557. NANNOFOSSILS FROM JAPAN I. MIocene DISCOASTERS FROM NOTO

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Introduction

This investigation was initiated during the ordinary and electronmicroscopic examination of the calcareous sediments from the Noto Peninsula, Central Japan. Micropaleontological studies of this region has been done by ICHIKAWA and others. ICHIKAWA et al. (1950, 1956, 1963, 1964 and 1967) dealt mainly with diatoms, pollen, spores and silicoflagellata, and ASANO (1953) studied Miocene foraminifera. Occurrence of calcareous nannofossils was reported by NISHIDA and SHIMAKURA (1967). In this paper present author treats only discoasters. Coccoliths and other nannofossils will be reported in the near future.

Since the stratigraphic value of discoasters was recognized by BRAMLETTE and RIEDEL (1954), an increasing number of papers has been published on the calcareous remains of the nannofossils in recent years, but the reports from Japan are meager. Most papers of them have been devoted to the description of the variety of discoasters from the early Tertiary, and few published have been devoted to the occurrence of these tiny fossils in the late Tertiary. Present study clarified a part of the Miocene discoaster assemblage from the district along the Sea of Japan.

Star-shaped, minute, calcareous, skeletal remains are included in the “form genus” named Discoaster. These organisms are supposed not to be living at present, and so there is no certainty of its relationship to the other calcareous nannofossils. In spite of the obscurity in taxonomical position of this nannofossil, discoasters are recognized as excellent guide fossils in the Cenozoic period.

In this paper, twenty-one species of Discoasters are presented with ordinary and electronmicroscopical investigations. Four new species of Discoasters are described. They are named Dis-
coaster gladiatus, D. japonicus, D. notoensis and D. trifurcatus. Type specimen will be preserved in the Department of Earth Science, Nara University of Education.

Acknowledgements

A part of the samples was collected by Assistant Professor Shiro Ishida of Kyoto University. Mr. Kazumi Matsukura and Mr. Hisashi Okuda of Nara University of Education helped the present author for the sampling in the field. The writer wishes to express his sincerest thanks to them. He received valuable suggestions from Dr. Toshiaki Takayama of Tohoku University. The writer wishes to express his thanks to Professor Misaburo Shimakura of Nara University of Education for his constant encouragement and valuable suggestions. Thanks are also due to Assistant Professor Tsutomu Honjo of Hokkaido University for his hearty encouragement. The authors grateful thanks due to Professor George DeFlandre of Paris and to Professor William W. Hay of Illinois University for the literatures.

Previous investigations

The studies of discoasters was initiated by Ehrenberg (1854) in his “Mikrogeologie”, but he considered it to be of inorganic origin. Jukes-Brown and Harrison (1892) figured several calcareous “Stellate bodies” from the Oceanic formation of Barbados. The first systematic work was done by Tan SN Hok (1927), who applied the name “Discaster” to the group from the late Tertiary of Indonesia. A few forms were described by Sukiowski (1930) from Poland, DeFlandre (1934), Bersier (1939) from the Molasse of the northern Alps and by Colom and Gamundi (1951) from the Middle Tertiary of Majorca. DeFlandre also vigorously studied from 1934 and summarized with his views on their systematic agreement in the “Traité de Paléontologie” (1952a) and more completely in the “Traité de Zoologie” (1952b).


From the Neogene of Japan, Discoasters are first reported by Takayama (1966, Oral presentation at the annual meeting of the Geological Society of Japan, at Kanazawa) from the upper Miocene of Chōshi, Honjo et al. (1967) and Minoura et al. (1967, Oral presentation at the annual meeting of the Geological Society of Japan, at Nagoya) from the Neogene of Bōsō, and by Nishida and Shimakura (1967, Oral presentation at the above mentioned meeting) from the Middle Miocene of Noto.
Samples studied and their stratigraphic relationship

The Noto Peninsula belonging geologically to a part of the Miocene Green Tuff region consists of the Neogene strata covering the basement of the Hida Complex. Calcareous nanofossil-bearing beds restricted to the Miocene beds. No pre-Neogene sediments exist under these Neogene beds and in the vicinity of these sedimentary basins.

Recent stratigraphical studies of the northeastern region of this peninsula were done by NAGAHAMA (1951), KUBO (1953), MASUDA (1954), ISHIDA and MASUDA (1956), MASUDA and ISHIDA (1956), and ISHIDA (1959). Geology of this peninsula was compiled comprehensively by KASENO (1965). HOSONO et al. (1949) and SUZUKI (1950) investigated the historical geology of the province of Noto. Researches for diatomite were done by ICHIKAWA and KASENO (1963) and the Fundamental Session of the Ishikawa Prefectural Society for the Study of Utilization of Diatomite (1966).

