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Evaluation of the Depositional Model of a Turbidite Gas Reservoir in the Recôncavo Basin Based on Electrical Log Analysis

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Abstract Summary

This study integrates the depositional model proposed by Caixeta (1988) with the broader turbidite system framework established by Galloway (1998), resulting in a refined genetic and architectural interpretation of the Maracangalha Formation in the Recôncavo Basin. By correlating local facies characteristics with universal depositional patterns, the research strengthens predictive models of reservoir distribution and quality. The work is grounded in an extensive technical archive inherited from Petrobras and incorporated into PetroReconcavo's database, including seismic surveys, field development plans, well logs, core descriptions, production data, and structural interpretations. This multidisciplinary dataset provides a robust foundation for testing classical models and validating them against field-scale evidence, ensuring practical applicability to exploration and production strategies.

Geological Setting

The Recôncavo Basin, northeastern Brazil, is a key example of an aborted Early Cretaceous intracontinental rift, formed during Gondwana breakup and the onset of South Atlantic opening (Milhomem et al., 2003). Structurally, it is an asymmetric NE–SW half-graben, bounded by high-angle normal faults and segmented by transfer zones (Teixeira Netto et al., 1984). A defining element of its evolution is the intense diapirism of overpressured shales in the Candeias and Maracangalha formations, mobilized during active rifting. Deposition and deformation occurred simultaneously: diapiric highs and interdiapir troughs confined turbidity currents, concentrating sand into amalgamated, laterally continuous bodies, while adjacent areas trapped chaotic debris flows and mud-rich facies, enhancing reservoir heterogeneity (Raja Gabaglia, 1991; Obermeier, 1996).

Figure 1.

Figure 2.

Within this framework, the Maracangalha Formation is a ~2,000m thick clastic succession subdivided into the Caruaçu and Pitanga members. The Caruaçu Member is dominated by channelized and lobe turbidites, which form the basin's best reservoirs due to their good porosity, permeability, and connectivity. The Pitanga Member, by contrast, is characterized by fine-grained massive sandstones and debris-flow facies with poor reservoir quality (Caixeta, 1988). Injectites linked to diapiric activity further influence reservoir architecture, acting either as high-permeability conduits that improve vertical connectivity or as heterogeneities that disrupt fluid flow (Hurst & Cartwright, 2007). This interplay of syn-sedimentary tectonics, diapirism, and turbidite sedimentation defines a petroleum system where high-quality reservoirs coexist with tight, low-quality facies, directly impacting hydrocarbon accumulation and distribution.

Figure 3.

Figure 4.

Figure 5.

Methodology

The correlation between Caixeta's (1988) depositional model for the Maracangalha Formation (Figure 6) and Galloway's (1998) turbidite system framework (Figure 7) was established through the integration of facies analysis and well-log pattern recognition, supported by facies description. Caixeta's model, which details the Caruaçu and Pitanga members - including in situ and remobilized delta-front sandstones, channelized turbidites, lobe turbidites, debris-flow deposits, and soft-sediment deformation structures (SSDS) - was systematically compared with the architectural elements proposed by Galloway. Following Galloway's methodology of rock-log correlation, gamma-ray signatures were employed as the main criterion to establish equivalence: coarsening-upward trends were associated with in situ delta fronts; block-shaped low gamma responses with channelized turbidites; serrated moderate values with lobe turbidites; and irregular, abrupt fluctuations with debris flows, remobilized delta fronts, or SSDS. This approach allowed the facies-based, field-scale observations of Caixeta to be framed within Galloway's broader genetic and architectural model, providing a consistent linkage between the local stratigraphy of the Maracangalha Formation and universal depositional patterns in deltaic–turbidite systems.

Figure 6.

Figure 7.

Results

Figure 8.

Conclusions

Channelized turbidites are the most effective reservoirs on the field, formed by thick, well-sorted sandstone bodies with block-shaped gamma-ray profiles with excellent porosity and permeability, ensuring high storage and transmissibility of hydrocarbons. Lobe turbidites represent laterally extensive reservoirs with serrated gamma-ray responses, with good porosity, low water saturation, and interbedded sandy layers that favor hydrocarbon accumulation. Debris-flow sandstones behave as tight sands, characterized by poor sorting, abundant clay matrix, and low permeability, acting mainly as internal flow barriers within the system. Delta-front sandstones show contrasting behavior: non-deformed facies have good porosity and permeability but high-water saturation, while remobilized facies exhibit heterogeneity and variable reservoir quality due to chaotic mixing of sand and mud. SSDS Facies with abrupt log variations linked to injectites and liquefaction. Holds moderate potential, combining preserved porosity with structural deformation, which introduces heterogeneities that partially compromise fluid flow. Injectites may play a critical dual role, acting as vertical high-permeability conduits that enhance connectivity between isolated sandy bodies, but also generating unpredictable heterogeneities that complicate reservoir performance.

