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Paleoceanographic Investigation from the Ostracodes of the Middle Miocene Chunbuk Formation in Pohang Basin

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포항분지 중기 마이오세 천북층에서 산출되는 개형충 화석을 이용한 고해양학적 연구

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The well preserved ostracodes of the Chunbuk Formation in Pohang Basin were analyzed isotopically to understand paleoceanographic conditions of the southeastern part of Korean peninsula which prevailed during the Middle Miocene. $\delta^{18}O$ values of the unaltered ostracodes from Seocheongri, Songhacdong, and Mulcheonri areas range from −2.2 to −0.7‰ (PDB), −0.7 to 0.0‰, and −2.0 to −0.8‰, and their corresponding paleotemperatures range from ca 20 to 27℃ (average=24℃), 17 to 20℃ (average=18℃), and 20 to 26℃ (average=23℃), respectively. Assuming the $\delta^{18}O$ composition of the Middle Miocene seawater was about −0.34‰ (SMOW), the paleotemperature of the Middle Miocene shallow seawater in the Pohang Basin was almost equal to or slightly higher than the present summer temperature (ca 16 to 20℃) near Pohang area.

Carbon isotopic value of *Cythere omotenipponica* is −0.8‰ (PDB), reflecting marine carbonate carbon composition. Carbon isotopic compositions of other ostracodes such as *Aurila okumurai, Trachyleberis niitsumai, Urocythereis* sp., *Urocythereis* cf. *gorokuensis*, and *Acanthocythereis mutsuensis* range from −5.2 to −3.4‰ (PDB), which might have secreted their shells out of equilibrium with ambient seawater. This disequilibrium was most likely to have resulted from metabolic (=vital) effect, rather than temperature or productivity.

포항분지 내의 천북층에서 산출되는 변질되지 않은 개형충 화석을 대상으로 중기 마이오세 동안에 한반도 남서부 부근에 영향을 주었던 고해양학적 조건을 이해하기 위하여 동위원소 분석을 실시하였다. 서정리, 송학동 및 물천리 지역의 변질되지 않은 개형충의 산소동위원소 성분은 각각 −2.2∼−0.7‰ (PDB), −0.7∼0.0‰과 −2.0∼−0.8‰이며, 이 성분에 의한 고해양해수의 온도는 각각 20∼27℃ (평균=24℃), 17∼20℃ (평균=18℃)과 20∼26℃ (평균=23℃) 정도이다. 만일 중기 마이오세 동안에 포항분지내 천해 해수의 산소동위원소 성분이 약 −0.34‰ (SMOW)이었다고 가정하면, 중기 마이오세 동안에 포항분지내 천해 해수의 고온도(paleotemperature)는 현재 포항부근 천해의 평균 여름 온도와 거의 비슷하였거나 약간 높았던 것으로 추정된다.

분석된 개형충 중 *Cythere omotenipponica*의 탄소동위원소 성분은 −0.8‰ (PDB)로서 해수내의 탄산염 이온의 탄소동위원소 성분을 잘 반영하고 있으나, *Aurila okumurai, Trachyleberis niitsumai, Urocythereis* sp., *Urocythereis* cf. *gorokuensis*, and *Acanthocythereis mutsuensis*와 같은 나머지 개형충의 탄소동위원소 성분은 −5.2∼−3.4‰ (PDB)로서 주위의 해수와 비평형상태를 이루고 있었던 것으로 나타난다. 이러한 결과는 고해양해수의 온도나 생산력의 차이에 의한 영향이라기 보다는 개형충 자체 내의 생리적 영향에 기인한 것으로 여겨진다.

INTRODUCTION

Ostracodes are microscopic, benthic crustaceans that have a bivalved, calcareous carapace and live in marine and nonmarine environments. Since they have dwelled in shallow marine environment, paleocenographic as well as paleoclimatologic information from ostracodes has been relatively poor compared to that from other planktonic microfossils such as foraminifers and calcareous nannoplanktons from Deep Sea Drilling Project and Ocean Drilling Project. Nonmarine ostracodes have been extensively used as a valuable tool to determine the paleotemperature, paleosalinity, and paleohydrochemistry based on their diversity (Forester, 1983; Forester and Brouwers, 1985; Forester, 1986; Forester, 1991), Mg and/or Sr contents (Chivas et al., 1983; Chivas et al., 1985; Chivas et al., 1986a, b; De Deckker et al., 1993), $\delta^{18}O$ composition (Lister, 1988), and coulpled stable isotopic and trace elemental data (De Deckker and Forester, 1988). However, geochemical investigation of marine ostracodes has been relatively few (e.g., Durazzi, 1977).

