

VOLCANO-SEDIMENTARY SEQUENCE OF NEOCOMIAN AGE IN CAMPOS BASIN (BRAZIL)

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ABSTRACT Igneous basic rocks with thin intercalations of volcanoclastic and sedimentary rocks constitute the economic basement of Campos Basin in the Brazilian continental margin. This volcano-sedimentary sequence has been a producer of hydrocarbons in three oil fields (Badejo, Linguado, and Pampo). Core analysis of 16 wells in which the volcanic section was sampled give the characterization of igneous basic rocks, volcanoclastic and sedimentary rocks. A classification for volcanoclastic rocks is here proposed based on the occurrence of these rocks in Campos Basin and on the nomenclature published in specialized literature. Autoclastic, pyroclastic, and epiclastic rocks were recognized as a function of the fragmentation process. The study of these rocks and their association made possible the recognition of the volcano-sedimentary model for the study area. In Campos Basin, one can recognize areas with subaqueous volcanism and areas with subaerial volcanism. Subaerial volcanism was marked by explosive episodes and it is represented by red volcanic tuffs. Subaqueous volcanism is marked by the mixture of basic lavas and sediments. These sediments were interpreted to be deposited in a lacustrine environment.

RESUMO SEQUÊNCIA VULCANO-SEDIMENTAR NEOCOMIANA NA BACIA DE CAMPOS (BRASIL) O embasamento econômico da Bacia de Campos, na margem continental brasileira, é constituído por rochas ígneo-básicas com finas intercalações de rochas vulcanoclásticas e rochas sedimentares. Esta sequência vulcano-sedimentar de idade neocomiana foi estudada em três campos produtores de hidrocarbonetos (Badejo, Linguado e Pampo). O estudo foi realizado a partir de análises petrográficas em amostras de testemunhos de 16 poços que atingiram esta sequência vulcano-sedimentar. As rochas vulcanoclásticas foram classificadas segundo a ocorrência na Bacia de Campos e a nomenclatura publicada na literatura especializada. Assim, em função do processo de fragmentação, foram reconhecidas rochas autoclásticas, piroclásticas e epiclásticas. Em função do estudo dessas rochas e de sua associação em área foi possível o reconhecimento do modelo vulcano-sedimentar para a área Badejo, Linguado e Pampo (Bacia de Campos). Nesta região são identificadas áreas com vulcanismo subaéreo e outras com vulcanismo subaquoso. Vulcanismo subaéreo é marcado por episódios explosivos e representado por tufos vulcânicos de cor vermelha. Vulcanismo subaquoso é marcado pela mistura de lava com sedimentos, que são interpretados como depositados em ambiente lacustrino.

INTRODUCTION The economic basement of Campos Basin is characterized by igneous basic rocks intercalated with thin layers of volcanoclastic and sedimentary rocks. This volcano-sedimentary sequence was sampled in 16 wells located in Badejo, Linguado, and Pampo oil fields (Fig. 1).

The study of the petrographic characteristics of these rocks and their distribution led to the definition of a volcano-sedimentary model for the study area.

CAMPOS BASIN Campos Basin, in eastern Brazilian continental margin, was related with the break-up of Gondwanaland. This period is well marked in Campos Basin area where reactivation old weakness lines in the Precambrian basement led to an extensive outflow of basic magmas.

This igneous suite of Neocomian age is located at the base of Campos Basin stratigraphic column. These basalts are overlapped by thick Cenozoic and Mesozoic rocks over thousand meters.

The depth of the volcano-sedimentary sequence top ranges between 2,800 and 3,200 m but its thickness, until the present, have not been able to be estimated.

The study area is located offshore of Rio de Janeiro state, between water depths of 95 m and 120 m comprising three oil fields: Badejo, Linguado, and Pampo (Tigre *et al.* 1983).

BASALT FLOWS The Early Cretaceous volcanic sequence is composed of basic lava flows that texturally and compositionally are represented by basalts. Diabases and rocks with trachytic textures can be mapped but the volume of their occurrences when compared with the basalts is very small.

