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Rock–Forming Nannofossils in Uppermost Jurassic–Lower Cretaceous Rock Units of Northwest Anatolia: *Nannoconus* and Its Resived Taxonomy

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Abstract: Nannoconids have been recorded in a rock-forming quantity in the uppermost Jurassic-Lower Cretaceous rock units in Northwest Anatolia, Turkey. Samples were collected from seventeen stratigraphic sections spanning the calciturbidities of the Yosunlukbayırı Formation and pelagic micrites of the Soğukçam Limestone. Because of rareness and difficulties for extracting of calcareous nannofossil species particularly zone markers in these type lithologies, nannoconids have particular attention in terms of biostratigraphy. Twenty nine species of nannoconids were recorded in the studied samples. Their taxonomy were revised and their stratigraphic ranges were given. The classification of genus *Nannoconus* is based on the gross morphology of the test, presence of central cavity or central canal, proportion of central cavity to thickness of the wall, proportion of height to width. Thickness of calcite elements, degree of horizontal intercept angle, type of apertures and degree of horizontal intercept angle, type of apertures, and degree of angle of apertural elements are also used for description of the species. Fluctuations in nannoconid abundance are related to lithological changes. High abundance of nannoconids in limestones indicates clear surface water palaeoenvironments without terrigenous influx. From the stratigraphical point of view, their importance was clarified by their high abundance peaks. Problematic zonal boundaries of the nannofossil zonation could be determined by major nannoconid bioevents.

Kuzeybatı Anadolu’nun Enüst Jura–Alt Kretase Kaya Birimlerinde Kaya Yapıcı Nannofosiller: *Nannoconus* ve Geliştirilmiş Taksonomileri

Özet: Nannoconid'ler Kuzeybatı Anadolu'da yüzeyleyen enüst Jura-Alt Kretase kaya birimlerinde kayanın tamamını oluşturacak bollukta kaydedilmiştir. Örnekler Yosunlukbayırı Formasyonu'nun kalsitürbiditlerinde ve Soğukçam Kireçtaşı Formasyonu'nun pelajik mikritik kireçtaslarında ölçülen onyedi stratigrafik kesit boyunca toplanmıştır. Bu tür litolojilerde kalkerli nannofosillerin, özellikle zon belirleyici türlerinin azlığı ve bunların kaya matriksinden zor çıkartılması biyostratigrafik açıdan nannoconidlere önem verilmesi gereğini ortaya koymuştur. Bu çalışmada taksonomileri geliştirilen ve stratigrafik dağılımları verilen yirmidokuz *Nannoconus* türünün sınıflandırılması testin genel şekline, merkezde kanal veya geniş boşluğun bulunmasına, merkezdeki boşluk genişliğinin testin duvarının kalınlığı ile olan oranına, testin yüksekliğinin enine olan oranına göre yapılmıştır. Ayrıca, test duvarını oluşturan kalsit elementlerinin kalınlığına, yatay eksenle yapmış olduğu açıya, açıklığın şekline ve çevresindeki kalsit birimlerinin yatayla yapmış oldukları açıya dayanılarak da bazı tür ve alt tür ayrımı yapılmıştır. Nannoconid bolluğundaki azalıp çoğalma litolojik değişimlerle ilişkilidir. Kireçtaşları içindeki nannoconid bolluğunun yüksekliği, nannoconidlerin karasal klastik malzemeden arınmış berrak yüzey suyu ortamınında yaşadığını gösterir. Stratigrafik açıdan önemleri onların bolluklarındaki çıkışlardır. Nannofosil zonasyonundaki bazı problemli sınırlar bu nannoconid biyo-olayları ile belirlenebilinir.

Introduction

Nannoconids are marine, calcareous organisms which played a significant, lithogenetic role in the formation of uppermost Jurassic and Lower Cretaceous calciturbidities of the Yosunlukbayırı Formation and particularly fine-grained, pelagic limestones of the Soğukçam Limestone, NW Anatolia (Plate 1). They have been recorded in extremely high abundance such as 1100 nannoconid individuals of 1420 total calcareous nannofossil individuals which have been encountered from 500 points of view of thin-section of Sample KEL-16 from the upper part of the Yosunlukbayiri Formation. For that reason, nannoconids can be informally named as a rock-forming nannofossils in this study. They are nannoliths, whose size varies from 3- 40 μm. The morphology of the test is relatively simple. Most of the species are conical, either truncated or more elongated. Some frequently occurring species are cylindrical and globular. In the axis of the cone (or cylinder) there is a central opening; a canal or cavity, which has apertures at both poles. The shape and diameter of the canal, as well as the size of the apertures, are the important characteristic of the species. The wall consists of very tiny calcite elements, about 0.5-2 μm thick, oriented perpendicular to and spirally surrounding an axial cavity or canal (Fig. 1A).

The main purpose of this paper is to present detailed taxonomy of this significant nannofossil group and to make some semi-quantitative approaches on them. Although the calcareous nannofossil biostratigraphy of the studied sections have been presented in Özkan (1993) and Özkan–Altıner (1996), the stratigraphic distributions of nannoconid species and their high abundance peaks which are very valuable bioevents for the Lower Cretaceous biostratigraphy will be also introduced and given in this paper.

In the present study, nannoconids were encountered from 410 samples which were collected from 17 stratigraphic sections spanning from the Tithonian to the Aptian. The sections were measured from the Yosunlukbayırı Formation and the Soğukçam Limestone, NW Anatolia, Turkey (Altıner *et al.*, 1991) (Fig. 2). The Yosunlukbayırı Formation consists of alternating green to cream coloured marl and micritic limestone that becomes detrital (calciturbidites) in the upper part. The Soğukçam Limestone, which overlies the Yosunlukbayırı Formation, consists of white to pink, porcalenoues micritic limestone (Altıner *et al.*, 1991).

Methods of Study

In the present study, nannoconids are encountered in thin-sections which their thickness is approximately 0.010 mm., as well as in smear-slides. Experiments have shown that the smear slide preparation methods including Monechi and Thierstein's method (1985) for hard lithologies, are not suitable for porcelaneous micritic limestone and calciturbidite (packstone, grainstone), because of the unfavourable lithologies. During usual smear slide preparation methods, where sediments are disaggregated, nannoconids in particular disintegrate into calcite plates and most of them are not recognisable as elements of nannoconids. Although the thin-section method is not commonly used to identify calcareous nannofossils, the recognition of these fossils, particularly nannoconids, is possible in thin-section, because of their high abundance in these lithologies. A single thin section contains numerous oriented and abundant oblique sections of nannoconids. In all species of nannoconids, test size and proportions vary with the orientation of sections (Fig. 1B and C). An exact image of the test can be only obtained from longitudinal sections of nannoconids. The delimitation of species has to be schematic if we want to obtain objectively quantifiable units. Attention has also been paid to the recognition of species from unoriented sections by comparing their size and proportions with the types of species or with the longitudinal sections of species. For this reason, simple morphometric measurements of the height, the maximum diameter and the diameter of the central cavity of the specimen have been made for the following species: *Nannoconus bermudezii, N. steinmannii steinmannii, N. steinmannii minor, N. kamptneri kamptneri, N. kamptneri minor, N. bucheri.* The results will be discussed in the remarks of related species.

Terminology of nannoconids (Plate 2; Fig. 1 A, B and C):

Components:

Element: Basic structural component of a nannoconid. Rhomboidal or subtriangular, broad and thin calcite crystals.

Wall: A structure consisting of an interlocking arrangement of elements enclosing a central opening.

Structure:

Cycle: A set of overlapping elements oblique to the vertical axis of the specimen.

Horizontal intercept angle: An angle between the inclined individual elements and the horizontal axis of the test.

Low horizontal intercept angle: Inclination of the cycle is less than 45° with respect to the horizontal axis of the test.

High horizontal intercept angle: Inclination of the cycle is greater than 45° with respect to the horizontal axis of the test.

Internal features:

Central opening: Perforation at the centre of nannoconids.

Central canal: Central opening $<$ 1µm in total diameter.

Central cavity: Central opening $>$ 1µm in total diameter.

Aperture: The terminal opening at both ends of the central opening of the specimen.

Restricted aperture: A very narrow aperture, $<$ 0.5µm in diameter.

Open aperture: A distinct opening is visible, $>$ 0.5µm in diameter.

Apertural elements: Terminal cycle of elements surrounding the aperture.

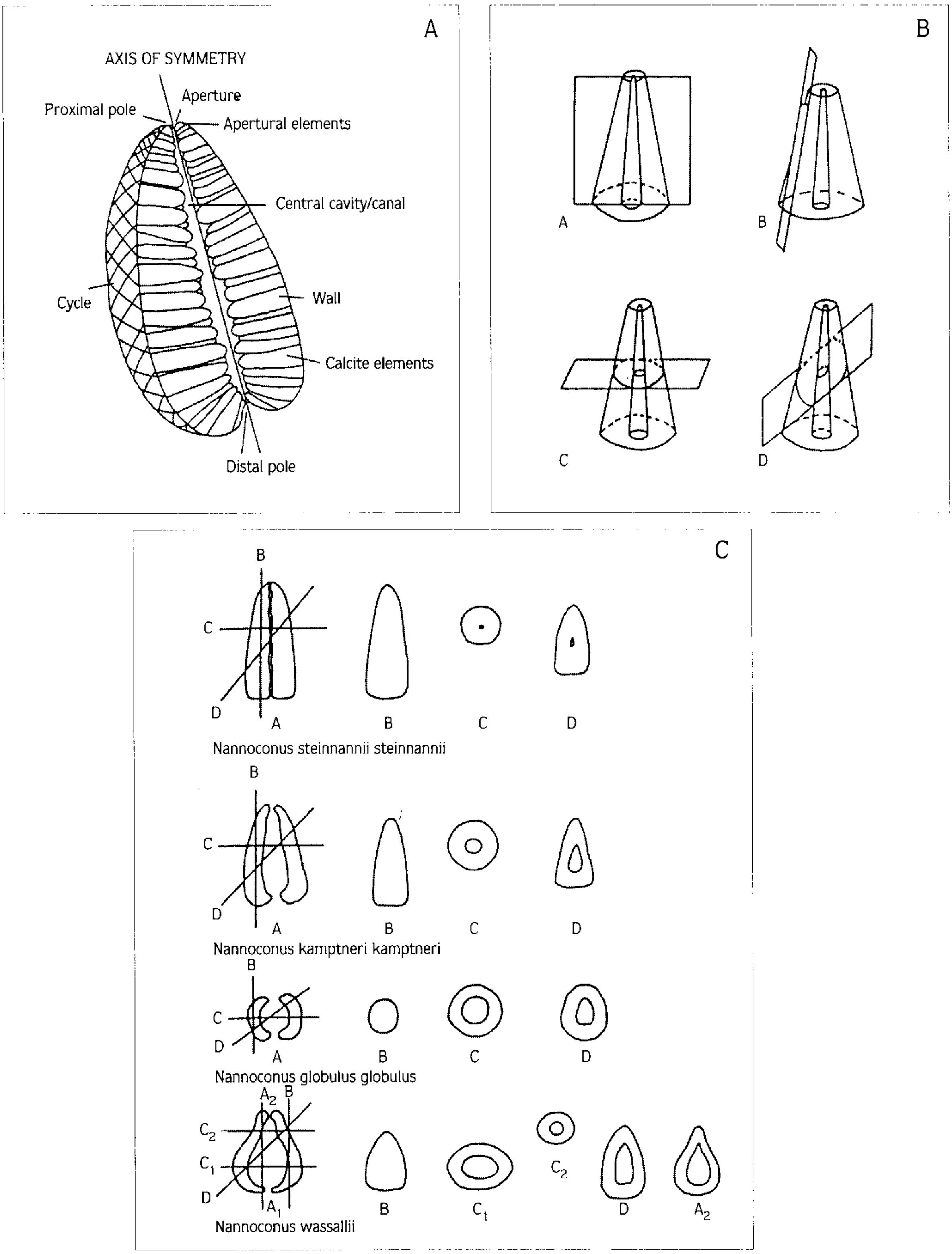


Figure 1. A) Terminology of nannoconids; B) Schematic sketches showing different orientations of nannoconid sections and c) examples from some important species. A. Longitudinal section; B. Tangential section; C. Transverse section; D. Oblique section. Not to scale.

