Trans. Proc. Palaeont. Soc. Japan, N. S., No. 117, pp. 247-253, April 30, 1980

713. URANIUM-SERIES AGE OF THE HIRADOKO AND UJI SHELL BEDS, NOTO PENINSULA, CENTRAL JAPAN*

AKIO OMURA

Department of Earth Sciences, Faculty of Science, Kanazawa University, Kanazawa, 920

Abstract. Th^{230}/U^{234} dating of ahermatypic coral shows that both the Hiradoko and Uji Shell Beds of the Noto Peninsula were formed at the same age, approximately 120,000 years ago. Some discriminations in faunal composition between these two shell beds are likely to have been caused by the difference in bathymetric control due to the submarine topography. The marine Hiradoko Terrace including these shell beds is correlative with the Shimosueyoshi Terrace in the southern Kanto area, which is traceable with the shoreline features in many parts of the world, formed during a late Pleistocene eustatic high sea stand. The elevation of the former shoreline for marine terraces around the Noto Peninsula, which are correlated with the Hiradoko Terrace, indicates an average rate of uplift varying from 1.2 m per 1,000 years in the northern end of the peninsula to 0.4 m per 1,000 years in the south during the last 120,000 years.

Introduction

Th^{230}/U^{234} ages averaging 120,000± 6,000 years old have been determined for solitary corals from the Hiradoko and Uji Shell Beds in the northern part of Suzu City, Ishikawa Prefecture. These are the first uranium-series dates available from marine terraces of Honshu, Japan, which now allow us to relate these beds to various Pleistocene events in other areas. Preliminary results of oxygen isotope ratio (O^{18}/O^{16}) analysis are also presented for some molluscan shells from these shell beds.

Late Pleistocene marine terraces are almost continuously distributed around the Noto Peninsula except the rocky coast in the northern part. In spite of extensive paleontologic, geomorphologic and structural studies of these terrace deposits, their chronologic assignment have remained uncertain, because either radiometric dates or such a time-indicative marker as tephra were not available.

The Hiradoko Shell Bed named by MOCHIZUKI (1932) who also described a molluscan fauna near Hiradoko, was formerly thought to be either a late Pleistocene or nearly Holocene age (*e. g.* ASANO, 1938). The Hokuriku Quaternary Research Group (abbreviated HQRG, hereafter; 1961) found another shell bed called the Uji Shell Bed, at a locality only 4 km east of the outcrop of the Hiradoko Shell Bed. From morphostratigraphic and paleontologic reasons, HQRG (1961) has suggested a probable correlation of the Hiradoko Shell Bed with the Shimosueyoshi Terrace deposit in the southern Kanto area. The Hiradoko Shell Bed was then stratigraphically

* Received September 7, 1979; read June 9, 1979 at Tatsunokuchi, Ishikawa Prefecture.

divided into two members, Upper and Lower. The Uji Shell Bed was separated from these members as having been deposited during a later transgression corresponding to another eustatic high stand of sea level ("Musashino transgression" in South Kanto) which occurred subsequent to the Shimosueyoshi transgression. UJIIE (1975) once argued a possibility that the Hiradoko Shell Bed is of Postglacial age based on its foraminiferal assemblage. However, these paleontologic and morphostratigraphic datings are less reliable than radiometric dates to identify and correlate subdivisions of the late Pleistocene, because faunal changes have been negligible during this short period of time and because of local variations in the rate of vertical displacement. The Hiradoko and Uji Shell Beds have been dated by the C^{14} method as being >30,000 and 21,200± 1,200 years B. P., respectively (FUJII, 1969). Such recent works as KASENO and HIRAYAMA (1976), FUJII (1976), MATSUURA (1977) and OTA and HIRAKAWA (1979) reviewed these previous views of age assignment and suggested that both of these shell beds may be formed during the same transgression phase.

