22nd Salt Water Intrusion Meeting

SWIM 2012

Armação dos Búzios·RJ

JUNE, 17·22

Proceedings

GROUNDWATER AND BIODIVERSITY: THE SINGULAR CASE OF THE MANGUE DE PEDRA, ARMAÇÃO DOS BÚZIOS, STATE OF RIO DE JANEIRO, BRAZIL

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Abstract. *Mangue de Pedra (Mangue = Mangrove and Pedra = Stone) is a mangrove with special characteristics because it develops on rocky substract and it is about 5 kilometers away from the river mouth. This mangrove is located in Gorda Beach, Búzios, Brazil. This singular situation is caused by the discharge of groundwater in the basis of palaeocliffs in this sector of the beach. The predominant lithology is a conglomerate. These sediments were deposited in fluvial environment, in alluvial fans controlled by the tectonic movement of the Pai Vitório Fault. This fault is located in the south limit of the Barra de São João Graben. It is a normal fault that puts side-by-side the Palaeoproterozoic orthogneiss of the basement and the Mio-pliocene conglomeratic sediments. Rubin & Almeida (2003) have mapped the fault in detail and identified 6 different units in 1:1000 scale. Those authors observed 60 m thick of fault rock filling, including a core with 3 m of breccia and ultracataclasites. Petrographic studies revealed 4 reactivation events in the rocks of Pai Vitório Fault. Oliveira (2007) has studied the mangrove of Praia Gorda. The author concluded that these plants have good structural patterns of development. The singular aspect of this vegetation is it rocky substratum, composed by gravel, coarse sand and little blocks of rock instead of muddy / organic sediments. The conglomerates are aquifers with medium to high favorability to explotation of groundwater. The recharge occurs in the top of palaeocliffs and in the active cliffs and the discharge occurs in the beach. This geological position creates the best conditions of salinity for development of mangrove over rocks and faraway of rivers. The Mangue de Pedra is a singular interaction between biodiversity and geodiversity (Mansur & Guedes, 2011).*

Keywords: Groundwater and Biodiversity

How the laymen understand the Gondwana: the popularization of geology for Non-scientific community.

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Schedule

8:20 am	1stº call to boarding
8:30 am	Final call to boarding and beginning of field trip
9:00 am	1stº stop – Palaeocliffs of Rasa Beach
10:00 am	2ndº stop – Forno Beach
10:50 am	3rdº stop – Lagoinha Beach
12:00 pm	4thº stop – Geribá Beach
13:00 pm	5thº stop - Lunch at Campos Novos Farm
14:20 pm	first call to boarding
14:30 pm	Final call to boarding
15:10 pm	6thº stop – Dama Branca dune
16:20 pm	7thº stop – Pontal do Atalaia
18:00 pm	Return to Atlantico Buzios Hotel

Sumary

1. Introduction and Geoconservation.

The area of our field trip has a great importance for the understanding of Gondwana geological evolution. For Geologist, it is a great place to observe several types of gneiss, basalts, conglomerates, and others; structures like faults, folds, intrusions like dikes and sills. For layman it is an opportunity to understand many process of our planet while enjoy a special landscape. The rocks and structures show information about the Búzios Orogeny and the Gondwana break-up and are very well exposed in a beautiful scenario.

Besides the great view and the beauty of the area, how can the general audience understand and observe the same type of information about the Gondwana as a scientist?

The geology and scenic beauty is enough to classify this area as a geological heritage of international importance, according to the concept of Brilha (2005) and its framework proposed by Mansur (2010). Based on this singularity, in 2001 the area was chosen as a pioneer for the introduction of Caminhos Geológicos Project.

The project, developed by the Geological Survey of the State of Rio de Janeiro, takes as a main objective the popularization of geology as part of a strategy in Geoconservation. One of the most efficient methods is the disclosure of the the areas geological history through the deployment of interpretive panels. In 2010 the project celebrated 10 years, accounting for almost one hundred panels displayed in streets, squares, roads and trails, along the Rio de Janeiro State. According to international standards and research the Caminhos Geológicos Project can be classified as a geoturistic and geoconservation project. Based on the geological context of Rio de Janeiro territory, the abundance of good outcrops in the area and the questions proposed by general audience during field trips, the project team decided to highlight the geological heritage of tectonic type in interpretive panels.

During project concept, the team involved had some question about how to make the public understand ideas related to tectonic evolution and geological process. This was a challenge, once geology is not a common subject discussed during science classes, especially in elementary and middle schools in Brazil. The other point was the time elapsed between the geological events recorded in the rocks and the non-persistence of these phenomena today. In order to minimize these problems, the team decided writes the panels using a popular language and a lot of diagrams, figures and photos.

This decision attracted more the interest of the population, NGOs and authorities in understanding the geological processes registered in these rocks. We passed, therefore, to a time when the asset value of rocks and geological processes has been understood. Since then, educational projects have been conducted with teachers, students and the community as a complementary activity. Also, many areas have been legally protected for their geological importance, and today we are discussing the establishment of a Geopark in the region.

Nowadays, the panels are quite a little different if compare to the firsts. The language is simplified, more pictures and photos are used and also the analogy between the information and common situations.

A poll; conducted among people reading the panels, showed us their interest in the geology that is explained on it. Besides the recognition of the population, Gondwana is quoted on the websites of tourism businesses on the Costa do Sol, outlining the earliest history of the region that has led to its beautiful and unique landscape.

Relating rocks of the state of Rio de Janeiro to the formation of Gondwana has been an effective strategy that enables citizens to take ownership of geological heritage in order to support geoconservation actions. The geosites, especially those in front of the sea, are in danger because of increasing construction work, buildings and touristic projects. The argument used is that these projects are important for the development of the region. But, in fact, it is the same as “killing the goose that laid the golden egg”, because the beauty will be destroyed and the scientific, teaching and touristic geosites will be lost.

2. Buzios Geology – an overview

The following is the full transcript of the Abstract of de paper "Cambrian orogeny in the Ribeira Belt (SE Brazil) and correlations within West Gondwana: ties that bind underwater" (Schmitt et al., 2008): "*At 530–490 Ma tectono-metamorphic event, the Búzios orogeny, is recognized within the Ribeira Belt, along the coast of SE Brazil. Tectonic evolution started with a Late Neoproterozoic marine basin and volcanic activity at c. 610 Ma. The rocks in this basin were affected by high-grade metamorphism at c. 530 Ma, coeval with deformational phases D1–D2, which generated compressive low-angle tectonic structures with top-to-NW tectonic transport. Large recumbent folds with NW–SE axes parallel to the main stretching lineation formed during D3 as the Cabo Frio tectonic domain, the focus of this study, collided with the Oriental terrane to the NW. D4 sub-vertical shear zones are limited in extent. A new U–Pb age of 501+6 Ma is reported for zircon from an amphibolite-facies shear zone related to either D3 or D4. Post-tectonic 440 Ma pegmatites mark the final stage of tectono-magmatic activity. The Cabo Frio tectonic domain has African affinities and is exotic to the Ribeira Belt. Middle Cambrian deformational and metamorphic ages are also reported from the 'Angolan' Pan-African belt, the southern Kaoko and Damara belts in Namibia, and the Cuchilla Dionisio–Punta Del Este terrane in Uruguay. The occurrence of Cambrian metamorphic rocks along the present African and South American coastlines shows that Mesozoic rifting closely follows Palaeozoic sutures of West Gondwana.*" (page 279).

