Speculative Petroleum Systems of the Southern Pelotas Basin, Offshore Uruguay*

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Search and Discovery Article #10832 (2016)
Posted February 1, 2016

*Adapted from extended abstract prepared in conjunction with poster presentation at AAPG/SEG International Conference & Exhibition, Melbourne, Australia, September 13-16, 2015, AAPG/SEG © 2016.

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Abstract

At present commercial oil accumulations in the Pelotas Basin have not been identified (as opposed to the other basins of the Brazilian Atlantic margin), nor the current geological knowledge allows to identify proven petroleum systems. In spite of that, this basin continues to be underexplored with a total of only 18 exploratory wells drilled in an area of more than 330,000 km^2, all of them located in its Brazilian portion. This study focused in the Uruguayan portion of the basin that has not been drilled yet. 2D and 3D seismic data acquired in this area reveal a promising hydrocarbon potential allowing the identification of stratigraphic plays that have analogies with accumulations discovered in other basins of both sides of the Atlantic not affected by halokinetic deformation (as in French Guiana and Ghana). The main purpose of this study is to evaluate the hydrocarbon potential of the southern part of the Pelotas Basin, defining the speculative petroleum systems (based on geophysical data). Sequence stratigraphy concepts were used as the main methodology to interpret the depositional sequences from 2D seismic sections of the Uruguayan portion of the Pelotas Basin and available well data. It is possible to identify a syneclise stage that preserves Permian geological units of a prerift phase corresponding to the Paleozoic intracratonic Paraná Basin; an Early Cretaceous continental synrift phase constituted by the volcanic-sedimentary infill of halfgrabens and SDRs; and a Cretaceous to Cenozoic postrift phase represented by a sedimentary stacking associated to successive transgressions and regressions of the sea level. The sequence analyses allowed interpreting the system tracts and identifying the distribution of the main elements of the potential petroleum systems. The source rocks of the speculative petroleum systems proposed in this study for the Uruguayan portion of the Pelotas Basin are represented by a Permian restricted marine source rock of the prerift phase, and two marine source rocks of the postrift phase of Aptian-Albian (OAE 1) and Cenomanian-Turonian (OAE 2) ages. The main reservoirs proposed are continental sandstones of the synrift phase and Cretaceous and Cenozoic turbidites from the postrift phase. The main regional seals are related to the postrift phase, represented by shales of the Aptian-Albian, Cenomanian-Turonian, and Paleocene marine transgressions.

Introduction

Nowadays, at least four exploration companies are developing exploration activities offshore Uruguay, particularly in the Pelotas Basin. This basin was generated during the fragmentation of the Gondwana supercontinent and subsequent opening of the South Atlantic Ocean. It stretches through the southern Brazilian Atlantic margin, entering its southernmost segment, to the Uruguayan continental margin. In its northern side, in Brazil, it limits with the Santos Basin through the Florianópolis High while in its southern side, in Uruguayan territorial waters, it limits with the Punta del Este Basin through the Polonio High.

There have not been any hydrocarbons discoveries in the basin and the existing geological information does not allow establishing known or hypothetical petroleum systems (Magoon and Dow, 1994). However, the basin is still underexplored, with a total of 18 exploratory wells drilled, all located in its Brazilian portion, in a surface of 250,000 km^2 (considering bathymetry of 3,000 meters), most of them situated in shallow waters. In addition, there are no wells drilled in the Uruguayan segment of the basin (study area) that represent an area of 80,000 km^2. The recently acquired 2D seismic data shows a promising geology, allowing the identification of potential source and reservoirs rocks and mainly stratigraphic traps, such as turbidites, which shows analogies with hydrocarbons accumulation of other Atlantic basins like Campos and Santos. The objective of this work is to evaluate the hydrocarbon potential and define the speculative petroleum systems present in the Uruguayan portion of Pelotas Basin.

Location

The study area represents the southernmost portion of the Pelotas Basin, located in the offshore of Uruguay between the following parallels: 34º 20□S and 36º 40□S, and the following meridians: 50º 50□W and 52º 50□W (Figure 1).

Geological Setting

Related to its tectonic evolution, three main megasequences in the Pelotas Basin can be recognized: prerift, sinrift, and postrift.

The prerift megasequence is not part of the evolution of the basin, being represented by preserved Paleozoic and Mesozoic lithologies, belonging to the intracratonic Paraná Basin, that were deposited in a syneclise stage before the genesis of Pelotas Basin. According to well data, the Paleozoic megasequence preserved in Pelotas Basin contains three formations deposited in a marine environment (Rio Bonito, Palermo, and Iratí formations) during the lower Permian (Bueno et al., 2007). The upper Paleozoic portion is represented by two formations (Teresina and Rio do Rastro formations) deposited in a fluvial-lacustrine-tidal environment, while the prerift Mesozoic sequence is composed by upper Jurassic aeolian-fluvial sandstone of the Botucatú Formation and the lower Cretaceous basaltic floods of the Serra Geral Formation (Milani et al., 1994). In relation to this megasequence, it is of particular significance the Iratí Formation, an organic rich black shale with an important source rock potential.

The sinrift megasequence deposits are filling half-graben structures in the proximal part of the basin, and are represented by the seaward dipping reflectors (SDRs) in the distal portion (Fontana 1987, 1996). This megasequence was reached by a few wells, in its proximal portion,

that encountered basalts of Barremian-Aptian age (Lobo et al., 2007) of the Imbituba Formation and conglomerates of the Cassino Formation (Bueno et al., 2007).

