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OSL-SAR DATING OF SEDIMENTS FROM BRAZILIAN AEOLIAN SYSTEM: DAMA BRANCA, RIO DE JANEIRO, MORPHODYNAMIC STUDY

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ABSTRACT

It has been reported that the formation and stabilization of coastal dune fields in Brazil have a dependence on the climate changes and Relative Sea Level (RSL) variations. A few topics regarding the morphodynamics of coastal aeolian systems in Brazil can be the RSL variations in the Holocene and weather conditions. In this work, a dune field known as "Dama Branca", located in the town of Cabo Frio, Rio de Janeiro, has been studied to understand its formation and stabilization. Dating by trapped charge dating techniques as Optically Stimulated Luminescence (OSL) using the Single Aliquot Regenerative protocol (SAR), help us to understand the formation and dynamics of aeolian systems in Brazil. Samples from a dune were collected from different heights and points for dating. The results obtained by OSL-SAR showed that ages decrease as the height from the dune base increase and older samples are found in deeper horizontal positions. The ages for the base of the studied dunes indicated that its stabilization occurred during the recess of the sea level.

1. INTRODUCTION

Aeolian systems have been extensively studied by many authors [1, 2, 3]. It has been reported that morphodynamics of those systems are influenced by geological factors as the Relative Sea Level (RSL) and the Relative Sedimentary Balance, *i.e.,* the ratio between absolute sediment balance (influx-efflux) and accumulation space [4]. Climatic factors as the rain, the wind strength and direction are mainly responsible for the sediment transport [5]. Mendes & Giannini [6] indicated the evolution of aeolian systems in Brazil as record of climatic changes, at least in places with no significant human interference.

Here, we are engaged in geochronological work of sediments collected from coastal plains in the state of Rio de Janeiro. More specifically, there are dune barrier formations along the coast near the town of Cabo Frio. We expect to find evidences of vertical and horizontal dynamic of the dune field, which is certainly influenced by the sea level fluctuations and climatic parameters. For this purpose, in this work, the dune field known as "Dama Branca" was studied. Samples from a dune were collected from different heights and points, for dating. OSL-SAR protocol, developed by Wintle & Murray [7], is summarized in Table 1 and it was used to estimate the accumulated dose, also known as Equivalent Dose (D_e), which is the total amount of natural radiation absorbed by the quartz grains.

Table 1 – OSL-SAR sequence used in this work (Protocol summary)

Step	Treatment	Observed
1	Dose D_i	--
2	Preheat (220 °C – 200 °C for 10 s)[(a)]	--
3	Stimulation for 100 s at 125 °C	L_i
4	Dose test D_t	--
5	Cut heat at 160 °C	--
6	Stimulation for 100 s at 125 °C	T_i
7	Return to 1	--

(a) 220 °C and 200 °C was used as preheat temperature in this work, more information is found on section 3

1.2. Dune Field Dynamics.

1.2.1. Relative Sea Level (RSL)

Termed as the most polemic factors controlling the Aeolic sedimentation, the RSL basically controls the amount of sediment that can be worked out by the wind, for example, to create a dune field [5]. Castro et. al. [8] constructed a RSL curve during the Holocene in the Rio de Janeiro coastline based on ^{14}C dating of mollusk shells, vermitides and other biological and geological evidences (Figure 1)

As we can infer, almost 5000 years back, the Relative Sea Level reached its maximum during Holocene (+2.5 m above the current level), since then, it is observed a trend towards to recess of the sea level. [9].