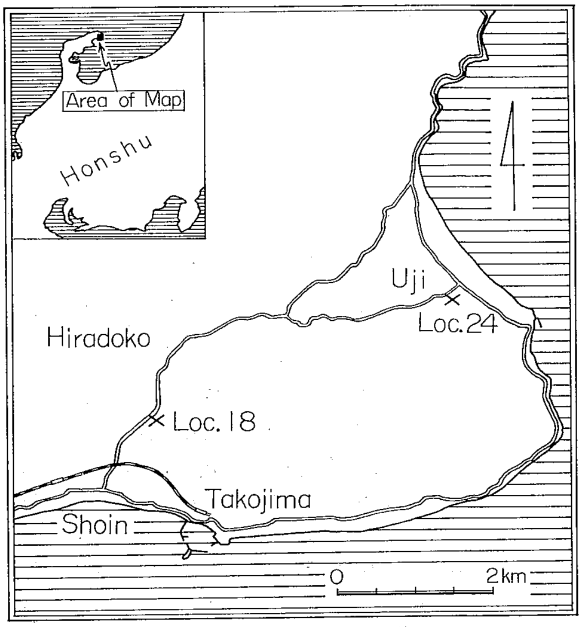

Fig. 1. Index map showing the localities where the analyzed coralline samples were collected. Locality number refers to those of MORI (1976, ms).

Materials and Locations

Analyses were made on five samples consisting of two species of ahermatypic solitary corals, *Cylindrophyllia minima* YABE et EGUCHI and *Heterocyathus japonicus* (VERRILL), from localities 18 and 24 of MORI (1976, ms) as shown in Fig. 1. The following locality descriptions refer to a 1 to 25,000 scale sheet (1970 edition) "Noto-Iida" of the Geographical Survey of Japan.

Loc. 18

Hiradoko Terrace of HQRG (1961). Longitude 137°18′16″E, latitude 37°27′04″ N, 30 m above the present sea level, at a quarry about 750 m south of Hiradoko, Suzu City.

Loc. 24

Uji Terrace of HQRG (1961). Longitude 137°20′51″E, latitude 37°27′51″N, 13 to 15 m above the present sea level, at an outcrop about 100 m west of the Honryuji Temple, Uji, Suzu City.

Methods and Results

The Th^{230}/U^{234} method of dating marine carbonate materials has been discussed by many workers (*e.g.* BROECKER, 1963; THURBER *et al.*, 1965; SAKANOUE *et al.*, 1967). The procedure for separating and purifying thorium and uranium isotopes is essentially the same as that was described by OMURA (1976). The overall chemical yield was checked by U^{232} and

Table 1. Isotopic composition and estimated ages calculated from Th^{230}/U^{234} ratios of solitary corals from Hiradoko and Uji Formations.

Stratigraphic Unit*	Material	Isotope Concentration				Activity Ratio			Estimated Th^{230} Age ($\times 10^3$yr)
		U^{238} (ppm)	U^{234} (dpm/g)	Th^{232} (ppm)	Th^{230} (dpm/g)	U^{234}/U^{238}	Th^{230}/Th^{232}	Th^{230}/U^{234}	
Hiradoko Formation	C. m.**	4.07 ±0.12	3.30 ±0.10	0.151 ±0.021	2.16 ±0.07	1.09 ±0.02	59.6 ±8.0	0.655 ±0.029	115^{+10}_{-8}
		3.83 ±0.08	3.06 ±0.06	0.116 ±0.022	2.04 ±0.07	1.07 ±0.02	72.9 ±13.6	0.667 ±0.026	119^{+9}_{-8}
		4.02 ±0.11	3.26 ±0.09	0.136 ±0.020	2.23 ±0.07	1.09 ±0.02	68.3 ±9.7	0.684 ±0.025	125^{+9}_{-8}
Uji Formation		3.83 ±0.10	3.18 ±0.08	0.105 ±0.016	2.13 ±0.05	1.11 ±0.02	84.3 ±12.6	0.670 ±0.025	120^{+9}_{-8}
	H. j.***	3.27 ±0.08	2.76 ±0.07	0.141 ±0.021	1.85 ±0.05	1.13 ±0.03	54.5 ±8.3	0.670 ±0.025	120^{+9}_{-8}

* according to the Hokuriku Quaternary Research Group (1961)
** *Cylindrophyllia minima* YABE et EGUCHI
*** *Heterocyathus japonicus* (VERRILL)

Th^{228} used as the yield tracers. Alpha-particle spectrometry was employed, using a multi-channel pulse height analyzer with silicon solid-state detectors.

Analyses of X-ray diffraction patterns prove that all the coral specimens have retained their original mineralogical composition as indicated by their aragonitic nature.