The postrift megasequence represents the marine sedimentation of the basin and can be divided in three main sequences according to Bueno et al. (2007): shelfal, transgressive, and regressive. According to these authors, the shelfal sequence is represented by Albian carbonate and siliciclastic deposits of the Porto Belo Formation, which were deposited in a shallow mixed-shelf environment. The transgressive sequence extends from Albian to Oligocene, being composed by thick layers of shales of the Atlântida and Imbé formations. The regressive sequence is formed by sandstones and siltstones of the Cidreira Formation of Neogene age.

Methodology

The methodology used is based on the concepts of sequence stratigraphy and was defined by Hubbard et al. (1985). It was applied to all the 2D seismic sections available of the area (Table 1) and consists of four main stages:

1) Identification of sequence boundaries.
2) Interpretation of internal attributes (system tracts, maximum flooding surfaces).
3) Development of a geological model: Generation of maps that shows the elements of the petroleum systems (source rocks, reservoirs, seals, etc.).
4) Structural analysis: identification of migration paths and structures.

Results

As a result of the interpretation, the three main megasequences that constitute the Pelotas Basin (prerift, synrift, and postrift) were identified and ten depositional sequences were recognized for the postrift megasequence (Figure 2).

The application of this methodology allowed proposing six speculative petroleum systems in the sense of Magoon and Dow (1994).

The first petroleum system proposed for the area is related with to the prerift phase. The source rock associated with this petroleum system is constituted by lower Permian organic rich black shales of the Iratí Formation, while the reservoir rocks are represented by upper Jurassic aeolian-fluvial sandstones of the Botucatú Formation. The seal is composed of lower Cretaceous basaltic flows of the Serra Geral Formation. This particular petroleum system named Iratí-Botucatú(?) is restricted to the proximal segment of the basin (Figure 3).

The second petroleum system proposed is related to the synrift megasequence and is represented by a Barremian age lacustrine source rock deposited in the hemigrabens. In this case, the reservoir rocks are constituted by alluvial-fluvial conglomerates and sandstones of the Cassino Formation, while the same lacustrine shales represent also the seal. This speculative petroleum system called Cassino-Cassino(?) is restricted to the central-west region of the study area (Figure 4) where the hemigrabens develop related to NE-SW trending faults.

The third petroleum system proposed is composed of a source rock of the postrift megasequence and a reservoir rock of the synrift megasequence. The source rock is composed of marine shales of Aptian-Albian age that represent the first marine transgression of the basin and were deposited during the first oceanic anoxic event of the Cretaceous (OAE1). The reservoir rocks are represented by aeolian sandstones interbedded with basaltic flows associated with the SDRs, in which the same basaltic flows act as a seal. This speculative petroleum system is named Atlântida-Imbituba(?) and develops in the central part of the area (Figure 5).

The fourth petroleum system proposed is related to the postrift megasequence, consisting of a source rock represented by marine shales of Aptian-Albian age and reservoir rocks associated with progradation fronts, channels, and turbidites of the upper Cretaceous and lower Paleocene. The main seals for this system are the marine shales related to the Cenomanian-Turonian and Paleocene transgressions. This speculative petroleum system develops in the distal part of the area (Figure 6) and is named Atlântida-Imbé(?).

The fifth petroleum system proposed develops in the postrift megasequence, consisting of a source rock constituted by marine shales of Cenomanian-Turonian age that represents the second marine ingression of the basin and were deposited during the second oceanic anoxic event of the Cretaceous. The reservoir rocks are represented by progradation fronts, channels, and turbidites of the Upper Cretaceous and Lower Paleocene. The main seals for this system are represented by the marine shales of the Paleocene transgressions. This speculative petroleum system is called Lower Imbé-Imbé(?) and develops in the central and distal part of the area (Figure 7).

The sixth and last speculative petroleum system proposed is related to the Cenozoic postrift megasequence and is composed by a source rock represented by marine shales of the Paleocene transgression and reservoir rocks represented by turbidites deposited during the Paleocene, Eocene, and Miocene. The main seals for this system are represented by the marine shales of the Paleocene and Miocene transgressions. This petroleum system is named Middle Imbé-Imbé(?) and develops in the distal part of the area (Figure 8).

Conclusions

The seismic sections of the Uruguayan portion of Pelotas Basin show a promising geology in a basin that is still underexplored. Potential sources, reservoirs, and seal rocks were identified in the three megasequences that compose the basin. Six speculative petroleum systems were proposed that develop in different part of the basin, both proximal and distal. Turbidites and other stratigraphic traps were recognized. All this suggests a basin with a large prospective potential.