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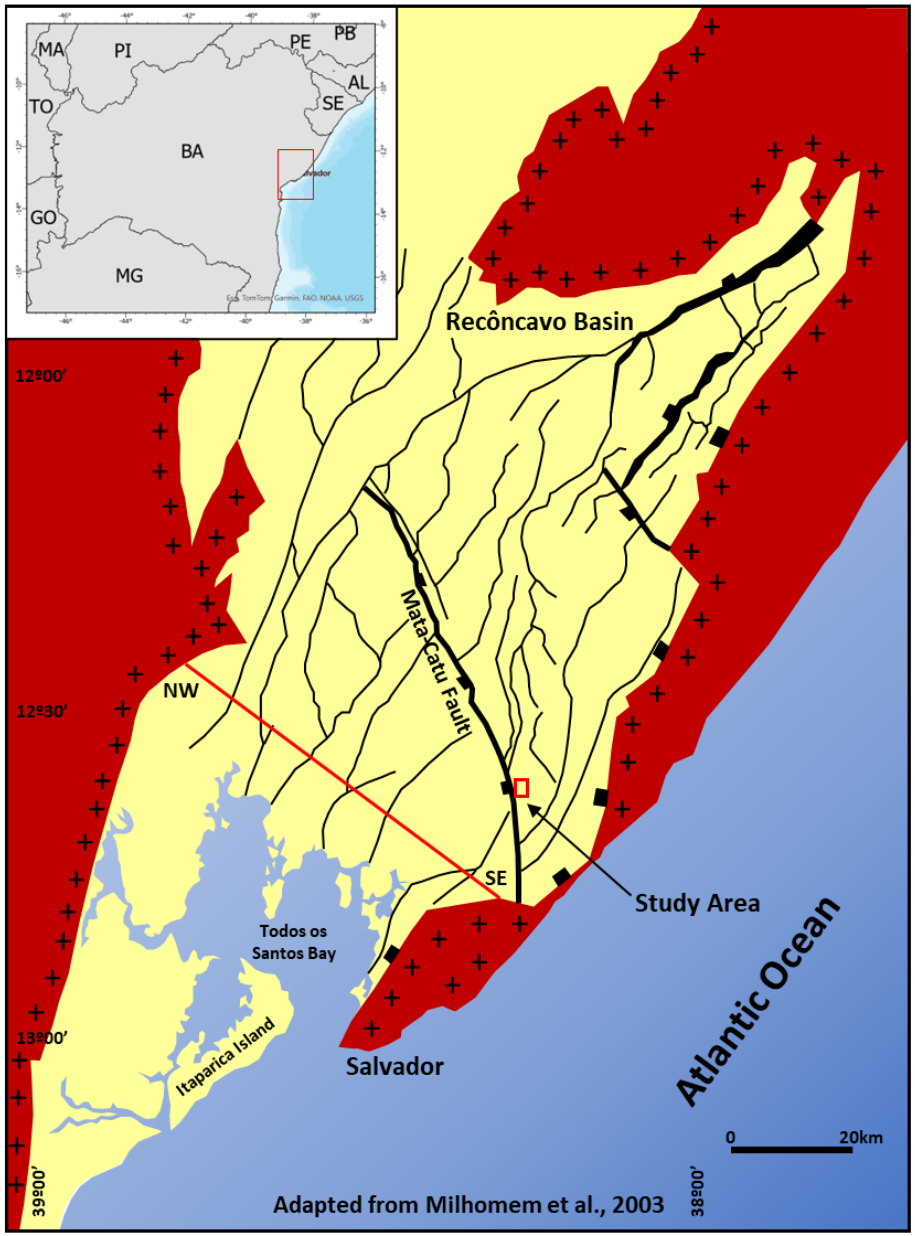

Figure 1. Location map of the study area in Northeastern Brazil (Bahia State) and geological framework of the Recôncavo Basin. (adapted from Milhomem et al., 2003).

