GEOLOGICAL SIGNIFICANCE OF SILICEOUS MICROFOSSILS FROM DOGO, OKI ISLANDS

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ABSTRACT—A combined siliceous biochronology from surface samples of Dogo, Oki Islands is presented. Samples from Karao and Minoura sections contain more abundant and diversified biosiliceous microfossils than those from Shionohama and Inoyama sections. All known siliceous microfossil groups were observed, and the biostratigraphic events recognized from the present study serve as an informational bridge for the early Middle Miocene succession between Japan and Korea.

Key words: Siliceous microfossils, early Middle Miocene, Oki Islands, Japan.

INTRODUCTION

Dogo Island is the largest of the Oki Islands in the Sea of Japan and is located about 60 km north of the Shimane Peninsula of Honshu (Yamasaki, 1984) (Fig. 1A). Geologically, various alkaline rocks occupy most of the island with limited marine diatomaceous sediments outcropping in the southern and western parts of the island (Fig. 1B). In spite of the commercial significance of these diatomites, most of the previous investigations on the island were focused on volcanic rocks (see Okubo, 1984 for a historical review). It was the discovery of Middle Miocene Miogypsina (Okubo and Takayasu, 1980) that renewed the interest of paleontologists and geologists. Okubo and Yokota (1984) suggested that the diatomites belong to the Denticulopsis lauta or D. lauta-D. hustedtii Zone of Koizumi (1973).

Geographically, the island, together with other smaller islands, is situated near the southern end of the Sea of Japan and represents the only land between the home islands of Japan and Korea. Analysis of contained microfossils from the island would, therefore, bridge the informational gap on these microfossils between the well-known Japanese occurrences and the Pohang Basin of Korea. Such an analysis was carried out under the U.S.—ROK (Republic of Korea) Science Cooperative Program (Ling et al., 1988).

In the meantime, Kobayashi visited the island as part of his doctoral research on the silicoflagellate biostratigraphy of Japan (Kobayashi, 1988). We present our combined results in this paper.

SAMPLES ANALYZED AND RESULTS OF STUDY

The outcrop samples examined for the biosiliceous microfossils were collected from four sections, Inoyama Quarry, Minoura Quarry, Shionohama Quarry (abandoned) and southwestern part of the Karao (tunnel) (Fig. 1C). All these sections are described in detail by Kobayashi (1988), and are briefly summarized together with the geological occurrence of microfossils (Table 1-4) in ascending order as follows:

Fig. 1. Index map showing geographical location of Dogo, Oki Islands (Fig. 1A). The distribution of commercial diatomaceous deposits of Dogo is marked with filled smaller circles, and the four outcrop sections are indicated with filled larger circles (Fig. 1B). The detailed sample locations are presented (Figs. 1C and 1D). INY, Inoyama Quarry section; KOT, Karao (Tunnel) section; MIN, Minoura Quarry section; and SHO, Shionohama Quarry section.
Table 1. Geological occurrence of selected key species of radiolarians, ebridians and archaeomonads from the Shionohama (SOH) section of Dogo, Oki Islands.

1. Shionohama section (SOH): Diatomite is exposed along the coastal road side facing Tsuma Bay between Kamo and Tsuma, and was once excavated for industrial purposes. The lower part of the section consists of fragile but hard mudstone, and the remaining strata can be divided into two parts, diatomite below and pumiceous sandstone above. Judging from the diatom assemblage (Actinocyclus ingens-Denticulopsis lauta Zone), the section is stratigraphically lower than the Inoyama and Minoura sections, but all of them belong to the Kumi Formation.