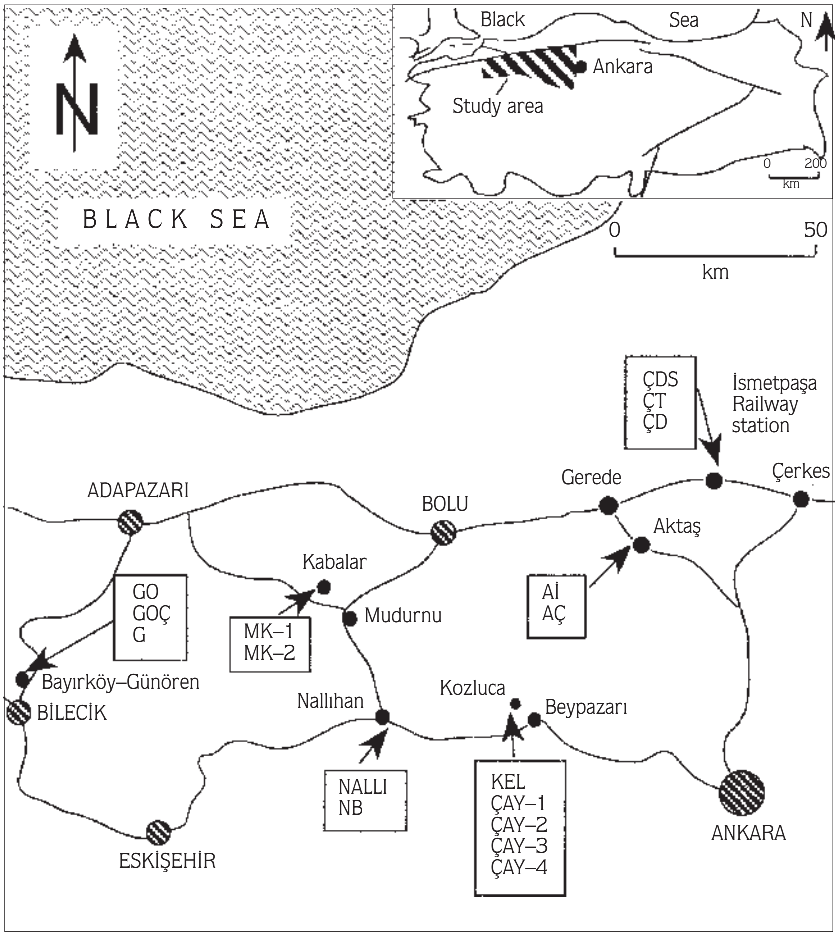


Figure 2. Location map of the study area and the stratigraphic sections.

High angle apertural elements: The elements surrounding the aperture which have an inclination of ≥ 10° to the horizontal axis of the specimen (LM) .

Low angle apertural elements: The elements surrounding the aperture which have an inclination of < 10° to the horizontal axis of the specimen (LM).

Classification

Kamptner (1931) who initially recognised *Nannoconus steinmannii*, proposed that the nannoconids were remains of a morphologically and systematically independent Protozoa group, *incertae sedis*. It was Brönnimann (1955) who ascertained that the morphological differences that had already been recognised, surpassed the limits of variability of one species, and who established the order of the individual features according to their taxonomic importance. According to Brönnimann (1955), the outline and the dimensions of the test, the axial canal or the internal cavity, the thickness and the composition of the walls, and the position and the diameter of the aperture are useful morphological features of nannoconid classification. Trejo (1960), Baldi-Beke (1965), Deres and Achéritéguy (1972, 1980), Aubry (1974) and Van Niel (1992) made some approaches to the classification of nannoconids.

Although 29 species of nannoconids were recognised in the studied samples, only the most common and stratigraphically important 21 of them have been described and discussed in this paper. Most of our studies are based on light microscope (LM) examination from mainly very thin thin-sections. Their classification is based on the gross morphology of the test (shape of test), presence of central cavity or central canal, proportion of diameter of the central cavity to thickness of the wall, proportion of height to width. The thickness of calcite elements, degree of horizontal intercept angle, type of apertures, and degree of angle of apertural elements are also used for description of the species. For the recognition of these features, the LM is preferable to the SEM. Because the external shape of nannoconids is similar e.g.,*N. colomii*, *N. steinmannii, N. kamptneri*, the SEM provides information concerning only their external morphology, wall structure and apertural plates. However, discrimination based on shape and diameter of the central cavity can not be recognised with the SEM. On the other hand, the way, in which sections are cut, such as oblique or tangential sections, can hinder their original morphological features.

Systematic Paleontology

Family NANNOCONACEAE Deflandre, 1959

Genus *Nannoconus* Kamptner, 1931

Type species: *Nannoconus steinmannii* Kamptner, 1931

Nannoconus bermudezii Brönnimann, 1955

Pl.3, fig.1; Pl. 4, figs. 1, 2

1955 *Nannoconus bermudezii* Brönnimann, p.37, pl.2, figs.1, 24, text-figs. 2d, 2e.

Description: A long, slender, slightly curved, conical nannoconid. A narrow central canal follows the outline of the test. The wall is composed of thick calcite elements which have a low horizontal intercept angle. There are restricted-type apertures at both poles which are made of high angle apertural elements.

Remarks: It differs from *N. steinmannii steinmannii* in having a long and curved-shaped test. According to Brönnimann (1955), *N. bermudezii* differed from all other cone-shaped forms by being about one and one-half to two times longer than them. In this study, biometric criteria are used for the recognition of this species. The biometric study shows that specimens with a ratio of height to diameter of the test of more than 2.25 belong certainly to *N. bermudezii.* For ratios between 2.0 and 2.25 the designation *Nannoconus* sp. should be employed, although these might be transitional forms between *N. bermudezii* and *N. steinmannii steinmannii* or only oblique sections of *N. bermudezii*. Specimens with a ratio below 2.0 should be included in *N. steinmannii steinmannii* although some oblique sections of *N. bermudezii* and *N. steinmannii steinmannii* might be included.

For biometric analysis, the diameter and the height of 71 specimens of *N. bermudezii* were measured in thin-section. The H versus D diagram shows the ranges of height and diameter of *N. bermudezii*, height ranges from 13-40µm and the diameter ranges from 6-16µm (Fig. 3A). Figure 3B shows that the 13-33µm height range occurs most frequently (Max.frequency, 9 = 20µm) and the average height of *N. bermudezii* is 21.92µm. As for its diameter, the 7-10µm range has the maximum frequencies (Max. frequency, 19= 8µm) and the average diameter of *N. bermudezii* is 8.53µm (Fig. 3C).

Dimensions: Height (H): 13-40µm; Diameter (D): 6-16µm.

Nannoconus bonetii Trejo, 1959

Pl.4, fig.3

1959 *Nannoconus bonetii* Trejo, p.131, figs.2a-f.

Description: An elongated, pear-shaped nannoconid. While the basal part of the test is globular, the conical, upper part dominates the structure. The distal and proximal parts are rounded, usually with a flat area in the centre. The height of the test is about two times longer than its diameter. The wide central cavity is also an elongated pear-shape, like the outline of the test. The wall is thin relative to the diameter of the central cavity. Thin calcite elements, which compose the wall, make a low horizontal intercept angle. The aperture at the distal pole is relatively larger than the aperture at the proximal pole, but both of them are restricted-type apertures. Both apertures are surrounded by high angle apertural elements.

Remarks: It differs from *N. kamptneri kamptneri* in having an elongated, pear-shaped central cavity and test. Its pear-shaped test is similar to that of *N. wassallii*, however, *N. bonetii* differs in having a predominant conical part.

Dimensions: H: 15-24µm; D: 11-16µm.; Diameter of central cavity (C): 1-3µm.

Nannoconus bucheri Brönnimann, 1955

Pl.1, fig.6; Pl.2, fig.7; Pl.3, fig. 2; Pl.4, figs. 4-7

1955 *Nannoconus bucheri* Brönnimann, p.39, pl.1, figs.1-3; 5-7: text-figs.2k-n.

Description: A large, subovoid or truncate-conical nannoconid. The central cavity is also truncated conical or ovoid in shape. The diameter of the central cavity is around twice the thickness of the wall. The wall is composed of medium to thick calcite elements which make medium to high horizontal intercept angles. An aperture at the distal pole is open-type, the other

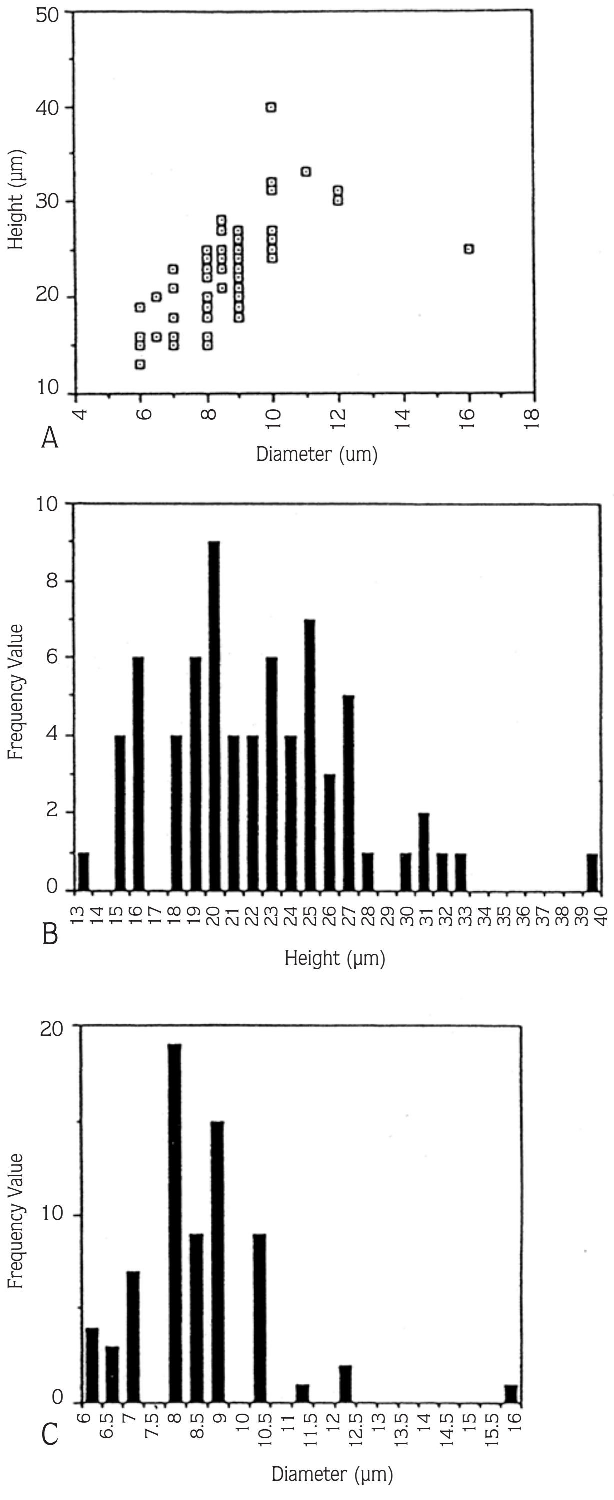


Figure 3. A) Height versus diameter of *Nannoconus bermudezii*; B) Frequency distribution of height of *N. bermudezii*; C) Frequency distribution of diameter of *N. bermudezii*.

aperture at the proximal pole is a restricted-type. The diameter of the apertures, which are surrounded by high angle apertural elements, are smaller than the diameter of the central cavity.

Remarks: *N. wassallii* is distinguished from *N. bucheri* by its pear-shaped central cavity and test. Tangential sections of *N. wassallii* could be mistaken for axial sections of *N. bucheri* but the presence of apertures at both terminal poles indicate this section belongs to *N. bucheri*. It differs from *N. bronnimannii* by its more ovoidal test and larger size. It is distinguished from *N. kamptneri kamptneri* by its more ovoidal test and larger central cavity.

For biometric analysis, the diameter, height and diameter of the central cavity of 58 *N. bucheri* specimens were measured in the thin-section. The H versus D diagram shows the ranges of height (8.0-18.5µm) and diameter (9.0-13.0µm) of *N. bucheri* (Fig. 4A). Figure 4B shows the frequency of height of *N. bucheri* with the 9-15µm height range occuring most frequently (Max.frequency, 12 = 10µm) and the average height of *N. bucheri* is 11.73µm. As for its diameter, the 10-12µm range has the maximum frequency (Max. frequency, 18= 11µm) and the average diameter of *N. bucheri* is 10.96µm (Fig. 4C). The diameter of the central cavity ranges from 3-6µm and the 4-5µm range has the maximum frequency (Max.frequency, 18= 4µm) (Fig. 4D). The average diameter of the central cavity of *N. bucheri* is 4.30µm.

Dimensions: H:11-18.5µm;D:9-13µm; C:3-6µm.

Nannoconus carniolensis lata Deres and Achéritéguy, 1980

Pl.4, figs. 9, 10

1980 *Nannoconus carniolensis lata* Deres and

Achéritéguy, p.27, pl.1, fig.8.

Description: A large thistle-shaped nannoconid. It has a thistle-shaped central cavity like its outline. The diameter of its central cavity is two times larger than the thickness of the wall. The wall is composed of thin calcite elements which make a low to medium horizontal intercept angle. Both apertures, which are surrounded by low angle apertural elements, are open-type apertures.

