INTERANNUAL MORPHOLOGICAL CHANGES OF BOA VIAGEM BEACH-NORTHEAST COAST OF BRAZIL

VARIABILIDADE MORFOLÓGICA INTERANUAL DA PRAIA DE BOA VIAGEM, LOCALIZADA NA REGIÃO NORDESTE DO BRASIL

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ABSTRACT

Boa Viagem and Pina are urban beaches highly economically important both locally and regionally providing protection for the southern coast of Recife, Pernambuco – Brazil. The objective of this paper is to study the interannual morphological changes which occur on these beaches in order to gather information on the erosion processes. For this purpose 6 topographical profiles were monitored, monthly, from August 2002 to December 2005, during spring tide. To establish the position of each profile it was considered whether the beach was protected by reefs, or not, and if there were coastal protection structures. The largest morphological variation was observed in profiles located to the extreme South and North of the area of study (profiles 1 and 5), as well as the profiles located immediately to the North of the coastal protection features (profiles 4A and 4B). Profiles located in the middle of the study area showed stability. As for sedimentary budget the following variations were observed: negative sedimentary budget in profiles P1 (-4.0 m^3/m), P4A (-22.0 m^3/m), P4B (-7.0 m^3/m) and P5 (-1.0 m^3/m); positive sedimentary budget in profiles P2 (+2.0 m^3/m) and P3 (+4.0 m^3/m). Profiles 2 and 3 presented a more consistent budget than those of the profiles located at the extremities of the area (profiles 1, 4A, 4B and 5). The profiles did not present morphologic variations in the beach environment like those mentioned in conventional literature. Profiles 2-1, 3-2 e 4A-3 do not present a linear relation between rates of sedimentary budget. However a positive linear relation between profiles 4B-3 and 5-4B was observed. Variations of accretion and erosion found in this study may be related to seasonal variations in the direction of currents along the coast.

Keywords: beach profile; sedimentary volume; morphology; coastal erosion; Brazil.

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INTRODUCTION

Changes in the beach environment can be measured, among others, through conventional topographic methods such as level or theodolite (Bird 1996). These methods can evaluate the sedimentary volume of a beach as well as monitor the advance or recession of the coastal line along a given time line (Larson & Kraus 1994; Clark & Eliot 1988; Lacey & Peck 1998; Swales 2002; Anfuso & Del Rio 2003). Coastal monitoring for long periods of time in places with contention structures permits evaluation of environment (Hamm et al. 2002; Thomalla & Vincent 2003) and quantification of spatial and time distribution of erosion and accretion in the beach environment (Anfuso & Del Rio 2003).

In Brazil studies related to erosion and accretion processes in the beach environment, as for example: Bittencourt et al. (1987), Muehe e Correa (1989), Calliari e Klein (1993), Bessa Júnior e Angulo (2003), were done in areas of medium latitudes, leaving a shortage of information in tropical areas. For these we find only studies by Krause e Soares (2004) in the Northern region of Brazil; Duarte (2002); Lima et al. (2004); Manso et al. (1995), Pontes e Araújo (2006) in Northeastern Brazil.

In Pernambuco, between the Cape of Santo Agostinho and the Island of Itamaracá there are signs of erosion that varies from moderate to severe, although there still isn't a precise diagnosis for the comprehension of local and regional causes (Manso et al., 1995, Muehe 1998). The construction and extension of the port of Recife resulted in severe coastal erosion in the city of Olinda (Pereira et al. 2003).

Boa Viagem and Pina are urban beaches with great economical importance, both locally and regionally, providing protection for the southern coast of Recife, Pernambuco – Brazil. Yet since the last decade it presents environmental problems, such as marine erosion processes, mainly in the portion located between the Plaza of Boa Viagem and Piedade beach, south area. The objective of this paper is to study the variability of the beach environment profile (Figure 1), to verify the erosive and/or accretion states and correlations.

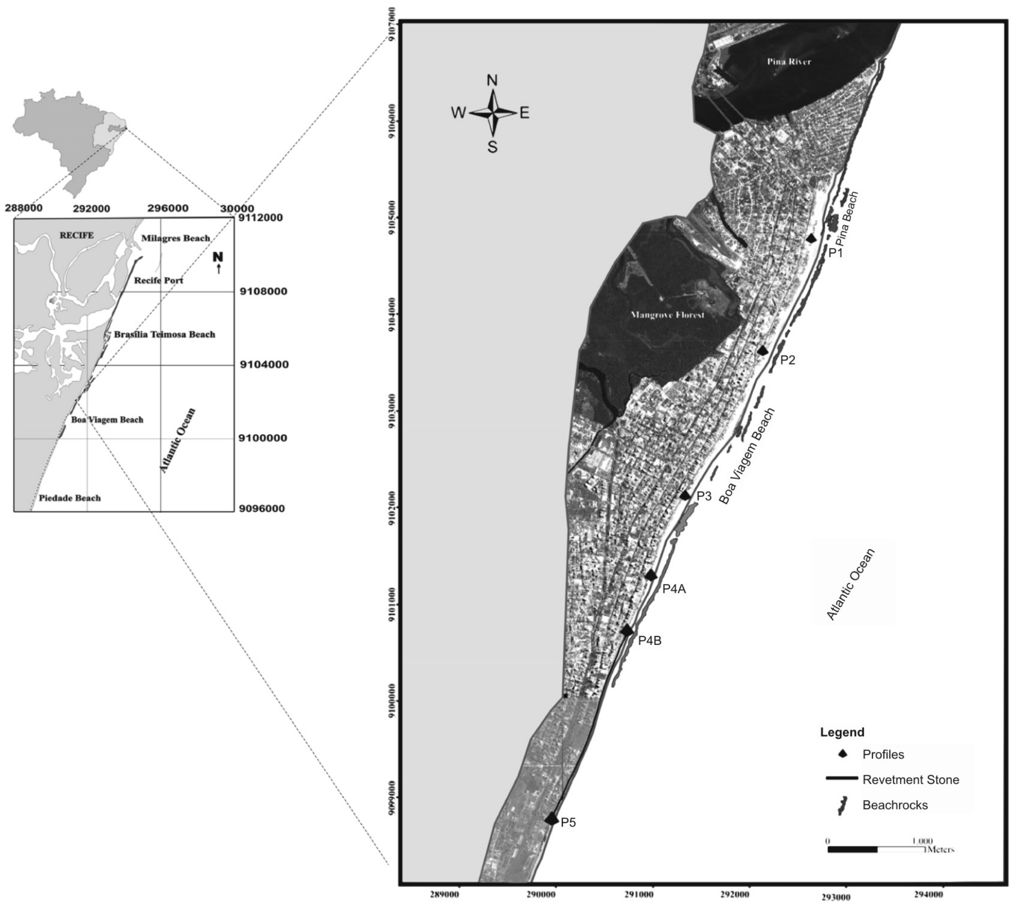


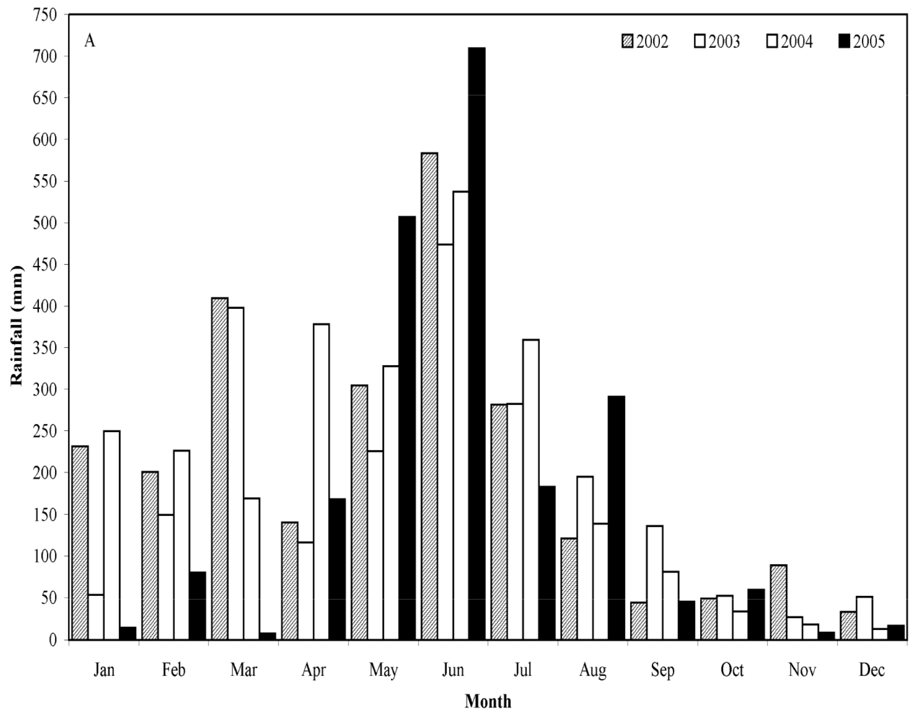
FIGURE 1 - LOCATION OF THE STUDY AREA AND MONITORED PROFILES

STUDY AREA

Pernambuco has got a coastline of 187 km, located in the Brazilian Northeast. The city of Recife is situated on the coast of Pernambuco, with characteristics of Quaternary sedimentation (Coutinho *et al.* 1997), presenting Pleistocene and Holocene marine platforms, marsh deposits, sandstone banks and coral reefs (Dominguez *et al.* 1990). Coutinho (1964 *apud* Muehe 2001) comments on the absence of deltas in the Pernambuco coast, due to reduced fluvial sediment contribution.

A relief with vertical amplitude of 4 m can be observed in the bathymetric profiles of the internal platform located in front of the city of Recife. This is apparently due to the presence of a line of submerged reefs. In a strait channel among the coastal reefs a fine material (mud and silt) can be found brought in by rivers through the estuary of Barras das Jangadas, which is then transported to the North (Kempf *et al.* 1967/9; Araújo *et al.* 2004).

The seasonal rhythm of the Brazilian Northeastern coast is defined by the rain regime. A raining season, with rainfall superior to 100 mm, and a dry period, that presents precipitations inferior to 100 mm (Andrade 1997). According to data furnished by INMET - Instituto Nacional de Meteorologia for the Recife station (Figure 2) during the years of 2002, 2003 and 2004 the highest precipitations occurred in the months of March and June; for the year 2005 between the months of April and July. The lowest precipitations occurred in the months of November and December, 2002 and 2005. For the monthly averages of wind, the highest speeds were observed in the months of August and September of 2002, and the lowest speed in the month of May 2004 (Figure 2). The direction of the winds is predominately in the southeast direction, and a larger variation between SE/E during the dry season and SE/S is observed during the raining season.