Although silicoflagellate occurrences are limited to only the upper part of the section, the assemblage is assignable to the Corbiscma triacantha Interval-zone. A few radiolarian species are characteristically limited to sample #4 of the lower section: Lychnocanoma sp. and Didimocystis mammifera. On the other hand, except for Cyrtocapsela tetrapera and Archaeomond mammilla, which make their initial appearance in sample #4, most of the radiolarians and ebridians and also one archaeomond including Eucytidium asanoi, Ebiropsis antiqua cornuta and Archaeosphaeridiurn pachyceon, are observed only in the upper part of the diatomite above sample #6 (Table 1).
2. Inoyama section (INY): The section is located southwest of Saigo (town), directly north of Oki Airport, and is one of the largest diatomite quarries on the island. Lithology of the area consists mainly of massive gray diatomites with a few layers of fine acidic tuff of the Kumi Formation. A nodular hard diatomite layer is observed near the base.

Of the seventeen samples examined, only eight contain siliceous microfossils. The section is assigned to the Corbisema triacanthus (silicoflagellate) Interval-zone or Denticulopsis lauta and D. hyalina (diatom) Zones, and considered as nearly coeval to the Shionoyama section.

Cyclocapsella tetrapera occurs sporadically throughout the section; on the other hand, Archaeomonas mammillosa is present only in its lower part, while both Eucyrtidium asano and Ebriopsis antia cornuta only make their appearance in the upper part with Sample #16 (Table 2).

3. Minoura section (MIN): Samples were collected from another large diatomite quarry located north of a harbor town, Minoura.

Eleven of the eighteen samples contain poorly to moderately preserved silicoflagellates which are very rare to common in abundance. The section is assigned to the Corbisema triacanthus (silicoflagellate) Interval-zone and Denticulopsis lauta and D. hyalina (diatom) Zones. Thus, the lower part of the section correlates with the upper part of the Inoyama section, but the entire Minoura section still belongs to the Kumi Formation.

Samples from the section contain abundant radiolarians, ebridians and archaemonomads (Table 3). Both Cyclocapsella tetrapera and Archaeomonas mammillosa nearly occur throughout the entire section, whereas Eucyrtidium asano and Ebriopsis antia cornuta were recovered above sample #6. The oldest occurrence of Eucyrtidium inflatum was noticed in sample #8, while the youngest appearance of Archaeosphaeridium pachyeros was observed in sample #14.

4. Karao (tunnel) section (KOT): Samples of the Karao section were collected along a road cutting about 200 m SW from the western end of the Karao Tunnel which is considered the best outcrop section from Dogo.
Table 3. Geological occurrence of selected key species of radiolarians, ebridiains and archaeomonads from the Minoura (MIN) section of Dogo, Oki Islands. See Table 1 for lithology.

Island in the abundance, diversity and preservation of its siliceous microfossils.

The samples from the section are essentially diatomite, and assignable to the Corbisera triacantha Interval-zone and Distephanus staurocanthus (silicoflagellate) Range-zone, and the Denticulopsis hyalina, D. hustedii, Crucidenticulopsis nicobarica, and D. praedimorpha (diatom) Zones.

Radiolarians, archaeomonads and ebridiains are also abundant in most of the samples. The initial appearance of Theocorys redondensis, and the last occurrence of Eucrytidium asanoi, Ebridiopsis antiqua cornuta, and Hermesium actinoporiform were recognized within the section (Table 4).

BIOSSTRATIGRAPHIC DISCUSSION

All known siliceous microfossils—archaeomonads, diatoms, ebridiains, radiolarians and silicoflagellates—were recovered from the land outcrops of Oki Island. As previously mentioned, samples from the Karao and Minoura sections contain more abundant and diversified microfossils than those from the Shionohama and Iinoyma sections. The geological occurrence of the key species is presented in Table 5 together with the relative stratigraphic position of the four sections, and the diatom (Koizumi, 1985) and silicoflagellate (Kobayashi, 1988) zonations. The age of these outcrop sections has been identified as early Middle Miocene.

