Sedimentation Effects on Bioluminescent Bays of Puerto Rico.

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Abstract- A comparative study between sediments of La Parguera bioluminescent bay and Puerto Mosquito Bay in Vieques was conducted from February 2004 to May 2004. The main objective of this research was to compare the differences of sediment composition and the Geology of the area. This study was undertaken to understand how natural and human induced factors may affect sediment composition and deposition and how that affects the quality and quantity of light in the water column of the bays. No previous research shows how sediments affect the dinoflagellates that produce the biluminescence in these bays. But, it is important to study the differences in the sedimenthology of both bays and how it may affect the life of these organisms. Sediments were collected every 24 days during 2 months using three sediment traps in each bay. XRD, sediment composition, sieving and sedigraph analyses were part of the methodology. Temperature measurements for both bays were aldo registered. The study shows that there is more sediment suspended in Puerto Mosquito in comparison to La Parguera, also that sediments in Puerto Mosquito are coarser in comparison to those in La Parguera Bay where they have the perfect weight to be suspended. Water was warmer in Vieques, wich could be related to sediment suspension in the bay and or the paucity of rain.

Introduction

Dense blooms of dinoflagellates with extremely high bioluminescence occur sporadically in tropical latitudes around the world. In lower latitudes, as a result of many topographic and meteorological conditions, certain bioluminescent bays exhibit persistent high concentrations of bioluminescent dinoflagellates (Walker, 1997).

Bioluminescence is a light emission phenomenon created by an organism, in this case a unicellular dinoflagellate, less than 1/500 th of an inch in diameter, called P*yrodinium bahamense* . These spinning flames are actually part animal because they can move around and part plant because they photosynthesize sunlight using chlorophyll. There are several bioluminescent creatures in both bays, but the *Pyrodinium* is the dominant light producer. Several theories have been developed of why this organisms glow, but it is generally accepted as a type of primitive defense mechanism. They do not really have any control over their luminescence, they simply emit a bright glow whenever they are agitated, or moved around. For a single-celled creature, the brief flash may make them seem larger than they really are and scare away their predator zooplankton. Because dinoflagellates are a type of phytoplankton, they absorb basic chemicals directly from the water they live and this is an important factor in their abundance. This organisms requires specific conditions for its living and reproduction. There are several mechanisms for high concentrations of dinoflagellates in a bioluminescent bay, it should be surrounded by mangrove trees, remotely located with a naroow entrance , keep warm water temperatures and calmed waters. The tourist exploitation of the places where this organisms live is making a irreversible damage to them.

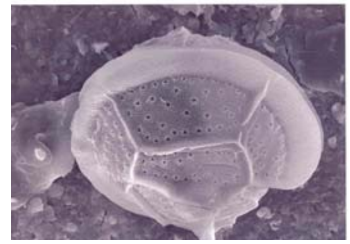


Fig 1. *Pyrodinium bahamense*

Fig. 2 Mangrove trees in La Parguera

La Parguera bioluminescent bay located at the southwest coast of Puerto Rico between 17˚58' N and 671 W and has an approximated depth of 4.5 meters in the inner zone and approximately 2.3 meters in the mouth of the bay. Puerto Mosquito bay is located at the south of Vieques between 18˚6 N and 62˚ 26' W and have a depth of 3.9 meters in the inner zone and 1.8 meters at the mouth.

Various scientists have denominated Puerto Mosquito in Vieques and La Parguera Bay in Lajas

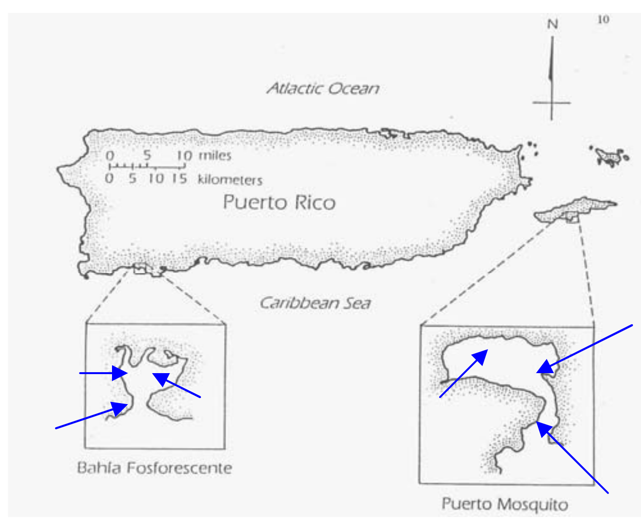


Fig.3 Study Area. Arrows indicate where the traps were placed.