Besides the context describe about the Buzios Orogeny and the precambrian rocks, several dikes related to the Gondwana break-up are found in the region. Most of them are basalts with low TiO_2. The approximately age for this rocks based on several geochronological analysis is 120 My.

Plus, alkaline rocks more recent and sediments, especially the Barreiras Group can be found in the region.

The figure 1 presents the geological map for Búzios and their vicinity.

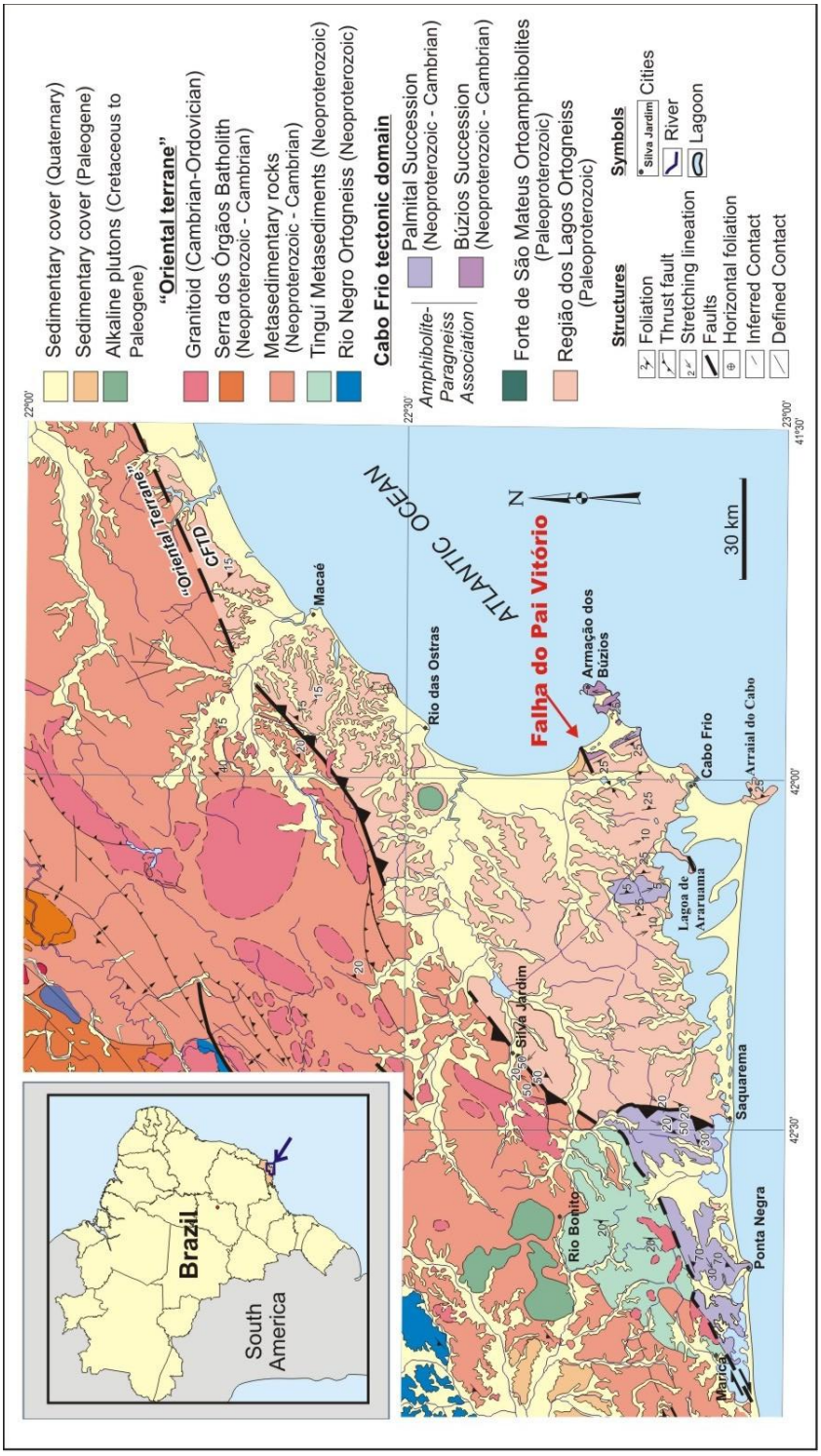


Figura 1 – Mapa Geológico da região entre Maricá e Macaé, com destaque para a Falha do Pai Vitório (modificado de Schmitt, 2001)

3. Palaeocliffs of Rasa Beach

Location: Located in a road which connect Buzios and Amaral Peixoto highway. The point is easily located by Caminhos geológico panel.

Coordinates: -22.731052^{o} / -41.972696^{o}

Description: Palaeocliffs. Deposits formed by the Pai Vitorio fault located close by during the period when the sea level were 4 meters higher around 5.100 years.

The Pai Vitório Fault, located in south limit of the Barra de São João Graben (Mohriak & Barros, 1990), is a normal fault that puts side-by-side the palaeoproterozoic orthogneiss and mio-pliocene conglomeratic sediments. These sediments were deposited in fluvial environment, in alluvial fans controlled by the tectonic movement of the Fault.

Rubin et al. (2003) have mapped the fault in detail and they identified 6 different units in 1:1.000 scale. These authors observed 60 m of thick of fault rocks, including a core with 3m of breccia and ultracataclasites. This regional structure has strike N70E and striations with dips which demonstrate normal movements. Petrographic studies revealed 4 events of reactivations in the rocks of Pai Vitório Fault.

Oliveira (2007) has studied the mangrove of Praia Gorda. The author concluded that these plants have good structural patterns of development. The diameter of the stems of the tree population indicates a relatively young shrub forest and he concludes that it is a mangrove in development stage. The singular aspect of this forest is it rocky substratum, composed by gravel, coarse sand and little blocks of rock.

The conglomerates are aquifers with medium to high favorability to explotation of ground water. They also have a high susceptibility to contamination. The recharge occurs in the top of paleocliffs and active cliffs and the discharge occurs in the beach. This geological position creates the best conditions of salinity for development of mangrove over rocks and far away of rivers. The Mangue de Pedra is a singular interaction between biodiversity and geodiversity.

Photos Palaeocliffs of Rasa Beach

4. Forno Beach

Location: Located between Foca and Brava beaches, from Usina Velha road through the center of the city.

