Petroleum Plays and Prospectivity in the Kwanza and Benguela Basins of Offshore Angola*

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Abstract

In 2011, PGS in association with Sonangol acquired a 12,700 km GeoStreamer® regional 2D grid to address the hydrocarbon potential of the Kwanza, Benguela and Namibe basins. The unexplored pre-salt section of the offshore deep basins of Angola holds tremendous potential for hydrocarbons. The Angolan basins have marked similarities with the pre-salt of the Brazilian margin which abutted the Angola offshore area prior to the opening of the South Atlantic (Figure 1). The Brazilian offshore margin has become a prolific hydrocarbon producer with giant discoveries such as the Tupi and Jupiter fields of the Santos Basin, and the more recent discoveries such as the Gavea of the Campos Basin. Analyses of oils from both sides of the Atlantic indicate similar source rocks, and seismic data show analogous structures.

The 2D seismic covering the Kwanza and Benguela basins has been migrated to depth. This gives us more accurate seismic imaging of the pre-salt structures, thus improving the regional understanding of tectonic evolution, structure and geology. The better understanding enhances our knowledge of pre-salt petroleum systems, and thus the prospectivity of the area.

Petroleum Geology

Both the Angolan and opposing conjugate Brazilian offshore basins are part of the Aptian Salt Basin geological province of the South Atlantic, which extends from the southern margin of the Niger Delta in the north, to the Walvis Ridge in the south (Brownfield and Charpentier, 2006). The basins of these countries share similar structural and stratigraphic characteristics due to their common origin during Late Jurassic to Early Cretaceous rifting of the proto-Atlantic. The geological history of these basins is commonly divided by basin development stages, each characterised by particular petroleum systems.

The syn-rift (pre-salt) stage is characterised by a series of asymmetrical horst and graben basins, within which thick sequences of continental (fluvial-lacustrine) sediments were deposited (narrow deep lakes, high clastic input, high algal bloom, plant detritus, anoxic bottom waters) leading to the formation of a world-class source rocks. Reservoir rocks range from conglomerates and sandstones shed from horst blocks to lacustrine and fluviatile sandstones.

As active rifting ceased, the early post-rift, or sag phase is characterised by the deposition of continental, fluvial and transgressive lagoonal rocks (Teisserenc and Villemin, 1990). The sag phase sediments of the Brazilian Conjugate Margin are of significant interest at the present time, due to the 2006 discovery of the Tupi Field (Figure 2). It is important to understand the significance of the rifted fault block topography underlying the field, which provides the structure for the growth of the reservoir carbonates. Subsequent related discoveries, e.g. the Jupiter Field, have focused exploration activities on the sag phase sediments on both sides of the South Atlantic. The sag phase sediments were overlain by an evaporite sequence, which accumulated as a result of repeated cycles of marine incursions across the Walvis Ridge into a restricted basin, and its subsequent evaporation. This evaporite sequence acts as a seal across the region.

Seismic Acquisition and Depth Migration

A 10 km dual-sensor streamer was deployed with a tuned source array with a volume of 4130 cu. in. A 15 second record length was acquired in combination with the long-offset streamer configuration to penetrate the syn-rift sediments of the Kwanza, Benguela and Namibe basins.

The geology of the Kwanza Basin is very complex, which has made the velocity model building a key part to the Pre-SDM work. The confluence of two oceanic currents in the basin made a simple water velocity function unsuitable for the lines, so a variable water velocity was used. Anisotropy was incorporated throughout the model building stages. The lack of well data available meant that the anisotropy parameters were estimated based on previous experience within the region. The sediment model was updated using a variety of migration algorithms – Kirchhoff and Reverse Time migrations, both in anisotropic mode. The model was updated by

picking RMO (residual moveout curves) using both offset and angle gathers. PGS's proprietary tomography software was used to update the velocity model. The resulting changes in velocity were firmly constrained by the geology – a key to the success of the model build was interactive interpretation of the horizons after each iteration of the model update.

