MORPHOLOGIC REINTERPRETATION OF SOME *DINOGYMNIUM* SPECIES WITH REMARKS ON PALAEOGEOGRAPHIC AND STRATIGRAPHIC DISTRIBUTION OF THE GENUS

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ABSTRACT

The Upper Cretaceous dinoflagellate genus *Dinogymnium* Evitt *et al.* (1967) possesses 32 species. Of these, *D. curvatum* (Vozzhennikova) Lentin & Williams, *D. kasachstanicum* (Vozzhennikova) Lentin & Williams, *D. sibiricum* (Vozzhennikova) Lentin & Williams and *D. sphaerocephalum* (Vozzhennikova) Lentin & Williams have been reinterpreted following the generic conception of the genus proposed by Evitt *et al.* (1967). The palaeogeographic and stratigraphic distribution of *Dinogymnium* species has been tabulated.

It has been concluded that the genus *Dinogymnium* is cosmopolitan, occurred mostly along 45°N and 45°S latitudes. It flourished best during Campanian-Maestrichtian time though made a humble beginning in Albian-Cenomanian.

INTRODUCTION

GYMNODINIALEAN fossils belonging to the family Dinogymniaceae were first recorded by Deflandre (1934) from an Upper Cretaceous sediment of France. These fossils were treated by him (1935, 1936, 1943, 1952, 1952a) and others, viz., Lejeune-Carpentier (1951), Deflandre and Cookson (1955), Cookson (1956), Klement (1957), Cookson and Eisenack (1958), Alberti (1961), Eisenack (1961, 1964), Manum and Cookson (1964), Downie and Sarjeant (1964), Norris and Sarjeant (1965), Drugg (1967), Evitt (1967), Vozzhennikova (1965, 1967), under the extant genus *Gymnodinium* Stein until the detailed morphological study of the genus by Evitt, Clarke and Verdier (1967) appeared, who realised the importance of an archaeopyle which does not occur in the living counter part and thus instituted a new genus *Dinogymnium*.

In the light of the present status of the genus it is desirable to reinterpret the diagnoses of the following species proposed in a simultaneous publication of 1967 by Vozzhennikova. She (1967, in English translation, 1971) described well preserved assemblage of these fossils from U.S.S.R. and established several new species, but did not consider the archaeopyle character which led her to misinterpret the orientation of the cysts.

The present re-evaluation of these species is solely based on the illustrations and descriptions provided from her publication (Vozzhennikova, 1967, in English translation, 1971). The holotypes as marked in the text show the presence of an opening at one end (Epitheca).

The holotypes mentioned in the present text, refer to the original description and photograph cited by Vozzhennikova (1967, in English translation, 1971).

Dinogymnium curvatum (Vozzhennikova) Lentin & Williams, 1973

Syn.

1967 — *Gymnodinium curvatum* Vozzhennikova, p. 43; pl. 1, figs. 10-12; pl. 4, figs. 2-3; Senonian of W. Siberia, U.S.S.R.

Reinterpreted Description: (Holotype pl. 1, fig. 10) — Theca strongly elongated and curved in an arciform manner. Hypotheca considerably smaller than epitheca, bell-shaped with an obtusely rounded antapex slightly bent over to one side. Epitheca has the shape of an elongated cone, somewhat curved in the middle. Apical end bluntly rounded. Transverse furrow annulate deep and with ribs extending from it giving a scalloped margin. Longitudinal furrow slit-like and apparently extending over both epitheca and hypotheca although its limits are not easy to determine. Surface of theca ribbed, finely granular. Apical archaeopyle present.

Dimensions — Holotype-length 91·3 μm, breadth 25 μm, length of epitheca 46·5 μm, length of hypotheca 36·52 μm, cingulum index 50. Width of transverse furrow about 3 μm. Other examples have a length

of 70-85 μm, breadth of 25-37·5 μm; length of epitheca 35-47 μm, length of hypotheca 35-37·5 μm, cingulum index 50-56; width of transverse furrow 3-4·5 μm.

Dinogymnium kasachstanicum (Vozzhennikova) Lentin & Williams, 1973

Syn.

1967 — *Gymnodinium kasachstanicum* Vozzhennikova, pp. 45-46; pl. 2, figs. 4a-b; pl. 3, figs. 9a-b; Maestrichtian of Kazakhstan, U.S.S.R.

