STRADNER 1959

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Wien 6.7.1967

Section I—Paper 60

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FIRST REPORT ON THE DISCOASTERS OF THE TERTIARY OF AUSTRIA AND THEIR STRATIGRAPHIC USE

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BY

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ABSTRACT. The Discoasteridae of the class Coccolithophorides so far encountered in the marine sediments of northern Austria up to the end of 1958 are described and illustrated. Both sides of the flat star- or rosette-shaped microfossils are depicted and explained. A detailed list of technical terms is included in the chapter on the systematics of the Discoasteridae. Only one specimen of each form-species is illustrated. The possibilities of the use of the discoasters as marker-fossils are discussed. It can be stated that discoasters can be used in establishing geologic boundaries by recording their occurrence in sediments. Because of the small dimensions of these fossils the chances of reworking into younger sediments are greater than with other microfossils. Therefore care has to be taken in evaluating the results of discoaster-diagrams, when "long-range" form-species have been found.

As far as can be judged from the present results the Paleocene-Eocene boundary as well as the Helvetium-Tortonium boundary are clearly expressed by changes of the assemblages of the discoasters.

RESUME. Ce mémoire décrit la famille des Discoastéridés de la classe des Coccolithophoridés trouvées jusqu'à la fin de 1958 dans les sédiments marins de l'Autriche du Nord; il en donne des illustrations. Les deux faces des microfossiles à forme d'étoile plate ou de rosette sont dépeintes et expliquées. Une liste détaillée des termes techniques est incluse dans le chapitre sur la systématisation des Discoastéridés, mais on n'illustre qu'un seul spécimen de chaque forme-espèce. On discute des usages possibles des discoasters comme fossiles-guides. On peut dire que les Discoasteridés servent à établir des limites géologiques du fait de leur apparition dans les sédiments. A cause de la faible dimension de ces fossiles, les chances de reprise dans des sédiments plus jeunes sont plus grandes que pour les autres microfossiles. Par conséquent, grand soin doit être pris dans l'évaluation des résultats des diagrammes lorsque l'on trouve cette espèce, en profondeur, sur une large étendue.

Autant que l'on puisse en juger des résultats présents, les limites du Paléocène-Eocène aussi bien que celles du Helvetium-Tortonium, sont clairement indiquées par les modifications des assemblages de discoasters.

Introduction

Among the calcareous microfossils the coccoliths undoubtedly are not only the smallest but also the most numerous. The study of the oval and the star-shaped relics of this class of fossil flagellates (Coccolithophorides) has within the last decade aroused the interest of more and more geologists the world over.

The family of the Discoasteridae, which as their name implies is characterized by flat star-shaped plates, was named by Tan Sin Hok in 1927. In 1950 Deflandre put the Discoasteridae on account of their optical property as single crystals into his new order of the Ortholithae. Those include the Discoasteridae, the Thoracosphaeridae and the Braarudosphaeridae.

As the discoasters of the family of the Discoasteridae occur locally in such great number that there are up to several millions of them to be found in one cubic inch, it is to be expected that they can furnish some valuable evidence to the petroleum geologist.

This preliminary report has been prepared not only

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to show what has been found in discoasters here in Austria yet, but also to point to the important fact that the study of these microfossils may be an additional help in biostratigraphy.

Systematics and Description of the Form-Species

In 1952 Lecal described a recent planktonic protist from the Mediterranean Sea as Discoaster planctonicus, the surface of which was covered with many five- and six-rayed stars. As this remarkable organism is not generally accepted as a living representative of the fossil discoasteridae, all discoasters described in this paper are considered as fossils "incertae sedis." For this reason new terms are applied for the systematic units according to the proposals of Deflandre and Deflandre-Rigaud (1948), e.g. manipulum for genus and centuria for species. Tan Sin Hok (1927) had divided his family of the Discoasteridae into three sub-families according to the arrangement of their arms. This subdivision of the family has not been in consequent use since the features of the central disc of the discoasters are often difficult to discern. For practical purposes usually one can suffice with the description of the outlines of the discoasters. Nevertheless it has to be emphasized that the exact study of the details of the central disc of these fossils may help in revealing the phylogeny of the Discoasteridae.

Descriptive Terms

The following terms are used for describing discoasters (see also Stradner 1958, p. 179):

Asterolith: The whole star or rosette-shaped body of a discoaster.

Asteroradius: A ray or arm of a discoaster.

Facies superior: The one side of the flat asterolith, on which the lineae interradiales are curved or crooked. Often they are bent to form a design similar to a germanic sun-rune.

Facies inferior: The other side of the asterolith, on which the lineae interradiales are straight. (Compare Deflandre 1934, fig. 16 and 1952, fig. 362 Y')

Linea interradialis: Line of division between two rays, also called suture-line. It is a groove, which can be followed from the centre of one side through the incisio interradialis to the centre of the other side. Sometimes situated on an elevated ridge.

Incisio interradialis: The incision between two rays.

Incisio terminalis: The terminal notch at the end of a ray or an arm.

Stella centralis: A small star-shaped adornment in the centre of the facies inferior.

Bulla centralis: A sturdy knob in the centre of the asterolith. Mostly developed on one side only.

Crista radialis: An elevated ridge extending from the centre of the asterolith to the end of the ray.

Discus centralis: The central disc; those parts of the rays which lie within the incisurae interradiales.

Ornatio: Little dark dots on the whole surface of the discoaster. They are dimples, which are rather difficult to see. Possibly caused by fossilisation, but often lineated, especially on the central disc.

Manipulus: Form-genus.

Centuria: Form-species.

In describing the two species of trochoasters, which also belong to the family of the Discoasteridae, an additional term is used:

Lamina basalis: The basal plate, on which the rays stand out in relief. It may be round or square.

Form Species of Discoasters

The following form-species of discoasters and trochoasters have been found in Austria before December 1958.

Class: Coccolithophorides Lohmann. Order: Ortholithae Deflandre. Form-family: Discoasteridae Tan Sin Hok. Form-genus: Discoaster. Tan Sin Hok.

Discoaster multiradiatus Bramlette & Riedel. Fig. 1.

Tan Sin Hok, 1927, p. 118, fig. 2. Deflandre, 1934, p. 61, fig. 2. Deflandre, 1952, p. 112, fig. 65. Bramlette & Riedel, 1954, p. 396, pl. 38, fig. 10. Stradner, 1958, p. 181, fig. 2-4.