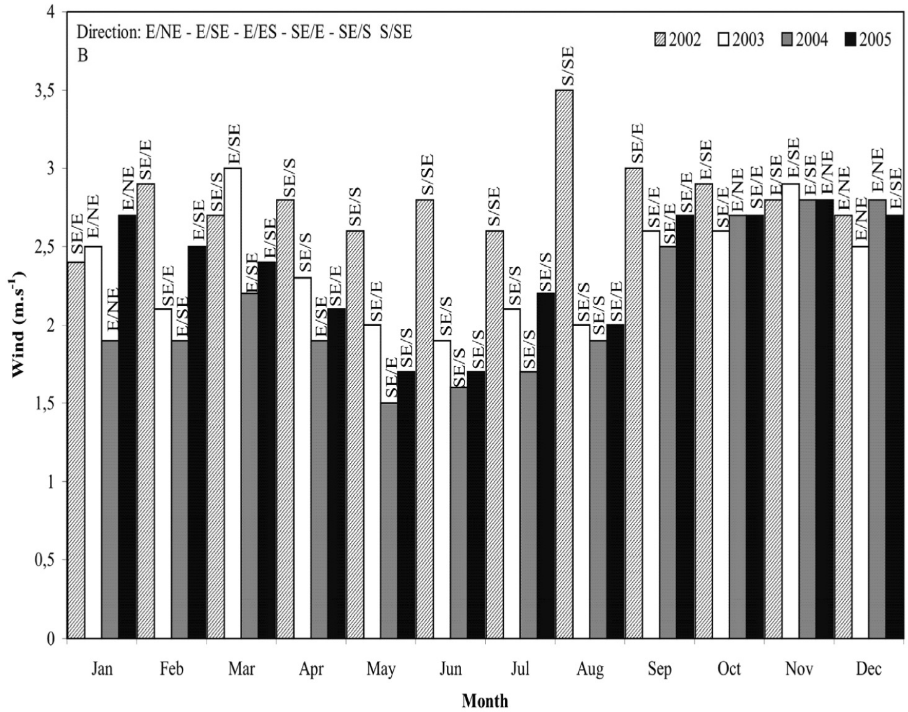


FIGURE 2 - MONTHLY AVERAGES FOR THE RECIFE STATION: A – RAINFALL PRECIPITATION (MM). B – VELOCITY ($m.s^{-1}$) AND DIRECTION OF WINDS

Sediment on the beaches of Boa Viagem and Pina are sand, being 80% grains of quartz and 20% bioclastic fragments. In the rainy season they are constituted of medium sand in the central part, fine sand in the extremities, and very fine sand in the northern part of the study area. In the dry season, the sediments are predominately constituted of fine sand (Gregório *et al.* 2004).

METHODS

Monthly surveys were done in 5 topographic profiles throughout the beach arc in the stretches between Pina beach and limits of the Boa Viagem beach (Recife) and Piedade (city of Jaboatão dos Guararapes), during the period from August 2002 to December 2005 (Figure 1). Profiles are spaced approximately 1,5 km from each other and distributed from North to South. Due to tropical storms in March 2004, profile 4A was transferred to profile 4B. Field work was always done during the lower sea level of spring tide. To establish each profile it was considered if the beach was protected by reefs and / or was open, and if there was the presence of coastal protection structures, as well as indicators of erosion and accretion. For topographic leveling the adopted method was “Stadia” (Birkemeier 1981) that presents an estimated error between 10 and 20 cm and allows monitoring of the sub aquatic profile (Tozzi & Calliari 1999). Due to the occurrence of shark attacks, the profiles in this study had to be limited, in the submerged portion, to a maximum depth of 20 cm.

The profiles were analyzed according to their temporal location, in the rainy season (March to August) and dry season (September through February), only to better comprehend the erosive process and accretion in different seasonal periods since wave data was not analyzed. With help from specific programs the volume of sand was calculated in each profile, being expressed by linear meter (m^3/m). The statistical rate of the data on sedimentary volume and the correlation rate between the profiles according to its distribution were calculated.

BEACH ENVIRONMENT

Sections of the beach environment are divided, according to Reading e Collinson (1976), in frontal dunes, backshore, beach or foreshore and shoreface. The frontal dunes are limited to the backshore in the inferior portion of the berm scarp. The backshore is located above the line of high tide, undergoing the action of waves during storms; its width is associated to the mean inclination of the beach. Beach or foreshore is the portion located between the superior limit of high tide and the inferior limit of low tide. The shoreface is always the submerged part of the profile, and is delimited with the beach at the level of low tide level, extending into the sea until there is no more sediment remobilization.

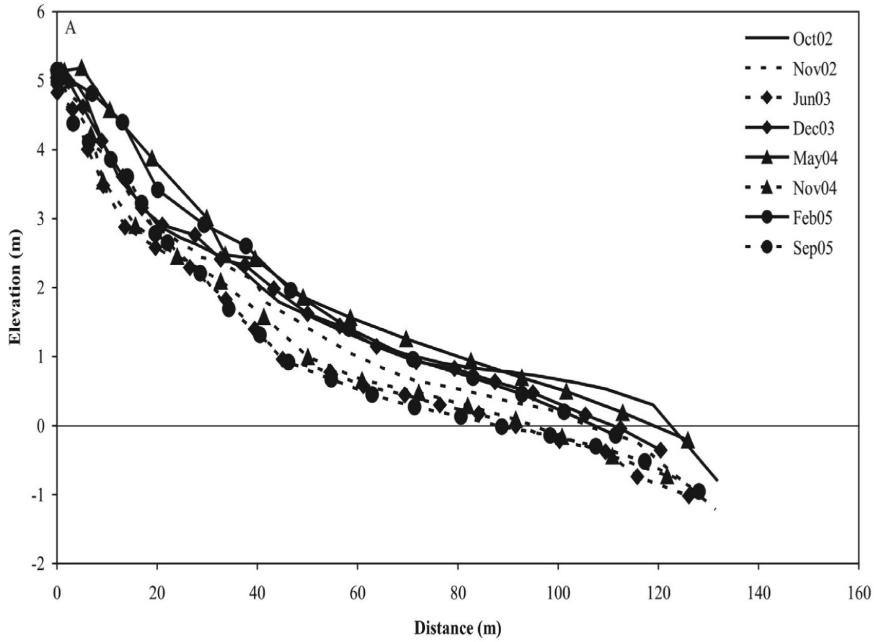
The northern portion of the study area is represented by the Pina beach and northern section of Boa Viagem beach. Portions observed on the beach environment: frontal dunes, backshore and foreshore, and shoreface, these being better developed in the extreme north of the area. In the central portion frontal dunes are not observed. Marine erosion contentions structures are presented to the Southern area. According to the division of a beach environment, analysis was done of the morphologic and volumetric variations on the 5 profiles, located in the beaches of Pina and Boa Viagem.

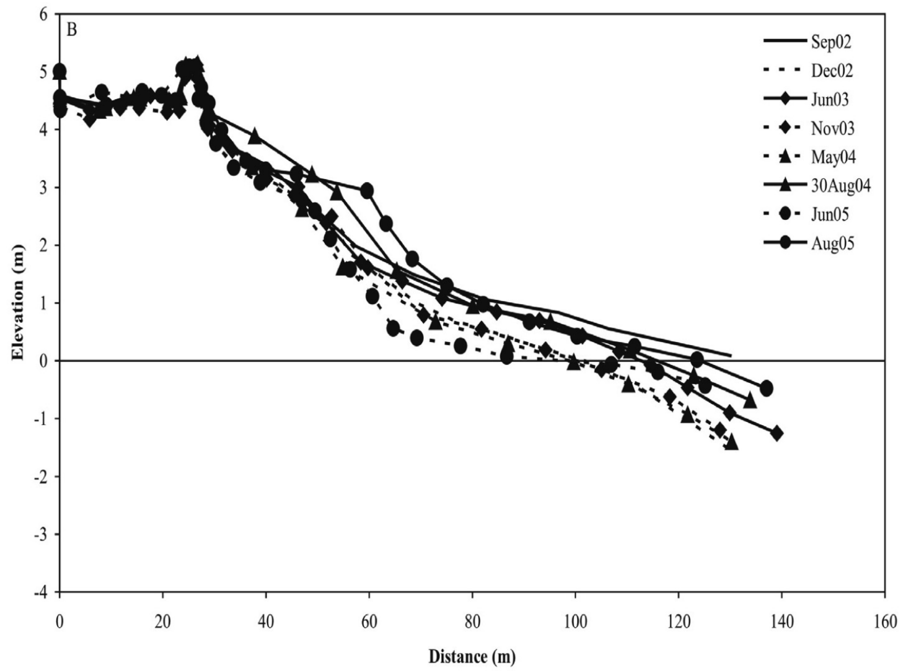
MORPHOLOGY

Profile 1 is located on the Pina beach, situated in a sheltered beach area, with a line of reefs that are not totally uncovered (Figure 1). Possesses a medium extension of 130 m (Figure 3A), and the fore dune possesses an average 10 m in width and 1.2 m in height. The backshore and foreshore present an average extension of 30.6 and 78.5 respectively, and the shoreface an average extension of 19.4 m. In the period between October 2002 and December 2002, the profile showed a higher morphological variation in the lower region of the foreshore and in the shoreface area, with sedimentary loss in these regions during the month of November. During the year 2003, there was sediment loss in the entire beach environment in the month of June, and sediment accretion during the month of December.

During the year 2004, in the month of May, this profile had sediment accretion throughout the entire beach environment, and loss in the same environment during the month of November. The year 2005 presented a larger sediment accretion in the month of February, and bigger loss during the month of September. During the monitoring period this profile presented morphological variation in all of its compartments.

Profile 2 located in the northern portion of the Boa Viagem beach, is in an area of open beach (Figure 1), and presents a well preserved beach environment, with a region of vegetated dunes, and a well developed backshore and foreshore region (Figure 3B). Possesses an average extension of 130 m and the distance from the starting point of the profile to the basis of the vegetated dunes is 22.72 m. The backshore region has an average 20.30 m, the foreshore and the shoreface area 60 m and 24.20 respectively.