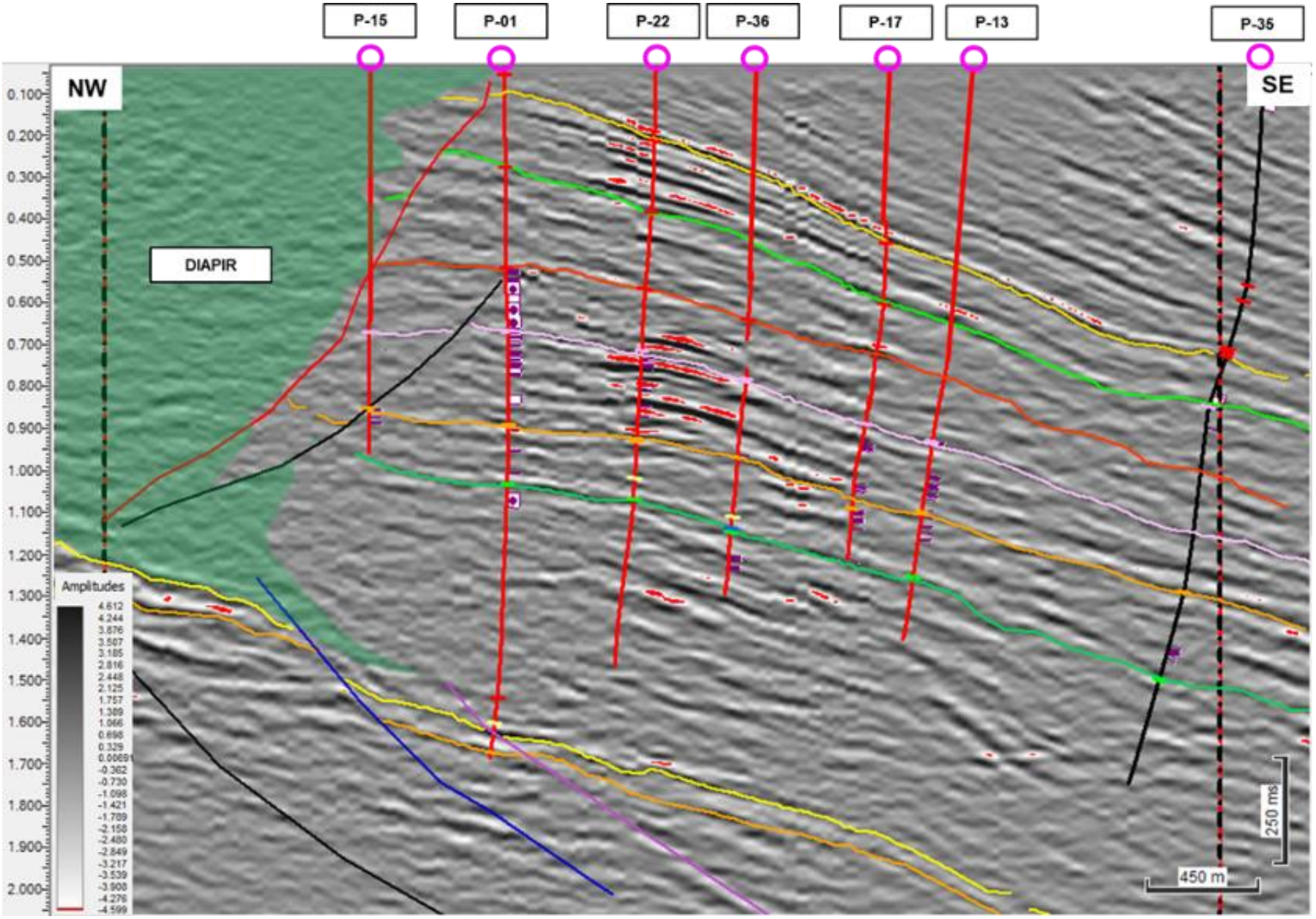

Figure 2. Cross-section illustrating the structural deformation generated by shale diapirism, highlighting its impact on the stratigraphic framework and reservoir compartmentalization.

