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# Observations on archaeopyle type in fossil dinoflagellate cyst species *Dingodinium cerviculum* Cookson & Eisenack 1958

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The archaeopyle type in fossil dinoflagellate cyst species *Dingodinium cerviculum* Cookson & Eisenack 1958 is interpreted based on the study of a rich suite of well-preserved specimens recovered from subsurface Lower Cretaceous sequence of Palar Basin, southern India. These cysts develop dissimilar periarchoepyle and endoarchaeopyle. The periarchoepyle is intercalary, involving more than one, probably three, anterior intercalary paraplates with free perioperculum. The endoarchaeopyle is combination type involving all the four apical and three anterior intercalary paraplates. The endoperculum is compound and is represented in two parts, an apical part which is simple, polyplacoid and adnate while the other part comprising intercalary paraplates is polyplacoid, free and probably compound. The archaeopyle formula is suggested to be  $?2-31/(4A)a31$ . In view of these observations, the diagnosis of *D. cerviculum* is emended herein.

**Key-words**—Dinoflagellate cysts, Morphology, Early Cretaceous, Palar Basin (India).

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## सारांश

अशिमत घूर्णीकशाभ पुटी जाति डिंगोडीनियम सर्विकुलम् कुक्सन व आइजेनेक 1958 में आर्कियोपाइल के प्रकार पर प्रेक्षण

खोवाजा अतीकुज्जमाँ, राहुल गर्ग एवं कृष्ण प्रसाद जैन

अशिमत घूर्णीकशाभ पुटी जाति डिंगोडीनियम सर्विकुलम् कुक्सन व आइजेनेक 1958 में विद्यमान आर्कियोपाइल के विभिन्न प्रकारों की व्याख्या दक्षिणी भारत में पलार द्रोणी के अधरि क्रीटेशी अनुक्रम की उपसतह से उपलब्ध सघन सुपरिरीक्षित प्रादशों के अध्ययन के आधार पर की गई है। ये पुटीयाँ विभिन्न प्रकार के पेरीआर्कियोपाइलों एवं अन्तःआर्कियोपाइलों का निर्माण करती हैं। पेरीआर्कियोपाइल अन्तर्वेशी है तथा इसमें एक से अधिक, सम्भवतया तीन स्वतंत्र प्रच्छदों से युक्त अग्रस्थ अन्तर्वेशी पैराप्लेट विद्यमान हैं। अन्तःआर्कियोपाइल संयोजित है जिसमें सभी चारों शीर्षस्थ एवं तीनों अग्रस्थ अन्तर्वेशी पैराप्लेट का संयोग है। अन्तःओपकुलम् संयुक्त प्रकार का है तथा दो भागों से बना है इसका शीर्षस्थ भाग सरल, पोलीप्लेकोयडी एवं संलग्न है तथा दूसरा भाग, जो अन्तर्वेशी पैराप्लेटों से युक्त है, पोलीप्लेकोयडी, स्वतंत्र तथा सम्भवतया संयुक्त प्रकार का है। आर्कियोपाइल का सूत्र  $?2-31/(4A)a31$  प्रस्तावित किया गया है। उक्त प्रेक्षणों के आधार पर डिंगोडीनियम सर्विकुलम् का निदान संशोधित किया गया है।

*DINGODINIUM* Cookson & Eisenack 1958 is a stratigraphically significant dinocyst genus with a wide geographic distribution during Late Jurassic-Early Cretaceous times. While erecting the genus, Cookson and Eisenack (1958, pp. 39-40) established two species, *D. jurassicum* and *D. cerviculum*, designating the former as the type species. Presence of an opening/archaeopyle was not described in any of these two species.

Subsequently several other species have been added to *Dingodinium* but there appears to be no

unanimity among workers regarding the type of archaeopyle. Sarjeant (1966) first documented the presence of an archaeopyle in *?Dingodinium albertii* as intercalary. Later Haskell (1969) described variable type of archaeopyle, usually apical and rarely epicystal or precingular, in *D. cerviculum*. On the contrary, Dodekova (1971) interpreted that *D. jurassicum* and *D. albertii* both had apical archaeopyle. Stover and Evitt (1978) in their generic analyses remarked that archaeopyle type in *Dingodinium* is uncertain, probably intercalary or

combination type (AI). Different views regarding archaeopyle type in *Dingodinium* species put forth from time to time by various workers are summarized in Table 1.