Basalts of Badejo, Linguado, and Pampo area are afanitic rocks, with colours grading from gray to red, fractures and vesicles. These lava flows underwent textural differentiation

process from the edge to the center of the body. This process is a function of the rate of cooling of the lava, (Hugues 1982).

From textural analysis, one can recognize three types of basalt that in this work be named (Table 1): B1 (hyaline), B2 (hemicrystalline), and B3 (holocrystalline).

Table 1 – Basalt types in Campos Basin, Brazil

TYPE	B1	B2	B3
Texture	Hyaline	Hemycrystalline	Holocrystalline
Composition	P, CPX, CH, S, M	P, CPX, O, M	P, CPX, O, M
Volcanic Glass	XXX	XX	X
Vesicle	XXX	X	X
Alteration	XXX	XX	X
Occurrence	Top and Base of Flow	Central Portions of Flow	Core in Thick Flow

P = Plagioclase, CPX = Clino-pyroxene, CH = Chlorite, S = Smectite, M = Magnetite, O = Olivine, X = rare, XX = frequent, XXX = abundant.

These lava flows cover large areas and the surface is normally planar, showing some roughness at the base.

Basalt flows, in Campos Basin, have thickness between 3 and 4 m, but, eventually, can reach 10 m. These individual flows can be separated by vesicle zones located on the top and on the base of the lava body.

Volcanoclastic and Sedimentary Rocks Associated With Lava Flows Volcanoclastic and sedimentary rocks are recognized in Campos Basin associated with lava flows.

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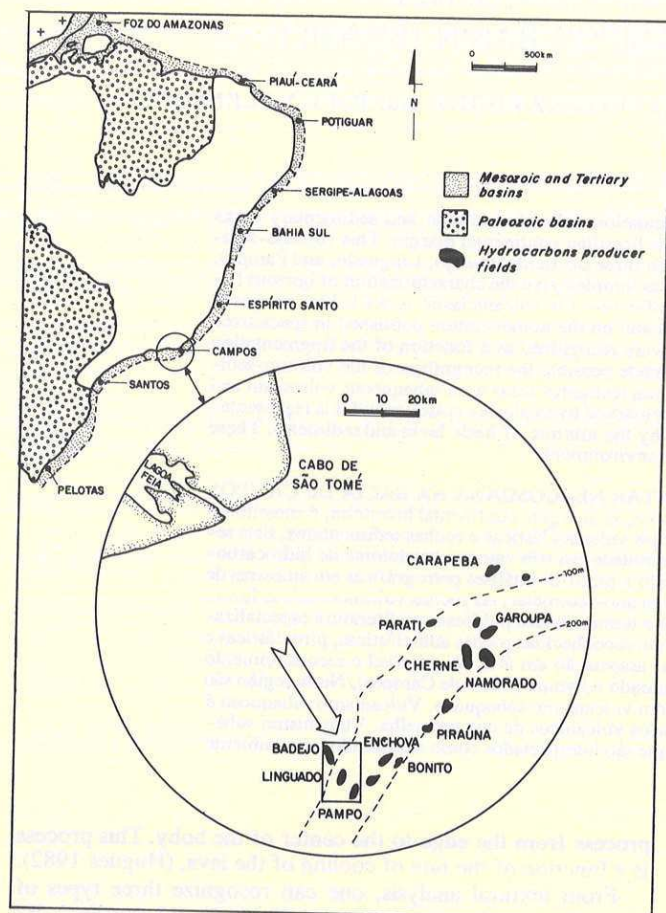


Figure 1 – The location of the studied area, Campos Basin offshore Brazil

The term volcanoclastic has been applied to those rocks composed of fragments associated with volcanic events. Sometimes is very common the mixture of these fragments with clastic material associated with sedimentary episodes (Fischer 1966). In these cases, when the sedimentary fragments are dominant, the usual sedimentary nomenclature is better to be used.

Many authors have been investigating texture and mineralogy of the volcanoclastic rocks (Fischer *op. cit.* Parsons 1969, Carozzi 1972, Pettijohn 1975) giving emphasis to the complexity of the utilized nomenclature.

