B-5.5.2 Study on the improvement of precision of the data for long-term variation of the seawater temperature

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Total Budget for FY 1996 1,958,000 Yen

Abstract Information on seawater temperatures is useful and important for the verification and improvement of predictive climate models. Stable isotope ratios and Sr/Ca ratios in biogenic carbonates, such as corals and fish otoliths, have the potential to provide this information, in particular to supply the historical data which is of particular value in predictive models. In the present study, we analyzed both elemental and isotope ratios in coral core samples and fish otoliths obtained along Western Australian coast, and compared the estimated water temperatures with SST data. The results are promising, and encourage further research on the establishment of the technique.

Key Words Global warming, Carbonate minerals, Sr/Ca/Mg ratio, stable isotope ratio

1. Introduction

The historical record of seawater temperature is useful and important for the verification and improvement of climate models for the prediction of global warming. Both Sr/Ca ratio [1-4] and stable isotope ratio [5] of biogenic marine carbonate minerals, such as corals and fish otoliths, vary in accordance with the ambient seawater temperature. These minerals have yearly ring structure and record the historical temperature change in each layer. Thus development of method to analyse elemental and isotopic ratios in each layer will provide us historical records which will provide basis for better understanding of global warming and for development of better prediction models.

Weather patterns in Southern Hemisphere are dominated by the El Nino - Southern Oscillation (ENSO) which is indexed by the difference in atmospheric pressure between Darwin (northern Australia) and Tahiti (SOI). Of particular importance is a recent finding of the occurrence of a south-bound current along Western Australian coast line (Leeuwin Current) and the control of its strength by ENSO event [6]. The current originates from the Warm pool around Western Pacific region, and thus is expected to reflect the ENSO events clearly. In this study, coral core samples and fish otoliths were obtained along Western Australia, and their elemental and isotopic analyses as well as comparison of estimated temperatures with SST data were conducted.

2. Experimental

Sampling sites of both corals and fishs were summarized in Figure 1. Coral core samples were obtained at Rowley Shoals and Abrolhos islands by the handy drilling system developed in our laboratory. The cores were sliced to 4 to 8 mm thickness by a diamond saw, and X-ray photographed to identify yearly bands. A core sample from Rowley Shoals was about 1.8 m length and was found to keep about 100 years history from now. On the other hand, the core sample from Abrolhos islands had discontinuities, although the total length, 3m, was thought to correspond to about 200 years. The samples for isotope and elemental analyses were taken by drilling each layer.

Fish otoliths were obtained from *Sardinops sagax*, a widely distributed surface fish, and *Pristipomoides multidens*, a deep water fish living below 100 m.

Elemental analysis was conducted by dissolving samples into a diluted nitric acid (1:100), being filtered and analyzed by ICP/AES. Stable isotope ratios of Oxygen were analyzed by a stable isotope mass spectrometer (VG, Optima) after obtaining pure CO_2 from the sample by the treatment with anhydrous phosphric acid.

3. Results and Discussion

3-1. Coral core samples

The result of elemental analysis along the Rowley Shoals sample was shown in Fig. 2. In addition to Sr/Ca ratio, Mg/Ca ratio was also found to vary, although in a reverse manner, according to the yearly ring structure. The seawater temperatures were estimated by a reported formula [1], and were compared with the SST data [7] (Fig. 3). As indicated in the figure, the estimated curve is similar to the SST data, but there are small quantitative differences between them. Similar small differences were also observed between estimated curves based on the formula by the different group [1, 2] (data not shown), suggesting that improvement of estimation is needed by taking more data. In addition to the above difference, a long-term trend of the temperature, which was not obvious in the SST data, was noted in the estimated curve. This may indicate either the difference in the observed depth (less than 1mm from the surface in SST while about 1m depth in corals) or the presence of some other unknown factor(s). Oxygen isotope study may provide keys to solve the problem.

3-2. Fish otoliths

A summary of isotope analysis, estimation of seawater temperatures, and SST data are compiled in Table 1. Generally speaking, estimated values of the surface fish, *S. sagax*, based on the cultivation experiments [8] fitted to SST data more closely. On the other hand, estimated data from the deep fish, *P. multidens*, were considerably lower than the SST data, probably reflecting their ecological characteristics. Although quantitative interpretation of the analytical data in fish otolith may be complicated because of the possible fractionation through food web, the development of method to predict seawater temperature from otoliths is important because of their unique potential of providing precise historical record of temperature variation in various places in the world ocean.

4. Conclusion

The results as summarized above were promising, and are encouraging more research for the establishment of method to estimate historical seawater temperature based on elemental and isotope signatures of biogenic marine mineral samples.