Asteroliths consist of more than 15 wedge-like rays, the distal ends of which are blunt or rounded. In the centre there can be a blank area or a knob. There are also forms to be found with sturdy central knobs on either sides. The suture-lines are slightly curved thus giving the impression of a contorted central area. Earliest occurrence in Austria: Paleocene (Thanetian) of Mattsee.

Discoaster barbadiensis Tan Sin Hok. sens. emend. Bramlette & Riedel. Fig. 2.

Tan Sin Hok 1927, p. 118, fig. 4. Deflandre 1934, p. 64, fig. 22 and 23. Bramlette & Riedel, 1954, p. 398, pl. 39, fig. 5a and 5b. Stradner, 1958, p. 183, fig.

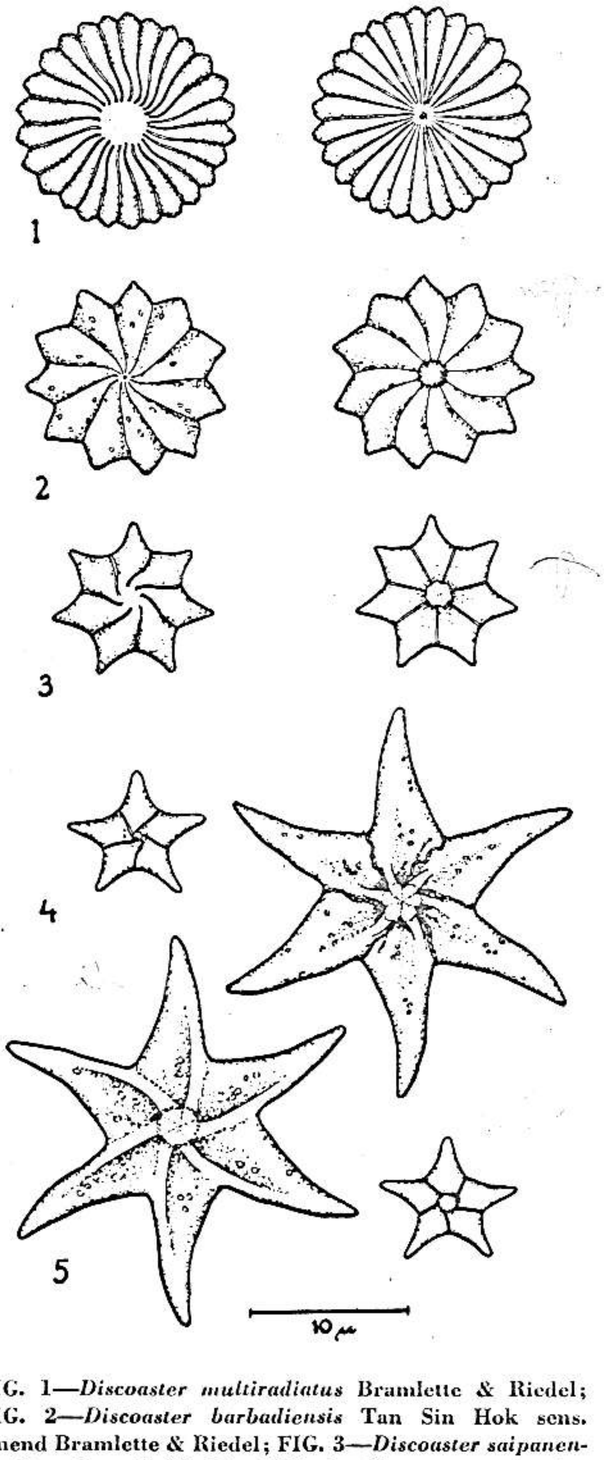


FIG. 1—*Discoaster multiradiatus* Bramlette & Riedel; FIG. 2—*Discoaster barbadiensis* Tan Sin Hok sens. emend Bramlette & Riedel; FIG. 3—*Discoaster saipanensis* Bramlette & Riedel; FIG. 4—*Discoaster quinarius* Ehrenberg; FIG. 5—*Discoaster lodoensis* Bramlette & Riedel.

11-14. Martini, 1958, pl. 5, fig. 24 a, b, c. For complete list of references see Martini 1958.

Rosette-shaped asteroliths dominate with eleven rays, which are united most of their length. The distal ends of the rays are blunt or round. The concave face has a high central stem, which in some Paleocene forms wears a crown. Earliest occurrence in Austria: Paleocene (Thanetian) of Mattsee.

Discoaster saipanensis Bramlette & Riedel. Fig. 3.

Bramlette & Riedel, 1954, p. 398, pl. 39, fig. 4. Martini, 1958, pl. 6, fig. 29 a, b.

The stellate asteroliths found in Austria do not show the prominent ray ridges very distinctly so that they resemble *Discoaster barbadiensis* more than *Discoaster lodoensis*. They are small and translucent with curved sutures on the convex face and straight sutures and a bulla centralis on the concave face.

Earliest occurrence in Austria: Middle Eocene (Lutetian) of Seeham.

Discoaster quinarius Ehrenberg, Fig. 4.

Ehrenberg, 1854, pl. 19, fig. 46. Bersier, 1939, p. 234, figs. 1-4, probably also 10-15.

Asteroliths stellate with five acute rays. More than 50% of the asteroliths of this form-species are five-rayed, the rest six-rayed, four-rayed or even three-rayed. The rays of *Discoaster quinarius* are at least as thick as broad, whereas *Discoaster saipanesis* has flat rays. Earliest occurrence in Austria: Lower Eocene (Ypresian) of Eitelgraben.

Discoaster lodoensis Bramlette & Riedel, Fig. 5.

Bramlette & Riedel 1954, p. 398, pl. 39, fig. 3a, b. Stradner 1958, p. 182, fig. 8 and 9. Martini, 1958, pl. 6, fig. 28 a, b, c, d.

Asteroliths usually having 6 long curved rays which on their convex edge are reinforced with a prominent ridge. The rays are all curved in the same way, that is seen from the slightly convex side of the asterolith to the left. This side wears a large central knob, whereas the flat or slightly concave side of the asterolith shows a prominent central star. Sutures are only rarely to be seen on the concave face. Earliest occurrence in Austria: Middle Paleocene (Thanetian) of Mattsee.

Discoaster currens, nov. cent. Fig. 6.

Derivatio nominis: currens (lat.) running.