A classification for volcanoclastic rocks is here proposed based on the occurrence of these rocks in Campos Basin and on the nomenclature proposed by Fischer (*op. cit.*), Wright & Bowes (1963), and Parsons (*op. cit.*). This classification (Table 2) is based on the origin of the volcanic fragments. Three groups are recognized when considering the proposed particle size of 2.0 mm (Wright & Bowes *op. cit.*). Wright & Bowes *op. cit.* associated volcanoclastic rocks with basic volcanism, calling attention to the predominance of fragments larger than 2.0 mm. They prefer to denominate these rocks as breccia in spite of the limit of 256 mm previously proposed by Wentworth & Williams (1932). This classification prove to be appropriated to Campos Basin volcanoclastic rocks although, sometimes, the volcanic fragments were rounded by thermal firing as result of the action of hot gases associated with volcanism.

According to table 2, it were possible to recognize epiclastic, pyroclastic, and autoclastic rocks. Autoclastic rocks

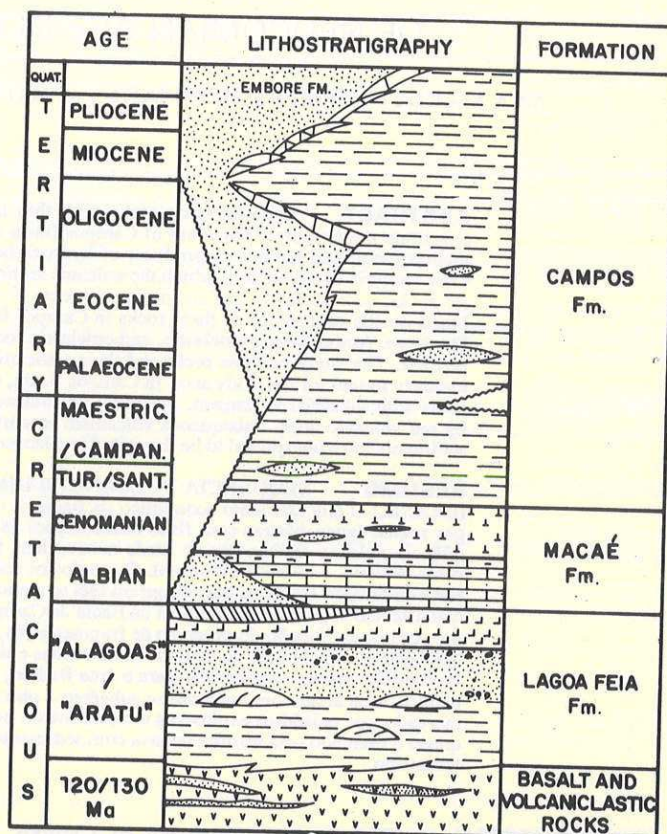


Figure 2 – Stratigraphic nomenclature of Campos Basin (after Barros 1980)

result from fragmentation of solid or semi-solid lavas by gas expansion or by flow movement. They are named friction breccias.

Table 2 – Proposed classification to the volcanoclastic rocks of Campos Basin Brazil

Volcanoclastic	< 2.0 mm	> 2.0 mm
Autoclastic	–	Friction Breccia
Pyroclastic	Tuff	Hydrovolcanic Breccia
Epiclastic	Volcanic Arenite	Volcanic Breccia

Pyroclastic rocks associated with volcanic explosions are represented by tuffs and hydrovolcanic breccias.

The rocks formed by fragments associated with alteration products of older volcanic rocks are called epiclastic. They indicate a quiet period during the volcanic event.

Because their sampling was imperfect, petrographical criteria (Table 3) were the most important parameter to recognize these rocks.