Coordinates: 24K 204695.09 m E e 7480052.77 m S

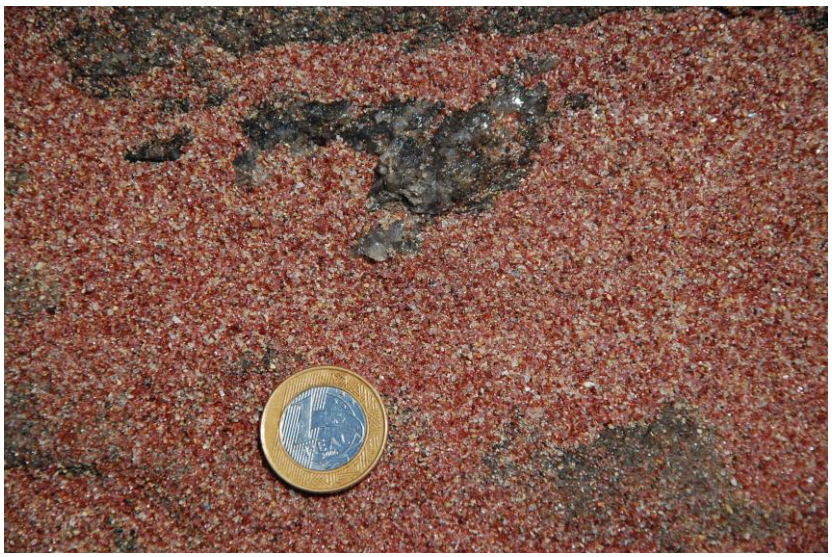
Description: Pink sand caused by the presence of garnet mineral. The gneiss that occurs in this beach shows the presence of garnet, kyanite and sillimanite. For general audience the most important feature here is the pink sand. The minerals are easily observed in the coast and concentrated in some areas in the beach.

Besides the pink sand, a quartz veil capture the attention of the visitors, in contrast with the dark gneiss and recumbents folds. Is one the most favorites spots for photography!

The sillimanite-kyanite pseudmorphys indicates other kind of scientific geological heritage, the one related to mineralogy.

During the fields trips in this place, we observed that the earth dynamic and the process which transform the mineral in the rock in sand represent the top of questions asked.

The Rio de Janeiro geological Survey team is working, in partnership with the Universities, in this panel.



Detail of Pink sand caused by garnet in the Forno Beach

5. Lagoinha Beach

Location: Beach located between Ferradura and Forno beaches.

Coordinates: -22.77057^{o} / -41.877867^{o}

Description: These rocks represents the session type of the Buzios Orogeny. They are represented by foliated and sometimes folded gneiss, which can indicate high pressure and temperature during the collision. Two panels, located in the top area close to the street and the other closed by the “lagoon” help the general audience understand and recognize minerals and structures.

The panels located in the top area, present Gondwana information since the collision to the break-up, and explain plate tectonic and continental drift. The other one, located closed to the “lagoon” show information related to the different kind of rocks (igneous, sedimentary and metamorphic), minerals and structures, such as folds.

Panel located close by lagoinha beach where the mineral are presented

Students learning about the gondwana break up in Lagoinha beach

Folded gneiss in Lagoinha beach

6. Geribá Beach

Location: located in the south portion of Geribá beach, closed by Tucuns beach boundary.

Coordinates: -22.781982^{o} / -41.915697^{o}

Description: The panel presents two sets of information divided by time. First, the oldest rock founded in Buzios area which age is around 2.0 billion years old and is represent by gneiss related to the Gondwana collision, named for the general audience as the “Brazilian Hymalaians”. Second, the youngest in the outcrop, a basalt dike related to the Atlantic Ocean opening around 130-120 My ago.
Structures, such as sliken side, are also presented in the panel.

Panel Located in Geribá Beach

7. Dama Branca Dune

Location : Front area of dune field between Arraial do Cabo e Cabo Frio Cities

Coordinates: -22.908904^{o} / -42.036047^{o}

Description: The Dama Branca is the biggest dune in the Southeast of Brazil and their movement is related to the wind which comes from Forte and Foguete beaches. Inside dune park is possible to observe small laggons, plants and animals typical for this kind of environment.

8. Pontal do Atalaia

Location: High area in Arraial do Cabo city.

Coordinates: 23K 806125.65 m E e 7453862.10 m S

Description: This is the most beautiful scenic area in the Arraial do Cabo city. In this outcrop is possible to see in a good day, the Araruama lagoon, small mountains and a great part of “Costa do sol” area.

This is the region where Rio de Janeiro coast line state changes a little their orientation, and also an important geological set: the boundary between Campos and Santos basins, both oil production basins. Just Campos Basin alone is responsible for around 80% of all oil production. These basins along with others in Brazilian coast line are related to the rift phase during the Gondwana, in the basal sequence occurs an extensive volume of magmatic rock represented by Cabiunas Formation in Campos Basin and Camboriú Formation in Santos basin, both are composed by basalts with ages around 120 My.

The challenge here is to show the general audience a geological monument that cannot be observed directly because is under the sea. In this case, the panel shows important tools like seismic sections and cross sections.

Other important feature here is the Cabo Frio Island. The island is formed by a syenite intrusion and around the area we found several alkaline dikes intrusions. Outcrop relationship show that the magmatic event happened in at least two different pulses. This syenite, according to the researches, represent the final track of a

hotspot that started in Poços de Caldas and finish here in Cabo Frio and is responsible for dozen of intrusions in this path.

The Cabo Frio island is represented in a panel that shows the different rocks that can be observed in both continental and island area. We invite the general audience to compare the features, once the boat tourism is very common in the area.

Two dikes generation at Pontal do Atalia

Precambrian rocks and magmatic intrusions in Cabo :Frio Island

9. A brief word about Campos Novos Farm.

Location: Located in the Amaral Peixoto highway, km 124 close to Buzios entrance.

Coordinates: -22.717467^{o} / -42.030814^{o}

History: The Santo Inacio Campos Novos farm was builded in the end of XVII century by the Jesuit priests, in 1759 the area was incorporated to the Portuguese Monarch and today together with an archeological site close by is protected by INEPAC.

Charles Darwin and Saint-Hilarie are the most famous gests in this farm, when working in the description of the area environment. Follow, a part of the Charles Darwin Journal about the Campos Novos Farm, were he stayed for two days in April, 1832:

" *but 15 miles before arriving at Addea de St Pedro nearly killed us together with waiting* ***an hour for breakfast****, the road lay on the borders of lacoon. shore composed of an* ***infinite shells: at ½ after 12 started again; the road passed through sand with broken shells, although***
*[page 11b]****"***

"some miles from the sea*. & the trees attested how long things have thus remained:*
we then entered the forest; ***beds of quartz boulders****; —*
after some miles came to Campa Novos good venda, in a open country. a pleasant change: very cool on the turf only 74?"

