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Basin scale geomechanical modeling during seismic processing: Pelotas Basin, offshore Brazil

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Abstract Summary

This work describes a workflow to anticipate pore pressure and petroleum system information during seismic processing. The methodology was performed with vintage 2D seismic data from Pelotas Basin, the still untouched and southernmost basin along the prolific continental margin of Brazil. The scope of the work was to gather relevant information by reprocessing available seismic data, particularly velocity data.

Introduction

It's common practice in the upstream O&G industry to address seismic processing, geomechanical modeling and petroleum system analysis with separated teams, working independently.Even considering the structures of the companies teams, this subdivision of work can cause some delay and possibly some loss of relevant business information. In this paper, we show an alternative integrated approach applied in a research project in the Pelotas Basin, led by the Seismic Imaging and Inversion Group (GISIS) at Universidade Federal Fluminense (UFF), in collaboration with Petrobras. Driven by the recent discoveries off the coast of Africa, in parallel with the characteristics of the formation of the continents, the Pelotas basin off the coast of Brazil is awakening new exploratory interests.

The proposed workflow, which is based on quantitative seismic interpretation (Avseth et al., 2005; Bowers, 2002; Dix, 1955; Dutta et al., 2021; Eaton, 1975; Gardner et al., 1974), can anticipate both geomechanical and petroleum system information during seismic processing. It's also suggested that the multidisciplinary approach of the methodology can compensate in part the scarcity of data in exploratory frontier areas, even in the case of reprocessing vintage seismic data, and can also add value to seismic processing deliverables.

Methodology

A basin scale intervalar velocity model (Figure 1) was produced with careful quality control both from NMO and image gathers. As the seismic processing was running in parallel (Zanato, 2022), it was easy to double-check the gathers, and to correct the model in real time. We also performed seismic interpretation of migrated lines, with focus in structural analysis and mechanical stratigraphy, to define the current deformation pattern in the studied area. A full regional geomechanical model with stresses and pore pressures was computed from this velocity model with the standard equations from Gardner and Eaton, considering the velocity gradients of normal compaction trends, and observing the rock strength limits interpreted from the active deformation. Some important features of the petroleum system were inferred from the estimated geomechanical model.

Results

The pore pressure model shows a very coherent correlation with the mechanical stratigraphy, as the estimated shallow hydrostatic regime (up to 9 PPG) coincides with the more faulted and fractured Neogene section. The less deformed Paleogene and Cretaceous successions bear consistent overpressure regimes. Severe pressure gradients, up to 14 PPG, were estimated in the Cretaceous section (Figures 2 and 3). Well data indicated overpressure gradients up to 12.8 PPG at the base of the Neogene section (see Figure 2 for well position), where the model predicted 11.5 PPG, supporting the computed overpressure trends, but probably missing an eventual extra fluid pressure (Bowers, 2002). Considering the petroleum system, the estimated overpressure regimes indicate good seal capacity and possible active hydrocarbon generation for the still not tested Paleogene and Cretaceous sections in the Pelotas Basin (Figure 4).