**Table 1—Different views on archaeopyle type in *Dingodinium* Cookson & Eisenack 1958**

AUTHOR	SPECIES	ARCHAEOPYLE TYPE
Cookson & Eisenack, 1958	<i>D. jurassicum</i>	No mention
	<i>D. cerviculum</i>	No mention
Eisenack, 1958	<i>D. europaeum</i>	No mention
Gitmez, 1970	<i>D. tuberosum</i>	Apical
	(= <i>Parvocavatus tuberosus</i> )	
Dodekova, 1971	<i>D. jurassicum</i>	Apical
	<i>D. albertii</i>	Apical
Davey, 1974	? <i>D. albertii</i>	Apical
Dodekova, 1975	<i>D. minutum</i>	Apical
Duxbury, 1977	<i>D. spinosum</i>	Apical
	(= <i>Parvocavatus spinosus</i> )	
Stover & Helby, 1987a	<i>D. cerviculum</i>	Apical
	<i>D. jurassicum</i>	Apical
Stover & Helby, 1987b	<i>D. swanense</i>	Apical
Brideaux, 1971	<i>D. cerviculum</i>	Intercalary/Apical
Sarjeant, 1966	? <i>D. albertii</i>	Intercalary
Habib, 1972	<i>D. cerviculum</i>	Intercalary
Habib, 1976	<i>D. cerviculum</i>	Intercalary
Jansonius, 1981 (in Mehrotra & Sarjeant, 1968)	<i>D. cooksoniae</i>	Intercalary (2a)
	<i>D. sanmartinoi</i>	Intercalary (2a)
Pothe de Baldis & Ramos, 1983	<i>D. sanmartinoi</i>	Intercalary (2a)
Stover & Evitt, 1978	<i>Dingodinium</i>	Intercalary or combination
	Cookson & Eisenack	(Apical + Intercalary)
Haskell, 1969	<i>D. cerviculum</i>	Variable
Mehrotra & Sarjeant, 1984	<i>D. cerviculum</i>	Variable
	<i>Dingodinium</i>	4A (1.4)a/I <sub>1</sub> or 4A (1.4)a/(I <sub>1</sub> P <sub>3</sub> ) or 4A (1.4)a/I <sub>1</sub> + P <sub>3</sub> , 4A(1.4)a/I <sub>1</sub> 4A(1.4)a/(I <sub>1</sub> P <sub>3</sub> ) or I <sub>1</sub> + P <sub>3</sub> 4A(1.4)a/I <sub>1</sub> + P <sub>3</sub> , 4A(1.4)a/(4A <sub>1</sub> - 4I <sub>1</sub> ) ?4A(1.4)/4A(1.4) or ?4A (1.4)a/4A(1.4)a

A perusal of published literature reveals that archaeopyle controversy in *D. cerviculum* is long existing. In earlier studies the periarchoepyle and endoarchaeopyle were not differentiated in the camocavate cysts of *Dingodinium* and the archaeopyle in general was defined as apical, intercalary, epicystal, combination or variable. Mehrotra and Sarjeant (1984) pointed out the dissimilar nature of periarchoepyle and endoarchaeopyle in *Dingodinium*. They based their observations on detailed study of *D. cerviculum* from subsurface Lower Cretaceous sequence of Cauvery Basin, East coast of India and review of published literature, documenting great variation in the archaeopyle type.

Recently a rich dinocyst assemblage containing well-preserved specimens of *Dingodinium cerviculum* has been recovered from subsurface Lower Cretaceous sediments from ca. 760 m deep bore-hole drilled near Puduvoyal in Chingleput District, Palar Basin. Our observations and interpretations of archaeopyle type in *D. cerviculum* based on this material, presented at the Brisbane meeting of the 7th International Palynological Congress (Khowaja-Ateequzaman *et al.*, 1988), are discussed in the present paper.

