Fusion of Enhanced Gravity and Magnetic Signatures for Continental-Oceanic Boundary (COB) Mapping: Offshore Gabon Example

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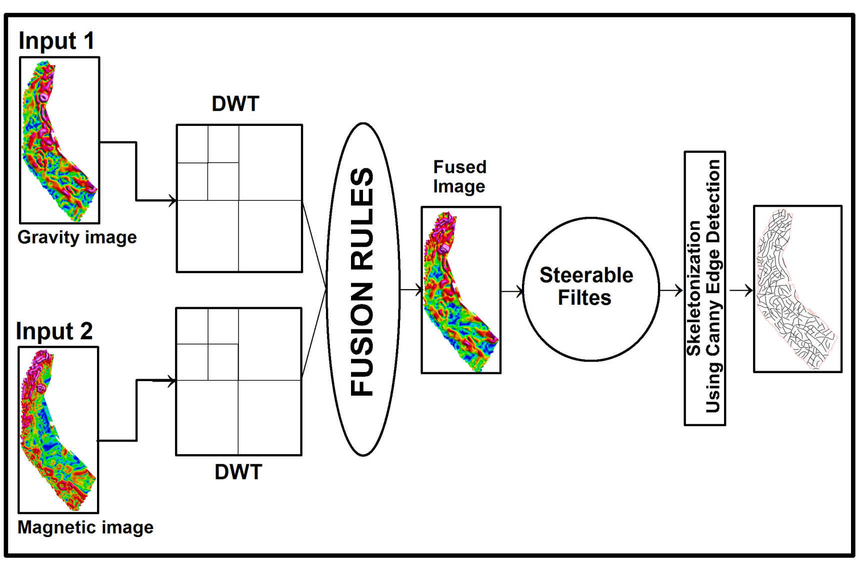
A reliable and accurate mapping of the continental-oceanic boundary (COB) becomes an increasingly important factor in various aspects of a deep-water petroleum exploration: geological (basin tectonics, petroleum potential), economical (acquisition programs, lease block boundaries) and, sometimes, political (continental margin claims). Different origin, lithologies, physical properties and tectonic histories of the oceanic crust and transitional-continental crust make a basis for differences in magnetization, density, sedimentary basement depth and structural deformation of their associated rock complexes. Accordingly, all these differences result in different amplitudes, wavelengths and spatial arrangement of gravity and magnetic anomalies (i.e. anomalous signatures / textures or structural grain) on both sides of the COB.

It was shown (Goussev et al., 2008) that one of the ways to make these differences better visible is the calculation of horizontal gradients of the downward-continued reduced-to-Pole magnetic field (Fig. 1) and depth-separation-filtered isostatic gravity (Fig. 2). The yellow dashed line is the mapped COB. Note that enhanced anomalous signatures have a mutually constraining character: high-amplitude closely-spaced magnetic signatures are on the oceanic side of COB (Fig. 1) and similar but less densely spaced gravity signatures with a distinct and continuous anomaly along the COB are on the continental side (Fig. 2).

However, a 100 km right-lateral displacement along NE-SW trending transfer fault has created a local ambiguity in correlation of the COB (circled area) as a strong gravity gradient anomaly here is not constrained by equally intense magnetic signatures and, hence, it could be caused by a structural deformation within the attenuated continental crust.

Additional opportunities for enhancement of local anomalous signatures to resolve this ambiguity we found in two advanced image processing techniques: fusion and steerable filtering. The applied flow-chart is shown below.



Our version of the fusion is based on a spectral decomposition with 2D discrete wavelet transform (DWT) to combine both grids. The fused image is shown on Fig. 3. The steerable filtering can be described as a 360^0 directional filtering with calculation of high-order derivatives and skeletonization-type (one pixel line width) visualization of obtained lineaments. The result of steerable filtering of the fused image is shown on Fig. 4.

After steerable filtering, the area of ambiguity in COB mapping (circled area) shows a distinctly different spatial arrangement of enhanced lineaments / anomalous signatures on opposite sides of the COB and effectively eliminates the ambiguity of its mapping here.

Conclusions:

1. Calculation of horizontal gradients of enhanced gravity and magnetic fields makes visible their anomalous signatures (structural grain) that are distinctly different and mutually constraining on opposite sides of the COB.
2. Difference in enhanced anomalous gravity and magnetic signatures and their mutually constraining character can be used as reliable criteria for the COB mapping.
3. Fusion combines the calculated gravity and magnetic gradient grids into one image where additional enhancement of differences in anomalous signatures on opposite sides of COB is achieved by application of a steerable filtering.
4. Cascaded enhancement of the anomalous gravity and magnetic signatures is capable to provide the accurate and laterally resolving mapping of the continental-oceanic boundary (COB) in structurally complex areas.

