The Korean Journal of Quaternary Research
Vol. 17, No. 2, pp. 1~7 (2003)

The Impact of Abrupt Climate Change on the Marine Ecosystem in the East Sea*

Im Chul Shin[1], Hi-Il Yi[2], Hyo-Sang Chung[1], Won-Tae Kwon[1], Jong-Hwa Chun[2], Hyun-Taek Oh[1]

[1]*Meteorological Research Institute, Korea Meteorological Administration, Seoul 156-720, Korea*
[2]*Korea Ocean Research and Development Institute, Paleoceanographic Environmental Research Center,*
Ansan P.O. Box 29, Seoul 425-600, Korea

ABSTRACT

Environmental changes caused by the abrupt climatic change are one of the important issues in the scientific community. In the East Sea, abrupt climatic shift, called Younger Dryas, is identified. The age of the Younger Dryas cold episode occurred at 11.2 ka. Overall, changes in circulation and bottom water conditions occurred during the Younger Dryas cold episode in the study area. Especially, climatic transition from meltwater spike to the Younger Dryas cold episode is characterized by significant shifts of oxygen isotope values, the coiling ratios of *Neogloboquadrina pachyderma,* and the planktonic foraminifers abundances.

The impact of abrupt climate change on the ecosystem is very significant. In the East Sea, the calcium carbonate secreting organism(foraminifers) is replaced by silicon dioxide secreting organisms(diatom, radiolarian) after the abrupt and severe cold climatic event. Based on the Doctrine of Uniformitarianism, at least climate change for the next 100 years would be severely influence on the marine ecosystem.

Keyword : climate change, East Sea, Younger Dryas, oxygen isotope, Neogloboquadrina pachyderma, bottom water, ecosystem

Introduction

Intergovernmental Panel on Climate Change(IPCC) reported that the temperature will rise 1.4-5.8℃ for the next 100 years (IPCC, 2001) (Fig. 1). IPCC was set up by the US in 1988 to establish an international consequence on climate change research. Approximately 3500 scientists from various areas are involved for the IPCC report. The original third full assessment covers about 2,500 pages. The IPCC concludes that the next 100 years temperature increase (including recent warming) is due to the human action. This is a big conclusion, and after they made the conclusion they have lots of pressures because their conclusion will affect the socio-economic structures very significantly.

What is the meaning of temperature increase and

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* The materials for this study are provided by Korea Ocean Research and Development Institute(KORDI). Parts of this research were done while ICS was in KORDI. Financial support for this research is from the project titled The Development of Regional Climate Change Scenario for the National Climate Change Report from the Meteorological Research Institute (METRI).

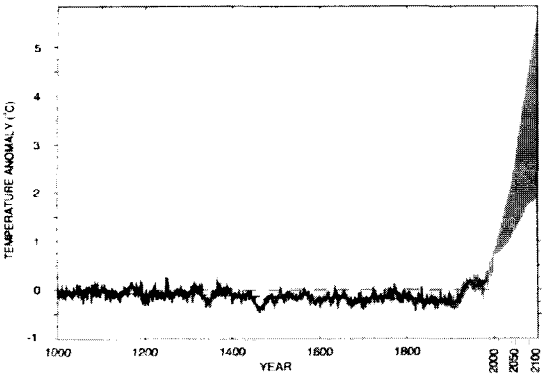

Fig. 1. Future predicted climate change(from IPCC 2001).

what happens if such an abrupt climate change occurs. To answer this question, it is crucial to examine the paleo-records since the instrumental records are no longer than 200 years.

Since the born of the Earth at 4.6 billion years, numerous climatic and its related environmental changes occurred. In the Geologic Time Table, each era, period, epoch, and age boundaries are characterized by climatic and environmental changes. In this paper, the latest Quaternary paleoclimatic and paleoceanographic histories in the East Sea are investigated.

To examine past climatic and its related environmental history, piston core 94PC-2 is used. Core 94PC-2 is 861 cm long and it was taken at a water depth of 1,302 m on the continental slope(Fig. 2). East Sea, a semi-enclosed marginal sea, is located between Korea and Russia in the west and Japan in the east. The East Sea is characterized by scarcity of shallow water areas. The average water depth is approximately 1,350 m and the maximum depth reaches 3,700 m. The surface water of the East Sea is connected with the Okhotsk Sea through Tatarskiy Strait(the sill depth is less than 15 m) and through Soya Strait(the sill depth of 55 m) to the North Pacific Ocean.