5. References

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Table 1. Summary of the results on a surface fish, *Sardinops sagax*

Sampling			Seawater temperatures		
Location	Season	$\delta^{18}O$ (‰ PDB)	Estimated (1)	Estimated (2)	SST (3)
Fremantle	Sept/Nov 1993	0.60 (0.54 - 0.99)	15.2	18.7	20.25
	Jan/Feb 1994	0.65 (0.51 - 0.77)	14.9	18.5	
Busselton	Oct, 1993	0.84 (0.67 - 1.02)	14.0	17.9	19.73
	Jan 1994	0.77 (0.70 - 0.85)	14.3	18.1	
Albany	Sept/Oct, 1993	0.88 (0.54 - 1.18)	13.8	17.8	17.73
	Jan/Feb 1994	0.98 (0.85 - 1.13)	13.3	17.5	
Bremer Bay	Sept/Oct 1993	1.00 (0.88 - 1.14)	13.2	17.5	18.20
	Jan/Feb 1994	0.92 (0.80 - 0.99)	13.6	17.7	
Esperance	Oct/Nov 1993	1.05 (0.87 - 1.15)	12.9	17.3	17.79
	Dec 93/Jan, 94	1.02 (0.94 - 1.10)	13.1	17.4	

(1) $\delta^{18}O = 3.58 - 0.196T$ (Kalish [8]); (2) $\delta^{18}O = 6.69 - 0.326T$ (kalish [9])
(3) Reynolds & Smith [7]; Average of 1989 ～ 93

Table 2. Summary of the results on deep water fish, *Pristipomoides multidens*

Sampling Location	$\delta^{18}O$	Seawater temperatures Estimated (1)	(2)	SST (3)
Ashmore	- 0.61 (- 0.97 — - 0.14)	21.4	22.4	28.6
Broome	- 0.43 (- 0.69 — - 0.17)	20.4	21.8	28.0
Pilbara	- 0.33 (- 0.71 — - 0.06)	20.0	21.5	26.6
Exmouth	0.34 (- 0.16 — 0.60)	16.6	19.5	24.7

(1), (2), (3): see Table 1.