Remarks: It is distinguished from *N. carniolensis carniolensis* by its larger size, broader central cavity and less prominent collar.

Dimensions: H: 8-10µm; D:10-12µm; C: 4-5µm.

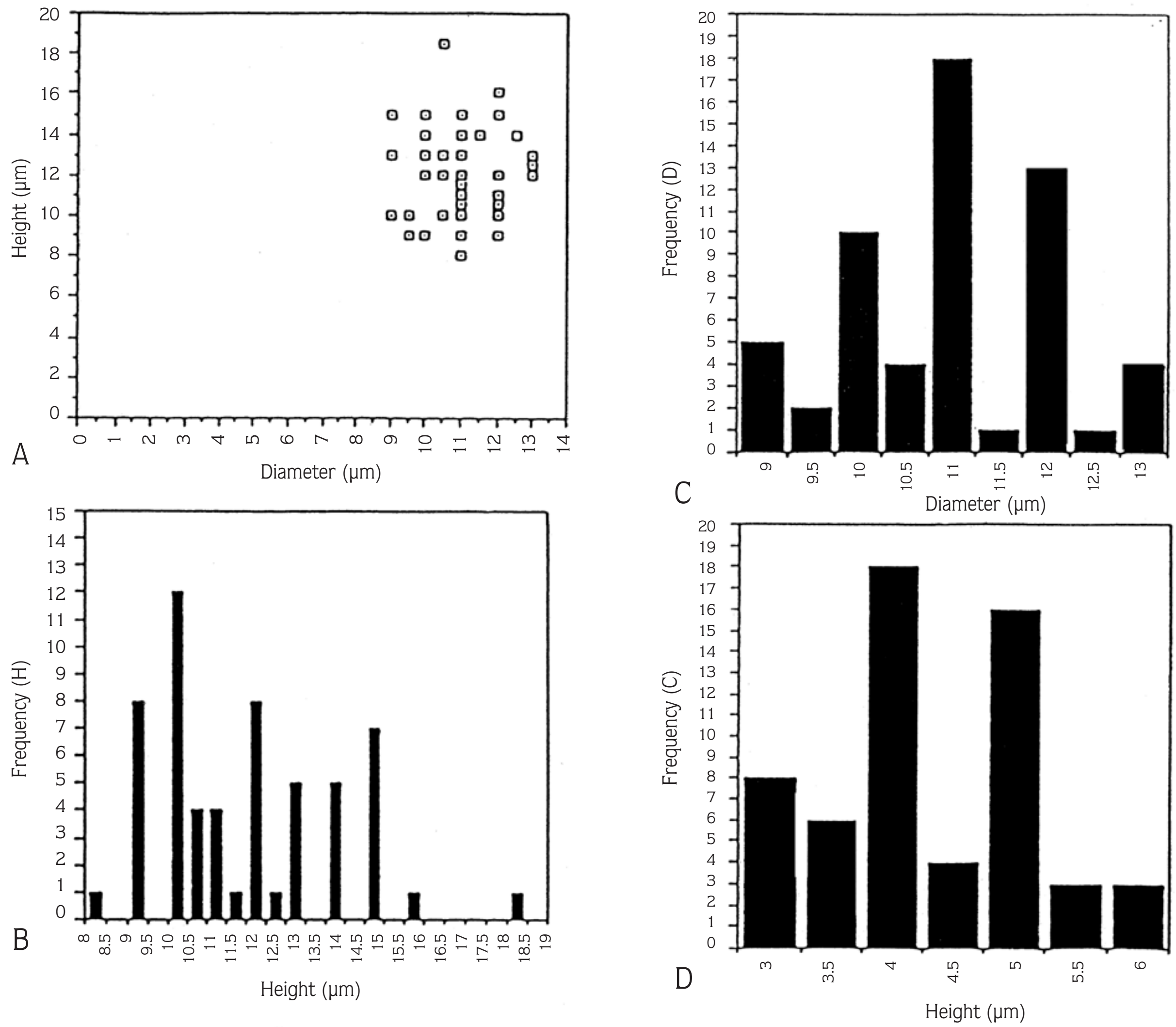


Figure 4. A) Height versus diameter of *Nannoconus bucheri*; B) Frequency distribution of height of *N. bucheri*; C) Frequency distribution of diameter of *N. bucheri*; D) Frequency distribution of diameter of the central cavity of *N. bucheri*.

Nannoconus cornuta **Deres and Achéritéguy, 1980**

Pl.4, fig.1

1980 *Nannoconus cornuta* Deres and Achéritéguy, p.17, pl.1, fig.3.

Description: A short cylindrical nannoconid. Its longitudinal section is almost rectangular in shape. The wall has an undulating outer surface. The central cavity is also rectangular in shape and its diameter is equal or broader than the thickness of the wall. The wall is composed of thin calcite elements which make a high horizontal intercept angle. The apertures, which are surrounded by high angle apertural elements, are small, open-type apertures.

Remarks: It differs from *N. bronnimannii* in having a cylindrical test and central cavity. It is distinguished from *N.* group *truittii* by its undulating outer surface.

Dimensions: H:10-14μm; D:11-15μm; C:3-4μm.

Nannoconus elongatus **Brönnimann, 1955.**

Pl. 4, fig. 8

1955 *Nannoconus elongatus* Brönnimann, p.38, pl.1, figs.10-14, text-figs.2v-y.

Description: An elongated, cylindrical nannoconid. Its longitudinal section is rectangular in shape. The height is always about one and a half times greater than the diameter of the test. The central cavity is straight in shape and its diameter is equal to the thickness of the wall or slightly narrower. The wall is composed of thin calcite elements which form low horizontal intercept angles. The two terminal apertures are open-type apertures which are equal in diameter to the central cavity.

Remarks: It differs from *N. truittii truittii, N. truittii frequens* and *N. minutus* in having different ratios of height to diameter: the diameter of *N. elongatus* is always less than its height.

Thomsen (1987) recognized the canal is narrower in limestones, where overgrowth both externally and internally was more pronounced. He also noticed intermediate forms between *N. elongatus* and *N. bonetii*.

Dimensions: H:10-15μm; D:6-10μm; C:1.5-2.5μm.

Nannoconus globulus globulus Brönnimann, 1955

Pl. 2, fig. 6; Pl. 4, fig. 13

1955 *Nannoconus globulus* Brönnimann, p.34, tab.2, figs.13, 18, 23, text-figs.3a,b.

1987 *Nannoconus globulus globulus* Brönnimann, Bralower, p.231,pl.8, fig.24.

Description: A subspherical or globular nannoconid. The large central cavity is spheroidal, like the outline of the test. The wall is composed of thin to thick calcite elements which make a high horizontal intercept angle. The test has two open-type terminal apertures which are narrower than the diameter of the central cavity. The apertures are surrounded by high angle apertural elements.

Remarks: It differs from all other species of *Nannoconus* in having globular test and large central cavity. It is distinguished from its subspecies *N. globulus minor* by its larger size and large central cavity.

Dimensions: H:7-13μm; D:9-18μm; C:3-6μm.

Nannoconus grandis Deres and Achéritéguy, 1980.

Pl. 3, fig. 3; Pl. 4, fig.15

1980 *Nannoconus grandis* Deres and Achéritéguy, p. 20, pl.1, fig.5.

Description: An large, elongated, subcylindrical or truncate conical nannoconid. The height of the test is about two times greater than the diameter of the test. A wide central cavity which preserves the outline of the test is two times larger than the thickness of the wall at the proximal part of the test and three times larger at the basal part of the test. The wall is composed of thin to medium calcite elements which make a medium to high horizontal intercept angle. The test has two open-type terminal apertures which are surrounded by high angle apertural elements.

Remarks: It differs from *N. kamptneri kamptneri* in having a large central cavity and test.

Dimensions: H: 25-29μm; D: 14-17μm; C: 7-10μm.

Nannoconus inconspicuus Deflandre and Deflandre-Rigaud, 1962.

Pl. 4, figs. 14, 16

1962 *Nannoconus inconspicuus* Deflandre and Deflandre-Rigaud, p. 2369, fig.10.

Description: A short, cylindrical nannoconid. The central cavity which is equal to or larger than the thickness of the wall, preserves the shape of the outline. The wall consists of thin calcite elements which make a low horizontal intercept angle. The terminal apertures are open-type apertures which are surrounded by low angle apertural elements.

Remarks: It differs from *N. minutus* in having a small, broader test. *N. infans* Bralower *et al.* (1989) is similar to *N. inconspicuus*, but its central canal is very narrow.

Dimensions: H: 3- 4μm; D: 5-6μm; C: 2-3μm.

Nannoconus kamptneri kamptneri Brönnimann, 1955

Pl.1, fig. 4; Pl. 2 , fig. 5,7; Pl.3, fig. 4; Pl. 5, figs. 4-7

1955 *Nannoconus kamptneri* Brönnimann, p.37, pl.2, figs. 14, 16,20,21, text-figs.3i-m.

1987 *Nannoconus kamptneri kamptneri* Brönnimann, Bralower in Bralower *et al.*, p.230, pl.8, figs.32, 33.

Description: A conical nannoconid. The height of the test is approximately two times greater than the diameter of the test. The central cavity is also conical, being rather wide in the distal part: the diameter of the central cavity is 2-3μm near the proximal (apex) pole and 3-4μm near the distal (base) pole. The wall has medium to thick calcite elements which make a medium to high horizontal intercept angle. The apertures at both terminal poles are open-type, large apertures which are surrounded by high angle apertural elements.

Remarks: It differs from *N. steinmannii steinmannii* and *N. colomii* in having a wide central cavity and large terminal apertures. It is distinguished also from *N. bonetii, N. bucheri* and *N. wassallii* by its narrower, conical, central cavity and its conical test.

For biometric analysis, the height, diameter and the diameter of central cavity of 110 specimens of *N. kamptneri kamptneri* were measured in thin-section. H versus D diagram shows the ranges of height (10-22µm) and diameter (6-14µm) of *N. kamptneri kamptneri* (Fig. 5A). Test height of 11-22µm (Max. frequency, 18 = 15µm) and test diameter of 8-9µm (Max. frequency, 28= 9µm) occur most frequently (Figs. 5B and 5C). The average height of *N. kamptneri kamptneri* is 14.66µm and the average diameter of same species is 8.88µm.

Dimensions: H:11-22µm; D: 6-14µm; C:1.5-6µm.

Nannoconus kamptneri minor Bralower in Bralower *et al.*, 1989

1989 *Nannoconus kamptneri minor* Bralower in Bralower *et al.*, p.230, pl.8, figs.25-27.

Remarks: It differs from *N. kamptneri kamptneri* in having smaller size. It is distinguished from *N. bronnimanii* by its more elongated, conical test (the height of the test almost equals the diameter of the test), and its open-type terminal apertures. The shape of the test changes stratigraphically becoming gradually more elongate. The earliest forms have almost equal width and length.

Biometric analysis was also carried out for *N. kamptneri minor*. The height, diameter and diameter of central cavity of 74 specimens of *N. kamptneri minor* was measured in thin-section. H versus D diagram shows the ranges of height (6.5-10µm) and diameter (5-8.5µm) of *N. kamptneri minor* (Fig. 5D). Test height of 7-10µm (Max. frequency, 19 = 10µm) and test diameter of 5.5-8µm (Max. frequency, 22 = 7µm) occur most frequently (Figs. 5E and 5F). The average height of *N. kamptneri minor* is 8.66 µm and the average diameter of the same species is 6.74µm.

Dimensions: H: 6.5-10µm; D: 5-8.5µm; C:1.5-3µm.

Nannoconus minutus Brönnimann, 1955

Pl. 5, fig. 1

1955 *Nannoconus minutus* Brönnimann, p.38, pl.2, figs.4, 6, 8, 12, text-figs.2t-u.

Description: A small, cylindrical nannoconid. The diameter of the test is equal to or slightly larger than the height of the test. The central cavity is cylindrical shaped, like the outline of the test. The diameter of the central cavity corresponds to about one third of the whole diameter of the test. The wall is composed of the thin calcite elements which make a very low horizontal intercept angle, almost perpendicular to the axis of the test. The terminal apertures are open-type apertures. The size of both apertures is the same as the diameter of the central cavity. The apertures are surrounded by high angle apertural elements.

Remarks: It differs from *N. truittii truittii* in having smaller size and less rounded basal portion of the test. It is distinguished from *N. elongatus* by its short cylindrical test.

Dimensions: H: 5-7µm; D: 5-6µm; C: 2µm.

Nannoconus multicadus Deflandre and Deflandre-Rigaud, 1962

Pl. 4, fig. 12; Pl. 5, fig.11

1962 *Nannoconus multicadus* Deflandre and

Deflandre-Rigaud, p.17, pl.1, figs. 10-13.

