

**PS Diagenetic Processes in Sabkha Deposits and Exploration Potential of the Intracratonic Parecis Basin,
Western Brazil***

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Search and Discovery Article #10223 (2010)

Posted January 25, 2010

*Adapted from poster presentation at AAPG Convention, Denver, Colorado, June 7-10, 2009

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Abstract

The Parecis Basin is a large intracratonic basin in western Brazil, with an area of approximately 500,000 km² and a sedimentary fill more than 6 km thick. Knowledge of the geology and stratigraphy of the basin is very scarce, and there are no petrologic studies published on its sedimentary rocks. The petrologic study of coastal sabkha deposits from the Paleozoic Pimenta Bueno Formation revealed that the diagenetic processes are largely facies-controlled, with substantial differences among tidal flat, deltaic and hypersaline lagoon deposits. The sequence of diagenetic processes indicates that diagenetic fluids of two main compositions were responsible for the precipitation of the authigenic minerals. Diagenesis was initially controlled by saline-alkaline, oxidizing porewaters that precipitated Fe oxide coatings, quartz and feldspar overgrowths, anhydrite, dolomite, calcite, chalcedony and microquartz cements. Later introduction of meteoric waters led to the precipitation of calcite, kaolinite and megaquartz. Deltaic sandstones from the Pimenta Bueno Formation show relatively good porosity and occurrences of residual bitumen. Such evidence, together with similarities in depositional facies and diagenetic evolution between the Pimenta Bueno Formation and the Carboniferous deposits of the Juruá Formation, important reservoirs of the Solimões Basin, western Amazon region, suggests good potential for hydrocarbon exploration in the Parecis Basin.

Introduction

The Parecis Basin in central Brazil covers an area of approximately 500,000 km² with a general W-E elongation (Figure 1). The age of the oldest rocks probably spans the Upper Proterozoic to the early Paleozoic (Ordovician to Siluro-Devonian), and sedimentation continued through the Late Paleozoic, Mesozoic and Tertiary (Siqueira, 1989; Teixeira, 2005; Bahia et al., 2006; Bahia et al., 2007). The PB-01-RO borehole (Figure 1) comprises 941 meters of continuous coring, with the top 108 m belonging to the Fazenda da Casa Branca Formation (Permo-Carboniferous?). The interval between 108 and 848 m corresponds to interbedded fine and coarse siliciclastic rocks, and the bottom 93 m comprise carbonate rocks and evaporites overlying siliciclastic rocks belonging to the Pimenta Bueno Formation (Siluro-Devonian?) (Figure 2).

Thin sections prepared from 31 samples impregnated with blue resin were examined by petrographic microscopy following staining for carbonates. Modal compositions were obtained by counting 300 points in each thin section. The occurrence habits and textural relationships among selected minerals were examined using a scanning electron microscope (SEM) equipped with an energy-dispersive X-ray analyzer (EDAX). The chemical composition of selected minerals was determined in a microprobe equipped with three spectrometers and a back-scattered electron detector (BSE). Oxygen, carbon and strontium isotopic analyses were performed in 11 samples.

This study aims at the elucidation of the diagenetic evolution of evaporites and siliciclastic sediments from the Parecis Basin, and at discussing the relationship between diagenetic processes and depositional facies. This work offers an insight into the petrological understanding of the Pimenta Bueno Formation, pointing to the potential implications for the petroleum exploration of this exploratory frontier.

Primary Texture and Composition of Sandstones

The sandstones occur mainly in the fluvial facies, where they are interbedded with mudstones and mud-chip conglomerates. They are mostly fine- to coarse-grained subarkoses. The framework grains are predominantly quartz, K-feldspar, plagioclase and rock fragments. Accessory minerals include biotite, muscovite and epidote. The most abundant rock fragments are sedimentary (very fine sandstones and siltstones) and plutonic in origin. Mud intraclasts are only locally abundant.

Diagenetic Constituents

The diagenesis of the rocks drilled in the PB-01-RO core is largely facies-controlled, with playa lake evaporites and fluvial sandstones displaying very different diagenetic processes and products. The diagenetic evolution of the analyzed samples from the Pimenta Bueno Formation is illustrated in [Figure 3](#).