According to ISHIDA (1959), the stratigraphic succession of the Miocene Noto Group in this region is established as follows:

Suzu formation
- Najimi black mudstone, with a glauconite-bearing flinty bed and partly diatomaceous beds.
- Iwakurayama liparite and Awagura tuff.
- Akagami hard shale, in part diatomaceous. Higashinnaalternation, with the Middle Miocene fauna.
- Yanagida formation
  - Basalts and dacitic sediments with the Middle Miocene flora and Bunolephodon annectens.
- Anamizu formation
  - Andesites, andesitic ryolastics and clastic sediments derived from them.

Calcareous nanofossils have been discovered from the Najimi mudstone, the lida diatomaceous mudstone, the Akagami shale, the Höjūji diatomaceous mudstone, the Wajima calcareous sandstone and the Wajima alternation. The lida diatomaceous mudstone is named for the diatomaceous part of the Awagura tuff. The Höjūji diatomaceous mudstone is also the name given to the diatomaceous part of the Akagami shale. The Wajima calcareous sandstone is correlated to the Iwakurayama liparite and the Awagura tuff horizon, and the Wajima alternation is correlated to the Higashinna alternation. These discosters occurring strata are regarded as the Middle or Upper Miocene in age. Their stratigraphic range extends from the Nishikurosawa to the Funakawa stage of the standard division in Japan, and it also corresponds to that from the late Kurosedani to the early Otogawa stage of the standard division in Hokuriku region, Central Japan.

Locality map of samples is shown in

Text-fig. 1. Sample locality map. Inset: Map of a part of the Far East showing the position of the Noto Peninsula.
text-fig. 1. The stratigraphic unit, location and the lithology for each sample are given below.


Method of the study

At the field, samples were collected taking care to eliminate the contamination. In the laboratory, after crushing the massive sample, the pulverized and shieved one under 100 mesh in size was used for the study. The shieved sample was soaked in about 5 percent solution of potassium hydroxide for more than a day for dispersion. Sometimes sodium hexametaphosphate was added to a concentration of about 1 percent in this dispersing procedure. Next, calcareous nanofossils were concentrated by the hydraulic procedure, repeatedly washing them to become so clean and pure as to be from any fine colloidal material. After all the finer material was eliminated, the sample was shieved to be under 250 mesh and then set upon the centrifugal separation at 1500 rpm. for 30 seconds. Next, the equal volume of sodium hypochloride solution was added, and boiled in water bath for 10 minutes to eliminate organic matter and silicious microfossils. Again, the process of centrifugal separation and the washing with water was repeated alternately. Through these procedure, specimens for ordinary and electron microscopy were prepared. For the optical microscopy, a drop of water with suspending nanofossils was spread on a slide glass, which was allowed to dry up, and the remained fossils were sealed in Pleurax. Carbon replica for the electron microscopy was made by the following procedures. Usually it is made by simply dropping the sample on a piece of thin glass and allowing it to dry up. Present author commonly used optical microscopic cover glass for this purpose. In the bell jar where the air was evacuated to about $1\times10^{-4}$ torr, evaporated carbon was attached on the surface of the specimen so that it attained a suitable thickness. The carbon coated specimen was then taken out of the jar and sectioned to squares of about $2\times2$ millimeters and floated on 5 percent hydrofluoric acid solution in a polyetlen dish till the glass was resolved out or separated. After being washed with water sufficiently, replicated carbon films were transferred to the bath of 10 percent hydrochloric acid, and kept for about 1 hour, and then washed again with water repeatedly. Fluorite which replaced the calcareous nanofossils was dissolved out or separated within about 1 hour. Replicated carbon film was scooped up by a 150 mesh copper net. Obtained carbon
replica was examined and its electron-micrographs was taken using the Japan Electron Optics Laboratory JEM-SS electronmicroscope. Prints made directly from the original negative reproduce the appearance of the nanofossils as seen on the fluorescent screen of the microscope with clear shadows which appear white on the print. Serial numbers were given to electronmicrographed negative film. In the following descriptions, type specimens used for observations are those electronmicrographed negative films for electronmicrographs, and prepares for opticalmicrographs. Besides these, concentrated and refined samples and prepatates for optical microscopy are preserved.

**Discoaster assemblage and discussion**

It has been pointed out by many investigators, namely, HAY and MOHLER (1967), COHEN (1965) and others, that some prosperous reappearance of nanofossils in younger strata through the reworking of original sources. In the Noto Peninsula the basement of the Noto Group consists of plutonic and metamorphic rocks belonging to the Hida metamorphic belt. No pre-Miocene strata are observed in this region. The lowest part of this group is the volcanic Anamizu formation derived from the Green Tuff earth movements. The succeeding Yanagida formation yields many plant fossils showing the Daishima type flora and the Higashinna alternation produces abundant molluscan fossils showing the Yatsuo-Kadonosawa type fauna. These Yanagida formation and the Higashinna alternation have been accepted as shallow sea deposits. Also, no Paleogene strata are known in the hinterland of this peninsula. From above reasons, any possibility of the secondary derivation of the nanofossils may be denied.