STRATIGRAPHIC SEQUENCES By analysing the formation process of the igneous rocks, volcanoclastic and sedimentary rocks, their characteristics and the areal association, it is possible to define the following stratigraphic sequence (Fig. 3):

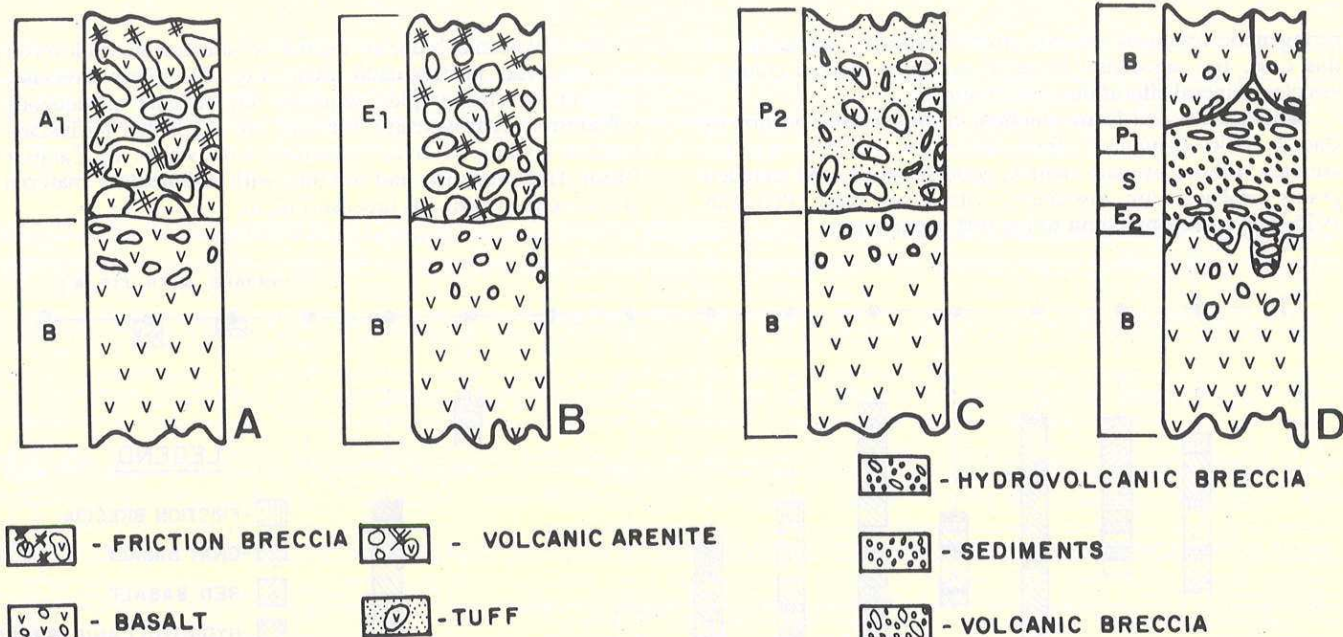


Figure 3 – Stratigraphic sequences comprising igneous basic rocks, volcaniclastic and sedimentary rocks in Campos Basin (after Secasu 1977)

Table 3 – Petrographical criterious used in the recognition of volcaniclastic rocks in Campos Basin, Brazil

	VOLCANIC-CLASTIC	PETROGRAPHICAL CRITERIOUS		
		FRAGMENTS	MATRIX	OTHERS
Auto-Clastic	Friction	Basalt (monolithologic)	–	–
	Tuff	Basalt Crystals	Argillaceous Glassy	–
PYROCLASTIC	Hydro-volcanic breccia	Basalt Volcaniglass	Quartz Feldspar	Reaction rim
	Volcanic arenite	Basalt Quartz Feldspar	Pseudo-matrix	Stratification
EPICLASTIC	Volcanic breccia	Basalt (monolithologic)	Quartz Feldspar	Grading

- Basalt (B) and friction breccia (A₁)
- Basalt (B) and volcanic arenite (E₁)
- Basalt and tuff (P₂)
- Basalt (B), volcanic breccia (E₂), sediments (S), and hydrovolcanic breccia (P₁)

These proposed sequences represent volcano-sedimentary events (Fig. 3).

VOLCANO-SEDIMENTARY MODEL From the distribution of the stratigraphic sequences in the studied area (Fig. 4), it is easy to verify that classical models of subaerial volcanism or subaqueous volcanism cannot be applied for this basic volcanic section. Here, distribution of stratigraphic sequences, along a north-south section crossing Badejo, Linguado, and Pampo fields, indicate interaction of volcanic and sedimentary processes. Four regions were characterized by predominance of two different stratigraphic sequences.