The evaporites have been greatly modified by diagenetic processes. Diagenesis in these rocks started with the early silicification of originally microbial, micritic muds ([Figure 4a](#)), followed by extensive replacement by dolomite and coarse anhydrite throughout the mesodiagenesis ([Figure 4b](#)). Gypsum and silica replaced dolomite and anhydrite under eodiagenetic and then telodiagenetic conditions ([Figure 4c](#)).

The fluvial sandstones display numerous diagenetic products. During eodiagenesis, hematite and clay coatings covered the grains, followed by multiple phases of quartz (and locally K-feldspar) overgrowths ([Figures 4d-e](#)). Mechanical compaction of mud intraclasts led to the formation of pseudomatrix, which was commonly replaced by dolomite during mesodiagenesis. The main mesodiagenetic process was the precipitation of sulfates (anhydrite and barite) and carbonates (calcite, dolomite and kutnahorite-ankerite-huntite) ([Figure 4f](#)). Telodiagenetic processes involved the formation of pore-filling, globular hematite, gypsum nodules and veins, and kaolinite. During a second mesodiagenetic stage, illite and anhydrite veins were formed.

Porosity and Compaction

Remaining intergranular porosity averages 5% of bulk rock volume in the sandstones, whereas secondary porosity, formed mainly due to the dissolution of K-feldspar grains and intergranular cements, forms up to 3%. Total macroporosity ranges from 0 to 19.9% (av. 7.9%). The sandstones show a moderate degree of compaction. Deformation of ductile intraclasts into pseudomatrix is common, but the scarcity of sutured and concave-convex contacts indicates that chemical compaction was not very effective. The average intergranular volume is relatively high (28%), possibly due to syn-compactional cementation by poikilotopic calcite and anhydrite, which locally supported the framework. Both compaction and cementation were important in reducing intergranular porosity, although compaction was slightly more effective than cementation.

Hydrocarbon Evidence and Exploration Implications

The occurrence of hydrocarbon generation, migration and possible accumulation elsewhere in the Parecis Basin is indicated by the presence of hydrocarbon residues in the PB-01-RO core (2% bitumen at depth 689.35 m), as well as by gas exudation along the Teles Pires River in Salto Magessi (Alves et al., 2008). Potential source rocks were sampled in the other boreholes in the Parecis Basin, and probably occur in the Lower Paleozoic sequence. According to geochemical data provided by ANP (National Petroleum Agency), organic-rich intervals between 3,976 and 5,122 m in the 2-SM-01-MT well vary between 0.9 and 3.0% of TOC (total organic carbon), with an average of 1.6%. The plot of oxygen index (S3) and the hydrogen index (S2) for this borehole shows that the organic matter in these rocks correspond to Type III, mostly terrestrial material, indicating some potential for gas generation.

The present study revealed that the Pimenta Bueno Formation has a good potential for trapping hydrocarbon accumulations within the Parecis Basin. The coarse-grained, fluvial sandstones observed in the PB-01-RO borehole show good porosities and comprise potential reservoirs, with the evaporites and playa-lake mudstones acting as seals. Such set of evidence indicates an attractive potential for the Parecis Basin, as well as the need for integrated geophysical, structural, stratigraphic, petrologic, and geochemical studies to assess the opportunities and risks involved in basin exploration.

Conclusions

The description of cores from the PB-01-RO borehole in the Parecis Basin revealed the occurrence of continental sabkha deposits, in which playa lake evaporites are interbedded with fluvial sandstones. This study provided the first insight into the petrology of the Pimenta Bueno Formation, revealing that the diagenetic processes observed in these rocks were controlled by the facies distribution, with evaporites and sandstones displaying different processes and products.

Moreover, it has shown that fluvial sandstones in the PB-01-RO show relatively good porosity and occurrences of residual bitumen, comprising potential reservoirs in the Parecis Basin. Potential source rocks and seals are the organic shales, and evaporites and playa-lake mudstones of the Pimenta Bueno Formation, respectively. The existence of an active petroleum system in the basin (attested by gas exudation along the Teles Pires River) suggests a good potential for hydrocarbon exploration in the Parecis Basin, especially for gas.

