Where Should We Drill in the Deep Waters of the Pelotas Basin, Southern Brazil and Uruguay?*

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Abstract

The Pelotas Basin is a very large strictly offshore marginal basin straddling Southern Brazil and Uruguay (Figure 1). It comprises one of the best examples of a volcanic passive margin displaying large wedges of seaward-dipping reflectors (SDR). Passive Margins can nowadays be classified as Magma-Poor or Sedimentary (Manatschal, 2004; Péron-Pinvidic et al., 2013 and 2015; Unternehr et al., 2010), Volcanic (Geoffroy, 2005; Stica et al., 2014), and Transitional (Zalán, 2014), once crustal structure, phased evolution and compositional filling of the associated rifts are taken into account. The three comprise a spectrum of passive margins resulting from different modes of thermo-tectonic evolution during the rupture and breakup of mega-continents (Zalán, 2015 and 2016).

The Pelotas Basin is underlain by an extremely deformed continental crust (highly stretched/thinned/faulted), covered by SDR-filled grabens that can achieve thicknesses of more than 20 km (Stica et al., 2014) (Figure 2). The width of the hyper-extended crust varies from slightly less than 100 km in Uruguay up to 350 km close to the boundary with the Santos Basin. Covering the Barremian-Aptian volcanic syn-rift formations (SDR) lies a typical post-rift Drift Stage sag basin formed during the thermal subsidence phase. This Late Aptian to Recent Drift Stage may attain thicknesses of up to 8 km of absolutely undisturbed sub-horizontal beds. The sag geometry of the Drift Stage is attained by maximum subsidence upon the volcanic rifts and gradual thinning of the strata towards the hingeline in the continental shelf and towards the oceanic crust (Figure 2). The essentially volcanic composition of the Rift Sequence and the dominant shale-sandstone composition of the Drift Sequence drive the focus of the exploration towards the thickest parts of the thermal sag basin, in the deep and ultra-deep waters.

Rich and mature marine source rocks (Cretaceous anoxic shales) have already been proved in the Late Aptian, Albian and Turonian, in both homologous margins (in Brazil and in Namibia). A secondary deltaic/marine Paleocene source rock can also be considered. Thick packages of reservoir rocks under the form of turbidite sandstones have recently been proved in Uruguay. The absolutely unfaulted and undisturbed nature of the drift strata and their upward thinning towards the continent and the ocean point to essentially stratigraphic traps as the targets of future exploratory wells. Furthermore, the absence of visible migration routes of tectonic nature clearly indicates that the submarine fans to be tested by ultra-deep wells should be the ones in direct contact with the source rocks (Figure 3), that is, preferably the Albian-Turonian fans, Campanian-Maastrichtian at most. This exploratory model is analogous to the successful model applied in the deep Ghanian and Ivorian waters

in the Equatorial Atlantic. The search should be focused towards packages of rocks displaying classical seismic-facies of submarine fans and channels, filled by turbidite deposition, pinching updip towards both margins of the sag basin. Contourites and contourite-modified turbidites may eventually constitute reservoirs as well (Viana et al., 2002; Mutti et al., 2014). Bright spots should not be expected because of the deep burial of the targets; although they could be a welcome surprise.

Figure 4 displays a high-resolution modern seismic section (acquired and processed by SPECTRUM) from the Pelotas Basin. All the components of the petroleum system described above can be observed in this section. The basal highly stratified beds of the Drift Stage section are probably representative of the source rock package. Right above them several features indicative of turbidite deposition can be envisaged. Planar, tabular shapes possibly indicate submarine fans while channel complexes are represented by superposed short, highly variable reflections displaying several incisions. All these reservoir features pinch out updip towards the continent. The closer these features are to the source rock package the higher will be the chances that they are filled with hydrocarbons generated in the petroleum kitchen situated at the base of the sag basin.