"At ***Campos Novos****, we fared sumptuously, having rice & fowls, biscuit & wine & spirits for dinner, coffee in the evening."*

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Field Trip to Rio de Janeiro Eastern Coast: Sun (and Salt) Coast, a glimpse of the Geological and Natural Environment"

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Maria da Gloria Alves – mgalvesuenf@gmail.com

Schedule

8:00 am	First call to boarding
8:20 am	Final call to boarding and beginning of the field trip
8:30 am	First Stop: Mangue de Pedra
9:30 am	Finish of the first stop.
10: 30 am	Second Stop: Rebio União
12:00 am	Lunch – Rebio
13:50 am	First call to boarding
14:00 am	Final call to boarding
15:20am	Third stop: Salina Carvalho – Vermelha Lagoon
16:30 am	Return to Atlântico Buzios Hotel.

Sumary

1. Welcome Message.

The area of our field trip represent one of the most beautiful and astonishing coast line segments in Brazil, called *"Sun Coast of Rio de Janeiro State*", located in Rio de Janeiro State, Southwest of Brazil .

The "Sun Coast" exposes a variety of environments and their features and is also a warm and dry area with good weather during most part of the year. The region is known by their special geology, historical sites, and differentiated fauna and flora, some endemic.

We are going to present in this field trip a small part of this special and beauty region by visiting three different points that present part of this diversity.

Welcome to the field trip and we hope you enjoy it!!!!

Regards,
Eliane, Gerson, Kátia e Maria da Gloria

Photo: National Geographic

1. Introduction

The purpose of this field trip is visit locations in *"Sun Coast of Rio de Janeiro*", located in the northeast part of Southeast area of Brazil which presents interesting hydrogeological and very peculiar Geology. Interpretative panels of its geology support the understanding of those features to non-geological audience. These panels are include in *"Projeto Caminhos Geológicos"* (*Geological Ways Project*), developed by the State government, and expose scientific information such as the amalgamation and break up of Gondwana palaeocontinent, sedimentary environments, hydrogeology, and other geological themes, to the non-scientific audience.

Environmental aspects, such as Holocenic stromatolites and carbonate deposition on hypersaline environments in Araruama lagoon system are also include in this field trip.

Buzios region is known as ***"The Brazilian Himalayas",*** evidences from continental collision, called Buzios Orogeny, and the Gondwana amalgamation are observed in several types of gneiss and amphibolites in different metamorphic grades, and deformation process evidenced by folds, fault and fractures systems.

The Gondwana break up is marked by the occurrence of dikes and sills, mostly diabase, which present ages around 120 Ma. The recent geological history in Buzios area is evidenced by plugs and dikes mostly formed by alkaline rocks and the palaeocliffs located in Rasa Beach (Barreiras Formation).

Búzios region also presents a saltwater-freshwater interface related features, such as "*Mangue de Pedra"* (Stone Mangrove) area in Gorda beach, which represents a unique small mangrove system over a rocky substrata located far away from a river out, and according to the recent research, its supply of freshwater is almost exclusively by groundwater.

The hypersaline Araruama lagoon system is one of the biggest of the world and presents features of special importance for the geology, biology, mining and history of Brazil.

The region possesses a rich endemic fauna and flora, including the "pau-brasil", the tree whose dye extracted from its wood baptized Brazil; and also the "mico leao dourado", the small monkey which became a symbol of fauna preservation in Brazil and worldwide, since its population has been on the brink of extinction and has recovered due to international efforts.

2. Buzios Geology – an overview

The Buzios regions is inserted, in a geologic context, inside Mantiqueira Province (Almeida *et al.* 1981) and represents an orogenic system dated from Neoproterozoic which producted the Gondwana amalgamation. The Province is divided in three different orogenic belts: Araçuai, Ribeira and Brasilia (Heilbron *et al*, 2004).

Buzios and vicinity are part of the Central Segment of Ribeira (Figure 1) fold belt and according to Heilbron *et al.* (2010) are associated with the convergence of São Francisco and Congo plate, plus a third plate/micro plate.

The Central Segment is divided in three major tectonic terranes: Oriental, Occidental and Cabo Frio (Trouw *et al.* 2000) with trend NW/W towards to São Francisco Craton (Figure 1). The boundary between the terranes is evidenced by thrust faults and shear zones. The Cabo Frio Terrain (Figure 2), in which the field trip area is including, represents the last collision episode around 520 Ma (Schmitt *et al.* 2004).

The Precambrian rocks (Figure 2) are represented by the following units: Região dos Lagos Complex, Buzios and Palmital sequences. The Região dos Lagos Complex represent the basal section of the terrain. It is formed by orthogneiss (Figure 3) from Região dos Lagos Unit intensely deformed (Figure 4), pegmatites and aplites oriented to SE-NW trend. U-Pb geochronological data from zircons shows ages in the interval between 2,03 to 1,96 Ga (Schmitt 2004). The chemical compositions vary from tonalite to sienogranite and due to mineralogical variation can be subdivided in other different types.

Buzios and Palmital sequences represent the Neoproterozoic rocks from Região dos Lagos Complex. Buzios sequence is composed (Figure 5) by kyanite, sillimanite gneiss with some variations to calc silicate rocks and mafic/ultramafic sections (Schmitt *et al.* 2008). Palmital Sequence is composed by sillimanite biotite garnet gneiss, some with

intercalation of aluminous gneiss, calc- silicate rocks and quartzite. This gneiss sometimes present sequences with more than 300 meters.