Results of these analyses are summarized in Table 1. The standard errors attached are derived from counting statistics (σ_1). Th^{230} ages are calculated on the assumption that samples were initially free of Th^{230} and that all the measured Th^{230} have originated only postmortemly from the disintegration of its parent U^{234}.

Discussions

The following evidences suggest that all of the estimated Th^{230} ages in Table 1 are reliable. First, the specimens are entirely free of recrystallization, as shown by the absence of calcite. Second, the Th^{230}/Th^{232} ratios are high compared with values of 1 to 2 which are commonly found in natural waters (KAUFMAN and BROECKER, 1963; THURBER *et al.*, 1965; VALLENTINE and VEEH, 1969; OMURA, 1976). A measurable but small amount of Th^{232} may have resulted from terrigenous materials which could not be removed from the cavity of corallites. Even if Th^{230} was contaminated altogether with Th^{232}, most of Th^{230} have already decayed out by the present. Hence, the influence of contaminant Th^{230} upon the Th^{230}/U^{234} ratios from which ages are calculated must be very small. Finally, the average U^{234}/U^{238} ratio of 1.10±0.01 is consistent with Th^{230} age of 120,000 years, considering the ratio at which U^{234}/U^{238} changes from 1.14 (KU *et al.*, 1977) to its secular equilibrium value of 1.00.

It is estimated from the Th^{230}/U^{234} ratios that the Hiradoko Shell Bed was formed 120,000±8,000 years ago and the

Uji Shell Bed, 120,000±9,000 years ago (Table 1). It may, therefore, be concluded that both shell beds were formed at the same time, approximately 120,000 years ago. These ages suggest that the Hiradoko Terrace including these shell beds is certainly correlative with the Shimosueyoshi Terrace in the southern Kanto area, because the latter has been dated to be 120,000 to 130,000 years old by the fission track method (MACHIDA and SUZUKI, 1971). The C^{14} dates, particularly of 21,200±1,200 years for the Uji Shell Bed, reported by FUJII (1969), are less reliable than Th^{230} dates shown in Table 1, because a small amount (only a few percent in weight) of contamination of modern carbonate can make an apparent C^{14} age in the range of 20,000 to 30,000 years old.

A preliminary analysis of oxygen isotope ratio (δO^{18}) was also carried out on some molluscan shells which were conspicuously occurred as a common species in both shell beds. As shown in Table 2, δO^{18} values obtained from samples of the Hiradoko Shell Bed are 0.3 per mil for aragonitic and 0.5 per mil for calcitic shells lower than those of the Uji Shell Bed. It may be estimated that the Hiradoko Shell Bed was formed in a water temprature of approximately 1 to 2°C higher than that of the Uji Shell Bed using the equation of HORIBE and OBA (1972) and also assuming that the differences in δO^{18} value are due to the water temperature of the environment where each shell bed was formed. Therefore, it may safely be assumed that the Hiradoko Shell Bed was formed on a shallower sea bottom than the Uji Shell Bed during the same high sea stand. Although the nature of substrata also should be one of the important factors controlling the molluscan assemblage as pointed out by MATSUURA (1977), some differences in faunal composition of these two shell beds, which were emphasized by HQRG (1961), appear to have been caused essentially by the difference in their inhabiting depth reflecting the submarine topography at that time.

Shoreline features standing at 2 to 10 m above the present sea level have been found in many places of the world, and they are thought to represent a eustatic high sea stand that occurred approximately at 120,000 years B. P. (*e. g.* OSMOND

Table 2. δO^{18} values of some molluscan shells from Hiradoko and Uji Shell Beds. Parenthesized figures mean number of specimens analyzed.

Shell Bed	Material	δO^{18}_{SMOW}
Hiradoko	Aragonite *Callista chinensis* (13) *Strombus japonicus* (5)	−1.02±0.22
	Calcite *Pecten albicans* (6)	−0.22±0.20
Uji	Aragonite *Callista chinensis* (11)	−0.72±0.31
	Calcite *Pecten albicans* (6)	+0.26±0.24