Acknowledgements

We wish to thank UNESCO for a ICSU/TWAS fellowship grant that allowed the trip of the first author to Sweden, CPRM/Geological Survey of Brazil for the unlimited access and sampling of the PB-01-RO core, ANP (National Petroleum Agency) for the logs and geochemical data from 2-SM-01-MT and 2-FI-01-MT, as well as the Federal University of Rio Grande do Sul – UFRGS, Brazil and Uppsala University, Sweden, for access to analytical facilities. Our thanks also extend to UNISINOS (Brazil) for thin-section preparation, and to H. Harryson (Uppsala University) for aid with the microprobe analyses.

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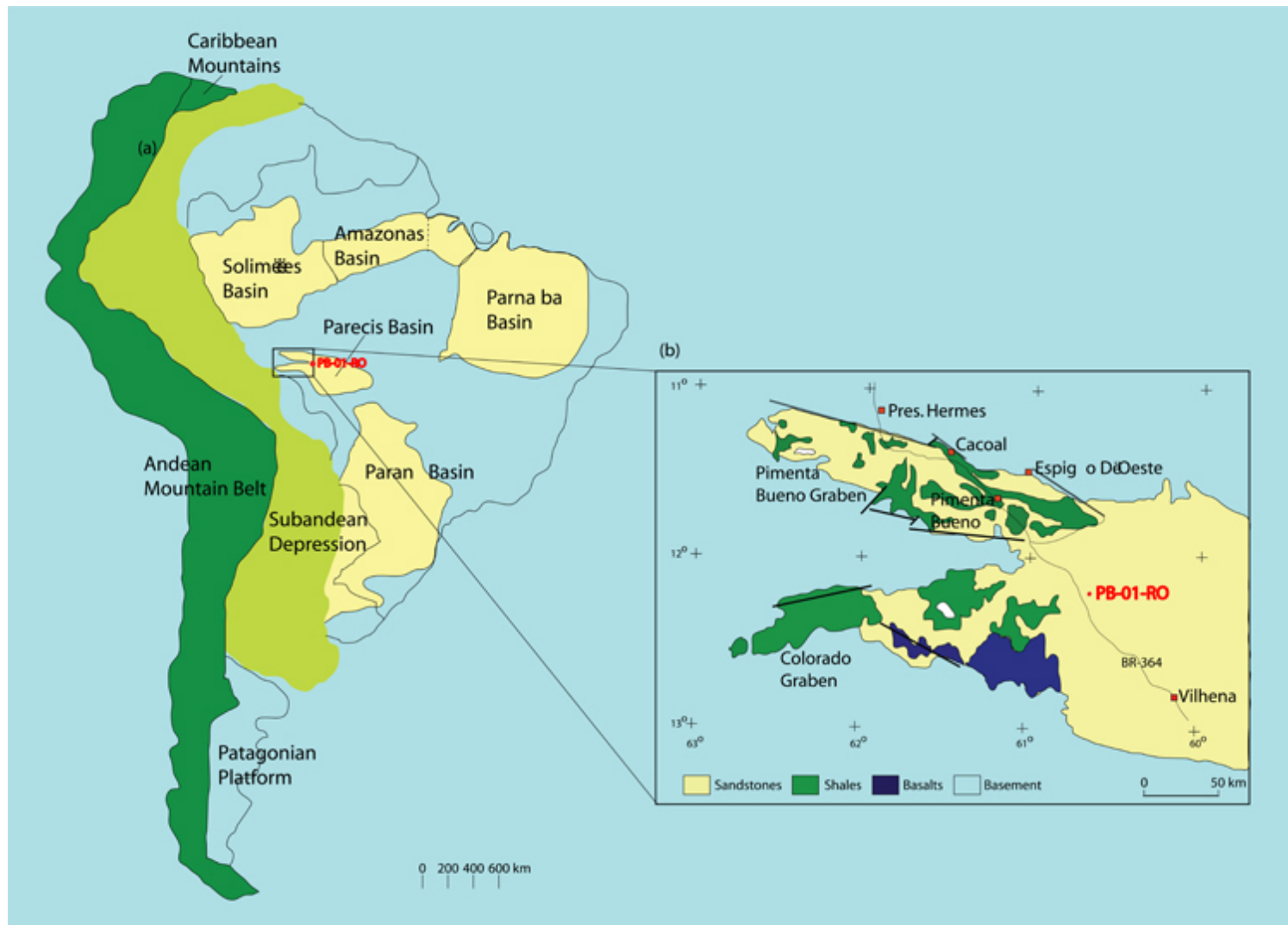


Figure 1. Location map of the Parecis Basin in western Brazil and of the PB-01-RO well in northwestern Parecis Basin (Modified from Siqueira, 1989).