Reinterpreted Description: (Holotype pl. 2, fig. 4) — Theca biconical; hypotheca somewhat smaller than epitheca with a triangular outline and a bluntly rounded, some what attennuated antapex. Epitheca triangular with concave sides, apical end broken although apparently rounded. Transverse furrow deep, somewhat twisted to left. Longitudinal furrow short and extending to the hypotheca. Thecal surface covered with ribbing which extends from the transverse furrow in the direction of the poles; many ribs, especially those on the hypotheca do not reach poles. Theca slender, pale yellow in colour. Archaeopyle apical.

Dimensions — Holotype-length 49·4 μm, breadth 35·1 μm, width of transverse furrow 3·5 μm.

Dinogymnium muticum (Vozzhennikova) Lentin & Williams, 1973

Syn.

1967 — *Gymnodinium muticum* Vozzhennikova, pp. 46-47; pl. 1, figs. 6-7; pl. 2, fig. 9; Senonian of W. Siberia, U.S.S.R.

Reinterpreted Description: (Holotype pl. 1, fig. 6) — Theca biconical. Epitheca slightly larger than hypotheca. Hypotheca short, broadly conical with one side straighter than the other giving the theca a somewhat slanting appearance. The epitheca resembles a bluntly truncated cone. Transverse furrow deep, annulate. Longitudinal furrow barely distinguishable but apparently slit-like. Thecal surface granular. Archaeopyle apical.

Dimensions — Holotype-length 47 μm, breadth 35 μm with a transverse furrow of about 2 μm. In other specimens the length is 47-57 μm, the breadth 23-25 μm, transverse furrow 2-3 μm; length of epitheca 26-30 μm, length of hypotheca 20-27 μm. Cl = 52·55.

Remarks — Presence of an archaeopyle is more conclusive in pl. 2, fig. 9 than pl. 1, fig. 6 (Vozzh. 1967, in English translation, 1971).

Dinogymnium sibiricum (Vozzhennikova) Lentin & Williams, 1973

Syn.

1967 — *Gymnodinium sibiricum* Vozzhennikova, p. 67; pl. 2, figs. 2-3a-b; pl. 3, figs. 2-3; Senonian of Western Siberia, U.S.S.R.

Reinterpreted Description: (Holotype pl. 3, figs. 2-3) — Theca biconical. Epitheca larger than hypotheca, conical with curved sides and a bluntly rounded apex; hypotheca helmet-shaped, bluntly rounded at the antapex. Transverse furrow deep, annulate, its ends extending to the ventral expansion of the longitudinal furrow. Longitudinal furrow only extends a short distance on to the epitheca and hypotheca. Theca finely dotted with numerous thin longitudinal ribs, which are sometimes joined together in pairs, and run from transverse furrow towards apical and antapical ends. Archaeopyle apical.

Dimensions — Holotype-length 67·6 μm, breadth 37·8 μm. Length of epitheca 43·2 μm, length of hypotheca 24·3 μm, width of transverse furrow 3·0 μm. Cl = 64. In other specimens the length is 67·3-65·6 μm, breadth 37·8-37·5 μm, length of epitheca 45·9 μm, length of hypotheca 21·6 μm, width of transverse furrow 4·5-3·5 μm.

Dinogymnium sphaerocephalum (Vozzhennikova) Lentin & Williams, 1963

Syn.

1967 — *Gymnodinium sphaerocephalum* Vozzhennikova, p. 70; pl. 2, fig. 7; pl. 3, fig. 1; Senonian of W. Siberia, U.S.S.R.

1967 — *Gymnodinium sphaerocephalum* var. *laevis* Vozzhennikova, p. 71; pl. 1, fig. 4; pl. 2, fig. 5; Senonian of W. Siberia, U.S.S.R.

1975 — *Dinogymnium assamicum* Jain *et al.*, p. 4; pl. 2, figs. 28-29; Maestrichtian of Assam, India.

Reinterpreted Description: (Holotype pl. 3, fig. 1) — Theca flask shaped or when put reverse resembles a parachute; hypotheca hemispherical, epitheca funnel shaped with a tubular process which may be either straight or curved and is bluntly truncated at the end. Transverse furrow annulate, deep. Position of longitudinal furrow indistinct although the furrow itself is probably slit-like. Ribs run from the transverse furrow towards the poles of the theca; they extend about half way across the hypotheca but do not reach the cupolar antapical part, whereas on the epitheca they extend almost to the apex. Apical archaeopyle present.

Dimensions — Holotype-length 81·0 μm, breadth 32·4 μm; length of epitheca 54·4 μm, length of hypotheca 27 μm; width of transverse furrow about 3 μm, width of apical end 7 μm, Cl = 66·6. In other examples the length is 56·0-66·6 μm, width 30·0-32·2 μm, length of epitheca 45·54 μm, length of hypotheca 27-28 μm and width of transverse furrow 3-5 μm.