Description: A long, cylindrical nannoconid with one or two constrictions. The height of the test is approximately two or three times larger than the diameter of the test. The central cavity is also cylindrical and its diameter is equal to the thickness of the wall. It becomes wider at the constrictions of the wall. The wall is composed of the medium to thick calcite elements which make a low horizontal intercept angle. The terminal apertures are open-type apertures whose sizes equal the diameter of the central cavity. The apertures are surrounded by high angle apertural elements.

Remarks: It easily differs from others nannoconids in having one or more constrictions. Deflandre and Deflandre-Rigaud (1962) noted two variations of this form; one with a single constriction in the cylindrical outer test wall, and a second with two constrictions. In this study, two constrictions are recorded (Pl. 4, fig. 12). It appears to be composed of two or three individuals of *N. truittii truittii* stacked top of each other.

Dimensions: H:20-27µm; D:9-13µm; C:2.5-3.5µm.

Nannoconus quadriangulus quadriangulus Deflandre and Deflandre-Rigaud,1962

Pl. 5, fig. 2

1962 *Nannoconus quadriangulus quadriangulus* Deflandre and Deflandre-Rigaud, p. 2639, figs.11, 12.

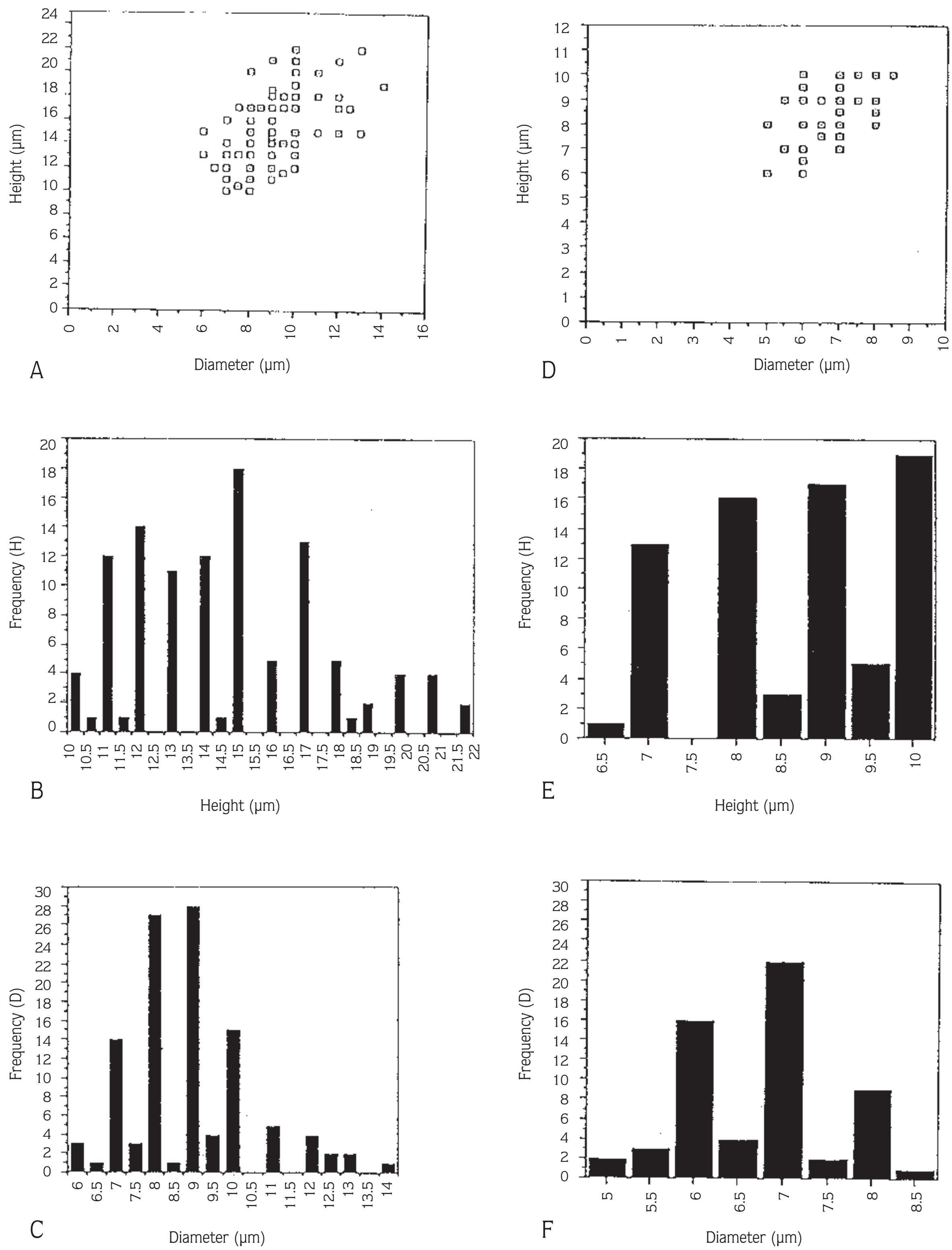


Figure 5. A) Height versus diameter of *Nannoconus kamptneri kamptneri*; B) Frequency distribution of height of *N. kamptneri kamptneri*; C) Frequency distribution of diameter of *N. kamptneri kamptneri*; D) Height versus diameter of *N. kamptneri minor*; E) Frequency distribution of height of *N. kamptneri minor*; F) Frequency distribution of diameter of *N. kamptneri minor*.

Description: A short, cylindrical nannoconid. The height is approximately equal to the diameter of the test. The central cavity is also cylindrical; its diameter approximately equals the thickness of the wall. The elements are thin and make a high horizontal intercept angle. The terminal apertures, which are surrounded by a low angle apertural elements, are open-type apertures.

Remarks: It differs from *N. elongatus* in having large central cavity and rectangular-shaped test. It is distinguished from *N. quadriangulus apertus* by its smaller size with thicker walls and thinner central cavity.

Dimensions: H: 5-8µm; D: 6- 8µm; C: 2-3µm.

Nannoconus quadriangulus apertus **Deflandre and Deflandre-Rigaud,1962**

Pl. 5 , fig. 3

1962 *Nannoconus quadriangulus apertus* Deflandre & Deflandre-Rigaud,p.2639, figs.13,14.

Remarks: It differs from *N. quadriangulus quadriangulus* in having wider central cavity and open-type aperture at the proximal pole.

Dimensions: H: 5-8µm; D: 6- 10µm; C: 3-5µm.

Nannoconus steinmannii steinmannii **Kamptner, 1931**

Pl. 2, fig.1-3; Pl. 3, figs. 5, 6, 8; Pl.5, fig. 8-10

1931 *Nannoconus steinmannii* Kamptner, p.289-291, text-figs.1-3.

1980 *Nannoconus steinmannii steinmannii* Kamptner - Deres and Achériteguy, p. 15,16, pl. 2, figs. 2, 8; pl. 3, fig. 3.

Description: A conical nannoconid. The height is approximately one and a half times longer than the diameter of the test. The straight central canal flares at the both terminal poles. The proximal part is rounded, usually with a flat area in its centre. The distal part is more pointed with some rounding. The wall consists of thin to thick calcite elements which make a low to medium horizontal intercept angle. The apertures are restricted-type apertures. Both apertures are surrounded by high angle apertural elements.

Remarks: It differs from *N. colomii* and *N. kamptneri kamptneri* in having straight central canal. It is distinguished from *N. bermudezii* by its smaller size and from *N. steinmannii minor* by its larger size.

For biometric analysis, the height and the diameter of 124 specimens of *N. steinmannii steinmannii* were measured in thin-section. The H versus D diagram shows the ranges of height (10.5-20µm) and diameter (6-11µm) of *N. steinmannii steinmannii* (Fig. 6A). Test height of 11-20µm (Max. frequency, 21 = 13µm) and test diameter of 7-9µm (Max. frequency, 48 = 8µm) occur most frequently (Figs. 6B and 6C). The average height of *N. steinmannii steinmannii* is 13.69µm and the average diameter of the same species is 7.72µm.

Dimensions: H: 11-20µm; D: 6-11µm.

Nannoconus steinmannii minor **Deres and Achéritéguy, 1980.**

1980 *Nannoconus steinmannii minor* Deres and Achéritéguy, p.16, pl.1, fig.7.

Remarks: It differs from *N. steinmannii steinmannii* in having smaller size and its relatively wider central canal. It is distinguished from *N. bronnimannii* by its central canal which is narrower than the thickness of the wall.

For biometric analysis, the height and the diameter of 59 specimens of *N. steinmannii minor* were measured in thin-section. The H versus D diagram shows the ranges of height (6-10µm) and diameter (4-9µm) of *N. steinmannii minor* (Fig. 6D). Test height of 7-10µm (Max. frequency, 16 = 8µm) and test diameter of 6-8µm (Max. frequency, 22 = 7µm) occur most frequently (Figs. 6E and 6F). The average height of *N. steinmannii minor* is 8.55µm and the average diameter of the same species is 7.29µm.

Dimensions: H: 6-10µm; D: 4-9µm.

Nannoconus truittii truittii **Brönnimann, 1955**

Pl. 1, figs. 1-3, 5; Pl. 2, fig. 4; Pl. 3, figs. 7, 9; Pl.5, figs. 12, 14

1955 *Nannoconus truittii* Brönnimann, p.38, pl.2, figs.2-5, 7, text-figs.2f-2j.

1980 *Nannoconus truittii truittii* Brönnimann - Deres and Achériteguy, p.24, pl.5, fig.10.

Description: A short, cylindrical nannoconid. Its diameter is usually greater than or approximately equal to its height. The basal portion is slightly rounded. The distal part is flat. The central cavity approximately equals to the thickness of the wall. The wall is composed of thin to thick calcite elements which make a low horizontal intercept angle. Both terminal apertures are rather large. The diameter of the distal aperture equals the diameter of the central cavity. The proximal aperture is smaller and a more restricted type aperture. Both apertures are surrounded by high angle apertural elements.

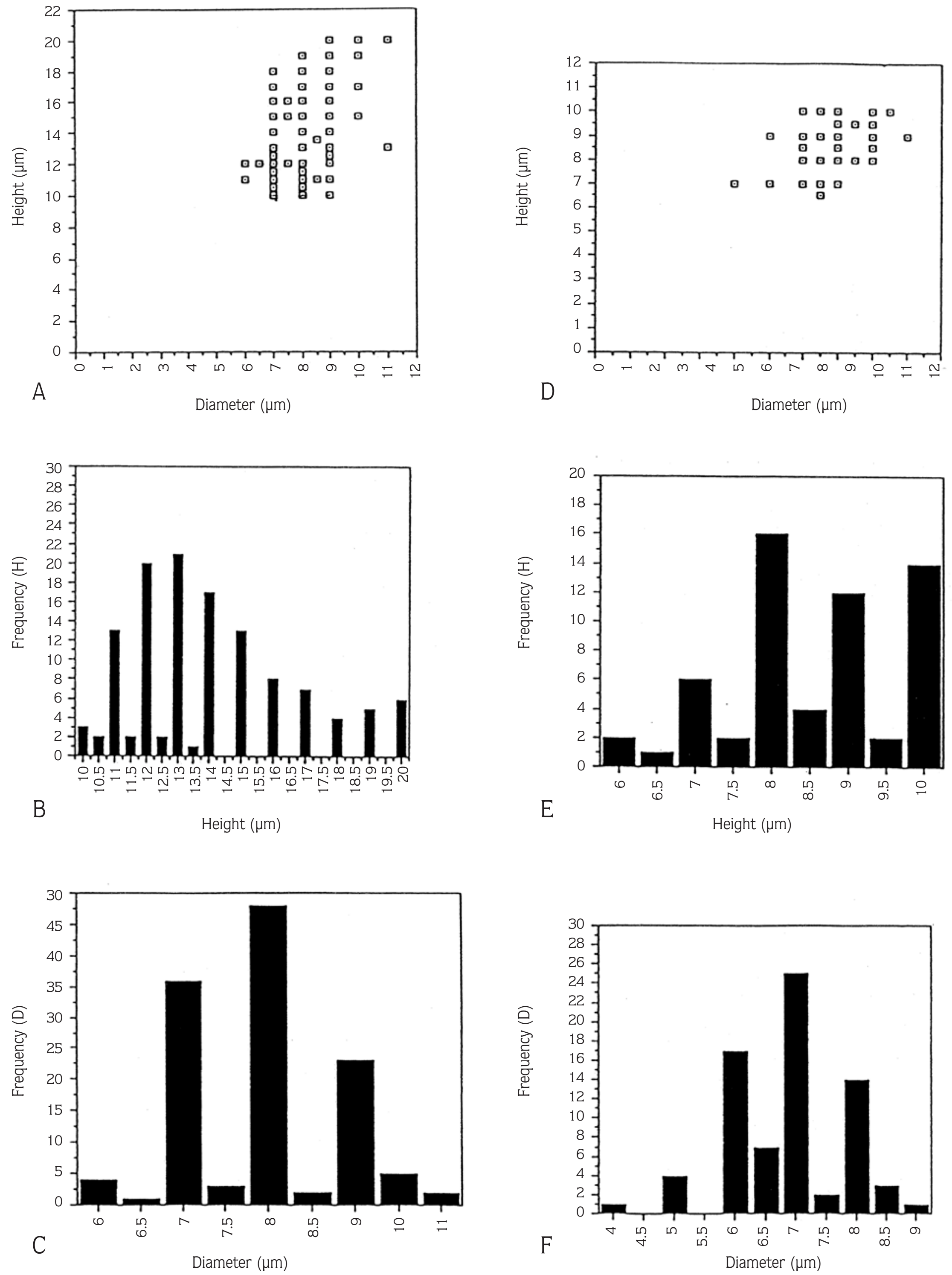


Figure 6. A) Height versus diameter of *Nannoconus steinmannii steinmannii*; B)Frequency distribution of height of *N. steinmannii steinmannii*; C) Frequency distribution of diameter of *N. steinmannii steinmannii*; D) Height versus diameter of *N. steinmannii minor*; E) Frequency distribution of height of *N. steinmannii minor*; F) Frequency distribution of diameter of *Nannoconus steinmannii minor*.