as the most amazing bioluminescent bays in the world. But La Parguera Bay has shown a decrease in its bioluminescence by approximately 80% in the past years compared with Puerto Mosquito (Walker, 1997). A comparative study of these two bioluminescent bays was conducted in 1996 by Alfredo Sanjuan and Juan Gonzalez. The main objective of that research was to determine how boats that enter to La Parguera bay move sediments and how this affects the bay. They found changes in the sediment structures where the upper layers represent an accumulations of finner sediments (particulated organic material) in comparison to the depper ones that present the normal conditions of the bay with coarser sediemts composed mostly of “diatomeas, espiculas”, ostracods, marine algae and mangroove leaves(Sanjuan and Gonzalez, 1996).

Marine sediments can be divided into three categories, based on their composition and mode of origin. Sediment composition provides important information about the origin of individual grains, and energy levels during transport and deposition, especially in areas dominated by clastic sediments of terrigenous(Grains which have been eroded from the land and carried to the marine environment , typically by rivers, wind, glaciers, erosion, slumping, and mass wasting) origins.

Clastic marine sediments can be divided into two broad categories; terrigenous and carbonate. The processes that are responsible for their formation and deposition can be different. Terrigenous sediments are most often of silicate origin(They are composed of quartz, feldspars and other minerals associated with an igneous origin). They are derived from the erosion of upland or coastal areas and transported over considerable distances to their ultimate environment of deposition. Terrigenous sediments can also be eroded carbonate that has been lithified and uplifted. A very clear relationship exist between grain size and energy level, coarser sediments generally reflect higher energy, while quieter areas are dominated by mud. Abrasion during transport may significally reduce the size of some rock fragments and may even be responsible for total destruction of others(Friedman, 1978). Suspension and tranportation of sediments depends on the size and/or weight of the particle.

In the marine environment carbonate sedimentation depends on factors such as, temperature, salinity, water depht, nature of water currents, light penetration and water turbidity(Miall, 1984). Under optimun conditions calcium carbonate accumulation can be extremely rapid, such conditions include, warm, clear, shallow water of normal marine salinity. Carbonate grains are controlled by the skeletal architecture of the organisms from which the organism is derived. Physical breakage by abrasion in agitated waters is one of the factors that break carbonates into lime mud.

The sorting in carbonate environments can be difficult. The variable grain size and the high porosity of some particles (*Halimeda* or foraminifera with natural pores and chambers) can make the more susceptible to transport than terrigenous sediments. Terrigenous sediments are derived from the breakdown of crystalline volcanic rocks. Although sedimentary rocks are eroded to provide grains, their constitutients are generally derived from the prior erosion of igneous or metamorphic rocks. The principal source of terrigenous marine sediments is river discharge. Rivers transport more than 18 x 19^9 metric tons of suspended solids to the worlds oceans annually (Holeman, 1968).

Suspended sediments affect the amount of light that enters the water column, therefore it is an important factor in the life of these organisms because of the need of light for photosynthesis. The objective of this research is to measure the impact of sediment movement, caused by different natural and human induced changes in the bays and how they are related to the dinoflagellate population.

Methodology

Sediment traps were made with 15cm wide and 15cm long *PVC* tubes with a rod of 2cm wide and 1 meter long for stabilizing the trap in the bottom. These traps were placed at three different places in both bays. The sediments were recollected every 24 days in a period of two months, and dried up in the laboratory. The weight of each one was calculated by separating the samples of the different traps into three groups.

Fig. 4 Buoys used.

The samples for XRD analyses were dried and pulverized and placed in sample holders. XRD analysis is a technique based on differential passage of X radiation through a sample onto a special film. Differences in composition (density) from place to place through the sample cause differences in attenuation. The result and variation in the amount of radiation that reaches the film creates differences in photographic density.