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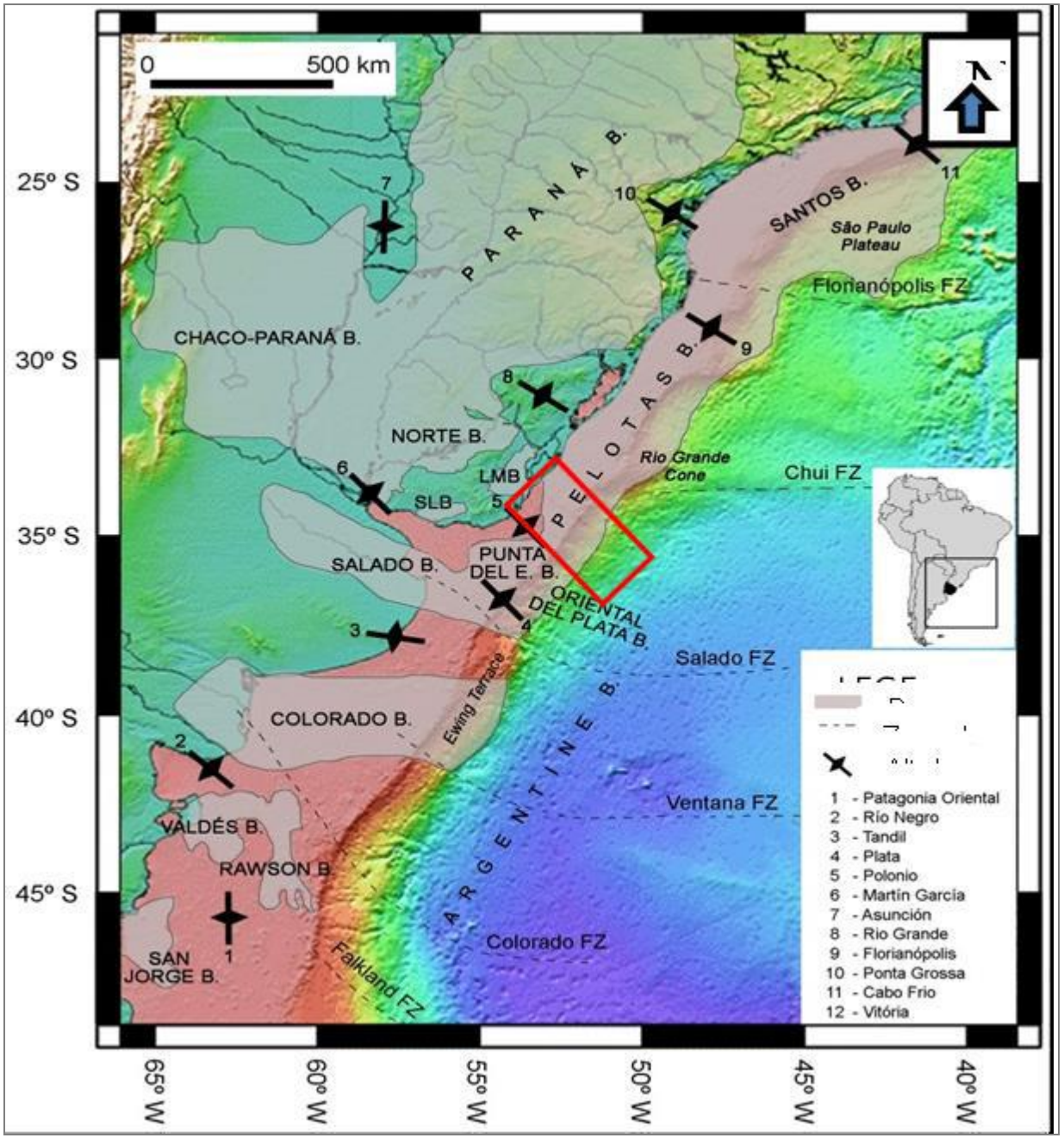

Figure 1. Location of the study area (red square) of the Pelotas Basin offshore Uruguay. Modified from Soto et al. (2011).