Prospectivity

The pre-salt petroleum play has been proven in the Angolan offshore. In 1992, the Falcao-1 well penetrated the pre-salt, encountering ~600 m of organic-rich lacustrine shales, and encountering reservoir-quality carbonates. In 1996, the Baleia-1 well also drilled into the pre-salt and encountered a 300 foot pre-salt oil column in a dolomitic reservoir with estimated in-place volumes exceeding 1 BBO (Henry et al., 2010). Understanding and exploitation of this resource had been slow to develop, though both Cobalt's 2011 Cameia discovery in Block 21, reported in Bloomberg (2010) as containing at least 1 BBO of crude oil, and Maersk's Azul discovery in Block 23, are indicators of the potential of the region.

Continuing discoveries in Brazil's pre-salt interval points the way to new exploration opportunities, and have implications in offshore basins along the opposing conjugate Angolan coast. Traps were formed during rift phases and include horsts and tilted fault blocks. These syn-rift structures are now visible in the depth-migrated seismic data, and are of great interest for hydrocarbon prospectivity.

Figure 3 shows a thickening of the pre-salt sedimentary package into the basin, with a significant Basement structure controlling distribution of syn-rift sediments. Sedimentary packages are also clearly imaged onlapping onto the Basement. These structures are analogous to that of the Tupi structure (Figure 2) and are highly encouraging to further seismic acquisition and exploration in the area.

Conclusions

There has been a huge demand for high quality, detailed and innovative seismic data which can be set in a regional context, in order to assist in the exploration, understanding and de-risking of this potentially prolific hydrocarbon province. The Kwanza and Benguela basins of offshore Angola are underexplored, frontier areas with the potential for significant hydrocarbon discoveries. Depth-migrated dual-sensor streamer seismic improves the imaging of syn-rift structures, with further implications for identification and mapping of prospects.

References

Brownfield, M.E., and R.R. Charpentier, 2006, Geology and total petroleum systems of the West-Central Coastal Province (7203), West Africa: U.S. Geological Survey Bulletin 2207-B, 52 p.

Henry, S.G., L. Sebastio, N. Kumar, A. Sebastio, and S. Venkatramen, 2010, Tupi's Conjugate: New Pre-salt Plays in the Angolan Offshore: AAPG Annual Convention, New Orleans, Louisiana, 11-14 April 2012. AAPG Search and Discover Abstract #90104. Web accessed 14 September 2012. http://www.searchanddiscovery.com/abstracts/pdf/2010/annual/abstracts/ndx_henry.pdf

Teisserenc, P., and J. Villemin, 1990, Sedimentary basin of Gabon – Geology and oil systems, *in* J.D. Edwards and P.A. Santogrossi, (eds.), Divergent/passive margin basins: American Association of Petroleum Geologists Memoir 48, p. 117-199.

Website

Carroll, J., and J. Polson, 2011, Goldman-backed Cobalt Jumps 37% After Angolan Oil Discovery: Bloomberg Businessweek News, December 20, 2011. Web accessed 14 September 2012. http://www.businessweek.com/news/2011-12-20/goldman-backed-cobalt-jumps-37-after-angolan-oil-discovery.html