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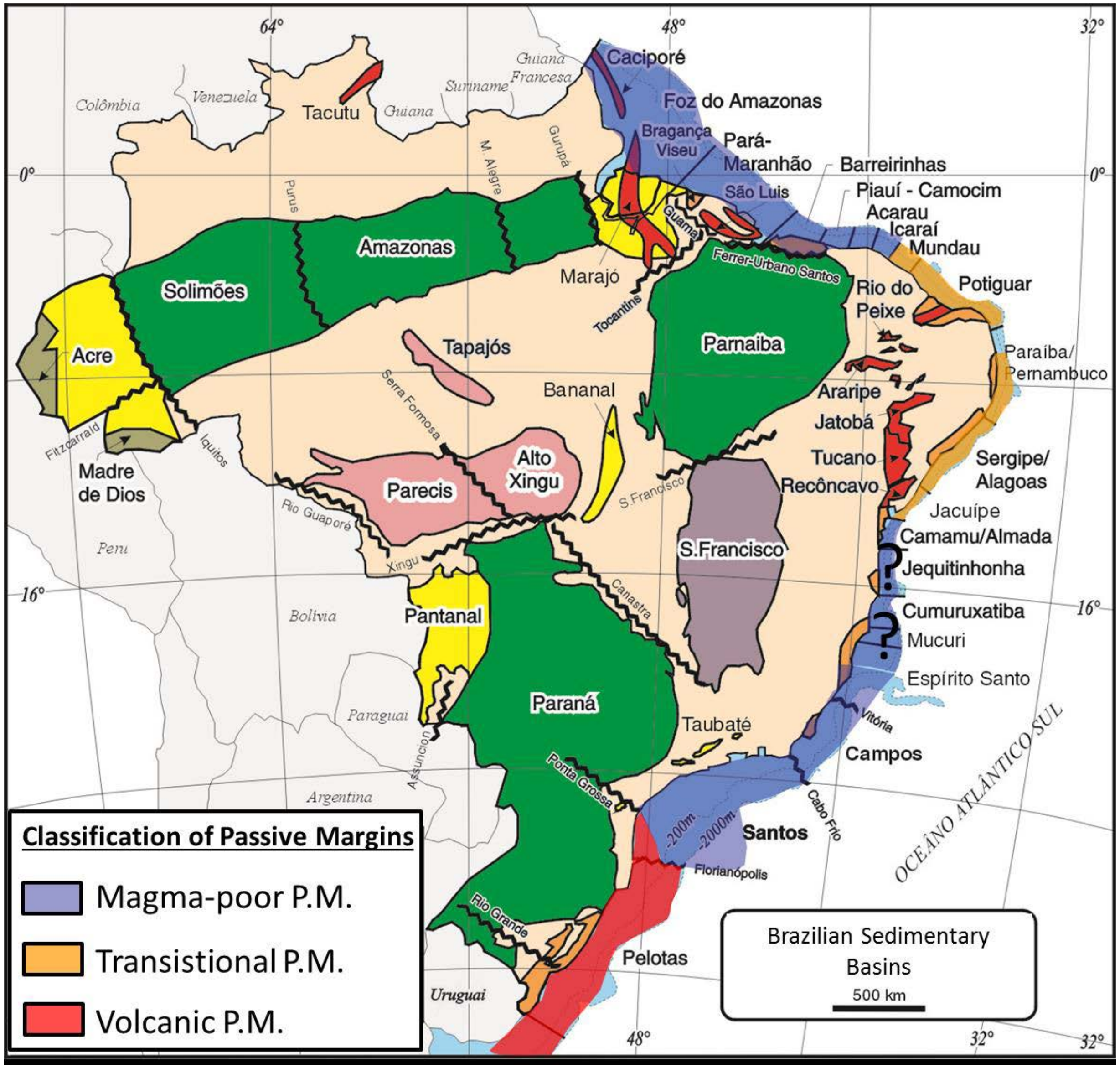

Figure 1. Map displaying the classification of the Brazilian passive margins (from Zalán, 2015). Passive margins are classified as Magma-Poor Passive Margins (MPPM, in blue), Volcanic Passive Margins (VPM, in red), and Transitional Passive Margins (TPM, in orange). Interrogation tags in Cumuruxatiba to Camamu-Almada basins indicate lack of adequate knowledge in order to surely classify those basins. Typical VPM filled with SDRs run from Argentina, through Uruguay, into Southern Brazil. The Pelotas Basin encompasses the Uruguayan and Southern Brazil SDR-filled margins.

