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Applications of AMS ^{14}C Measurements in Environmental and Economical Problems

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1 Introduction

Radiocarbon dating is based on the known decay rate of the radioisotope ^{14}C in organisms after their death. Under normal conditions the worldwide carbon cycle is constant in nature. The amount of ^{14}C that decays in a period of time is balanced by the amount that is produced in the upper atmosphere, by nuclear reactions involving fast particles from the cosmic rays mainly originating from the Sun. A radioactive CO_2 is then formed and enters in the food chain when it is absorbed by plants during the photosynthesis process. The result is that all living organisms have roughly the same ratio $^{14}C/^{12}C$ as the atmosphere. After death the replacement of ^{14}C ceases. Hence, by measuring the residual ^{14}C concentration in organic samples it is possible to calculate the time elapsed since the material was originally formed. The net result is that the ^{14}C content lags the atmosphere and the amount depleted can be directly related to a radiocarbon age. The situation is different when the life form exists in the ocean due to the slow exchange of CO_2 from the atmosphere to the ocean. In this case, ocean reservoir correction to the radiocarbon dating results has to be applied.

The use of ^{14}C for dating began some 50 years ago and was based on the detection of the decay of this radioisotope, by conventional decay counting methods. In the last 25 years radiocarbon dating by accelerator mass spectrometry (AMS) has become a powerful and preferred method to dating. AMS is an analytical technique for measuring the concentrations of rare isotopes on samples

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chemically separated from the original sample to be studied. The technique uses a tandem accelerator and its beam transport system as an ultra-sensitive mass spectrometer to provide several steps of mass and charge analysis and to ultimately identify individual atoms directly. The most common application of AMS is radiocarbon dating. Comparing to decay counting method ,AMS is far more sensitive and it can also be applied on samples as small as 50μg. The accurate measurement of small variations of the $^{14}C/^{12}C$ ratios by AMS allows the study of geomagnetic effects, environmental problems, climatology, oceanography, hydrology, geology, archaeology, anthropology, bio-medicine and material sciences, among other research fields [1, 2].

In this paper we describe, as example of the AMS ^{14}C wide applications, two experiments related to relevant economical and environmental questions. The AMS measurements were performed at the 14 UD Tandem accelerator of the Australian National University.

2 The influence of upwelling waters to the local biological production at Arraial do Cabo

We performed an experiment concerning the isotopic signature of the waters that form the upwelling system of Arraial do Cabo, located in the Brazilian South East coast, with applications in the fields of Oceanography and Marine Ecology. We assess the contribution of the wind-driven coastal upwelling of Arraial do Cabo to the local biological production, within a more general study dealing with relevant economical and ecological questions such as the dependence of commercial fish species on this source of allochtonous nutrients. The ^{14}C concentrations of three different types of water were measured in seaweed tissues. Some of the results have already been reported[3]. The Brazilian surface waters are called Tropical Water (TW) and are usually warm and poor in nutrient concentrations and productivity. This oligotrophic water originates from the South Equatorial Current and it is transported by the Brazil Current (BC) along the continental shelf, reaching depths down to 200m. Below the TW, a high nutrient and cold water circulates in an opposite direction, compared with the TW. This water is known as the South Atlantic Central Water (SACW), and it originates at the Sub-Tropical Convergence. In the Arraial do Cabo region, due to climatic and topographic aspects of the local coast, there is the upwelling of the SACW to the surface. This upwelling is responsible for a high biological productivity in this region, with important direct regional economical consequences, since this coastal region is one of the main sardine production centers in Brazil.

The variation of the carbon isotopic compositions was investigated in a population of seaweed called *Ulva sp.* Upwelling events were simulated in the laboratory, in order to study three regimes: total upwelling (SACW), partial upwelling (mixed water) and no-upwelling (TW). Water samples were collected at 70 m depth (SACW) and at 10 m (TW). The seaweed *Ulva sp.* samples were collected

in the intertidal region of an adjacent coastal area, and were submitted to acclimation during 48 hours. The seaweed was cultivated during seven days, in controlled conditions, into the two mentioned types of water and also a mixture of them. The net primary production (NPP) in the seaweed tissues and the dissolved inorganic nutrients (DIN) in the waters were determined. The total production during the whole experiment was highest for the SACW and lowest for the TW, indicating the importance of the upwelling nutrients for the biological production. The AMS ^{14}C measurements are shown in figure 1. There is a clear indication of difference in the isotopic signature of the water sources. We believe that the present results contribute to opening new perspectives for the use of ^{14}C as a tracer of the biological production in upwelling areas.

