing is a 3D cube of points representing the centres of magnetic bodies detected from the magnetic data through an automated procedure. The ACM method was applied to profile data extracted from the TMI grid.

Conclusions

The new spectral technique called Multi-Window-Test (MWT) was used to detect magnetic susceptibility and density contrasts within the sedimentary section at stations located on a regular mesh covering the project area. Lateral correlation between stations allowed the identification of several horizons. The results derived from marine magnetic and gravity data show a good correlation with seismic data and well intersections. The Energy Spectral Analysis method was successfully applied in the Rovuma Basin and the new MWT technique proved to be a valuable tool in mapping sedimentary horizons from the potential field data.

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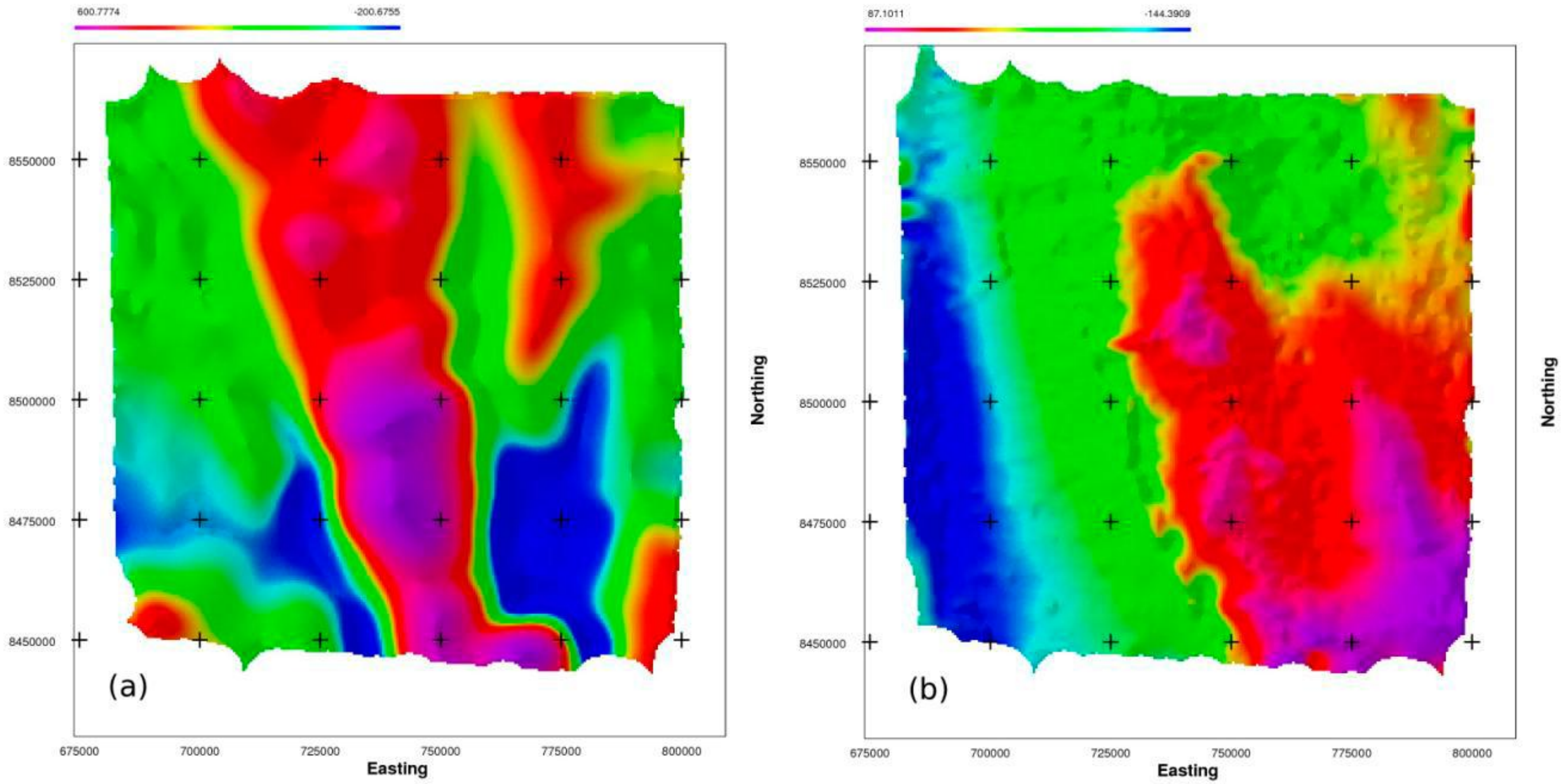