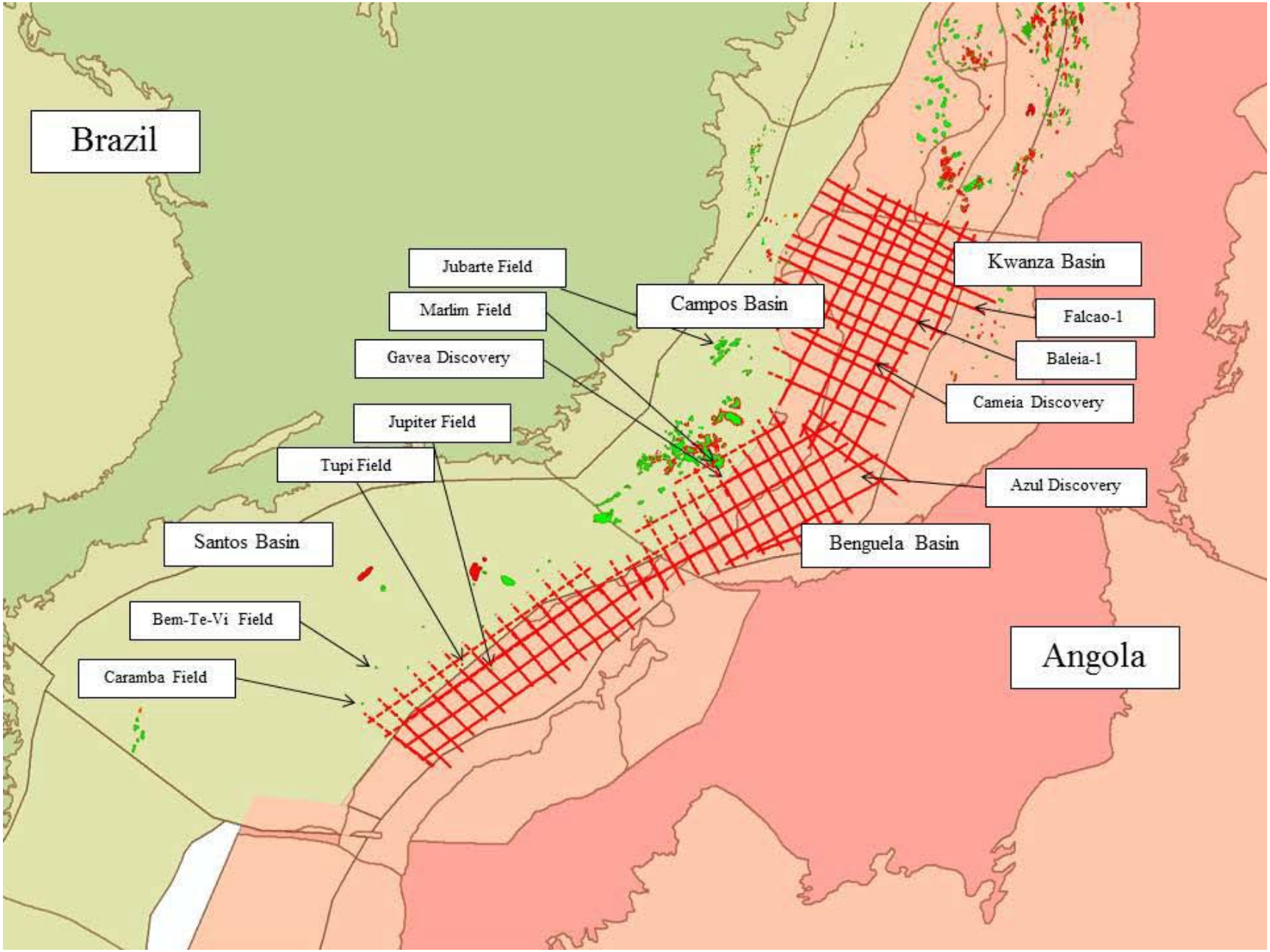

Figure 1. Plate reconstruction at 122 Ma (Aptian), showing the close alignment of the Brazilian and Angolan margins with significant pre-salt oil discoveries. Reconstruction by Geotech (2011).