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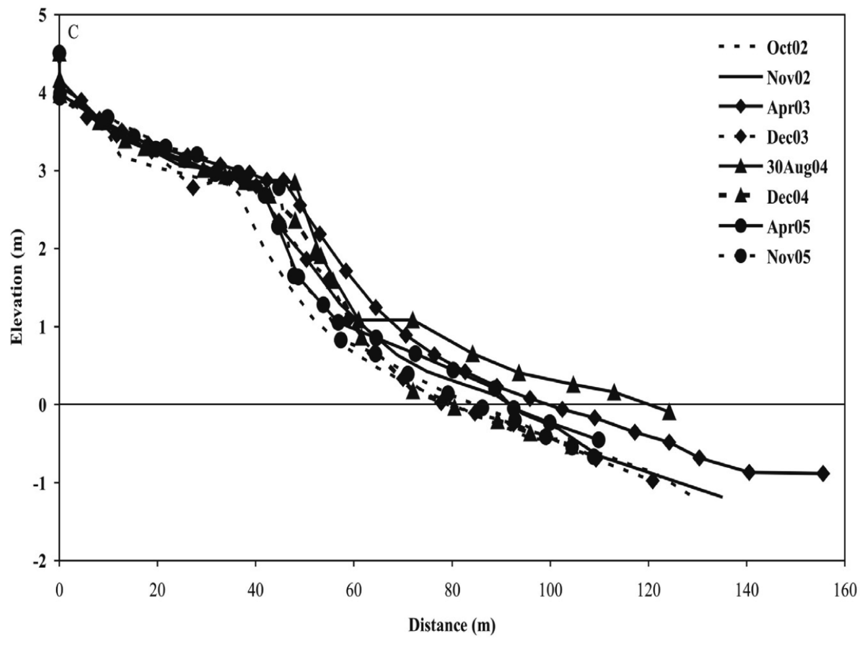
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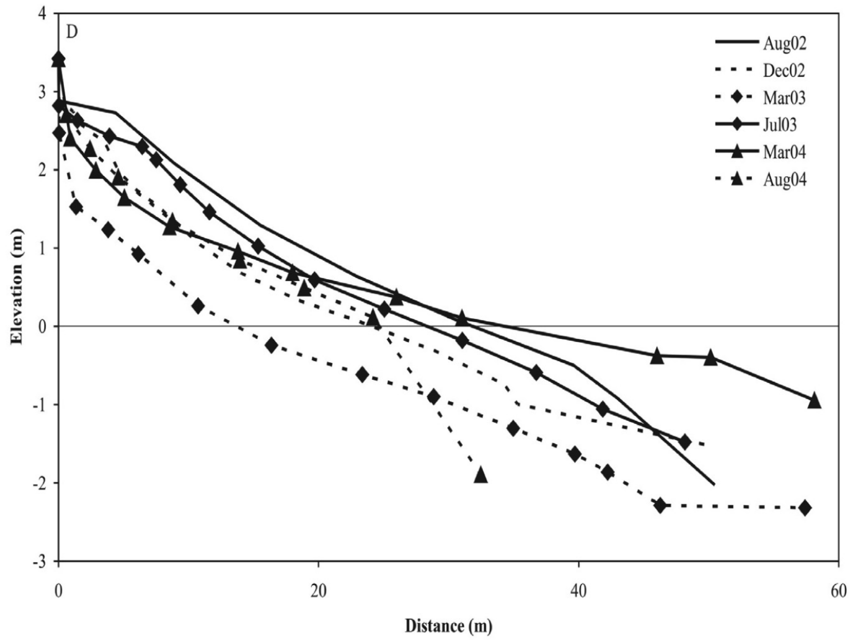
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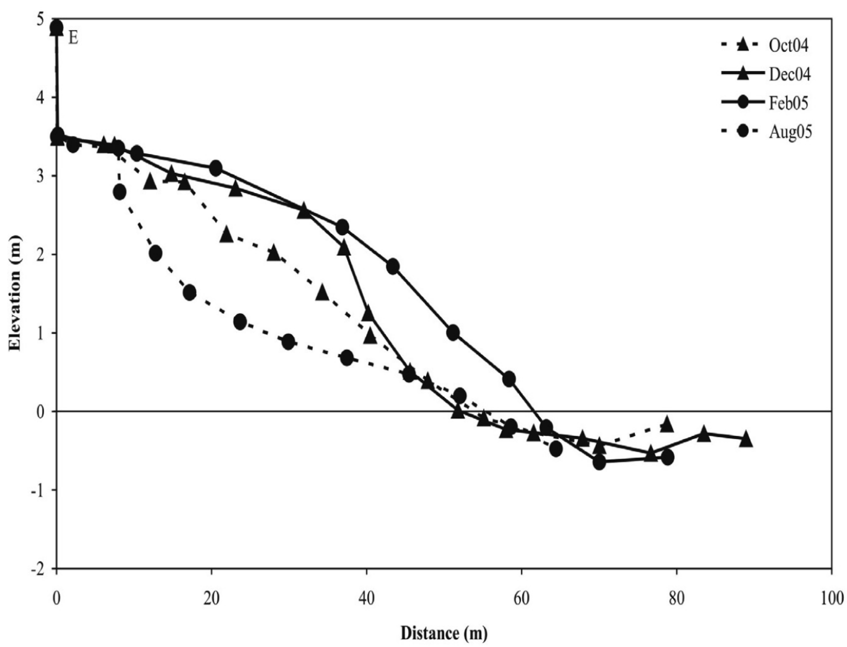
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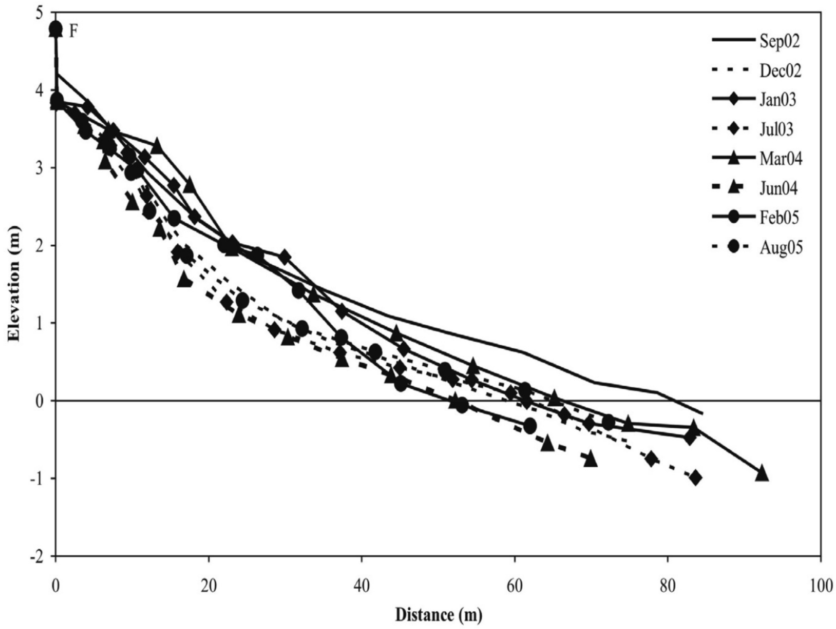


FIGURE 3 - MORPHOLOGICAL VARIATIONS IN PROFILES: A - PROFILE 1. B - PROFILE 2. C – PROFILE 3. D - PROFILE 4A. E - PROFILE 4B. F - PROFILE 5, WITH REPRESENTATION OF THE MOST SIGNIFICANT MONTHS

Between the months of August and December 2002, the profile had sediment accretion in the foreshore region during the months of September, and loss in the shoreface region in the month of December. In 2003, during the month of June there was sediment accretion in the lower foreshore region and loss in the month of November in the shoreface region. For the year 2004, in the month of March, sediment accretion occurred in the foreshore and shoreface regions with loss in the month of May throughout the entire beach environment, with the exception of the dune region. In 2005, the biggest sedimentary loss occurred in the month of June in the foreshore and shoreface regions, with sediment accretion during the month of August for both environments. The biggest morphological variations observed in this profile occurred in the foreshore and shoreface regions, being the backshore a steady area.

Profile 3 is located in the center-north part of the Boa Viagem beach, not presenting frontal dunes (Figure 1) and is located in a sheltered area (between two lines of reefs). It has got a developed backshore and foreshore regions (Figure 3C), with mean width of 50.13 m and 52.93 m respectively and shoreface of 38.17 m. For the period of September through December 2002, in the month of October, the profile presented bigger sedimentary loss in the entire beach environment and accretion in the lower region of the backshore, foreshore and shoreface in the month of November.

For the year 2003, the profile had sediment accretion in the entire beach environment during the month of April and, in the month of December, sedimentary loss in the region of the lower foreshore. During the year 2004 at the end of the month of August there was sediment accretion in the higher and lower foreshore region and in the area of the shoreface. However, the sediment loss was observed in these same areas during the month of December. In 2005, the biggest loss of sediments occurred in the month of September, in the backshore region with sediment accretion in the foreshore region during the month of December. The biggest morphological variations in profile 3 were observed in the foreshore and backshore regions.

Profile 4A, to the North of the coastal protection feature present in the beach of Boa Viagem (Figure 1), is located in an area protected by reefs, and the backshore region is practically non existent. Possesses an average extension of 50 m and an average foreshore width of 33.61 m, and the shoreface has a mean rate of 18.36 m (Figure 3D). In the period of August through December 2002 presented sedimentary loss in the entire beach environment being more accentuated in the month of November.

The year 2003 presented a great erosive process, being necessary intervention on the part of Recife's City Hall, with the placement of sacks of sand in the backshore area, in the months of January through March. In the month of March, the profile lost sediments in the entire beach environment, with sedimentary accretion in the backshore and superior foreshore region in the month of July. In 2004 sediment accretion in the foreshore and shoreface regions were in the month of March, and in the month of August there was loss in the entire beach environment. Due to tropical storms that occurred in the month of August 2004, the starting point of the profile was lost, and this profile was transferred north to Profile 4B.

Profile 4B is located in an area protected by reefs (Figure 1), to the North of the coastal protection feature, 300m away from Profile 4A. The region doesn't present frontal dunes, but presents a wide foreshore region (Figure 3E). Possesses a mean backshore width of 20.6 m; a foreshore with 40.72 m and an area of shoreface of 22.9 m. In relation to the period ranging from August to December 2004, in the month of October there was sedimentary accretion in the superior foreshore region and in the month of December loss in the lower foreshore region and shoreface. For 2005, there was sediment accretion in the month of February in the backshore and foreshore regions, and in the month of August loss in the backshore and superior foreshore regions. The largest morphological variations observed in this profile occurred between the foreshore and backshore regions.

Profile 5 is located south of the limit of the coastal protection feature (Figure 1). It is located in an open area, with the backshore region little developed and with wide foreshore (Figure 3F). Presents an average extension of 70 m, the backshore region has an average width of 15.47 m, the regions of foreshore and shoreface of 55.57 and 20.59 m respectively. For the year 2002 between August and December, the profile had sediment accretion in the regions of foreshore and shoreface in the month of September, and lost sediments in the same regions during the month of December.

For the year 2003, the profile had sedimentary accretion in the entire beach environment during the month of January and loss in the regions of foreshore and shoreface in the month of July. In relation to 2004, during the month of June there was sedimentary loss in the entire beach environment and in the month of October there was accretion in the shoreface region. In the month of February of 2005 there was sediment accretion in the foreshore region and loss of these sediments in the month of August and accretion in the shoreface region. The highest morphological variations were observed in the foreshore and shoreface regions during the monitoring period.

SEDIMENTARY VOLUME

The results of the rates in the sedimentary volume of all the profiles for the period of August 2002 to December 2005 are represented graphically on Figures 4, 5, 6, 7, 8, e 9. The analysis of these results permitted the observation of the behavior of the sand budget in the profile in a given time line as well as between profiles.

Profile 1 presented a negative sedimentary budget of 4.0 m^3/m (Figure 4). The highest volume was observed in the month of May 2004 (217 m^3/m) and the lowest in the month of September (115 m^3/m). This profile did not present recovery in its sedimentary volume for the whole monitored period. Positive sedimentary budget was only observed in two months (May 2004 and February 2005).