Very few paleoceanographic studies using stable isotopes and trace elements from calcareous skeletons have been carried out so far in Korea. Woo (1989) analyzed the stable isotopic compositions of Recent cultured pearls, and stated that the oxygen isotopic composition of the pearl layer reflects the growth temperature during summer. Paik et al. (1992) analyzed the oxygen isotopic contents of the mollusks from the Songjeon Formation (Eoil Basin), and reported the anomalously high temperature range (26-32℃) of shallow seawater. Kim (1992) analyzed oxygen isotopes of planktonic and benthic foraminifers from the Pohang Core B, and suggested that the surface sea temperature of the Pohang Basin is estimated at 18.4 to 23.2℃. The objective of this study is to analyze the oxygen isotopic compositions of the ostracodes from the Chunbuk Formation and to infer the paleoceanographic condition prevailing during the Middle Miocene from the paleotemperatures of shallow seawater in which ostracodes inhabited.

GEOLOGIC SETTING

The Pohang Basin, the largest sedimentary basin along the eastern coast of the Korean peninsula, includes the Miocene sedimentary rocks which are up to 10 km thick (Chough, 1983). The sedimentary rocks are composed of two units: the lower unit, mainly derived by mass flow deposits forming Gilbert-type fan delta, alluvial fan, and steep-faced slope systems (Chough et al., 1993), and the upper unit, composed of hemipelagic to pelagic sediments. The stratigraphic division of the sequence is conventionally divided into several formations, which is still debatable (Um et al., 1964; Kim, 1965; Yoon, 1975; Yun, 1985; Choe and Chough, 1988). Recent sedimentological study suggested that the several fan deltas developed at different times, which make them difficult to divide into several formations only according to lithologic characters. Noh (1994) suggested a new scheme which divided the Miocene sedimentary rocks into two formations which are the Chunbuk Formation and the Pohang Formation, based on lithology and genetic relationship among strata. The Chunbuk and Pohang Formations are the lower and upper units, mentioned above. Thus, the Chunbuk Formation for this study refers to the lower unit, which was mainly deposited by mass flows. However, the distribution of the studied sections (Fig. 1) is followed after the geologic map by Um et al. (1964). The sampling localities (Seocheongri, Songhacdong, and Mulcheonri areas) consist of gravelstones interbedded with massive sandstones. The Seocheongri section shows gravelstones interbedded with massive fine to medium sandstones. Within the sandstone units, carbonate concretions are present and numerous fossils such as pectenids, oysters, gastropods, and other bivalves can be observed. This section was suggested to have been deposited in the topset of the fan delta system (Chough et al., 1993). The Songhacdong section is characterized by thick crudely stratified gravelstone with a few

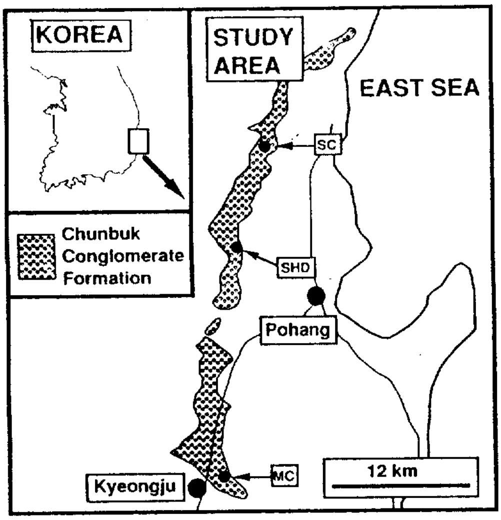

Fig. 1. Location map showing the distribution of the Chunbuk Formation and the study areas. The study areas are shown by arrows. SC=Seocheongri, SHD=Songhacdong, MC=Mulcheionri.

intercalations of massive fine to pebbly sandstones (Huh, 1991). The gravelstone unit is occasionally cemented, and this cemented unit contains oysters, bivalves, and corals as well as ostracodes in the matrix. This section appears to have been deposited at the bottomset of the fan delta system (Chough et al., 1993). Despite the fact that this section was deposited in fairly deep setting (ca 500 m deep?), the fossil assemblage including shallow marine ostracodes, corals and oyster fragments indicates that the shells were transported from the shallow marine environment nearby. The Mulcheonri section is mostly composed of massive fine to coarse sandstones with a few beds of mudstones in the upper part of the section. Carbonate concretions contain numerous fossils such as bivalves and gastropods. Detailed sedimentological information is lacking in this section, however, the fossil assemblage (ostracodes, bivalves including oysters, and gastropods) suggests that this section was probably deposited in shallow marine environment.

