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MARINE RESERVOIR CORRECTION IN THE SOUTH OF VIETNAM ESTIMATED FROM AN ANNUALLY-BANDED CORAL

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ABSTRACT. We measured radiocarbon in an annually-banded coral core collected from Con Dao Island, Vietnam, 90 km from the mouth of the Mekong River, and estimated the regional correction of the marine reservoir age (ΔR value). Twelve samples were continuously taken from the annual bands (AD 1949–1960) which were clearly identified under UV light (~352 nm) as well as by X-radiography. The ^{14}C content of the samples was determined using an accelerator mass spectrometer at the National Institute for Environmental Studies, Tsukuba, Japan. Results provide a $\Delta^{14}C$ time series showing a relatively steady value of –48.6 ± 4.6‰ for the period of 1949–1955 and an abrupt increase starting from 1956 that indicates a quick response to the atmospheric testing of nuclear bombs. Using the prebomb ^{14}C data, the ΔR value in the south of Vietnam is estimated to be –74 ± 39 yr.

INTRODUCTION

The marine reservoir age (R value), defined as the difference of conventional radiocarbon age between the atmosphere and surface seawater, is essential for ^{14}C dating of marine samples (e.g. coral skeletons, shells) (Stuiver and Braziunas 1993). The global distribution of atmospheric ^{14}C is almost uniform. On the other hand, seawater ^{14}C concentration varies markedly according to region, depth, and water mass because of global ocean circulation, local upwelling, stratification, and freshwater impact (e.g. Ostlund and Stuiver 1980; Stuiver and Ostlund 1983). Thus, the R value differs regionally. The difference between the regional R value and the model-based globally-averaged R value is termed the regional correction of the marine reservoir age (ΔR value) (Stuiver and Braziunas 1993). The ΔR value is equivalent to the difference between the ^{14}C age of regional surface seawater and the model-based globally-averaged marine ^{14}C age. Therefore, the ΔR value is necessary to correct the ^{14}C age of marine samples and contributes to the understanding of regional oceanography. Because the natural equilibrium of global ^{14}C distribution was broken by atmospheric testing of nuclear bombs in the 1950s and the early 1960s, the ΔR value (or regional R value) is generally estimated from ^{14}C measurements of known-age marine samples formed before the early 1950s, when the influence of the atmospheric testing was negligible or nil (i.e. prebomb period). In this study, the ΔR value in the south of Vietnam is estimated through the ^{14}C analyses of annual bands of coral skeletons collected from Con Dao Island.

MATERIALS AND METHODS

In May 2000, a 68-cm-long core (5.5 cm in diameter) was vertically drilled from the top of a living coral colony of *Porites* sp. in Con Dao Island (08°39′36″N, 106°33′07″E), Vietnam, 90 km from the mouth of the Mekong River (Figure 1). This island, lying on the broad shallow continental shelf of the South China Sea, is strongly influenced by the East Asian monsoon, a seasonally-reversing wind system, as well as by the discharge from the Mekong River. These geographical settings suggest

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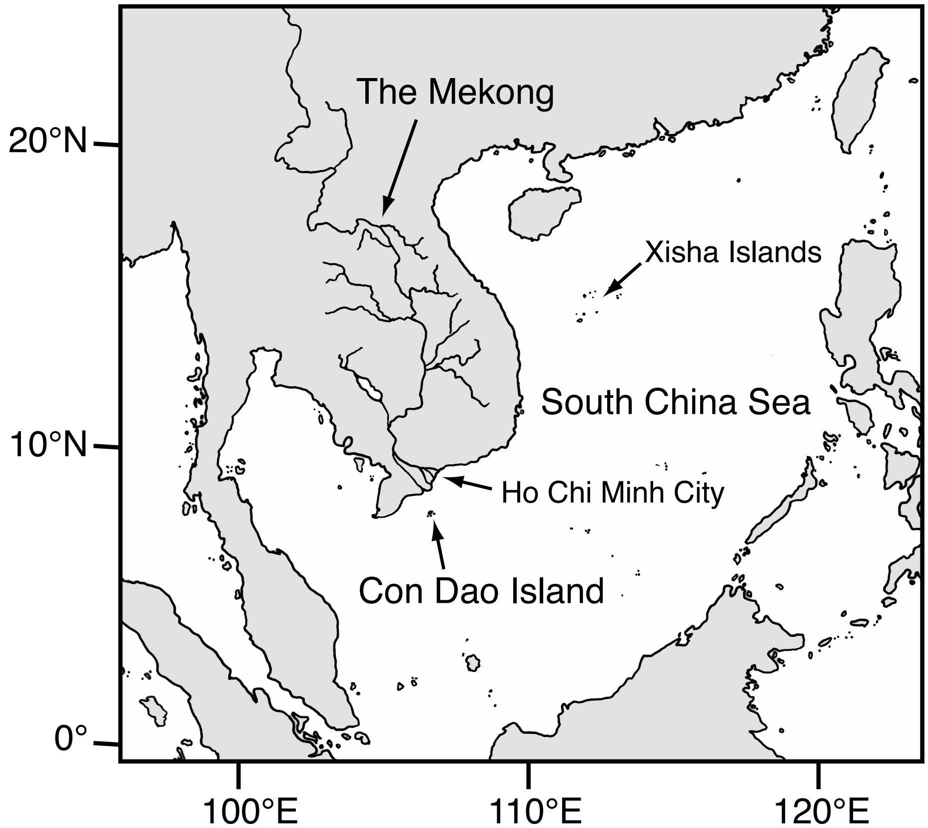