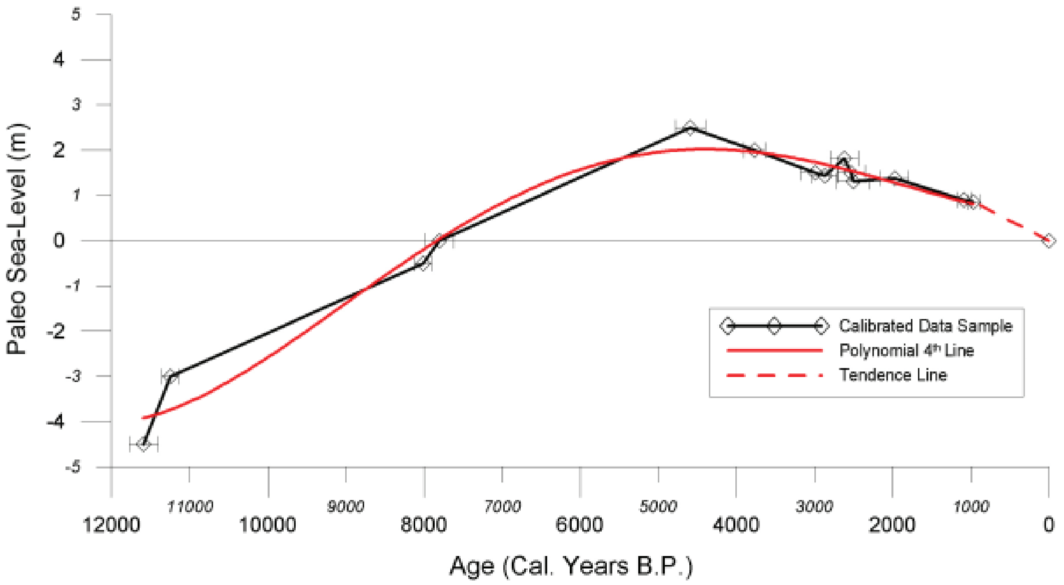

Figure 1. Relative sea-level variation curve for the coast of the state of Rio de Janeiro, southeastern Brazil. Black Color: Curve constructed from a linear trend line defned by averaging the calibrated ages at 2 σ. Red Color: Curve constructed by a fourthdegree polynomial [8].

1.2.2. Climatic Factors.

The wind action and amount of precipitation can be decisive to the formation and stabilization of a dune field. Cabo Frio region weather is considered semi-arid, with negative balance of precipitation/evaporation [6]. The rainfall at Arraial do Cabo (a few km far from Cabo Frio) is about 800 mm/year, rather low value.

2. MATERIALS AND EXPERIMENT

Sediments age measurements using OSL-SAR protocol iare based on the radiation energy deposition during the burial time of quartz grains. In this method, the grains are considered radiation dosimeters, the dose accumulated during the years is measured using OSL-SAR. Knowing the dose rate of natural radiation delivered to the sample we can infer how long the sediments have been buried using (equation 1). The sunlight is responsible for "bleaching" the OSL, TL (Thermoluminescence) and ESR (Electron Spin Resonance) signal [10], so that the age of a grain is counted since its last exposition to the sunlight up to the date when it was collected [10].

$$\mathbf{Age} = \frac{\mathbf{Equivalent\ Dose\ (mGy)}}{\mathbf{Annual\ Dose\ Rate\ (mGy/year)}}$$

(equation 1)

Figure 2 (a) and (b) show the points of sample collection used in this work. Samples were collected using PVC tubes of 3 m long and 3 cm in diameter to take sediments from the dune base. Samples were also taken from 2 m (2DB20 and DB 20) 3 m (DB 30) and 4 m (DB 40) above the base using a 1 m long and 3 cm diameter PVC tube (Table 2). Tubes containing samples were emptied in red light environment. The sand amount within ten centimeters of each tube edge was discarded to prevent contamination by bleached grains. Only the sediments in the last 30 cm of each tube were taken for measurement.

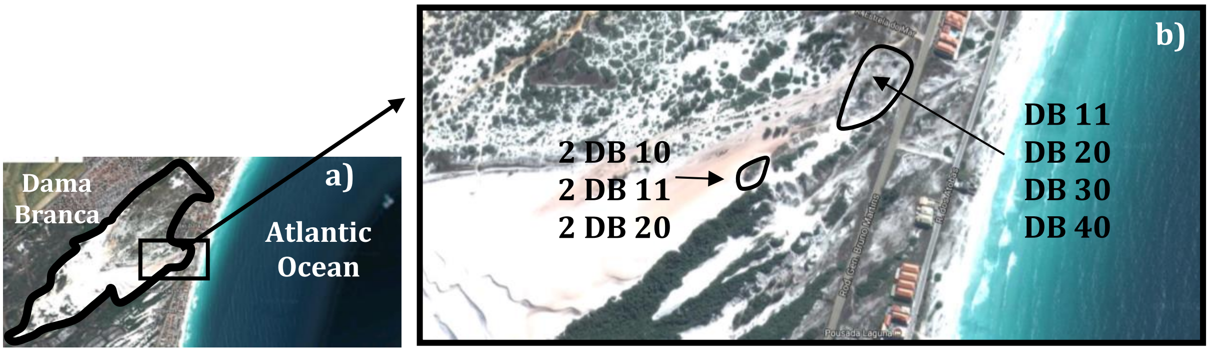

Figure 2: (a) Dama Branca formation and (b) the dunes where samples have been collected for OSL dating at ECU (picture from Google Maps)