Asteroliths of triradiate shape, the rays resembling those of Discoaster lodoensis. On one face of the asterolith the ridges of the curved rays run together to a little triradiate star; on the other face there is a tiny knob. This new form-species seems to be closely related to *Discoaster lodoensis,* from which it was separated as there are no regular four-radiate links between the two form-species in the Austrian material. For the type-series and its variability see Stradner, 1959.

Type location: Mattsee, Station 133, Stratum typicum: Paleocene (Thanetian).

Discoaster (?) furcatus Deflandre. Fig. 7. Deflandre, 1954, p. 54, pl. XIII, fig. 14.

Three-armed calcareous corpuscle with three or four thorns projecting from the ends of its arms. This microfossil is being rearranged into a new form-genus, as far as known, into *Marthasterites* by its author. Its optical properties under polarized light differ from those of *Discoaster tribrachiatus.* Earliest occurrence in Austria: Upper Cretaceous of the Gosau, but also found in the Miocene (Helvetium) of Göllersdorf and Limberg.

Discoaster tribrachiatus Bramlette & Riedel. Fig. 8.

Bramlette & Riedel, 1954, p. 397, pl. 38, fig. 11. Stradner, 1958, p. 181, fig. 5 and 6. Martini, 1958, pl. 2, fig. 8a, b.

Asteroliths of triradiate form without any suture lines on either side. No central knob. The arms are slightly conical towards their end and often curved like the ribs of an umbrella. Some asteroliths have a wide terminal notch. Earliest occurrence in Austria: Middle Paleocene (Thanetian) of Mattsee.

Discoaster rotans, nov. cent. Fig. 9.

Derivatio nominis: rotans (lat.) turning.

Asteroliths of similar shape as those of *Discoaster tribrachiatus* from which they differ in the bifurcation of their arms. One of the two endings of an arm is a short stub, whereas the other is a sturdy curved spine, the terminal notch being shallow and oblique. Seen from the convex side of the asterolith all three spines point counter-clockwise, thus giving the asterolith somewhat a resemblance to a germanic sun-rune.

Type location: Mattsee Station 133. Type formation: Middle Paleocene (Thanetian).

Discoaster contortus, nov. cent. Fig. 10. Stradner, 1958, p. 187, 188, fig. 35 and 36.

Asteroliths consisting of six arms of which three on each side are connected in a similar way as those of *Discoaster tribrachiatus.* The angle of contortion be-

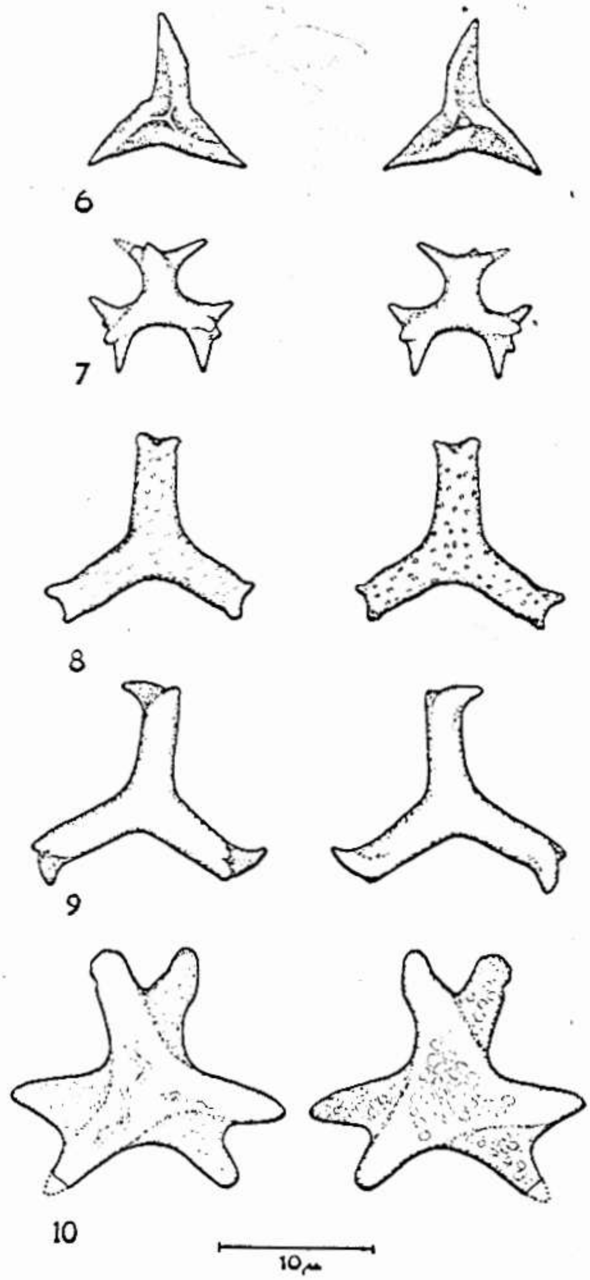


FIG. 6—*Discoaster currens* nov. cent.; FIG. 7—*Discoaster (?) furcatus* Deflandre; FIG. 8—*Discoaster tribrachiatus* Bramlette & Riedel; FIG. 9—*Discoaster rotans* nov. cent.; FIG. 10—*Discoaster contortus* nov. cent.

