CALCAREOUS NANNOPLANKTON FROM THE SEOGUIPO FORMATION OF CHEJU ISLAND, KOREA AND ITS PALEOCEANOGRAPHIC IMPLICATIONS

Songsuk Yi[1], Hyesu Yun[2], Duck-Keun Choi[1], Sun Yoon[3], and Gi-Won Koh[4]

[1] Dept. of Geological Sciences, Seoul National Univ., San 56-1 Sinrim-dong, Kwanack-gu, Seoul, Korea
[2] Dept. of Geology, Chungnam National Univ., 220 Kung-dong, Yusung-gu, Taejon, Korea
[3] Dept. of Geology, Pusan National Univ., 30 Changjeon2-domh, Keumjeong-gu, Pusan, Korea
[4] Water Resources Development Office, Cheju-do provincial Goverment, 312-1 Yeon-dong, Cheju, Korea

ABSTRACT

Twenty species of calcareous nannofossils belonging to 11 genera are identified from the Seoguipo Formation in Cheju island, Korea. On the basis of the marker species, the Seoguipo Formation is biostratigraphically assigned to the *Pseudoemiliania lacunosa* Zone (NN19), which corresponds to the combined zones of *Emiliania annula - Emiliania ovata* (CN13a - CN14a) of latest Pliocene and Early Pleistocene. Generally, cold-water species is dominant in the lower part, whereas warm-water one in the upper part. This is interpreted the palaeoceanographic condition has changed from cooling to warm phase. The change in floral composition and abundance of specific species allows the recognition of 4 ecostaratigraphic units in the Seoguipo Formation and the migration of oceanographic frontal boundary. According to nannofossil distribution in the study area, the position of an oceanographic boundary between warmer water and cooler water appeared to have oscillated north-south over the Korea Strait and Cheju island in response to glacial and interglacial cycles. The geologic time of the interpreted paleoceanographical changes determined by nannofossil biochronology is well agreed with the results obtained from the Japan Sea (East Sea) and Japan-Sea side of Japan.

Key words: Nannoplankton, Seoguipo Formation, Bio- and Ecostratigraphy, alaeoceanography, Cheju island, Korea.

INTRODUCTION

Cheju Island located 90 Km off southern coast of Korea at 33° 12′ - N33° 34′N, 126° 10′ - 126° 58′E was formed by Late Cenozoic volcanic activity (Figure 1). The Seoguipo Formation, the highly fossiliferous marine formation, seems to be deposited just before insetting of Quaternary volcanism, since it underlies Pleistocene volcanic rocks that covered most part of the island. The Seoguipo Formation is mainly composed of sandstone with minor amount of interbedded conglomerate and mudstone. It is well developed at subsurface level all over the island and only exposed on southern coast of Seoguipo. The subsurface Seoguipo formation is encountered in core samples of bore holes drilled numerously in the island.

Yokoyama (1923) first reported molluscan fossils from these sedimentary deposits designating its geologic age as Upper Pliocene. Haraguchi (1931), who described diverse invertebrate faunas such as mollusks, brachiopods, echinoids, corals and fish teeth, named this fossiliferous sedimentary formation the Seikiho (Seoguipo) Formation of Pleistocene epoch. After Haraguchi's research, numerous works including detailed field survey, paleontological, magnetostratigraphic, and sedimentological studies were carried out for determination of geologic age, depositional environment, and stratigraphical zonation (Kim, 1972; Won, 1975; Tamanyu, 1990; Lee, M.W., 1982a, 1982b; Kim, 1984; Nomura, 1984; Yun et al., 1987; Min et al., 1986; You et al., 1987; Yoon, 1988; Lee E.H., 1990; Yoon, 1995). However, there was no consensus for the geologic age of the Seoguipo Formation suggesting different ages such as Pliocene, Pleistocene, or Pliocene to Pleistocene (Table 1). Several studies analyzed paleoclimate and paleoceanographic conditions of the Seoguipo formation based on molluscan fauna and isotope data (Yoon, 1988; Amano, 1994; Park et al., 1994; Woo et al., 1995). The results for the water temperature are also contradictory reporting warm or cold glacial environment during deposition of the formation.

Cheju island is located in oceanic pathway to the Japan Sea. This area was paleoclimatologically and tectonically sensitive area and often affected by small- or large-scaled changes of tectonic (Inoue, 1982) or climatological settings. The climatic or sea-level changes may cause subsidence or uplift which in turn affect current system and biofacies. Therefore, biofacies analysis may deductively provide a clue in the climatic and tectonic history of this area, which is not only important for the development of Cheju island and the Korea Strait, but also for the evolution of the Japan Sea during late Pliocene and Pleistocene (Muza, 1992; Rahman, 1992).