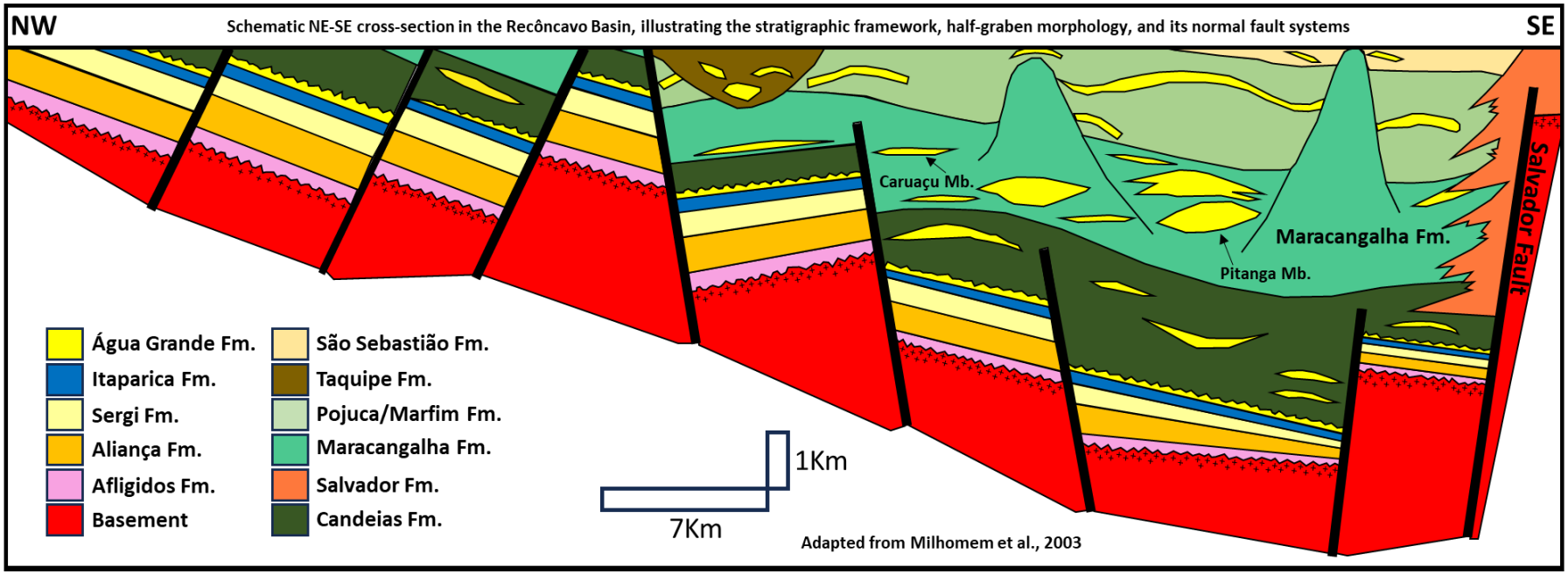

Figure 3. Schematic NW–SE cross-section (highlighted in red) across the Recôncavo Basin, illustrating its stratigraphic architecture, half-graben morphology, and associated normal fault systems (adapted from Milhomem et al., 2003).