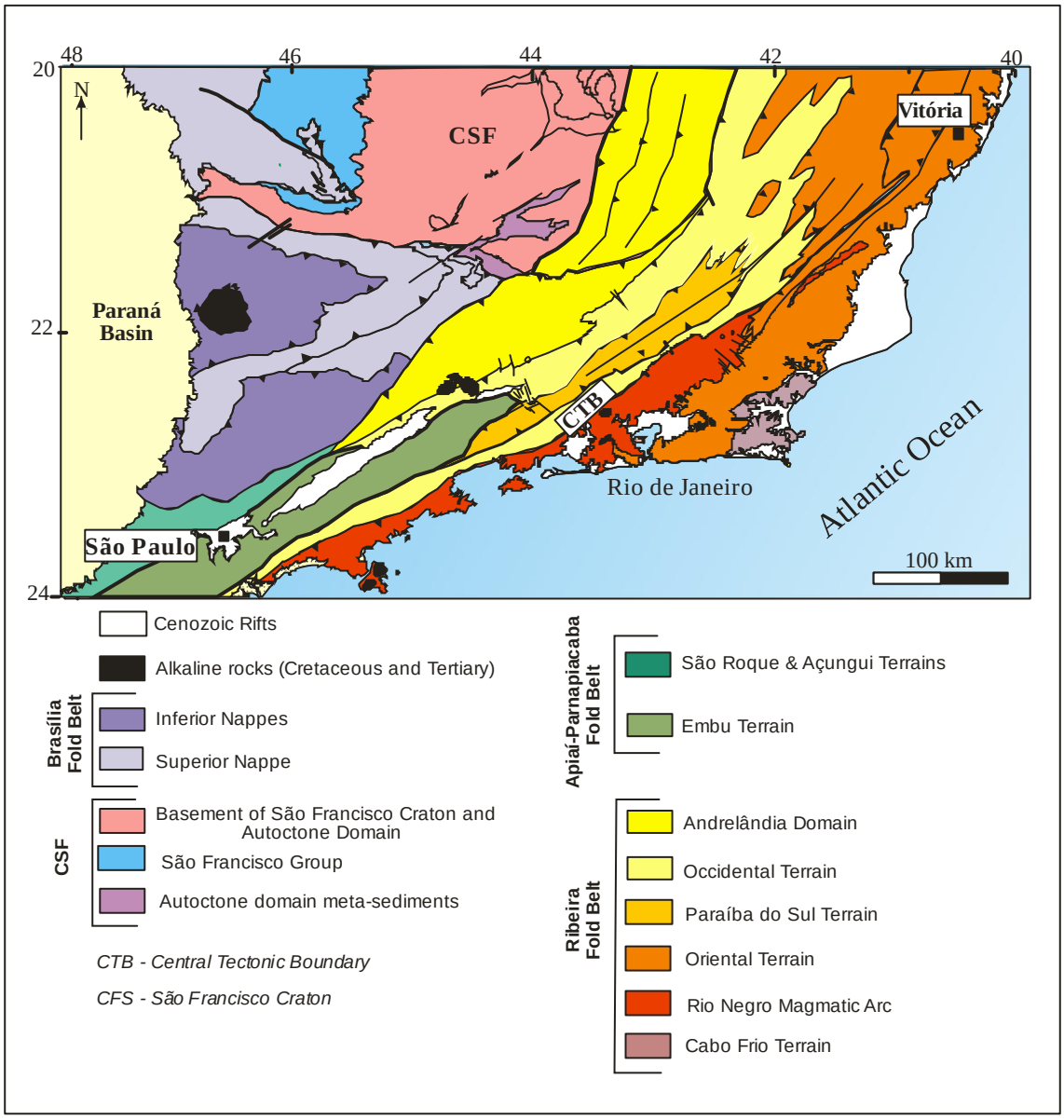

Figure 1 – Tectonic Map for Central Segment of Ribeira Fold Belt. Modiffied from Heilbon et al. (2010)

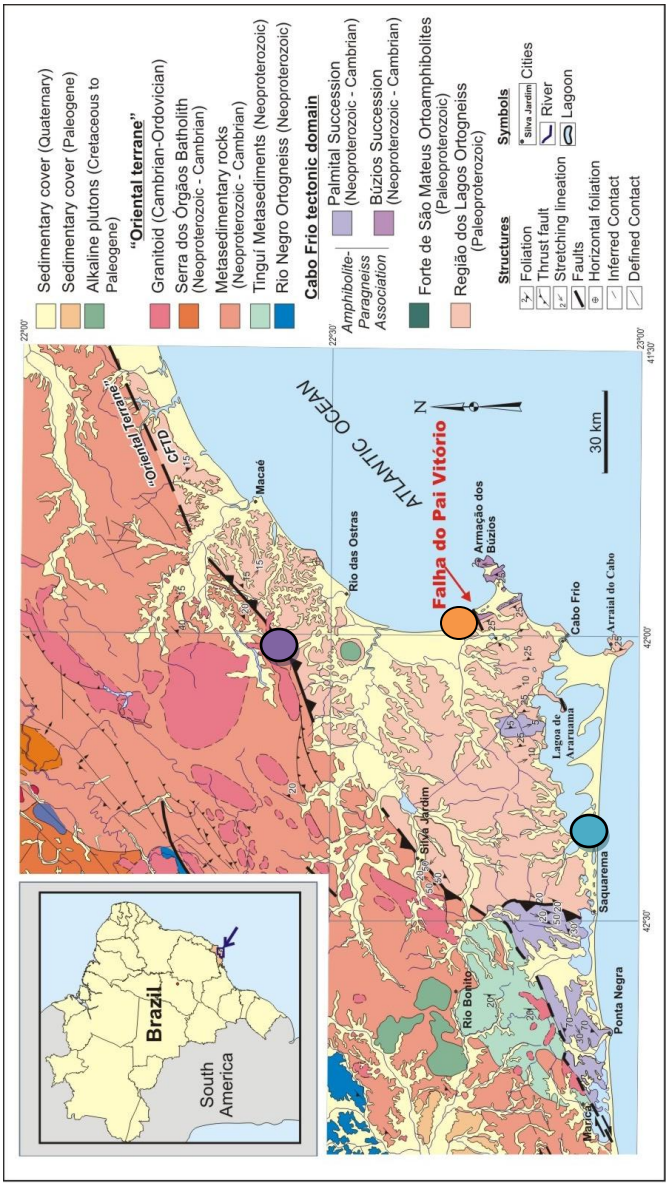

Figure 2. Geologic Map for Buzios and their vicinity, observed the Pai Vitório Fault, located close to Gorda Beach (modified from Schmitt, 2001. Circles: Point 1 - Orange: Mangue de Pedra; Point 2 - Purple: Reserva Biológica União; Point 3 - Blue: Salina Carvalho

3) Orthogneiss and aplites from Região dos Lagos Unit. Conchas Beach - Cabo Frio.

4) Intense deformation in Orthogneiss from Região dos Lagos Unit. Forte Beach - Cabo Frio

5) Gneiss from Buzios Sequence. Notice the pink/reddish sand due the presence of garnet. Brava Beach - Buzios.

Several dikes/sills of tholeiitic magmatism (Figure 2) intruding Precambrian rocks from Cabo Frio Terrain are found in the area. The bodies are related to the Gondwana break up and opening of South Atlantic Ocean in a period between ca. 120 - 130 and represent part of the Serra do Mar Dike Swarm System. The Swarm system in the Buzios area shows a structural trend following the main basement structure direction to NE-SW. Most of the intrusions are diabase and porphyritic and equigranular are the most common texture. The bodies are continues and sometimes really thick (Figure 6).

Moreover, another magmatic pulse is register in the area. This one, of younger age, is represented by stocks such Cabo Frio Island (Figure 7) and Morro de São João, sills/dikes (Figure 8) with alkaline composition associate to the reactivation of Brazilian platform and evolution of "Sudeste rift system". The ages vary from 60 to 52 Ma. Some researches indicates that the alkaline magmatism could represent a hotspot track, with W-NW trend, beginning in the interior of the country (Poços de caldas area) and finishing in Cabo Frio Island, which represent the last occurrence in continental area. According to some authors, the hotspot track is represented by Vitoria-Trindade chain and shows evidence of a rotation in a South America plate. Also they suggest that the hotspot could be the responsible for oil maturation in Campos and Santos sedimentary basins, which accounts for 74% of oil and gas production in Brazil.