Occurrence of Discoaster in each sample is shown in text-figure 2. This figure does not show any numerical presenta-
tion. Throughout all samples, predominant species are *Discoaster brouweri*, *D. challenger*, *D. deflandrei*, *D. gemmifer*, *D. saipanensis*, *D. tani* and almost all species have six rays. Very rarely five or four rayed *D. brouweri* and five rayed *D. deflandrei* were observed. Occurrences of *D. aster*, *D. barbadiensis*, *D. dilatus*, *D. lodoensis* and *D. trifurcatus* are restricted in a certain member of formations in this region, e.g., *D. aster* in the Hōjūji diatomaceous mudstone, *D. barbadiensis* and *D. lodoensis* in the Najimi mudstone, and *D. dilatus* and *D. trifurcatus* in the Iida diatomaceous mudstone. Discoasters are meager in the Wajima alternation. In the Sekino-hana and the Nanao calcareous sandstone, coccoliths appear commonly but no discoasters are recognized.

According to MARTINI and BRAMLETTE, (1963), *Discoaster kugleri*, *D. exilis* and *D. aff. D. deflandrei* are particularly significant species in the Middle Miocene (Helvetian?) cut by the experimental Mohole Drilling. *D. exilis* did not occur but *D. kugleri* and *D. deflandrei* are common throughout the Onnagawa and the Funakawa stage in Noto region. The Onnagawa stage is regarded as the Middle Miocene and the Funakawa as the Middle to Upper Miocene in Japan. *D. hamatus*, *D. brouweri*, *D. pentaradiatus* and *D. bolli* are reported from the Middle Miocene (Tortonian?) of the above drilling. Among them, *D. brouweri* only occurred from Noto peninsula. MARTINI and BRAMLETTE (loc. cit.) also say that *D. brouweri* and *D. pentaradiatus* have their lower limits near the base of

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<th>PALEOCENE</th>
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<td><em>Discoaster trifurcatus</em></td>
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Text-fig. 3. Stratigraphic range chart of Discoasters. Solid line: Reported range by many investigators of the world. Cross symbol: Present occurrence.
this unit in the above mentioned drillcore. But *D. browneri* occurs throughout the Onnagawa and the Funakawa stage in Noto.

On the other hand, WRAY and ELLIS (1965) have reported that the time of extinction of Discoasters, such as *Discaster exilis*, *D. hamatus*, *D. pentaradiatus*, *D. surculus*, *D. variabilis*, *D. browneri*, *D. bollii*, *D. kegleri* and *D. challengerii*, are approximately the Pleistocene boundary in the Gulf Coast Area on the basis of their examination of about 600 samples of drill cuttings.

Text-figure 3 shows the tentative stratigraphic range chart of Discoasters. Thick lines represent the stratigraphic ranges of discoasters reported by many investigators in the world. Cross symbols show the occurrence from this peninsula. *Discaster gennifer*, *D. saipanensis* and *D. tani* were still living in Noto in the Middle Miocene time. Extinction of these species seem to be somewhat delayed in our region as compared with Europe and America.

KAMPTNER (1967) reported the occurrence of *D. aster*, *D. browneri*, *D. challengerii* and *D. perplexus* from the Challenger deep-sea sample collected at the Station 338 (lat. 21°15'N, long. 14°02'W, depth 1990 fathoms). Earlier, BLACK and BARNES (1961) described *D. perplexus* from the same sample. MCLINTYRE et al. (1967) found *D. browneri* and *D. challengerii* from Atlantic deep-sea core V16-23 (lat. 13°15'N, long. 40°40'W, depth 4885 m) taken by the Vema, research vessel of the Lamont Geological Observatory. COHEN (1964) also reported the occurrence of *D. perplexus* from Caribbean core samples A-240-M1 (lat. 15°26'N, long. 68°30'W, depth 4180 m) and A-254-BR-C (lat. 15°17'N, long. 72°53.5'W, depth 2968 m), taken by the Woods Hole Laboratory research vessel *Atlantis* in 1959 and 1960 respectively. From the Pacific Ocean, present author (unpublished) found the occurrence of *D. browneri* from the deep-sea sample of St. 21 (lat. 0°29.6'S, long. 160°36.7'E, depth 2940 m) taken by the Oceanographical Laboratory of University of Tokyo research vessel Hakuhō-Maru in 1968. From these deep-sea occurrences, present author supposes that *D. browneri*, *D. challengerii* and *D. perplexus* have possibly extended their stratigraphic range to the Pleistocene.

**Systematic description**

Genus *Discaster* TAN SIN HOK, 1927.