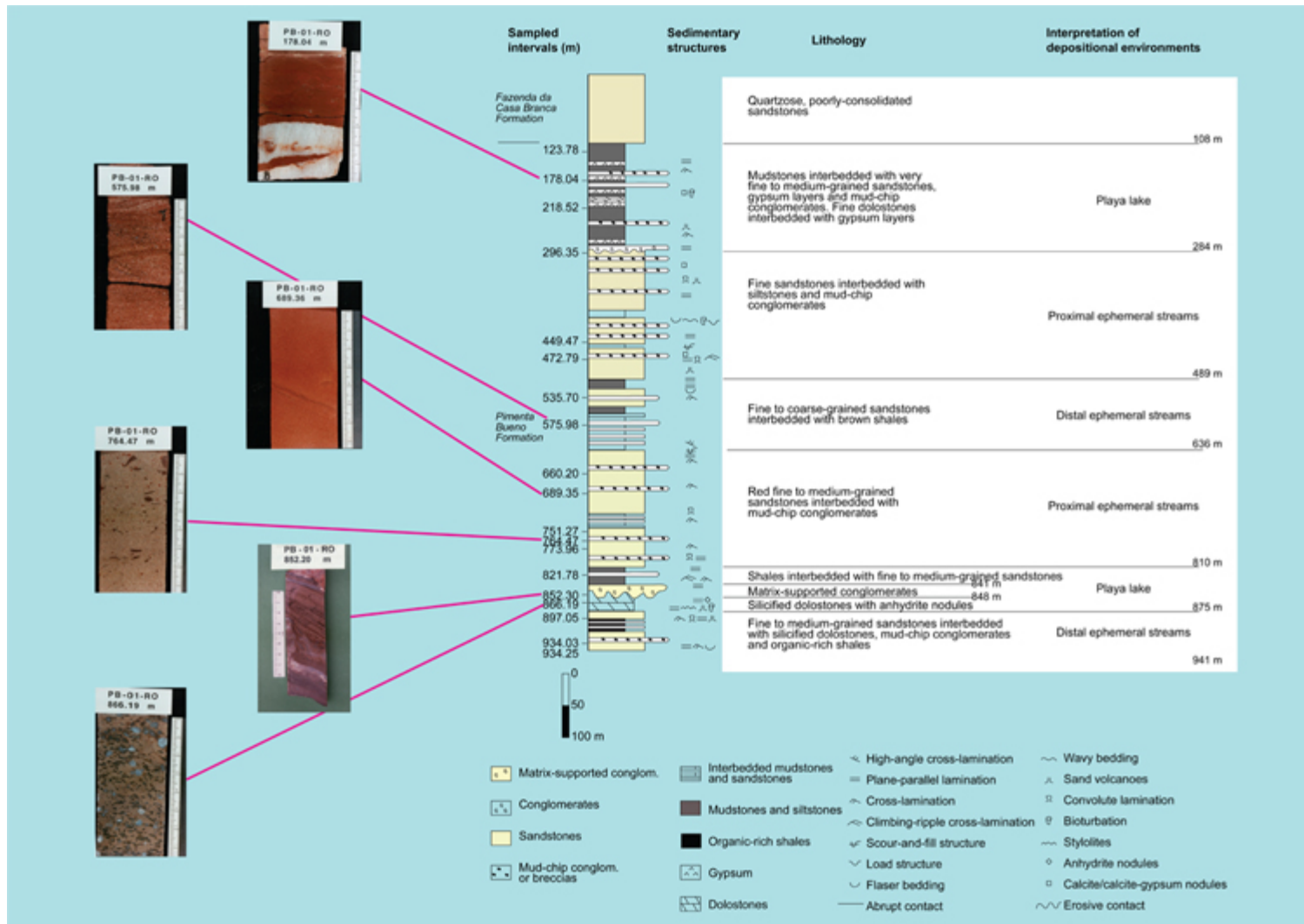


Figure 2. Schematic representation of the rocks in the PB-01-RO well, with their interpreted depositional environments.