Stratigraphic sequences A and C predominate in Badejo

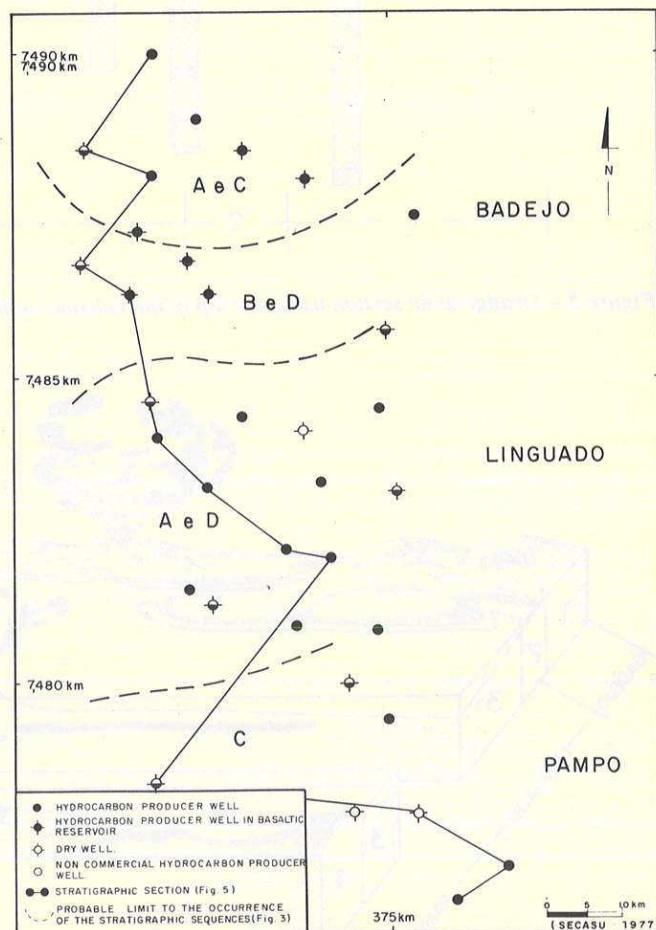


Figure 4 – Schematic distribution of the volcano-sedimentary sequences to Badejo, Linguado, and Pampo fields, Campos basin

field, the first area from north to south according to figure 4. These sequences (A and C) are characterized by tuffs and friction breccias. The latter are common in basaltic sequences of subaerial conditions. Tuffs with red colours and incipient

pedogenetic fractures are indicative of subaerial volcanism. In this case, the associated basalt flows have reddish colours, vesicles, mineral alterations, and fractures.

Sequences B and D are common in the southern portion of Badejo field (Linguado field in figure 4). The volcanic arenites without primary matrix, good selection, and rounded grains probably are associated with coast lines (Pettijohn 1975) and represent a limit to the tuff occurrence.

Hydrovolcanic breccias related to subaqueous volcanism are observed in Linguado field (Fig. 5). These breccias, common in stratigraphic sequence D, indicate subaqueous volcanism. Hydrovolcanic breccias are originated by instantaneous cooling of lavas in contact with water. In Campos Basin, fragmentation and mixture with sedimentary material are associated with this breccia (Fig. 6).

