Multiple alkaline tephra layers from Ulleung Island detected by INAA in the southern Japan Sea

Chungwan Lim
(Supervisor: Kazuhiro Toyoda)
Division of Environmental Science Development, Graduate School of Environmental Science, Hokkaido University

1. Introduction

The importance of establishing the precise rate and mode of climate response in different parts of the world cannot be over-emphasized in global paleoclimate (Nakagawa et al 2003). Tephrochronology provides time-parallel marker horizons that allow precise correlation between environmental and climatic records of the past. But the detection of cryptotephra horizons (tephra horizons that are invisible to the naked eye) for addressing abrupt climatic change has never been examined until quite recently. Instrumental neutron activation analysis (INAA) is useful for the supersensitive and effective detection of alkalic tephras, as well as the identification of the source volcanoes. The tephra framework should be tougher based on the detection and the identification of some unknown alkalic explosive volcanism that provides many distal tephra layers.

The occurrence of Ulleung Oki (U-Oki) tephra, distributed across the southwestern Japan, originated in an explosive eruption of alkali magma from the caldera in Ulleung island ca. 9,300 ^{14}C yr BP (Machida and Arai, 2003). The U-Oki tephra is regarded as an important time-marker during the Last Deglaciation to study paleo-sea level and paleo-oceanographic environments in the Japan Sea (Machida et al., 1984). However, it is suggested that some unknown alkaline ash fall events, which are probably from the Ulleung island, had happened besides U-Oki tephra between AT (Aira-Tanzawa) and K-Ah (Kikai-Akahoya) layers (e.g., Domitsu et al., 2002).

Machida et al. (1984) reported seven depositions events of pumice layers (U1-U7) on Ulleung island in the late Quaternary eruptive history. Recently, AMS ^{14}C aging of the pumice layers demonstrated that the deposition ages of U4, U3, and U2 are ca. 9,800~12,100 ^{14}C yr BP, ca. 7,500~8,000 ^{14}C yr BP, and ca. 4,900 ^{14}C yr BP, respectively (Nakamura et al., 2004). Thus, the distribution of U-Oki is presently considered to be contemporary with the U4 deposit of pumice on the Ulleung Island. The alkaline tephra from continental volcano has significantly different characteristics with the general tephra erupted by island arc volcanism. Fukuoka (1988) reported that Ta/Sc elemental ratio of glass shard is about 15, whereas the average Ta/Sc value in typical sediments is below 0.1.

Toyoda et al. (2004) firstly demonstrated that instrumental neutron activation analysis (INAA) is the supersensitive and effective detection of alkaline cryptotephras. Cryptotephra are tephra horizons that are invisible to the naked eye. Toyoda et al. (2004)

detect unknown alkaline cryptotephras from down-core profiles of the Ta/Sc ratio in a piston core from Lake Biwa and the eruption age is considered to be 583 years before the fallout of U-Oki.

2. Description of samples and analysis

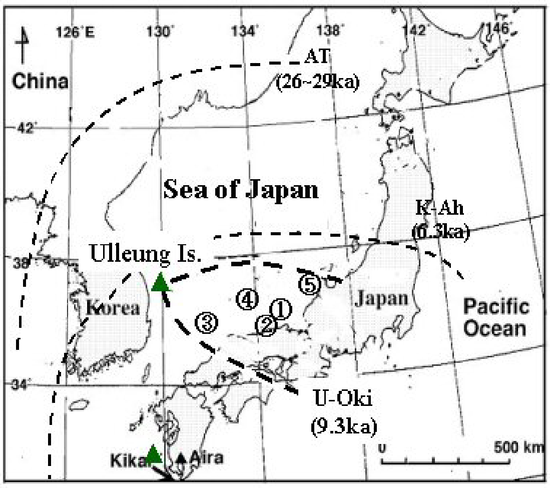

Fig. 1. The Ulleung island and locations of sampling pelagic sediments in the Japan Sea.

In this study, we are performing INAA determination of 12 elements in about 1200 samples taken from five cores in the southwest Japan Sea, about 100 mg of each powdered sample was irradiated together with standard rock samples for 20 minutes at a neutron flux of $5.3x10^{13}$ n/cm^2/sec and a epithermal flux of $1.3x10^{13}$ n/cm^2/sec in the JRR-4 reactor of the Japan Atomic Energy Agency. Gamma-ray measurements were made at cooling intervals of 30-60 days.

Precision and accuracy of data were checked by analysis of standard rocks, and no systematic error was observed. The variation for INAA measurements was below 5 % for Sc, Th, Hf, and below 8 % for Ta.