Figure 1 Location map of Con Dao Island, Vietnam (08°39′36″N, 106°33′07″E), where a core sample was drilled from a living coral colony (*Porites* sp.) in May 2000.

considerable influences of the atmosphere and freshwater on surface seawater. The core was cut along its longitudinal axis with a diamond saw to produce 6-mm-thick skeletal slabs. The skeletal slabs were ultrasonically cleaned with a large amount of distilled water renewed repeatedly, dried in a clean plastic box for a week, photographed under long wavelength UV light (~352 nm), and X-rayed. The X-ray photo revealed density banding, while the UV photo showed luminescent banding, both of which were very clear. The total number of the banding patterns in the X-ray photo is exactly the same as that in the UV photo. Average width of the banding patterns is ~12 mm, which is a typical annual growth rate of *Porites* coral skeletons. Thus, we assumed that both of the luminescent and density banding patterns represent annual growth bands. Since Con Dao Island is close to the mouth of the Mekong River, organic content of the coral sample may be relatively high. In order to remove the possible organic contamination, the following chemical treatment procedure was applied to the slabs: (1) cleaning with 5 L of Milli-Q water at room temperature for 1 hr; (2) cleaning with 5 L of 5% H_2O_2 aqueous solution at 50 °C for 30 min; (3) cleaning with 5 L of Milli-Q water at room temperature for 30 min; (4) cleaning with 5 L of 0.5 M NaOH aqueous solution at room temperature for 1 hr; (5) cleaning with 5 L of Milli-Q water at room temperature for 30 min, which was repeated 3 times with Milli-Q water renewed each time; and (6) drying in a clean plastic box at room temperature for 1 week. All of the cleaning steps were achieved with ultrasonic agitation. Twelve subsamples were continuously taken from the annual bands of AD 1949–1960, including the prebomb period (1 subsample per annual band). About 10 mg of coral powder from each subsample was converted to CO_2 in a vacuum line by dissolution in H_3PO_4, then to graphite at ~630 °C on an iron powder catalyst (1.0 mg) with H_2 gas as the reductant (Kitagawa et al. 1993). The "new" NIST oxalic acid standard (HOxII) and ^{14}C-free $CaCO_3$ were converted to graphite as a standard and a blank material, respectively, in the same vacuum line in the same condition. These graphite materials were individually pressed into a target and measured for $^{14}C/^{12}C$ and $^{13}C/^{12}C$ ratios using an accelerator mass spectrometer at the National Institute for Environmental Studies, Tandem accelerator for Environmental Research and Radiocarbon Analysis (NIES-TERRA). Each target was measured for 10 min per 1 cycle, which was replicated to 11 cycles, resulting in ~100,000–190,000 ^{14}C counts for each subsample.