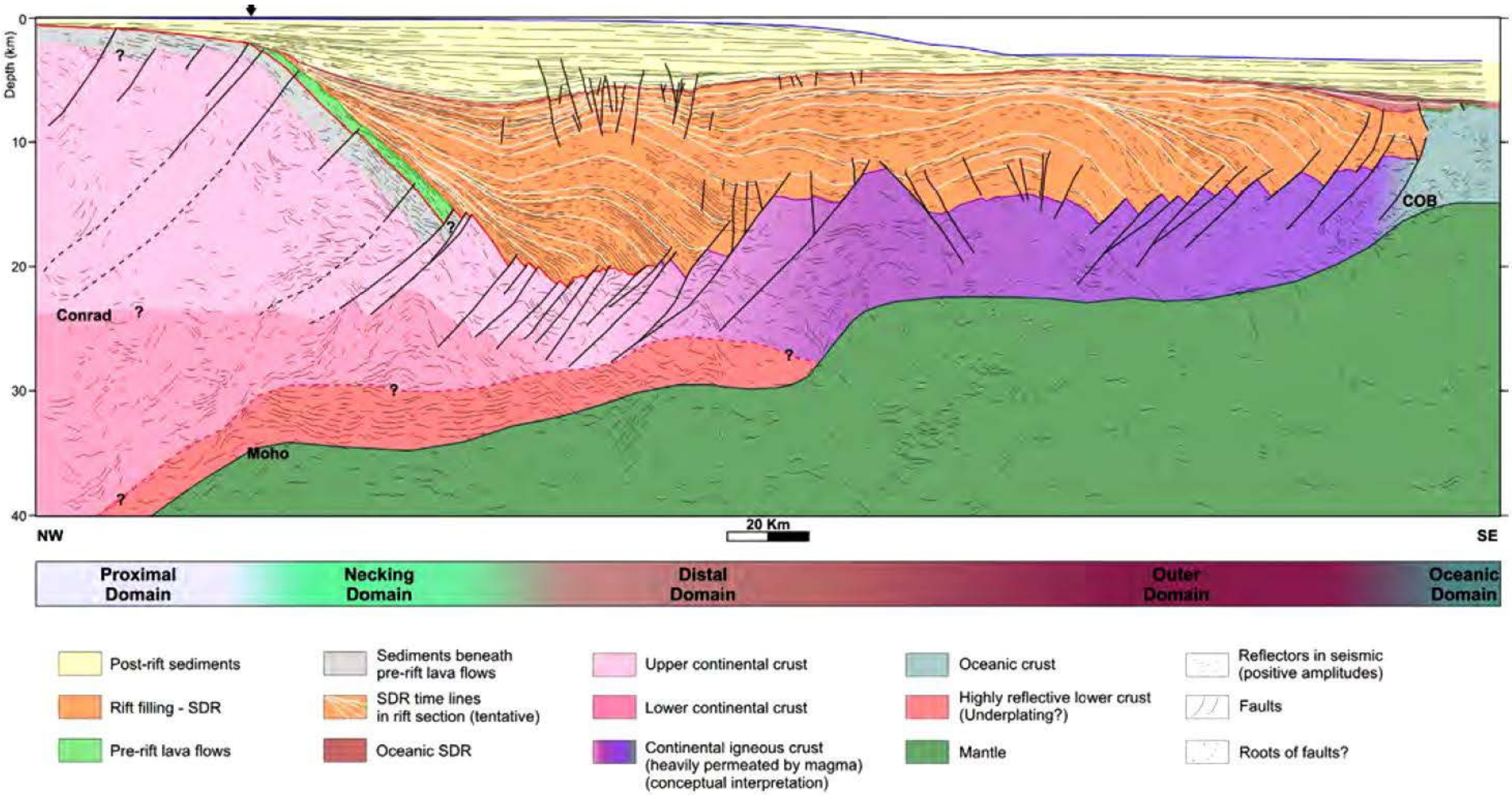

Figure 2. Geoseismic dip section of the northern Pelotas Basin according to Stica et al. (2014), depicting the several tectonic domains of the continental crust. This profile shows a dramatic necking of the continental crust, beyond which the crust is highly attenuated and hyper-extended. The SDR reach gigantic proportions, representing the Rift Stage (orange colour) of the volcanic continental margin. The Drift Stage (yellow colour) is undisturbed by faults and folds and displays a typical sag basin profile, reaching a maximum thickness of 7-8 km above the Necking Domain. It is the basal portion of this sag basin and its marginal areas that constitute the target for exploration of stratigraphic traps filled with hydrocarbons generated at the deepest portions of the sag.