Fig.1 shows that the distribution areas of U-Oki, K-Ah, and AT tephras around Japan. The numbers from 1 to 5 in Fig.1 indicate the locations of core sites in this study. Samples were taken from the five piston cores at 1.2 cm intervals, collected during the research cruise of National Institute of Advanced Industrial Science and Technology (AIST) (Table 1).

The detections and distribution of alkaline tephra deposited in Japan Sea in these two cores (1 and 2) is already analyzed, in contrast with the results of the three remaining cores (3, 4, and 5) under analysis. Therefore, the distribution and stratigraphy of the former two cores (1 and 2) are suggested and then discussed.

3. Results and Discussion

Fig.2 indicates historical changes in the Ta/Sc ratio of the sediments at the southern of Japan Sea. The analysis of a core (GH 872-308) has revealed some peaks in the vertical distribution of Ta / Sc ratio in the upper and lower parts of U-Oki layer, as well as the strong peak at U-Oki layer (Fig.2).

Table 1. Sampling sites of piston core

Core No.	Core Name	Location		Water Depth (m)	Sub-bottom Depth (m)
		Latitude	Longitude		
1	GH87-2-KT	36°23'25"N	134°47'24"E	1157	452
2	GH87-2-308	35°57'33"N	134°26'54"E	316	303
3	GH86-2-D	36°07'59"N	131°48'00"E	1502	221
4	GH86-4-P510	36°43'27"N	133°54'05"E	1328	627
5	GH88-2-303	37°04'28"N	136°03'55"E	508	428

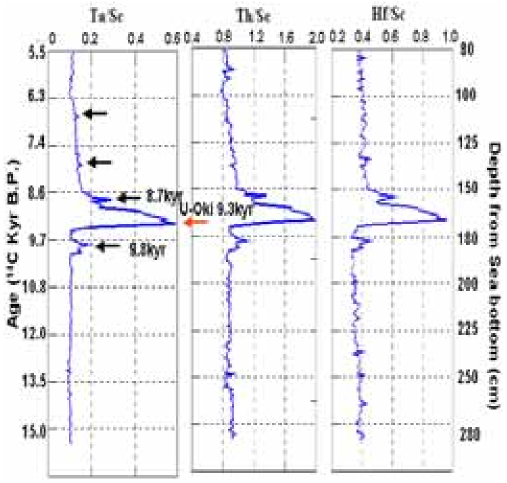

Fig. 2. Vertical distribution pattern of the Th/Sc, Ta/Sc and Hf/Sc rates in the GH 872-308 Core. Black arrows indicate the depth of Ta/Sc peaks.

The lowest peak of Ta/Sc, which is discriminated from U-Oki layer, indicates a contribution by alkaline tephra component. The peak is correlated with the few peaks in the upper layer of U-Oki reported alkaline cryptotephra layer 10 cm below U-Oki in the Lake Biwa core (Toyota et al, 2004). The arrows indicate tephra are probably due to re-deposition of U-Oki by turbid current.

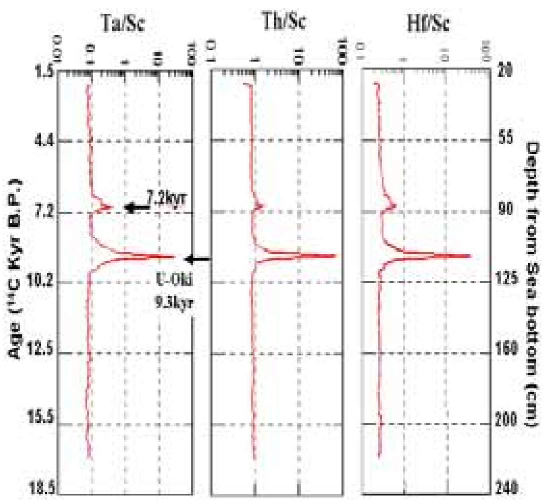

Fig. 3. Vertical distribution pattern of the Th/Sc, Ta/Sc and Hf/Sc rates in the GH87-2-KT Core. Black arrows indicate the depth of Ta/Sc peaks

Fig.3 shows a strong peak of Ta/Sc was detected about 20cm above the U-Oki layer in another core (GH87-2-KT). Fig. 3 offers the key to an understanding of possibility to another tephra layers. It is for this reason that EPMA analysis reveals that the tephra glasses separated from the anomalous layer sediment have different sizes from that of U-Oki and alkaline composition similar to that of U-Oki. We consider that the unknown alkaline tephra is probably originated from the eruption of Ulleung island which also makes the pumice layer of U3 on the land.