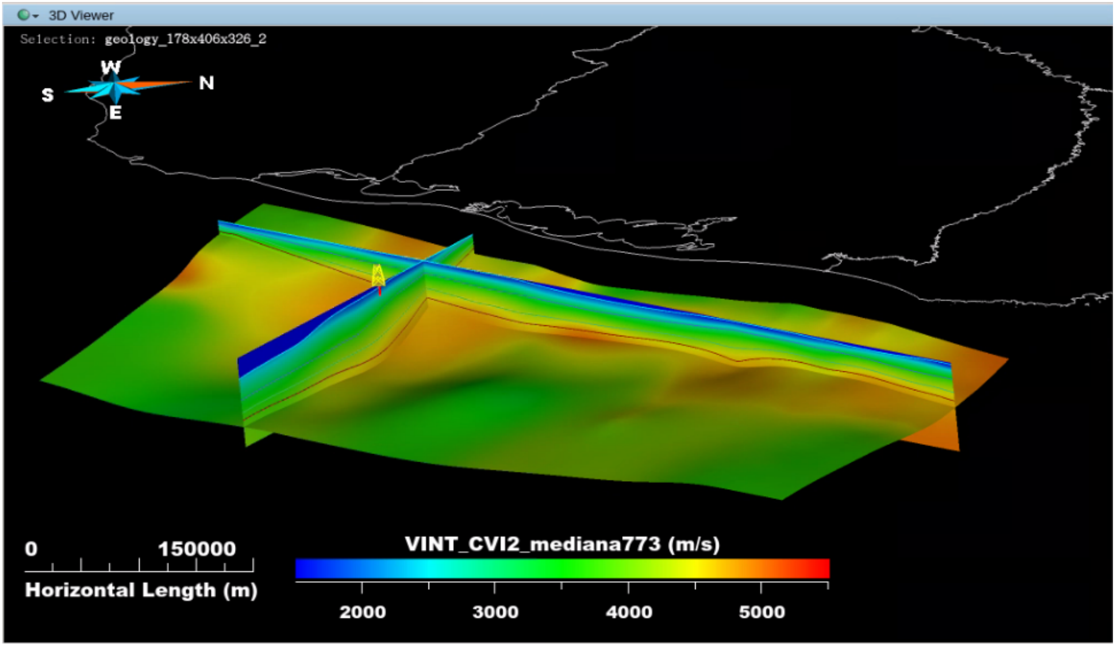

Figure 1: Basin scale intervalar velocity model in Pelotas Basin, southern Brazilian continental margin.

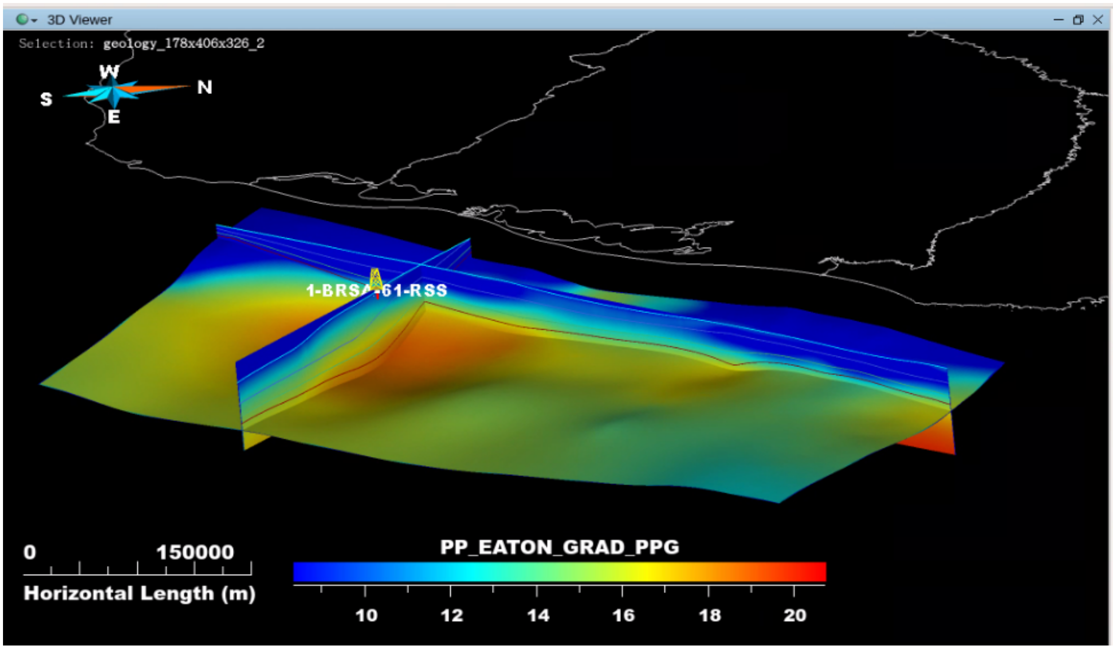

Figure 2: Basin scale pore pressure gradient model in Pelotas Basin, southern Brazilian continental margin. The well indicated in the model was used to evaluate the predicted pore pressure trends.