The surface water of the East Sea flows out via Tsugaru Strait (the sill depth of 130 m). These shallow sill depths block the water connection between the East Sea and the North Pacific Ocean. For example, during the glacial the sea-level was approximately 130 m lower than the present sea level (Oba *et al.*, 1991). These low sea-level prevents water circulation between the East Sea and adjacent north Pacific making the anoxic basin. Another word, the East Sea is very sensitively responding to the climatic changes.

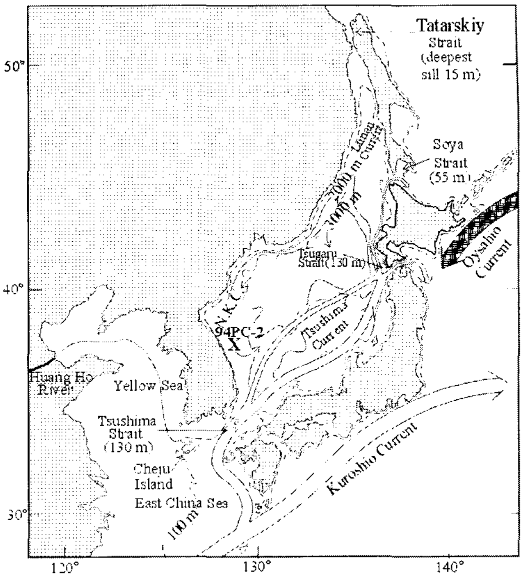

Fig. 2. Location of Core 94PC-2

The climate and ecosystem of the East Sea is governed by the position and the amount of influx of the Kuroshio Current. A branch of the Kuroshio Current enters the East Sea through the East China Sea. The main Kuroshio Current moves up to north and is divided into two currents: Tsushima and Kuroshio Current. The main Kuroshio Current passes south of Japanese Islands, while the Tsushima Current passes through the southern part of the Korea Sea(Park and Yi, 1995).

Front exists at 40 °N except for coastal areas. Warm water mass exists in the south of the front region, while cold water mass exists in the north of the front. The greatest horizontal temperature and salinity change occur near 40 °N(Bradshaw, 1959).

Exchange between water bodies in the East Sea and the surrounding water bodies(from the Okhotsk Sea, the North Pacific Water, and the Kuroshio Water) are limited. Therefore, the East Sea contains its own peculiar water mass(called East Sea Proper Water) below the upper few hundred meters(approximately 500 m in water depth) from the sea surface water (Moriyasu, 1972). The surface waters are well-mixed, cold, fresh, and oxygenated(Keigwin and Gorbarenko, 1992). In the East Sea, temperature below 200 m is 0.1-0.3 °C, the salinity is 34.0-34.1‰, and the dissolved oxygen is 5-6 ml/l(Oba *et al.,* 1991).

Materials and Methods

Sediment samples from piston core are used for the quantitative analysis of foraminifers. For micropaleontological analysis, all samples are carefully selected in a 1-2 cm sampling intervals in each core depth. Sediments are analyzed using the traditional micropaleontological method such as wet sieving.

Approximately 10 g of dried sediment from 94PC-2 is used for foraminiferal study. For quantitative analysis of foraminifera, wet sediment samples stored in the oven at 50 °C until it completely dried(usually 2 days), then weighted. Tap water is added in the dried sample to disaggregate the sediment. Then, the samples are washed with 63 μm sieve. If necessary, some samples put in the ultrasonic cleaner to disaggregate clay particles easily. Fractions greater than 63 μm are collected in the beaker and dried at 50 °C oven until it dried.

Planktonic and benthic foraminifers are counted in a greater than 63 μm size fractions under the 40 magnification binocular microscope. Foraminifers are sand sized microfossils. They are usually ranges from 1 to 2 mm. Greater than 2 mm foraminifers are rarely occurring in the sediment. If some samples contain greater number of foraminifers, the sediment samples are splitted with Otto microsplitter until a reasonable aliquot remains for counting. Then, number of planktonic and benthic foraminifers is expressed as a number in 10 g of original dried sediment.