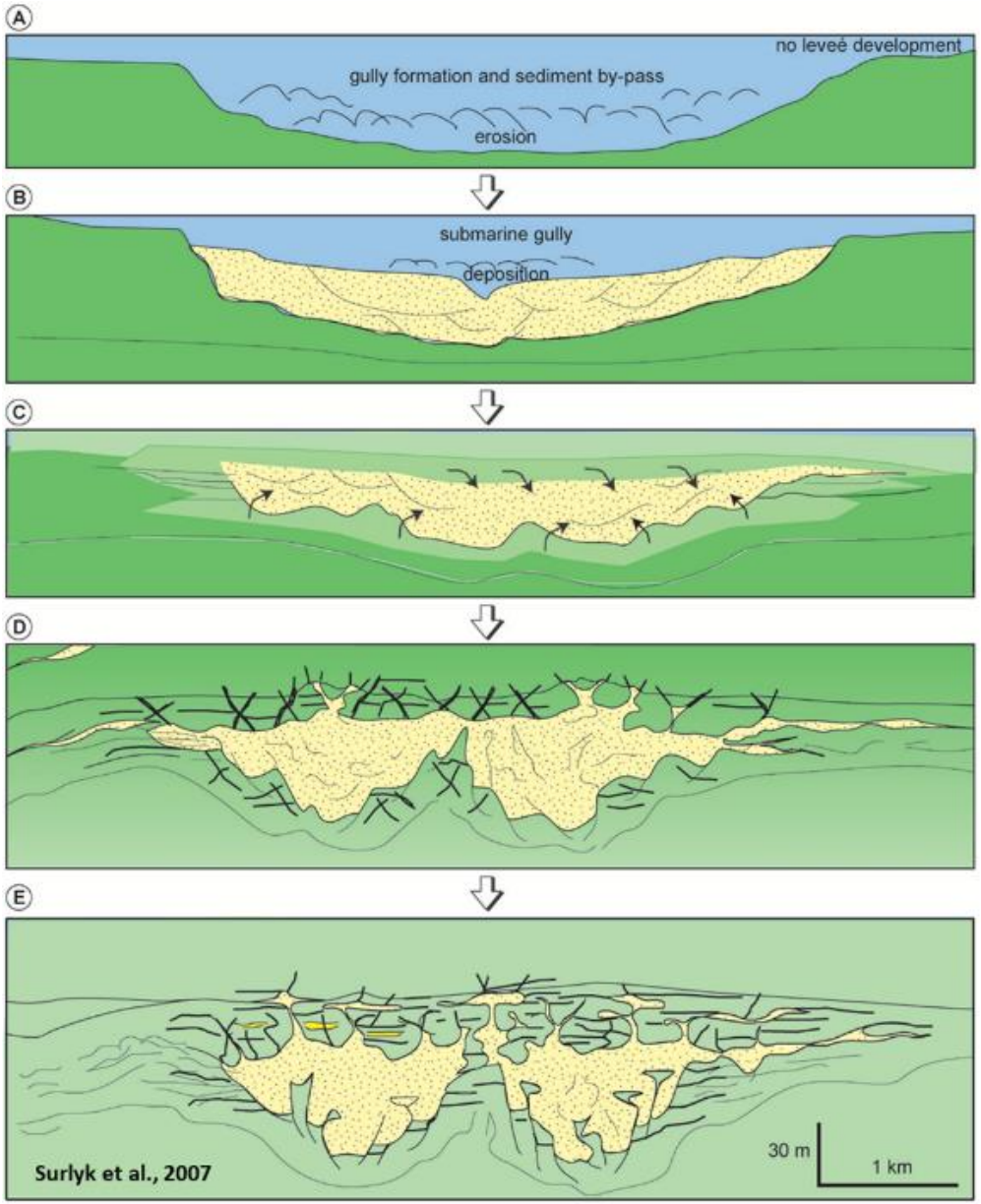

Figure 4. Successive stages of sand remobilization and injection in the Katedralen Member, Hareelv Formation, Jameson Land: (A) slope gully formation; (B) deposition of thick, structureless sands; (C) shallow burial and initial remobilization; (D) deeper burial with fractures and sill/dike injection; (E) final remobilization and fracturing. (Surlyk et al., 2007).