Table 2: Depth and Height of sampling

Sample name	Horizontal depth (m)	Height
2DB10	2	Dune's base (0m)
2DB11	1	Dune's base (0m)
DB11	1	Dune's base (0m)
2DB20	1	1 m (from dune's base)
DB20	1	2 m (from dune's base)
DB30	1	3 m (from dune's base)
DB40	1	4 m (from dune's base)

Samples have been wet sieved to retain grains from 212 to 150 μm (2DB20 and DB20) and from 150 to 90 μm (DB11, DB30, DB40, 2DB10 and 2DB11). Then, samples were chemically washed in the following sequence:

- HCl 10% followed by H_2O_2 27% and HF 48% for 40 min and HCl 10%: To remove carbonates, organic material, feldspars as well as the outer layer of the quartz grains to exclude the α-radiation contribution. A repeated treatment with HCl was done at the end to wash off residual compounds created by HF attack.

- Density separation using sodium polytungstate solutions at densities of 2.75 g/cm³ and 2.65 g/cm³: To remove heavy minerals and remaining feldspars, respectively.

The OSL measurements were carried out using a Risø TL/OSL DA-20 at the ECU Luminescence Laboratory. The reader is equipped with a $^{90}Sr/^{90}Y$ beta radiation source and blue LEDs (470 nm) and IR LEDs (870 nm) for stimulation. A Hoya U-340 filter (290-370 nm) was used to separate the OSL signal from the stimulation blue light. Equivalent Dose (D_e) estimation of each sample was determined by the Common Age Model and Central Age Model developed by Galbraith, et. al. [11] using at least 16 aliquots. A Canberra Ge-Li gamma ray spectrometer at LACIFID, Physics Institute of the University of São Paulo was used to determine the ^{40}K, thorium and uranium concentrations to estimate the Annual Dose Rate using the calculations proposed by Ikeya [10]. Cosmic ray contribution was calculated using the Prescott & Stephan [12] considerations regarding latitude, longitude, height and depth of sampling.

3. RESULTS AND DISCUSSIONS

The Equivalent Dose was determined by constructing a linear dose-response curve for at least 24 aliquots of each sample using the SAR protocol. Figures 3 and 4 show the histograms of the calculated D_e, which bin sizes have been calculated using the Freedman-Diaconi's formula. The temperature of 220 °C has been determined as the preheat temperature using the plateau test. For DB20, DB30 and 2DB20 a high recuperated signal was obtained using 220 °C preheat temperature, changing it to 200 °C led to a reduction of this unwanted effect.

