[PS]Geochemistry and Organic Petrography of Aptian-Albian Source Rocks in the Araripe Basin, Northeastern Brazil*

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Abstract

The Mid-Cretaceous is a key interval for oil and gas exploration in Brazilian basins, with tens of billions of barrels of oil discovered. The northeastern Brazil interior Araripe Basin, correlative to the prolific marginal basins, was formed by the reactivation of Precambrian basement structures related to the rift phase. A geochemical characterization of Aptian-Albian organic shales aimed at the determination of their generation potential and correlation with coeval Equatorial Atlantic source rocks. Ten samples of organic shales from the 3 members of the Santana Formation were analyzed. XRD analyses indicate quartz, smectite and calcite as the essential mineralogy, with subordinate gypsum, pyrite, illite and kaolinite. The lower Crato Member samples comprise 87% amorphous organic matter (AOM; aggregated, flaky, yellow-brown and granular under white light and yellow fluorescent under UV excitation), 11% phytoclasts (opaque, woody, equidimensional to pseudomorphic) and 2% palynomorphs. The intermediate Ipubi Member samples contain 68% AOM (mostly granular, highly reworked and oxidized), 15% phytoclasts (opaque, fungi, thin and fibrous tissues) and 7% palynomorphs. The uppermost Romualdo Member samples contain 68% AOM (translucid, granular, preserved), 26% phytoclasts (elongated, dark brown, fungi) and 6% palynomorphs. There is a progressive upwards decrease in AOM and increase in phytoclasts. The few palynomorphs are basically spores and Classopolis pollens, associated with gymnosperms, indicative of arid climates. TOC varied from 1 to 29.5 wt%, reflecting facies and stratigraphic variations, but with overall excellent hydrocarbon generation potential. Kerogen is mostly type II, indicating a mixed lacustrine and marine origin, with two Ipubi samples of type I (lacustrine) kerogen. HI varies from 2.1 to 243.1 mg HC/g, indicating reasonable to excellent generation potential. Pyrolysis Tmax of 361 to 433 degrees C, spore coloration index 3-4, and vitrinite reflectance of 0.29-0.6% Rrandom suggest immature to marginally mature organic matter. The intervals with better generation potential are stratigraphically located in the high-accommodation systems tract at the base of the Ipubi Member, correlative to the Trairi and Ponta do Tubarão Layers in the Ceará and Potiguar Basins, respectively. Araripe Basin Aptian-Albian organic shales reveal important information for the exploration of coeval Equatorial Margin petroleum systems.

Reference Cited

Assine, M.L., 2007, Bacia do Araripe: Boletim de Geociências da Petrobrás, v. 15/2, p. 371–389.

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The Mid-Cretaceous is a key interval for oil and gas exploration in Brazilian basins, with tens of billions of barrels of oil discovered. The northeastern Brazil interior Araripe Basin (Fig. 1), correlative to the prolific marginal basins, was formed by the reactivation of Precambrian basement structures related to the rift phase.

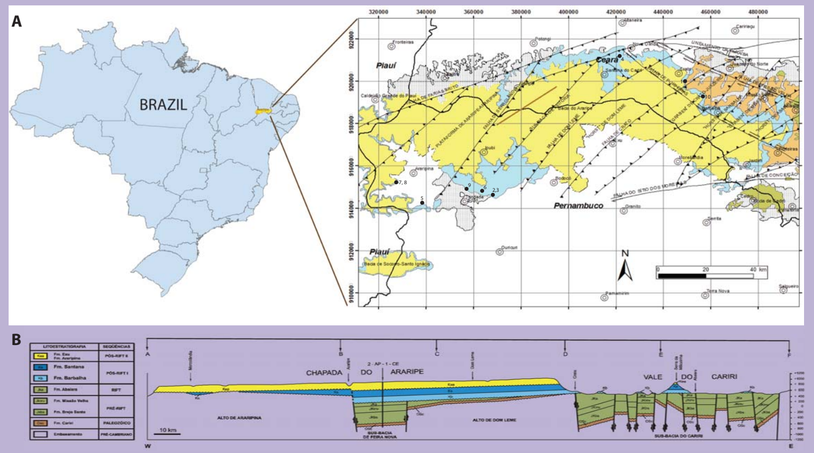


Figure 1 - Location of the Araripe Basin in northeastern Brazil and a geological/structural map with the location of studied samples (1-10) (A); Regional cross section, with the studied interval in blue (B) (modified from Assine, 2007)