Sieve analysis measures grain diameter by allowing sand to settle through a set of sieves. Each sieve is a cilinder floored with a wire-mesh screen with squares appertures of fixed dimensions(Prothero and Schwab, 1999). Phi units express grain size as the negative logaritm of grain diameter in millimeters to the base 2. Wet sieving was used after mixing the sample with sodium metaphosphate at 0.5%. This process was used to separate the clay from the sand. The samples were washed and dried for normal dry sieve analysis. Sediments larger than 4 Φ were separated and taken to the sedigraph machine. Sedigraph is an x-ray process that "sieve" sediments > 4 Φ using sodium methaphosphate to separate clay from sand. Sorting was used to express the number of significant size classes in the samples, this may reflect variations in the velocity and the ability of a particular process to transport and deposit (Prothero and Schwab, 1999). Skeweness was measured to understand the symmetry of the distribution. As the skeweness becomes positive the sediemnt is coarser.

For sediment composition, the samples were washed with Clorox until the sample fezzes stops, they were washed, dried and weighed for second time. The lost material was the organic. Then, it was washed with HCl at 10%, this process takes the carbonates away, the sample was dried and weighted again. Everything left were terrigenous materials.

Fig. 5 Thermometer.

Thermometers were placed in each bay, in order to measure temperature every two hours. The measurements were averaged by time of the day and tables were prepared.

Sediment mineralogy of the bay was compared to the geology of the area that surrounds it using geological maps and rock samples to understand the origin of the minerals present in the sediments.

Results and Discussion

February 16,2004 - March 11, 2004	
Parguera I	96.6g
Parguera II	73.9g
Parguera III	n/a*
Vieques I	n/a*
Vieques II	n/a*
Vieques III	66.9g
March 11, 2004 - April 4,2004	
Parguera I	n/a*
Parguera II	n/a*
Parguera III	66.9g
Vieques I	n/a*
Vieques II	24.4g
Vieques III	24.6g

Table 1.Sediment collected in 24 days period

* indicates traps that were stolen or lost.

The amount of sediment recorded in La Parguera was significally higher than the collected in Vieques as shown in table 1; this confirms the results from Sanjuan and Gonzalez in their investigations of 1996. As they suggested, the reason for higher sediment suspension could be due to the tourism exploitation of the ecological place. As shown in Figure 6, boat traffic is extremely higher in La Parguera than in Vieques.

This may be re-suspending the sediments and creating currents that may be responsible for the abrasion that keeps breaking the sediments.

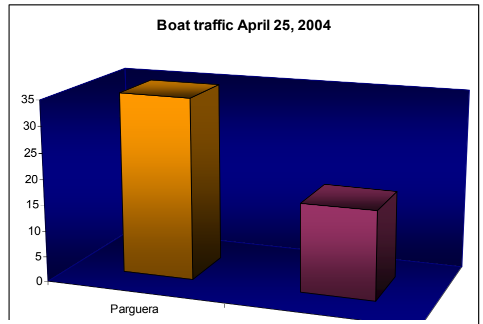


Figure 6. Boat traffic

The sediments of La Parguera (Figure 8) show a high composition of terrigenous fine grained sediments; previous works demonstrated that there has been a change in the size and composition of the sediments (Sanjuan and Gonzalez, 1996).

There is a layer of fine sediment of terrigenous origin covering the coarser carbonate sediments that shows the previous conditions of the bay (Margalef, 1961). This sediment layer must be the one that boats and ocean currents could have resuspended and this might be related to changes in the water temperature in the bay, thus making it colder compared to Vieques as we can see in Figure 7. These changes in temperature could produce different conditions affecting the dynamics of the dinoflagellates and other organisms. As we can see in Figure 8, the sediment composition in the mouth of the Vieques Bay (Vieques mouth refers to Vieques I in the samples and tables) are mostly coarser grained carbonates, that is not easily resuspended. Less boat traffic may also help to keep sediment deposited and light can warm up the waters. The clear waters of this bay allows the growth of organisms that produce carbonate sediments and the proliferation of the *Pyrodinium bahamense* as previously demonstrated by the high populations of this organism in this bay (Walker, 1997).