The following parameters are used as a proxy measure for the paleoclimatic and paleoenvironmental history: oxygen and carbon isotopic ratios, planktonic/benthic foraminifers ratio, planktonic foraminifera fragmentation(%), absolute abundance of planktonic foraminifers, and the coiling ratios of left-coiled planktonic foraminifer *Neogloboquadrina pachyderma.*

Results and Discussion

Silts and clays are dominant components in most of the core intervals in core 94PC-2. Planltonic and benthic foraminifers are rarely occur most of the core intervals except for core intervals of 106-120 cm. Several sampling intervals between 106 and 120 cm contain planktonic foraminifers ranging from 6,000 to 130,000 individuals in a 10 g of dried sediment. Especially downcore 116 cm core depth contains almost exclusively planktonic foraminifers under the 40 x binocular microscope. Number of planktonic foraminifers at 116 cm core depth is approximately 130,000 individuals in a 10 g of dry sediment. The planktonic/benthic foraminifera ratios ranges from 94 to 100 % at core intervals of 106120 cm. Planktonic/benthic foraminifera ratio increases with water depth in Asiatic coast (Waller, 1960) and can be used as a paleobathymetric proxy(Luning *et al.,* 1998). The sediments from the target interval (106-120 cm) of this study are deposited under the normal deep water conditions.

Within *N. pachyderma* countings, left-coiled *N. pachyderma* ranges from 72 to 85 % at the core intervals of 106-120 cm. Left-coiled N. *pachyderma* ranges from 68 to 85 % among whole planktonic foraminifera at the core intervals of 106-120 cm.

