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Geochronology of recent sediments from the Cariaco Trench (Venezuela) by Alpha Spectrometry of ^{210}Pb (^{210}Po).

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Abstract. ^{210}Pb concentration in marine sediments of the Cariaco Trench (North-East of Venezuela) was measured through the analysis of ^{210}Po alpha emissions, which can be assumed to be in secular equilibrium with ^{210}Pb. The analysed sediment core has a length of 1.9 m. The results allowed to apply the CF:CS dating model (Constant Flux and Constant Supply). The sedimentation rate was estimated to be 0.25 cm/y. As far as we know this is the first α- dating carried out in the country, performed with an alpha spectrometer recently funded by the IAEA.

Keywords: Geochronology, ^{210}Pb, ^{210}Po, sediment dating, alpha spectrometry
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INTRODUCTION

In the last 200 years the impact on the natural environment has been increasing considerably due to the development of industrial activities. Their wastes reach the rivers and then the food chain. These waste also is deposited on the sea and lake beds. In 1963, Goldberg observed that sediment dating could be done through the analysis of ^{210}Pb concentrations. The principles of the method relies on the environmental dynamic of ^{222}Rn daughters, in particular the ^{210}Pb which can be used as a time marker. Due to its half-life (22.3 y), the method allows sediment dating of about 150 years. In the present work α Spectrometry was used to quantify ^{210}Po (in equilibrium with ^{210}Pb) in the sediment samples of Cariaco Trench, and a geochronological model was applied.

THEORY

The ^{210}Pb present in sediments has two possible sources. A fraction in secular equilibrium with the ^{226}Ra in the sediment ($^{210}Pb_{eq}$) and a fraction deposited from the atmosphere ($^{210}Pb_{ex}$)[1, 2, 3]. The determination of $^{210}Pb_{ex}$ in a given layer, is made by subtracting the concentration of total ^{210}Pb and $^{210}Pb_{eq}$. The ^{210}Pb can be measured indirectly through ^{210}Po which is its decay product and is an α emitter [E_α = 5,305 MeV]. The $^{210}Pb_{eq}$ can be estimated assuming that the concentration of ^{226}Ra in the sediment is constant along the core, and that there is no migration of the isotopes between the

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layers. Thus, we can measure the ^{210}Pb in sufficiently deep layers, in which the $^{210}Pb_{ex}$ has decayed, which corresponds to the $^{210}Pb_{eq}$ that remains constant throughout the profile.

The ^{210}Pb precipitates from the atmosphere and accumulates in the surface of soils and sediments. In the case of marine and lake sediments, where each layer is buried by new layers, the amount of ^{210}Pb from the atmosphere that incorporates into each layer ($^{210}Pb_{ex}$) decreases exponentially with time. If we know the $^{210}Pb_{ex}$ initial activity A_0 in any layer and measure current activity A, it can be calculated the time t since it was deposited on the surface [1]

$$t = -\frac{1}{\lambda_{210}} ln\left(\frac{A}{A_0}\right) \tag{1}$$

where λ_{210} is the decay constant of ^{210}Pb and t is the age of the corresponding layer.

Each study site has its own peculiarities that must be taken into account for the dating of sediments. There may be variations in the sedimentation rate, which is reflected in the ^{210}Pb profile. Another variable to be considered is the atmospheric $^{210}Pb_{ex}$ rate of supply, which depending on the transfer function, could change over time. The transfer function (dimensionless) reflects the geochemical processes involved in the $^{210}Pb_{ex}$ ions association with sedimentary particles [1]. A critical parameter is the $^{210}Pb_{ex}$ rate of supply P to successive layers

$$P\left[\frac{\text{Bq}}{\text{cm}^2\text{s}}\right] = \phi F \tag{2}$$

where ϕ is the transfer function and F is the atmospheric flux of ^{210}Pb. If r is the sediment mass flux [kg/cm^{2}s] that is deposited to form a layer, then the initial activity concentration of $^{210}Pb_{ex}$ is

$$C_0\left[\frac{\text{Bq}}{\text{kg}}\right] = \frac{P\left[\frac{\text{Bq}}{\text{cm}^2\text{s}}\right]}{r\left[\frac{\text{kg}}{\text{cm}^2\text{s}}\right]} = \frac{\phi F}{r} \tag{3}$$

and the $^{210}Pb_{ex}$ concentration in a layer of age t is $C = C_0 e^{-\lambda_{210} t}$ By measuring C, t can be calculated if we can estimate C_0 of some appropriate model to suit local conditions (average weather conditions and stability of environmental conditions).

STUDY SITE AND METHODOLOGY

The Cariaco Trench is a depression of the earth crust. It stretches from west to east and consists of two major depressions: The western is the largest and has a depth of over 1400 m, while the eastern reaches over 1300 m deep [2]. The sediment core used (thanks to the Department of Oceanology and Coastal Sciences at IVIC), was extracted from the eastern depression of the trench (10 30 N 64 40 W). The core extraction was performed using a piston corer on January 2004 during an expedition to the area aboard the Oceanographic Ship Hermanos Ginés of La Salle Foundation of Natural Sciences (FLASA-Marina) under the Project CARIACO [4]. Due to its depth the hydrodynamic regime is characterized by low currents, the environment is anoxic, so there is no sediment bioturbation. Therefore, this natural depression provides a unique opportunity for a dating study by ^{210}Pb in sea sediments.

