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Using a cesium-137 (^{137}Cs) sedimentary fallout record in the South Atlantic Ocean as a supporting tool for defining the Anthropocene

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ABSTRACT

Human civilization is causing many changes to the global environment, such as the widespread presence of coastal cities and air, soil and water pollution. A new stratigraphic term for the current age, the Anthropocene, has been proposed and is differentiated from the Holocene by anthropogenic alterations. This study evaluated the occurrence and distribution of an artificial radionuclide, cesium-137 (^{137}Cs), in coastal sediments of the South Atlantic Ocean through analysis of a large number of sediment cores covering a wide latitudinal band (0°–35°S). The age of this radionuclide's horizon of maximum activity is validated with unsupported lead-210 (^{210}Pb) dating and its use is directly related to the peak of the past atmospheric fallout from nuclear tests in 1963, showing its radioactive record to be a short- to mid-term chronostratigraphic marker in helping to define the beginning of the Anthropocene. The presence of fallout ^{137}Cs follows a latitudinal pattern with a mid-latitude maximum at approximately 35°S and lower values toward the equator. This result agrees with observations reported in the international literature regarding the deposition of fallout radioactivity.

1. Introduction

Radionuclides are elements that emit various types of particles and eventually become stable. With the discovery of radioactivity at the end of the 19th century (Mould, 1995; Mietelski, 2010) and with the advent of techniques that enabled the detection of particles associated with radioactivity, a new frontier was opened in many areas of the Earth sciences, because these radionuclides can be used as tracers for physical, chemical and biological processes (Cochran et al., 2006; Santos et al., 2008).

The creation and development of technologies related to the use of atomic energy were driven by the construction and testing of atomic warheads and the production of electronuclear energy, and nuclear medicine treatments (Carlson, 1995), especially during World Wars I and II and the Cold War (Hewlett and Duncan, 1969). This was when the first artificial, man-made radionuclides were created.

However, this progress gave birth to environmental concerns regarding accidents at nuclear plant, the use and proliferation of atomic weapons, the biological effects of radiation and the disposal of radioactive wastes (French, 1996; Hiyama et al., 2012; Sovacool, 2011). All of these events released large amounts of radionuclides to the environment, and led to the establishment of Environmental Radioactivity to study phenomena of this nature (Vandecasteele, 2004).

This field is particularly concerned with the widespread contamination caused by the detonation of nuclear devices. Between 1945 and 1996, more than 500 atmospheric, submarine and underground tests were performed (NRDC, 2002), most of those at sites located in the Northern Hemisphere. Between 1961 and 1962, after the end of a ban enacted by the United States and the former USSR, both superpowers executed a large number of

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tests with high yield devices, surpassing the previous tests in terms of radioactivity released to the environment (Cirincione, 2008). This period is identified as the peak in the liberation of artificial radionuclides.

The following year, 1963, is considered to be the year of maximum fallout from those nuclear tests. This is because, after an atmospheric nuclear explosion, the subsequent distribution of radionuclides released occurs according to movements of air masses and results in the deposition of radioactive materials as minute particles after approximately one year (Kathren, 1984).

Recently, Crutzen and Stoermer (2000) proposed a new stratigraphic term, the Anthropocene Epoch, given the changes that human civilization is causing to the global environment, differentiating the current geological age from the Holocene. Waters et al. (2014) proposed several potential means to define the beginning of the Anthropocene, such as the deposition of metallic mining wastes, chemical evidence of human activities preserved in the cryosphere, and radioactive peaks in soils and sediments from nuclear accidents and nuclear tests.