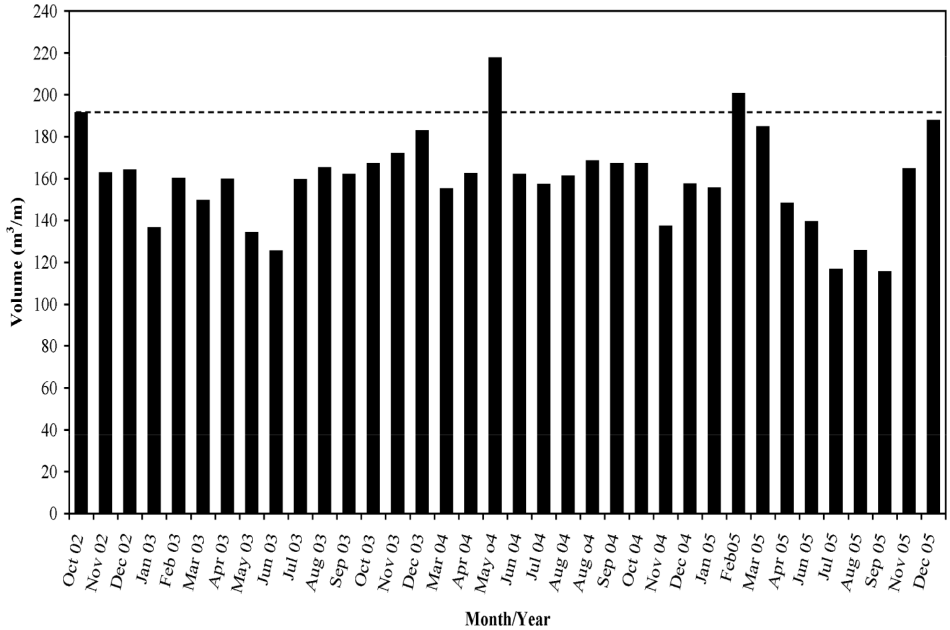


FIGURE 4 - VOLUMETRIC VARIATIONS IN PROFILE 1

During the monitored period, profile 2 presented a positive sedimentary budget, in the order of 2.0 m^3/m. The highest rate in the sedimentary volume was observed in the month of August 2005 (Figure 5), in the order of 293 m^3/m, while the lowest rate also observed during the year of 2005, was in the month of June (224 m^3/m). This profile didn't present great deficit of sediments for the whole monitored period (Figure 5), and the positive rates represented the majority of the months monitored.

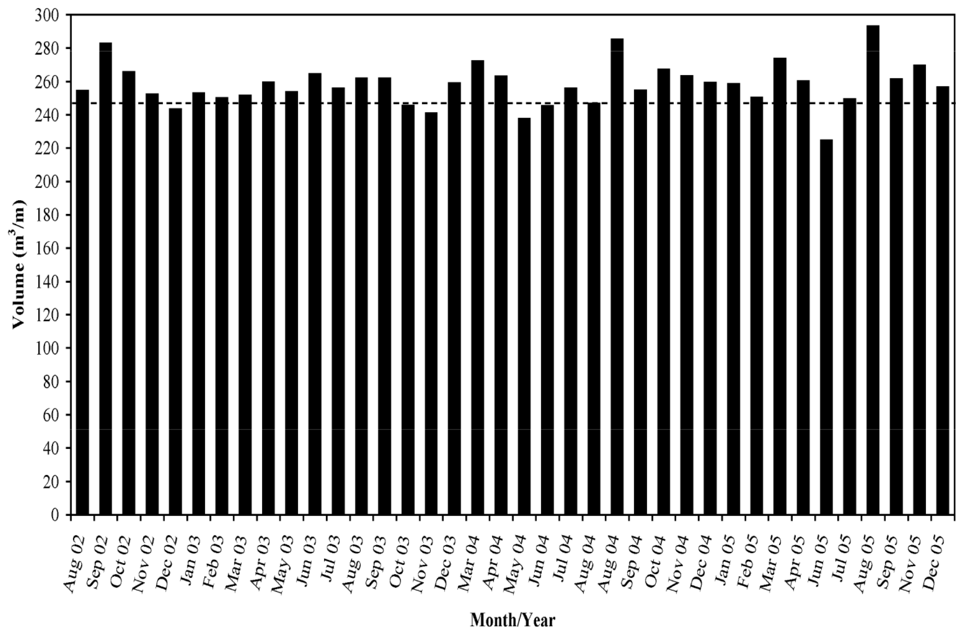


FIGURE 5 - VOLUMETRIC VARIATIONS IN PROFILE 2

For the period between September 2002 and December 2005 profile 3 presented a positive sedimentary budget of 4.0 m^3/m (Figure 6). The month of August 2004 presented the highest sedimentary volume, 257 m^3/m, and the month of October 2002 the lowest rate (201 m^3/m). In relation to the sedimentary budget, as observed for Profile 2, this profile did not present great sediment deficit for the entire monitored period either. The positive rates represented the majority of the months that were monitored.

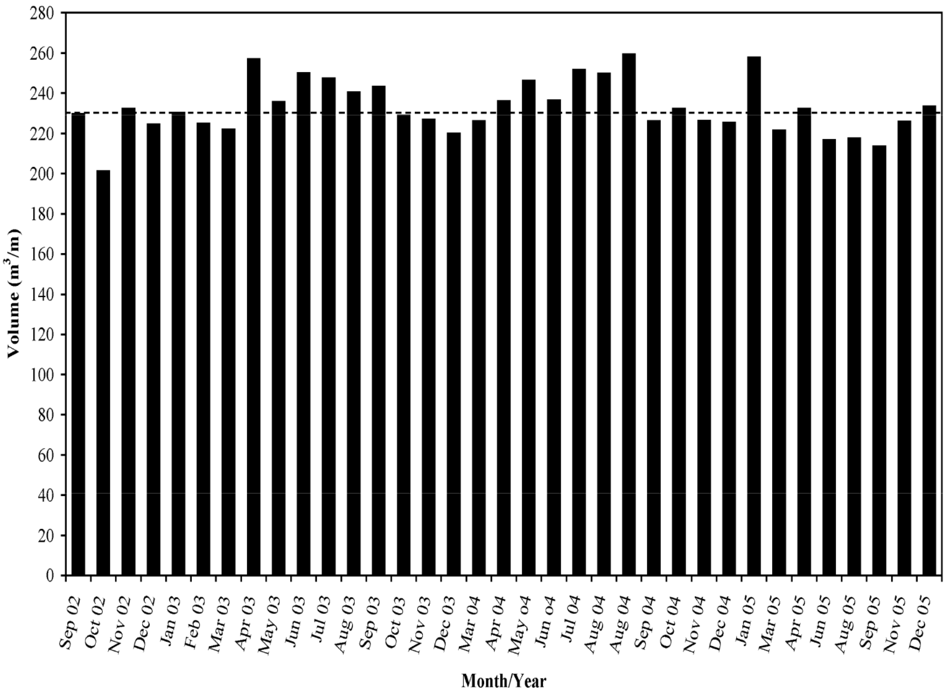


FIGURE 6 - VOLUMETRIC VARIATIONS IN PROFILE 3

Between August 2002 and August 2004 a negative sedimentary budget was observed in profile 4A, in the order of 22.0 m^3/m (Figure 7). The month of August 2002 corresponds to the month of highest sedimentary volume, in the order of 65 m^3/m. The lowest rate was observed during the month of March 2003 (21 m^3/m). For the entire monitored period, this profile presented a great deficit of sediments, being more decisive in the month of March 2003.

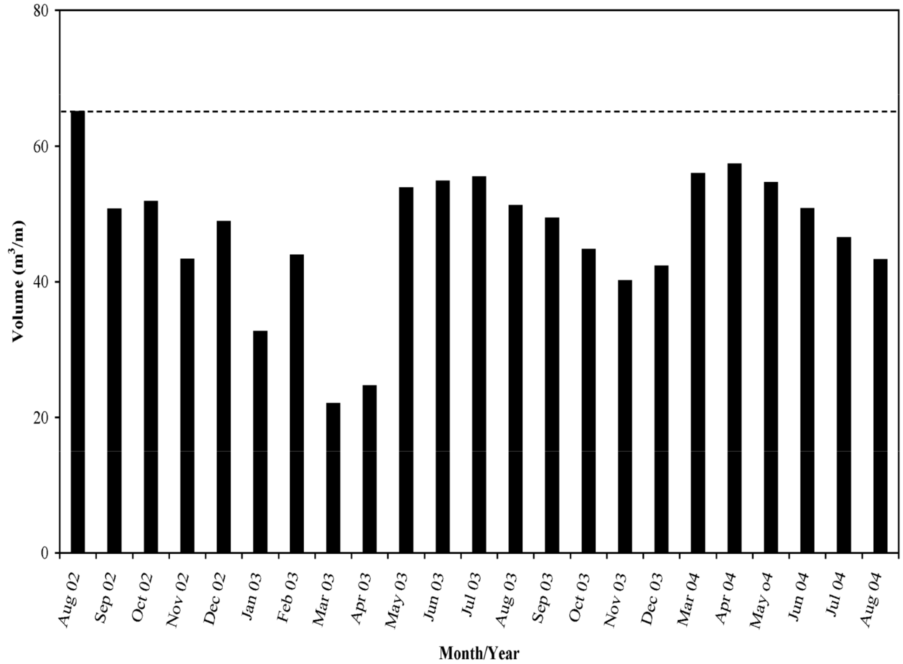


FIGURE 7 - VOLUMETRIC VARIATIONS IN PROFILE FOR 4A

For the period between August 2004 and December 2005, profile 4B presented a negative sedimentary balance, in the order of 7.0 m^3/m (Figure 8). The highest volume observed was during the month of February 2005 (148 m^3/m), and the lowest rate in the month of August 2005 (81 m^3/m). The highest rate in sedimentary volume was observed in the months of March 2004, January, February, and November 2005. The lowest rates were in the months of August and September 2005.

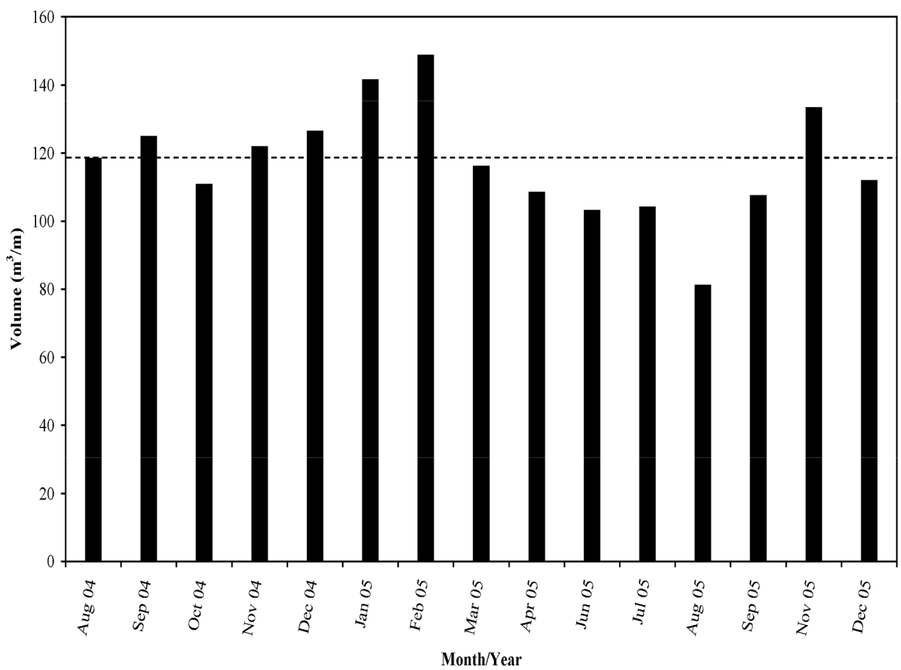


FIGURE 8 - VOLUMETRIC VARIATIONS IN PROFILE 4B

During the period ranging from August 2002 to December 2005, profile 5 presented a positive sedimentary budget of 1.0 m^3/m (Figure 9). The highest sedimentary volume (68 m^3/m) was observed in the month of September 2002 and the lowest rate in the month of June 2004 (39 m^3/m). Profile 5 presented the highest rates of sedimentary volume in the months of October 2002, January 2003 and March 2004. The lowest rates were observed during the months of December 2002, February 2003 and in the period from March to August 2004. As it was observed in profile 1, the negative rates also represent the majority of monitored months.