Remarks: It differs from *N. minutus* in having larger size, and from *N. elongatus* by its smaller size. It is distinguished from *N. truittii frequens* and *N. truittii rectangularis* by its almost equal height and diameter.

Dimensions: H and D: 6- 12µm; C: 2-4µm.

Nannoconus truittii frequens Deres and Achéritéguy, 1980.

Pl. 2, figs. 8,9

1980 *Nannoconus truittii frequens* Deres and Achéritéguy, p.24, pl.1, fig.10.

Remarks: A long, cylindrical nannoconid. It differs from *N. truittii truittii* and *N. truittii rectangularis* in having larger size and cylindrical test.

Dimensions: H:11-13µm; D:8-10µm; C:3-4µm.

Nannoconus truittii rectangularis Deres and Achéritéguy, 1980.

Pl. 2, figs. 10, 11; Pl.5, figs. 13, 15

1980 *Nannoconus truittii rectangularis* Deres and Achéritéguy, p.25, pl.1, fig.11.

Remarks: A short, cylindrical nannoconid. It differs from *N. truittii truittii* and *N. truittii frequens* in having short cylindrical test.

Dimensions: H: 6-8µm; D: 9-11µm; C: 3-4µm.

Nannoconus vocontiensis Deres and Achéritéguy, 1980.

Pl. 5 , fig. 16

1980 *Nannoconus vocontiensis* Deres and Achéritéguy, p.26, pl.1, fig.6.

Description: A truncated conical or oval shaped-nannoconid. The height is greater than the diameter of the test. The central cavity preserves the outline of the test, it is twice the width of the wall. The wall is composed of thin to medium calcite elements which make a low to medium horizontal intercept angle. Both terminal apertures are open-type apertures with diameters equal to the diameter of the central cavity. The apertures are surrounded by low angle apertural elements.

Remarks: It differs from *N. bucheri* and *N. wassallii* in having ovoid shaped central cavity and test.

Dimension: H: 13-16µm; D:10-14µm; C:5-7µm.

Nannoconus wassallii Brönnimann, 1955.

Pl. 1, fig. 7; Pl. 3, figs. 11, 12; Pl. 5, figs. 17-19

1955 *Nannoconus wassallii* Brönnimann, p.39, pl.1, figs.4,8,9,15,17,21;pl.2, fig.22, text- fig.2o-2s.

Description: A large, pear-shaped nannoconid. The central cavity is also pear-shaped and its diameter is approximately twice wider at the proximal pole and three times wider at the distal pole, than the thickness of the wall. The wall consists of the medium to thick calcite elements which make a medium to high horizontal intercept angle. Both terminal apertures are restricted-type apertures with diameters smaller than the diameter of the central cavity. The apertures are surrounded by high angle apertural elements.

Remarks: It differs from *N. bucheri* and *N. vocontiensis* in having large pear-shaped central cavity and test.

Dimensions: H:13-27µm; D:11-25µm; C:5-9µm.

Lithogenetic and Paleoenvironmental Significance of Nannoconids

The Late Jurassic-Early Cretaceous interval represented a particularly important period in the development of calcareous nannofossils in terms of diversity and abundance. Calcareous nannofossils first appeared in the Late Triassic and suffered a relatively major extinction event at the Triassic-Jurassic boundary (Bown and Özkan, 1992). The Early Jurassic and Mid Jurassic were times of more gradual increase in species numbers. Second extinction events began in the Oxfordian and Kimmeridgian and continued into the Tithonian (Bown and Özkan, 1991). This extinction became masked by the occurrence of a major Jurassic radiation which was characterised by the cryptogenetic appearance of a number of nannolith groups, for example, *Conusphaera*, *Polycostella* and *Micrantholithus.* The radiation continued without a break into the earliest Cretaceous, particularly in the latest Tithonian, by the first appearance of *Nannoconus*, and other new groups diversified and the Jurassic coccolith lineages were rejuvenated (Bown *et al.*, 1991).

The Tithonian radiation coincided with the first occurrence of pelagic carbonates which can be solely attributed to the presence of calcareous nannofossils particularly *Conusphaera, Faviconus*, and *Polycostella* as observed in this study (ÇAY-4-, KEL-Sections). However, in the earliest Berriasian, there was a sharp change in the nannofossil assemblages from a high abundance of these

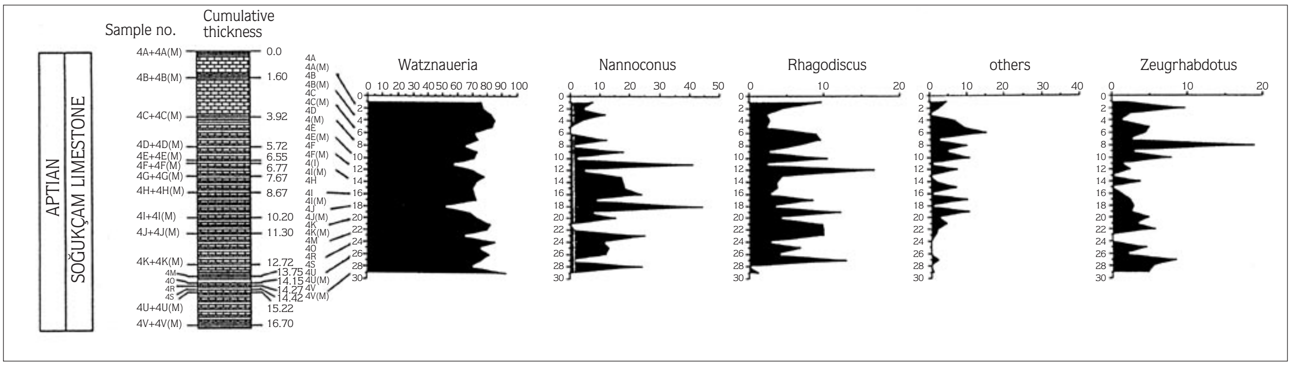


Figure 7. Distribution (% curves) of the most abundant nannofossil taxa counted in the Aptian of NB-section (M: Marl levels).

species to a high abundance of *Nannoconus* with the first occurrences of small *Nannoconus* at the base of the *Calpionella* Zone (Zone B) (Altıner and Özkan, 1991). These carbonate deposits, typified by the Maiolica Formation in North and Central Italy and the Yosunlukbayırı and Soğukçam Limestone formations in the study area, were restricted to Western Tethys and reflect a significant shift in carbonate deposition from shelf areas to open ocean areas (Roth, 1986).

Regional studies have pointed out that *Nannoconus* is indicative of continental margins, shallow plateaus, and epicontinental sea conditions (Thierstein, 1976; Roth and Bowdler, 1981; Roth and Krumbach, 1986). Noël (1968), Dufour and Noël (1970), Noël and Manivit (1978), and Noël and Melguen (1978) also pointed out that nannoconids are indicative of clear surface waters without terrigenous input. Fluctuations in nannoconid abundance are related to lithological changes (Fig.7). The diversity and abundance of nannoconids in marls are low. This can be explained by dilution effects of clastic input in marls. This well known relationship suggests that, at least during Early Cretaceous, nannoconids are the most important constituents of the Tethyan limestone. For this reason, Premoli-Silva *et al.*(1989) interpreted the nannoconids as a carbonate productivity index.

It is evident that the occurrence and fluctuations in abundance of nannoconids must be related to important palaeoenvironmental/palaeoceanographical changes. The plate configurations and their relatively rapid change may cause unstable oceanographical conditions such as an alteration of the equatorial current system, and/or a decline in upwelling currents and nutrient levels. A drastic decline of fertility as indicated by radiolarian decline near the close of the Jurassic is documented by both the change to white limestone deposition and the drastically changed faunal composition of the radiolarian assemblages (Baumgartner *et al*, 1980). One of the reasons for this change is an alteration of the Tethyan (and Atlantic) water-circulation pattern. Another reason may be the gradual lowering of global temperatures and thus fertility during the latest Jurassic and Early Cretaceous (Fischer and Arthur, 1977). If nannoconids represent low fertility indices, as suggested by Coccioni *et al.* (1992) and Erba (1994) then this may indicate a significant palaeoceanographical change in the Western Tethys at this time, from eutrophic conditions (high nutrient availability) to oligotrophic conditions (low nutrient availability) on the Trophic Resource Continuum which is described by Hallock (1987).

Within the framework of the palaeogeographical evolution of the NW Anatolian carbonate platform during Callovian-Aptian interval, the calcareous nannofossil associations investigated in this study are recorded from a carbonate succession composed of calciturbidites grading vertically into porcellaneous micritic limestones: This carbonate platform, named as the Biga-Bursa-Bilecik Platform, and the rapidly subsiding Mudurnu Trough, bordering the platform, evolved in the three fundamental stages in NW Anatolia (Altıner *et al.*, 1991) (Fig. 8, stages I-III). In stage I, as a result of the regional subsidence in the Callovian time interval the continental domain of southern part of NW Anatolia was entirely covered by carbonate deposits of pelagic character. The Liassic Bayırköy Formation was overlain unconformably by the Callovian pelagics in the Biga-Bursa-Bilecik Platform, while in the Mudurnu Trough, the pelagic carbonates started to cover the Mudurnu volcanics after a short transitional period. In stage II (Fig.8), both paleogeographic domains displayed important changes in sedimentation. In the Biga-Bursa-Bilecik Platform,

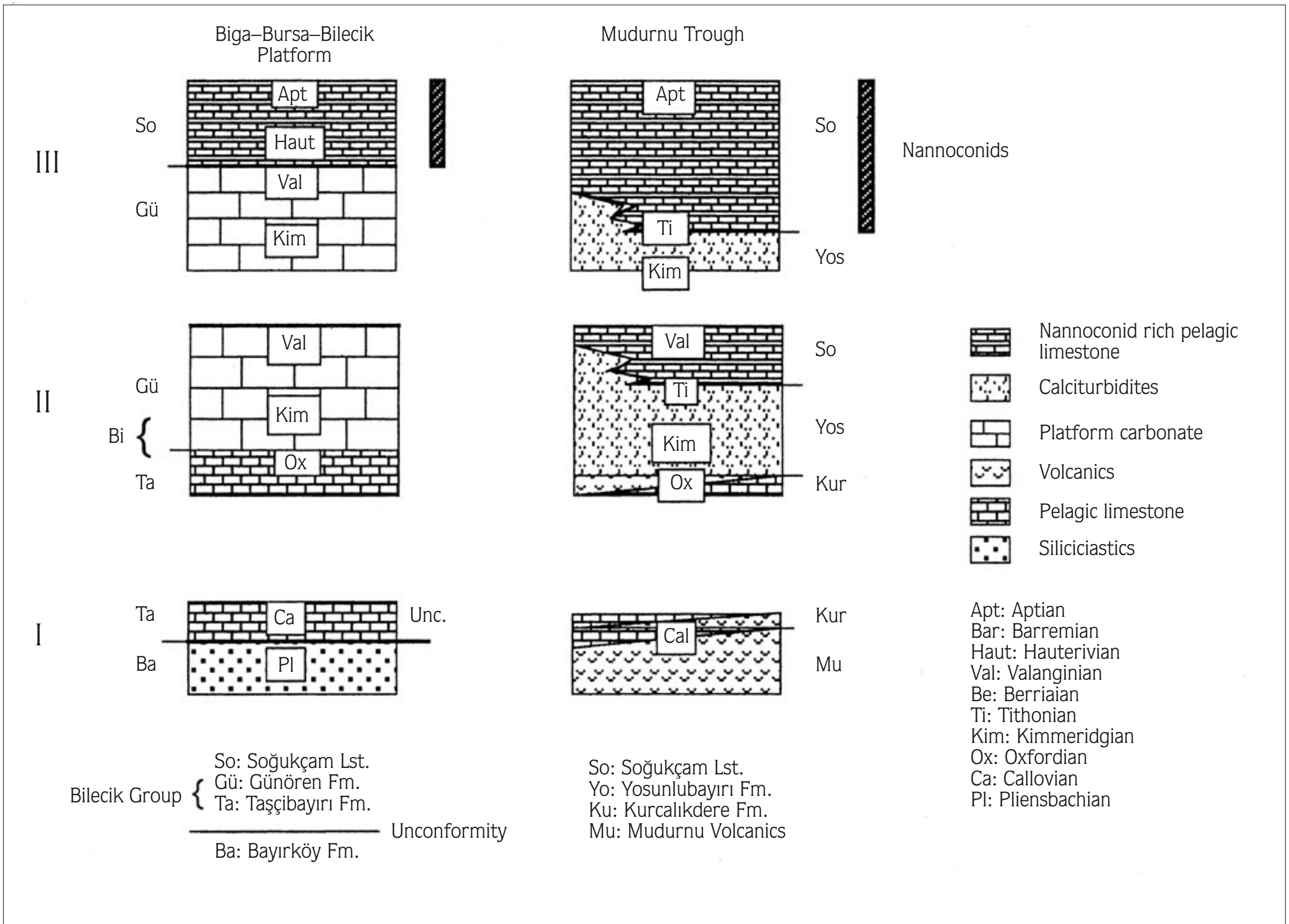


Figure 8. Paleogeographical evolution of the NW Anatolia. Three stages (I-III) in the Callovian-Aptian evolution of the Biga-Bursa-Bilecik Platform and the Mudurnu Trough. Note the diachronic occurrence of nannoconids in both domains.