The studies of Zalasiewicz et al. (2015) and Waters et al. (2015) proposed 1945 (the Trinity explosion, the first nuclear test) as the GSSA (Global Standard Stratigraphic Age, i.e., the starting point) of the Anthropocene, due to the clear presence of artificial radionuclides from past nuclear explosions. To date, there has been no

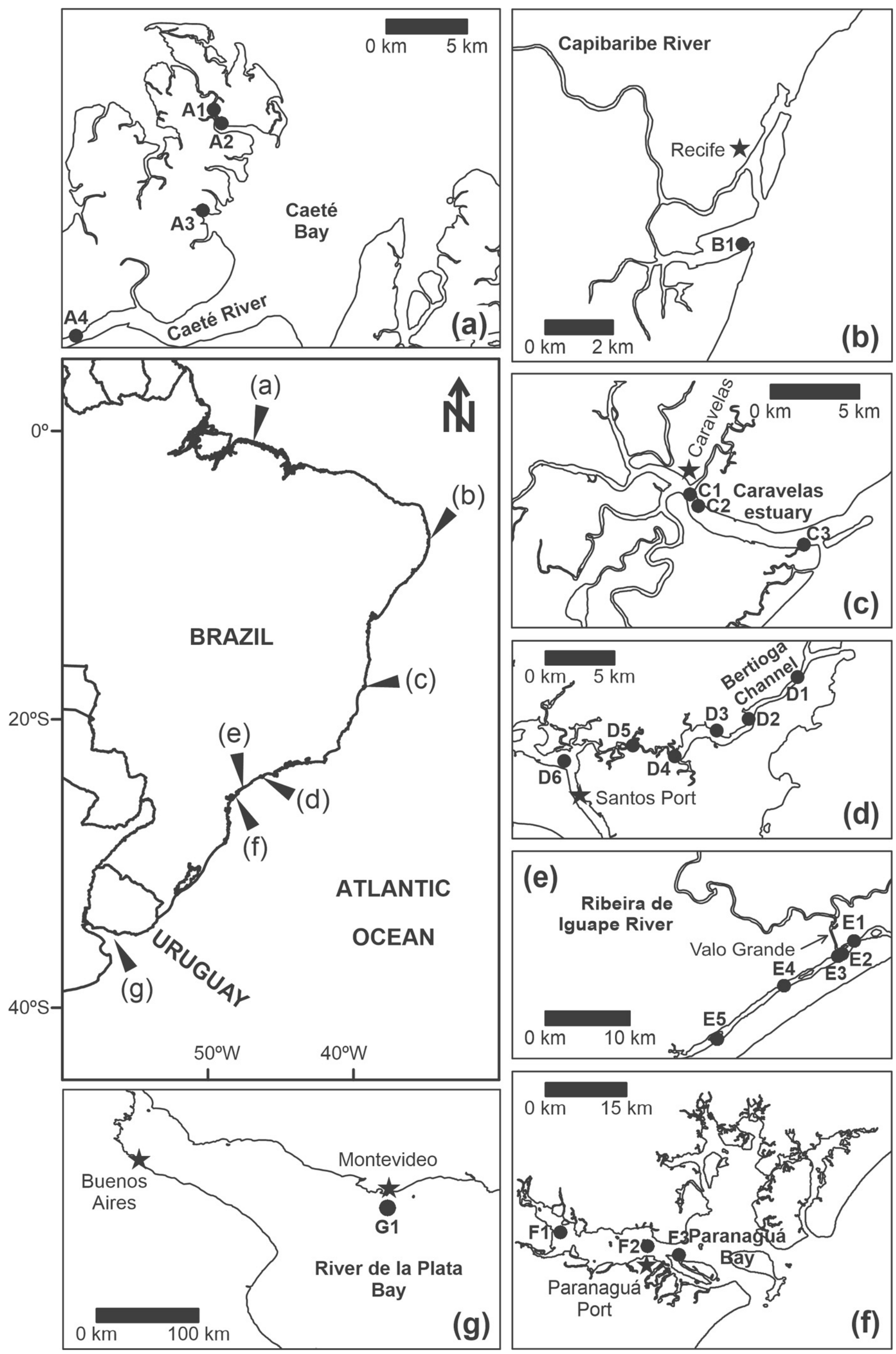

Fig. 1. Coastal systems along the South American coast of the South Atlantic Ocean. (a) Caeté Bay (PA, Brazil), (b) Capibaribe River mouth (PE, Brazil), (c) Caravelas Estuary (BA, Brazil), (d) Santos-São Vicente Estuarine System (SP, Brazil), (e) Cananeia-Iguape Estuarine Complex (SP, Brazil), (f) Paranaguá Bay (PR, Brazil) and (g) De la Plata Estuary (Uruguay).