METHODS

Ostracode specimens were collected from three outcrops (Seocheongri, Songhacdong, and Mulcheonri) in Pohang Basin (Fig. 1). For the separation of ostracodes, samples were disintegrated using sodium sulphate method (Huh, 1991). Isotopic results were obtained from Korea Basic

Table 1. Carbon and oxygen isotopic compositions of the ostracodes from the Chunbuk Formation in Pohang Basin. Paleotemperature was calculated using the equation by Epstein et al. (1953) for calcitic shells [$T(℃)=16.0-4.14\ (\delta^{18}O_{calcite}-\delta^{18}O_{water})+0.13\ (\delta^{18}O_{calcite}-\delta^{18}O_{water})^2$], assuming that the oxygen isotopic composition of penecontemporaneous seawater was −0.38‰(SMOW).

Sample No.	Taxon	$\delta^{13}C$	$\delta^{18}O$	T (℃)	Remarks
Ph-Sc-2-1-1	*Aurila okumurai*	−4.05	−4.03		altered
Ph-Sc-2-1-2	*Trachyleberis niitsumai*	−3.39	−1.14	21.9	
Ph-Sc-2-3-1	*Trachyleberis niitsumai*	−4.96	−3.26		altered
Ph-Sc-2-3-2	*Trachyleberis niitsumai*	−5.09	−2.05	26.1	
Ph-Sc-2-3-3	*Trachyleberis niitsumai*	−5.13	−2.21	26.8	
Ph-Sc-2-4	*Urocythereis* sp.	−4.42	−1.46	23.3	
Ph-Sc-2-6	*Acanthocythereis mutsuensis*	−5.21	−0.7	19.9	
		Average		23.6	
Ph-SHD-1	*Cythere omotenipponica*	−0.79	−0.67	19.8	
Ph-SHD-2	*Acanthocythereis mutsuensis*	−3.89	−0.03	17.0	
		Average		18.4	
Ph-Mc-1-1-1	*Kotoracythere* sp.	−3.69	−1.96	25.6	
Ph-Mc-1-1-2	*Acanthocythereis mutsuensis*	−4.51	−1.19	22.1	
Ph-Mc-1-1-3	*Acanthocythereis mutsuensis*	−3.49	−0.80	20.3	
Ph-Mc-2-1	*Urocythereis* cf. *gorokuensis*	−3.86	−3.20		altered
		Average		22.7	

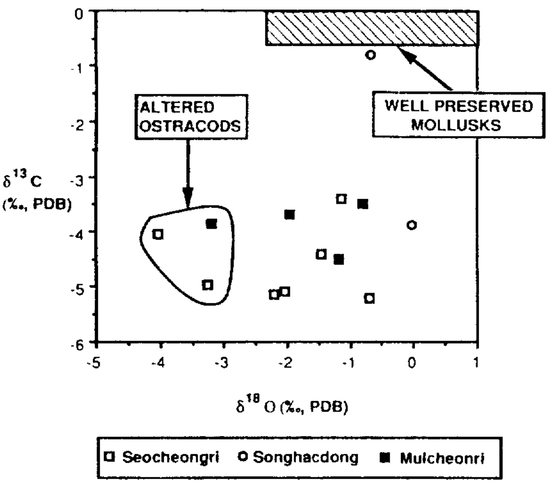

Fig. 2. Scatter diagram of $\delta^{18}O$ vs. $\delta^{13}C$ for the ostracodes analyzed according to the locality. Isotopic data of well preserved molluks are from Woo et al. (submitted to Journal of Geological Society of Korea).