Several intervals in the post-rift Aptian-Albian Santana Formation (Fig. 2) display high organic contents (>10% TOC). This study is a geochemical characterization of the organic shales aimed at the determination of their generation potential and correlation with coeval Equatorial Atlantic source rocks.

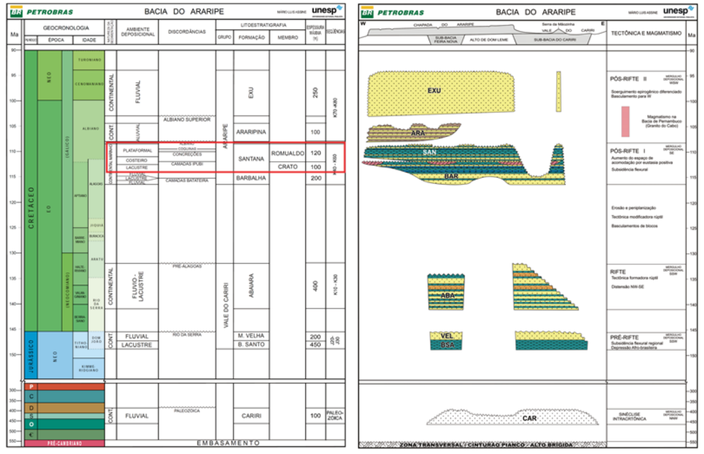
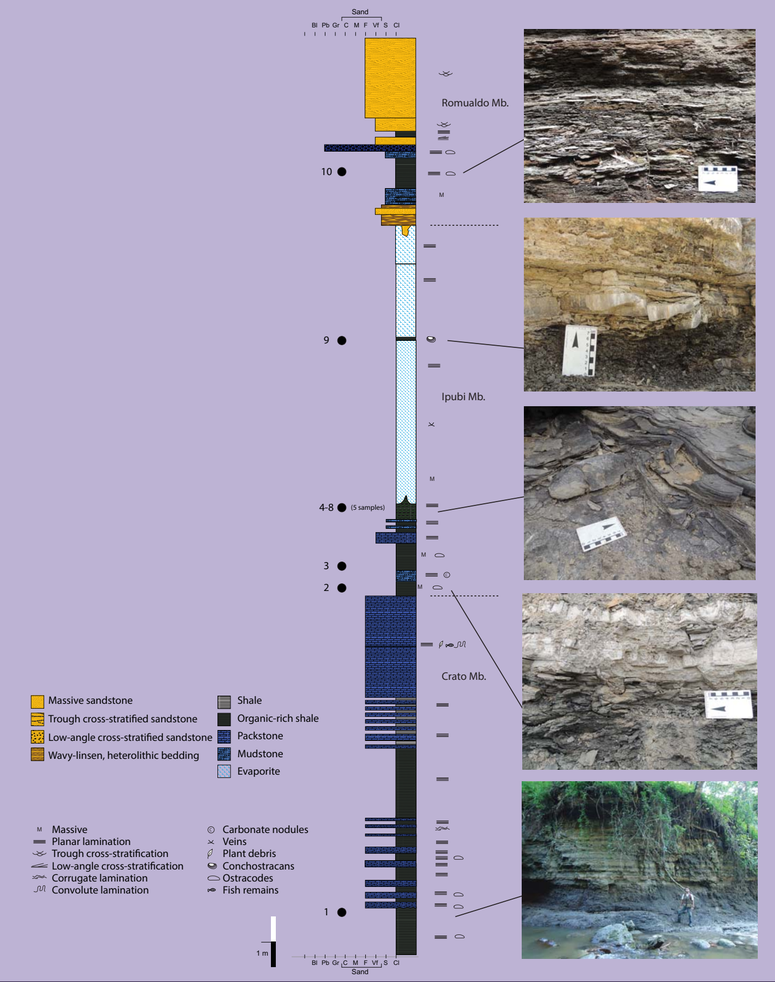