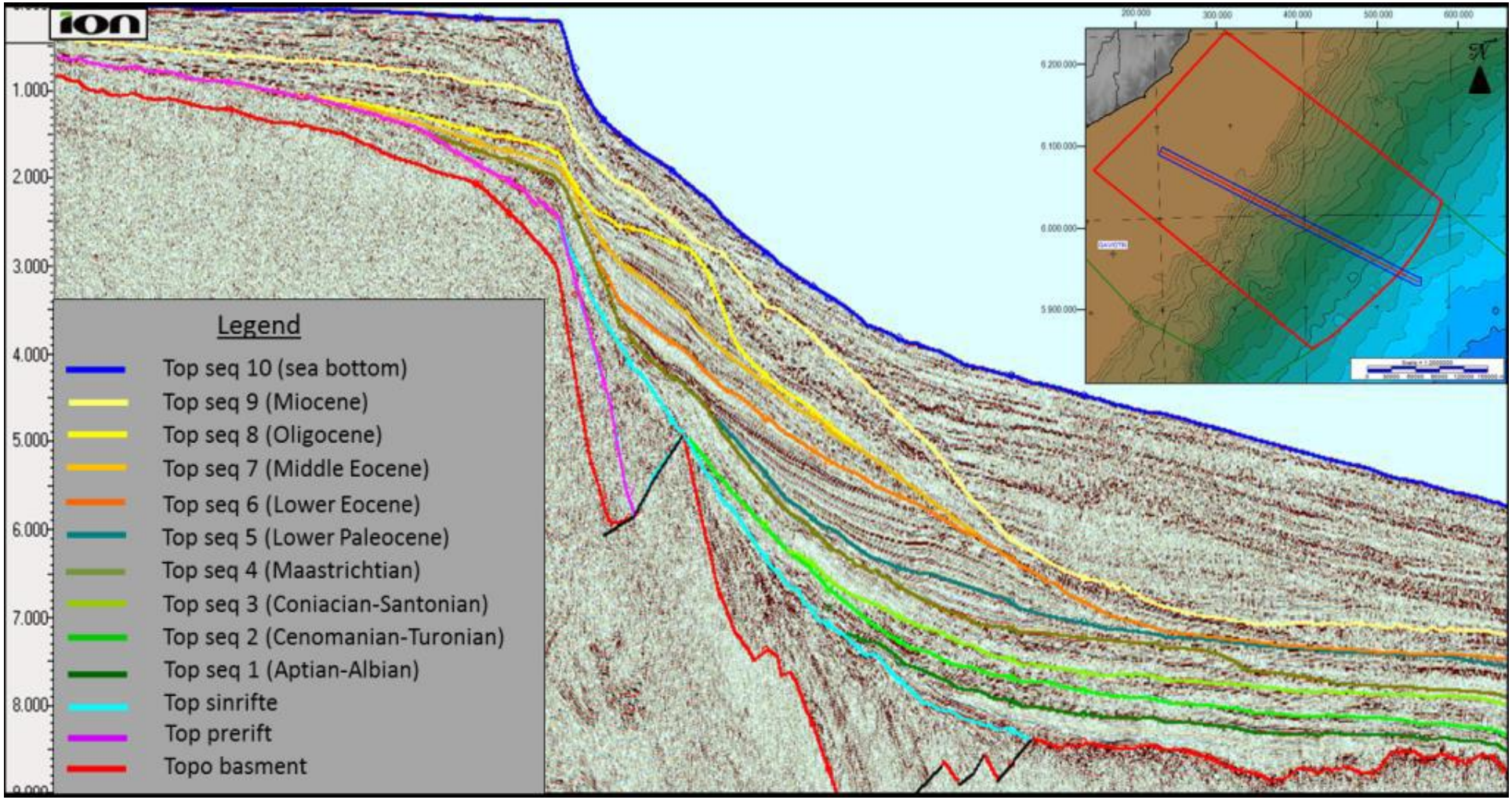

Figure 2. Interpreted 2D dip seismic section of the Pelotas Basin (offshore Uruguay).