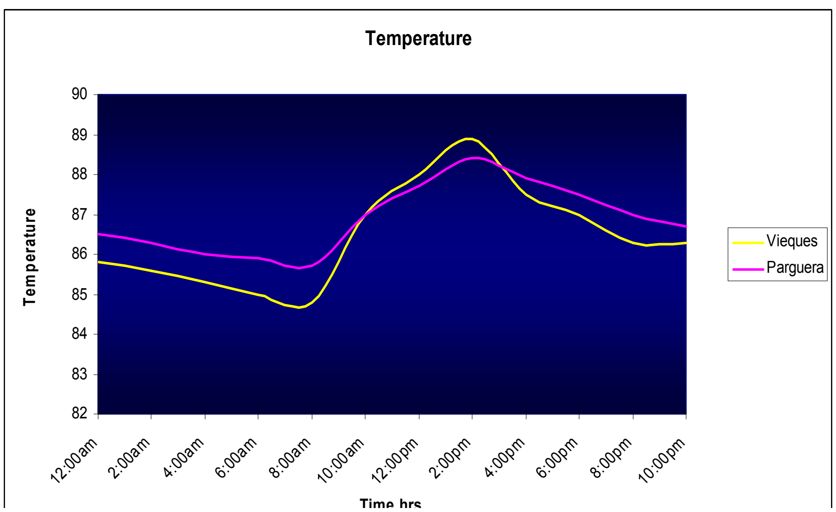
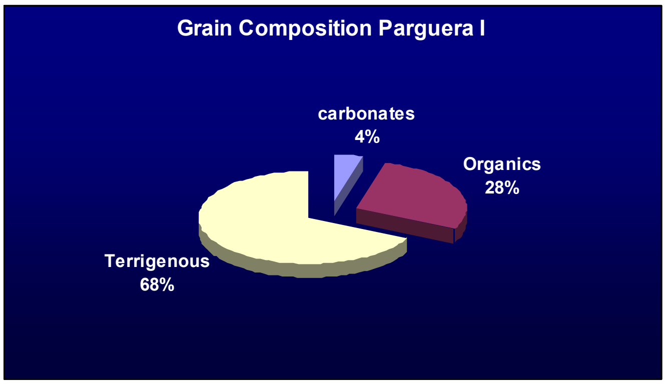
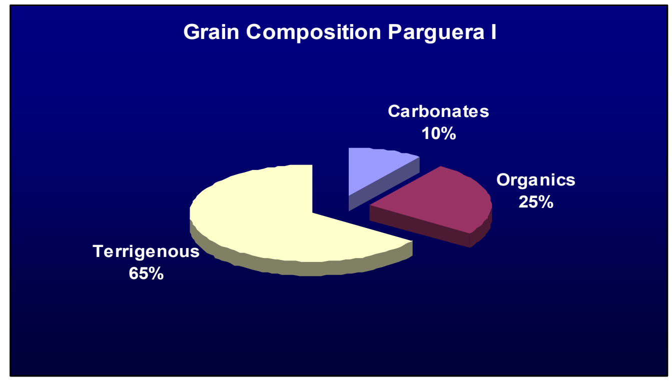


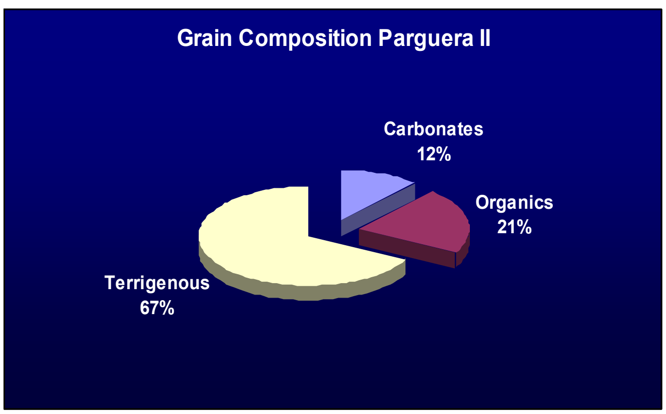
Figure 7. Average temperatures for the studied period.

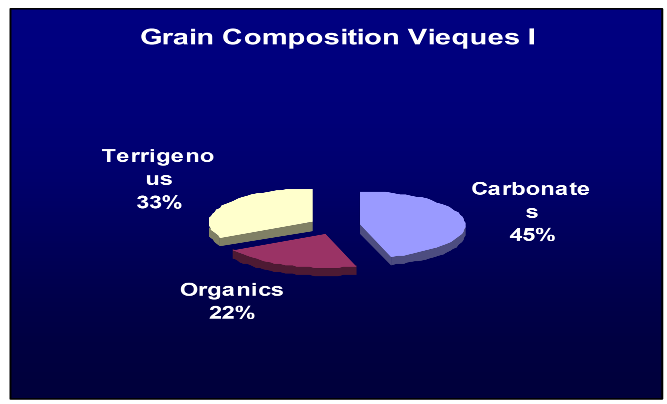
There is a difference in the Geology of the area that surrounds the bay as we can see in Figures 11 and 12. La Parguera Bay is surrounded by volcanic rocks which when are eroded become terrigenous sediment, that is exactly what we found in the sediment composition of this bay. These terrigenous sediments stay suspended, affect the light and therefore affect the conditions for carbonate sedimentation. In the other hand Vieques is mostly composed of limestone and sandstone, this leads to the higher carbonate mineralogy that we found in the sediments.