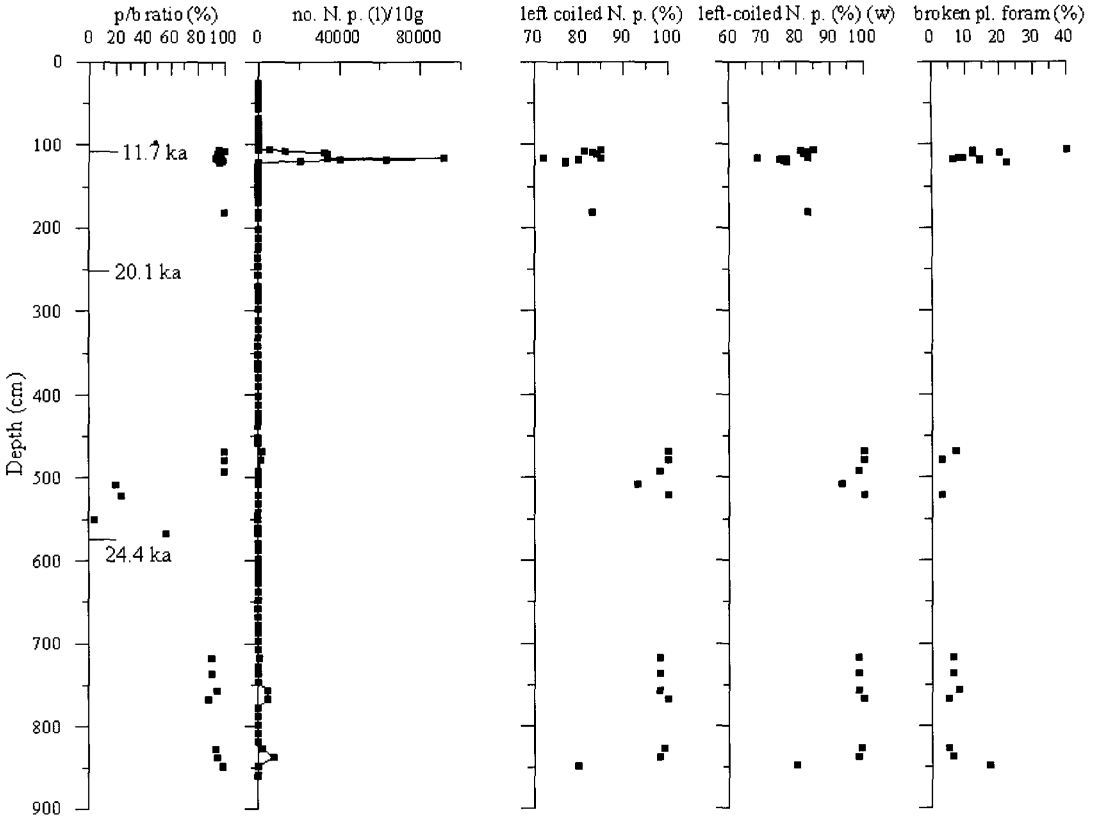

Fig. 3. Paleoceanographic proxy from core 94PC-2 (p/b denotes for planktonic/benthic foraminifers ratio; no. N. p. (l)/10g denotes for number of left-coiled *Neogloboquadrina pachyderma* in a 10 g of dried sediment; left couled *N. p.* (%) denotes for the relative percentage of *N. pachyderma* within *N. pachyderma*; left-coiled N. p. (%) (W) denotes for the left-coiled *N. pachyderma* among whole planktonic foraminifers; pl. denotes for the planktonic foraminifers).

Number of left-coiled planktonic foraminifer at core intervals from 106 to 120 cm ranges from 5000 to 90,000 individuals in a 10 g of dried sediment(Fig. 3).

Sediment from downcore intervals of 106-120 cm of core 94 PC-2 is characterized by extremely high number of planktonic foraminifers compared to those of other core intervals. Number of planktonic foraminifers is directly reflecting the planktonic foraminifers productivity. Also, number of planktonic foraminifers is correlated with food supply (Berger, 1969). But, both productivity and food supply can not explain the extremely high number at core 94 PC-2. To understand this, oxygen isotope data from Park *et al.*(1997) are plotted (Fig. 4). A significant shift of oxygen isotope values occurs from downcore 115 cm to 105 cm. The δ O^{18} value at 115 cm downcore depth is -0.41 per mil and at 105 cm is 3.81 per mil. This greater than 4 per mil difference in oxygen isotope value is not solely due to the temperature differences.

The oxygen isotope values reflect temperature and global ice volume as well as freshwater input.

A well-defined cooling event of the Younger Dryas is defined in the northern part of the Ulleung Basin based on the significant shift of oxygen isotopes. The AMS radiocarbon age of 110 cm downcore depth is 11.7 ka (Park *et al.,* 1997). A meltwater spike occurs

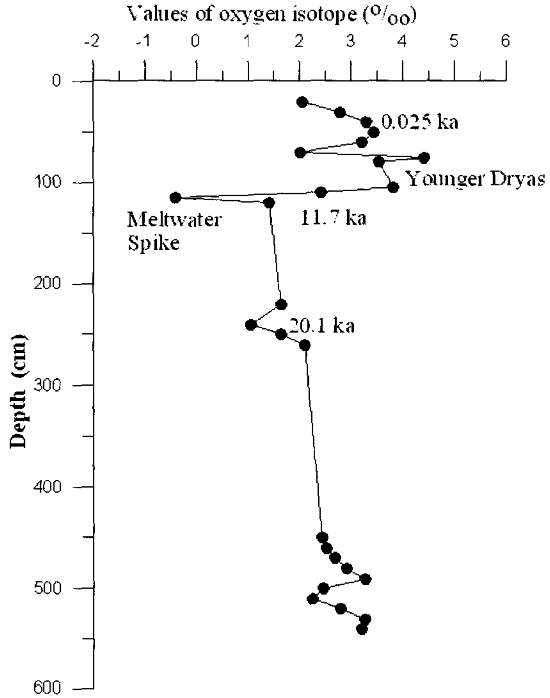

Fig. 4. Downcore variations of oxygen isotope values from core 94PC-2.

slightly older than 11.7 ka at core 94 PC-2. This meltwater spike is well matched with the result of Marchitto and Wei's (1995). Generally, the residence time of Younger Dryas meltwater is 500 years(Broecker, 1990). Dramatic surface water temperature and salinity change occurred within a short period(less than 1,000 years within the limited resolution) in the Ulleung Basin.