All the Ta/Sc anomalous samples in this study are rich in thorium, hafnium, light REEs, etc. These element ratios also suggest the contribution of alkaline tephra at these anomalous layers in two cores.

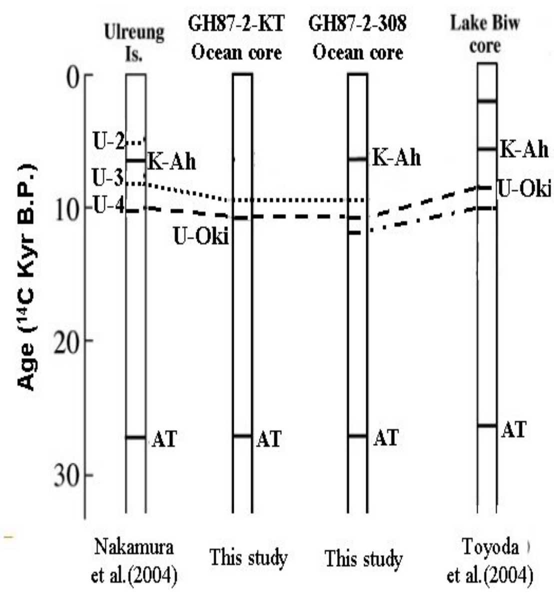

Fig. 4. Description of stratigraphic correlation using the ^{14}C age and tephra layers from the two cores.

Fig.4 summarizes the results of the tephra layer in the two ocean cores and two reference core (Nakamura et al 2004 and Toyoda et al 2004) plotted against

^{14}C age. The U-Oki event stratigraphy for the Last Glacial–Holocene transition in Japan Sea from two cores is compared with tephrostratigraphy of Ulleung Is. core by Nakamura (2004) and related to the Lake Biwa core result (Toyoda et al. 2004)(Fig.4). The detection of alkaline tephra layer in the upper part between GH87-2-KT and GH87-2-308 cores corresponds to the Ulleung island core by Nakamura as the U-3 layer. The age for the sediments from the tephra event was obtained by interpreting 7.2 ^{14}C kyr BP.

In addition, another alkaline tephra layer at the lower part of U-Oki from the GH87-2-308 core has relevance to the Lake Biwa core (Toyoda et al.)(Fig.4). The age of the lower part of U-Oki layer has been estimated to 9.3 ^{14}C kyr BP in the core. These correlations give very precise age estimates for the alkaline tephra events.

4. Expected result

We will show the distribution and stratigraphy of alkaline tephra deposited in the southwest Japan Sea during the late-glacial/Holocene with the results of the three remaining other cores (GH86-2-D, GH86-4-510, GH 88-2-303) under running analysis.

We also propose that this information should be utilized to estimate the development of new methodology for demonstrating the importance of high-resolution climatic studies and to capable of coaxing small amounts from the most obdurate samples, so that time frames and site-linkage techniques that were used in past environmental studies are improved in terms of future environmental studies in Earth.

Acknowledgement

I deeply thank Dr. Ikehara of AIST, National Institute of Advanced Industrial Science and Technology, Japan for providing the core samples and critical and constructive comments. I also thank Dr, Chun of the Korea Ocean Research and Development Institute, since he performed the EPMA analysis and provided guidance through this work. Neutron Activation Analysis was carried out at the Inter-University Laboratory for the common use of Nuclear Facilities

References

Domitsu, H., Shiihara, M., Torii, M., Tsukawaki, S., and Oba, M. (2002). Tephro-stratigraphy of the piston cored sediment KT96-17 P-2 in the southern Japan Sea. *Journal of Geological Society of Japan* 108, 545-556.

Fukuoka, T. (1988) Correlation of Tephra layers by trace elements abundance in glass shards. *Chemistry and chemical industry* 41, 909-911.

Machida, H. and Arai, F. (2003). Atlas of tephra in and around Japan. Revised Edition, Univ. of Tokyo Press, Tokyo.

Nakagawa, T., Kitagawa, H., Yasuda, Y., Tarasov, P.E., Nishida, K., Gotanda, K., Sawai, Y. and Yangtze River Civilization Program Members (2003). Asynchronous climate changes in the North Atlantic and Japan during the Last Termination. *Nature* 299, 688-690.

Nakamura, T. (2004) C-14 wiggle-matching analysis of charred wood sample for the high-precision determination of volcano eruption. *Research report of Grants-in-Aid for Scientific Research by MEXT* (13480020).

Toyoda K. and Shinozuka, Y. (2004). Validation on arsenic as a proxy for lake level change during the past 40,000 years in Lake Biwa, Japan. *Quaternary International* 123-125, 51-61.