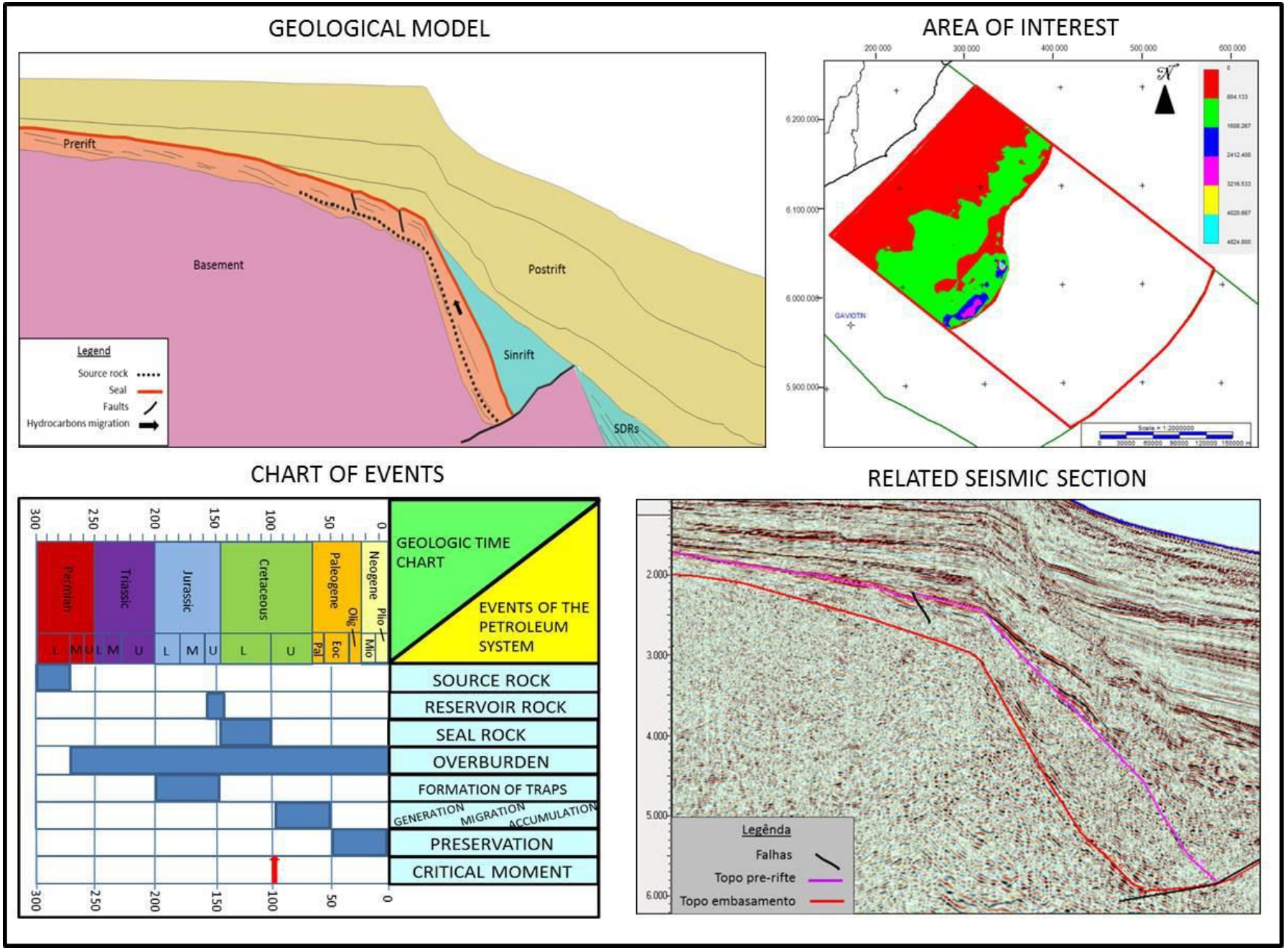

Figure 3. The Iratí-Botucatú(?) speculative petroleum system of the prerift megasequence showing the geological model, area of occurrence, chart of events, and a related seismic section.

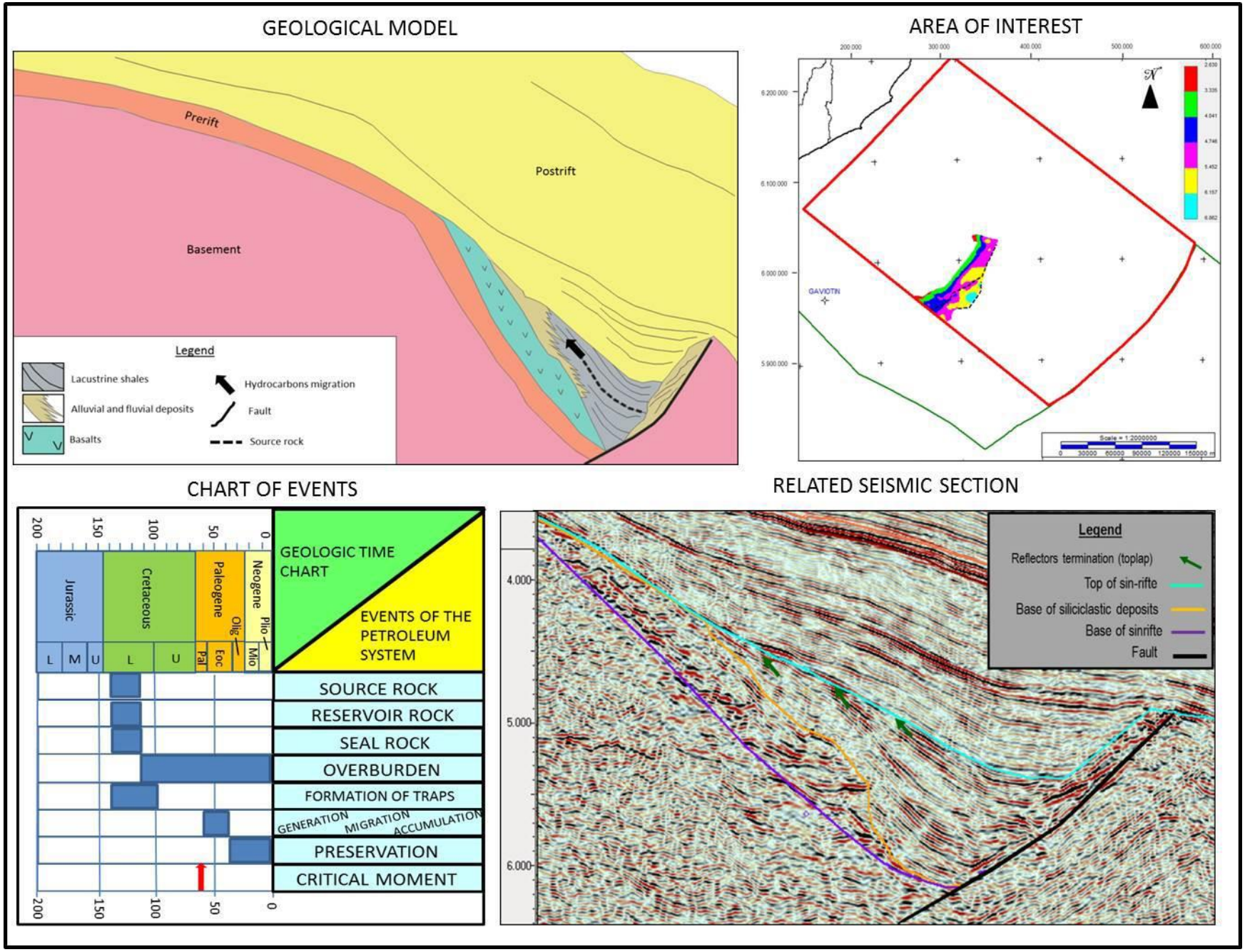

Figure 4. The Cassino-Cassino(?) speculative petroleum system of the synrift megasequence showing the geological model, area of occurrence, chart of events, and a related seismic section.