Figure 2 - Stratigraphic chart of the Cretaceous in the Araripe Basin (Assine, 2007), with the studied interval marked in red.

Ten samples of organic shales from different intervals in the Santana Formation were analyzed, as shown in the composite section below. Total organic carbon varied from 1 to 29.5 wt%.



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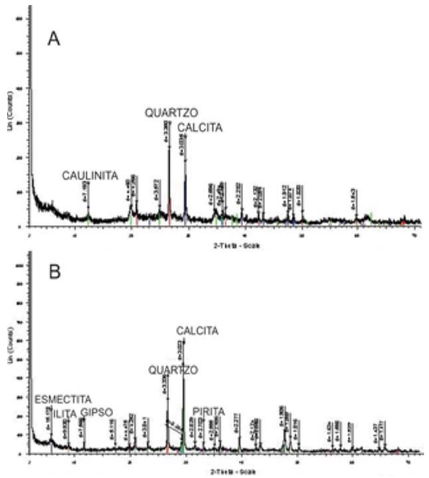
Study methods included X-Ray diffractometry (XRD), organic petrography under transmitted and reflected light, measurement of spore color index and vitrinite reflectance, and organic geochemistry (Total Organic Carbon, pyrolysis Rock Eval and elemental analyses).



XRD indicates that quartz, smectite and calcite are the essential minerals, with subordinate gypsum, pyrite, illite and kaolinite, as illustrated by the XRD of a sample from the Crato Member (A) and another one from the Ipubi Member (B).

Petrographic analysis showed different proportions of amorphous organic matter (AOM), phytoclasts and palynomorphs in the samples (Tab. 1). There is a progressive decrease upwards in AOM and increase in phytoclasts. The few palynomorphs are basically spores and Classopolis pollens, associated with gymnosperms, indicative of arid climates.

Sample	Member	AOM	Phytoclasts	Palynomorphs	Vitrinite Reflectance (% Ro)	Spore Coloration Index
1	Crato	260	33	7	Absent	3.0
2	Ipubi	237	48	15	0.60	3.5
3	Ipubi	269	31	Absent	0.44	Absent
4	Ipubi	204	77	19	Absent	3.5
5	Ipubi	275	25	Absent	0.29	Absent
6	Ipubi	212	35	53	Absent	3.5
7	Ipubi	188	61	51	0.48	3.0
8	Ipubi	270	24	6	Absent	4.0
9	Ipubi	178	84	38	0.74	4.0
10	Romualdo	267	32	1	Absent	3.0

Table 1 - Types of organic matter in the samples (quantification with 300 points), vitrinite reflectance (in Rrandon) and spore coloration index.