et al., 1965; VEEH, 1966; BROECKER *et al.*, 1968; KONISHI *et al.*, 1974; KU *et al.*, 1974). The marine terraces correlated with this high stand age are traced almost continuously around the Noto Peninsula. The former shorelines for the terraces correlative with the Hiradoko Terrace are, however, not within the 2 to 10 m range of elevations because of the tectonically active nature of this area. For example, OTA (1975) concluded that the height of the former shoreline for the Hiradoko Terrace varies from 110 m at the northern end of the peninsula to 20 m in the south and that the peninsula could be divided into eight blocks, each of which seemed to tilt south or southeastwards on the basis of the height distribution of the former shorelines. The elevation of the former shoreline for the Hiradoko Terrace is close to 70 m above the present sea level near Hiradoko, Suzu City (OTA and HIRAKAWA, 1979). The Hiradoko Upper Shell Bed may, therefore, be interpreted as having been deposited in waters of about 40 m deep. This estimation is consistent with the bathymetric range inferred by the molluscan faunal analysis of MATSUURA (1977). Assuming that the Hiradoko Terrace was formed 120,000 years ago, when sea level stood eustatically 2 to 10 m in higher than the present, there appears to have occurred a tectonic uplift on the order of between 60 and 68 m in this segment of the coast during the past 120,000 years, or as approximate average uplift rate of 0.5 to 0.6 m per 1,000 years. These rates of uplift can be estimated also for other parts of the Noto Peninsula where the Hiradoko Terrace is preserved. A maximum rate of the uplift is 1.2 m per 1,000 years in the northern end and a minimum, 0.4 m per 1,000 years in the south of the peninsula.

Acnowledgments. The author is most grateful to Mr. Kazunori MORI, an undergraduate student of the Department of Earth Sciences, Faculty of Science, Kanazawa University, for his effort to pick up a great number of those small solitary coral specimens from the Hiradoko Shell Bed. Thanks are also due to Prof. K. KONISHI of the Kanazawa University for his continuous encouragement throughout this study and for reading the manuscript, and to Dr. Kei MORI of the Institute of Geology and Paleontology, Faculty of Science, Tohoku University, for his valuable suggestion for identification of the coral samples. The alpha spectrometries of uranium and thorium isotopes were taken by means of the counter system in the Low Level Radioactivity Laboratory of the Kanazawa University. A part of this work was financed by a Grant-in-Aid (No. 464265) for Scientific Research from the Japanese Ministry of Education.

References

ASANO, K. (1938): Geologic age of the Hiradoko Shell Bed (in Japanese). *Jour. Geol. Soc. Japan*, vol. 45, p. 321–322.

BROECKER, W. S. (1963): A preliminary evaluation of uranium series inequilibrium as tool for absolute age measurement on marine carbonates. *Jour. Geophys. Res.*, vol. 68, p. 2817–2834.

——, THURBER, D. L., GODDARD, J., KU, Teh-Lung and MATTHEWS, K. J. (1968): Milankovitch hypothesis supported by precise dating of coral reefs and deep-sea sediments. *Science*, vol. 159, p. 297–300.

FUJII, S. (1969): C^{14} dates of three shell beds indicating high sea stand (in Japanese). *Earth Science (Chikyu Kagaku)*, vol. 23, p. 216–218.

—— (1976): The problem of the Uji Transgression (in Japanese with English abstract). *Bull. Japan Sea Res. Inst., Kanazawa Univ.*, no. 8, p. 27–35.

Hokuriku Quaternary Research Group (1961): Quaternary deposits on the marine terrace of Hiradoko, Noto Peninsula, Central Japan (in Japanese with English abstract). *Earth Science (Chikyu Kagaku)*, no. 54, p. 1-19.

HORIBE, S. and OBA, T. (1972): Temperature scales of aragonite-water and calcite-water systems (in Japanese with English abstract). *Fossils (Kaseki)*, nos. 23/24, p. 69-79.

KASENO, Y. and HIRAYAMA, T. (1976): Topography and geology of Suzu City (in Japanese). in *"History of Suzu City"* (edit. K. WAKABAYASHI), vol. 1, p. 47-110.

KAUFMAN, A. and BROECKER, W.S. (1965): Comparison of Th^{230} and C^{14} ages for carbonate materials from Lakes Lahontan and Bonneville. *Jour. Geophys. Res.*, vol. 70, p. 4039-4054.

KONISHI, K., OMURA, A. and NAKAMICHI, O. (1974): Radiometric coral ages and sea level records from the Late Quaternary reef complexes of the Ryukyu Islands. *Proc. 2nd Int. Coral Reef Symp.*, vol. 2, p. 595-613.