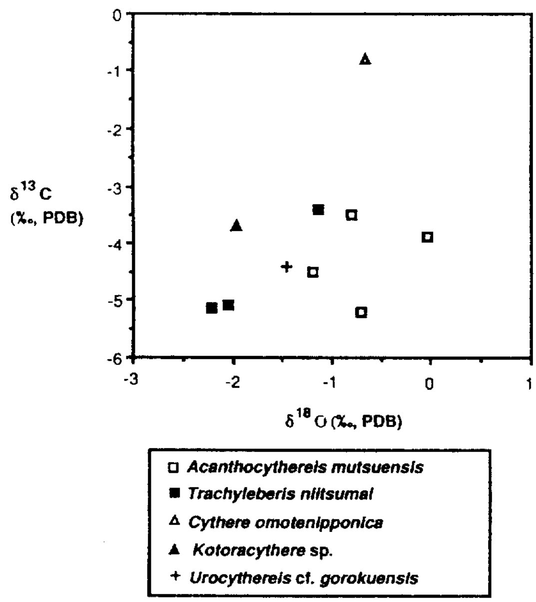

Fig. 3. Scatter diagram of $\delta^{18}O$ vs. $\delta^{13}C$ for the ostracodes analyzed according to the taxon.

Science Center. About 1-2 mg of the ostracodes (about 5 to 6 specimens) was reacted with 100% phosphoric acid at 90℃ for 5 minutes using a cold trap, and CO_2 gas is automatically injected and analyzed by mass spectrometer (VG Prism II). Analytical error of carbon and oxygen isotopes is ± 0.2‰. All the oxygen and carbon isotopic values of ostracodes are reported relative to PDB, unless designated as SMOW.

RESULTS AND DISCUSSION

Stable isotopic compositions of the ostracodes analyzed for this study are listed in Table 1. $\delta^{18}O$ compositions of all the ostracodes range from −4.03 to 0.03‰ (Fig. 2). Most of these values are coincident with those of well preserved mollusks (−2.4 to +1.3‰) in the Pohang Basin (Woo et al., submitted) except for the three samples. These three samples may have been diagenetically altered due to the following reasons:

1. Texturally well preserved, co-existing mollusks show similar oxygen isotopic compositions from −2.4 to +1.3‰ (Woo et al., submitted).

2. If these three shells secreted their shells in oxygen isotopic equilibrium with ambient seawater from which the shell grew, the paleotemperature was abnormally high for shallow seawater (ca 31 to 36℃).

It can not be ruled out that *Aurila okumurai and Urocythereis* cf. *gorokuensis* might have secreted their shells out of oxygen isotopic equilibrium with ambient seawater, because only one specimen was analyzed for both species. However, *Trachyleberis niitsumai* was probably diagenetically altered, because $\delta^{18}O$ value of the same species from the same locality is within the range of the calcite equilibrium (Figs. 2 & 3). Thus, $\delta^{18}O$ values of the unaltered ostracodes (or ostracodes reflecting isotopic equilbrium) from Seocheongri, Songhacdong, and Mulcheonri areas range from −2.2 to −0.7‰, −0.7 to 0.0‰, and −2.0 to −0.8‰, respectively. Paleotemperature can be calculated using the following equation by Epstein et al. (1953) for the ostracodes, because the original mineralogy of ostracodes is a low Mg-calcite:

$$T(℃)=16.0-4.14(\delta^{18}O_{calcite}-\delta^{18}O_{water})+0.13(\delta^{18}O_{calcite}-\delta^{18}O_{water})^2$$

where, T=the temperature at which ostracodes

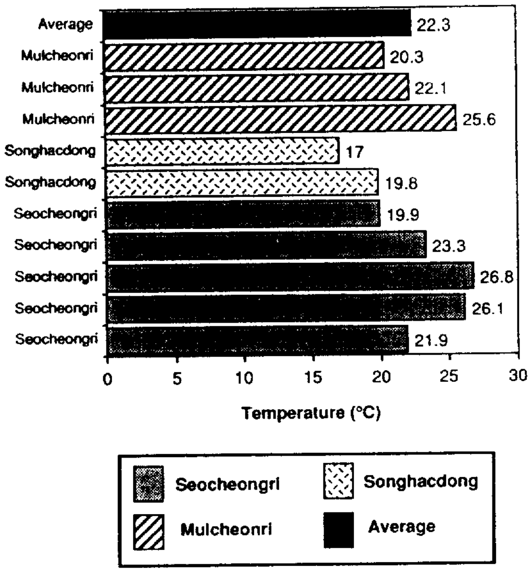

Fig. 4. Paleotemperatures calculated and averaged from the $\delta^{18}O$ compositions of the ostracodes in Mulcheonri, Songhacdong, and Seocheongri areas of the Pohang Basin.

grew.

$\delta^{18}O_{calcite}$ = oxygen isotopic composition of ostracodes (vs. PDB).