RESULTS AND DISCUSSION

Results are reported as $\Delta^{14}C$ (‰) and conventional ^{14}C age (yr BP) according to the calculation procedure in Stuiver and Polach (1977) (Table 1). The $\Delta^{14}C$ calculation includes corrections for isotope fractionation to a $\delta^{13}C$ value of –25‰ (relative to PDB) and for radioactive decay between the years of ^{14}C measurement and skeletal formation. These data are not corrected for the Suess effect (the ^{14}C dilution due to fossil fuel CO_2) that is extended into the oceans (Stuiver and Quay 1981; Druffel and Suess 1983; Stuiver and Braziunas 1993). The $\Delta^{14}C$ variation of 1949–1955 shows a relatively steady value of –48.6 ± 4.6‰ (mean ± SD, n=7), followed by an abrupt increase to –10.3‰ in 1960. The abrupt increase starting from 1956 indicates a quick response to the atmospheric testing of nuclear bombs. The $\Delta^{14}C$ time series is compared with the data of the South China Sea reported in Southon et al. (2002) (Figure 2: all the data are not corrected for the Suess effect). Our results are generally in accord with Southon et al. (2002). The data in Ho Chi Minh City (Saigon), located beside the mouth of the Mekong River, is in excellent agreement with our data. On the other hand, the values in Con Dao Island and Ho Chi Minh City seem to be higher than those in the Xisha Islands (by ~10‰), suggesting that the region close to the delta of the Mekong is more influenced by air-sea gas exchange and/or freshwater discharge than the Xisha Islands. The ΔR values are calculated by subtracting the model marine ^{14}C age of 473 BP for 1950 (Stuiver et al. 1998a,b) from the conventional ^{14}C ages of the prebomb data (see Table 1), resulting in ΔR = –74 ± 39 yr (mean ± SD, n=7) in Con Dao Island. Using the Southon et al. (2002) prebomb data in Figure 2 and the same model as we used above (Stuiver et al. 1998a,b), the mean ΔR value in the South China Sea is estimated to be –3 ± 50 yr (mean ± SD, n=9). This value seems to be slightly higher than the value of Con Dao Island, which is consistent with the suggestion that the region close to the Mekong delta is more influenced by air-sea gas exchange and/or freshwater discharge.

Table 1 ^{14}C data of an annually-banded coral sample from Con Dao Island in the south of Vietnam, and calculation of ΔR values.

Year (AD)	$\Delta^{14}C$ (‰)	± 1 σ (‰)	^{14}C age (yr BP)	± 1 σ (yr)	Model age (yr BP)	ΔR (yr)
1960	–10.3	3.9	—	—	—	—
1959	–14.8	3.5	—	—	—	—
1958	–14.5	4.6	—	—	—	—
1957	–27.7	2.6	—	—	—	—
1956	–28.5	3.2	—	—	—	—
1955	–45.4	3.7	370	31	473	–103
1954	–45.3	2.6	370	22	473	–103
1953	–55.6	2.5	458	21	473	–15
1952	–52.1	3.0	429	25	473	–44
1951	–42.4	3.1	348	26	473	–125
1950	–51.0	3.3	422	28	473	–51
1949	–48.5	4.2	401	35	473	–72

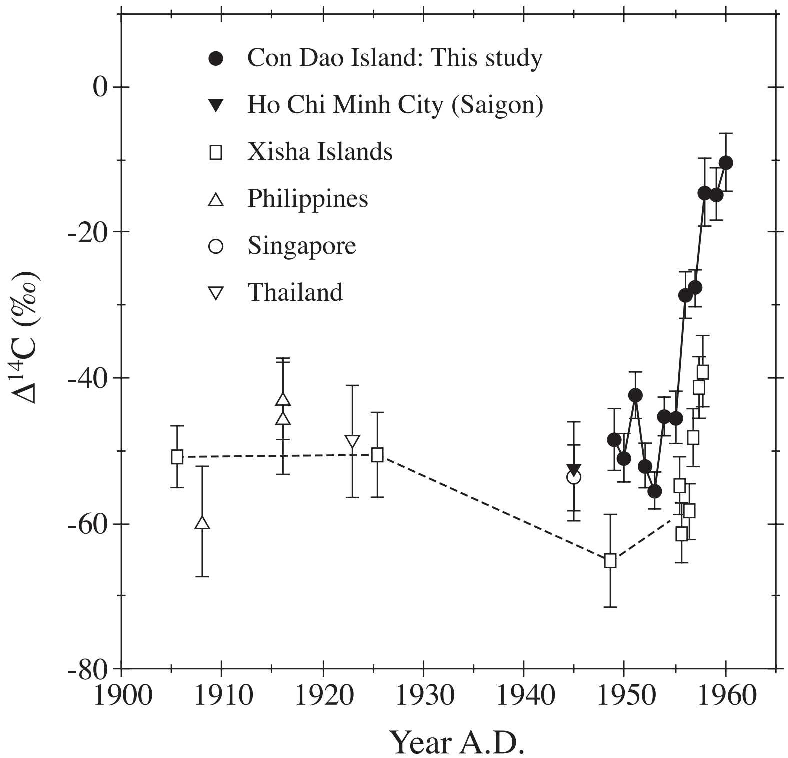

Figure 2 Comparison between $\Delta^{14}C$ results in Con Dao Island (this study) and several sites in the South China Sea (Southon et al. 2002).

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