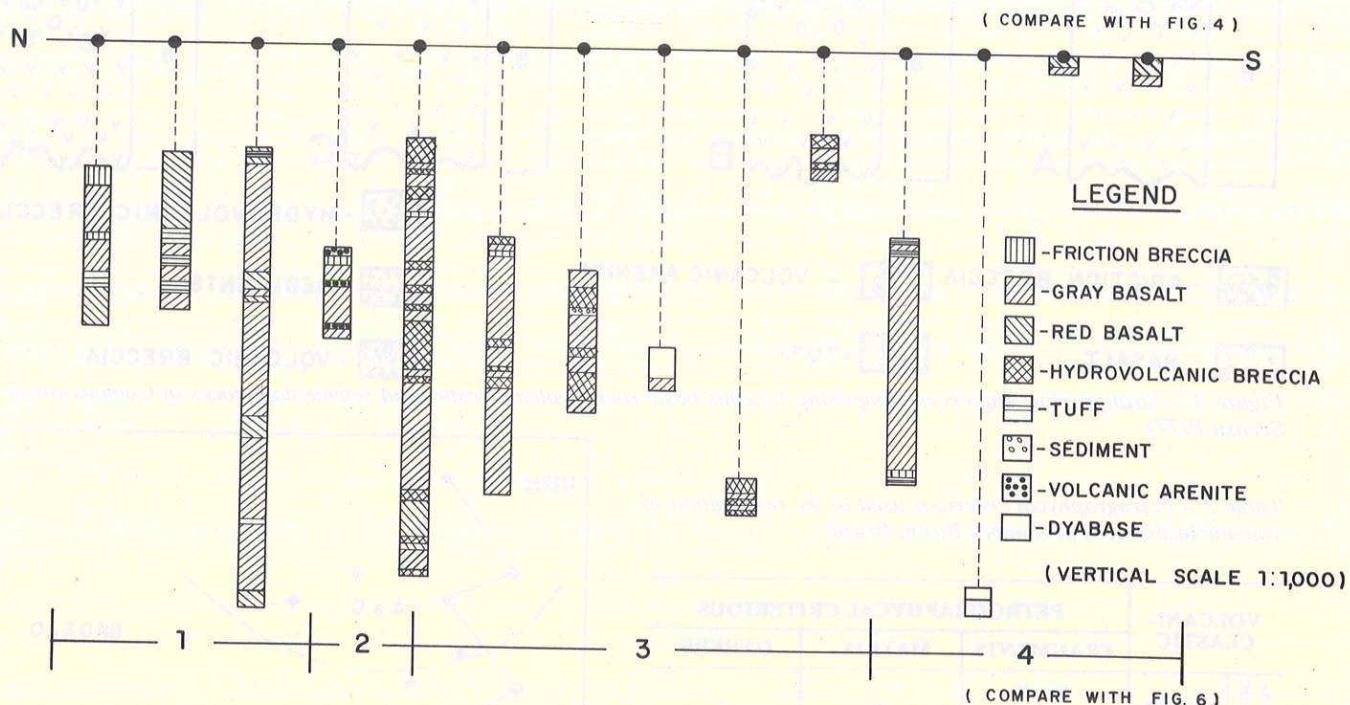


Figure 5 – Stratigraphic section using the top of the volcano-sedimentary sequence calculated by electric logs