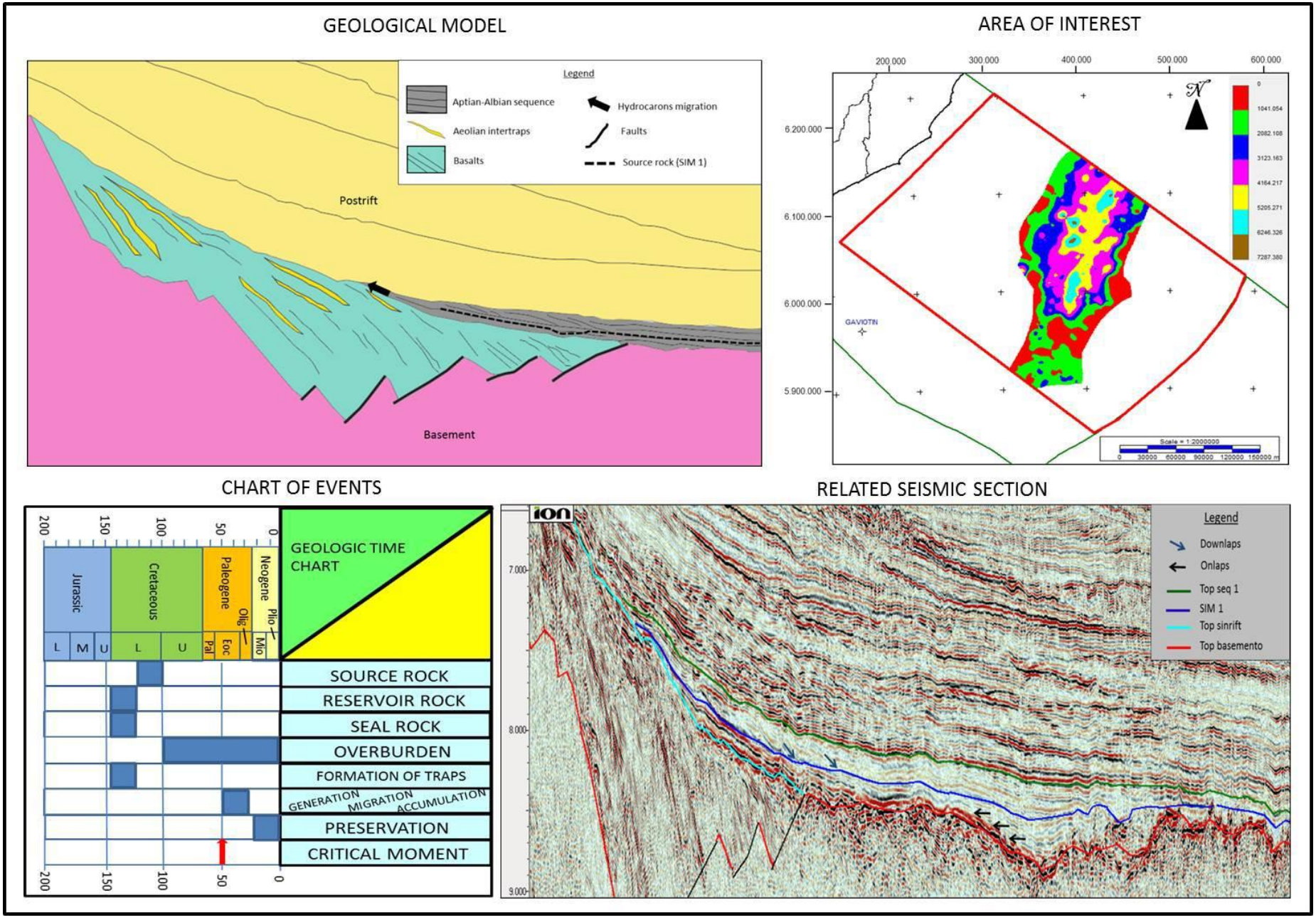

Figure 5. The Atlântida (Aptian-Albian)-Imbituba(?) speculative petroleum system with a source rock of the postrift megasequence and reservoir rocks of the synrift megasequence, showing the geological model, area of occurrence, chart of events, and a related seismic section.