Among radiolarians, successive extinctions (last occurrence) of Eucrytidium asanoi and Cyrtocapsella tetrapora from the island is in good agreement with what observed from coastal sections along the Sea of Japan on Honshu; the former disappears near the top of the Denticulopsis nicobarica Interval-zone and the latter slightly above the base of the D. praedimorpha (diatom) Zone (Takayanagi et al., 1984). A level of sharp decrease in abundance has been used by Nakaseko and Sugano.
Table 4. Geological occurrence of selected key species of radiolarians, ebridians and archaeomonads from the Karao Tunnel (KOT) section of Dogo, Oki Islands. See Table I for lithology.

Table 5. Summary of geological occurrence of selected key species of radiolarians, ebridians and archaeomonads from four outcrop sections of Dogo, Oki Islands with the reported diatom (Koizumi, 1985) and silicoflagellate (Kobayashi, 1988) zonations.
Fig. 2. Polycystine radiolarians from Dogo, Oki Islands. 181× magnification unless otherwise indicated. 1, Collosphaera sp. KOT 13, R-1 (X34 / 3); 2, Stylatractus universus, MIN 17, R-1 (Q33 / 2); 3, Flustrilla sp. A., MIN 11, R-1 (M36 / 2); 4, Flustrilla sp. B., MIN 11, R-1 (K25 / 2); 5, Circuliscus sp. cf. C. microporus, MIN 12, R-1 (K11 / 0); 6, Spongopyle osculosa, MIN 18, R-1 (N30 / 2); 7, Spongoidiscus sp., SOH 12, R-1 (Y14 / 3); 8, Thecosphaera akiacensis, MIN 17, R-1 (O13 / 3); 9, Spongocore puella, KOT 1, R-1 (O25 / 1); 10, Larnacantha polycantha, INY 16, R-1 (Y38 / 4); 11, Sphaeropyle langi, KOT 1, R-1 (D28 / 0); 12, Trissocyclid sp. 1, KOT 7, R-1 (Q3 / 3), ×226; 13, Trissocyclid sp. 2, SOH 10, R-2 (X13 / 3), ×226; 14, Trissocyclid sp. 3, KOT 1, R-1 (U7 / 1), ×226; 15, Didymocystis mammiforma, SOH 4, R-1 (37 / 4); 16, Cyrtocapsella tetrapera, MIN 12, R-1 (C34 / 0).
Fig. 3. Siliceous microfossils from Oki, Dogo Islands. 181× magnification unless otherwise indicated. 1, Stichocorys delmontensis, KOT 13, R-2 (E25 / 1); 2, Eucyttidium asanoi, SOH 10, R-1, (020 / 4); 3, Eucytidium inflatum, KOT 8, R-1 (010 / 0); 4, Anthocorys (? akitaensis, MIN 14, R-1 (S30 / 2); 5, Dicyocorys bicornis, KOT 6, R-1 (Q32 / 3); 6, Lychnocanoma sp., KOT 1, R-1 (J7 / 0); 7, Phormosthychus cornul, KOT 6, R-1 (R29 / 0); 8, Ammodockium rectangular, SOH 10, R-1 (N8 / 4), ×724; 9, Etripsis antiqua cornul, MIN 8, L-2 (R7 / 1), ×724; 10, Etripsis antiqua antiqua MIN 6, L-2 (S15 / 0), ×724; 11, Hermesinum adriaticum, KOT 6, L-2 (Q3 / 0), ×724; 12, Hermesinum actinoporum, MIN 8, L-2 (S38 / 3), ×724; 13, Hermesinum actinoporum, MIN 8, L-2 (V37 / 1), ×724; 14, Archaeomonas mammillosa, SOH 4, L-2 (S4 / 2), ×724; 15, Archaeosphaeridium sp., INY 8, L-2 (G5 / 4), ×724; 16–17 Archaeosphaeridium pachyceros, different focus levels. SOH 10, L-2 (J7 / 2), ×724.
(1973) to define the top of their *Cyrtoecapsella tetrapera* Zone. A recent radiolarian study from the Suzu area on the Noto Peninsula by Funayama (1988) places the boundary of subzones a and b of the *Eucyrtidium inflatum* Zone at this level. In spite of this agreement, it is interesting to note here that no specimens of *Lithopera renze renze* were observed in the examined Dogo samples. On the other hand, the initial appearance of *Thecocorys redondensis* was recognized during the present study below the extinction level of *Eucyrtidium asanoi*.