The lowermost **Crato** Member samples comprise 87% amorphous organic matter (AOM; aggregated, flaky, yellow-brown and granular under white light, and yellow fluorescent under UV excitation), 11% phytoclasts (opaque, woody, equidimensional to pseudomorphic) and 2% palynomorphs.
The intermediate **Ipubi** Member samples contain 68% AOM (mostly granular, highly reworked and oxidized), 15% phytoclasts (opaque, fungi, thin and fibrous tissues) and 7% palynomorphs.
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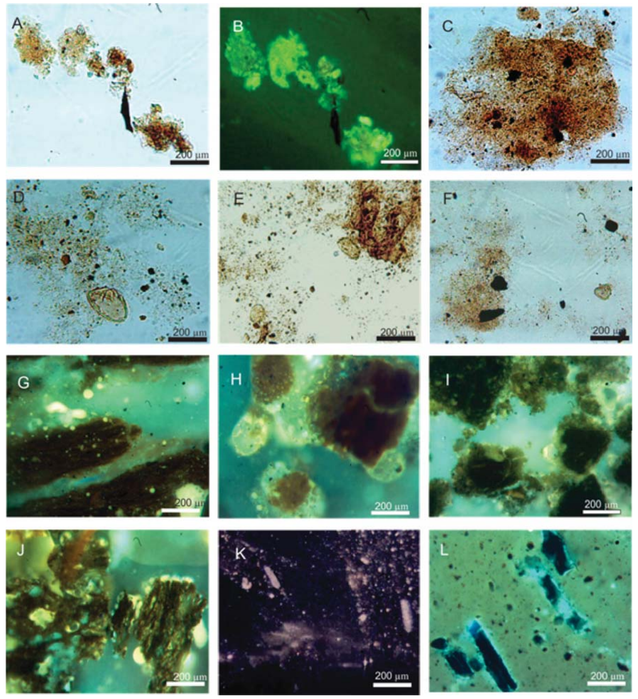

A – Dispersed AOM associated with opaque phytoclast (transmitted light), Ipubi Member. B – Dispersed AOM associated with opaque phytoclast (reflected light), Ipubi Member. C – Pelicular AOM, possibly algal reworking (transmitted light), Ipubi Member. D, E – Pollen grains (Classopollis) associated with AOM and dispersed, opaque phytoclasts with moderate reworking (transmitted light). F – Beige AOM (with dispersed, opaque phytoclasts in the center) and spores on the right, Romualdo Member. G – Bitumen associated with mineral matter (reflected light), Crato Member. H – Liptinite and bitumen in sample from Crato Member (reflected light). I, J – Bitumen impregnation in sample from Ipubi Member (reflected light). K, L - Vitrinite fragments dispersed in mineral matrix (pyrite), under transmitted (K) and reflected (L) light.

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Kerogen is mostly type II, indicating a mixed lacustrine and marine origin, with two Ipubi samples of type I (lacustrine) kerogen (Fig. 4). S_2 varies from 2 to 243 mg HC/g, indicating reasonable to excellent generation potential.

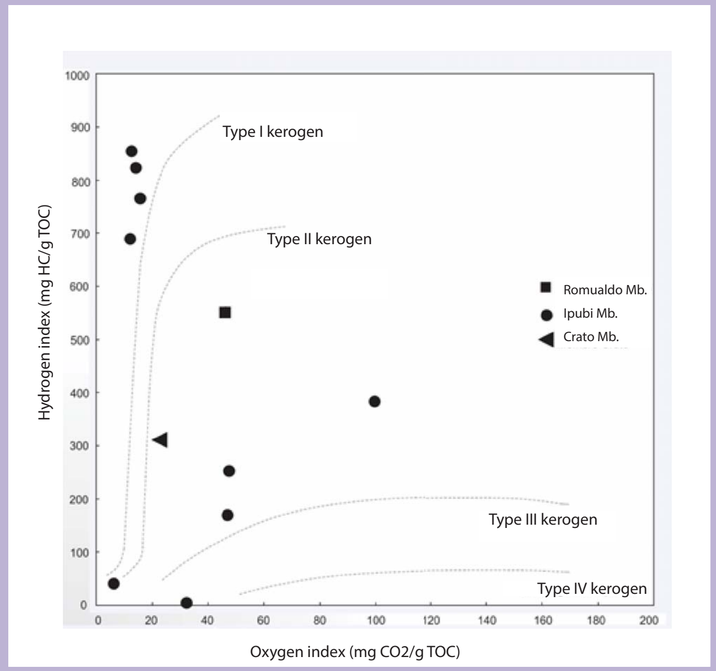

Figure 4 - Modified Van Krevelen diagram, showing the relation between hydrogen and oxygen indices and the type of organic matter in studied samples.