References:

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2. Hassan, H.H., and Peirce, J.W., 2008. Fusion of airborne gravity and magnetic images for improved detection of structural control. CSEG-CSPG-CWLS Convention. Technical Program Expanded Abstracts. Calgary.
3. Hassan, H.H., and Peirce, J.W., 2007. Mapping geological features in HRAM data using 2D steerable filters and its comparison to 2D wavelet transform. 77th Annual SEG Convention. Technical Program Expanded Abstracts. San-Antonio.

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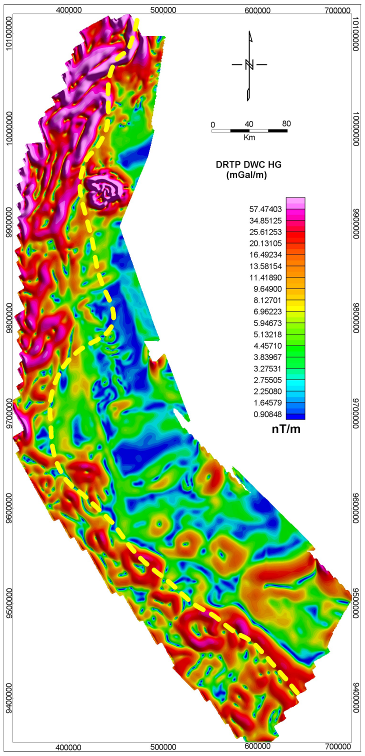

Fig. 1

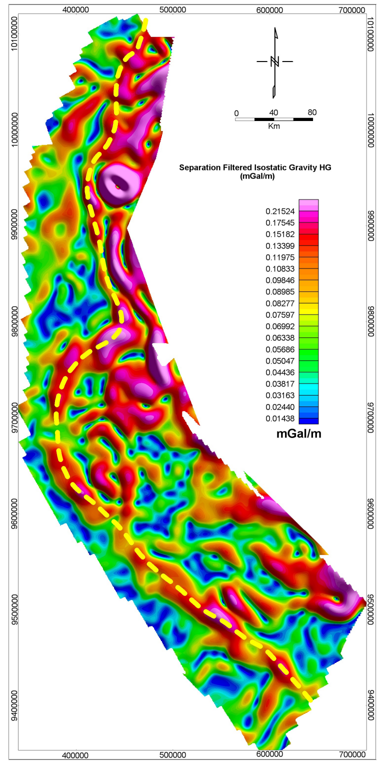

Fig. 2

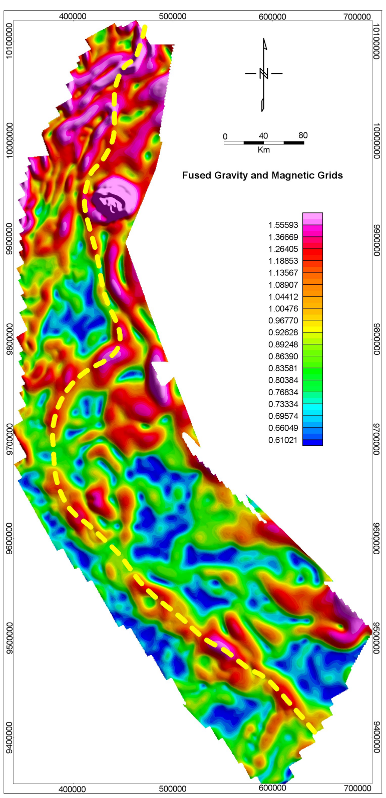

Fig. 3

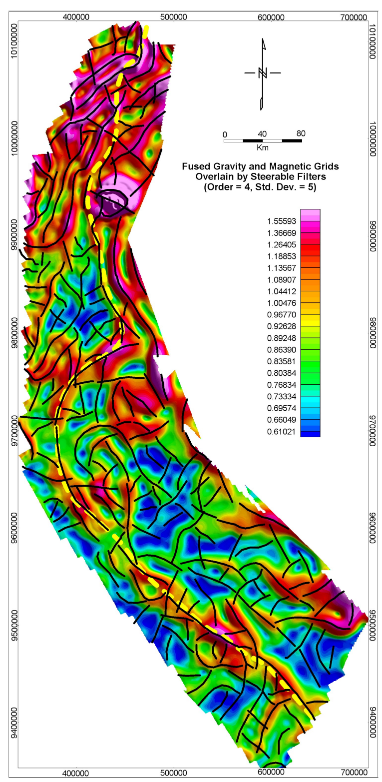

Fig. 4