Remarks — The reinterpreted description of *Dinogymnium sphaerocephalum* proposed here indicates no morphological differentiation with *D. assamicum* Jain *et al.* (1975), recently described from India and *D. sphaerocephalum* var. *laevis* (Vozzhennikova) Lentin & Williams (1973), except for minor features like lower range of cingulum index (50-57), length of epitheca, presence or absence of a few or no ribs on the hypothecal region. These characters are considered within the specific circumscription as extent of variation.

Stratigraphic Remarks — The geochronologic distribution of the known *Dinogymnium* species (Table 1) indicates that the genus made its humble start during Albian with a single specimen referred to *Dinogymnium* sp. A. Like-wise Cenomanian is represented by a single species *D. westralium*. Turonian is better represented by three species from Western Siberia, U.S.S.R. alone. Only a single species *D. heterocostatum* is known from Coniacian, whereas Santonian is marked by *D. albertii*, *D. microgranulosum* and *D. acuminatum*. Most of the species have been described from unclassified Senonian and therefore, it is difficult to comment upon the abundance of its species in Lower Senonian. The Campanian, Maestrichtian and Upper Senonian records of the genus are maximum. Recent discoveries of *Dinogymnium* from Upper Cretaceous Maestrichtian) sediments of India, W. Africa, Brazil, Texas, U.S.A and Grand Banks made by Jain *et al.* (1975), Jain and Millepied (1975), Herngreen (1975), Zaitzeff and Cross (1970) and Williams and Brideaux (1975) respectively, have further strengthened the Upper Cretaceous importance of the genus supporting the contention of Evitt *et al.* (1967, p. 5) that the diversity of forms and abundance of both specimen and species appear to have been greatest during the Campanian-Maestrichtian time. Williams and Brideaux (1975, p. 15) have also echoed the same opinion.

The Tertiary records of the genus are not unknown. Evitt (1973), De coninck (1969) and Stanley (1965) reported it from Danian (Palaeocene) and Ypresian (Eocene). But Harker and Sarjeant (1975, p. 228) have rejected them as reworking or sample pollution. Recently Schumaker and Chateauneuf (1976) have described *D. acuminatum* from Palaeocene of Belgium. The edge of this assemblage appears to be doubtful. Thus the genus is restricted only to the Upper Cretaceous.

Palaeogeographic Remarks — At present *Dinogymnium* is represented by 32 recognizable species (Table 1), all recovered from marine sediments. It is reported from Canada, U.S.A., South America (Brazil), Europe, England, W. Africa, India, U.S.S.R. (W. Siberia), Western and Southern Australia Grand Banks (Atlantic continental margin) and Arctic Canada. The distribution pattern reproduced on Map 1 shows its maximum quantitative and qualitative representation along 45° North and South. It's extent further north or South of 45° is minor, but significant. The confirmation of latitudinal distribution pattern of the genus *Dinogymnium* shall depend more upon further records from different parts of the world. Recently Gordon (1973, pp. 277-278) has concluded that by the end of Early Cretaceous time, marine transgression had connected the Arctic ocean with the Tethys, through a series of Straits across Europe. In the Albian, many ammonoid families