Figure 1. Reduced To the Pole (RTP) image (a); Bouguer gravity image (b).

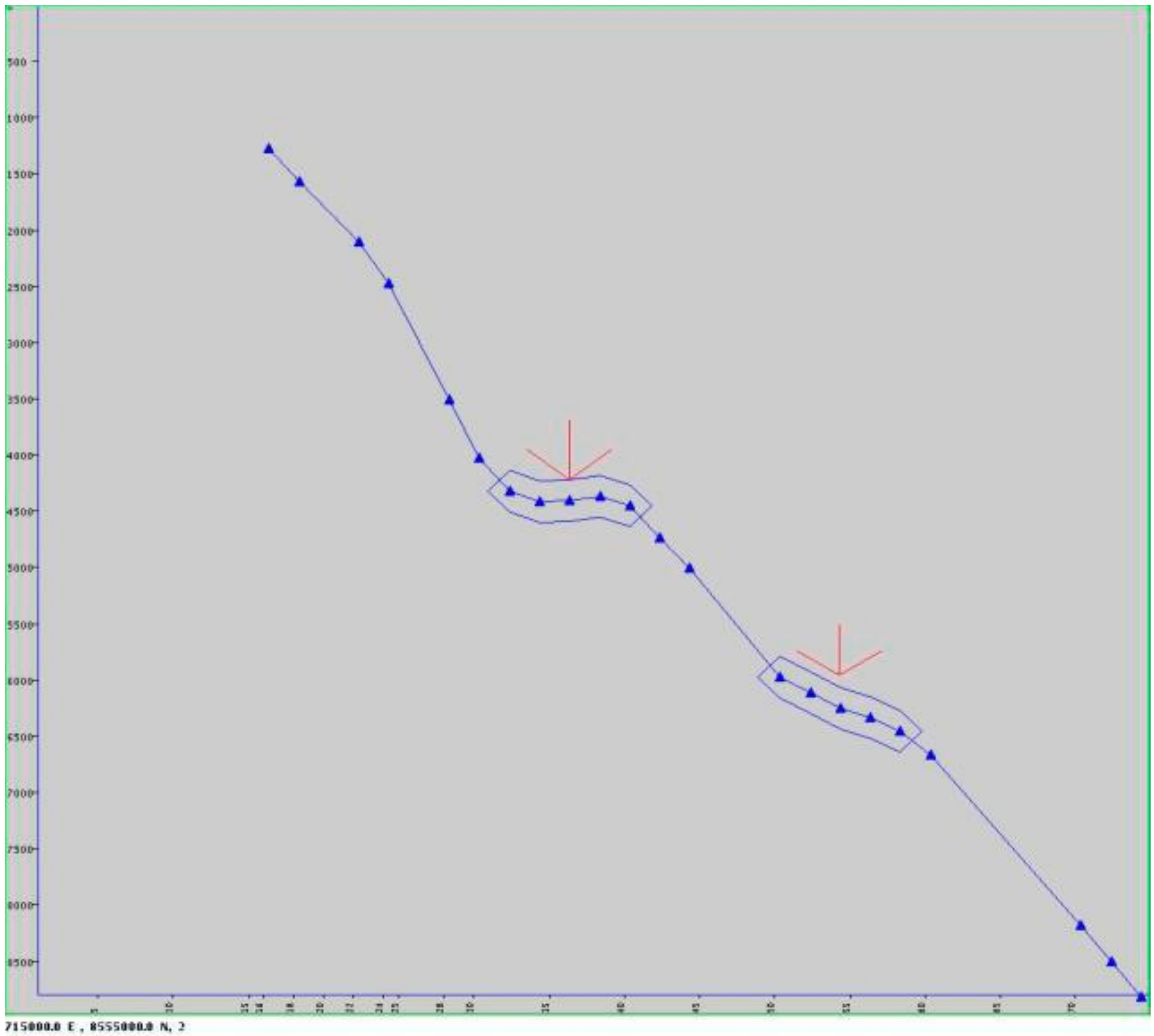

Figure 2. Example of MWT depth vs. window size graph.