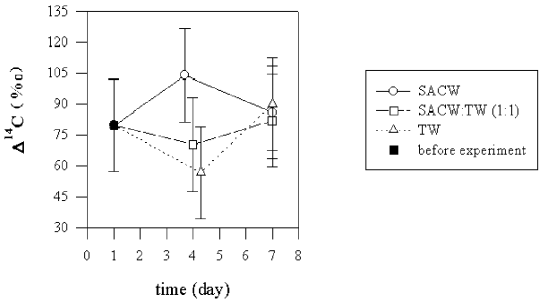

Fig.1 : Variation of the ^{14}C values in the *Ulva* sp. seaweed tissue.

3 The Investigation of Mercury Deposition at Remote Amazon Region

Atmospheric mercury can be transported large distances before it is deposited in lakes, oceans, rivers and soils and can be directly related with the frequency and intensity of natural fires. An increase in the Hg flux is a strong indicator of disturbance in a forest ecosystem related to abrupt changes in the water balance, and its changes reflect changes in the ocean and average regional temperatures. In regions where the geological background of mercury is negligible, as at remote lakes of the Amazon region, the Hg accumulation rate archived in sediment cores may be a powerful tool for the interpretation of the paleoclimatology and paleoecology of the region. Mercury (and carbon) fluxes can be obtained from the product of the sedimentation rate, bulk density and mercury (carbon) concentration. The sedimentation rate can be obtained from the ^{14}C - AMS dating of samples from the sediment cores.

Our results were obtained from sediment cores from a remote lake in northern Amazonia, at the Pico da Neblina National Park. Some of the results were published recently[4]. The chronology of the samples was obtained by ^{14}C-AMS measurements. Three different sedimentation regimes, representing paleocli-

matic processes that influenced the characteristics of the deposited material, are clearly observed. The first, from ∼41500 to ∼26000 yr. BP (Pleistocene), and the last, from 18000 yr. BP to the present (Tardiglacial and Holocene), correspond to steady sedimentation rates. There is a hiatus between ∼25000 and ∼18000 yr. BP. At ∼18000 yr. BP (Last Glacial Maximum-LGM), there is a sudden input of ∼20 cm of clastic material. Therefore, from ∼25000 to ∼18000 yr BP, the sedimentation rate could not be calculated. Figure 2 shows the mercury and carbon fluxes obtained. Although there are significant fluctuations in the mercury flux, it is clear that the average flux since the LGM was much higher than prior to the LGM. This increase in the mercury deposition rate after the LGM may be linked to drier periods and a higher frequency of forest fires. Previous works suggest the occurrence of a dry period in the Amazon region during the Holocene period from ∼7000 to 4000 yr. BP, favoring forest fires. Clear peaks of both carbon and mercury fluxes are observed at ∼34000 yr. BP, also coincident with reported forest fire events. Nowadays, the mercury flux in the Amazonia is hundred times larger than in the Holocene, due to gold mining activities.

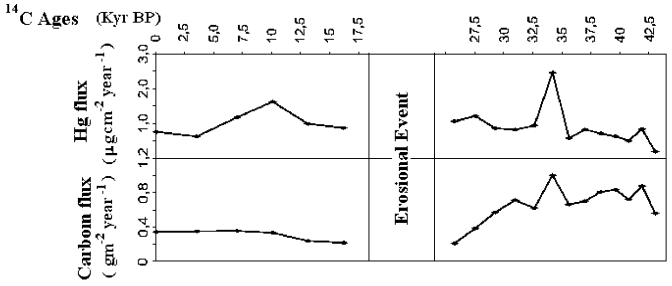

Fig.2 : Mercury and carbon fluxes obtained from sediment cores in a lake in Amazonia. The chronology was obtained by AMS.

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References

[1] 1. C. Tuniz, J.R. Bird, D. Fink and G.F. Herzog (1998) Accelerator Mass Spectrometry, CRC Press, Boca Raton (Florida)

[2] L. K. Fifield, Rep. Prog. Physics 62 (1999), 1223

[3] K.C. Ferraz et al., to be published in Braziliam Journal of Physics

[4] G.M. Santos et al., Radiocarbon 43 (2001), 801