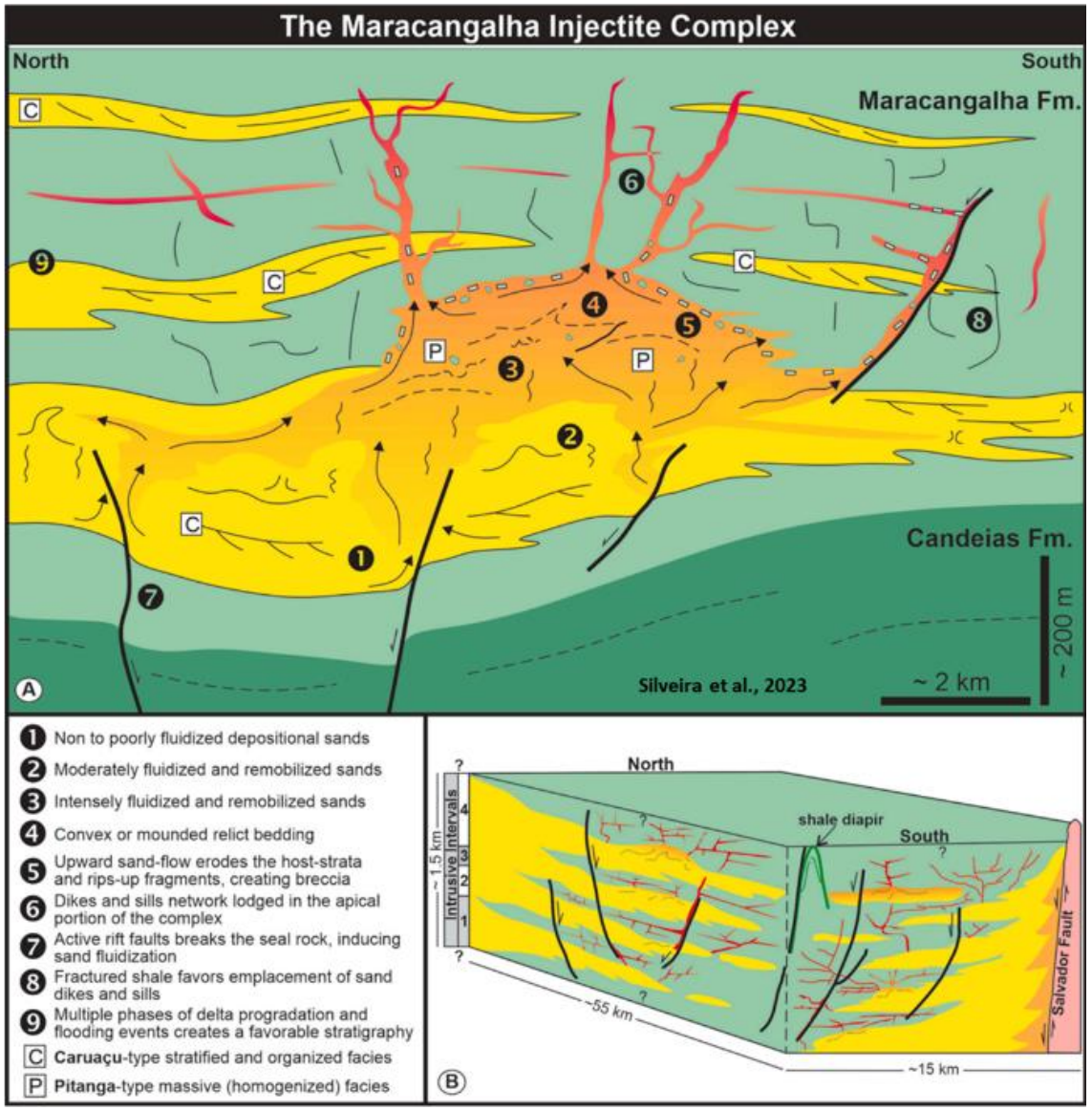

Figure 5. (A) Conceptual model of sand fluidization, remobilization, and injection in deltaic facies of the Maracangalha Formation within an intrusive interval. The Caruaçu and Pitanga members differ in the deformation degree caused by upward fluid flow. (B) Schematic 3D block diagram showing deltaic progradation and flooding events that filled the "Maracangalha Lake," creating favorable stratigraphy for sandstone intrusions. (Silveira et al., 2023).

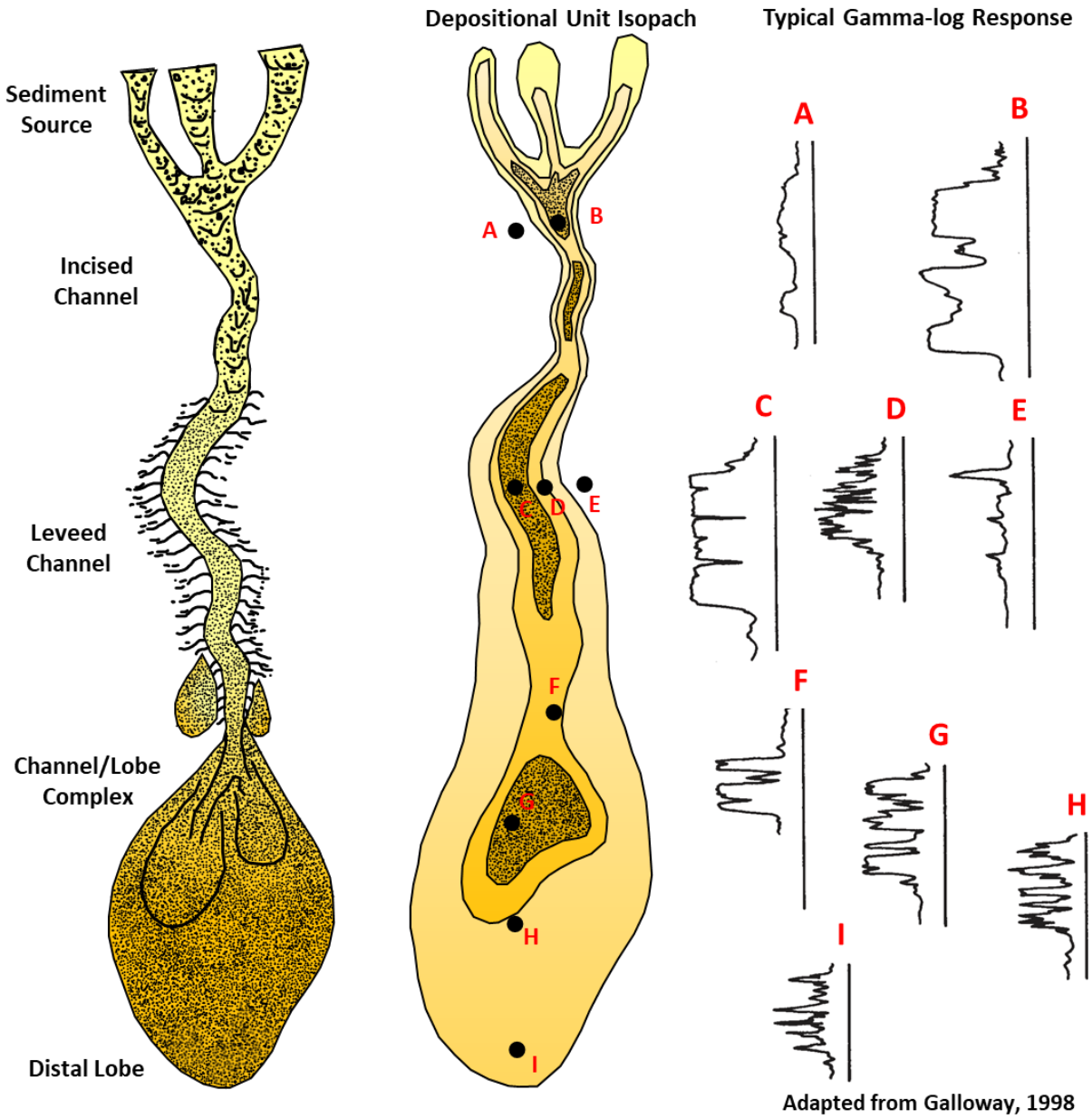

Figure 6. Geomorphic elements, depositional unit, isopach, and typical log response, (Adapted from Galloway, 1998).