One of solutions related to the debatable results of the Seoguipo formation is to analyze fossil contents section by section, and thus to establish the biozonation, subdivision of geologic age and paleoenvironmental conditions. The detailed analysis of nannofossil assemblages enables fine zonation and gives information on paleoenvironmental fluctuation during the Seoguipo time. Thus, Its resolving power contributes in determining geologic time, frequency, and sort of paleoceanographic changes during deposition of the Seoguipo formation, which are necessary for better understanding of the paleoclimatic and tectonic history of the Cheju island and neighboring area.

NANNOFOSSIL FLORA

Twenty species of calcareous nannofossils belonging to 11 genera are identified from 20 samples from the Seoguipo Formation. Nannofossils are generally common to abundant. However, dominance of a few species changes throughout the formation showing uneven distribution. The dominant species are *Gephyrocapsa* spp. (small), *Coccolithus pelagicus*, *Pseudoemiliania lacunosa*, *Gephyrocapsa caribbeanica*, and *G.* oceanica in ascending order of the formation. The minor species include *Braarudosphaera bigelowii*, *Calcidiscus leptoporus*, *C. macintyrei*, *Ceratolithus cristatus*, *Coccolithus* sp. *Helicosphaera carteri*, *H.* sp., *Pontosphaera japonica*, *P. discopora*, *Reticulofenestra asanoi*, *R.* spp. (small), *Syracosphaera pulchra*, *S.* sp., *Umbilicosphaera hulburtiana* and *U. sibogae.*

The nannoflora in the formation shows transition from cold subpolar to warm subtropical assemblage. Abundance of the typical cold-water indicator, *C. pelagicus* varies greatly within the formation. *C. pelagicus* is extremely abundant in the lower part of formation and gradually decreases upward upto few to barren. Subtropical nannofossils such as, G. *caribbeanica*, *G.* spp. (small), *G. oceanica*, *C. leptoporus*, *U. sibogae*, *S. pulchra*, and *C. cristatus* are common in the upper part of formation.

The assemblage characteristics change in response to the paleoceanographic conditions during deposition of the formation and hence allow recognition of four ecostratigraphic units in outcrop section of the Seoguipo Formation (Figure 2). Unit I (SGF 1-2) contains dominant *G.* spp. (small), common *P. lacunosa* and *Reticulofenestra* spp. (small), and few of C. pelagicus. The flora of these strata consists of mixtures of warm and cold-water species. Unit II (SGF 3-10) is characterized by a prominent peak in abundance of cold-water species, *C. pelagicus.* Unit III (SGF 11-18) shows abrupt decrease of *C. pelagicus* and increase of subtropical to tropical species including G. spp. (small), *G. caribbeanica*, *G. oceanica.*, *C. leptoporus*, *U. sibogae*, *S. pulchra*, and *C. cristatus*. The change from cold to warmer flora and increase of oceanic species took place suddenly at SGF 11. Unit IV (SGF 19, 85S30) revealed dominance of *G. oceanica*, G. *caribbeanica*, *S.* spp. (small), U. *hulburtiana* and barren of *C. pelagicus.*

NANNOFOSSIL BIOCHRONOLOGY

The Seoguipo Formation yields the Pleistocene marker species such as, *G. caribbeanica*, *G. oceanica*, *P. lacunosa*, *C. macintyrei*, and *R. asanoi* (Table 2, Figure 2). Among them *G. caribbeanica* the first appearance datum (FAD 1.66 Ma; Takayama and Sato, 1986) of which has been used for the determination of the Pliocene-Pleistocene boundary is first recognized at sample SGF 5. *G. oceanica* (FAD 1.57 Ma; Haq et al., 1977), another important indicator for the Pliocene-Pleistocene boundary, occurs at sample SGF 7. *C. macintyrei* with the last occurrence datum (LAD) of 1.48 Ma (Wei and Gartner, 1993) was encountered in sample SGF 5, although the occurrence of *C. macintyrei* may not be properly detected because of its rarity in the samples, and be expected in the somewhat younger samples. Compiling all these data, the Pliocene-Pleistocene boundary can be drawn between SGF 4 and SGF 5. Consequently, the lowermost part (SGF 1-4) can be presumed to be older than 1.66 Ma belonging to latest Pliocene.

The sample SGF 7 indicates the lower boundary of Zone CN14a defined by the first appearance of G. oceanica (1.57 Ma). The presence of *P. lacunosa* (LAD 0.465 Ma; Wei and Gartner, 1993) indicates that the uppermost part of formation is older than 0.465 Ma in age . The specimens of R. *asanoi* with FAD of 1.17 Ma (Muza, 1992, p. 164) is first found in the sample SGF 10 at the end of cooling phase. Therefore, the upper section of the sample SGF 10 is younger than 1.17 Ma. This species is lastly recorded in the sample SGF 18, near the upper boundary of formation, suggesting that this layer is older than the LAD of *R. asanoi* (0.83 Ma; Takayama and Sato, 1987).

