

Sedimentation rates in Kagoshima Bay, Southwestern Japan, using the ^{210}Pb method

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Abstract

To understand the pattern of sedimentation rates as fundamental physical parameter of coastal environment, the ^{210}Pb dating method was applied to core samples collected from Kagoshima Bay, Southwestern Japan. The sedimentation rate varied at each location within the bay ($0.08\text{--}0.30\text{ g}\cdot\text{cm}^{-2}\cdot\text{y}^{-1}$), and the rate at the bay-head area was less than that at the centre of the bay. The inventory of ex^{210}Pb has a lower value in the bay-head area. The low ex^{210}Pb inventory at Stn.5' is considered to be due to physical, and chemical conditions in the bay-head area.

1. Introduction

Kagoshima Bay lies on a volcanic front of southwestern Japan, where several calderas form a line from the north to the south. The mouth of the bay opens to the East China Sea. Submerged calderas are connected by a narrow and shallow channel, and the bay head area is a semi-closed bay (fig. 1).

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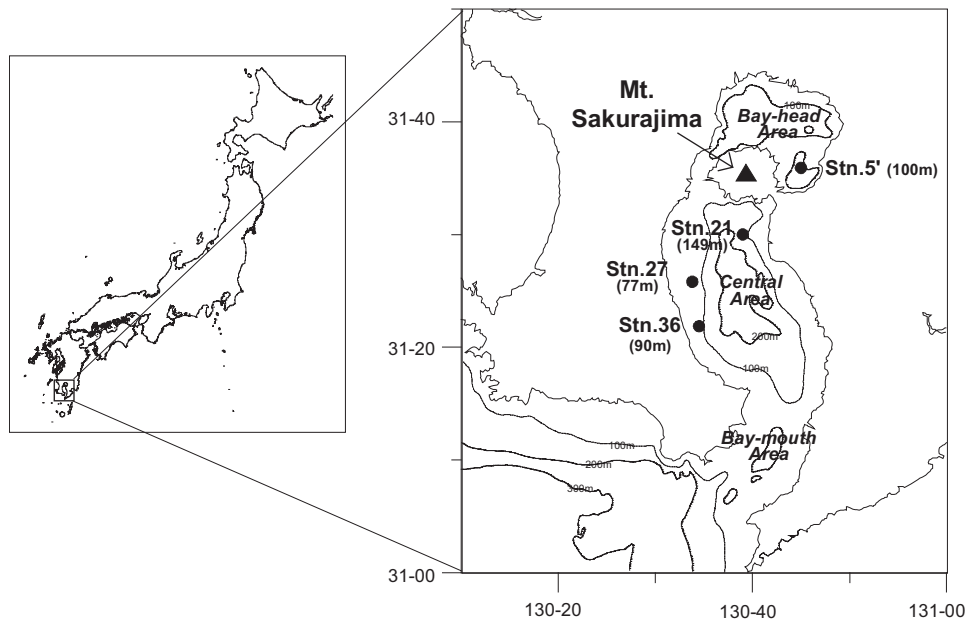


Fig. 1: Location of Kagoshima Bay and sampling sites of sediment core.

The ^{210}Pb ($T_{1/2} = 22.3\text{ y}$) method has routinely been used for dating the upper layers of various lake and/or marine sediments. Measuring the sedimentation rate using the ^{210}Pb method is based on atmospherically derived ^{210}Pb , which is also referred to as excess ^{210}Pb (ex^{210}Pb). To understand the pattern of sedimentation rates as fundamental physical parameter of coastal environment, the ^{210}Pb dating method was employed to core samples collected from this bay.

2. Sampling and method

Sediment core samples were collected at four sites in Kagoshima Bay during the R/V Nansei-maru expedition in August 2002 (fig. 1).

Cores were collected using a KK-type corer (Kimata *et al.*, 1960) with an acrylic pipe measuring 60 cm in length and 5 cm in diameter. Each core (5–15 cm long) was cut into 1 cm thick slices. After being dried and ground, samples (5–10 g) were subjected to spectrometric analysis using planar-type Ge-detectors maintained at the Ogoya Underground Laboratory in Japan. For each sample, γ -counting was usually performed over 1–2 days and ^{210}Pb and ^{226}Ra activities were determined using the γ -ray peaks

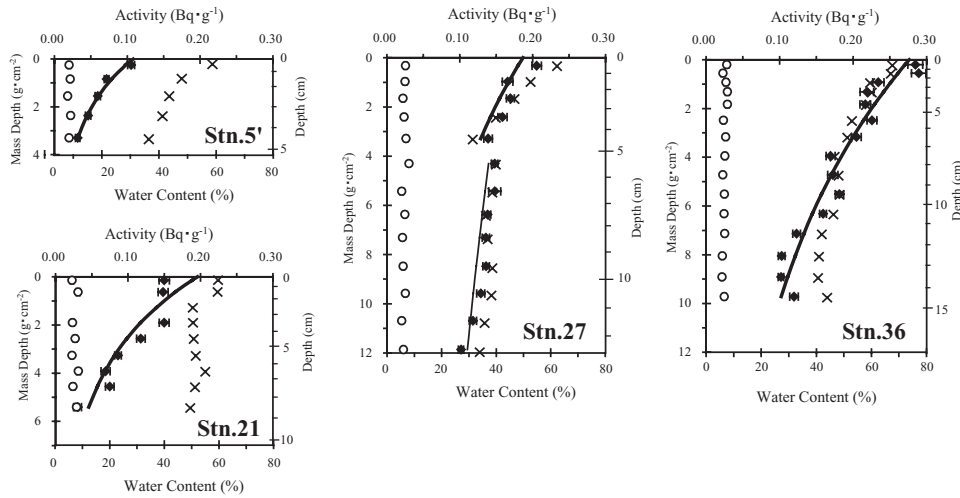


Fig. 2: Vertical distributions of water contents (\times), $ex^{210}\text{Pb}$ (\bullet) and ^{226}Ra (\circ) activities in sediment cores.

at 46 and 186 keV, respectively. The precision of the analyses, based on counting statistics, was 8% for ^{226}Ra and 4% for ^{210}Pb , respectively.