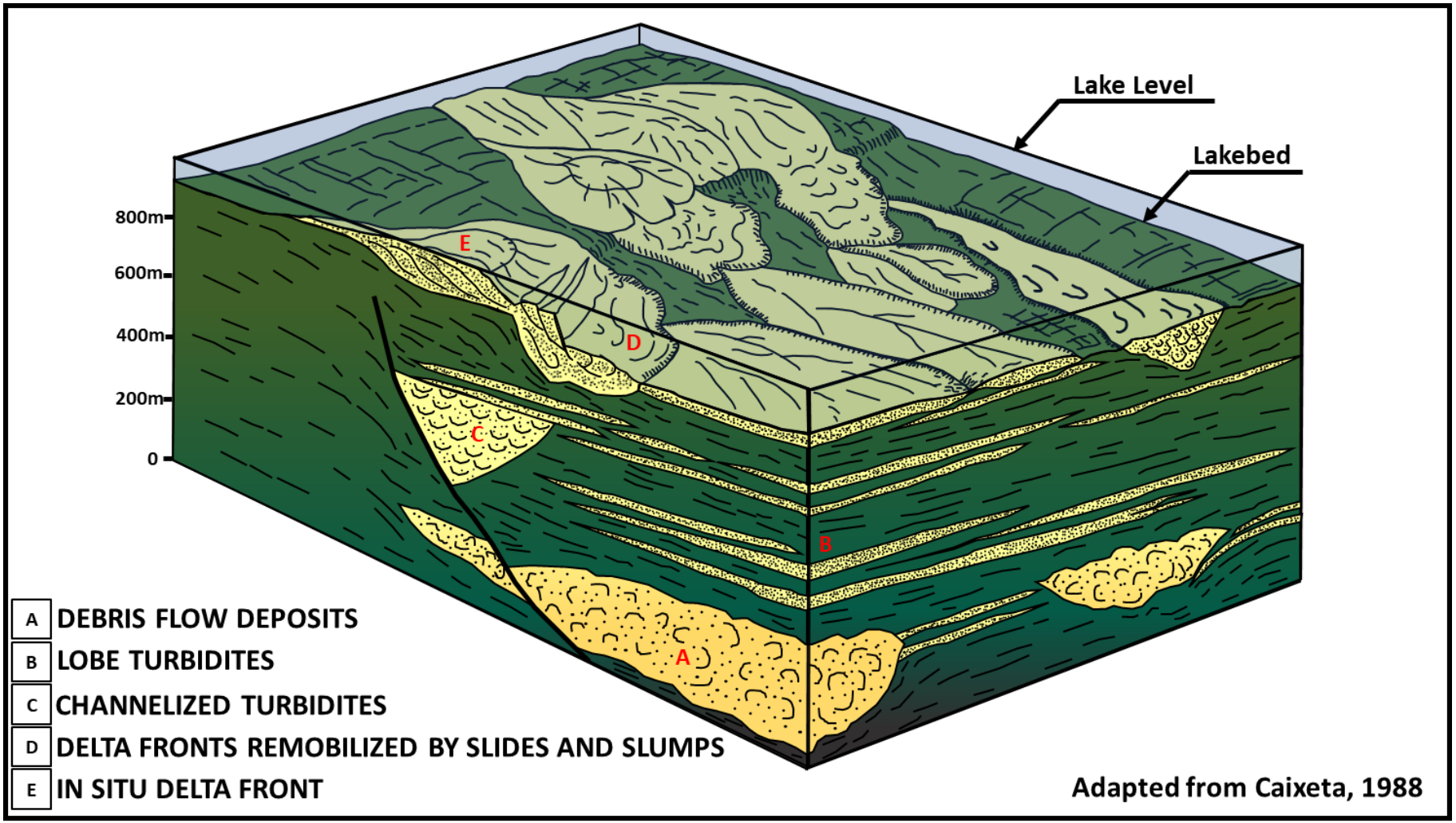

Figure 7. Illustrative block diagram of the faciological evolution, tectonic pattern, and physiography of the lake bottom during the Upper Serra River Stage (Lower Cretaceous) in the Jacuípe area. (Adapted from Caixeta, 1988).