All figured specimens are lodged with the museum, Birbal Sahni Institute of Palaeobotany, Lucknow, India. The specimen locations in the slides has the reference of mechanical stage coordinates of Olympus BH-2 microscope no. 274090.

## OBSERVATIONS

More than 200 selected specimens of *Dingodinium cerviculum* have been examined under Phase Contrast and Nomarski Differential Interference Contrast Microscopy. The present suite of *D. cerviculum* is unique as it contains both excysted and unexcysted cysts, the former strikingly dominates the assemblage. Apart from these, a few well-preserved specimens also display partially opened up archaeopyle. Availability of such

## PLATE 1

(All photomicrographs in Nomarski Differential Interference Contrast).

- 1-7. *Dingodinium cerviculum* Cookson & Eisenack 1958  
1-3. Slide no. BSIP 10149, Coordinates: 20.4 × 159.3. 1. Complete specimen, ca × 800; 2, 3. Same specimen (portion magnified) in left lateral and right lateral views respectively, ca × 2000.  
4-6. Slide no. BSIP 10150, Coordinates: 16.9 × 131.8. 4. Complete specimen ca × 800; 5-6. Same specimen (portion

magnified) in left lateral and right lateral views respectively, ca × 2000.

7. Magnified portion of a specimen showing intercalary part of endopericulum in three pieces as well as paraplate 2a to be of standard hexa type, Slide no. BSIP 10151, Coordinates: 13.8 × 130.9, ca × 2000.