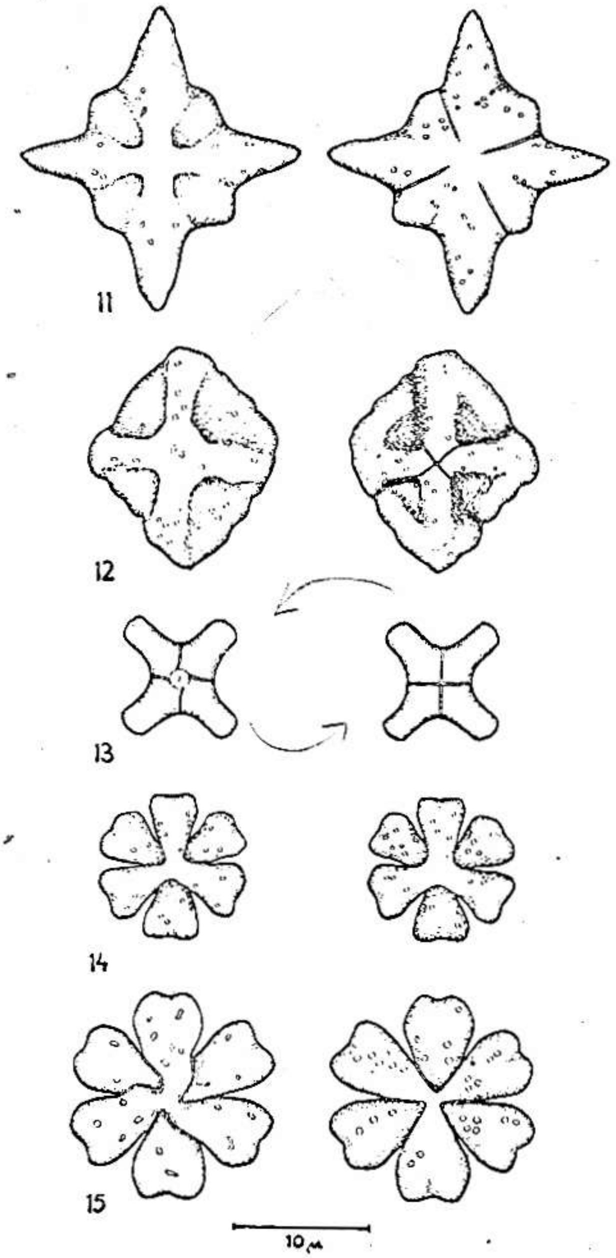


FIG. 11—*Trochoaster austriacus* nov. cent.; FIG. 12—*Trochoaster swasticoides* Martini; FIG. 13—*Discoaster cruciformis* Martini; FIG. 14—*Discoaster molengraaffi* Tan Sin Hok; FIG. 15—*Discoaster molengraaffi* Tin Sin Hok.

tween the pair of ray-groups is about 40°, so that the rays are on either face of the asterolith alternatively high and low, the angles between them alternatively 40° and 80°. No sutures, generally no central knob.

Type location: Göllersdorf. Type formation: Miocene (Helvetium). Possibly reworked from the Cretaceous where similar forms were found.

Discoaster cruciformis Martini, fig. 13. Martini, 1958, pl. 2, fig. 9 a, b.

Asteroliths in the form of a cross with blunt beams. The cross-shaped outline is expanded in the direction of two opposite incisions, so that the axes of the rays do not meet in one centre, but in two focuses. A similar state can be found on the trochoasters (Martini, pl. 5, fig. 26 a, b, and 27 a, b). Earliest occurrence in Austria: Middle Paleocene (Thanetian) of Mattsee.

Discoaster molengraaffi Tan Sin Hok. Figs. 14, 15 and 24.

Tan Sin Hok, 1927, p. 120, text fig. II, 9 and 10.

The rays of the asteroliths are united in two groups of three each, the angles between the connected rays being 120 degrees. The outline of the rays resembles those of *D. deflandrei* with the difference that the incision between the rays is never rounded, but acute. The rays have a more wedge-like shape. The terminal notch is not so pronounced as in *D. deflandrei* or *D. distinctus.* There are also forms to be found in which the arrangement of the rays is not alternatively, but identical on both sides (Fig. 15 and Stradner, 1, p. 186, fig. 27). Earliest occurrence in Austria: Middle Eocene (Lutetian) of Holzmannberg.

Discoaster tani Bramlette & Riedel, fig. 16-17.

Bramlette & Riedel, p. 397, pl. 39, fig. 1.

Asteroliths, five- or six-rayed, with slender rays of almost equal width. Terminal notch small. On the superior face there is a star of elevated ridges which are on one side lined by the central parts of the sutures. The inferior face has straight suture-lines. Also the sub-species nodifer Bramlette & Riedel, fig. 17, is found occurring together with the form-species. Earliest occurrence in Austria: Middle Eocene (Lutetian) of St. Pankraz.

Discoaster binodosus Martini. Figs. 18-19. Martini, 1958, pl. 4, fig. 18 a, b and 19 a, b.

Asteroliths with usually 7 rays, which have one and sometimes even two pairs of sturdy bilateral knots.

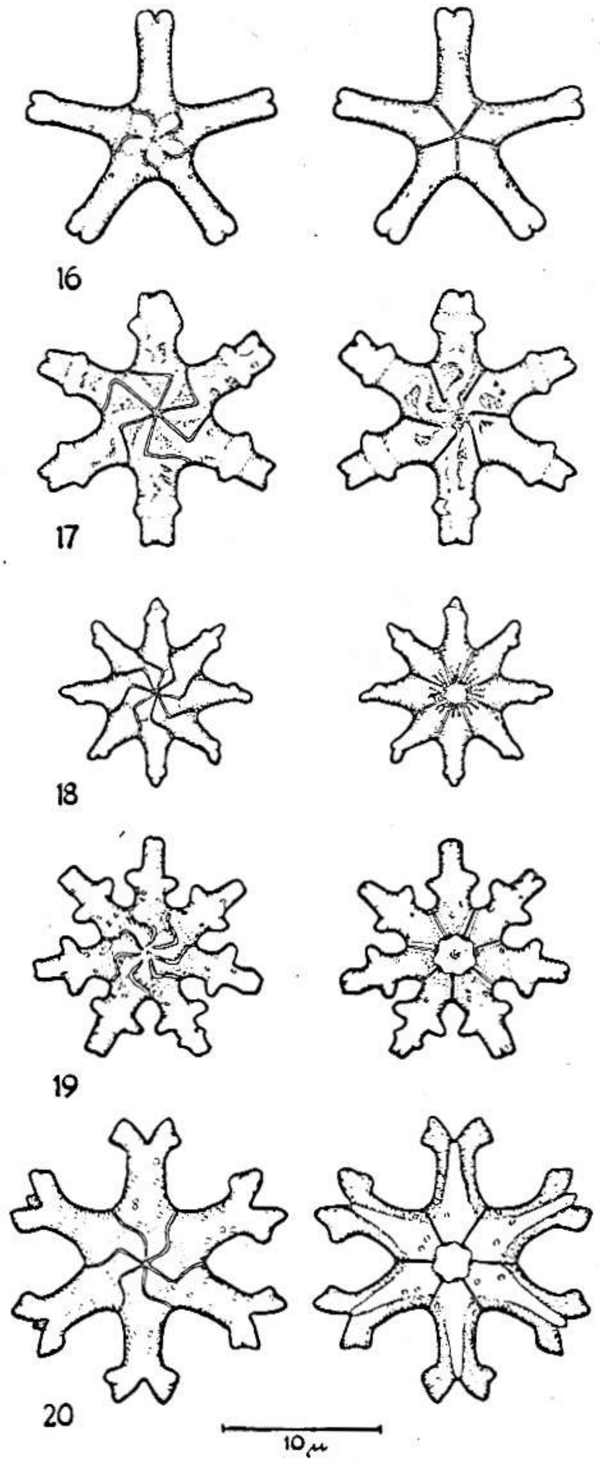


FIG. 16—*Discoaster tani* Bramlette & Riedel; **FIG. 17—*Discoaster tani var. nodifer*** Bramlette & Riedel; **FIG. 18—*Discoaster binodosus*** Martini; **FIG. 19—*Discoaster binodosus v. hirundina*** Martini; **FIG. 20—*Discoaster distinctus*** Martini.