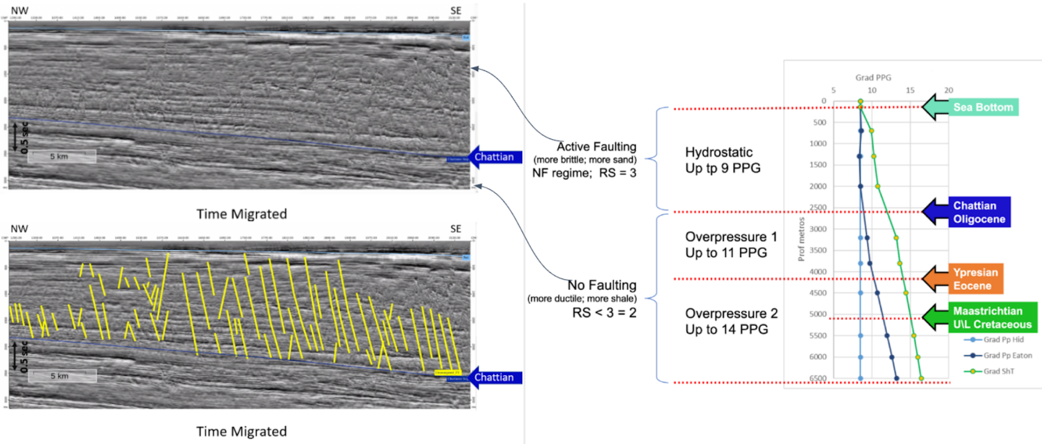

Figure 3: Example of Pore Pressure (Grad Pp Eaton – dark blue curve) and Fracture (Grad ShT – green curve) gradients estimated from seismic velocities in the studied area. Observe the control of the pore pressure regimes according to the interpreted mechanical stratigraphy. The Neogene hydrostatic regime (more connected pore systems) is correlated with active faulting (NF is Normal Fault stress regime; RS = 3 is the Stress Ratio assumed, so the Minimum Horizontal Effective Stress was set to 1/3 of the Vertical Effective Stress). Overpressure regimes are correlated with less deformed (less connected pore systems) in the Paleogene and the Cretaceous (RS = 2 is the stress ratio assumed, so the Minimum Horizontal Effective Stress was set to 1/2 of the Vertical Effective Stress).

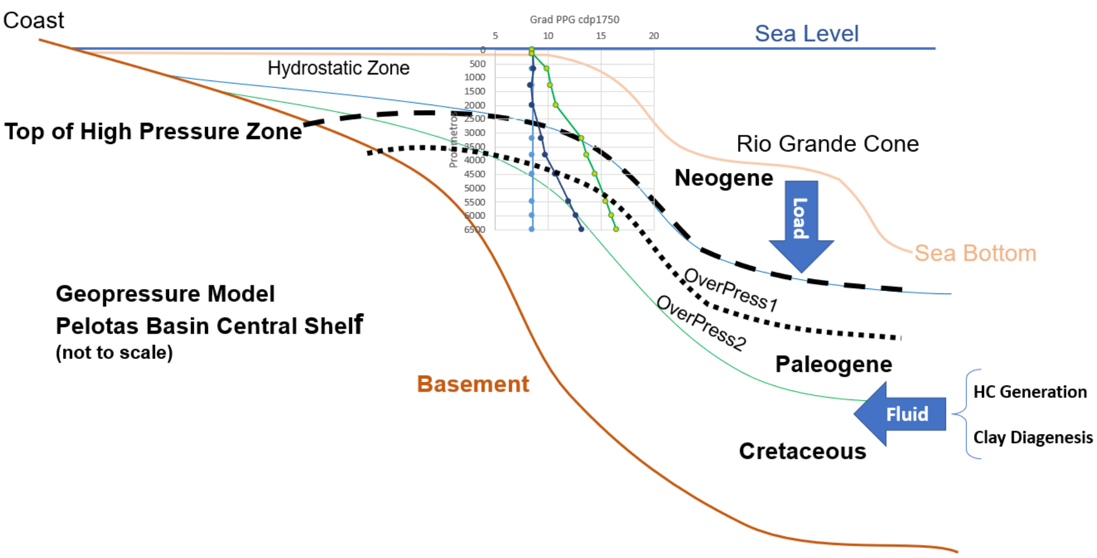

Figure 4: Geologic section showing the general geopressure model of pore pressure domains and seal properties in Peltas Basin. The hydrostatic pressure regime indicates low seal potential in proximal domains and in the Neogene section. On the contrary, seal potential is certainly high in overpressure zones. The load of the Rio Grande Cone sedimentary wedge caused extra compaction, reducing the volume of pore systems in the deeper portions of the shelf, and in Cretaceous successions. Additionally, the weight of the Cone brings more fluid to the system, through hydrocarbon generation and clay diagenesis. Both pore volume reduction and fluid volume increase produce the observed overpressure regime (Bowers, 2002). Not to scale.

Conclusions

The proposed workflow shows that it´s possible to add value to early deliverables of seismic processing, anticipating significant business information in frontier exploration areas, even from low-cost reprocessing of vintage 2D seismic data. It's important to observe that the Pelotas Basin belongs to the Austral sector of the rift and breakup of the Gondwana occurred in Early Cretaceous. Huge hydrocarbon discoveries have been reported in this sector along the counterpart African margin in ultra-deep water, offshore Namibia. The Pelotas Basin may share, in deep-water, the same prolific plays.

Acknowledgments

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