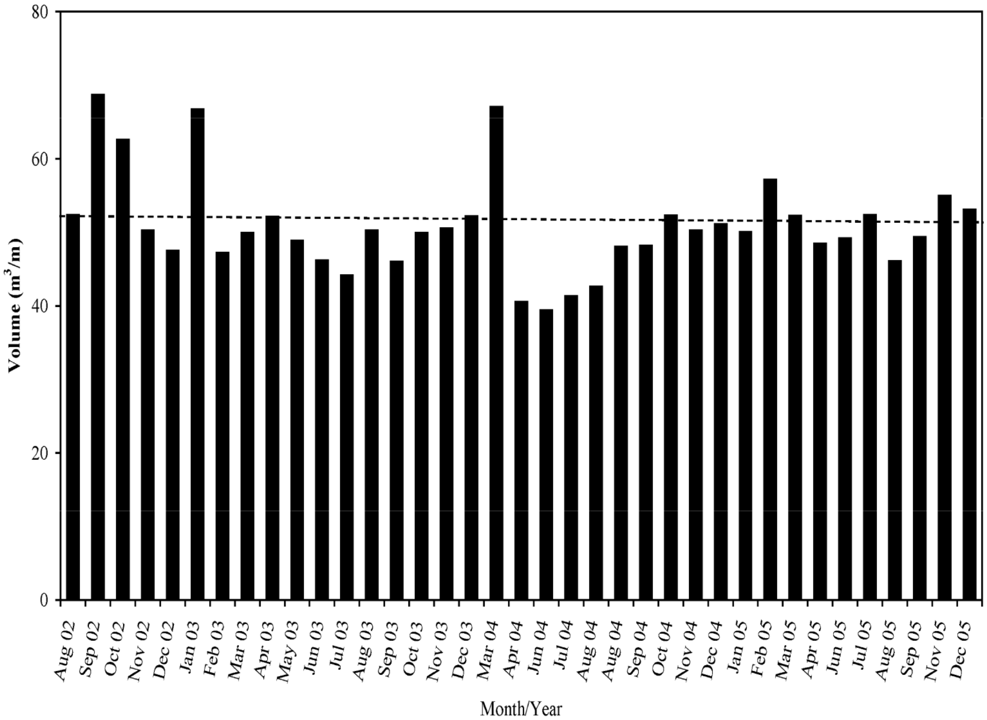


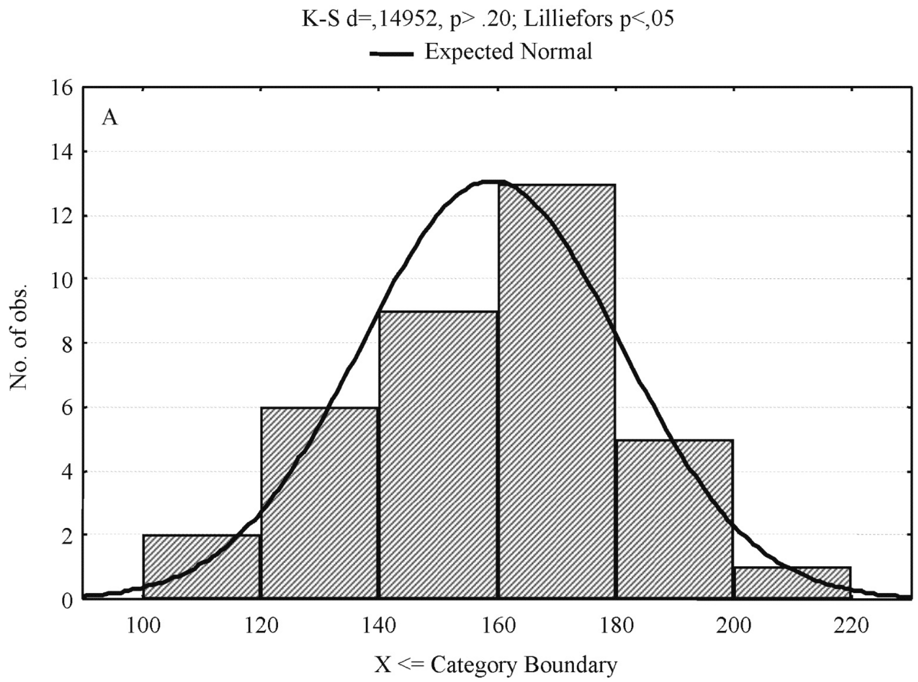
FIGURE 9 - VOLUMETRIC VARIATIONS IN PROFILE 5

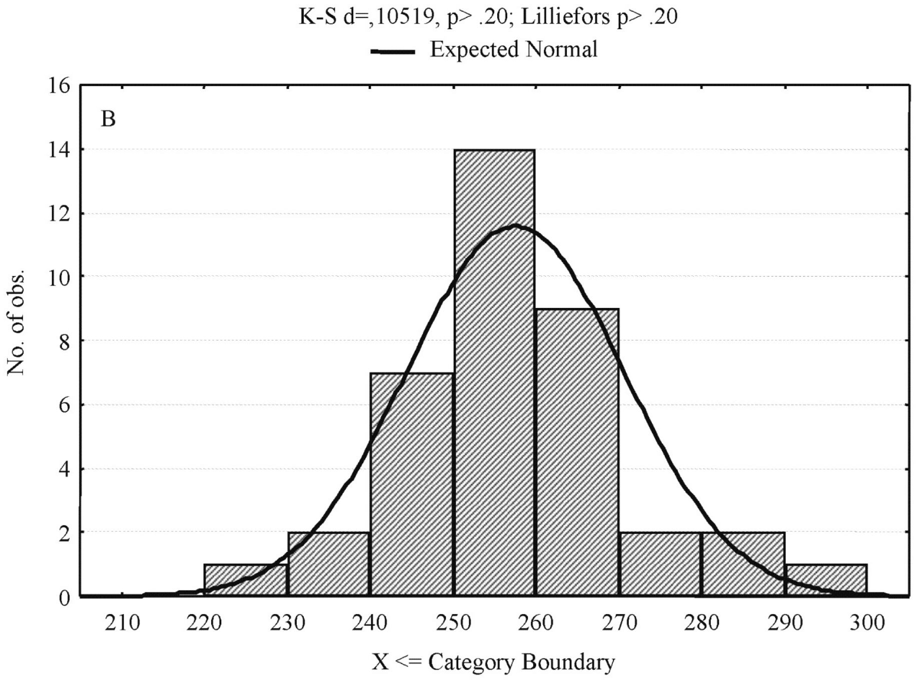
In order to make clear the volumetric variation observed through the time line, a statistical treatment was given to the data of sedimentary volume. The statistical results of the profiles are represented on Table 1 and in Figures 10 and 11.

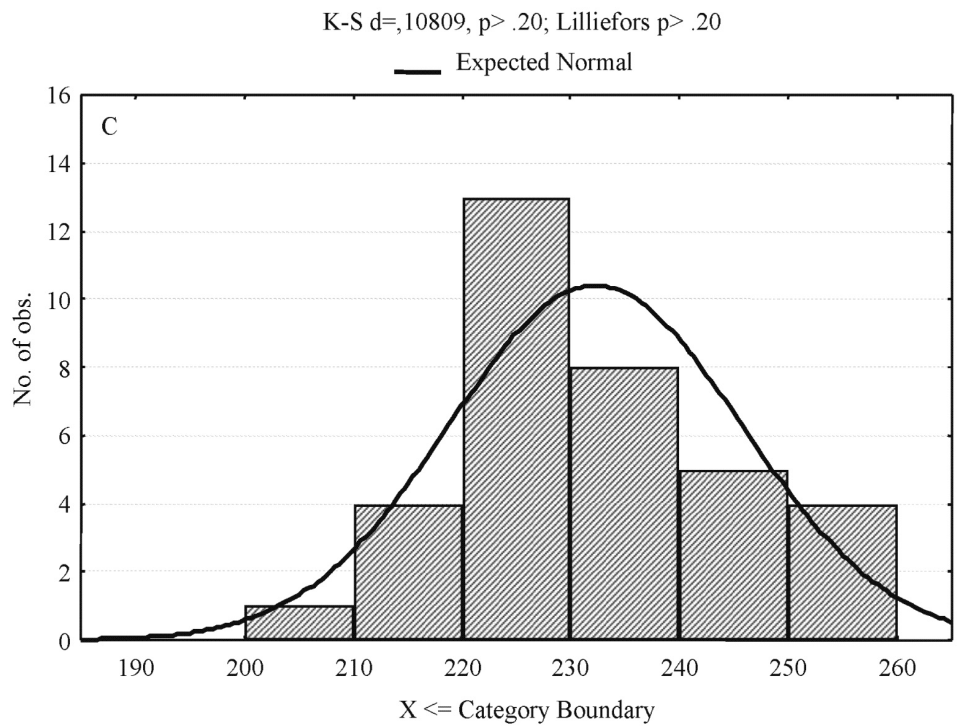
TABLE 1 - STATISTICAL RESULTS FOR THE VOLUMETRIC VARIATION OF PROFILES

	P 1	P 2	P 3	P 4A	P 4B	P 5
Mean	159.02	257.5	232.25	46.56	116.66	50.45
Median	161	257	230	49	115	50
Mode	161.00	Multiple	226	Multiple	Multiple	52
Maximum	217	293	259	65	148	68
Minimum	115	224	201	21	81	39
Variance	483	171.6	180.02	104.16	276.38	44.47
Std. Dev.	21.97	13.09	13.41	10.2	16.62	6.66
Coef. Var.	13.64	5.08	5.77	21.52	14.24	13.2

It was observed that the rates between the mean and medium sedimentary volume of the profiles are close to one another, presenting a symmetrical distribution (Table 1 and Figure 10). Except that in profile 4 A, this rates presents a bigger difference, as well as between the maximum (65) and minimum (21) rate. However, it is also observed that in relation to the degree of dispersion of the rates in relation to its average, just profile 5 presented (Table 1 and Figure 10) a lower rate of standard deviation (6.66) and a smaller rate of the variance (44). The smallest coefficients variation were only in profiles 2 (5.08) and 3 (6.4). The other profiles presented a high coefficient variation (Table 2), mainly profile 4A (21.52).