The suture-lines of the superior face are crooked as in *Discoaster mirus* and in many other discoasters. The suture-lines of the inferior face are situated on elevated ridges. The rays are thinner near the central knob than near the periphery. The sub-species *Discoaster bin. bin.* Martini is found occurring together with the sub-species *Discoaster bin. hirundinus* Martini. The latter has terminal notches (Fig. 19). Earliest occurrence in Austria: Middle Eocene (Lutetian of Oichtental.

Discoaster distinctus Martini, fig. 20. Martini 1958, pl. 4, fig. 17 a, b.

Asteroliths with usually six arms which have an almost rectangular, deep terminal notch. Two lateral knobs broaden each ray near its distal ends. The superior face shows crooked suture-lines, the inferior face has straight suture-lines, a central star-shaped knob and ridges which extend far out into the rays and often even more, so that their ends can be seen within the terminal notch. Earliest occurrence in Austria: Middle Paleocene (Thanetian) of Mattsee.

Discoaster gemmeus, nov. cent. Fig. 21.

Derivation nominis: gemmeus (lat.) gleaming.

Asteroliths with eight or nine rounded rays which are united most of their length. The superior face has crooked suture-lines like in *Discoaster mirus,* the inferior face has high ridges which unite in the centre to a cone-shaped structure. Between these ridges suture-lines only can be seen near the periphery. Sometimes a central pore is visible. This new form-species is easily to be found because of its strong light-friction in low magnification. The asteroliths appear to have a gleaming emerald colour because of their considerable thickness.

Type.location: Mattsee, station 133. Type formation: Middle Paleocene, (Thanetian).

Discoaster hilli Tan Sin Hok. Fig. 22.

Tan Sin Hok 1927, p. 120. Jukes-Browne & Harrison, 1892, p. 178, fig. 3. Deflandre, 1934, p. 64 and 65, fig. 27 and 28. Stradner, 1958, p. 186, fig. 30.

Asteroliths have 7-10 subcylindrical stout rays with rounded ends. Usually no terminal notch. Crooked suture-lines on the superior face, straight ones on the inferior face. In some Eocene materials more abundant than the rather similar *Discoaster mirus.* Earliest occurrence in Austria: Middle Eocene (Lutetian) of Mattsee.

Discoaster mirus Deflandre. Fig. 23.

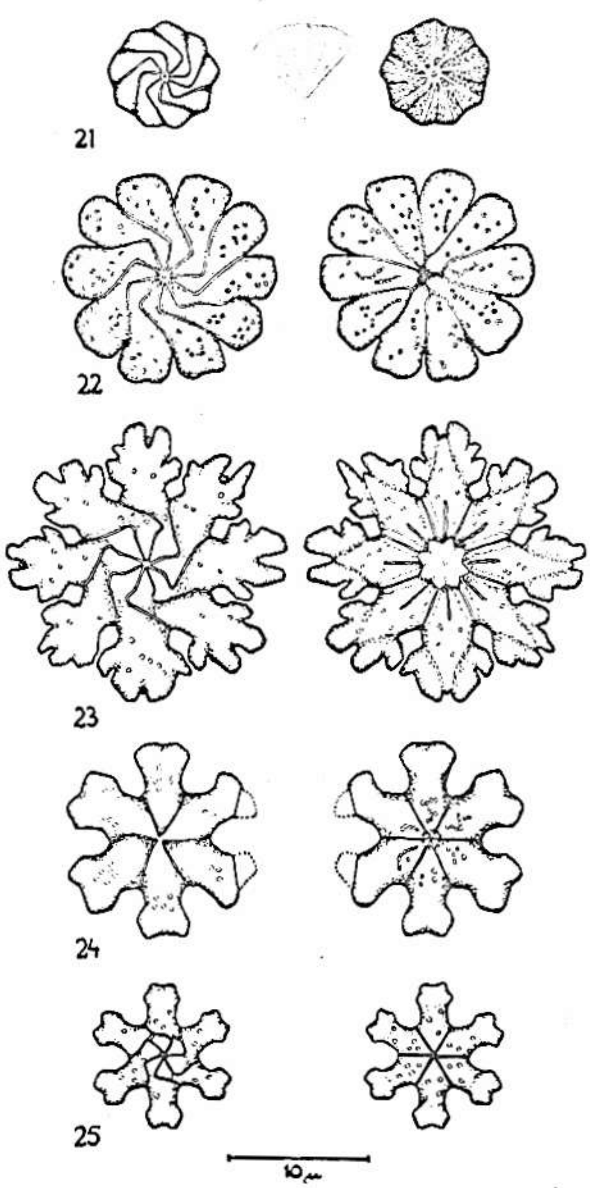


FIG. 21—*Discoaster gemmeus* nov. cent.; FIG. 22—*Discoaster hilli* Tan Sin Hok; FIG. 23—*Discoaster mirus* Deflandre; FIG. 24—*Discoaster cf. molengraaffi* Tan Sin Hok; FIG. 25—*Discoaster deflandrei* Bramlette & Riedel.

Deflandre 1952, p. 465, fig. 362 z. Deflandre 1954, p. 54, fig. 118. Stradner 1958, p. 186, fig. 28 and 29.

Asteroliths consisting of 7-10 sturdy rays, the ends of which have a lobed outline. The superior face shows crooked suture-lines, whereas those of the inferior face are straight. Between the suture-lines of the inferior face there are short furrows extending about a third of the length of the radius in centrifugal direction. Thus the number of the intersections near the centre of the inferior face is doubled, according to Deflandre's original description. Earliest occurrence in Austria: Middle Paleocene (Thanetian) of Mattsee.

Discoaster deflandrei Bramlette & Riedel. Fig. 25, not 24.