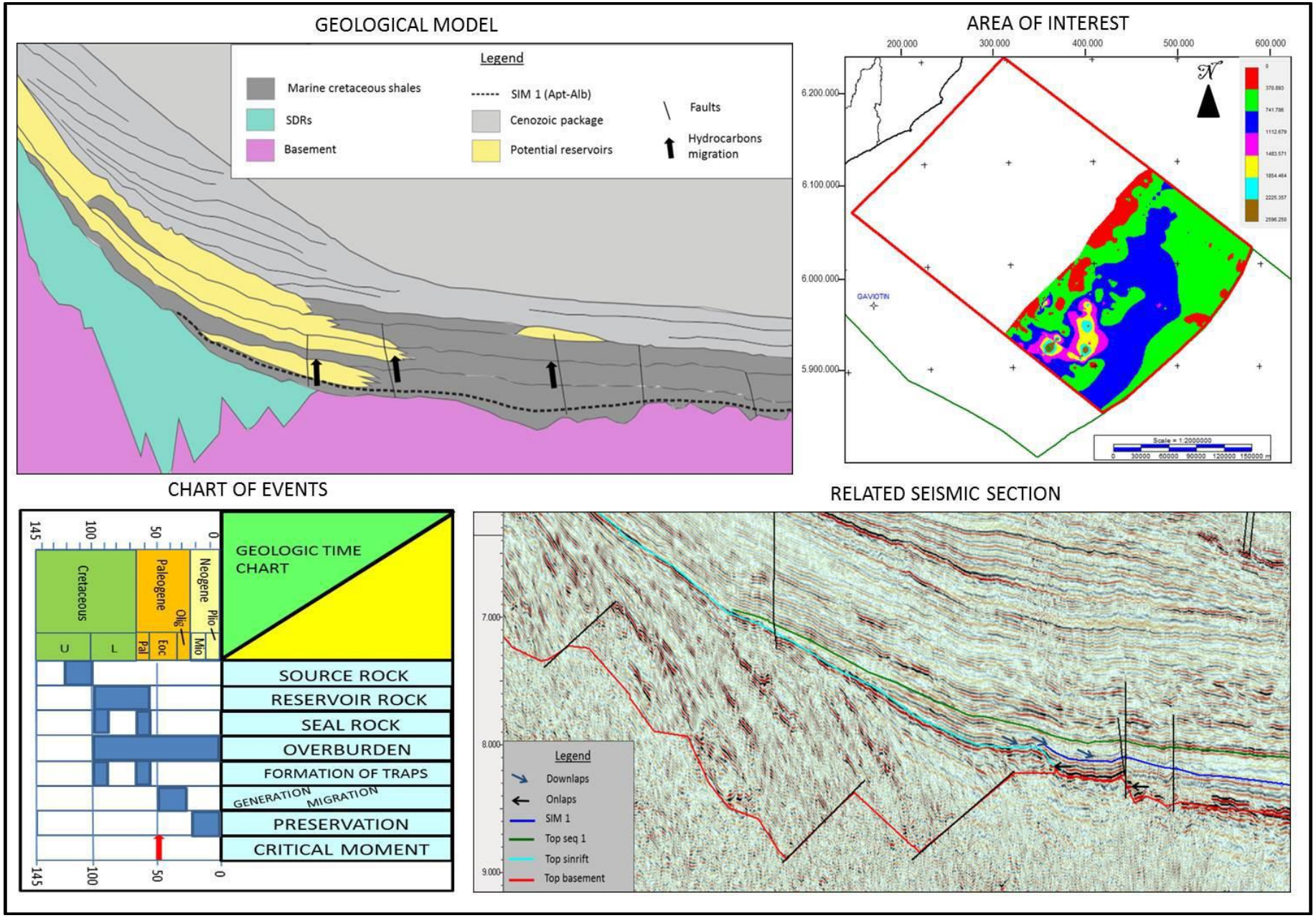

Figure 6. The Atlântida (Aptian-Albian)-Imbé(?) speculative petroleum system of the postrift megasequence showing the geological model, area of occurrence, chart of events, and a related seismic section.