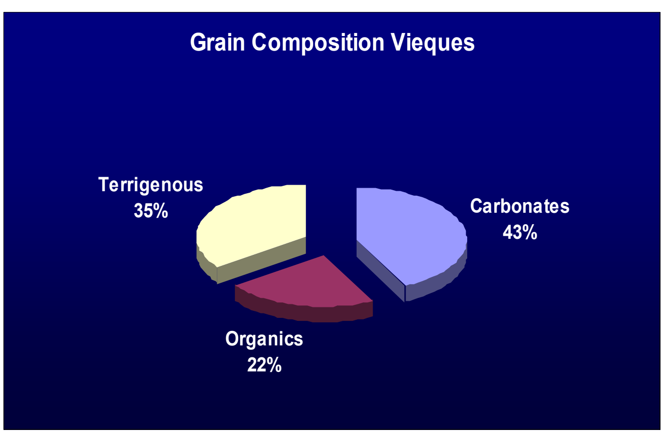
February 16, 2004 - March 11, 2004 **March 11, 2004 – April 4, 2004**











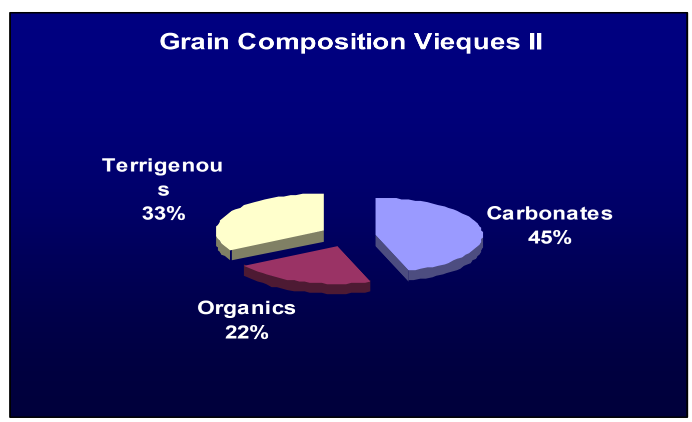


Table 8. Grain Composition of the two collections.

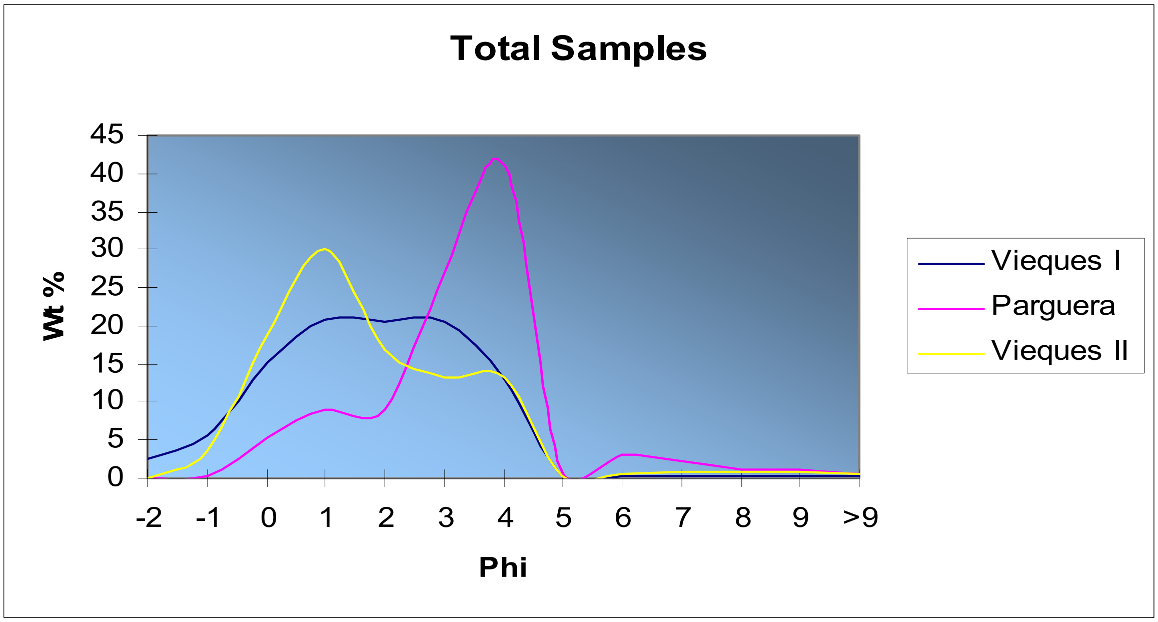


Figure 9. Weight percentage of the total samples.