regressive carbonates of the Kimmeridgian-Valanginian Günören Formation were laid down over Oxfordian pelagics. However in the rapidly deepening Mudurnu Trough, calciturbiditic Yosunlukbayırı started to be deposited in the Kimmeridgian and later, Nannoconid-rich Soğukçam Limestone appeared earliest in the Tithonian. The lower boundary of this formation was highly diachronic in the Mudurnu Trough (Fig. 8). Since this sedimentation was partly controlled by the calciturbiditic influx. In stage III, the Biga-Bursa-Bilecik Platform suddenly collapsed in the Valanginian- Hauterivian times and was covered by the same Nannoconid-rich pelagic micrites of the Soğukçam Limestone. This regional homogenization within the depositional environments has been recorded by calcareous nannofossils in northwest Anatolia, in particular nannoconids.

Stratigraphic Importance of Nannoconids

Because of rareness of the some nannofossil zone markers in the samples, nannoconids, which are the principal rock-forming constituents were used to define problematic zonal boundaries. As a result of semi-quantitative analysis of calcareous nannofossil, 4 distinct abundance peaks of nannoconids were recorded in the Tithonian-Aptian time interval (Özkan, 1993 and Özkan–Altıner, 1996). Figure 9 indicates the stratigraphic distribution of nannoconids and their abundance peaks which were recorded in this study.

* The first dramatic increase in nannoconid abundance was recorded at the base of the *Nannoconus steinmannii steinmannii* Zone of the Lower Berriasian.

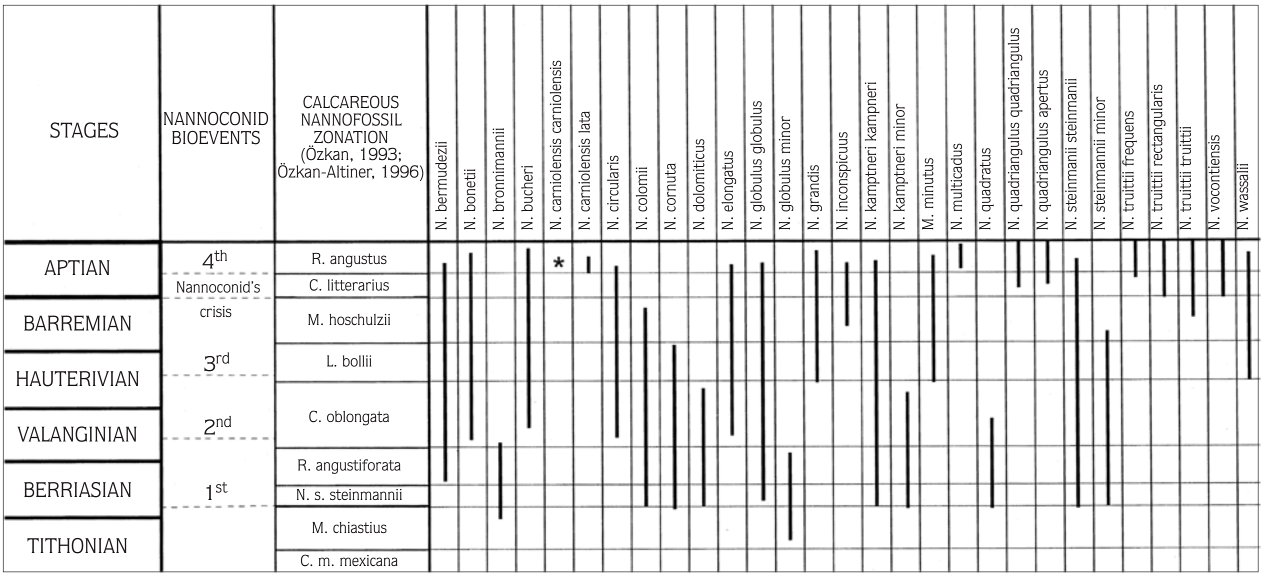


Figure 9. Stratigraphical distribution of *Nannoconus* species in the studied samples.

* The second abundance peak in particular, high abundances of *N. steinmannii steinmannii* and *N. bermudezii* was recorded just above the base of the *Calcicalathina oblongata* Zone.

* The third abundance peak which is characterised by extremely abundant *N. bermudezi*, was recorded at the base of the *Lithraphidites bollii* Zone. This bioevent coincides with the first occurrences of *N. wassalii* and *N. grandis*.

* The forth dramatic increase in abundance of nannoconids was recorded at the base of *Rhagodiscus angustus* Zone.

In addition to these bioevents, the distinct decrease in abundance of nannoconids "Nannoconid crisis" (Erba, 1994) at the base of the *Chiastozygus litterarius* Zone was recognised along with the first occurrence of *N. truittii* group *truittii* and dramatic decrease of abundance of *N. bermudezii, N. steinmannii steinmannii, N. bonetii, N. wassallii, N. bucheri*, successively. These zones and bioevents have been calibrated with planktonic foraminiferal zonation (Altıner, 1991) and calpionellid zonation (Altıner and Özkan, 1991) which have been already established for the same samples.

Conclusions

As a result of the analysis of 410 samples which were collected from the Yosunlukbayırı and Soğukçam Limestone formations, nannoconids were recorded in a rock-forming quantity. Due to their lithogenetic importance, nannoconids have received particular attention. Nannoconids were encountered in very thin thin-sections as well as in smear slides. Taxonomy of 21 *Nannoconus* species have been revised and present their detailed stratigraphic ranges. In order to recognition of species from unoriented sections of specimen, simple morphometric measurements of the height, the maximum diameter and the diameter of the central cavity of the specimen have been made for some important species. Hence, some closely related species can be easily distinguished from each other, even, in unoriented sections by using the ranges of these morphometric measurements. Because of rareness and difficulties for extracting of the calcareous nannofossil species particularly zone markers in this type lithology (micritic limestone), nannoconids have received particular attention in terms of biostratigraphy. By using of their four high abundance peaks and one sharp decline in abundance, the problematic zonal boundaries of the nannofossil zonation could be fixed.

Plate 1. (SEM: Scanning Electron Microscopy; LM: Light Microscopy; TS: Thin-section; SS: Smear slide; BS: Broken Surface; OS: Oblique Section; LS: Longitudinal Section; TgS: Tangential Section; TrS: Transverse Section)

1. Photomicrograph of nannoconid-bearing micritic limestone. a. *Nannoconus truittii truittii*, OS; b. Distal view of *Watznaueria barnesae*. SEM, X 2700; BS, Sample no. NB-2C, Late Aptian.

2. Photomicrograph of nannoconid-bearing micritic limestone. a. *Nannoconus truittii* gr. *truittii*, OS; b. Side view of *Watznaueria* sp.. SEM, X 3400; BS, Sample no.NB-2C, Late Aptian.

3. Photomicrograph of nannoconid-bearing micritic limestone. LS and OS of *Nannoconus truittii truittii*; LM, one-nicol, X 2000; TS, Sample no. NB-2A, Late Aptian.

4. Photomicrograph of nannoconid-bearing micritic limestone. a. *Nannoconus kamptneri kamptneri*, LS; b. *Nannoconus* sp., TrS; LM, one-nicol, X 1500; TS, Sample no.NB-6A, Barremian-Aptian.

5. Photomicrograph of nannoconid-bearing micritic limestone. a. *Nannoconus truittii* gr. *truittii*, OS; b. Side view of *Watznaueria barnesae*. SEM, X 3400; BS, Sample no.NB-2C, Late Aptian.

6. Photomicrograph of nannoconid-bearing micritic limestone. a. *Nannoconus bucheri*, LS; b. *Nannoconus* sp., TrS; LM, one-nicol, X 1600; TS, Sample no. NB-4F, Late Aptian.

7. Photomicrograph of nannoconid-bearing micritic limestone. a. *Nannoconus wassalli*, TgS,b. *Nannoconus* sp., TrS; LM, one-nicol, X 1700; TS, Sample no.NB-6A, Barremian-Aptian.

Plate 2. 1. Side view and close-up of the calcite elements of *Nannoconus steinmannii steinmannii*, arrows indicate different orientation of the calcite elements. SEM, X 5550; SS, Sample no. AÇ-14, Berriasian.

2. Oblique view and close-up of the basal part of *Nannoconus steinmannii steinmannii*, arrows indicate different orientation of the calcite elements. SEM, X 6100; SS, Sample no. AÇ-14, Berriasian.

3. Top view and close-up of the constricted-type, apical aperture and high angle apertural elements of *Nannoconus steinmannii steinmannii*; SEM, X 6750; SS, Sample no. AÇ-14, Berriasian.

4. Obliquely broken specimen and close-up of the central cavity, pointed end of calcite elements of *Nannoconus truittii* gr. *truittii*. SEM, X 5000; BS, Sample no. NB-2C, Late Aptian.

5. Arrow indicates the cast of the central cavity of *Nannoconus kamptneri kamptneri*. SEM, X 3750; BS, Sample no. NB-4A (Lst), Late Aptian.

6. Longitudinal section of *Nannoconus globulus globulus*; LM, one-nicol, X 1600; TS, Sample no. NB-6M, Barremian.

7. Photomicrograph of nannoconid-bearing micritic limestone a. *Nannoconus kamptneri kamptneri*, LS; b. *Nannoconus bucheri*, LS. Arrow indicates medium horizontal intercept angle; LM, one-nicol, X 1600; TS, Sample no.NB-6A, Barremian-Aptian.

8. Longitudinal section of *Nannoconus truittii frequens*; LM, one-nicol, X 2400; TS, Sample no. NB-4A, Late Aptian.

9. Same specimen; High focusing; Showing high horizontal intercept angle.

10. Longitudinal section of *Nannoconus truittii rectangularis*; LM, one-nicol, X 2600; SS, Sample no. NB-4F (B), Late Aptian.

11. Same specimen; High focusing; Showing medium horizontal intercept angle.

Plate 3. 1. *Nannoconus bermudezii* Brönnimann, 1955; LS; SEM, X 2500; BS, Sample no. ÇDS-1, Valanginian.

2. *Nannoconus bucheri* Brönnimann, 1955; LS; SEM, X 1650; BS, Sample no. NB-2C, Late Aptian.

3. *Nannoconus grandis* Deres and Achéritéguy, 1980; LS; SEM, X 2200; BS, Sample no. NB-2C, Late Aptian.

4. *Nannoconus kamptneri* kamptneri Brönnimann, 1955; LS; SEM, X 3400; BS, Sample no. ÇAY-7, Barremian.

5. *Nannoconus steinmannii steinmannii* Kamptner, 1931; LS; SEM, X 2500; BS, Sample no. ÇAY-88, Valanginian.

6. *Nannoconus steinmannii steinmannii* Kamptner, 1931; LS; SEM, X 4000; BS, Sample no. ÇD-5, Valanginian.

7. *Nannoconus truittii* gr. *truittii* Brönnimann, 1955; LS; SEM, X 4000; BS, Sample no. NB-2C, Late Aptian.

8. *Nannoconus steinmannii steinmannii* Kamptner, 1931; LS; SEM, X 2700; BS, Sample no. ÇAY-7, Barremian.