Bramlette & Riedel, 1954, p. 399, pl. 39, fig. 6 and text fig. 1 a, b, c. Stradner 1958, p. 184, fig. 17 and 18. Martini 1958, pl. 5, fig. 23 a-c.

Asteroliths with usually six bifurcate rays of angular outline. The rays are rather broad and enclose rounded sinuses (incisiones interradiales). The superior face has crooked suture-lines, the inferior face straight ones. On the latter is a central star. Closely resembles certain forms of *Discoaster molengraaffi* in outline (fig. 24), but not in the suture-lines of the superior face. In Austria only found from the lower Oligocene upwards. Earliest occurrence in Austria at Puchkirchen in cores of the lower Oligocene (Lattorfium).

Discoaster challengeri Bramlette & Riedel. Fig. 26.
Bramlette & Riedel, 1954, p. 401, pl. 39, fig. 10.

Asteroliths mostly with six slender bifurcate rays. The terminations enclose an angle of less than 90° and have a hardly visible screen extended between them. The convex face of the asterolith has a central star, the tips of which reach to the incisiones interradiales. The concave face has sturdy ridges which run in the direction of the rays and end in a round elevated knob. They are united in the centre to a star-shaped, sometimes to a hemidiscoasterid figure (similar to *Discoaster molengraffi*). Earliest occurrence in Austria: Middle Miocene (lower Tortonium) of Frättingsdorf and Baden.

Discoaster perforatus nov. cent. Fig. 27.

Derivatio nominis: perforatus (lat.), perforated.

Asterolith six-rayed with slender asteroradii, which shortly before their pointed endings are enlarged to give space to a round performation. The central disc is resembling that of *Discoaster challengeri* with which it is found occuring together.

Type location: Frättingsdorf. Type formation: Miocene, Tortonium (Lower Lagenid Zone).

Discoaster musicus nov. cent. Fig. 28.

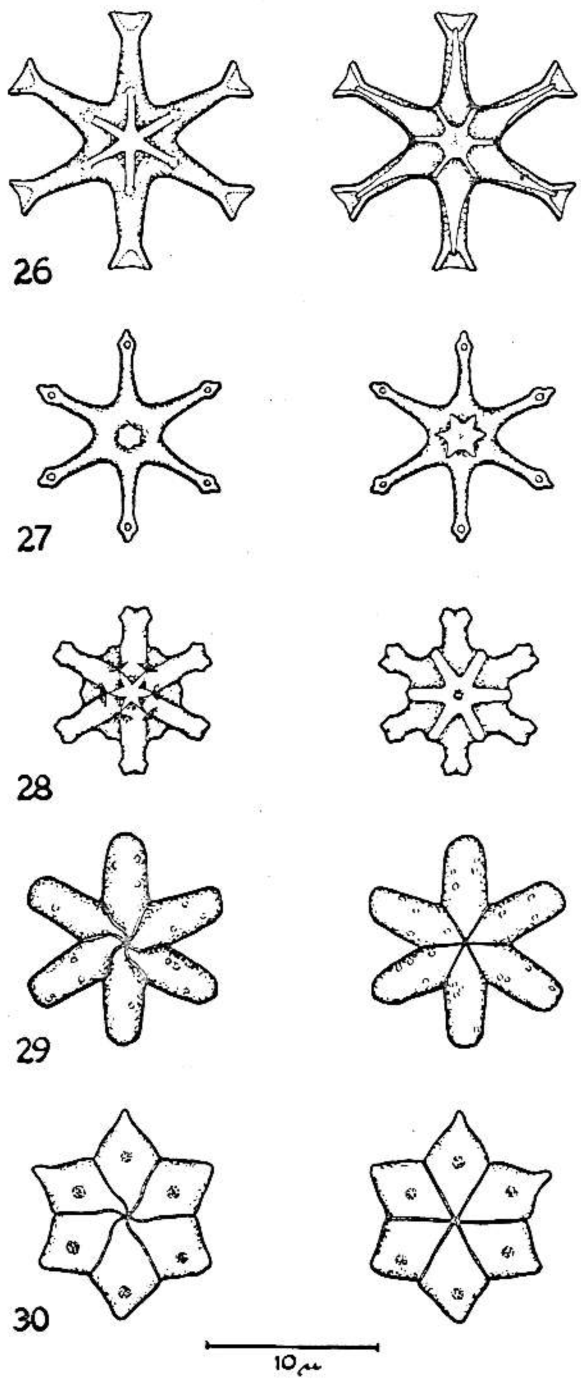


FIG. 26—*Discoaster challengeri* Bramlette & Riedel; FIG. 27—*Discoaster perforatus* nov. cent.; FIG. 28—*Discoaster musicus* nov. cent.; FIG. 29—*Discoaster aster* Bramlette & Riedel; FIG. 30—*Discoaster ornatus* nov. cent.

Derivatio nominus: musicus (lat.) musical. Dedicated to my dear music-loving parents (The author).

Asteroliths with six short rays and a richly decorated central area. The rays have slightly enlarged ends with a shallow terminal notch and two lateral knots resembling those of slender asteroliths of *Discoaster distinctus*. The tips of the large central star of the convex face can be seen as extra interstitial corners of the central disc. On the concave face the rays reach as broad ridges to the centre. The central area of this face can be decorated by an additional star. Type location: Frättingsdorf. Type formation: Miocene, Lower Tortonium (Lower Lagenid Zone).

Discoaster aster Bramlette & Riedel. Fig. 29.

Bramlette & Riedel, 1954, p. 400, pl. 39, fig. 7.

Asteroliths with 5-7 slightly tapering straight rays the ends of which are rounded. The sutures of the superior face are somewhat curved, those of the inferior face are straight. It seems possible that also other form-species contain asteroliths of a similar outline (homoeomorphs). Earliest occurrence in Austria: Oligocene (Rupelium) of Puchkirchen.

Discoaster ornatus nov. cent. Fig. 30.

Stradner 1958, p. 188, figs. 37 and 38.

Derivatio nominis: punctis "ornatus" (lat.), "decorated" with dots.

Asteroliths 6- 9-rayed with pointed ends and a pore at the distal half of the ray. The rays are rather broad, the incisions between them are acute. The smaller the asterolith, the bigger the pore. The pores are similar to those of *Pemma rotundum* Klumpp (Braarudosphaeridae Deflandre), but they are not so near the centre as with *Pemma*. The superior face has curved or crooked suture-lines, the inferior face straight ones.