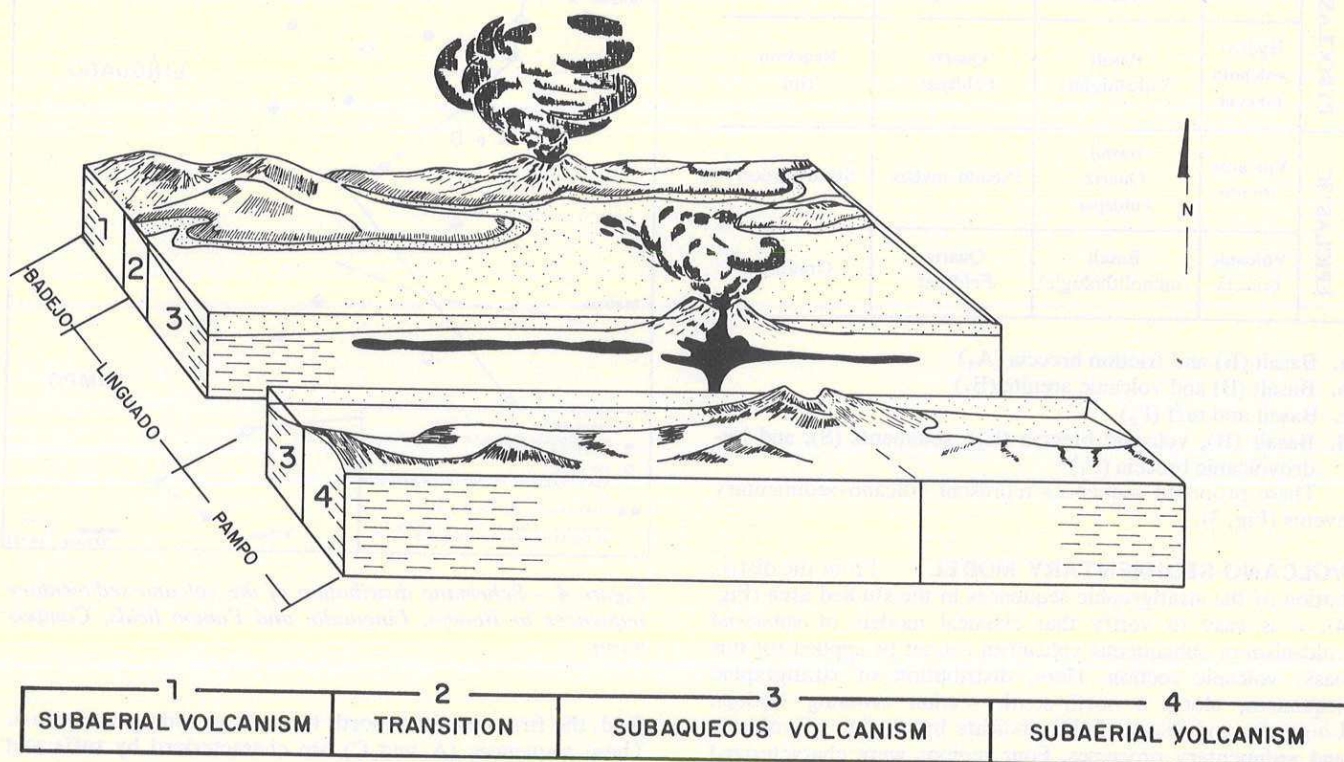


Figure 6 – Volcano - sedimentary model to Badejo, Linguado, and Pampo oil fields, Campos Basin (after Jones 1969)

In Linguado field, lava flows have gray colours associated with rare vesicles and few fractures when compared with basalts of Badejo field.

The stratigraphic sequence C is the most common in Pampo field (Fig. 5) with tuffs and red lava flows.

In Campos Basin, by the distribution of these volcanic stratigraphic sequences, one can recognize areas with subaerial volcanism and areas with subaqueous volcanism with pyroclastic manifestations (tuffs) (Fig. 6).

Subaqueous volcanism (Linguado Field) is marked by mixture of basic lavas and sediments. These sediments were interpreted to be deposited in a lacustrine environment. Jones (1969) described similar sequences in Gergovia region (France) and associated to lacustrine environment.

HYDROCARBON OCCURRENCE Hydrocarbon production in the volcanic sequence is related, until the present moment, with subaerial volcanism (Badejo field). In Badejo field, the basalt is fractured and has a lot of mineral alterations. These features are in agreement with increase in vesicle numbers. Basalt with these features (alteration, fractures, and vesicles) can be a reservoir rock showing very low permeability values when compared with conventional reservoir rocks (arenites).

Volcaniclastic and sedimentary rocks associated with the basalt do not show characteristics of reservoir rocks.

CONCLUSIONS The economic basement of Campos Basin in eastern Brazilian continental margin is characterized by a volcano-sedimentary section of Neocomian age.

Volcaniclastic rocks associated with basalts are classified based on the occurrence of these rocks in Campos Basin and on the nomenclature published in specialized literature. Autoclastic, pyroclastic, and epiclastic rocks were recognized as a function of fragmentation process.

Sedimentary rocks indicate quiet periods in the volcanic episode. The study of these rocks and their association made possible the recognition of the volcano-sedimentary model for the study area, characterized by subaerial and subaqueous volcanism. Subaerial volcanism was marked by explosive episodes and it is represented by red volcanic tuffs. Subaqueous volcanism is marked by the mixture of basic lavas and sediments. These sediments were interpreted to be deposited in a lacustrine environment.

Basalts associated with subaerial volcanism like in Badejo field can be hydrocarbon reservoir rocks although permeability values are low.

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Pequenas causas, grandes efeitos. Os equilíbrios da natureza estão suspensos por um fio.

Roger Heim, *Un naturaliste autour du monde*