9. *Nannoconus truittii* gr. *truittii* Brönnimann, 1955; LS; SEM, X 5300; BS, Sample no. NB-4F (Lst), Late Aptian.

10. *Nannoconus wassallii* Brönnimann, 1955; OS; SEM, X 2600; BS, Sample no. NB-2C, Late Aptian;

11. *Nannoconus wassallii* Brönnimann, 1955; LS; SEM, X 2100; BS; Sample no. NB-4F (Lst), Late Aptian.

Plate 1

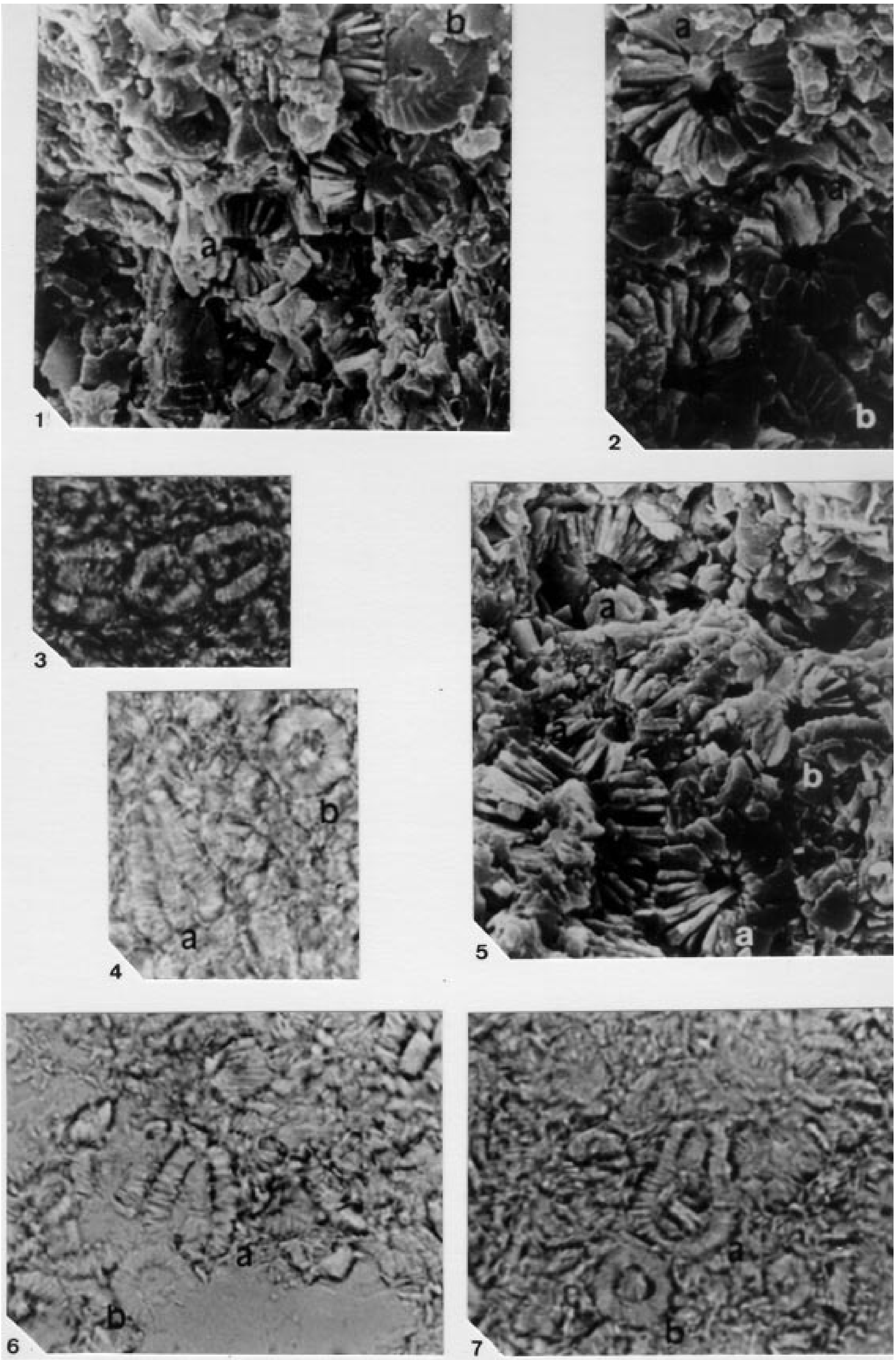


Plate 2

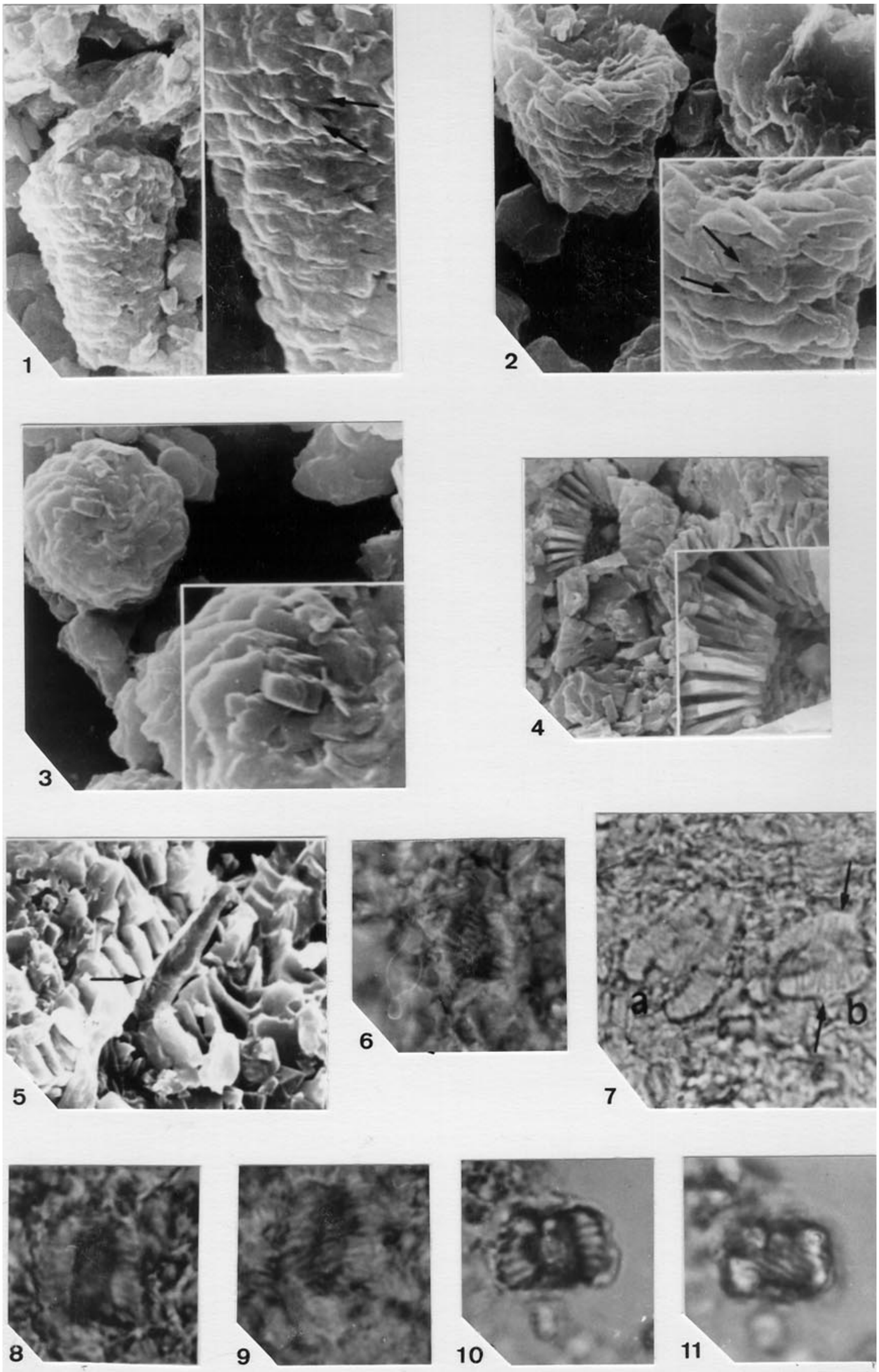


Plate 3

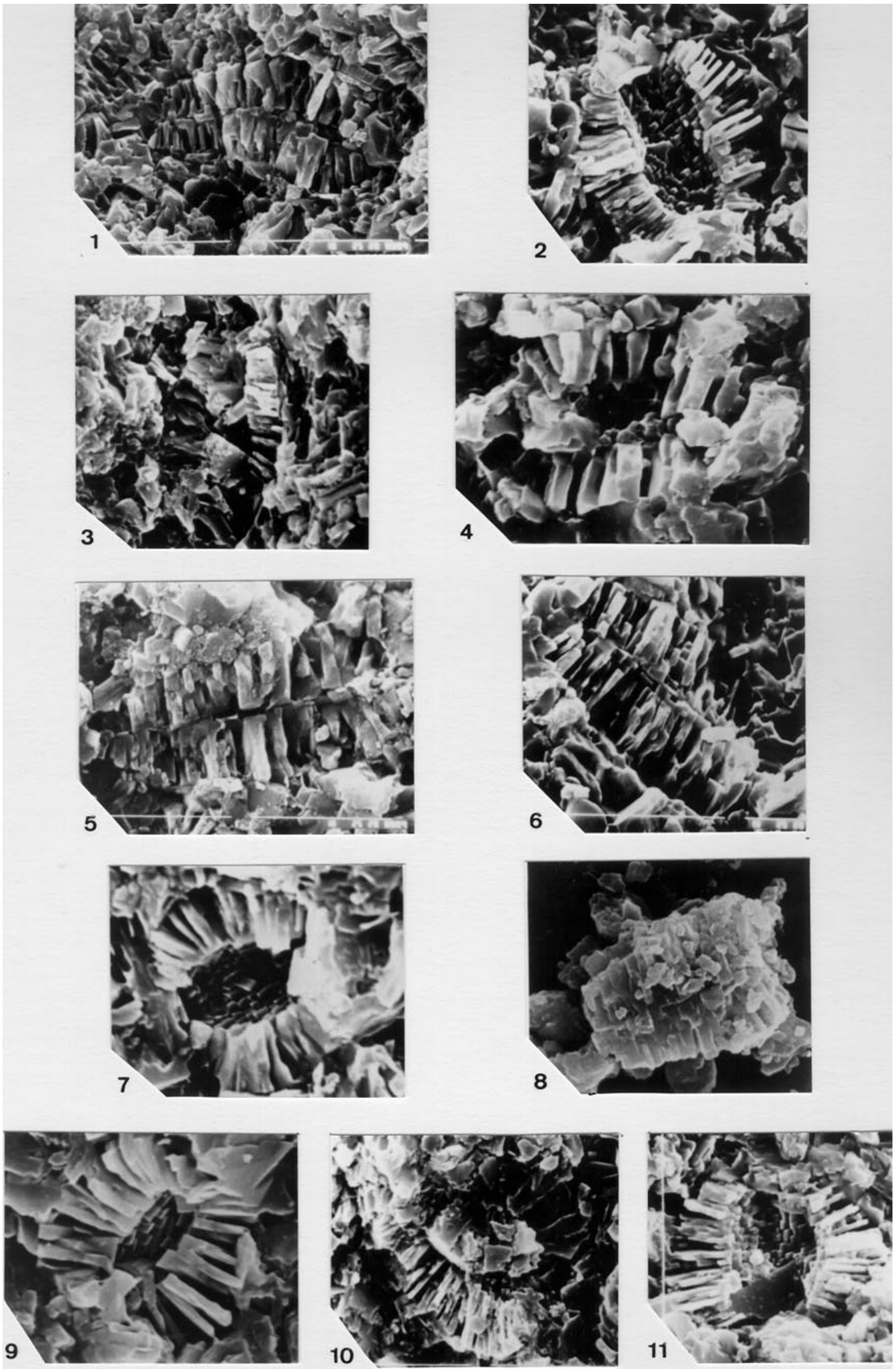


Plate 4.
1. *Nannoconus bermudezii* Brönnimann, 1955; LS; LM, one-nicol, X 1350; TS, Sample no. ÇAY-115, Hauterivian.
2. *Nannoconus bermudezii* Brönnimann, 1955; LS; LM, one-nicol, X 1400; TS, Sample no. ÇAY-114, Hauterivian.
3. *Nannoconus bonetii* Trejo, 1959; LS; LM, one-nicol, X 1400; TS, Sample no. NB-6A, Barremian-Aptian.
4. *Nannoconus bucheri* Brönnimann, 1955; LS; LM, one-nicol, X 1600; TS, Sample no. NB-6A, Barremian-Aptian.
5. *Nannoconus bucheri* Brönnimann, 1955; LS; LM, one-nicol, X 1450; TS, Sample no. NB-6A, Barremian-Aptian.
6. *Nannoconus bucheri* Brönnimann, 1955; LS; LM, one-nicol, X 1450; TS, Sample no. NB-6A, Barremain-Aptian.
7. *Nannoconus bucheri* Brönnimann, 1955; LS; LM, one-nicol, X 1700; SS, Sample no. NB-5, Barremian-Aptian.
8. *Nannoconus elongatus* Brönnimann, 1955; LS; LM, one-nicol, X 1900; SS, Sample no. GO-üstü, Albian.
9. *Nannoconus carniolensis lata* Deflandre and Deflandre-Rigaud, 1962; LS; LM, one-nicol, X 1200; TS, Sample no. NB-4F, Late Aptian.
10. *Nannoconus carniolensis lata* Deflandre and Deflandre-Rigaud, 1962; LS; LM, one-nicol, X 1200; TS, Sample no. NB-4F, Late Aptian.
11. *Nannoconus cornuta* Deres and Achéritéguy, 1980; LS; LM, one-nicol, X 1200; TS, Sample no. KEL-5, Berriasian.
12. *Nannoconus multicadus* Deflandre and Deflandre-Rigaud, 1960; LS; LM, one-nicol, X 1450; TS, Sample no. NB-6A, Barremian. 13. *Nannoconus globulus globulus* Brönnimann, 1955; LS; LM, one-nicol, X 1400; TS, Sample no. NB-6M, Barremian.
<None>14. *Nannoconus inconspicuus* Deflandre and Deflandre-Rigaud, 1962; LS; LM, one-nicol, X 1200; TS, Sample no. MK-46, Late Aptian. 15. *Nannoconus grandis* Deres and Achéritéguy, 1980; LS; LM, one-nicol, X 1400; TS, Sample no. NB-6A, Barremian-Aptian. 16. *Nannoconus inconspicuus* Deflandre and Deflandre-Rigaud, 1962; LS; LM, one-nicol, X 1600; TS, Sample no. NB-2A, Late Aptian.

Plate 5.