KU, Teh-Lung, KIMMEL, M.A., EASTON, W.H. and O'NEIL, T.J. (1974): Eustatic sea level 120,000 years ago on Oahu, Hawaii. *Science*, vol. 183, p. 959-962.

——, KNAUSS, K.G. and MATHIEU, G.G. (1977): Uranium in open ocean: concentration and isotopic composition. *Deep-Sea Res.*, vol. 24, p. 1005-1017.

MACHIDA, H. and SUZUKI, M. (1971): Absolute age of volcanic ash and chronology of the late Quaternary by fission track method (in Japanese). *Kagaku*, vol. 41, p. 263-270.

MATSUURA, N. (1977): Molluscan fossils from the Late Pleistocene marine terrace deposits of Hokuriku region, Japan Sea side of Central Japan. *Sci. Rep., Kanazawa Univ.*, vol. 22, p. 117-162.

MOCHIZUKI, K. (1932): Hiradoko Shell Bed and the Tertiary formations around the Suzu Cape (in Japanese). *Jour. Geol. Soc. Japan*, vol. 39, p. 26-37.

MORI, K. (1976, ms): The marine terraces in the northeastern region of Noto Peninsula, Central Japan (in Japanese with English abstract). *Grad. Thesis, Dept. Earth Sci., Fac. Sci., Kanazawa Univ.*, 46p.

OMURA, A. (1976): Thorium and protactinium isotopes in some present-day hermatypic corals and their implications to dating. *Trans. Proc. Palaeont. Soc. Japan*, N.S., no. 101, p. 271-290.

OSMOND, J.K., CARPENTER, J.R. and WINDOM, H.L. (1965): Th^{230}/U^{234} age of the Pleistocene corals and oolites of Florida. *Jour. Geophys. Res.*, vol. 70, p. 1843-1847.

OTA, Y. (1975): Late Quaternary vertical movements in Japan estimated from deformed shorelines. *Quaternary Studies, Royal Soc. New Zealand Bull.*, vol. 13, p. 231-239.

—— and HIRAKAWA, K. (1979): Marine terraces and their deformation in Noto Peninsula, Japan Sea side of Central Japan (in Japanese with English abstract). *Geogr. Rev. Japan*, vol. 52, p. 169-189.

SAKANOUE, M., KONISHI, K. and KOMURA, K. (1967): Stepwise determination of thorium, protactinium and uranium isotopes and their application for geochronological studies. *Radioactive Dating and Methods of Low-Level Counting, IAEA, Vienna*, STI/PUB/152, p. 313-329.

THURBER, D.L., BROECKER, W.S., BLANCHARD, R.L. and POTRATZ, H.A. (1965): Uranium series ages of Pacific atoll coral. *Science*, vol. 149, p. 55-58.

UJIIE, H. (1975): Geological history of the Japan Sea; revealed by sediments (in Japanese). *Natural Sciences and Museum*, vol. 42, p. 55-66.

VALLENTINE, J.W. and VEEH, H.H. (1969): Radiometric ages of Pleistocene terraces from San Nicolas. *Geol. Soc. Amer. Bull.*, vol. 80, p. 1415-1418.

VEEH, H.H. (1966): Th^{230}/U^{238} and U^{234}/U^{238} ages of Pleistocene high sea level stand. *Jour. Geophys. Res.*, vol. 71, p. 3379-3386.

能登半島平床および宇治貝層の放射年代：能登半島珠洲市北方の平床および宇治貝層から単体サンゴ（*Cylindrophyllia minima* と *Heterocyathus japonicus*）を見出し，Th^{230} 成長法によって，それらの放射年代を求めた。その結果，両貝層が同一高海水準期（約120,000年前）の産物であり，両貝層を含む平床段丘は関東地方の下末吉段丘と対比されることが明らかになった。なお，従来より指摘されてきた両貝層間の軟体動物動物群の差は，同一海水準における深度差によると考えられる。このことは，両貝層間の共通種として多産する *Callista chinensis* および *Pecten albicans* 殻の予察的な δO^{18} 値の測定結果からも支持される。また平床段丘面の旧汀線高度から，平床付近で垂直方向の地殻変動率が 0.5-0.6 m/1,000 yr であり，能登半島全域を通してみた場合，その最大が北端付近の約 1.2 m/1,000 yr，最小が南部の 0.4 m/1,000 yr であることが推定される。
大村明雄