Type location: Matzen oilfield. Type formation: Miocene, Tortonium.

Form-genus Trochoaster Klumpp

Trochoaster austriacus nov. cent. Fig. 11.

Derivatio nominis: austriacus (lat.) Austrian.

Asteroliths consisting of 4 rays which are almost twice as long as the radius of the basal plate. The basal plate seems to be derived in this new form-species from parts of the rays, as can be concluded from the course of the suture-lines. On one face the rays are united in the center to a slender, low relief cross, on the other side the suture-lines can be seen dividing the asterolith into four similar rays of irregular symmetry. Type location: Holzmannberg. Type formation: Middle Eocene (Lutetian).

Trochoaster swasticoides Martini. Fig. 12.

Martini 1958, pl. 5, fig. 27 a, b.

Asteroliths with rhombic outline and a sturdy diagonal cross in relief appear on one side and a swastica-shaped diagonal cross with suture-lines on the other. The Austrian specimens of this form-species are most robust than those of N.W. Germany described by Martini. Earliest occurrence in Austria: Lower Eocene (Ypresian) of Eitelgraben.

For a more detailed description of the type localities, the preparation numbers of the types, and the variability of the type-series see Papp, 1959 and Stradner, 1959.

Methods of Investigation

The fossil sediments in which discoasters occur or are suspected to occur are dissolved by boiling them in water or in 30% H_2O_2. Residue which settles is examined for its fossil contents. One drop of turbid liquid is decanted on a coverglass (15x15 mm), and dried. A drop of canada balsam is allowed to harden on this coverglass with the help of moderate heat. Then a second coverglass (18x18 mm) is lowered on the balsam while hot and molten. The pair of coverglasses with the discoasters sandwiched in between them is turned over and mounted on a microscopic slide by means of two gummed paper strips. For a more detailed description see Stradner, 1958, p. 179-180.

By using this method discoasters can be viewed from both sides. Already in 1934 Deflandre has made the important discovery that discoasters differ on opposite sides. It will be of great advantage in the investigations on the phylogeny of these fossils, if this discovery will be made full use of in all further descriptions of discoasters. Especially the study of the important step of evolution between the late Tertiary discoasters and their older predecessors can be faciliated by the observacation of both sides of the asteroliths.

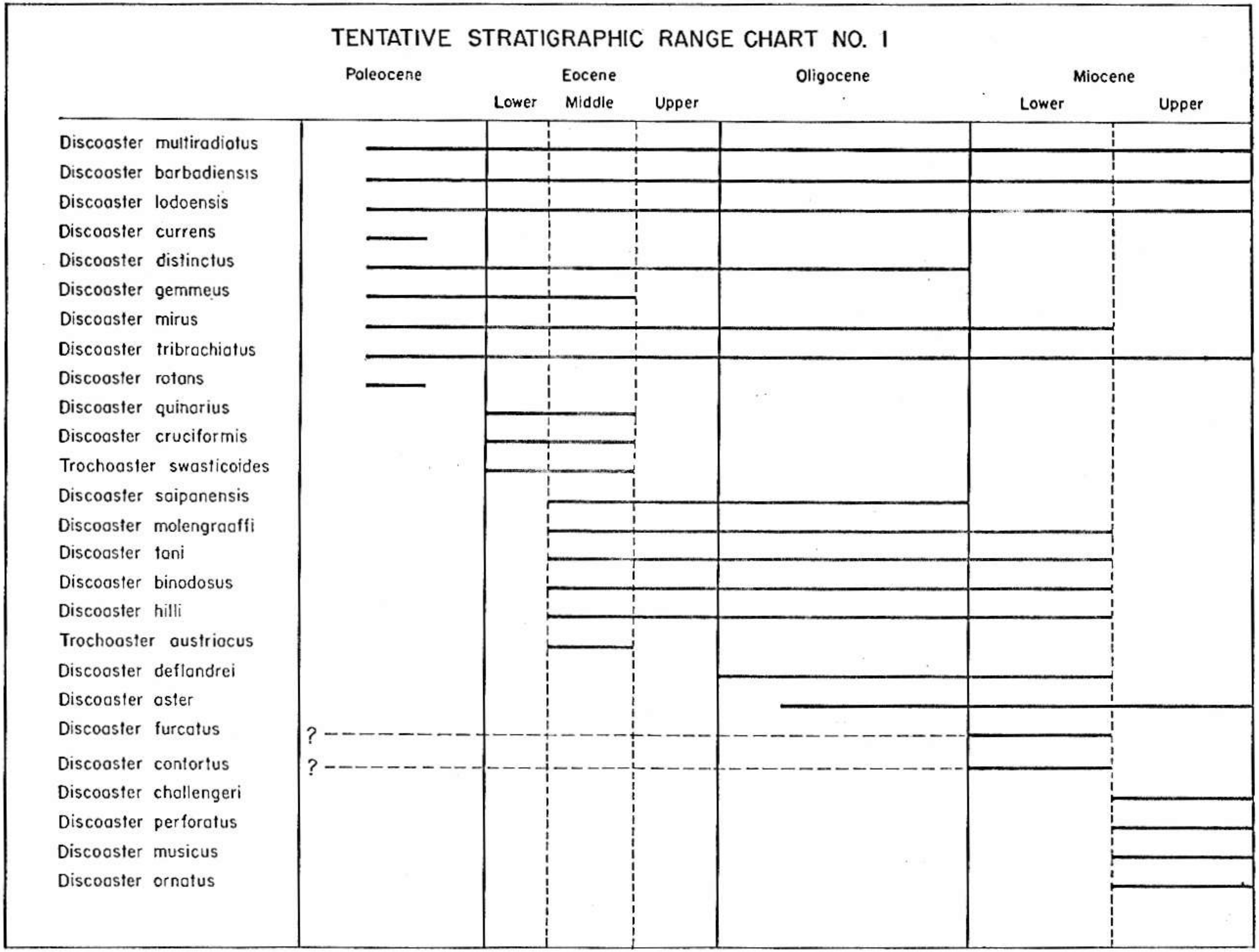
Also liquid mediums, such as a saturated solution of $CaCl_2$ in H_2O, can be used for the microscopical examination of discoasters. The use of a microscope with high magnification is by all means necessary. Drawings are still to be considered the most appropriate means to illustrate the features of these tiny fossils, as with large magnifications only one optical level can be reproduced in a photograph.