U P P E R   C R E T A C E O U S   SERIES

Sl. No.	Species of *Dinogymnium* Evitt *et al.* (Stage / Locality)	Albian: Saskatchewan (A)	Cenomanian: Western Australia (I)	Cenomanian: Saskatchewan (A)	Turonian: Assam, India (H)	Turonian: France, Europe (F)	Turonian: Germany, Europe (F)	Turonian: Hungary, Europe (F)	Turonian: England, Europe (F)	Turonian: Belgium, Europe (F)	Turonian: W. Australia, Australia (I)	Turonian: W. Siberia, U.S.S.R. (G)	Turonian: Senegal, W. Africa (D)	Turonian: California, U.S.A. (B)	Coniacian: Assam, India	Coniacian: Europe, Europe	Coniacian: W. Australia, Australia	Coniacian: Wyoming, U.S.A. (C)
1.	*D. acuminatum* Evitt *et al.* (1967)																	
2.	*D. albertii* Clarke & Verdier (1967)																	
3.	*D. avellana* (Carpentier) Evitt *et al.*																	
4.	*D. biconicum* Jain & Millepied (1975)																	
5.	*D. cerviculum* Cookson & Eisenack (1958)																	
6.	*D. cretaceum* (Deflandre) Evitt *et al.*																	
7.	*D. curvatum* (Vozzhennikova) Lentin & Williams (1973)																	
8.	*D. decorum* (Deflandre) Evitt *et al.*																	
9.	*D. denticulatum* (Alberti) Evitt *et al.*																	
10.	*D. digitus* (Deflandre) Evitt, *et al.*											+						
11.	*D. digitus* subsp. *crassus* (Vozzhennikova) L. & W.											+						
12.	*D. digitus* subsp. *indicus* Jain *et al.* (1975)																	
13.	*D. euclaensis* Cookson & Eisenack (1958)																	
14.	*D. heterocostatum* (Deflandre) Evitt *et al.*																	+
15.	*D. heterocostatum* subsp. *kolpaschevi* (Vozzh.) L. &. W.																	
16.	? *D. hexagonum* (Deflandre) Evitt *et al.*																	
17.	*D. hyalinum* (Vozzh.) Lentin & Williams																	
18.	*D. kasachstanicum* (Vozzh.) Lentin & Williams																	
19.	*D. laticinctum* (Deflandre) Evitt *et al.*																	
20.	*D. longicornis* (Vozzhennikova) Harland (1973)																	
21.	*D. major* Jain & Millepied																	
22.	*D. marthae* (Deflandre) Evitt *et al.*																	
23.	*D. microgranulosum* Clarke & Verdier (1967)																	
24.	*D. mitratum* (Vozzhennikova) Lentin & Williams																	
25.	*D. muticum* (Vozzhennikova) Lentin & Williams																	
26.	*D. nelsonense* (Cookson) Evitt *et al.*																	
27.	*D. sibiricum* (Vozzhennikova) Lentin & Williams																	
28.	*D. sphaerocephalum* (Vozzhennikova) L. & W.																	
29.	*D. strombomorphum* (Deflandre) Evitt *et al.*																	
30.	*D. undulosum* Cookson & Eisenack																	
31.	*D. vozzhennikovae* Lentin & Williams											+						
32.	*D. westralium* (Cooks. & Eis.) Evitt *et al.*		+															
33.	*D.* sp. A in Davey, 1970	+																
34.	*D.* sp. B in Davey, 1970			+														
35.	*D.* sp. in Manum & Cookson, 1964																	