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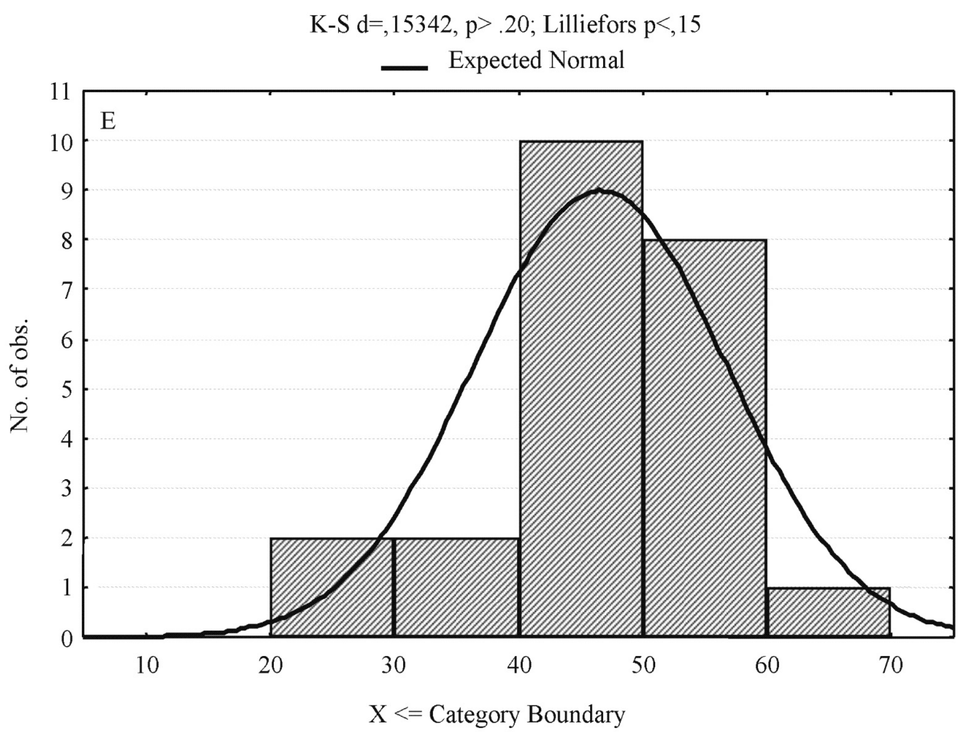
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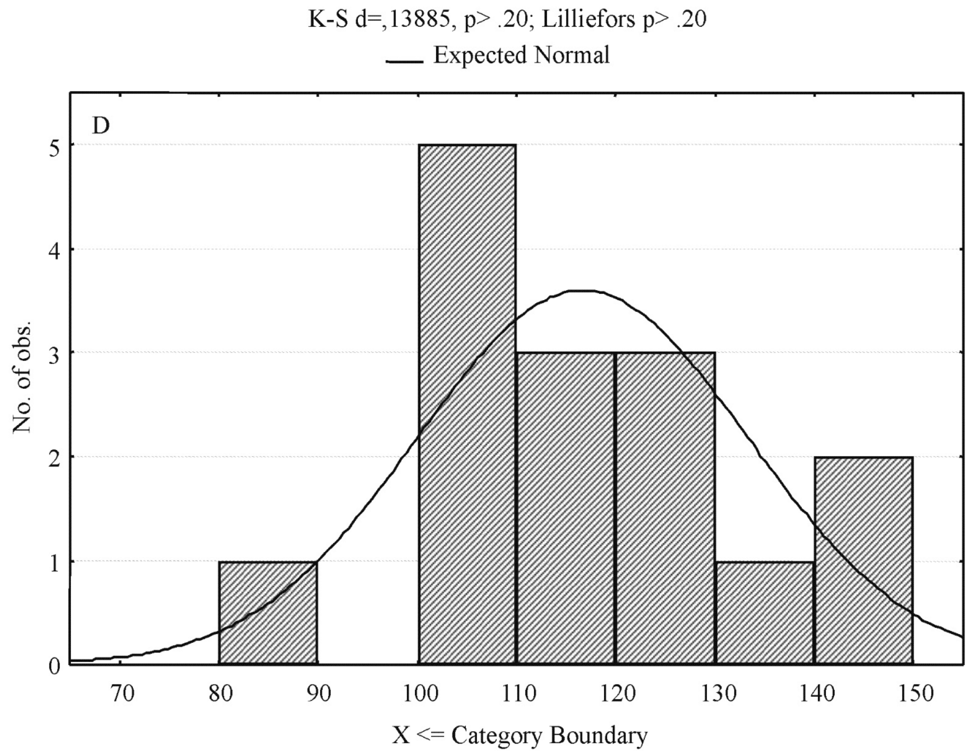
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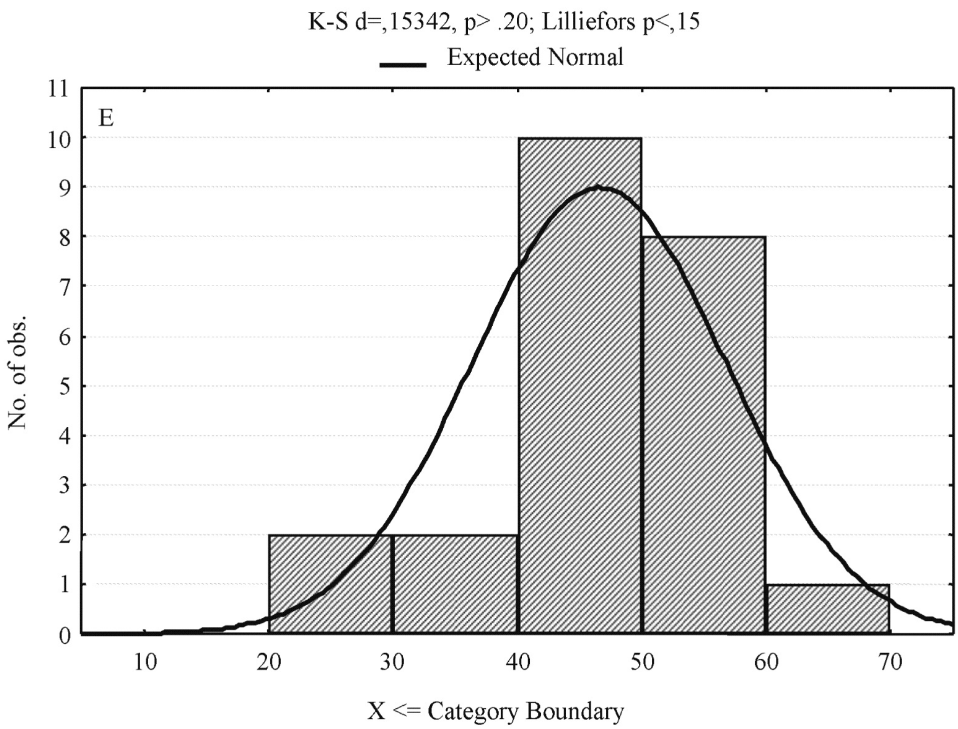
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70
X <= Category Boundary

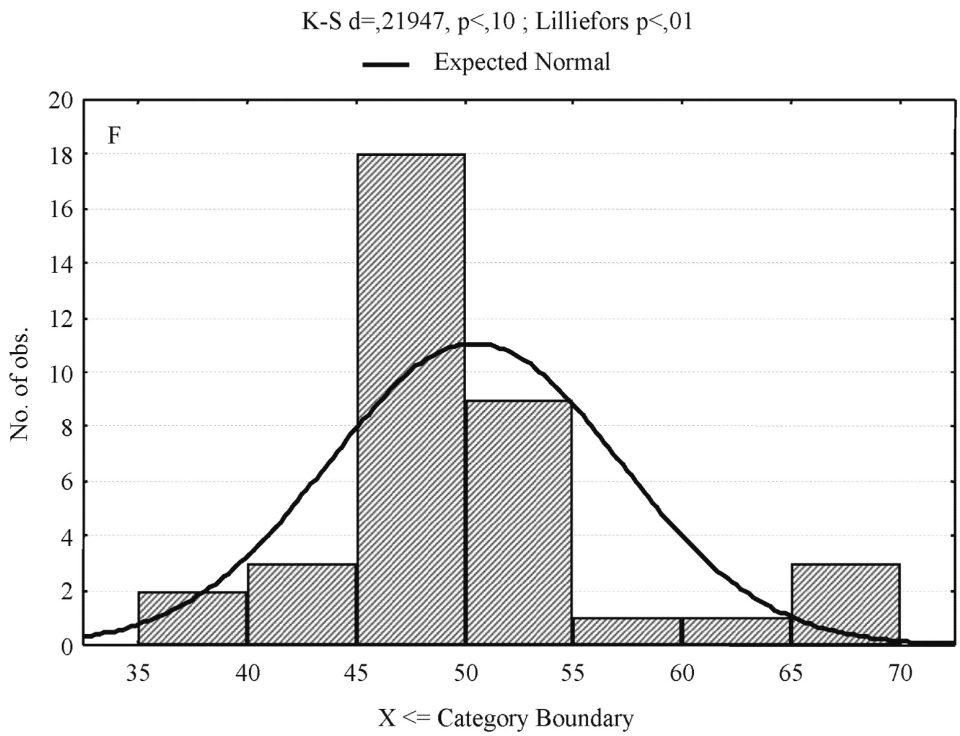


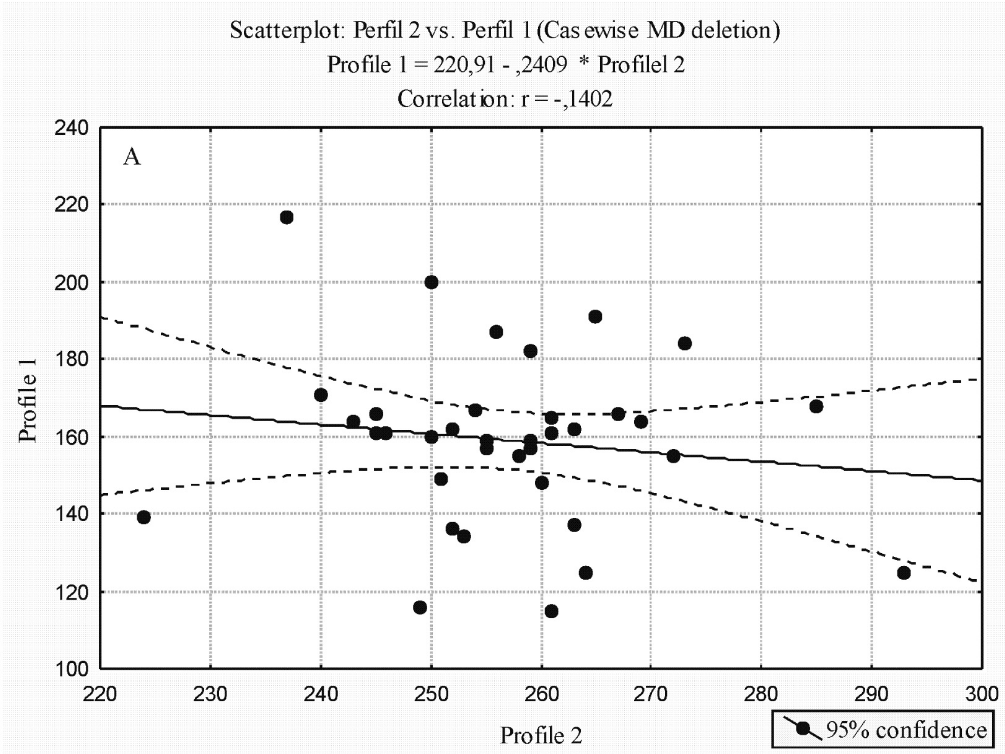
FIGURE 10 - HISTOGRAMS: A – PROFILE 1. B - PROFILE 2. C- PROFILE 3. D - PROFILE 4A. E - PROFILE 4B. F - PROFILE 5