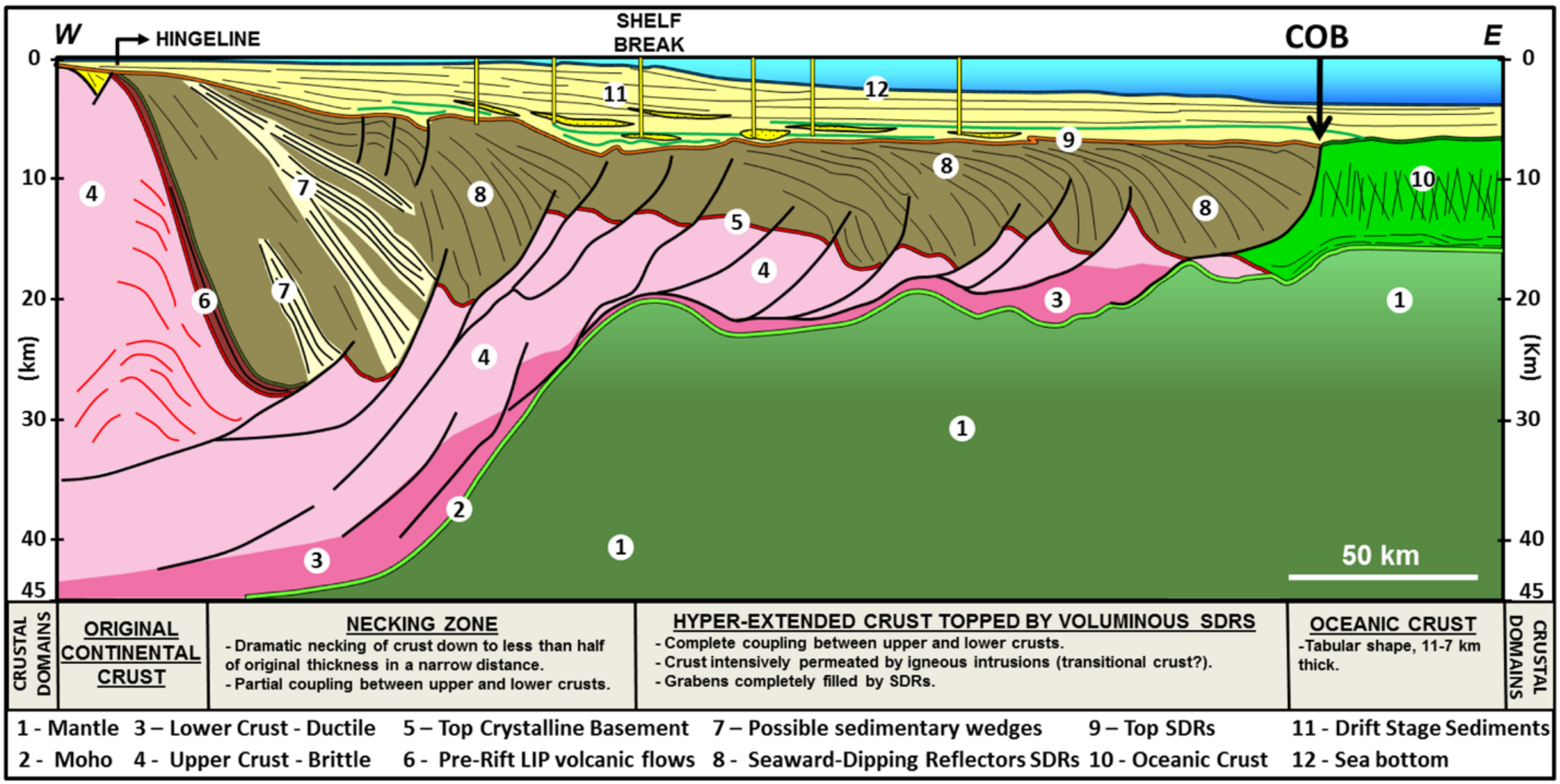

Figure 3. Schematic geological model valid for the Volcanic Passive Margin Pelotas Basin of Southern Brazil, displaying the common strain domains of the continental crust (pink colors) and its blurred contact with oceanic crust without an intervening exhumed mantle. Based on Zalán (2014 and 2015). Potential hydrocarbons accumulations should be sought in the Drift Stage stratigraphic pinch outs of turbidite bodies (yellow wells). Since there is no deformation in the drift section, the closer the turbidites are to the basal mature source rocks (green strata in 11) the greater their chance of having had access to the migration of hydrocarbons.