Sl. No.	Santonian: Assam, India	Santonian: France, Europe	Santonian: Germany, Europe	Santonian: Hungary, Europe	Santonian: England, Europe	Santonian: Belgium, Europe	Santonian: W. Australia, Australia	Santonian: W. Siberia, U.S.S.R.	Santonian: Senegal, W. Africa	Santonian: California, U.S.A.	Santonian: Grand Banks, Atlantic Continental Margin	Campanian: Assam, India	Campanian: France, Europe	Campanian: Germany, Europe	Campanian: Hungary, Europe	Campanian: England, Europe	Campanian: Belgium, Europe	Campanian: W. Australia, Australia	Campanian: W. Siberia, U.S.S.R.	Campanian: Senegal, W. Africa	Campanian: California, U.S.A.	Campanian: Alberta, Canada (A)	Campanian: Grand Banks, Atlantic Continental Margin
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Sl. No.	Maestrichtian: Assam, India	Maestrichtian: France, Europe	Maestrichtian: Germany, Europe	Maestrichtian: Hungary, Europe	Maestrichtian: England, Europe	Maestrichtian: Belgium, Europe	Maestrichtian: W Australia, Australia	Maestrichtian: W Siberia, U.S.S.R.	Maestrichtian: Senegal, W. Africa	Maestrichtian: California, U.S.A.	Maestrichtian: Texas, U.S.A. (C)	Maestrichtian: Grand Banks, Atlantic Continental Margin	Maestrichtian: Alagoas, Brazil (E)	Senonian (Unclassified): Assam, India	Senonian: France, Europe	Senonian: Germany, Europe	Senonian: Hungary, Europe	Senonian: England, Europe	Senonian: Belgium, Europe	Senonian: Western & Southern Australia, Australia	Senonian: W. Siberia, U.S.S.R.	Senonian: Senegal, W. Africa	Senonian: California, U.S.A.	Senonian: Arctic Canada, Graham — Island	Senonian: Brazil, S. America
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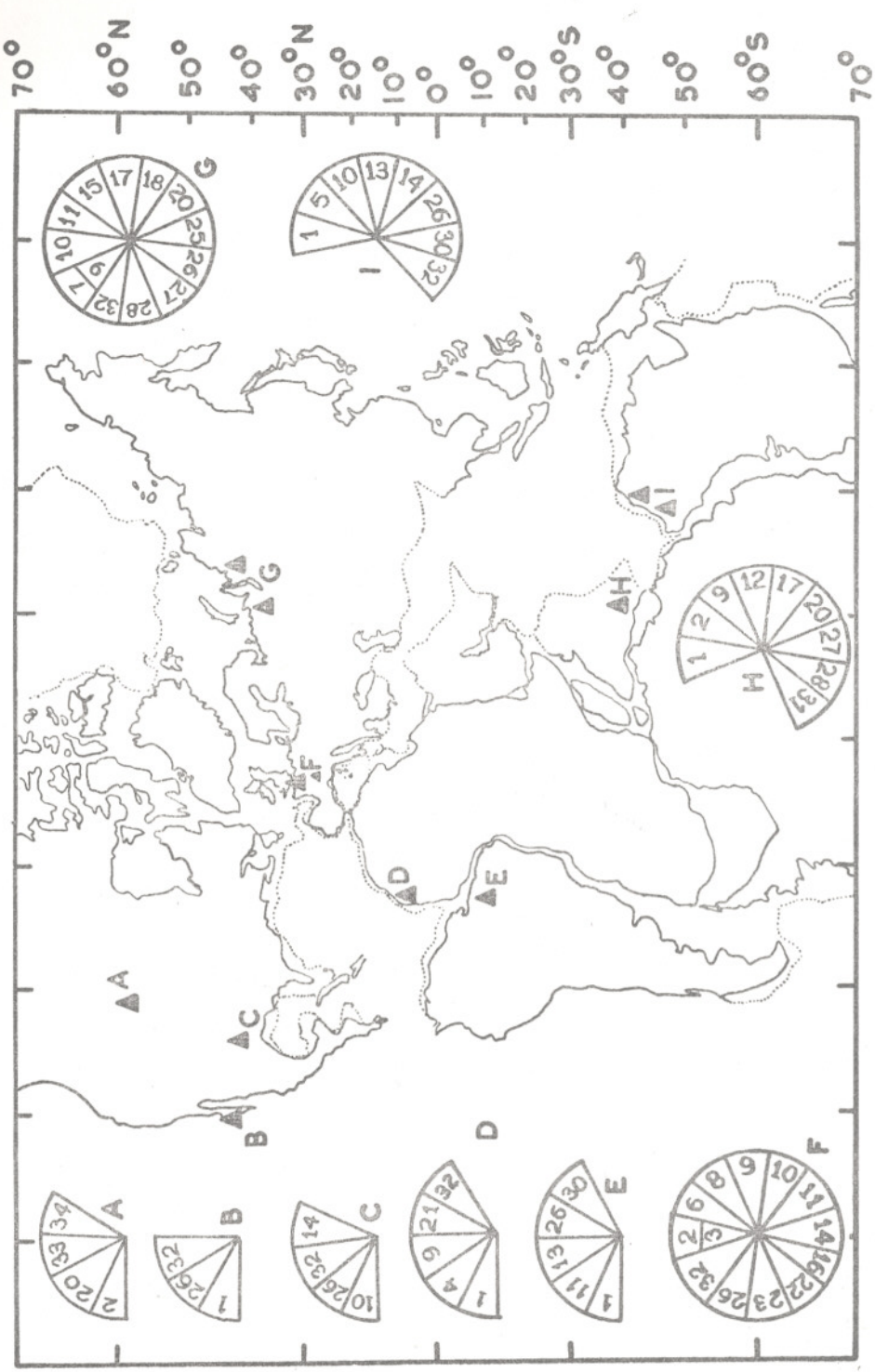
Table 1 — Global palaeogeographic and stratigraphic distribution of *Dinogymnium* species.
+? — Shows the presence but the present author has doubts.
? — Shows doubtful age.



Late Cretaceous map (After Hughes, 1973) showing palaeogeographic distribution of *Dinogymnium* species. Numbers and alphabets correspond with species number and geographic location cited in Table 1 respectively.

had already become cosmopolitan and the old differentiation between boreal and Tethyan ammonoid assemblages had weakened. Marine transgression progressed during early Late Cretaceous time until possibly the most extensive Phanerozoic global submergence had been attained. He (1973, p. 278) further stated that the temperature conditions during the Late Cretaceous appeared to have been fairly equable. The cosmopolitan distribution of most of the species of the *Dinogymnium* favours the temperature equivalence hypothesis during Late Cretaceous.

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