Submission code: RN90AGDR4G

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Study on the Viscoelastic Behavior of the Sirius-1 well discovery off the Colombian Coast

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Introduction

Conducted by Petrobras in 2022, the Sirius-1 discovery in the Guajira Offshore basin has opened a significant exploratory frontier along the Colombian coast. The evolution of the Caribbean Plate, characterized by its active tectonics, is directly related to the structural configuration and depocenters of the Guajira Offshore basin, which has governed deposition sequences since the Eocene epoch. The Sirius-1 well confirmed the presence of turbiditic reservoirs within the Uitpa Formation from the Lower Miocene, with gas accumulation. A notable feature of this discovery is the pronounced seismic signal response, characterized by a clear type 2 amplitude versus offset (AVO) anomaly, high orthogonal deviation, and excellent structural control, along with the presence of flat spots. These direct hydrocarbon indicator (DHI) features identified at Sirius-1 are also observed in other prospects within the same area, contributing to the low risk associated with this new exploratory frontier.

Method and/or Theory

In the presence of gas, viscoelastic effects become significantly important in the propagation of seismic signals. As seismic waves propagate through a viscoelastic medium, they experience attenuation and dispersion phenomena, resulting in increased energy loss for higher frequencies and phase distortion of the signal. In addition to this intrinsic absorption characteristic of the medium, the combination of the dominant frequency of the signal with the thickness of the geological layers can lead to destructive effects on certain components of the signal, resulting in an extrinsic absorption effect of the medium that occurs independently of viscosity. One method to quantify these phenomena is through the quality factor (Q), a dimensionless measure indicative of the amount of energy loss per wave cycle. Numerous techniques exist for estimating this parameter, which can utilize either conventional seismic data or data from vertical seismic profiles (VSP).
The VSP data from the Sirius-1 well exhibited an unexpected increasing frequency content in deeper receivers. To better understand this phenomenon, we simulate elastic and viscoelastic synthetic VSP acquisitions on layered models considering different thickness scenarios.

Results and Conclusions

The results demonstrated how the distribution of geological layers and their thickness can influence the constructive or destructive interference of the seismic signal, leading to, respectively, extrinsic attenuation or gains in certain frequency components of the data. The increasing frequency content observed on the deepest receivers of Sirius-1 well is explained by the constructive signal interference responding to a specific layer thickness - approximately 50 m. It is anticipated that with appropriate correction of this absorption phenomenon, the characteristics of DHIs will be better recognized, thereby contributing to the identification of potential prospects in this exploratory frontier.

Acknowledgments

The authors thank Petrobras and Ecopetrol for authorizing this publication.