Thus, it is clear that the Seoguipo Formation comprises latest Pliocene to Early Pleistocene nannofloras. The lower boundary is older than 1.66, while the upper one is slightly younger than 0.83 Ma. The calcareous nannofossil biostratigraphy of this formation is assigned to the *P. lacunosa* Zone (NN19) (Martini, 1971), which corresponds to the combined zones *E. annula* to *E. ovata* (CN13a - CN14a; Okada and Bukry, 1980) of latest Pliocene to Early Pleistocene.

The FAD and LAD of index nannofossils such as *G. caribbeanica*, *G. oceanica*, *P. lacunosa*, *C. macintyrei*, *R. asanoi* and the characteristic nannflora of four ecostratigraphic units recognized in outcrop section are also observed in 12 core samples of Cheju Island. These facts imply that the outcrop and subsurface strata are the same ones. The ecostratigraphic units and its appearing order, one cold-dominant transitional, cold, warm-dominant transitional, and warm phase from botton to top- can be used as a good stratigraphic tool in Cheju Island.

PALEOCEANOGRAPHY

Four ecostratigraphic units established by basis of the floral composition reflect paleoceanographic conditions. The lowermost section, Unit I is characterized by co-existence of cold subpolar and warm subtropical water masses. The cooler water influence increases upward reaching its peack in the middle part of the core (Unit II). It deteriorates toward the upper part (Unit III) until it is totally resplaced in Unit IV by effect of warmer water. This is interpreted cooling phase has begun in the Unit I, culminated in the Unit II, and finally faded out at the upper section (Unit III and IV). This seems to be reflected by glacial and interglacial cycle rather than local influence of warm-water current. Comparing the cooling phase with biochronological data, it is certain that glacial cycle in the study area started shortly before 1.66 Ma (FAD of G. *caribbeanica*) and halted around 1.17 Ma (FAD of *R. asanoi*).

The distribution of calcareous nannofossils in the Seoguipo formation also records the position of an oceanographic frontal boundary between warmer water derived from a branch of the Kuroshio Current as it entered the Japan Sea to the north and cooler water introduced into the western portion of the Japan Sea derived from the Liman Current. This oceanographic front oscillated back and forth in response to proceeding cooling phase. It probably lied near Cheju island in the Unit I and III, whereas south and north of the island in the Unit II and IV, respectively.

REFERENCES

Amano, K., 1994, An attempt to estimate the surface temperature of the Japan Sea in the early Pleistocene by using a moluscan assemblage. Paleogeography, Paleoclimatology, Paleoecology, vol. 108, pp. 369-378.

Haraguchi, K., 1931, Gelogy of Saishu Island. Bulletin on the Geological Survey of Chosen (Korea). vol.10, pt. 1, pp. 1-34, pl. 1-9 (In Japanese); pp. 1-12, pl. 1 (In English).

Inoue, E., 1982, Geological problems on Cretaceous and Tertiary rocks in and around Tsushima-Korea Straits. United Nations ESCAP, CCOP Technical Bulletin, vol. 15, pp. 85-121.

Kim, B. K., 1972, A stratigraphic and paleontologic study of the Seogwipo formation. The Memoirs for Professor Chi Moo Son's Sixtieth Birthday. pp. 169-187. (In Korean with English abstract).

Kim, B. K., 1984, Pliocene brachiopods from the Seogwipo Formation of Jeju Island, Korea. Journal of the National Academy of Sciences, Republic of Korea, Natural Sci.ences Series, vol. 23, pp. 167-190, pls. 4.

Lee, M. S., 1982a, Geology of Jeju vocanic Island, Korea. The journal of the Japanese Association of Mineralogists, Petrologists and Economic Geoologists, Vol. 77, pp. 55-64. (In Japanese with English abstract).

Lee, M. W., 1982b, Petrology and geochemistry of Jeju volcanic Island, Korea. Sciences Report of the Tohoku University, Sendai, 3 series , vol. 15, no. 2, pp. 177-256.

Lee, M. W., 1982b, Petrology and geochemistry of Jeju volcanic Island, Korea. Sciences Report of the Tohoku University, Sendai, 3 series , vol. 15, no. 2, pp. 177-256.

Lee, E. H., 1990, Pleistocene ostracoda from the marine sedimentary strata of the Cheju Island, Korea. Unpublished PH. D. Thesis, Korea University., 400p.