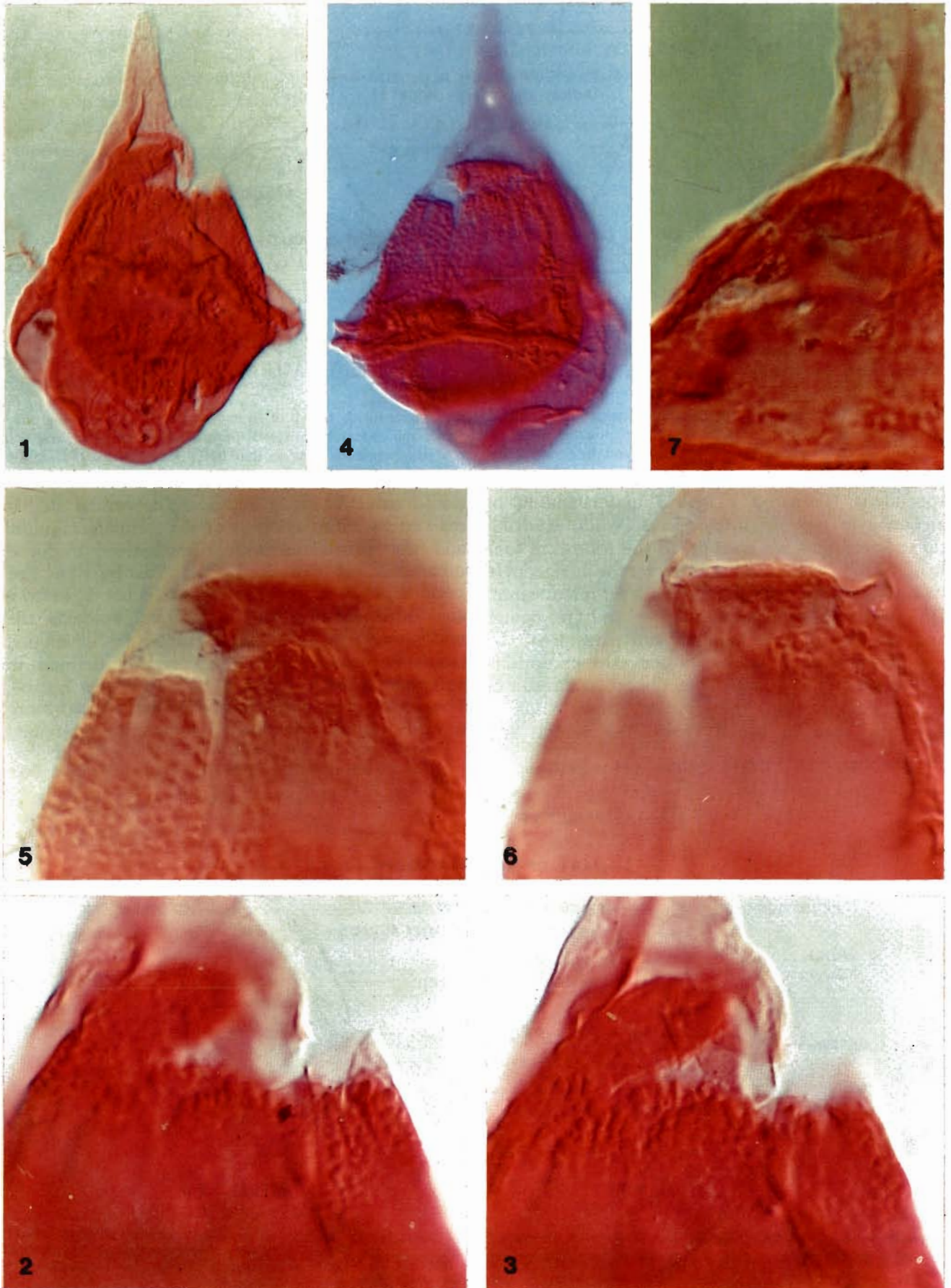
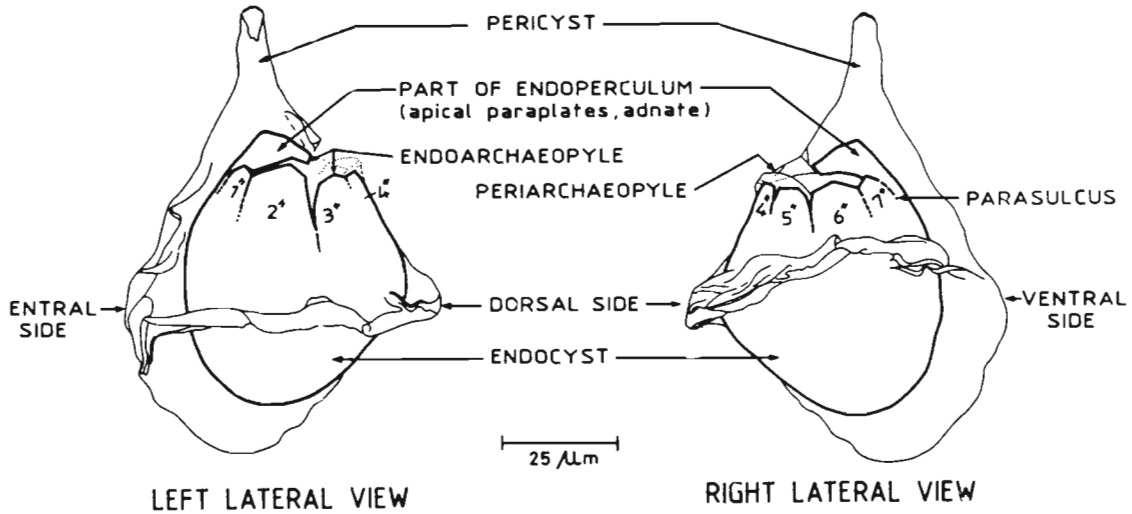