Similar radiolarian events and datum levels were also documented recently from the Korean Peninsula. In Miocene sections of the Pohang area (Ling et al., 1988), occurrence of *Eucyrtidium asanoi* was rare, but the sequence of initial appearance of *Thecocorys redondensis* followed by the last occurrence of *Cyrtoecapsella tetrapera* in ascending order affirms the significance of these datum levels. A near coincidence of the extinction of *Corbisema triacantha* (silicoflagellate) with that of *Cyrtoecapsella tetrapera* provides an additional criterion for recognizing the above events.

Finally, the confinement and extinction of *Archaeoecphaeridae pachyceros* within the *Denticulopsis hyalina* Zone and *Corbisema triacantha* Interval zone here recognized provide a further important biostratigraphic datum for the area and thus help link such occurrences between the Noto Peninsula (Bachmann, 1964) and the Pohang area of Korea (Ling and Kim, 1983; Ling et al., 1988).

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TAXONOMIC NOTES

Most of the siliceous microfossils observed during the present study have been discussed in various, recent and readily accessible publications; therefore only the original and most recent reference are presented below together with some remarks. Most of the representative taxa are illustrated in Figs. 2 and 3. The location of illustrated specimens in the strreni strips are indicated by section, sample number, slide number and position in England Finder in brackets. All slides examined for the present paper will be deposited permanently in the micropaleontology collection of the Department of Geology, Northern Illinois University.

Archaeomonads:

Archaeomonas mamilllosa Tynan, 1960, p. 37, pl. 1, fig. 9; Bachmann, 1964, p. 113, pl. 7, figs. 2, 2a; Ling and Kim, 1983, p. 248, pl. 1, figs. 1-4. (Fig. 2-14)

Archaeoepchaeridium pachyceros Deflandre, 1933, p. 88, figs. 40, 41; Bachmann, 1964, p. 113, pl. 7, figs. 4, 5, 5a; Ling and Kim, 1983, p. 248, pl. 1, figs. 7, 8. (Figs. 2-16, 17)

Archaeoepchaeridium sp. Ling and Kim, 1983, p. 248, 249, pl. 1, figs. 5, 6 = Archaeoepchaeridium sp. cf. *A. ornatum* Deflandre, Tynan, 1960, p. 37, pl. 1, fig. 15. (Fig. 2-15)

Ebridians:

Ammodochium rectangulare (Schulz) Deflandre, 1932, p. 303-305, figs. 1-13 = Ebrinia antiqua var. rectangulare Schulz, 1928, p. 274, figs. 72a-d. (Fig. 2-8)

Ebrinia antiqua antiqua (Schulz) Ling, 1977, p. 215, pl. 3, figs. 17, 18 = Ebrinia antiqua Schulz, 1928 (part), p. 273, 274, fig. 69b (only). (Fig. 2-10)

Ebrinia antiqua cornuta Ling, 1977, p. 215, 216, pl. 3, figs. 19-22 = Ebrinia antiqua Schulz, 1928 (part), p. 273, 274, figs. 69c and f (only). (Fig. 2-9)

Herminium adriaticum Zachariasson, 1906, fig. Loeblich et al., 1968, p. 168, fig. 40, pl. 40, figs. 9a-c, 10. (Fig. 2-11)

Herminium actinoporum Deflandre, 1951, p. 46, 68, figs. 151, 152. (Figs. 2-12, 13)

Radiolarians:

Anhcyores ? actiensiak Nakaseko, 1959, p. 128; Nakaseko et al., 1965, fig. 2; Ling, 1971, p. 696, 697, pl. 2, figs. 17, 18. (Fig. 2-4)