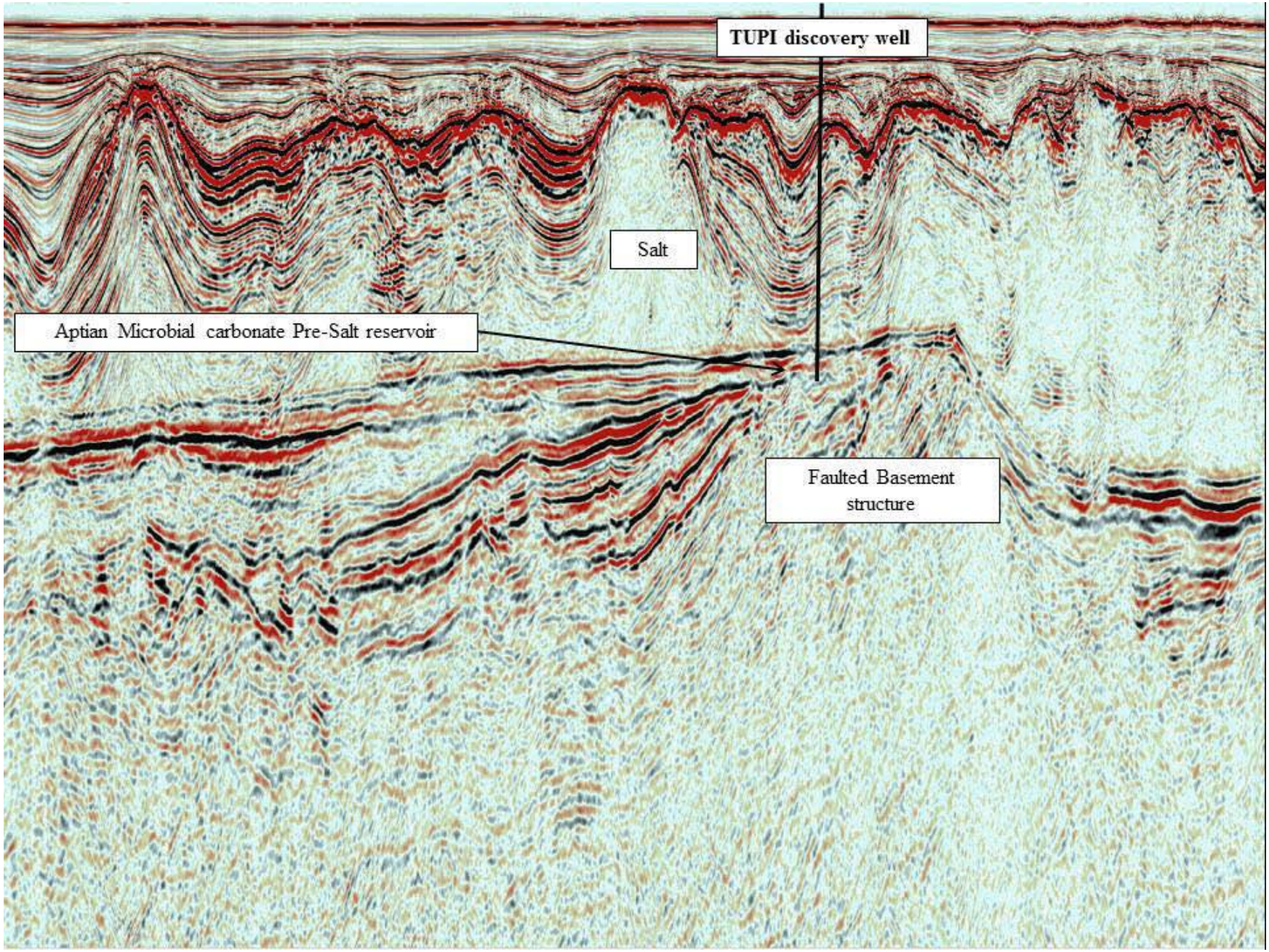

Figure 2. Seismic line across the Lula Field (depth-migrated dual-sensor streamer 2D line).