The Cariaco Trench is a basin that receives sediment inputs from rivers Unare, Neverí (the major contributors to eastern depression), Manzanares and Tuy (major contributors to western depression). The grain size of suspended matter in the Cariaco Trench varies from 2 to 80 μm [5]. The clay fractions can hold different contaminants (i.e. heavy metals), so the study of their contents in the sediment and the geochronology will redound in significant information on the recent environmental impact in the area.

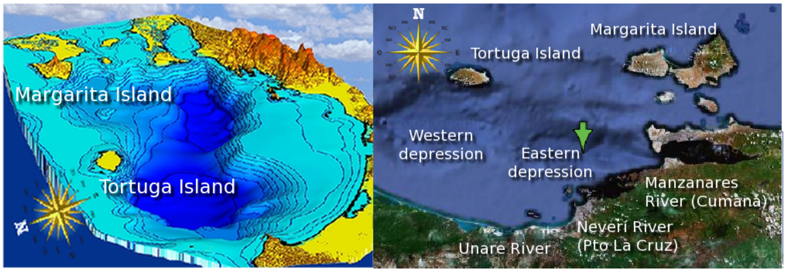

FIGURE 1. Location and bathymetry of the Cariaco Trench (Venezuela)[4, 6]

For processing the samples the tracer used was ^{209}Po ($t_{1/2}$ = 102 y, Eα = 4883 keV (80%) and 4885 keV (20%)) (Eckert & Ziegler), to each 300mg of sample was added an aliquot with 115 Bq. A microwave digestion was performed, then the Po was selfdeposited on Cu planchets [7] using a variation of methods previously reported [8, 9]. The spectrometer used, model OCTET PLUS, has 8 cameras with detectors Ultra-As 450 mm^2, with their respective electronics and multi-channel system. Typical counting times were 3 to 4 days per sample.

RESULTS AND DISCUSSION

The geometrical detection efficiency was 14.3(2) %. The radiochemical recovery was 69(1) %. ^{210}Pb (^{210}Po) concentrations profile is shown in the figure 2.

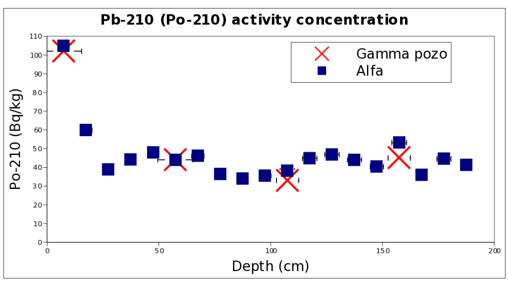

FIGURE 2. ^{210}Po activity concentration along the core of sediments from the Cariaco Trench.

All values were decay corrected (of the corresponding fraction of $^{210}Pb_{ex}$) until the date of the sediment extraction. Below 25 cm the ^{210}Pb (^{210}Po) remains almost constant, with an average of $^{210}Pb_{eq}$ = 42(1) Bq/kg. The four measurements with a Gamma Spectrometer (well detector) are quality controls.

In the first two layers the ^{210}Pb concentrations are significantly higher than the average for lower layers. The sediment layer from 5 to 10 cm has a ^{210}Pb concentration of 105(5) Bq/kg and that from 15 to 20 cm of 60(4) Bq/kg. Due to the low number of usable points, we used the CF:CS model as it allows a reasonable approximation of the sedimentation rate and age of sediment layers with ^{210}Pb concentrations above average for deep layers[7]. The age difference Δt between the two top layers of sediment can be calculated using equation 1, thus Δt = 39(7) y. Since these two layers are separated by 10 cm, the calculated sedimentation rate is $\frac{\Delta Z}{\Delta t} = 0.25(4)\frac{cm}{year}$. Assuming this accumulation rate has been constant over the studied time interval, and extrapolating this age difference to the initial layer (depth 0 cm), the age of section 1 (5 to 10 cm) is 30(5) y, and that of section 2 (15 to 20 cm) is 71(12) y.

CONCLUSIONS AND RECOMMENDATIONS

Total ^{210}Pb was determined by Alpha spectrometry, via ^{210}Po, in 19 samples of a Cariaco's Trench core. The trend is consistent with a previous work done by Gamma Spectrometry (LEGe)[2]. Some founded systematic differences are because in this work intercomparison samples were used instead of certified standards for calibration. After the second layer (20 cm) the values of $^{210}Pb_{ex}$ are too small to be discriminated from $^{210}Pb_{eq}$ fluctuations (42(1) Bq/kg). The ^{210}Pb for the first two layers are significantly above the equilibrium value. This allows the application of CF:CS model. The obtained sedimentation rate is low, 0.25(4) cm/y. We are currently conducting analysis by TXRF to the samples to measure heavy metals in the sediments of the Cariaco Trench, so we will study the industrial activity impact in this area of eastern Venezuela.

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