3. Result and discussion

The water content of the surface layer (0–1 cm) ranged from 60–70% at each location (fig. 2). The cores from Stn.5' and Stn.36 appeared not to have been subject to mixing, because the water content of the core samples exhibited an approximately exponential decrease due to gravitational compaction.

Activity of $ex^{210}\text{Pb}$ shows the exponential decrease due to decay, reflecting the time that had elapsed since deposition (fig. 2). Conversely, the surface layer at Stn.21 appears to have been subject to mixing by some physical force and/or bioturbation from constant $ex^{210}\text{Pb}$ activity in the mixed surface layer (0–2 cm) ($0.15 \text{ Bq}\cdot\text{g}^{-1}$). At Stn.27, $ex^{210}\text{Pb}$ and water content profiles in the upper layer (0–5 cm) differ from those in lower layers (> 5 cm), implying that a change has occurred in the rate of sediment deposition.

The sedimentation rate (ω : mass flux) varied at each location within the Bay ($0.08\text{--}0.30 \text{ g}\cdot\text{cm}^{-2}\cdot\text{y}^{-1}$) (table 1). At Stn.27, the difference between the upper (0–5 cm) and lower layers (> 5 cm) of the $ex^{210}\text{Pb}$ profile indicate a disruption in the sedimentation rate at this site. The ω value from the center of the bay ($31^{\circ}27' \text{ N}$, $130^{\circ}38' \text{ E}$; depth: 221 m) was previously reported to be $0.21 \text{ g}\cdot\text{cm}^{-2}\cdot\text{y}^{-1}$ (^{210}Pb method; Honda, 2005), which is consistent with that measured in this study (Stn.21) for the same area.

Table 1: Sedimentation rates and ex^{210}Pb inventories in Kagoshima Bay.

Core	Water depth	Sediment depth	ex^{210}Pb activity	Sedimentation rate		ex^{210}Pb Inventory
				Mass flux	Accumulation rate	
	(m)	(cm)	C_0^{*1} ($\text{Bq}\cdot\text{g}^{-1}$)	ω^{*2} ($\text{g}\cdot\text{cm}^{-2}\cdot\text{y}^{-1}$)	R ($\text{cm}\cdot\text{y}^{-1}$)	I_{calc}^{*3} ($\text{Bq}\cdot\text{cm}^{-2}$)
Stn.5'	100	0-5	0.11	0.080	0.11	0.28
Stn.21	149	0-9	0.20	0.12	0.18	0.73
Stn.27	77	0-13	0.19		–	5.2
		(0-5)	–	0.27	0.36	(0.57)
		(> 5)	–	1.0	0.93	(4.6)
Stn.36	90		0.28	0.30	0.45	2.7

*1: ex^{210}Pb activity at 0 cm on a fitting line.

*2: sedimentation rate from a fitting line.

*3: ex^{210}Pb inventory by integrated fitting line from 0 cm until ∞ depth.

Fitting Line: $C = C_0 \cdot \exp\{-\lambda_{210\text{Pb}} \cdot (\Sigma/\omega)\}$

C : ^{210}Pb concentration, $\lambda_{210\text{Pb}}$: decay constant, Σ : mass depth, ω : sedimentation rate (mass flux).

Based on the thickness of sediment, measured from the surface to a pumice-bed marker layer that had been deposited approximately 100 years ago, Hayasaka *et al.* (1976) estimated that the sedimentation rate (R accumulation rate) at the bay-head was approximately $0.5\text{--}4.2\text{ mm}\cdot\text{y}^{-1}$. At Stn.5' near the bay head, the thickness of the sediments above the pumice bed that formed after the eruption of Mt. Sakurajima in 1914 was approximately 10 cm (Hayasaka *et al.*, 1976), which corresponds to an R value of $1.1\text{ mm}\cdot\text{y}^{-1}$. Using the bulk density of dry sediment collected from Stn.5' ($0.76\text{ g}\cdot\text{cm}^{-3}$) and the value derived for R ($1.1\text{ mm}\cdot\text{y}^{-1}$), the ω value becomes $0.08\text{ g}\cdot\text{cm}^{-2}\cdot\text{y}^{-1}$, which is consistent with the estimations of ω at Stn.5' in this study.

The inventory of ex^{210}Pb calculated from the fitting curve ranged from $0.28\text{--}5.2\text{ Bq}\cdot\text{cm}^{-2}$ (table 1), and shows a lower value in the bay-head area. The bay-head area is separated from the central area by a shallow channel (depth: $< 40\text{ m}$). In summer, the vertical distribution of water temperature at the bay-head area becomes stratified and the pH of the bottom water

decreases to < 7 due to gas coming from submarine volcanic eruptions (Kamada, 1977). The low $ex^{210}\text{Pb}$ inventory at Stn.5' is considered to be due to such physical and chemical conditions in the bay-head area.

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