Martini, E. ,1971, Standard Tertiary and Quaternary nannoplankton zonation. In, Farinacci, A. ed., Proceedings II Planktonic Conference, Roma, 1970, vol. 2, pp. 739-785.

Min, K. D., Won, J. S. and Hwang, S. Y., 1986, Paleomagnetic study on the volcanic and sedimentary rocks of Jeju Island. The Journal of the Korean Institute of Mining Geology, vol. 19, no. 2, pp. 153-163. (In Korean with English abstract).

Muza, J. P., 1992, Calcareous nannofossil biostratigraphy from the Japan, site 798 and 799 evidence of an oscilationg Pleistocene oceanographic frontal boundary. In, Pisciotto, K., Ingle, J. C.Jr., von Breymann, M. T. and Barron, J., et al., Proceedings of the Ocean Drilling Program, Scientific Results, vol. 127/128, Pt. 1, pp. 155-169 College Station, TX (Ocean Drilling Program).

Nomura, R., 1984, Notes on the Cassidulinid foraminifera from Jeju Island, Korea. The memoirs of teh Faculty of Education Shimane University, vol. 18 (Natural Science), pp. 21-23.

Okada, H. and Bukry, D. 1980, Supplementary modification and introduction of code numbers to the low-latitude coccolith biostratigraphic zonation (Bukry, 1973; 1975). Marine Micropaleontology, vol. 5, no. 3, pp. 321-325.

Rahman, A., 1992, Calcareous nannofossil biostratigraphy of leg 127 in the Japan Sea. In, Pisciotto, K. A., Ingle, J. C. Jr., von Breymann, M. T., Barron, J. et al., Proceedings of the Ocean Drilling Program, Scientific Results, vol. 127/128, Pt. 1, pp. 171-186 College Station TX (Ocean Drilling Program).

Takayama, T. and Sato, T. 1987, Coccolith biostratigraphy of the North Atlantic Ocean, Deep Sea Drilling Project Leg 94. In Ruddiman, W. F., Kidd, R. B., Thomas, E., et al., Initial Reports of DSDP, Vol. 94, (Pt. 2) U.S. Goverment. Printing Office), pp. 651-702.

Tamanyu, S., 1990, The K-Ar ages and their stratigraphic interpretation of the Cheju Island volcanica, Korea. Bulletin of the Geological Survey of Japan, vol. 41, no. 10, pp. 527-537.

Wei, W. and Gartner, S., 1993, Neogene calcareous nannofossils from sites 811 and 819 through 825, offshore Northeastern Australia. In McKenzie, J. A.,Davies, P. J., Palmer-Julson, A., et al., Proceedings of the Ocean Drilling Program, Scientific Results, vo. 133 College Station, TX (Ocean Drilling Program), pp. 19-37.

Won, C. K., 1975, Study of geologic development and the volcanic activity of the Jeju Island. Journal of Science, Kun Kook University, vol. 1, pp. 7-48. (In Korean with English abstract).

Won, J. K., Matsuda, J., Nagao, K., Kim, K. H. and Lee, M. W., 1986, Paleomagnetism and radiometric age of trachytes in Jeju Island, Korea. The Journal of the Korean Institute of Mining Geology, vol. 19, no. 1, pp. 25-33.

Woo, K. S., Cheong, D. K. and Park, B. K., 1995, Paleoceanographic investigation from the clacareous skeleton of the Pleistocene Seoguipo Formation, Cheju Island, Korea. The Journal of the Korean Society of Oceanography, vol. 30, no. 3, pp. 216-226.

Yokoyama, M., 1923, On some fossil shells from the Island of Saishu in the Strait of Tsushima. Journal of the College of Science, Imperial University of Tokyo, vol. 44, art. 7, pp. 1-9, pl. 1.

Yoon, S., 1988, The Seoguipo molluscan fauna of Jeju Island, Korea. Saito Ho-on Kai Special Publication (Professor T. Kotaka Commem.orative volume), pp. 539-545.

Yoon, S., Koh, G. W. and Kim, I. T., 1995, Development history of Cheju Island. Bulletin of Cheju-do Province Goverment, vol. 98, pp. 148-164 (In Korean).

You, H. S., Koh, Y. K. and Kim, J. Y., 1987, Nannofossils from the Seoguipo Formation in Cheju Island, Korea. Journal of the Paleontological Society of Korea, vol. 3, no. 2, pp. 108-121.

Yun, S. K., Han, D. S. and Lee, D. Y., 1987, Quaternary geology in the Southern part of Jeju Island. Korea Institute of Energy and Resources, Research Report, KR-86-2-(B)-2, pp. 1-64 (In Korean with English abstract).