Tentative Stratigraphic Range Chart

The materials available for this preliminary report cover the range from the middle Paleocene to the upper Miocene. Only microfossils found within the territory of Austria were considered. Cretaceous samples as well as recent sediments collected during the Austrian Deep Sea Expeditions could not be included in this report. They will be dealt with in following publications on Austrian discoasters (see bibliography).

Arranging the occurrences of discoasters in Tertiary marine sediments in a table (Chart No. 1) according to their geologic age proves that there are evidently younger and older form-species. In this chart the discoasters were not arranged according to their similarity or systematic relation, but in respect to their first occurrence in the sediments. Nevertheless some groups which are similar in outline as well in suture-lines occur in sediments of similar age. Though some of the Paleocene form-species will finally prove to reach farther back into geologic time than now can be expressed in this chart, the form-species *Discoaster tani, D. binodosus, D. saipanensis,* and *D. hilli* seem to be restricted to sediments younger than lower Eocene. A very promising aspect is given by the late Tertiary form-species such as *Discoaster challengeri, D. perforatus, D. musicus* and *D. ornatus.* They have not been found so far occurring earlier than middle Miocene in Austrian sediments. With their delicate structure, their typical outline and in some sediments their great percentage in the assemblage (about 90% in the Tortonium of Nussdorf/Vienna and even more in some Italian and Roumanian materials) they will most probably be useful in establishing time-horizons.

Planktonic organisms are very fast in their distribution in worldwide oceans because they are carried by the oceanic drifts and currents. The time required for a new species to encircle the globe is infinitely small as compared to the millions of years of a geologic formation. For practical purposes it can be neglected. The first appearance of a new species of planktonic organisms can therefore be considered as approxi-


TENTATIVE STRATIGRAPHIC RANGE CHART NO. 1
Paleocene
Eocene
Oligocene
Miocene
Lower
Middle
Upper
Lower
Upper
Discoaster multiradiatus
Discoaster barbadiensis
Discoaster lodoensis
Discoaster currens
Discoaster distinctus
Discoaster gemmeus
Discoaster mirus
Discoaster tribrachiatus
Discoaster rotans
Discoaster quinarius
Discoaster cruciformis
Trochoaster swasticoides
Discoaster saipanensis
Discoaster molengraaffi
Discoaster tani
Discoaster binodosus
Discoaster hilli
Trochoaster austriacus
Discoaster deflandrei
Discoaster aster
Discoaster furcatus
Discoaster contortus
Discoaster challengeri
Discoaster perforatus
Discoaster musicus
Discoaster ornatus
?
?

mately instantaneous as compared with the geological time scale. For this reason the Discoasteridae will prove to furnish valuable marker-fossils in geologic correlations. As Bramlette & Riedel already said in 1954: "Present data indicate the probability that the discoasters may aid in world-wide correlation of certain Tertiary time horizons."

The more descriptions of Discoasteridae assemblages even of small geologic areas are published, the easier will the intercontinental correlation be accomplished within the near future.

Discussion on the Possibility of the Use of Discoasters in Biostratigraphy.

Questions and Answers

Q. Do discoasters and similar fossils show differences during geologic time? *A.* Yes. There are marked differences between the assemblages of the early and late Tertiary.

Q. Can discoasters be used as marker-fossils? *A.* Yes, in a limited way. As some of them are apparently of long geologic range, only their first occurrence can be used to mark geologic boundaries.

Q. Did the discoasters really have such a long geologic range or do we have to consider many findings as reworked specimens? *A.* At the present time the question of whether some of the form-species are of short or long life cannot be answered definitely because the scope of the materials investigated is not broad enough. As soon as more authors of different countries have published their statistics it will be possible to decide whether the discoasters of the alpine region, which is a geologically very unstable one, have been reworked or whether they simply have died out slowly. In the Tertiary in the Alpine Foreland there must have been much reworking.

Q. Why does this group of microfossils arouse so much interest? *A.* Because as fossils of planktonic organism they are abundant in marine sediments the world over. They are cosmopolitically distributed. Their study is very encouraging in respect to the world-wide correlation of marine sediments. Therefore discoasters will be of practical interest for the petroleum geologist.

Q. Why can it be assumed that the discoasters and similar fossils are of planktonic origin? *A.* Because of their enormous abundance in certain sediments (e.g. Lutetian or Miocene). Only small organisms with a sufficient large living space (lebensraum) could have been able to produce several millions of fossils per cubic inch. No benthonic organisms are known which could have furnished such a quantity of fossils.

Q. What group of microfossils do the discoasters occur with? *A.* The discoasters are not only in their optical properties under polarized light, but also in their distribution associated with the coccoliths, so that we might assume that they are remnants of planctonic unicellular organisms. They occur in greatest numbers in fossil *Globigerina* ooze.

Q. Have living discoasters been observed? *A.* Except one interesting find described by Lecal no study of living discoasters has been made. Therefore they are generally still named as fossils incertae sedis.

Q. Where are laboratories working on the problems involved in the Discoasteridae and their biostratigraphy? *A.* As far as now known to the author investigations are being carried on in France, in Germany, in Poland, in the U.S.A. in the U.S.S.R., and here in Austria. A detailed report on the latest in literature on discoasters is given in Erdoel Zeitschrift, 1959.

For information on discoasters of other countries and continents the reader is referred to the beautifully got up and thorough publications by Bramlette & Riedel, Deflandre, and Martini. (Compare bibliography).

Acknowledgments

For help in the preparatoin of this paper and for materials and stratigraphic data the author is greatly indebted to Dr. Dr. mont. h. c. K. Friedel, Österreichische Mineralölverwaltung; to Dir. Dr. R. Janoschek and Dr. E. Braumüller, Rohölgewinnungs A. G., to Dr. A. Papp, Prof. of Paleontology at the University of Vienna; for literature and valuable advice to Prof. M. N. Bramlette and Dr. W. R. Riedel, Institute of Oceanography, University of Los Angeles; to Prof. Dr. G. Deflandre, Directeur de Laboratoire à l'Ecole Pratique des Hautes Etudes, Paris; to Prof. Dr. E. Kamptner, Nat. Hist. Mus. Vienna; and to Dr. E. Martini, Geol. Pal. Institute of the University of Frankfurt/am/Main. For further advice the author wants to say many thanks to Dir. Prof. Dr. H. Küpper and, last but not least, to Dr.

R. Grill, chief geologist, Geol. Bundesanstalt in Vienna.

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