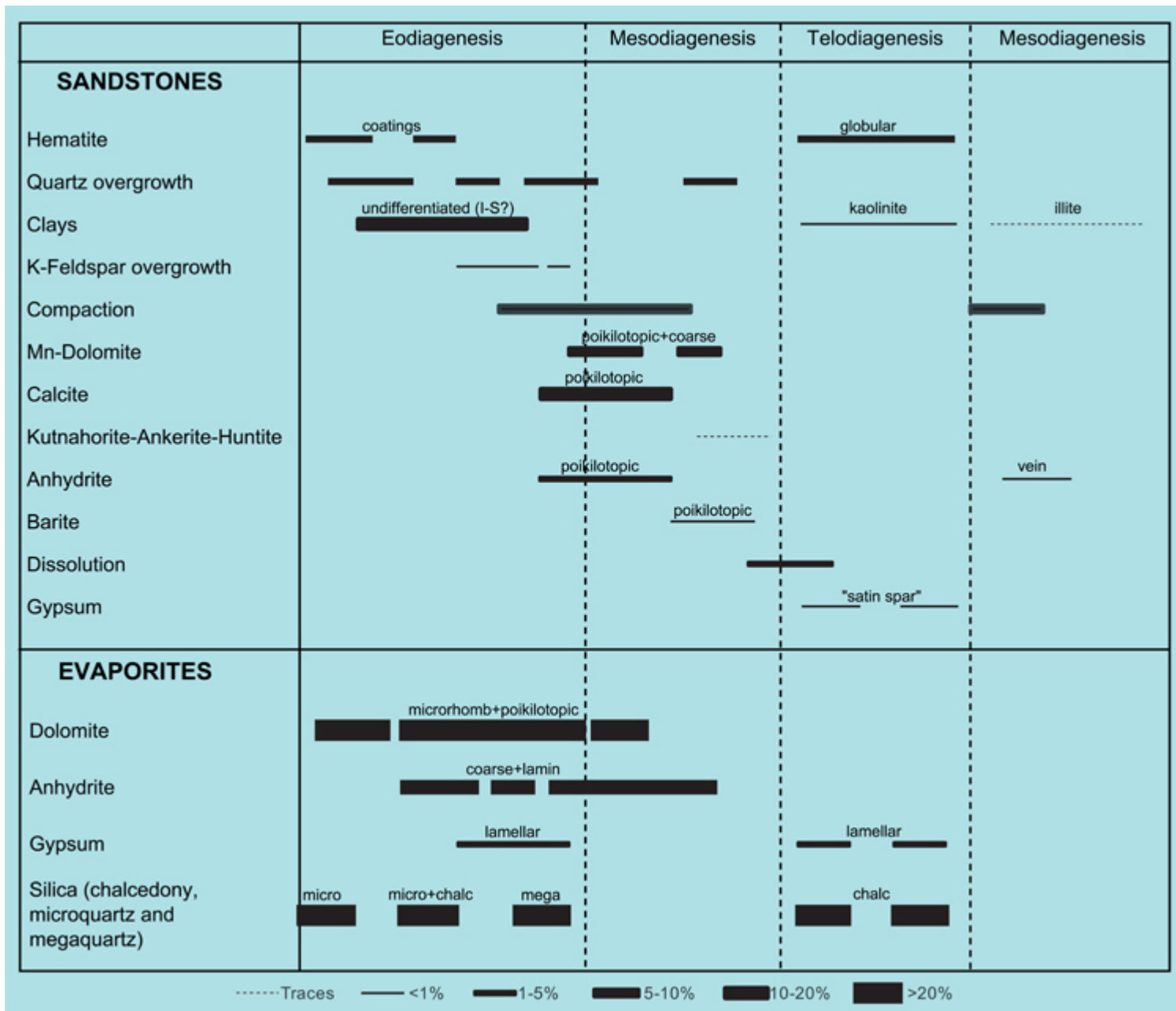


Figure 3. Generalized sequence of the diagenetic processes and products for sandstones and evaporites in the Pimenta Bueno Formation.