1. *Nannoconus minutus* Brönnimann, 1955; LS; LM, one-nicol, X 1500; SS, Sample no. ÇAY-86, Valanginian.
2. *Nannoconus quadriangulus quadriangulus* Deflandre and Deflandre-Rigaud, 1962; LS; LM, one-nicol, X 1200; TS, Sample no. MK-46, Late Aptian.
3. *Nannoconus quadriangulus apertus* Deflandre and Deflandre-Rigaud, 1962; LS; LM, one-nicol, X 1200; TS, Sample no. MK-46, Late Aptian.
4. *Nannoconus kamptneri kamptneri* Brönnimann, 1955; LS; LM, one-nicol, X 1750; TS, Sample no. NB-6A, Barremian-Aptian.
5. *Nannoconus kamptneri kamptneri* Brönnimann, 1955; LS; LM, one-nicol, X 1700; TS, Sample no. NB-6A, Barremian-Aptian.
6. *Nannoconus kamptneri kamptneri* Brönnimann, 1955; LS; LM, one-nicol, X 1500; SS, Sample no. AÇ-14, Berriasian.
7. *Nannoconus kamptneri kamptneri* Brönnimann, 1955; LS; LM, one-nicol, X 1500; SS, Sample no. AÇ-14, Berriasian.
8. *Nannoconus steinmannii steinmannii* Kamptner, 1931; LS; LM, one-nicol, X 1400; SS, Sample no. NB-6E, Barremian.
9. *Nannoconus steinmannii steinmannii* Kamptner, 1931; LS; LM, one-nicol, X 1500; SS, Sample no. ÇAY-86, Valanginian.
10. *Nannoconus steinmannii steinmannii* Kamptner, 1931; LS; LM, one-nicol, X 1500; TS, Sample no. ÇAY-88, Valanginian.
11. *Nannoconus* aff. *N. multicadus* Deflandre and Deflandre-Rigaud, 1960; LM, one-nicol, X 998; TS, Sample no. NB-6A, Barremain-Aptian.
12. *Nannoconus truittii truittii* Brönnimann, 1955; LS; LM, one-nicol, X 1600; TS, Sample no. MK-46, Late Aptian.
13. *Nannoconus truittii rectangularis* Deres and Achéritéguy, 1980; LS; LM, one-nicol, X 1000; TS, Sample no. MK-46, Late Aptian.
14. *Nannoconus truittii truittii* Brönnimann,1955;High focusing; Showing high horizontal intercept angle.
15. *Nannoconus truittii rectangularis* Deres and Achéritéguy, 1980; LM, one-nicol, X 2000; TS, Sample no. NB-2A, Late Aptian.
16. *Nannoconus vocontiensis* Deres and Achéritéguy, 1980; LS; LM, one-nicol, X 1200; TS, Sample no. NB-6A, Barremian-Aptian.
17. *Nannoconus wassallii* Brönnimann, 1955; LS; LM, one-nicol, X 1900; TS, Sample no. NB-6A, Barremian-Aptian.
18. *Nannoconus wassallii* Brönnimann, 1955; LS; LM, one-nicol, X 1500; TS, Sample no. NB-4F, Late Aptian.
19. *Nannoconus wassallii* Brönnimann, 1955; LS; LM, one-nicol, X 1350; TS, Sample no. NB-4F, Late Aptian.

Plate 4

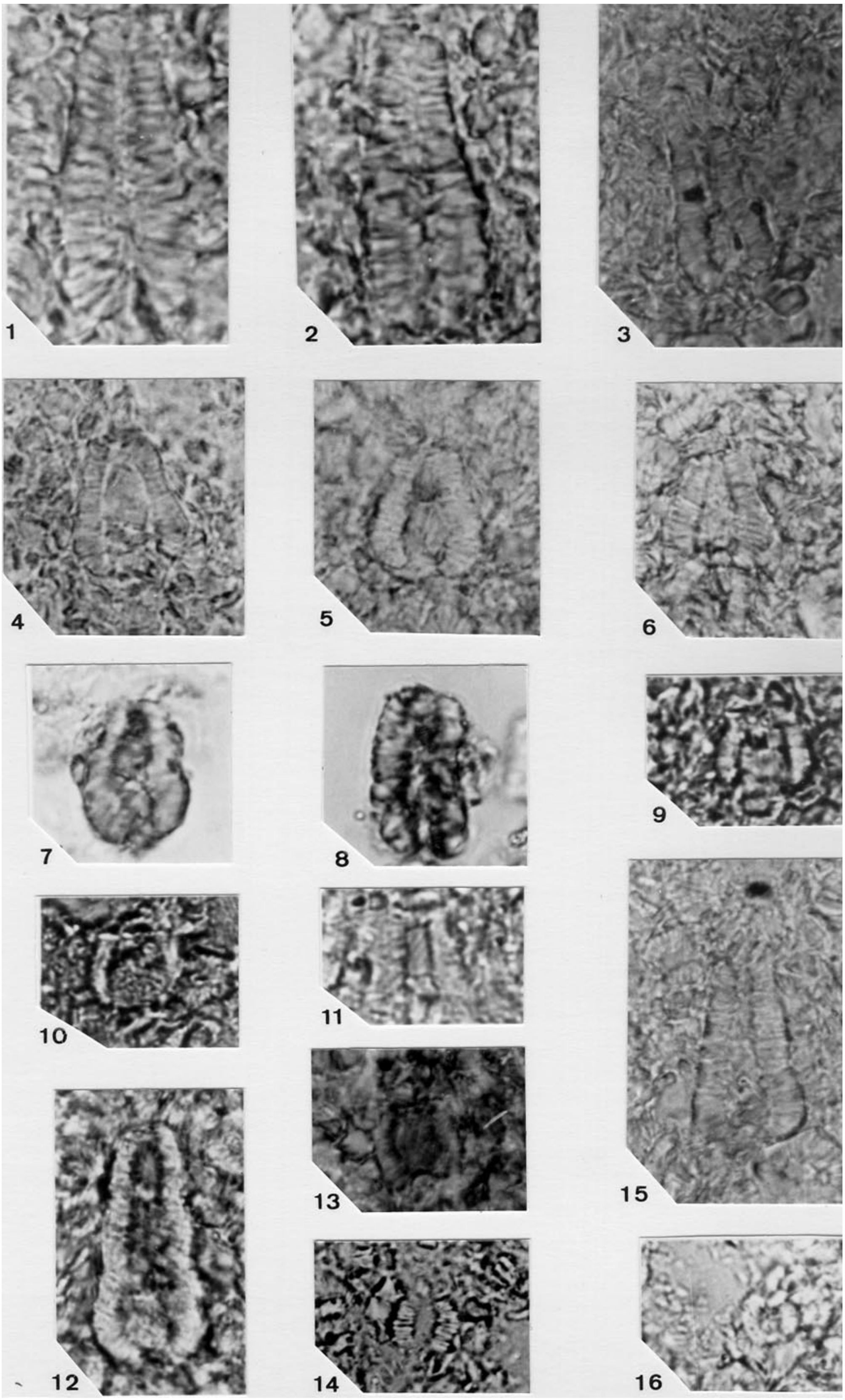
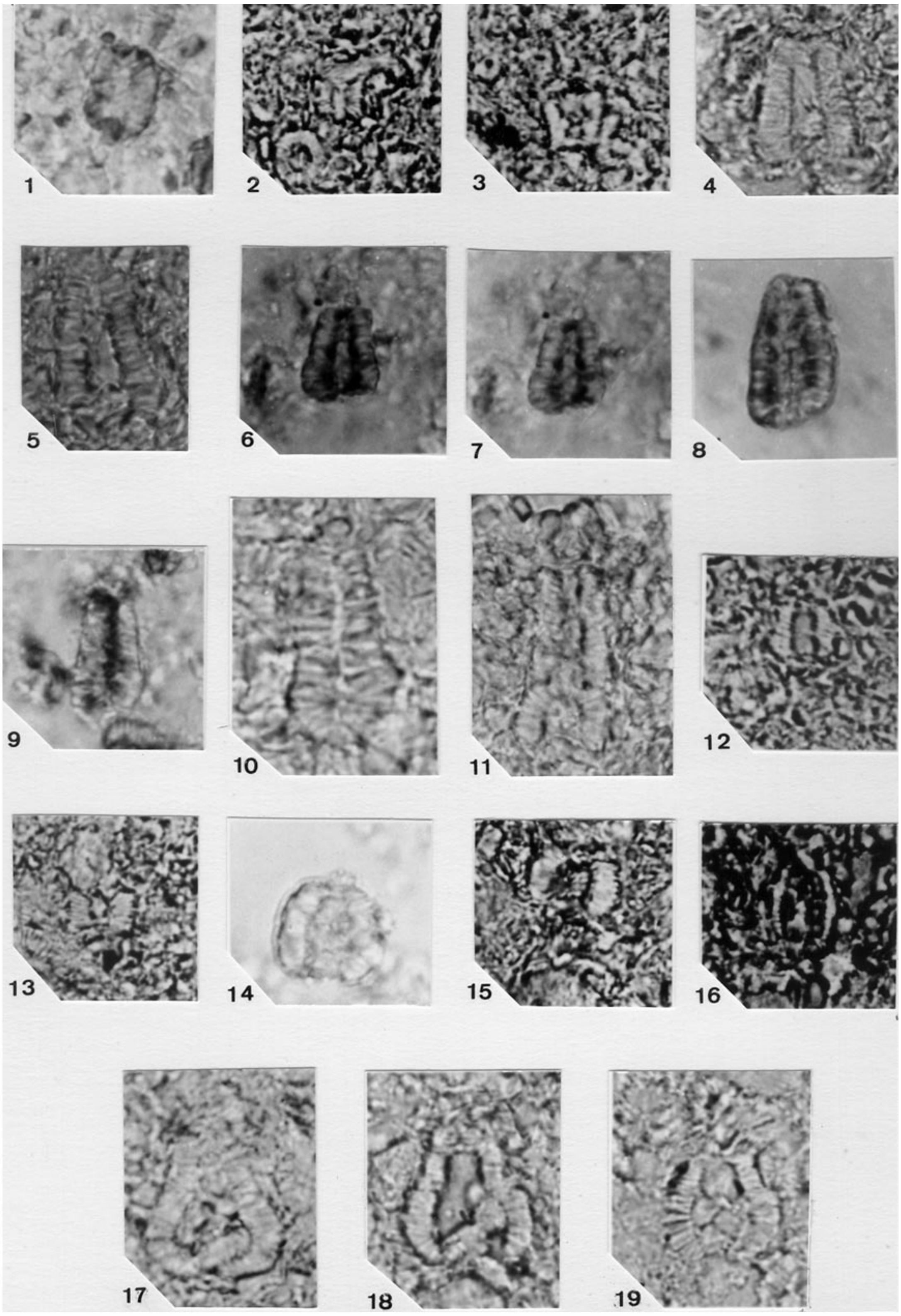


Plate 5



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