*Discaster aster* BRAMLETTE & RIEDEL, 1954.

Pl. 15, fig. 1

*Discaster stella* (EHRENBERG), COLOM & GAMUNDI, 1951, pl. 25, fig. 6.

*Discaster aster* BRAMLETTE & RIEDEL, 1954, p. 400, pl. 39, fig. 4; BRAMLETTE, 1957, p. 249, pl. 61, fig. 4; STRADNER, 1959a, p. 8, fig. 29; LEVIN, 1962, pp. 270, pl. 43, fig. 3; LEVIN & JOERGER, 1967, p. 171, pl. 3, figs. 14-15; KAMPTNER, 1967, pl. 24, fig. 127.

Remarks.—This asterolith has six bluntly pointed rays varying in width and degree of separation. Outline are somewhat irregular. Total diameter 13 microns.

Hyptotype.—NC-1P-1. Hōjūji diatomaceous mudstone.

Present occurrence.—Middle Miocene (Onnagawa) of Noto, Japan.

Reported stratigraphic range.—Upper Eocene to Upper Miocene.

*Discaster barbadiensis* TAN SIN HOK, 1927.
557. Miocene Discoasters from Noto

Pl. 15, fig. 2.

**Discaster Barbadiensis** Tan Sin Hok, 1927, text-fig. II-4.

"coccolithe" Deflandre, 1934, fig. 12.

**Heliodiscoaster Barbadiensis** Tan Sin Hok, Deflandre, 1934, figs. 22 & 23.

**Hemidiscoaster Barbadiensis** Tan Sin Hok, Colom & Gamundi, 1951, pl. 25.

**Discaster Barbadiensis** Tan Sin Hok, sens. emend., Bramlette & Riedel, 1954, pp. 398-399, pl. 39, fig. 5a-b; Gardet, 1955, p. 526, pl. 7, fig. 68a-b; Bramlette, 1957, p. 249, pl. 61, fig. 10; Martini, 1958, p. 366, pl. 5, fig. 24a-c; Manivit, 1959, p. 369, pl. 10, figs. 1-5; Stradner, 1959a, pp. 2-3, fig. 2; Stradner & Papp, 1961, pp. 95-96, pl. 28, figs. 1-2; Bramlette & Sullivan, 1961, p. 158, pl. 11, fig. 2; Bouché, 1962, p. 89, pl. 3, figs. 1-4; Hay & Towe, 1962, p. 515, pl. 10, figs. 3 & 5; Sullivan, 1964, p. 189, pl. 10, figs. 1-2; Honjo et al., 1967, text-figs. 3-4; Takayama, 1967, pl. 8, fig. 3; Levin & Joerger, 1967, p. 172, pl. 3, figs. 17a-b; Hay et al., 1967, pl. 1, figs. 9-11.

Remarks.—This asterolith has usually six rays which are thin, elongated, bluntly pointed and not bifurcated. Total diameter 12 microns.

Hypotype.—NC-13P-1. Akagami shale. Present occurrence.—Middle (Onnagawan) and Upper Miocene (Funakawan) of Noto, Japan.

Reported stratigraphic range.—Upper Oligocene to Upper Pliocene.

**Discaster Challenger** Bramlette, & Riedel, 1954.

Pl. 15, fig. 5.

**Discaster Mohlengraaffi** Tan Sin Hok, var. r, text-fig. II-11.

**Hemidiscoaster Mohlengraaffi** Variété à bras plus maigres, Deflandre, 1934, text-fig. 11.

**Hemidiscoaster mohlengraaffi** Tan Sin Hok, Deflandre, 1952a, text-fig. 66; Deflandre, 1952b, text-fig. 362u.

**Discaster Challenger** Bramlette & Riedel, 1954, p. 401, pl. 39, fig. 10; Bramlette, 1957, p. 248, pl. 61, fig. 2; Martini & Bramlette, 1963, p. 851, pl. 103, figs. 11-12; Hay et al., 1967, pl. 4, figs. 9-10; McIntyre et al., 1967, pl. 3, fig. d; Kamptner, 1967, p. 164, pl. 24, fig. 130.

Remarks.—Asterolith with six rays which are subcylindrical, distally bifurcated into short, round termination. Widening of rays in central area is not
pronounced. In the central area, there is a small, circular knob. Total diameter 12 microns.

_Hypotype._—NC-9P-1. lida diatomaceous mudstone.

_Present occurrence._—Middle (Onnagawan) to Upper middle Miocene (Funakawan) of Noto, Japan.

_Reported stratigraphic range._—Upper Oligocene to Lower Pliocene.