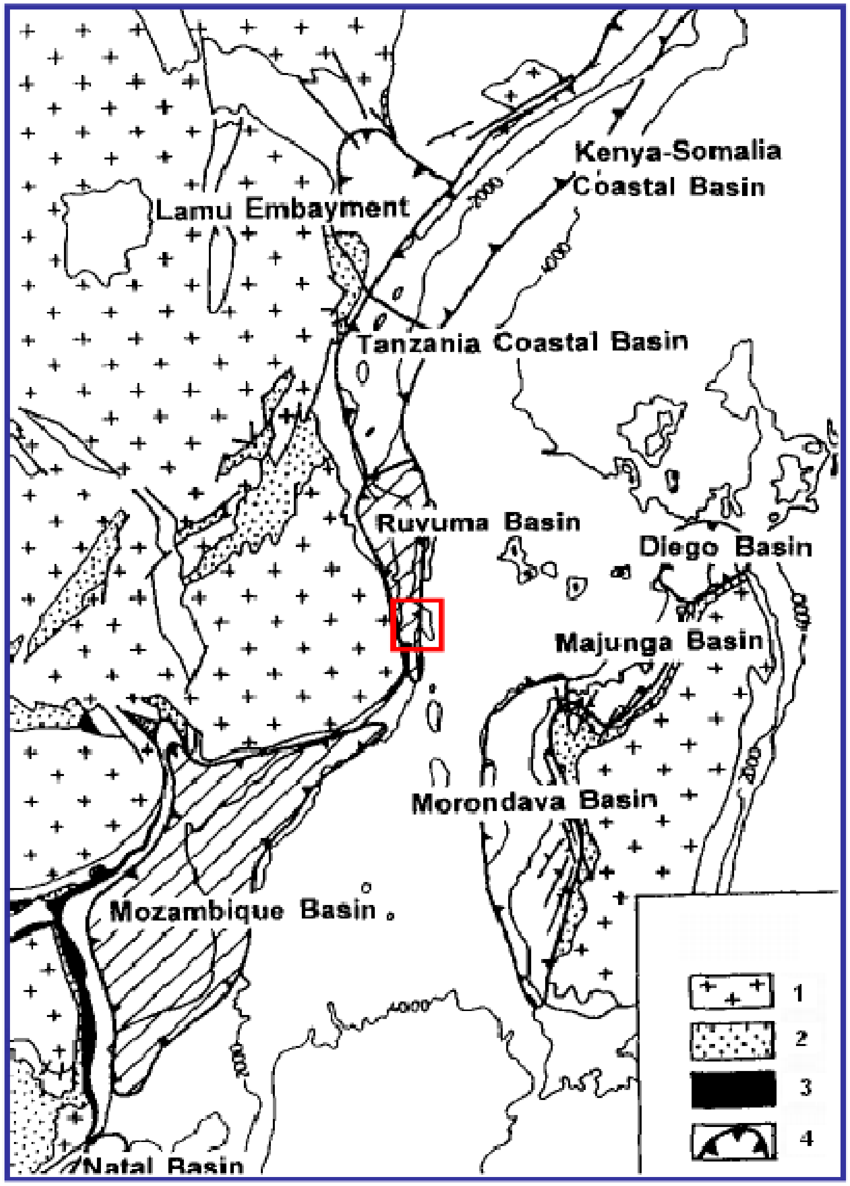

Figure 3. Marginal basins of East Africa, showing the location of the study area marked in red: 1 = basement; 2 = Karoo sediment outcrops; 3 = Karoo volcanic outcrops; 4 = marginal sedimentary basins.