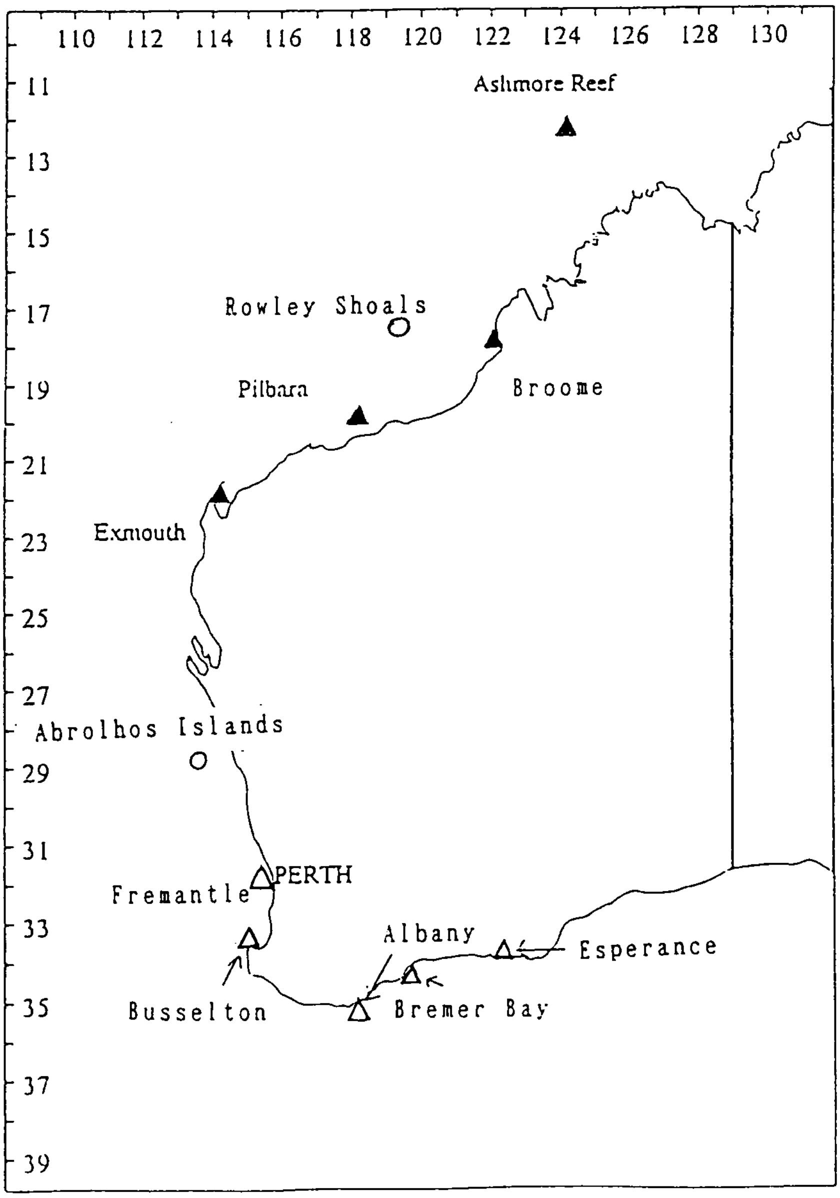

Fig. 1 Map of Western Australia showing sampling locations

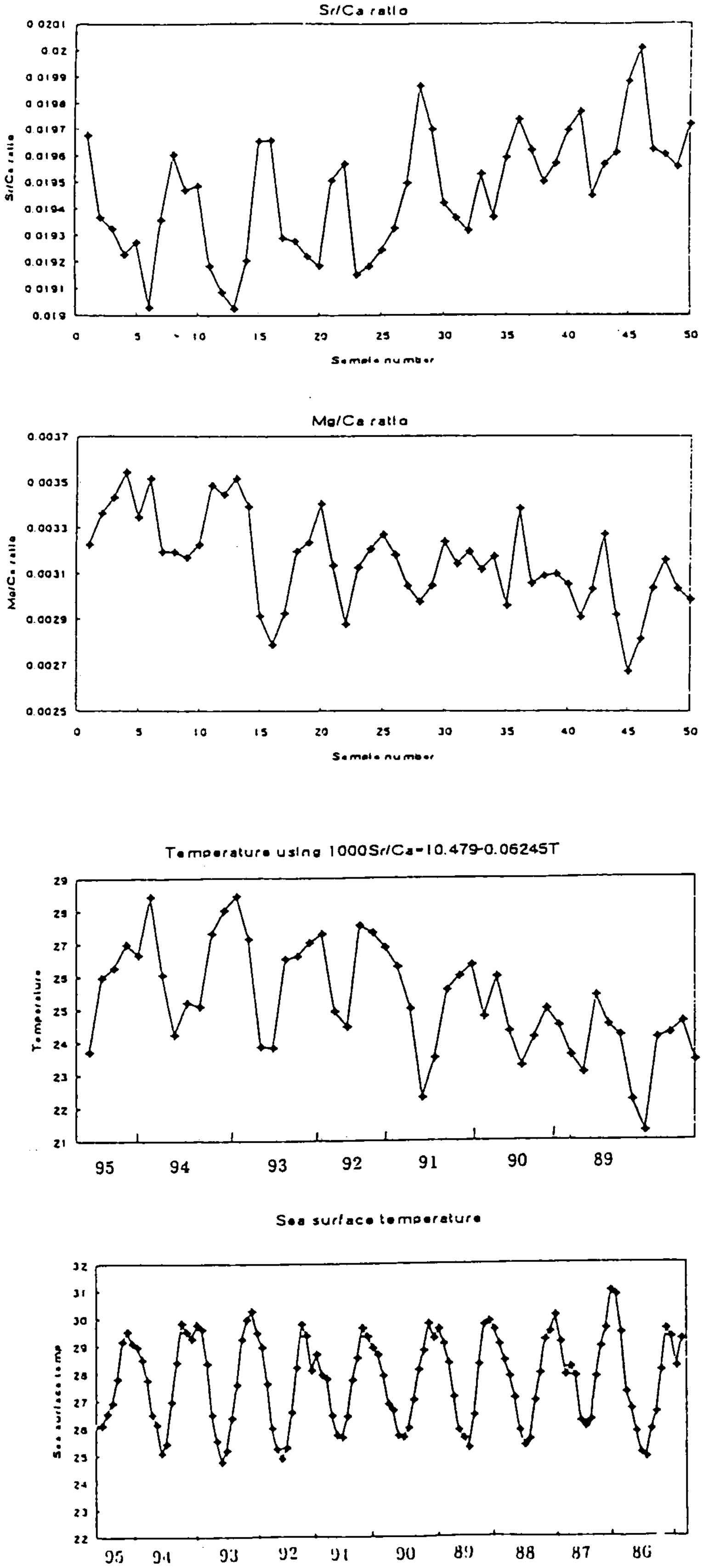

Fig. 2 Sr/Ca and Mg/Ca ratios along coral core samples from Rowley Shoals, estimated (based on the literature [1]) seawater variation, and SST [7] data (order from top to bottom)