Young units are representing by Barreiras Formation (Figure 9) and Quaternary sediments (Figure 10). Barreiras formation has Pliocene to Miocene age and it is represented by conglomeratic to sand deposits. The conglomeratic (Figure 11) area present gravel size grains in which the shape vary from rounded to angular, the matrix is formed by sand and sometimes a large quantity of clay is present. The occurrence of these deposits, especially in palaeocliffs, that occur very close to the beach line indicates that sea level were lower than today and most of the sediment produced by fluvial system is submerse (Morais, 2001, Morais & Mello 2003). The recent sediments in the area are represented by Pleistocene to Holocene deposits and associated to Araruama and other associated lagoons, Paraíba do Sul delta deposits and coast line sediments. Dunes field are common in Cabo Frio area and also close to the Araruama lagoon system.

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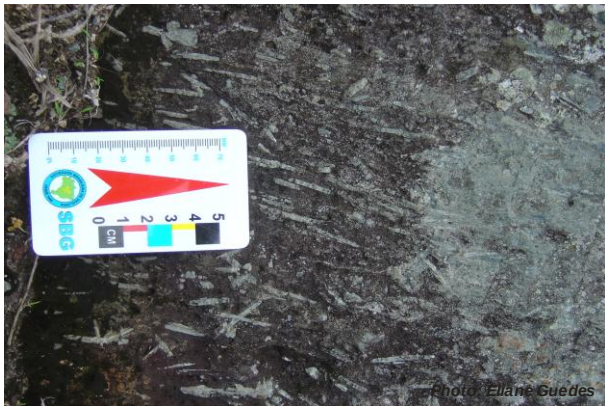
6) Exemple of tholeiitic magmatism related to Gondwana Break-up. Ponta das Poças.

7) Cabo Frio Island View. Note the small beach consider one of the most perfect in Brazil.



8) Detail of magmatic flow texture in alkaline dike. Pontal do Atalaia - Arraial do Cabo.

9) Palaecliffs from Barreiras Formation.

10) Conglomerate from Barreiras Formation. Note the different gravel size and sediment selection. Rasa Beach - Buzios.

11) Cabo Frio dune field, recent sediments.

3. First stop: Mangue de Pedra (Stone mangrove)

Location: Gorda Beach

Coordinates: 22º43'56.63" S; 41º58'23.22" O

Description: Some requirements are necessary for the existence of a mangrove. Besides the location in a zone of intertropical climate, the mix of salt water and freshwater is essential, in addition to that the vegetation protection against strong marine waves. The Stone Mangrove (or Rocky Mangrove), studied by Oliveira (2007), located in Gorda Beach, presents plants that have good structural patterns of development. The diameter of the stems of the tree population indicates a relatively young shrub forest and he concludes that it is a mangrove in development stage. The singular aspect of this forest is the rocky substratum, composed mostly by gravel, coarse sand and some blocks of rock, another interesting feature is related to distance around 5 km away from the closest river mouth.

From the beach, the tectonic breccias of Pai Vitório fault and the sedimentary deposits (Figure 3) can be observed. They are palaeocliffs formed during the period when the sea level were 2.8 meters higher around 5,100 years B.P

The Pai Vitório Fault, located in south limit of the Barra de São João Graben (Mohriak & Barros, 1990), is a normal fault that puts side-by-side the palaeoproterozoic orthogneiss and mio-pliocene conglomeratic sediments of Barreiras Formation (an important geological unit which extends for thousands of kilometers from North to Southeast in Brazilian Coast line). Morais *et al.* (2006) have interpreted these gravelly deposits as being a result of alluvial fan controlled by tectonics.

Rubin *et al*. (2003) have mapped the fault in detail and they identified 6 different units in 1:1.000 scale. These authors observed 60 m of thick of fault rocks, including a core with 3m of breccia and ultracataclasites. This regional structure has strike N70E and striations which demonstrate normal movements. Petrographic studies revealed at least 4 events of reactivations in the rocks of Pai Vitório Fault.

The main characteristic of the Barreiras Formation in this area is the occurrence of conglomerates (matrix-supported and clast-supported conglomerates).

Conglomerates are aquifers with medium to high favorability to exploitation of groundwater. Based on this statement, new research project have been developed in the area to prove that the groundwater is responsible for supply freshwater to the mangrove. The singular growth of mangrove trees is caused by the discharge of groundwater at the base of palaeocliffs in this sector of the beach.

The recharge occurs in the top of paleocliffs, active cliffs and the discharge occurs in the beach (Figure 12). This geological position creates the best conditions for salinity development of mangrove over rocks and far away of rivers. The Mangue de Pedra is a singular interaction between biodiversity and geodiversity.

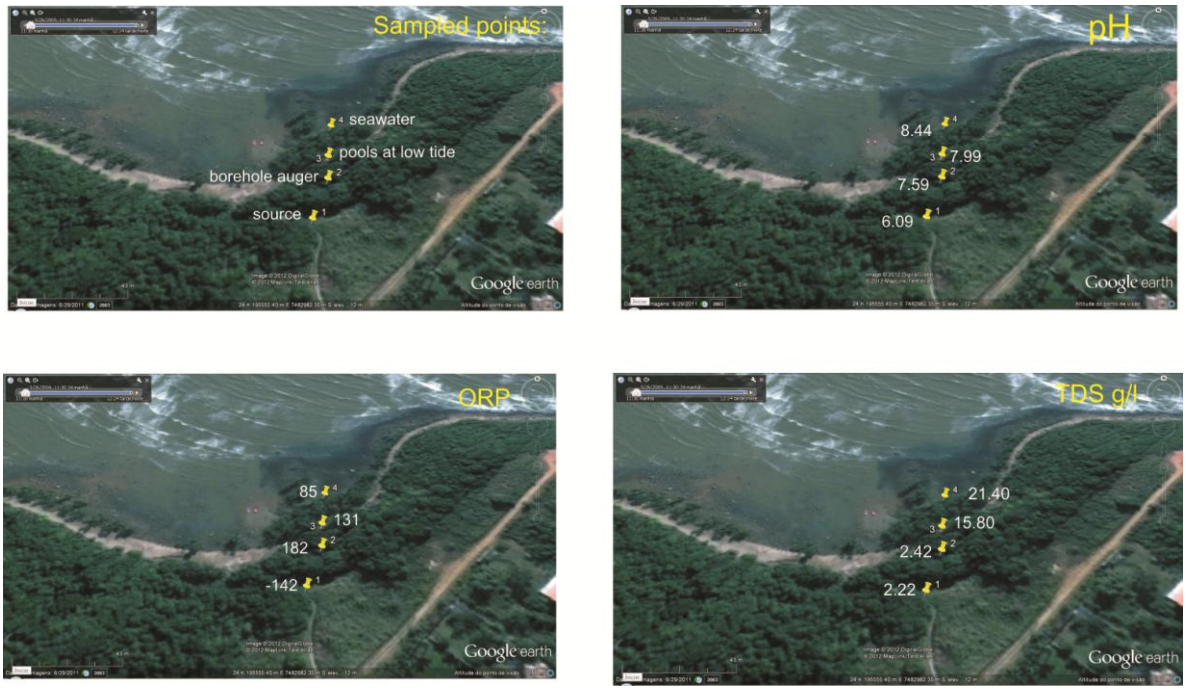


Figure 12 – Sampled points in Mangue de Pedra.