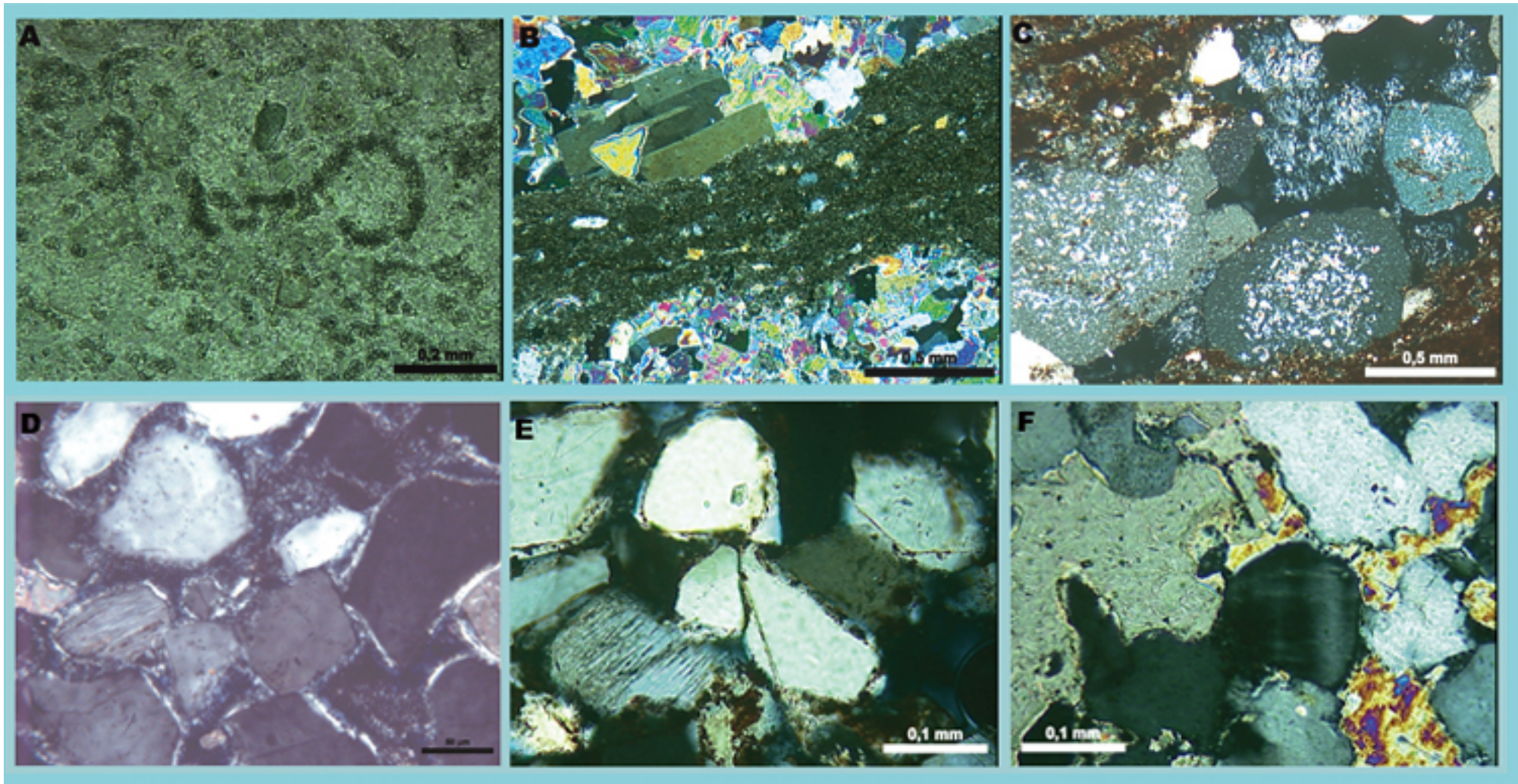


Figure 4. (A) Micro-rhombic dolomite replacing originally microbial, micritic mud, being replaced by anhydrite (10x, parallel polarizers PPL – 897.05); (B) Microdolomite and anhydrite replacing the original, laminated sandy micritic mud (5x, crossed polarizers XLP – 897.05); (C) Anhydrite inclusions occur within gypsum and calcite-gypsum nodules (5x, XLP – 178.04); (D) Undifferentiated clay coatings covered by clay rims in the fluvial sandstones (40x, PPL – 123.78); (E) Quartz overgrowth engulfing hematite coatings in sandstone (20x, PPL – 689.35); (F) Poikilotopic calcite replacing intergranular anhydrite cement (20x, XLP – 821.78).