_Pl. 15, fig. 6; Pl. 17, figs. 2, 3._

_Discoaster deflandrei_ BRAMLETTE & RIEDEL, 1954, pp. 399–400, pl. 39, fig. 6, text-fig. 1a–c; BRAMLETTE, 1957, p. 249, pl. 61, fig. 6; MARTINI, 1958, pp. 363–364, pl. 5, fig. 23a–c; MANIVIT, 1959, p. 367, pl. 9, fig. 4; STRADNER, 1959a, p. 7, fig. 25; MARTINI, 1961, p. 13, pl. 3, fig. 27; STRADNER & PAPP, 1961, pp. 71–72, pl. 10, figs. 1–6; SULLIVAN, 1964, p. 189, pl. 11, figs. 8–9; LEVIN & JOERGER, 1967, p. 172, pl. 4, figs. 1–2; TAKAYAMA, 1967, pl. 8, fig. 2; HAY et al., 1967, pl. 2, figs. 6–9.

_Remarks._—Asterolith, consisting of a central disc with six broad, bifurcated rays which are generally as long as, or a little longer than, the radius of the central disc. Outline of the widened, bifurcated parts of the rays is rounded or somewhat angular. Terminal notches are angular, rather than rounded. Spaces between the rays are subcircular, approximately as broad as the narrowest part of the rays and half as broad as the widest part of them. Total diameter 15 microns.

_Hypotype._—NC-13P-1. Akagami shale. NC-13R-26 & NC-1R-44.

_Present occurrence._—Middle (Onnagawan) to Upper middle Miocene (Funakawan) of Noto, Japan.

_Reported stratigraphic range._—Middle Eocene to Middle Miocene.

_Discoaster dilatus_ HAY, 1967.

_Pl. 16, fig. 7._


_Remarks._—Asterolith, with six rays, widened towards ends that are linear or slightly concave. Inter-ray notches are deep. Total diameter 7 microns.

_Hypotype._—NC-30P-1. lida diatomaceous mudstone.

_Present occurrence._—Middle Miocene
(early Funakawan) of Noto, Japan.

Reported stratigraphic range.—Lower Miocene.

*Discoaster aff. D. distinctus*  
*MARTINI, 1958.*

Pl. 15, fig. 9.

*Discoaster distinctus*  
*MARTINI, 1958, p. 363, pl. 4, figs. 17a–b.*

Remarks.—Paired nodes toward the tips of the rays are conspicuous. But, present specimen differs from the holotype in the width of the rays. The rays expand gradually towards periphery and broaden at the end. Total diameter 20 microns.

Hypotype.—NC-13P-1. Akagami shale.  
Present occurrence.—Middle (Onnagawan) to upper middle Miocene (Funakawan) of Noto, Japan.

Reported stratigraphic range of *D. distinctus*.—Middle Paleocene to Upper Oligocene.

*Discoaster cf. D. distinctus*  
*MARTINI, 1958.*

Pl. 15, fig. 8.

*Discoaster distinctus*  
*MARTINI, 1958, p. 363, pl. 4, fig. 17a–b.*

Remarks.—The paired nodes that tent towards the tips of the rays are conspicuous. A conical and circular knob, in central part. Present specimen has rather wide and thick rays, and wider central area compared with the holotype. Total diameter 20 microns.

Hypotype.—NC-13P-1. Akagami shale.  
Present occurrence.—Middle (Onnagawan) to the Upper middle Miocene (early Funakawan) of Noto, Japan.

*Discoaster cf. D. divaricatus*  
*HAY, 1967.*

Pl. 15, fig. 7.

*Discoaster divaricatus*  
*HAY, 1967, p. 451, pl. 3, figs. 7–9.*

Remarks.—Six rayed asterolith with broad, bifurcating tips having a distinct notch. Inter-ray spaces subangular. Present specimen differs from the holotype in the wide central disc. Total diameter 13 microns.

Hypotype.—NC-1P-1. Höjūji diatomaceous mudstone.  
Present occurrence.—Middle Miocene (Onnagawan) of Noto, Japan.

Reported stratigraphic range of *D. divaricatus*.—Lower to Middle Miocene.

*Discoaster gemmifer*  
*STRADNER & PAPP, 1961.*

Pl. 15, fig. 10.

*Discoaster gemmifer*  
*STRADNER & PAPP, 1961, pp. 69–71, pl. 8, fig. 5 & pl. 9, figs. 1–2; STRADNER, 1961, text-fig. 83; BOUCHÉ, 1962, p. 90, pl. 3, figs. 17 & 21, text-figs. 23–29; LEVIN, 1965, p. 270, pl. 43, fig. 4.

Remarks.—Asterolith has six rays which bifurcate into two tips, and bluntly terminated. Central area is wide. Total diameter 17 microns.

Hypotype.—NC-13P-1. Akagami shale.  
Present occurrence.—Middle lower (Nishikurokawan) to upper middle Miocene (Funakawan) of Noto, Japan.

Reported stratigraphic range.—Throughout the Eocene.