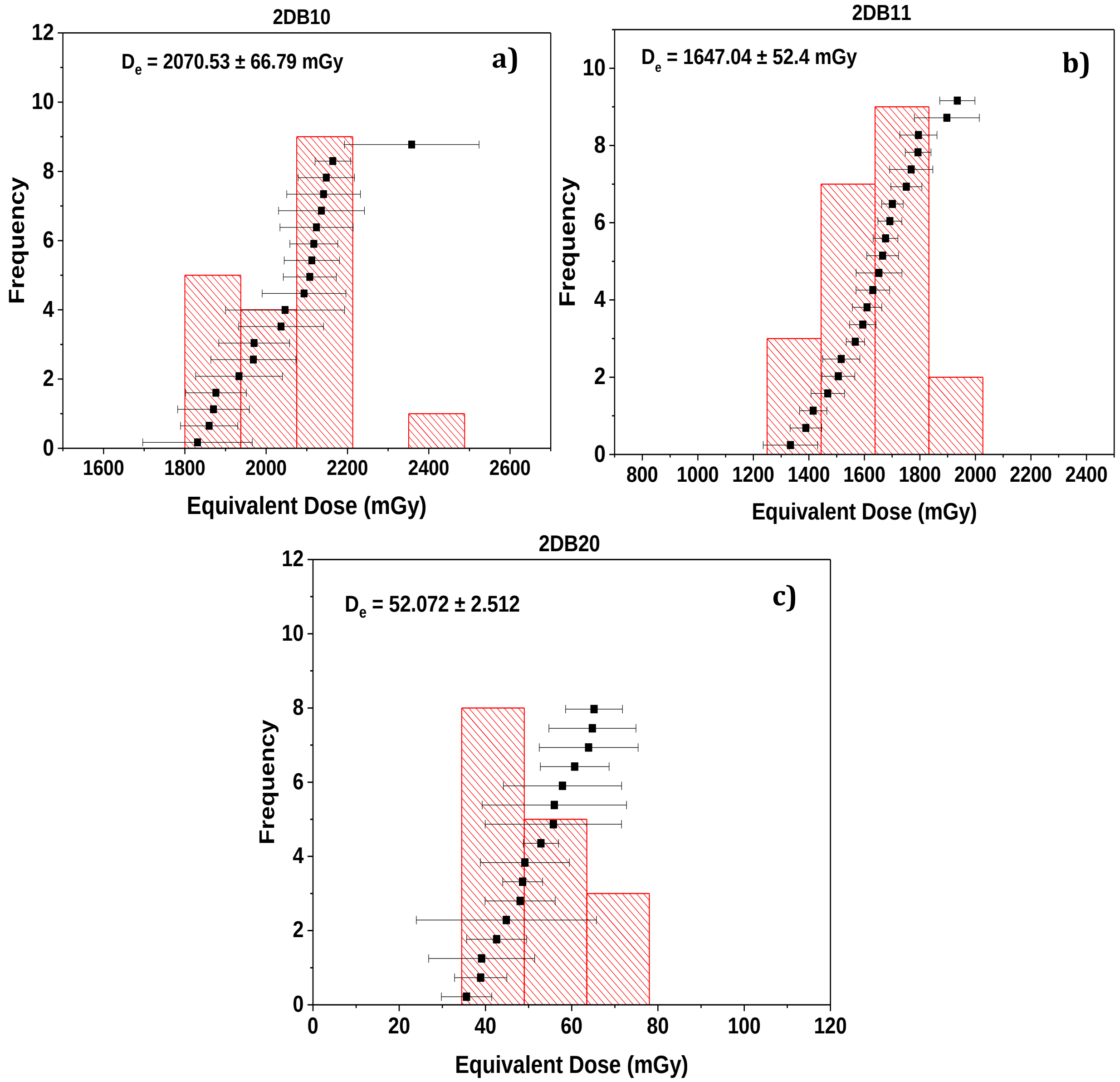

Figure 3: Histograms of Equivalent Dose for a) 2DB10, b) 2DB11 and c) 2DB20

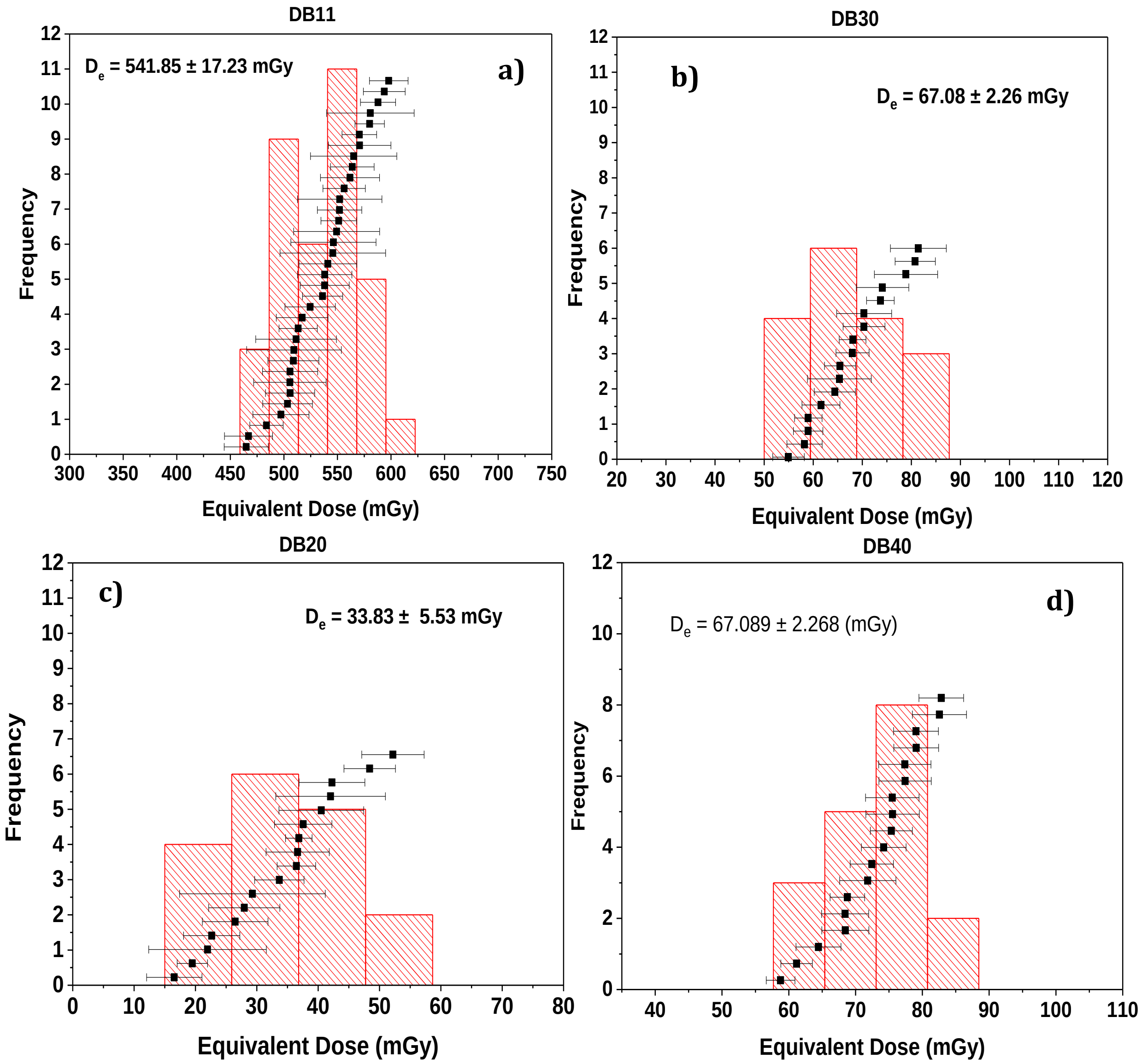

Figure 4: Histograms of Equivalent Dose for a) DB11, b) DB30, c) DB20 and d)DB40

The ages were obtained using the equation 1. Table 3 shows the Equivalent Dose, Annual Dose Rate from uranium and thorium decay series and ^{40}K including the cosmic ray contribution and the age.

Table 3 – Ages obtained using OSL-SAR protocol.

Equivalent Dose (mGy)	**Sample**	**Annual Dose Rate (mGy/year)**	**Age (k years)**
2,071 ± 67	**2DB10**	0.5762 ± 0.219	3.59 ± 0,25
1,647 ± 52	**2DB11**	0.5362 ± 0.0222	2.91± 0.21
542 ± 17	**DB11**	0.5578 ± 0.0201	0.97 ± 0.04
52.1 ± 2.5	**2DB20**	0.5565 ± 0.0219	0.09 ± 0.08
34.8 ± 5.5	**DB20**	0.5599 ± 0.1711	0.06 ± 0.01
67.8 ± 2.3	**DB30**	1.378 ± 0.058	0.049 ± 0.004
67.1 ± 2.1	**DB40**	1.374 ± 0.052	0.049 ± 0.004

The ages shown on table 3 indicate that samples from the dune's base (2DB10, 2DB11 and DB11) were always older due to the better stabilization. In the case of 2DB10 and 2DB11, both samples belong to the same mound, but 2DB10 is deeper. The age difference between them is 0.69 ± 0.04 kyears, showing that for the horizontal stabilization was required a great period, which can infer a great activity of geological in rebuilding the sediment until its final establishment.