Circococis sp. cf. *C. microporus* (Stöhr) = Porodiscus microporus (Stöhr) Renz, 1974, p. 194, pl. 15. Remarks: Except for possessing an opening (pyleume?), the Dogo specimens are considered as con-specific with those reported previously as *Tematodiscus microporus* Stöhr, 1880, p. 108, pl. 4, fig. 17 = Circococis microporus (Stöhr) Kozlova in Petrushevskaya and Kozlova, 1972, p. 526, pl. 19, figs. 17. (Fig. 1-5)

Collophera sp. (Fig. 1-1)

Cyrtoecapsella tetrapera (Haeckel) Sanfilippo and Riedel, 1970, p. 145, pl. 1, figs. 13-15 = Cyrtoecapsa tetrapera Haeckel, 1887, p. 152. (Fig. 1-16)

Dicyphophon bisornis (Ehrenberg) = Lhohomella ? bisornis Ehrenberg, 1861, p. 300, 1872, p. 296, 297, pl. 2, fig. 7. (Fig. 2-5)

Didymocystis mammifera (Haeckel) Sanfilippo and Riedel, 1980, p. 1010 = Cannartidium mammiferum Haeckel, 1887, p. 375, pl. 39, fig. 16. (Fig. 1-15)

Eucyrtidium asanoi Sakai, 1980, p. 709, pl. 7, figs. 12a-b, 13a-b, 14a-b. (Fig. 2-2)

Eucyrtidium inflatum Kling, 1973, p. 636, pl. 11, figs. 7, 8, pl. 15, figs. 7-10. (Fig. 2-3)

Flustrella sp. A. Remarks: Except for the first (innermost) system, the specimens show a simple, planispirally coiled ring of similar width throughout. A few radial spines (? present only locally. (Fig. 1-3)

Flustrella sp. B. Remarks: The specimens with numerous concentric rings with slight increase of width are grouped under the present taxon. (Fig. 1-4)

Larnacantha polycantha Campbell and Clark, 1944, p. 30, 31, pl. 5, figs. 4-7. (Fig. 1-10)

Lychnocoma sp. Remarks: The specimens possess three short feet. (Fig. 2-6)

Pharchistiochaortus corbula (Harting) Nigrini, 1967, p. 85, pl. 8, fig. 9, pl. 9, fig. 3 = Lithocampe corbula Harting, 1863, p. 12, pl. 1, fig. 21. (Fig. 2-7)

Pterocoryx langi Dreyer, 1889, p. 13, pl. 4, fig. 54. (Fig. 1-11)

Spongocore puella Haeckel, 1887, p. 347, pl. 48, fig. 6. (Fig. 1-9)

Spongocidus sp. (Fig. 1-6)

Sichocorys delmontiis (Campbell and Clark) Sanfilippo and Riedel, 1970, p. 451, pl. 1, fig. 9 = Eucyrtidium delmontiis Campbell and Clark, 1944, p. 36, pl. 7, figs. 19, 20. (Fig. 2-1)

Stylactractus universus Hays, 1970, p. 215, pl. 1, figs. 1, 2. (Fig. 2-1)

Thecoephaera actiensiak Nakaseko, 1971, p. 63, pl. 1, figs. 4a-b. (Fig. 1-8)

Thecocorys redondois (Campbell and Clark) Kling, 1973, p. 638, pl. 11, figs. 26-28 = Thecocorys redondois Campbell and Clark, 1944, p. 49, pl. 7, fig. 4.

Trissocyclus sp. 1. Remarks: The specimens are characterized by large sagittal lattice pores and lattice bars. (Fig. 1-12)

Trissocyclus sp. 2. Remarks: Lattice shells with the appearance of a
smooth thin sheet which is perforated by small, circular pores. (Fig. 1-13)
Trissocyclid sp. 3. Remarks: Similar to the above Trissocyclid sp. 2 except that the lattice shell extends below the basal ring, which is also perforated by similar pores. (Fig. 1-14)

REFERENCES