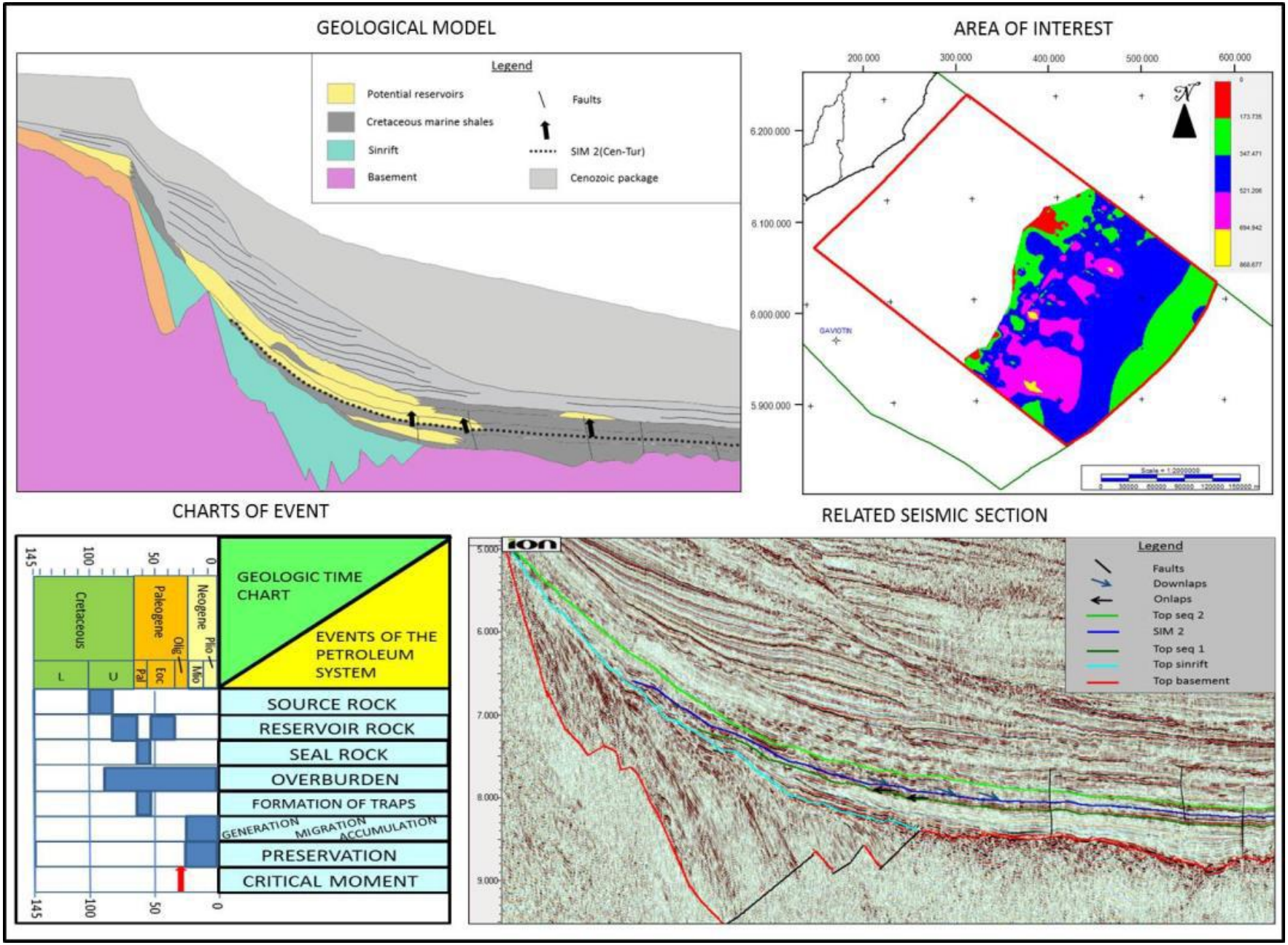

Figure 7. The Lower Imbé (Paleocene)-Imbé(?) speculative petroleum system of the postrift megasequence showing the geological model, area of occurrence, chart of events, and a related seismic section.

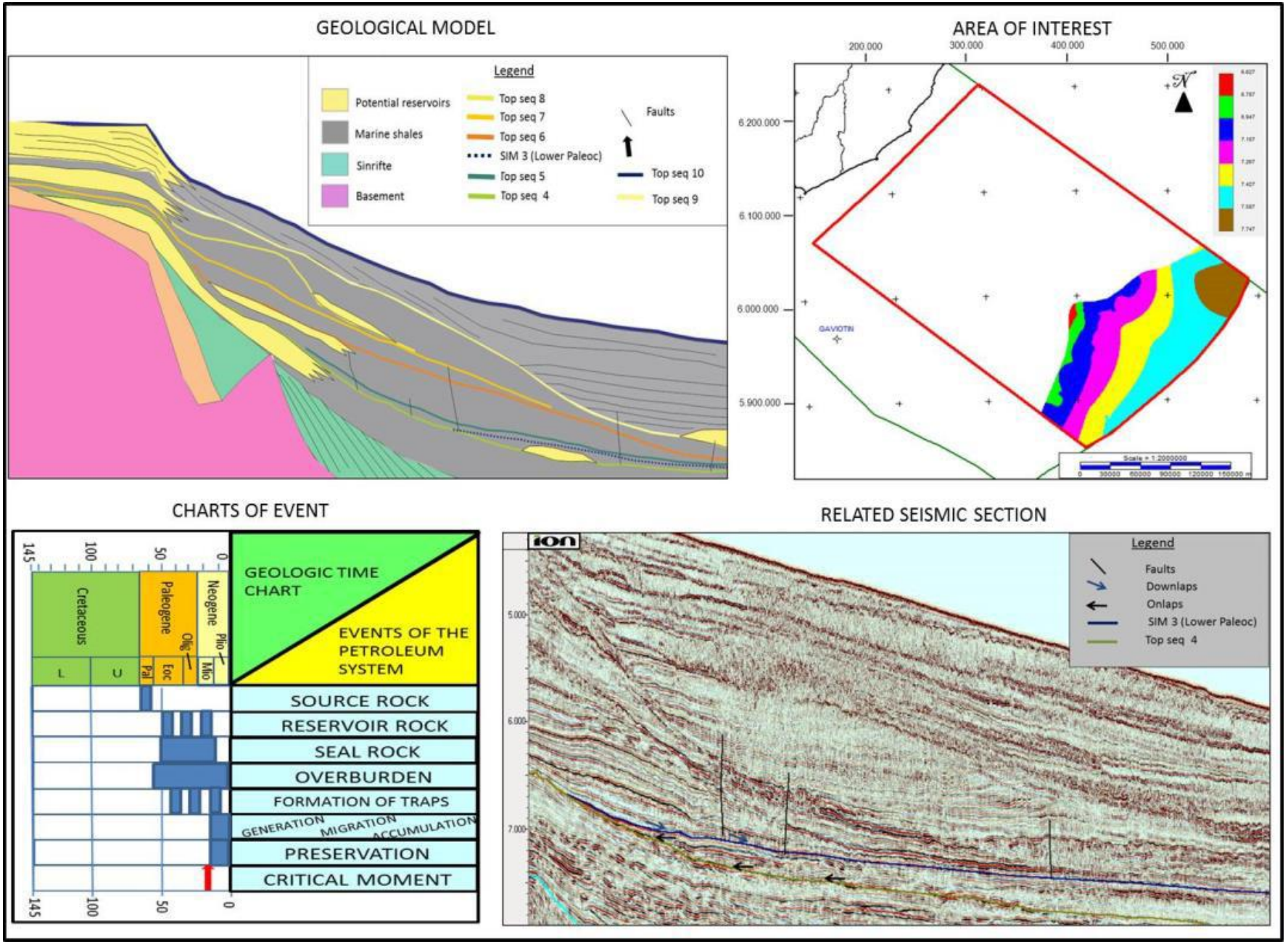

Figure 8. The Middle Imbé (Paleocene)-Imbé(?) speculative petroleum system of the postrift megasequence showing the geological model, area of occurrence, chart of events, and a related seismic section.

Data	Year of acquisition	Length (km)
2D seismic	2007	5904
2D seismic	2013	1042

Table 1. Details of the 2D seismic data interpreted.