$\delta^{18}O_{water}$ = oxygen isotopic composition of ambient seawater from which the ostracodes grew (vs. SMOW).

To calculate the composition of $\delta^{18}O_{water}$, the relationship between salinity and $\delta^{18}O$ of surface seawater (Williams, 1977) is used. This relationship was originally suggested for Pacific shallow seawater at 13°S, however, this relationship was the closest approximation which can be applied for the watermass affecting the Korean peninsula. Thus, the $\delta^{18}O$ of the Middle Miocene surface seawater (vs. SMOW) can be calulated by the following equation:

$$\delta^{18}O_{water} = 0.553 \times \text{salinity} - 19.35$$

Since averaged annual salinity value near Pohang area is 34.3‰ (Fisheries Research and Development Agency, 1986), $\delta^{18}O$ value of the surface seawater during the Middle Miocene would have been −0.38‰. Therefore, the paleotemperatures of the shallow seawater of the Seocheongri, Songhacdong, and Mulcheonri areas range from ca 20 to 27°C (average = 24°C), 17 to 20°C (average = 18°C), and 20 to 26°C (average = 23°C), respectively (Table 1, Fig. 4). Recent temperature data of surface seawater near Pohang area show that temperature variation is significant throughout the year from 10 to 20°C. It is known that most of the organisms secret their shells during the warm period (summer) of the year, and the recent temperature of the surface seawater (10~30 m deep) near Pohang area range from 17 to 19°C between August and October (Fisheries Research and Development Agency, 1986). Thus, the calculated paleotemperature of the shallow seawater near Pohang area during the Middle Miocene was almost equal to or slightly higher than the observed present-day temperature. It is not clear why the paleotemperature of the Songhacdong area is relatively lower than those of the other two areas. Perhaps, the sediments in Songhacdong area might have been deposited in relatively deeper water (Huh, 1991).

Carbon isotopic compositions of the well preserved ostracodes analyzed for this study show two distinctive groups (Fig. 3). Carbon isotopic value of *Cythere omotenipponica* is −0.8‰ (PDB), reflecting marine carbonate carbon composition. However, carbon isotopic compositions of the other ostracodes such as *Aurila okumurai, Trachyleberis niitsumai, Urocythereis* sp., *Urocythereis* cf. *gorokuensis*, and *Acanthocythereis mutsuensis* range from −5.2 to −3.4‰ (PDB). These low carbon isotopic values could result from the following causes:

1. The ostracode shells were diagenetically altered. This implies that the diagenetic system was closed with respect to both oxygen and carbon isotopes (Woo et al., 1993). Oxygen isotopic values merely reflect the ambient seawater, whereas the isotopically light carbon was introduced by decay of organic matter during shallow burial (bacterial oxidation or sulfate reduction zone).

2. The most of the ostracodes analyzed for this study did not secret their shells in carbon isotopic equilibrium with ambient seawater.

The former cause is quite unlikely, because the other altered mollusks such as *Crassostrea* sp. show more negative carbon isotopic values (ca −15 to −10‰; Woo et al., submitted). Especially, in these oysters, only chalky layer was filled with secondary calcite crystals whereas other calcitic layer such as foliated layer in pectenid and oyster has been intact (Woo et al., 1991).

Therefore, it appears that the low carbon isotopic contents indicate that the ostracodes might have secreted their shells out of carbon equilibrium with ambient seawater. This disequilibrium was most likely to have resulted from metabolic (=vital) effect, rather than temperature or productivity, because the $\delta^{13}C$ of calcite is relatively insensitive to change in temperature (Anderson and Arthur, 1983) and the $\delta^{13}C$ values of well preserved mollusks reflect marine carbonate carbon (Fig. 2; Woo et al., submitted).

CONCLUSIONS

The oxygen isotopic compostions of the well preserved ostracodes of the Chunbuk Formation in Pohang Basin show that the paleotemperature of the Middle Miocene shallow seawater in Pohang Basin was almost equal to or slightly higher than the present summer temperature near Pohang area. Also, except for one species (*Cythere omotenipponica*), the carbon isotopic values of the other ostracodes (*Aurila okumurai, Trachyleberis niitsumai, Urocythereis* sp., *Urocythereis* cf. *gorokuensis*, and *Acanthocythereis mutsuensis*) suggest that the ostracodes might have secreted their shells out of equilibrium with ambient seawater.

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