*Discoaster gladius*  
*NISHIDA, sp. nov.*

Pl. 17, fig. 4.

*Discoaster cf. Brouweri*  
*(LIGATA), DEFLANDRE, 1934, text-fig. 26.*

Diagnosis.—Broad central area. Ray is wide in basal part and narrow at the tip suddenly. Distinct central ridge in rays.
Description.—Asterolith, with six rays having short, pointed termination. Central area is wide and on the center of the surface, there is a knob. Ray is wide at the proximal part and become narrower outward, and its shape is rather triangular with pointed corners. Central ridge of the ray is distinct, but it does not extend into the central area. Total diameter 8 microns.

Remarks.—Short, pointed, triangular rays and broad central area are conspicuous features in this species.

Holotype.—NC-13R-30. Akagami shale.

Present occurrence.—Middle (Onnagawan) to Upper middle (early Funakawan) Miocene of Noto, Japan.

Other occurrence from Japan.—Mr. Hisatake Okada of Hokkaido University reported of this species from the Miocene of Boso peninsula, Japan, as Discoaster sp. at the 75th autumn meeting of the Geological Society of Japan.

Discoaster japonicus NISHIDA, sp. nov.

Pl. 17, fig. 5.

Diagnosis.—Broad central area. Short rays with rounded termination.

Description.—Asterolith, consisting of a broad central disc with six short, broad, roundly terminated rays which are about one third of the radius of the central disc in length. Spaces between rays are wide, shallow and circular. Large stellate knob in the central disc. Total diameter 8 microns.

Remarks.—Broad central disc and short, broad, roundly terminated rays are remarkable. Differs from Discoaster gladiatus in the width and length of the rays, and the shape of the central knob.

Holotype.—NC-4R-111. Hōjūji diatomaceous mudstone.

Present occurrence.—Middle (Onnagawan) to Upper middle (early Funakawan) Miocene of Noto, Japan.

Discoaster kugleri MARTINI & BRAMLETTE, 1963.

Pl. 15, fig. 11; Pl. 16, figs. 1, 2.

Discoaster kugleri MARTINI & BRAMLETTE, 1963, p. 853, pl. 102, figs. 11-13.

Remarks.—This asterolith has six thick rays and large, flat central area. A small knob in the central area. Total diameter 16 microns.

Hypotype.—NC-13P-1. Akagami shale.

Present occurrence.—Middle (Onnagawan) to Upper middle (early Funakawan) Miocene of Noto, Japan.

Reported stratigraphic range.—Middle Miocene (Helvetian).

Discoaster lodoensis BRAMLETTE & RIEDEL, 1954.

Pl. 15, fig. 12.

Discoaster lodoensis BRAMLETTE & RIEDEL, 1954, p. 398, pl. 39, fig. 3; MARTINI, 1958, pp. 366-367, pl. 6, fig. 28; STRADNER, 1959a, p. 3, fig. 5; MANIVIT, 1959, p. 361, pl. 6, figs. 4-5; STRADNER, 1961, p. 86, text-figs. 84-85; STRADNER & PAPP, 1961, pp. 92-93, pl. 25, figs. 3 & 5; BRAMLETTE & SULLIVAN, 1961, p. 161, pl. 12, figs. 4-5; HAY & TOWE, 1962, p. 514, pl. 10, figs. 2, 4 & 6; BRONNIMANN & RIGASSI, 1963, pl. 11, fig. 2; SULLIVAN, 1964, p. 191, pl. 11, fig. 14; SULLIVAN, 1965, p. 42, pl. 10, fig. 14; TAKAYAMA, 1967, pl. 8, fig. 4.

Remarks.—Stellate asterolith, consisting of six rays joined together at their proximal half or one third portion. Furcating distal portion of the rays is tapering gradually to a sharp point, and curves. A rays are similar in the plane of the asterolith. In the central portion,
a knob projects from one surface. Total diameter 12 microns.


_Present occurrence._—Upper middle Miocene (late Funakawan) of Noto, Japan.

_ Reported stratigraphic range._—Middle Paleocene to Upper Miocene.

_Discoaster notoensis_ NISHIDA, sp. nov.

Pl. 17, fig. 6.

_Diagnosis._—Brunt-shaped ray with blunt, arcuated termination.

_Description._—Asterolith, with six brunt-shaped rays with bluntly arcuated termination. Rays are joined together at the proximal three fourth portion of their length and the proximity is inconspicuous. Total diameter 7.8 microns.

_Remarks._—Rays show narrow sector-shaped with somewhat angular distal margin.

_Holotype._—NC-13R-36. Akagami shale.

_Present occurrence._—Middle Miocene (Onnagawan) of Noto, Japan.


Pl. 16, fig. 9.