TOC varied from 1 to 29.5 wt%, reflecting facies and stratigraphic variations.
Pyrolysis Tmax of 361 to 433 ºC, spore coloration index 3-4, and vitrinite reflectance of 0.29-0.6% Rrandom suggest immature to marginally mature organic matter.

Samples	Member	TOC (wt%)	S1 (mg HC/g)	S2 (mg HC/g)	S3 (mg CO2/g)	Tmax (°C)	Hydrogen index (S2x100/TOC)	Hydrogen index (Sx100/TOC)	Production index (S1/[S1+S2])
1	Crato	2.34	0.29	7.44	0.49	433	318	21	0.04
2	Ipubi	1.22	1.62	2.08	0.57	361	170	47	0.44
3	Ipubi	1.63	2.51	4.18	0.78	372	256	48	0.38
4	Ipubi	7.36	0.10	3.08	0.47	433	42	6	0.03
5	Ipubi	17.97	7.04	137.67	2.84	411	766	16	0.05
6	Ipubi	18.08	8.29	154.58	2.32	413	855	13	0.05
7	Ipubi	24.70	8.70	170.63	2.98	404	691	12	0.05
8	Ipubi	29.50	9.17	243.12	4.06	407	824	14	0.04
9	Ipubi	1.01	0.04	0.05	0.33	0	5	33	0.44
10	Romualdo	2.44	0.36	13.56	1.13	427	556	46	0.03

CONCLUSIONS

- Except for sample 9 (interbedded with gypsum layers of the Ipubi Member), all the studied samples have good to excellent hydrocarbon generation potential (S2 = 2-243 mg HC/g).
- Organic shales in the Crato Member and Romualdo Members have type II kerogen, while the Ipubi Member displays types I, II and III kerogen, reflecting the diverse origin of organic matter, with marine and continental contribution and algal influence, as indicated by hydrogen and oxygen indices.
- SCI and Tmax indicate that the samples analyzed are immature to marginally mature.
- Vitrinite was not found in all the samples, but where present, reflectance values also point to immature organic matter.
- Integration of organic geochemistry and petrography with sedimentology suggest that the studied organic shales were deposited under anoxic conditions in a water body subject to algal blooms. Preservation of organic matter under these conditions was favored mainly during the deposition of the Ipubi Member, immediately before evaporitic conditions were set in, leading to the precipitation of anhydrite and gypsum. This interval presents the best hydrocarbon potential, despite the low degree of thermal maturation.
- The interval with better generation potential is stratigraphically located in the high-accommodation systems tract at the base of the Ipubi Member, correlative to the Trairi and Ponta do Tubarão Layers in the Ceará and Potiguar Basins, respectively.
- Lithologic and stratigraphic similarities between the Aptian-Albian organic shales in the Araripe Basin and coeval units in the Equatorial margin (e.g. Mundaú, Paracuru and Uruburetama Formations in the Ceará Basin; Pescada, Alagamar and Açu Formations in the Potiguar Basin) and Parnaíba (Corda/Grajaú/Codó and Itapecuru Formations) Basins highlight the significance of the studied deposits for the exploration of Equatorial Margin and intracratonic petroleum systems in Brazil (Fig. 5).

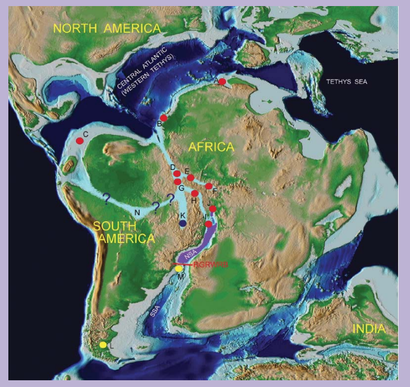

Figure 5 - Paleogeographic reconstruction of the Aptian, proposed by Arai (2014), displaying the relation between the Araripe Basin (H), the intracratonic Parnaíba Basin (G) and the equatorial marginal Ceará (E) and Potiguar (F) basins.

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