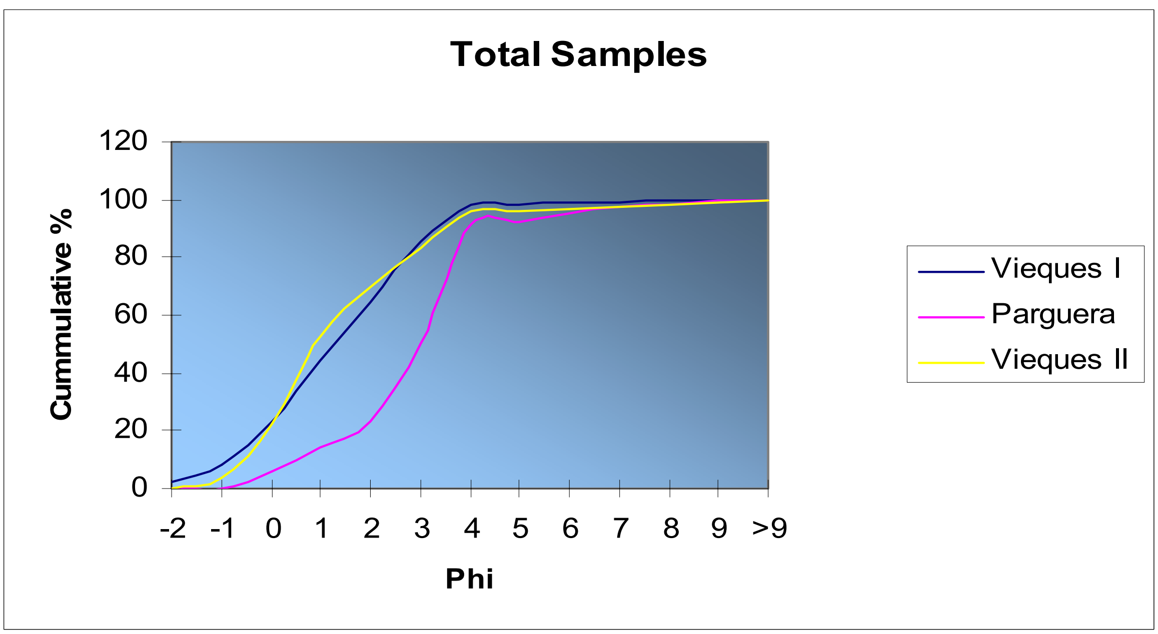
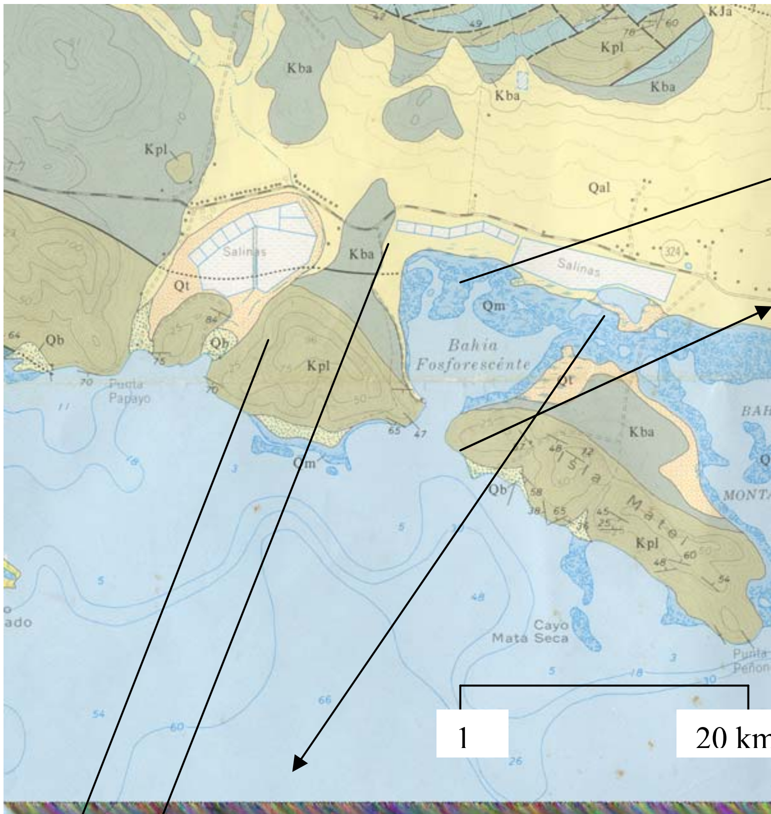