_Discoaster perplexus_ BRAMLETTE & RIEDEL, 1954, pp. 400–401, pl. 39, fig. 9; BLACK & BERNES, 1961, p. 144, pl. 24, fig. 1; STRADNER & PAPP, 1961, p. 100, pl. 30, figs. 1–7; COHEN, 1964, p. 246, pl. 5, figs. 4a–c & pl. 6, figs. 4a–b; TAKAYAMA, 1967, p. 195, pl. 4, fig. 9; HAY et al., 1967, pl. 5, figs. 10–12; KAMPFNER, 1967, p. 165, pl. 23, figs. 118–119 & pl. 24, fig. 125.

_Remarks._—This asterolith is small, thin, discoidal, with circular outline characterized by the straight distal margins of the rays. Twelve, very elongated triangular rays, joined together with their whole length. Total diameter 6 microns.

_Hypotype._—NC-1P-1. Höjūji diatomaceous mudstone.

_Present occurrence._—Middle (Onnagawan) Miocene to Upper middle (early Funakawan) Miocene of Noto, Japan.

_ Reported stratigraphic range._—Upper Oligocene to Upper Miocene, and Recent deep-sea deposit.


Pl. 16, fig. 10.

_Discoaster saipanensis_ BRAMLETTE & RIEDEL, 1954, p. 398, pl. 39, fig. 4; BRAMLETTE, 1957, p. 249, pl. 61, fig. 7; MARTINI, 1958, p. 367, pl. 6, figs. 29a–b; STRADNER, 1959a, p. 3, fig. 3; MANIVIT, 1959, pp. 359–361, pl. 6, figs. 1–3; STRADNER & PAPP, 1961, pp. 90–91, pl. 22, figs. 5–7; LEVIN, 1965, p. 270, pl. 43, figs. 2a–b; HAY et al., 1966, pl. 11, figs. 8–9 & pl. 13, fig. 1; HAY et al., 1967, pl. 1, figs. 4–6; LEVIN & JOERGER, 1967, p. 172, pl. 3, fig. 16.

_Remarks._—Stellate asterolith, with six straight rays, joined together at the portion approximately half of their length to the proximity and taper to sharp points. A stem project from central disc. Total diameter 9 microns.

_Hypotype._—NC-22P-1. Najimi mudstone.

_Present occurrence._—Middle (Onnagawan) to Upper middle (Funakawan) Miocene of Noto, Japan.

_ Reported stratigraphic range._—Middle Eocene to Upper Oligocene.

_Discoaster tani_ BRAMLETTE & RIEDEL, 1954.

Pl. 16, figs. 3, 11, 12.

_Discoaster tani_ BRAMLETTE & RIEDEL, 1954, p. 397, pl. 39, fig. 1; DEFLANDRE & FERT,
Shiro NISHIDA

1954, pl. 11, figs. 13-17; BRAMLETTE, 1957, p. 250, pl. 61, fig. 8; MARTINI, 1958, pp. 359-360, pl. 3, fig. 13a-b; STRADNER, 1959a, p. 5, fig. 16; STRADNER, 1959b, p. 479, text-figs. 43-44; STRADNER & PAPP, 1961, pp. 82-83, pl. 16, figs. 3-4; LEVIN, 1965, p. 171, pl. 43, fig. 6; HAY et al., 1966, p. 396, pl. 11, fig. 6; HAY et al., 1967, pl. 1, fig. 1; LEVIN & JOERGER, 1967, p. 172, pl. 4, fig. 3a-b.

Remarks.—Asterolith, with six or five rays. Rays rather heavy and of almost uniform width, abruptly truncated. Total diameter 8 microns.

Hypotype.—NC-4R-96. Höjüji diatomaceous mudstone.

Present occurrence.—Middle lower (Nishikurokawan) to Upper middle Miocene (Funakawan) of Noto, Japan.

Reported stratigraphic range.—Middle Eocene to Upper Oligocene.

Discoaster trifucatus NISHIDA, sp. nov.

Pl. 16, fig. 4.

Diagnosis.—Trifurcated termination of the rays.

Description.—Asterolith, with six rather thin rays which are subcylindrical, distally trifurcated into short, rounded terminations. As the present figure is the electronmicroscopical shadowgraph, surface details are not observable. Total diameter 10 microns.

Holotype.—NC-9S. Iida diatomaceous mudstone.

Present occurrence.—Middle (early Funakawan) Miocene of Noto, Japan.

Explanation of Plate 15

Light micrographs, 2000 x.

Fig. 1. Discoaster aster BRAMLETTE & RIEDEL.

Hypotype NC-1P-1. Höjüji diatomaceous mudstone. Mishima, Uwado-cho, Suzu City.

Fig. 2. Discoaster barbadiensis TAN SIN HOK.


Fig. 3. Discoaster brouweri TAN SIN HOK.

Hypotype NC-13P-1. Akagami shale. Awazu, Suzu City.