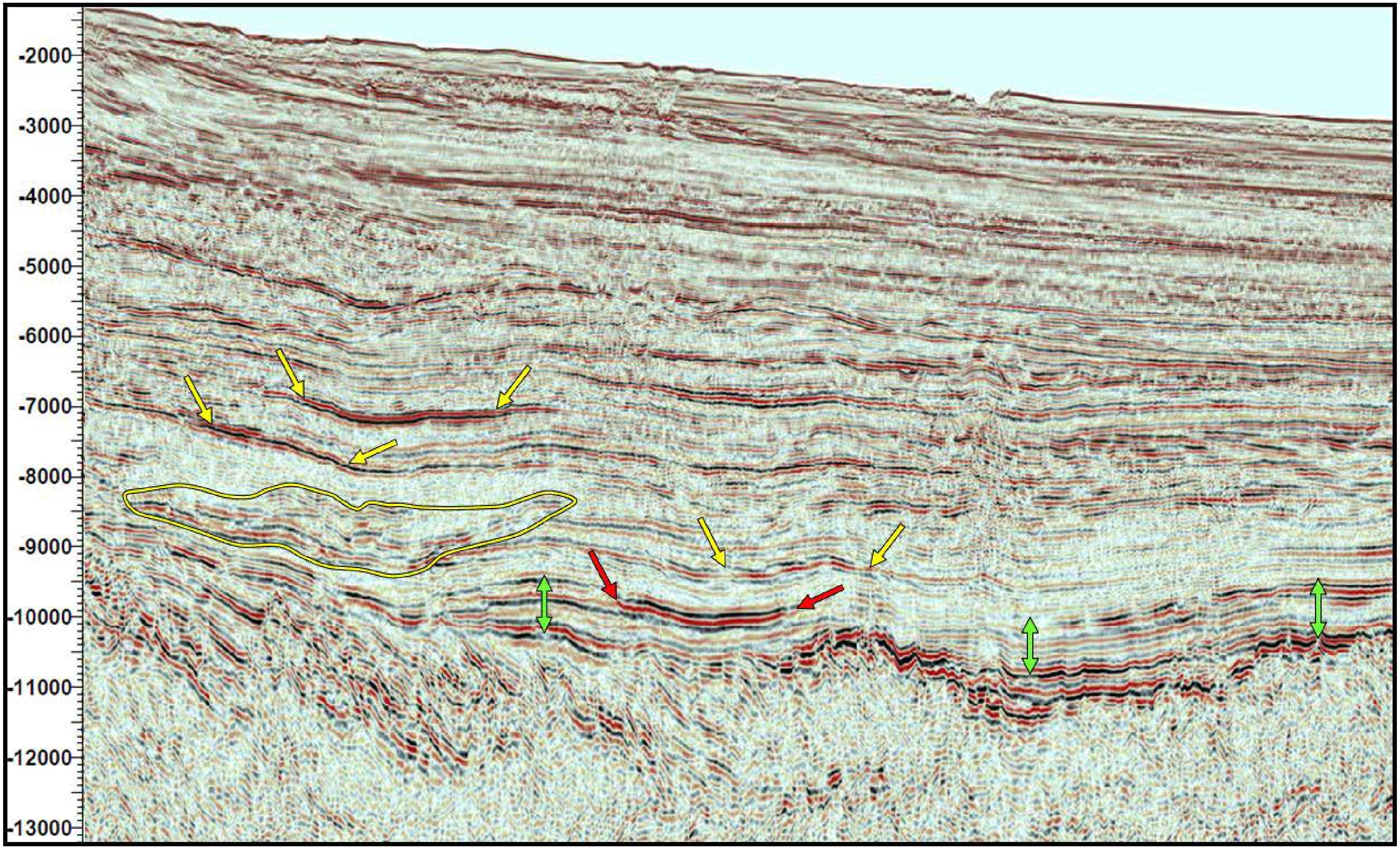

Figure 4. Portion of a SPECTRUM dip-oriented (NW-SE) seismic section in the Pelotas Basin (PSDM, meters) illustrating the promising petroleum system of the Drift Stage section in the ultra-deep waters of the basin. Vertical green arrows depict the typical seismic facies (highly stratified, parallel, continuous reflections) of a source rock package, including Aptian to Turonian marine anoxic organic-rich shales. Inclined yellow arrows indicate possible turbidite fans with mild to strong amplitude anomalies. Yellow continuous line encircles seismic facies suggestive of a thick channelized turbidite system. Strong bright spot highlighted by red arrows may be igneous in origin. SDR dipping to the right are visible below the unfaulted drift section.