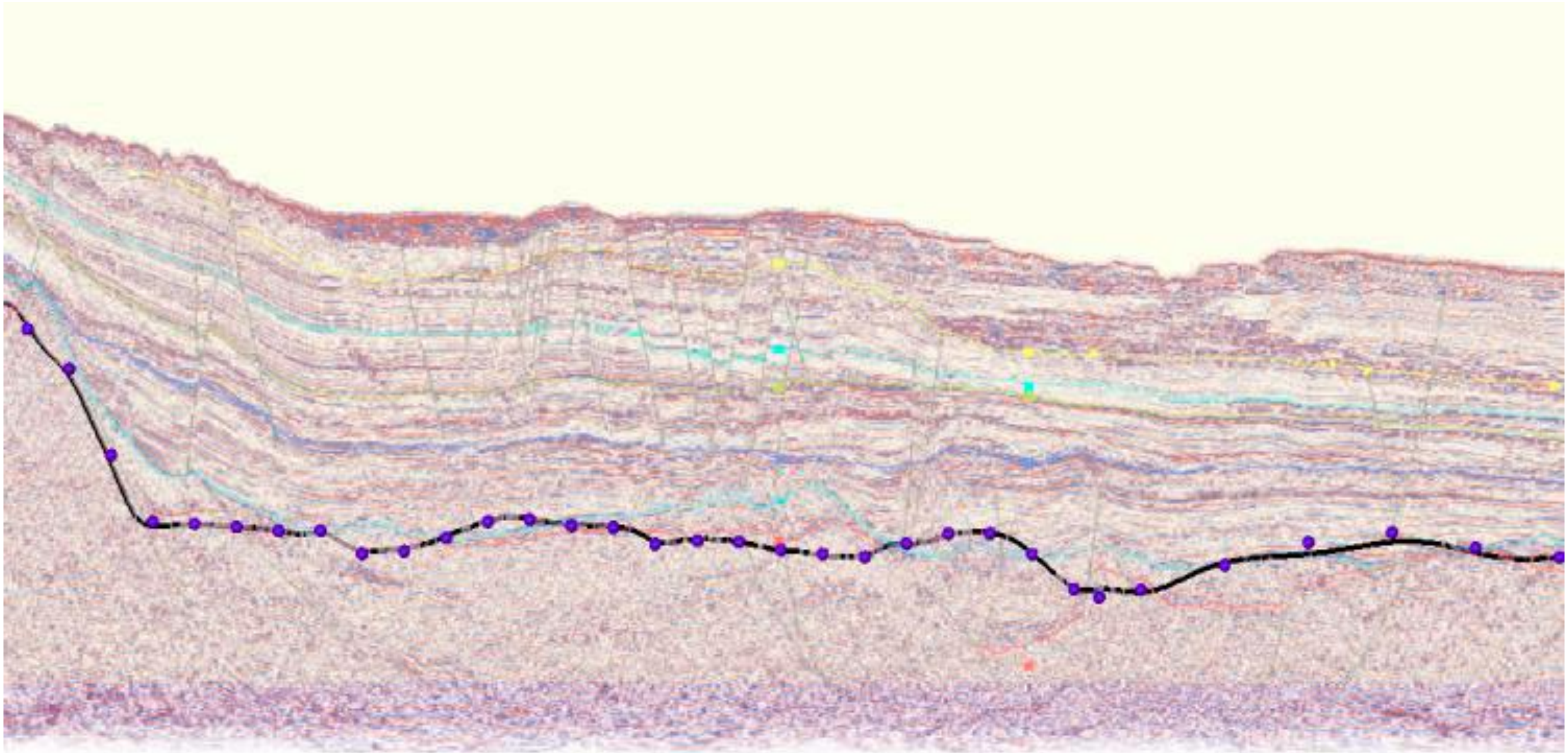

Figure 4. Comparison of magnetic data interpretation (blue dots) with seismic, along Line 06.