Figure 10 Cummulative percentage of the total samples.



Qm - Areas containing Extensive growth of mangroves. Underlain by fine sand and silt trapped by mangrove roots.

Kpl- Parguera Limestone- volcanic rocks and chert with minor serpentinite and Amphibolite ; chert clasts in the Cerro Vertero as much as 1m; conglomerate grades upward to medium to thin bedded grayish-orange to pale yellowish brown volcaniclastic calcarenite locally containing glauconitic beds, thin beds of silicified mudstone, interbeds (to 10m) of calcareous mudstone and sparse lenses of coarse grained light-gray bioclastic limestone which consist of skeletal debris including fragments of mollusks, solitary corals, and larger foraminifera; calcarenite grades.

Kba- Basaltic andesite- porphyritic basalt and andesite, , phenocrysts of plagioclase and various combinations of clinopyroxene, orthopyroxene, hornblende, oxyhornblende, and rare olivine.

Qb- Beach Deposits- Sand and minor gravel; consist of rounded fragments of shell debris, volcanic rocks, chert, and locally quartz.

Qal- Alluvium- Clay, silt, sand and gravel in stream valleys; merges with colluvium along valleys walls and at a valley heads, form large fans which grades to the Caribbean sea, in the north east part of the area consist of sand and gravel fan deposits which grade into silt and clay of the Lajas Valley.

Figure 11. Geologic Map of La Parguera Quadrangle

QTu – Sedimentary deposits undivided Marine limestone, calcarenite, sandstone, shale, marl, chalk, sand and clay; and alluvial landslide beach, dune, swamp, marsh and reef deposits.

Figure 12. Geologic map of Vieques Island.

Conclusions

The objective of this research was to examine the differences between sediment compositions and its relationship with the geology of the area, as well as temperature changes in both bays. As the results and interpretations demonstrated, there is a difference in sediment mineralogy as well as a difference in sediment suspension between the two bays. The difference in the sediment mineralogy is related to the difference in the geology of the area. Other factors like abrasion may be contributing to the process of sediment breaking changing them from carbonates to lime mud. Now that we know the difference in the sediments of the two bays and where can they be coming from, also the impact this may be having in these organisms, it is very important that we try to stop the human impact in these bays so we can enjoy the beautiful bioluminescence in future years.

References

Seixas Guerrero, C. E., 1988, Patrones de distribución espacial y sucesión temporal en poblaciones de dinoflagelados de la Parguera : MS Thesis, Univerity of Puerto Rico, Marine Sciences.

Walker, L.A., 1997, Population dynamics of dinoflagellates in two bioluminescent bays: Bahia Fosforescente, La Parguera and Puerto Mosquito, Vieques. V1. 51 pages.

Sanjuán, A. E. y Gonzáles J.G., 1996, Inventario de embarcaciones visitantes de la bahía bioluminiscente de la Parguera, su relación con ingresos económicos generados y cambios en la estructura del ecosistema. 19 pages.

Seliger,H.H., Carpenter J.H., Loftus M., and Mc Elroy W.D. Mechanisms for the accumulation of high concentrations of dinoflagellates in a bioluminescent bay.

Prothero, Shuwab. 1999. Sedimentary Geology. An introduction to sedimentary rocks and stratigraphy, W.H Freeman and Company 82-89.

Friedman, G.M. and Sanders, J.E., 1978, Principles of Sedimenthology. John Wiley & Sons, Inc. 27-63

Miall, A.D., 1984. Principles of Sedimentary Basin Analysis. Springer-Verlag New York Inc.353-376.

Reading, H.G., 1978. Sedimentary Environments: Processes, Facies and Stratigraphy. Blackwell Science. 37-61.

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