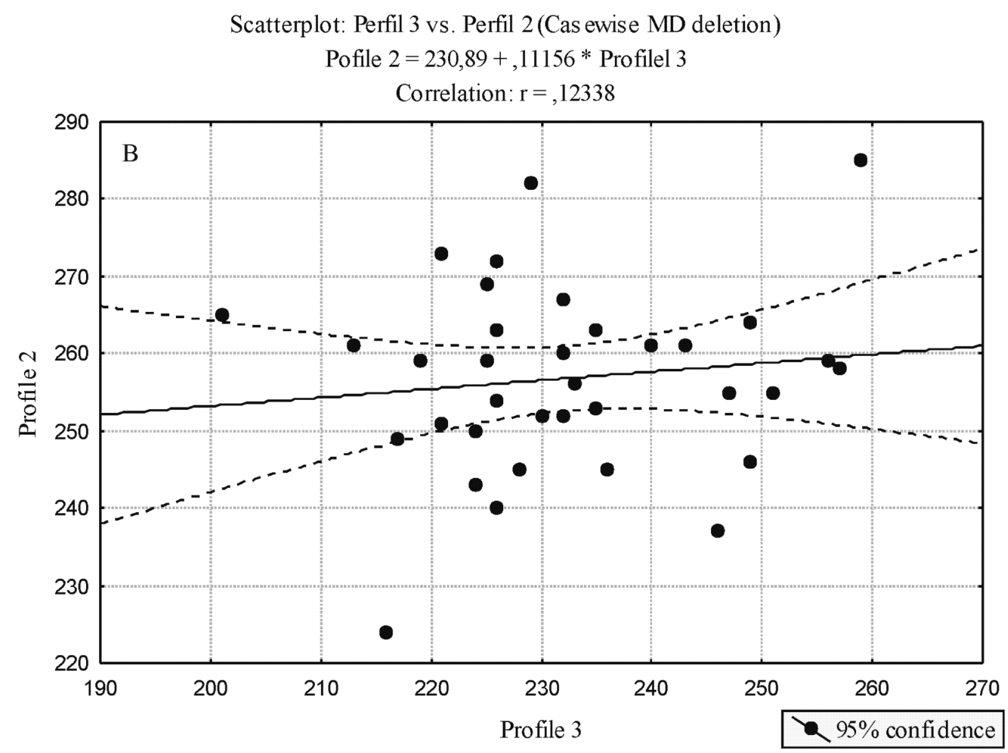
The results from Pearson's correlation (Table 2 and Figure 11) between the profiles from South to North, reveals that between profiles 2 and 1 there is an absence of linear relation (-0.14) in its sedimentary volume rates (Table 2 and Figure 11A). There is also an absence of relationship between profiles 3-2 and 4A-3, presenting rates of 0.06 (Table 3 and Figure 11B).

TABLE 2 - RESULTS OF PEARSON'S CORRELATION BETWEEN PROFILES

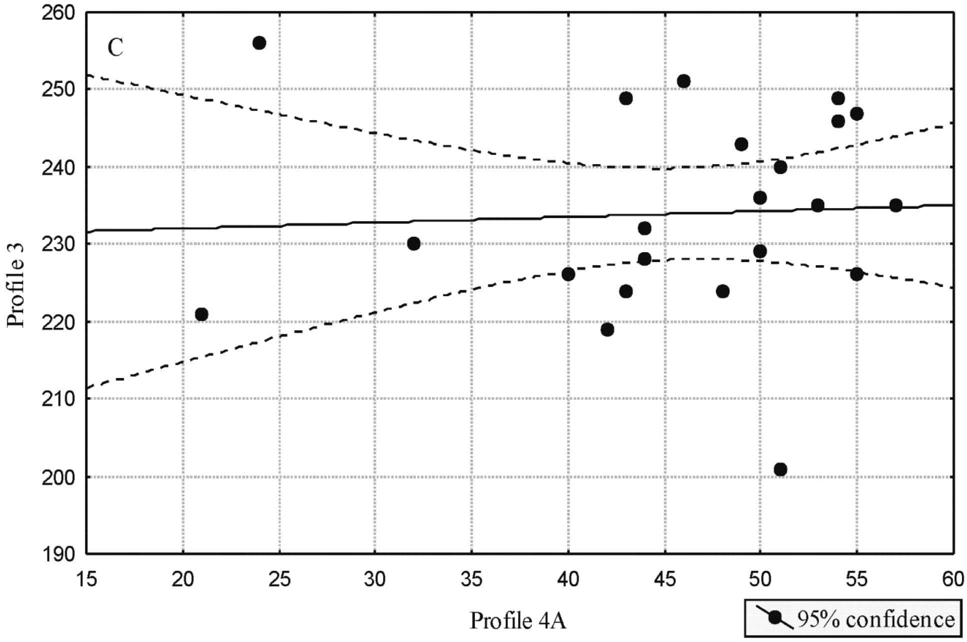
Profile	P 1	P 2	P 3	P 4A	P 4B
P 1					
P 2	-0.14				
P 3		0.06			
P 4			0.06		
P 4B			0.51		
P 5				0.09	0.61

A poor positive correlation was observed between profiles 4B and 3 (Table 2 and Figure 11D) with a rate of 0.51, that is, as the rate of the volume of the profile 4B increases or decreases, the rate in profile 3 also increases or decreases. This was observed in the year of 2005, for the months of January, March, June, November and December.

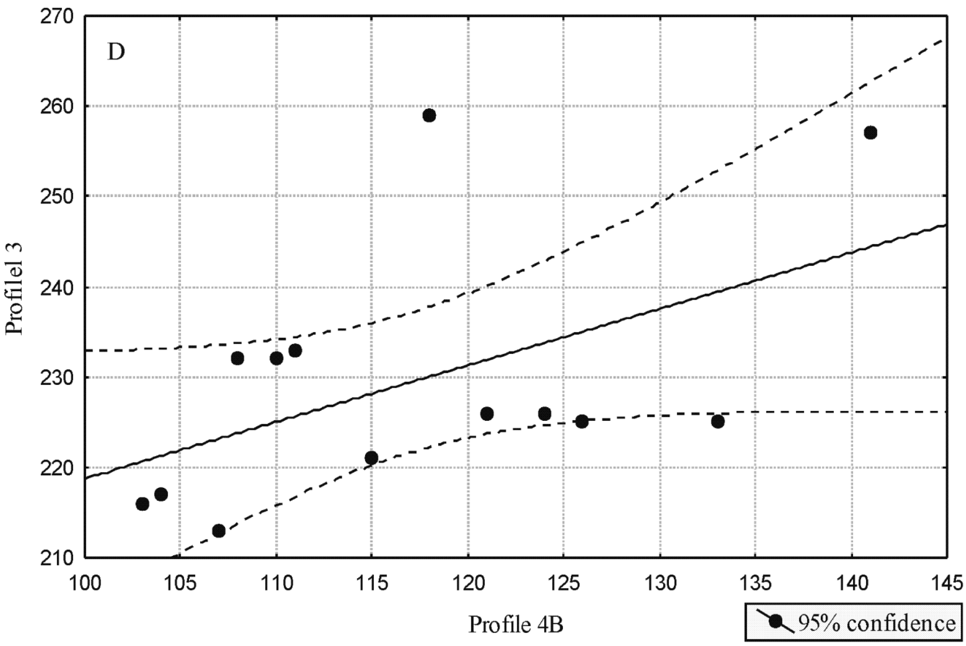

Scatterplot: Perfil 2 vs. Perfil 1 (Casewise MD deletion)
Profile 1 = 220,91 - ,2409 * Profilel 2
Correlation: r = -,1402
A
Profile 1
Profile 2
240
220
200
180
160
140
120
100
220
230
240
250
260
270
280
290
300
95% confidence

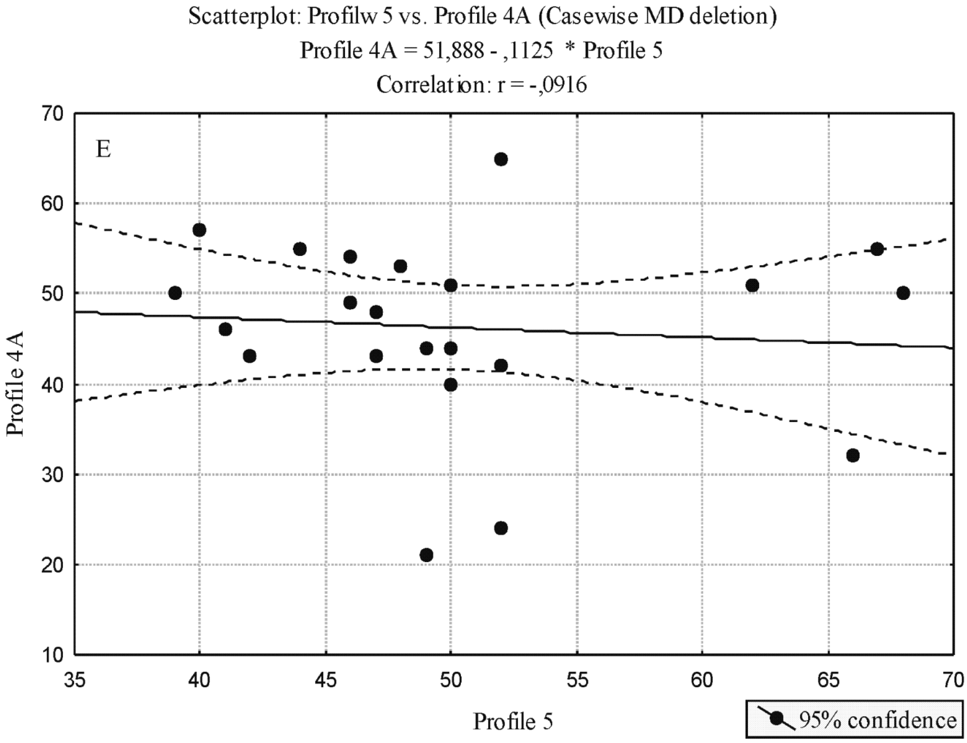

Scatterplot: Perfil 3 vs. Perfil 2 (Casewise MD deletion)
Pofile 2 = 230,89 + ,11156 * Profilel 3
Correlation: r = ,12338
B
Profile 2
Profile 3
290
280
270
260
250
240
230
220
190
200
210
220
230
240
250
260
270
95% confidence

Scatterplot: Profile 4A vs. Profilel 3 (Casewise MD deletion)
Profile 3 = 230,54 + ,07474 * Profilel 4A
Correlation: r = ,05519



Scatterplot: Profile 4B vs. Profile 3 (Casewise MD deletion)
Profilel3 = 156,10 + ,62639 * Profilel 4B
Correlation: r = ,51378