As shown in Fig. 1, IPCC predicts that the future 100 year's climate will be increased abruptly. We can deduce the future conditions from the result of core 94 PC-2.

Melting ice observed globally(Nisber, 2003; Wang and Key 2003). Glaciers have been thinning and retreating since the mid 19th century. Now, Switzerland's have declined a third in volume since 1860, but now the pace is accelerating (Krajick, 2002). Vostok ice in Antarctica also melts 10 cm in each year(Irion, 2001). If ice melts, low salinity water would reach to the ocean through rivers. The low salinity water will greatly influence the water mass property in the East Sea. In general, water mass is characterized by temperature, salinity, and dissolved oxygen. The surface water can not sink to the deeper part of the East Sea due to the low salinity of surface water. Therefore, heat can not be transported to the deeper part. Furthermore, dissolved oxygen from surface water can not easily be transported to the deeper part of the East Sea. Dissolved oxygen in the water column will be used up animals then, the deep water would be an anoxic. Blocking of heat transport from the surface water also would make the deep and bottom water as a cold conditions. This cause the cooling event, called Younger Dryas.

Planktonic foraminifer *N. pachyderma* can be used as a paleotemperature indicator. Both right- and left-coiled *N. pachyderma* occur from polar to temperate areas (Bandy, 1972). Left-coiled *N. pachyderma* occurs in cold surface waters, whereas right-coiled *N. pachyderma* occurs in relatively warm surface water temperatures compared to that of the left-coiled form(Jenkins, 1967; Kennett, 1968, 1970; Bandy, 1972; Ortiz and Mix, 1992, Thunell and Sautter, 1992, Park and Shin, 1998). Right- and left-coiled *N. pachyderma* live different water masses, and the boundary between these realms is defined by waters around 8 C in spring in the northeast Pacific(Arikawa, 1983). The great variations of *N. pachyderma* during and after the Younger Dryas indicate that there was a significant temperature fluctuations including water mass properties.

The ecosystem in the East Sea changed from calcium carbonate rich during glacial to silicon dioxide rich during interglacial. Foraminifers are very abundant during glacial. Foraminifers(calcium carbonate) and radiolaria (silicon dioxide) are equally occur in the beginning of the Younger Dryas(11.2 ka) cold period. Then, almost all foraminifers disappear and radiolaria dominates during the interglacial in the study area. Ecosystem change triggered by abrupt climatic changes in the East Sea provides very important information to better understand the impact of future climatic changes on the ecosystem.

In the East Sea, the preservation condition of planktonic foraminifers shows very significant difference just before and after the abrupt climatic shift, that is Younger Dryas cold episode at approximately 11.2 ka. It is well known that the preservation of planktonic foraminifers (fragmentation) is a very sensitive indicator of the bottom water condition(Martinez *et al.*, 1999). In this study, planktonic foraminifers fragmentation comprises less than 10 % during the glacial. Then, planktonic foraminifers completely dissolved away and replaced by radiolaria toward the younger time period. This indicates that the East Sea is represented by carbon dioxide rich corrosive bottom waters during the interglacial compared to that of glacial.

Conclusion

Great fluctuations of the number of planktonic foraminifers, and the number and relative abundance of the coiling-direction of planktonic foraminifer *N. pachyderma*, and relative percentages of broken planktonic foraminifers occur during the climatic transition from warm to cold around 11 ka. The climatic transition pattern is sharp. The bottom water condition was very unstable as evidenced by the fluctuations of the percentage of broken planktonic foraminifers.

Climatic change(Younger Dryas) altered the ecosystem very significantly. Sediments from the climatic transition(approximately 11 ka) contain mixed assemblages of diatoms(silicon dioxide secreting phytoplankton) and foraminifers(calcium carbonate secreting zooplankton). However, the planktonic foraminifers are almost all (more than 95 %) broken indicating carbon dioxide rich corrosive bottom waters). Sediments below the climatic transition (older than 11 ka) is made of very well preserved planktonic foraminifers. However, sediments above the climatic transition(younger than 11 ka) are composed of diatoms and radiolarians. This is only based on the analysis of one core. It is necessary to analyze more cores to understand the impact of abrupt climate change on the ecosystem.

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