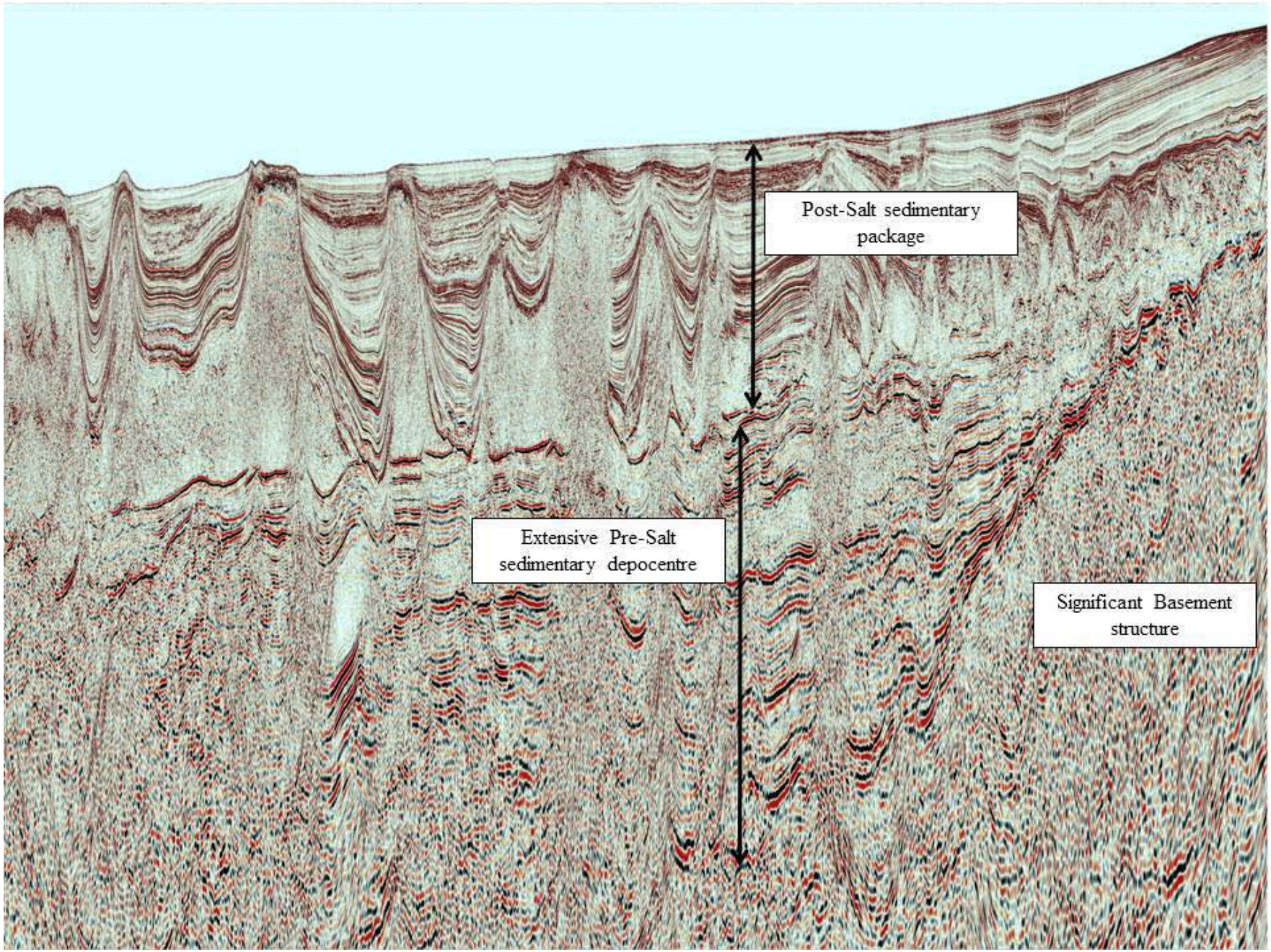

Figure 3. Section of a 2011 2D dip line in the Kwanza Basin (interim depth-migrated GeoStreamer® line).