4. Second Stop: Rebio União

Location: BR 101 / Rio das Ostras

Coordinates: 22°25'37.04"S and 42° 2'11.40"O

4.1 – Brief History

The lands which later became the União Biological Reserve (REBIO União) correspond to "*União Farm*", whose owner in the 19th century, Mr. Joaquim Luiz Pereira

de Souza, was the father of Washington Luís, a former President of Brazil.

The area was also a property of the British Company "*The Leopoldina Railway Company Limited*", which acquired it in 1939 to supply charcoal to ancient steam locomotives. Later on, during the 1950's, a serious financial crisis led the company to be handed over to the Brazilian State. With the change of the energy source to the trains from charcoal to fuel oil, eucalyptus plantation objective switched to the production of railway ties. This new function of the eucalyptus trees lasted until 1996, and the production of railway ties became the main activity in the União farm.

In 1994 União Farm received the first families of golden lion tamarins, coming from threatened small forest fragments elsewhere in the region. The presence of golden lion tamarins in the area and its extensive and well preserved Atlantic Rainforest became a priority for conservation.

A large mobilization of the scientific community and international NGOs, public environmental institutions and environmentalists from different countries, enabled the transformation of the area into a Conservation Unit.

On April 22, 1998 Brazilian Vice-President, Marco Antonio de Oliveira Maciel, signed a Decree to Establish the União Biological Reserve, in order to ensure the protection and recovery of remnants of Atlantic Rainforest and associated formations and the dependent typical fauna, especially the golden lion tamarin (*Leontopithecus rosalia*).

The Biological Reserve REBIO União, a Conservation Unit of the Integral Protection Group, is managed by the Chico Mendes Institute for Biodiversity Conservation (ICMBio).

4.2 – General features

The native vegetation to União Biological Reserve is characterized as a Lowland Atlantic Rainforest (36%) and Slope Atlantic Rainforest (47.1%) retains a rich fauna typical of Atlantic Rainforest, including some endemic and endangered species. Eucalyptus forest makes 8.6% of the area, an exotic species introduced way before the Conservation Unit was founded and will be replaced by native forest in time. 249 native species of trees occur. It is also representative the occurrence of bromeliads, orchids and vines, easily observed on the bark of trees. Some studies point União Biological Reserve as the maximum biodiversity of Atlantic Rainforest in Rio de Janeiro State.

The Reserve retains a rich fauna typical of Atlantic Rainforest, including some endemic and endangered species. It houses one of the largest populations of wild golden lion tamarin *Leontopithecus rosalia*, which represents 20% of all living animals today in Nature. This population is of fundamental importance for the conservation of primate species, endemic to the Atlantic coast.

Medium and large size mammals include the endangered species *Bradypus torquatus*- toed sloth, *Lutra longicaudis* - otter, *Leopardus pardalis* - ocelot, *Puma concolor* - puma, among others. Although not endangered, but also important for

maintaining the ecological balance, many other mammal species occur in the Reserve: capybara, pacca, wild pork, agouti, armadillo, raccoon, skunk, dog-eating fox, monkey, small anteater, among others. With regard to bats, three species are considered locally rare and one is in the list of the threatened fauna of the State of Rio de Janeiro.

The Reserve also has a significant avifauna, mainly dependent on the environment and slope of the Atlantic Rainforest. A wide variety of species of fish, amphibians, reptiles and insects, also occur, which still requires studies to be better known.

Water resources are abundant in the reserve, with three main basins: Macaé river, São João river and Rio das Ostras river. Abundant small rivers drain the area, which has a considerable number of springs.

4.3. Scientific Research and Environmental Education

The Brazilian Biological Reserves have, as a major objective, the development of scientific research. The União Biological Reserve, due to its excellent natural conditions and high biodiversity, offers great opportunities for the development of these scientific activities, paramount for its management and conservation. It is also important for the training of professionals in natural sciences. The most renowned research institutions in Brazil develop some of its projects in the União Biological Reserve, generating knowledge about the flora, fauna and abiotic environment.

The technique of translocation (movement of individuals of the same species within its area of natural occurrence) of golden lion tamarins developed in the União Biological Reserve enable the animal wild population to increase by 20%, making it the second largest population of the species in nature, being crucial to reverse the threat of extinction.

Raising awareness of environmental issues and promote attitudes of respect and protection of natural resources conservation area and the surrounding region are the purposes of the Environmental Education Program of União Biological Reserve Union. To achieve them it is important to develop activities with partnerships consistent with the environment which can help to improve the quality of life of local residents.

Accordingly, the Environmental Education Program is committed to the development of internal and external actions in the Reserve.

In rural and urban communities surrounding the Conservation Unit, especially in schools, educational activities are developed, systematic, continuous, aiming to make students aware of the importance of Atlantic Rainforest biodiversity conservation, stimulating the development of respect attitudes and formation of critical consciousness in relation to environmental issues.

To provide a greater interaction between the União Biological Reserve and surrounding communities, an interpretative trail was developed within the area and a Community Center was built. These structures work integrated in the reception organized groups for educational purposes.

The track, preserving its history, was named "Pilão Interpretative Trail." It shows

part of the living creatures' wealth of the Atlantic Rainforest, the importance of forests in water conservation and to interpret the natural elements and ecological processes of vital importance to the environment. The Community Center, located strategically in the beginning of the "Pilão Trail," is where groups of visitors receive a warm welcome and general information about the Reserve, in which activities are designed to be educational. Besides being used by the Reserve, is also available to partner institutions, for achievements in meetings, lectures, courses and other events related to the environment.

To get to know the "Pilão Interpretive Trail" as well as use the Community Center, you must schedule in advance with the staff of the Biological Reserve's Environmental Education staff.

Promote some attitudes of respect for the environment:

- Do not cause forest fires. They contribute to the degradation of environmental quality and biodiversity loss.
- Do not buy animals, do not hunt, discourage hunting. Do not seize and hold captive wild animals.
- Preserve the springs and riparian vegetation and litter in place. Avoid consuming improperly withdrawn products of our natural areas and encourage the consumption of environmentally friendly products. Report damage to the environment.
- Collaborate and participate in campaigns and activities in defense of nature in your community.
- Join the defense of the Atlantic Rainforest with simple actions of everyday life. Protecting the forest makes it recycle and maintain a multitude of life forms.