As the height increases, the younger is the sediment. In the case of DB20, DB30 and DB40 (2 m, 3 m and 4 m higher from DB11 position, respectively), the ages indicate a difference of 0.91 ± 0.03 kyears between DB11 and DB20 and 0.921 ± 0.036 kyears between DB11 and DB30 and DB40. In the case of 2DB20 (1 m higher from 2DB11 position) the age difference is 2.82 ± 0.17 compared to 2DB11. The studied dunes, accordingly to the presented results, were formed by a well-established sediment at the base with a recent established sediment mounted above.

The RSL is responsible for sediment supply which will be worked by wind action, thus forming a dune field. The ages found for the sediments at the base (2DB10, 2DB11 and DB11) indicate that the sea level was descending. Accordingly to Giannini [5] the lowering in the RSL increase the availability of sand as the sediment once submerged is now exposed. These ages are in agree with results presented by Angulo [9].

3. CONCLUSIONS

OSL-SAR protocol is a suitable technique for measuring the equivalent dose of sedimentary quartz grains. Seven samples were measured and ages determined. Comparing the ages was clear that the studied dunes from "Dama Branca" dune field are formed by well-established sediments at the base and young sediments mounted above, showing the importance of sediments dating to understand the morphodynamic of dune fields. The NRTL (Natural Residual Thermoluminescence) is also employed to study the sediment transport by wind and sea action [13]

Comparing the ages determined for the sediments at the base with the RSL it be can concluded that the formation of Dama Branca was influenced by the recess of the sea level, which is coherent with result presented by Angulo [9]

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