Fig. 4. Discoaster aff. D. challengeri BRAMLETTE & RIEDEL.

Hypotype NC-9P-1. Iida diatomaceous mudstone. Morikoshi, Suzu City.

Fig. 5. Discoaster challengeri BRAMLETTE & RIEDEL.

Hypotype NC-9P-1. Iida diatomaceous mudstone. Morikoshi, Suzu City.

Fig. 6. Discoaster deflandrei BRAMLETTE & RIEDEL.

Hypotype NC-13P-1. Akagami shale. Awazu, Suzu City.

Fig. 7. Discoaster divaricatus HAY.

Hypotype NC-1P-1. Höjüji diatomaceous mudstone. Morikoshi, Suzu City.

Fig. 8. Discoaster cf. D. distinctus MARTINI.

Hypotype NC-13P-1. Akagami shale. Awazu, Suzu City.

Fig. 9. Discoaster aff. D. distinctus MARTINI.

Hypotype NC-13P-1. Akagami shale. Awazu, Suzu City.

Fig. 10. Discoaster gemmifer STRADNER & PAPP.

Hypotype NC-13P-1. Akagami shale. Awazu, Suzu City.

Fig. 11. Discoaster kugleri MARTINI & BRAMLETTE.

Hypotype NC-13P-1. Akagami shale. Awazu, Suzu City.

Fig. 12. Discoaster lodoensis BRAMLETTE & RIEDEL.

References


—— & Kaseno, Y. (1963): Diatomaceous


KUBO, Y. (1953): Geology of the Yanagida

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Explanation of Plate 16

Figs. 1-3. Electronmicrographs of carbon replica.
Fig. 4. Electronmicroscopical shadowgraph of intact Discoaster. Magnification of Figs. 1-4 are not 2000×.
Figs. 5-12. Lightmicrographs. 2000×.

Figs. 1-2. Discostear kugleri MARTINI & BRAMLETTE.
Akagami shale. Awazu, Suzu City.

Fig. 3. Discostear tani BRAMLETTE & RIEDEI.
Hypotype NC-4R-96. Hōjūji diatomaceous mudstone. Hōjūji, Uwado-chō, Suzu City.
Carbon replica. 7000:1.

Fig. 4. Discostear trifurcatus NISHIDA, sp. nov.

Figs. 5-6. Discostear brouweri TAN SIN HOK.

Fig. 7. Discostear dilatus HAY.
Hypotype NC-30P-1. Iida diatomaceous mudstone. Iida-chō, Suzu City.

Fig. 8. Discostear cf. D. challenger BRAMLETTE & RIEDEI.

Fig. 9. Discostear perplexus BRAMLETTE & RIEDEI.
Hypotype NC-1P-1. Hōjūji diatomaceous mudstone. Morikoshi, Uwado-chō, Suzu City.

Fig. 10. Discostear saipanensis BRAMLETTE & RIEDEI.

Figs. 11-12. Discostear tani BRAMLETTE & RIEDEI.
557. Miocene Discoasters from Noto

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(1967): First report on nannoplankton
Shiro NISHIDA


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**Akagami** 赤神  
**Anamizu** 六水  
**Awagura** 菊原  
**Awazu** 萩津  
**Bōsō** 対総  
**Chōshi** 銚子  
**Daishima** 台島  
**Funakawa** 船川  
**Hida** 飛騨  
**Higashiinai** 東印内  
**Hōjūji** 法住寺  
**Hokuriku** 北陸  
**Iida** 飯田  
**Ishikawa** 石川  
**Iwakurayama** 岩倉山  
**Jike** 寺家  
**Kadonosawa** 門沢  
**Kamogaura** 鴨ヶ浦  

**Kawai-chō** 河井町  
**Morikoshi** 森脇  
**Nājī** 南志見  
**Nanao** 七尾  
**Nishikurosawa** 西黒沢  
**Noroshi** 奈瀨  
**Noto** 能登  
**Onna-gawa** 女川  
**Otagawa** 音川  
**Rokuga-saki** 龍ヶ崎  
**Sekino-hana** 関ノ鼻  
**Suzu** 琵琶湖  
**Togi** 富来  
**Tsurugijō** 鈴吹  
**Uwado-chō** 上戸町  
**Wajima** 岩見泽  
**Yanagida** 柳田  
**Yatsuo** 八尾

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**Explanation of Plate 17**

Electronmicrographs of carbon replica

Fig. 1. *Discoaster browneri* **Tan Sin Hok.**

Figs. 2-3. *Discoaster deflandrei* **Bramlette & Riedel.**

Fig. 4. *Discoaster gladius* **Nishida, sp. nov.**

Fig. 5. *Discoaster japonicus* **Nishida, sp. nov.**

Fig. 6. *Discoaster notoensis* **Nishida, sp. nov.**