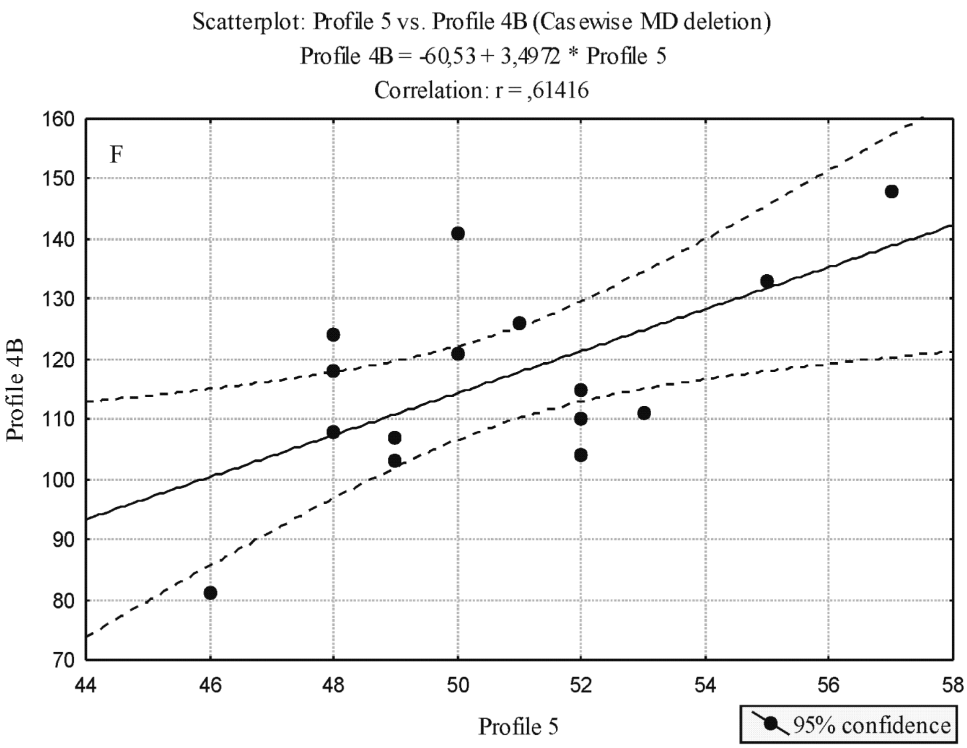


FIGURE 11 - A – CORRELATION BETWEEN PROFILES 2 AND 1. B – BETWEEN PROFILES 3 AND 2. C – BETWEEN PROFILES 4A AND 3. D – BETWEEN PROFILES 4B E 3. E – BETWEEN PROFILES 5 AND 4A. F – BETWEEN PROFILES 5 AND 4B

On profiles 5 and 4A linear relation between rates (-0.09) was not observed. However, there is a positive relation between profiles 5 and 4B with a rate of 0.61 (Table 2 and Figures 11E and 11F). As profile 5 increases or decreases its rate in the sedimentary volume, the same process occurs in the rates of profile 4B, for the month of December 2004; and in the year 2005 between the months of March, April, July, August, November and December. However only the months of March, November and December 2005 coincide with the months between profiles 4B-3 and 5-4B.

DISCUSSION

Studies by Wright e Short (1984), Aubrey e Ross (1985), Wright *et al*. (1985), Bird (1996), Masselink e Pattiaratchi (2001), among others, presented the profile of a beach result which corresponds to an adjustment to seasonal cycles, with erosion occurring in more energetic conditions during the winter, and accretion in conditions of a calmer sea during winter.

However, this adjustment seems not to occur in the studied area. For example, profile 1, located to the North of the studied area, presented great morphological variations in the entire beach environment. Yet the period in which these variations occur corresponds to different times of the year. On the other hand, a larger occurrence of sedimentary deficit was observed during the dry season, with only a low rate observed in the rainy season. For the months with greater deposition of sediment it was observed 50% for both periods, rainy and dry, respectively.

The biggest morphological variation of profile 2 occurred in the backshore and superior foreshore regions and between inferior foreshore and shoreface region. The occurrence of the smallest sedimentary deficit was observed in the rainy season as well as in the dry season, whereas sedimentary accretion occurred mainly during the rainy season. Profile 3 presented the biggest changes between the foreshore and the shoreface region and as in the previous profiles the accretion or sedimentary deficit also occurred in different periods. The rates with lowest volume are found during the dry season and the highest rates were mainly observed during the rainy season, contrary to what is found in current literature.

Profiles 4A and 4B present morphological variations in the entire beach environment and sedimentary deficit for the whole period. Also, like the other profiles, they present rates of highest and lowest sedimentary volumes in both periods, rainy and dry. Profile 5, located to the South of the coastal protection feature has its largest morphological changes throughout the entire beach environment and had the highest and lowest rates of sedimentary volume in the rainy and dry season, as it was already observed for profiles 1, 4A and 4B. However, the occurrence of a smaller rate was observed during the raining period.

In relation to the statistical parameters for analysis of the results on sediment balance it was observed that profiles 1, 3 and 4B presented a higher standard deviation in relation to its averages, and the lowest rate was observed in profile 5. However, the profiles that presented the lowest coefficient variation were profiles 2 and 3; the coefficient variation is a relative measurement that indicates the percentage relationship between the standard deviation and the mean data. Profiles 2, 4A and 4B had multiple modes, that is, presented more than one rate with similar results and profiles 1, 3 and 5 is unimodal. Pearson’s correlation was done between profiles from south to north for according to Coutinho *et al.* (1997) and Bittencourt *et al.* (2005), this is the direction of the coastal current, showing that profiles 2-1, 3-2, e 4A-3 do not have a linear relation. This means that when a profile increases or decreases its rate the same process occurs in the following profile. However this only coincides in the months of March, November and December 2005, between profiles 4B-3 and profiles 5-4B.

According to Rollnic @ Medeiros (2004), the liquid transport to the surface on the beaches of Boa Viagem and Piedade (located near the southern part of the area of study) is southbound. In the intermediary layer the transport is offshore (5.8 to 31.6 $cm.s^{-1}$); bed load transport is less intense, even with the increase in velocity, varying from 7.2 to 21.9 $cm.s^{-1}$ in the direction of the coast, except near the mouth of the Jaboatão River (to the South of the area of study), which is in the direction of the sea. The offshore transport of the intermediary layer could explain the absence of correlation between the profiles.

The direction of the transport along the coastline is related to the angle of incidence and wave heights has an important part in the sediment budget of the Brazilian coast, (Martin *et al.* 1998). According to the referred literature in the South Atlantic (Martin *et al.* 1987; Dominguez *et al.* 1992; Martin *et al.* 1998; Bittencourt *et al.* 2005; Tessler & Goya 2005), there are waves generated by winds in the E-SE direction. Between the boundaries of the states of Alagoas-Pernambuco and the city of Touros (in the state of Rio Grande do Norte) the coast has more or less a north-south direction, where the angle of incidence is small and as a result doesn’t have good sediment transport (Martin *et al.* 1998; Bittencourt *et al.* 2005). The waves approach the coastline in parallel and a small change in the angle of incidence of the waves produces a change in the direction of the currents. Where there is the convergence of cells the sedimentary budget is positive, in contrary directions the sedimentary balance is negative (Martin *et al.* 1998).

Between the states of Alagoas (Miai) and Rio Grande do Norte (Genipabu), the Holocene plains are poorly developed or absent, and the sedimentary deficit is perceived by the presence of exhumed beachrock (Bittencourt *et al.* 2005), being these exhumed under the face of the beach by retraction of the coastline (Semeniuk & Searle 1987; Bittencourt *et al.* 2005). According to Komar (1998), the coastal sedimentary supply is applied using the mass conservation principle, where the ratio is measured between the time and quantity of sand subtracted from the system.

In the studied area, throughout its 8 km of extension, there is the presence of beachrocks, which present the following situations: open beaches, sheltered beaches and/or sheltered by beachrocks. In the case of profile 1, where the existent beachrock line is not totally uncovered during low tide, also presents a line of beachrocks in the foreshore of the beach, which is exhumed during some months of the year, independent of the rainy or dry season. Profiles 2 and 3, located in the middle section of the study area are located is open areas and semi open areas respectively, and are the ones that present a larger balance and a positive sedimentary budget, this way not demonstrating a relation between accretion or erosive process with the presence of beachrocks for coast protection. As for profiles 4A and 4B, located in sheltered areas, they presented higher sediment loss, even with the beachrock protection.

During the survey period, the profiles did not present likeness to models and studies in morphological and volumetric changes in existing literature, for the cited beaches, as for example the studies of Larson e Kraus (1994), Morton *et al.*, (1995), Lee *et al.*, (1998), Gornitz *et al.*, (2002), Allan e Komar (2006), Short (2006), Wright e Short (1984), Wright *et al.*, (1985), Short (2003), Masselink e Pattiaratchi (2001), Eliot *et al.*, (2006), Short (2006). The seasonal cycles of the beaches are attributed to variations in the levels of wave energy (Komar 1998), but not all beaches are characterized by seasonal variations of incident waves, some beaches are narrower in the summer and wider in the winter (Masselink & Pattiaratchi 2001).

Alongside the coastline of Perth (Australia) the variations are not caused only by the level of wave energy, but reflect seasonal variations caused by changes in the direction of the current along the coast (Masselink & Pattiaratchi 2001). In the Brazilian coast this situation is also observed at the Armação Beach (in the region of the city of Salvador, Bahia) by Dominguez *et al.* (1992), Martin *et al.* (1998), Bittencourt *et al.* (2005); in the coast of the state of Rio Grande do Sul by Esteves *et al.* (2002); in the coast of the state of Rio Grande do Norte by Chaves (2006), where coastal erosion seems to be the consequence of the lack of sedimentary supply throughout the coastline, as well as the bed load morphology in the erosive and depositional process through the effects of wave refraction.

The variations of deposition or erosive processes found in this study could, probably, be related to seasonal variations of the currents throughout the coastline.

CONCLUSIONS

The biggest morphological variations were observed in the profiles located to the North and South of the studied area (profile 1 and 5), as well as to the north of the jetties (profiles 4A and 4B). These profiles present variations in the entire beach environment. Profiles 2 and 3, located in the center part of the area of study presented its biggest morphological variations between the foreshore and shoreface regions, and presented themselves more balanced than the profiles that were found in the extremes of the study area.

The profiles did not show a relation between deposition or erosive process with the presence of beachrock for coastal protection, since Profiles 4A and 4B are found in protected areas and profiles 2 and 3 are located in open areas and semi opened areas, respectively, are the ones that present greater balance and positive sedimentary budget.

Neither did the profiles present morphologic variations according to the variation in the beach environment mentioned in conventional literature. They presented variations in different seasonal periods, but according to studies in the coastal zone of Brazil, and in Australia, some beaches do not follow the seasonal rhythm, and that variations are not only caused by the level in wave energy, but reflect the seasonal changes caused by the change in the direction of the current along the coast. The study area is also located in a region where there is evidence of sedimentary deficit, manifested by the presence of exhumed beachrock.

Profile 4A presented a negative sedimentary balance for the entire survey, being extinct after the last tropical storm that occurred in the month of August 2004. Profile 4B also presented a negative sedimentary budget, with great variation in its morphology in the entire beach environment. Profiles 2-1, 3-2, 4A-3 didn't present a linear relation between its sedimentary volume rates. However a positive linear relation was observed between profiles 4B-3, 5-4B. This means that when a profile increases or decreases its rate, the same process occurs in the following profile.

Probably the erosion found in the study area is related to the same process that occurs in other areas of the Brazilian coast, like the one found in the beaches of Salvador, Rio Grande do Norte and in southern Brazil. However, for such an affirmative it is necessary a more profound study on the direction of currents and sub cellules of the environment.

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