5. Third Stop – Salina Carvalho

Location: Lagoa Vermelha (Red Lagoon) Praia Seca (Dry Beach)

Coordinates: 22°55'31.53" S; 42°22'26.42" W

Description: The Lagoa Vermelha is part of Araruama lagoon system, with a 220 km^2 area. According to Primo & Bizerril (2002) the Araruama Lagoon is the "largest perennial hypersaline lagoon in the world".

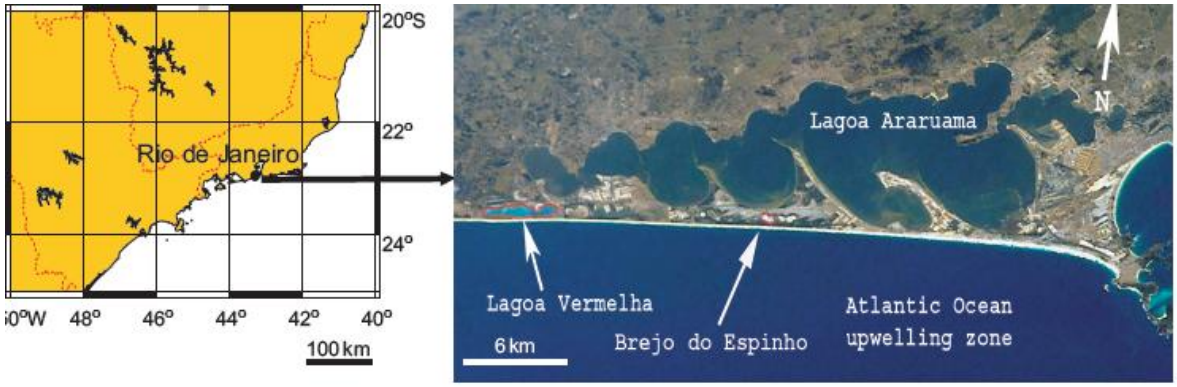


Figure 13 – Lacation map of Araruama and Vermelha Lagoon (Sánchez-Roman et al., 2008)

The evolution of this lagoon system begins in the Pleistocene (120,000 years B.P.) and it is evident, in the records of its development, the changes in sea level along the Quaternary. Several small lagoons were formed in the external beach ridge, the Massambaba sandbar: Vermelha, Pitanguinha, Pernambuca, dos Brejos do Pau-Fincado, Espinho, Grande, Mosquito e Lagoa Azul. All of them are hypersalines, but not connected with the sea. The exception is the Araruama Lagoon (connected by the Itajuru Channel = "stone mouth" in the language of the Indians, the former inhabitants of the region).

The climatic conditions in this area are peculiar due to the occurrence of a sea upwelling zone offshore, that contributes to the semi-arid climate characteristic for the region. These special conditions lead to a strong interannual variability of the regional climate, whereby evaporation exceeds precipitation (Barbiére, 2002, in Sánchez-Roman *et al.*, 2008, page 169).

According to Vasconcelos & McKenzie (1997), the Lagoa Vermelha is a shallow water body with a maximum depth of 1.7 m and an area of approximately 2.4 km^2. Its margins are bordered by algal material. The region has an annual evaporation deficit of 470mm. A barrier dune about 400 m wide separates the lagoon from de Atlantic Ocean and serves as a conduit for recharging sea water. The lagoon is also recharged by meteoric water seeping though Pleistocene dunes on its continental side. Because of the domain of groundwater as the source of recharge to the lagoon, the sediments are essentially autochthonous chemical precipitates. Salinity varies between brackish and hypersaline, depending on the precipitation/evaporation rate and on the rain water/sea water rate in groundwater inflow.

Brejo do Espinho lagoon water has a typical seawater Mg/Ca molar ratio of ~ 5, indicating a seawater origin modified by evaporation and dilution processes. The occurrence of stromatolite microbial mats (Figure 14) in Vermelha, Pitanguinha, Pernambuco, Brejo do Espinho, Salina Julieta and Araruama lagoons has been described since the 1990's. Dolomite methabolism by cyanobacteria in these hypersaline environments in Araruama

lagoon system , and the presence of stromatholiths, transformed the area in important natural laboratory to the planetary evolution study (Vasconcelos, 1988, Vasconcelos, 1994, Vasconcelos & Mckenzie, 1997; Burns *et al.*, 2000).

Figure 14. Stromatolites of Lagoa Vermelha (Photo: Crisogono Vasconcelos)

The microbial model of dolomite formation (Vasconcelos & Mckenzie, 1997) was conceived in Vermelha lagoon and has been used to explain the "dolomite problem", as it became known impossibility to explain the formation of this mineral at low temperatures since its discovery in 1791 (Burns et al., 2000; Mackenzie & Vasconcelos, 2009). The formation is credited to the action of sulfate-reducing bacteria (*Desulfovibrio brasiliensis*), which metabolize, in anoxic and hypersaline environment, dolomite. Regarding microbialites, hypersaline lagoons and salinas are locals where those cyanobacteria develop. In Vermelha lagoon, between Saquarema and Araruama, stromatholiths and stratified dolomitic deposits are found.

According to Vasconcelos et al. (2006) "In this study, we investigate if the Lagoa Vermelha hypersaline lagoon system is a suitable analogue for mineral formation on the shallow-water continental shelves of the early Earth, by considering the complete environment of the microbial mat with its underlying sediment as one unique biogeochemical system." (page 176). They conclude "Moreover, geochemical, mineralogical and microbiological characteristics of Lagoa Vermelha support its classification as an important fossil environment, particularly as an analogue for the Precambrian environments where the metabolic pathways within microbial mats were more related to the formation of Mg-calcite and Ca-dolomite than today." (page 182).

It is interesting to cite the studies of magnetic multicellular bacterial organisms in Araruama Lake (Keim et al., 2006, Abreu et al., 2007), which shows the variety of living organisms in hypersaline environments with special characteristics in the area.

MINING HERITAGE

Due to their comprehensive extents, the calcareous sea shells of the lagoon system were exploited for more than 50 years by the National Company of Alkalis and some independent miners. The Mining Heritage consists of sea salt mining areas, currently in the process of disappearance and replacement by urban development. As a product of the salt, halite and gypsum are produced. The INEPAC (2004) conducted an inventory in the region called “The Way of Salt”. It presents 11 historic salt mining areas, some with records from the nineteenth century. In this same study, it is mentioned that the salt was already explored in the region by the Indians before the arrival of the Portuguese. According to the Intermunicipal Consortium Lakes - St. John (www.lagossaojoao.org.br/la-usos.htm) "The salt in the pond was known to Araruama Indian tribes, who gathered it from natural deposits. Gabriel Soares de Souza, in the book “Descriptive Treaty of Brazil” in 1587 reported: - by this bay {in this case the Araruama lagoon} one enters the tide by far inland, which is very low, where from January 20 until February all the water curdles very quickly, and with no sea drying, the Indians take the salt sour, very white, in large amounts, at low waters, without ever getting dry. [...]

Figure 15. Salt mining in Lagoa Vermelha

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