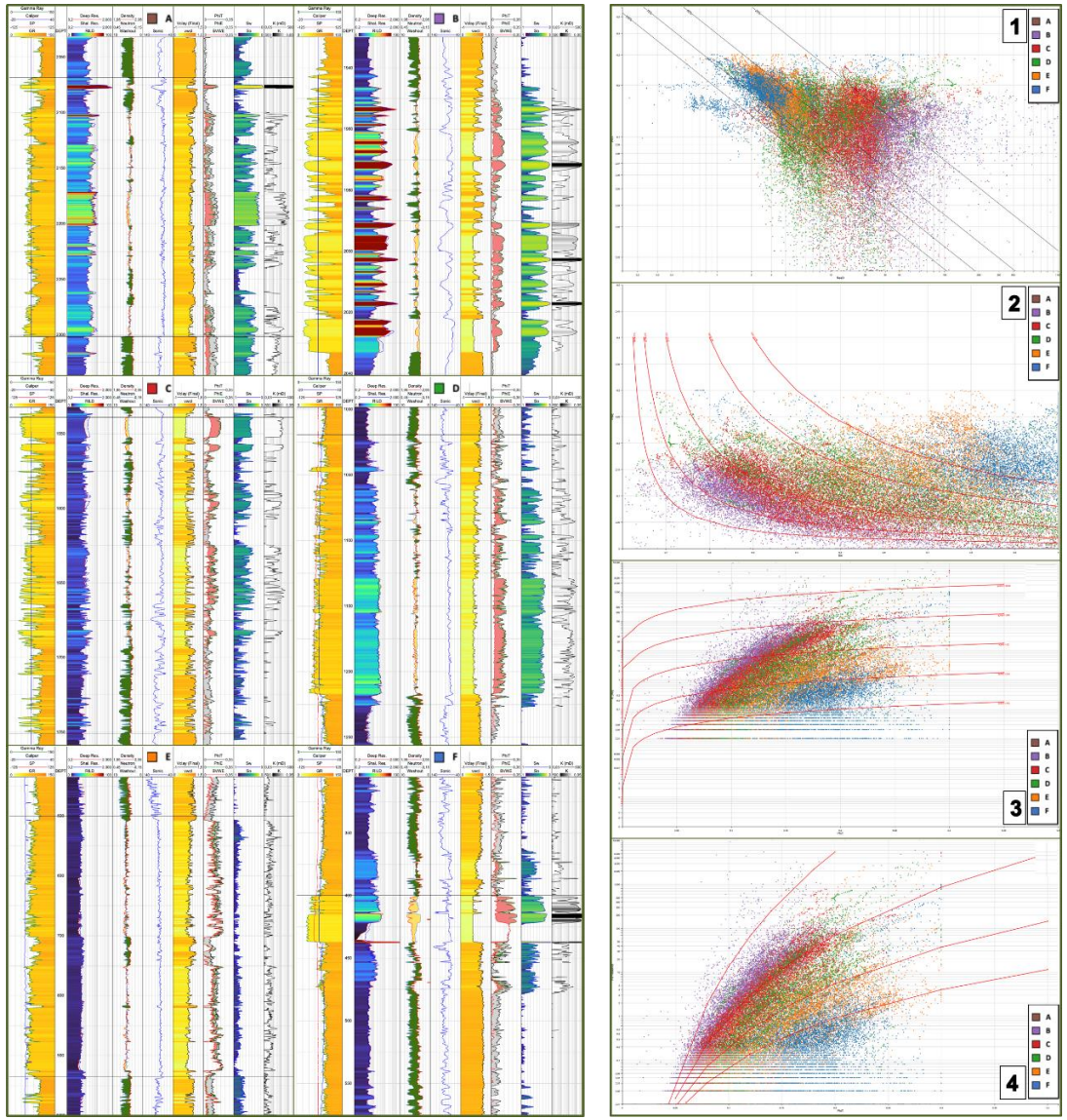

Figure 8. Representative log profiles of the six electrofacies identified in the Caruaçu Member, integrated with their corresponding petrophysical crossplots: (1) Pickett, (2) Buckles, (3) Winland, and (4) Lucia K–Φt. Each electrofacies is shown with a type log and crossplot interpretation, enabling direct correlation between depositional architecture and petrophysical response. Facies classification: A = Debris-flow sandstones; B = Lobe turbidites; C = Soft-sediment deformation structures (SSDS); D = Channelized turbidites; E = Remobilized delta-front sandstones; F = Non-deformed delta-front sandstones.