PLATE 1

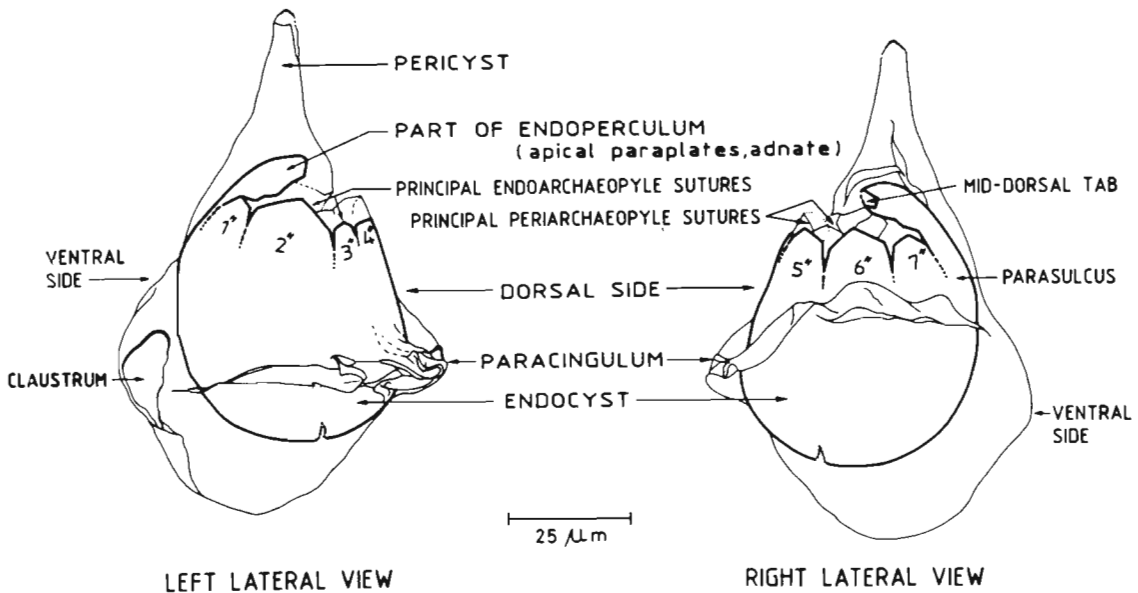


**Text-figure 1**—*Dingodinium cerviculum* Cookson & Eisenack 1958: Camera lucida sketch of an excysted specimen showing offset endings of the helicoid periparacingulum, position of periarchoepyle and endoarchaeopyle, disposition of pre-cingular paraplates with accessory endoarchaeopyle sutures and the adnate apical part of endoperculum, slide no. BSIP 10150; Coordinates: 17.0 × 131.5.

specimens facilitated a logical understanding of archaeopyle type in this species. While studying these specimens we considered the following four features most significant to interpret the archaeopyle type (i) cyst orientation, (ii) wall layer relationship, (iii) paraplate topology and shape, and (iv) nature and position of paracingulum and parasulcus.

*D. cerviculum* is one of the rare exceptions where the cyst is laterally compressed. As a result of lateral compression, the cyst in strewn slide is generally seen in lateral views. The ventral and

dorsal sides lie along margins. The ventral side is marked by offset endings of the periparacingulum and the parasulcus with comparatively reduced ornamentation (Pl. 2, fig. 1; Text-fig. 1). The periphragm is extremely thin and smooth without any ornamentation or parasutures, whereas the endophragm is thick with extensively developed tabular ornamentation which is well-defined in epiendocyst (Pl. 1, figs 2, 3, 5, 6; Pl. 2, figs 2, 3, 6). The endocyst is eccentrically placed, shifted more towards dorsal side and is sometimes appressed



**Text-figure 2**—*Dingodinium cerviculum* Cookson & Eisenack 1958: Camera lucida sketch of an excysted specimen showing adnate apical part of endoperculum, mid-dorsal tab, and principal periarchoepyle sutures, slide no. BSIP 10149; Coordinates: 20.4 × 159.3.

along the precingular and postcingular areas on the dorsal side (Pl. 1, figs 1, 4; Pl. 2, figs 1, 4, 7). The periphragm and endophragm are distinct from each other towards anterodorsal side where periarthaeopyle and endoarthaeopyle are developed.

**Periarthaeopyle**

The periarthaeopyle is characterized by an opening invariably developed on the anterodorsal side of the epipericyst at the base of the apical horn and much above the periparacingulum, corresponding to anterior intercalary paraplate position (Pl. 2, figs 1-3; Text-fig. 1). The interpretation of periarthaeopyle type at times becomes difficult owing to distorted principal periarthaeopyle sutures along the adapical and adcingular margins of the opening. These arthaeopyle sutures always remain confined exclusively on to the dorsal surface and are never found to extend beyond the middle of the epipericyst along the anticipated precingular and apical paraplate contact margins. The occurrence of many-angled principal periarthaeopyle sutures and large size of opening suggests that more than one, probably three, anterior intercalary paraplates must have been displaced (Pl. 1, figs 1-3; Text-fig. 2).

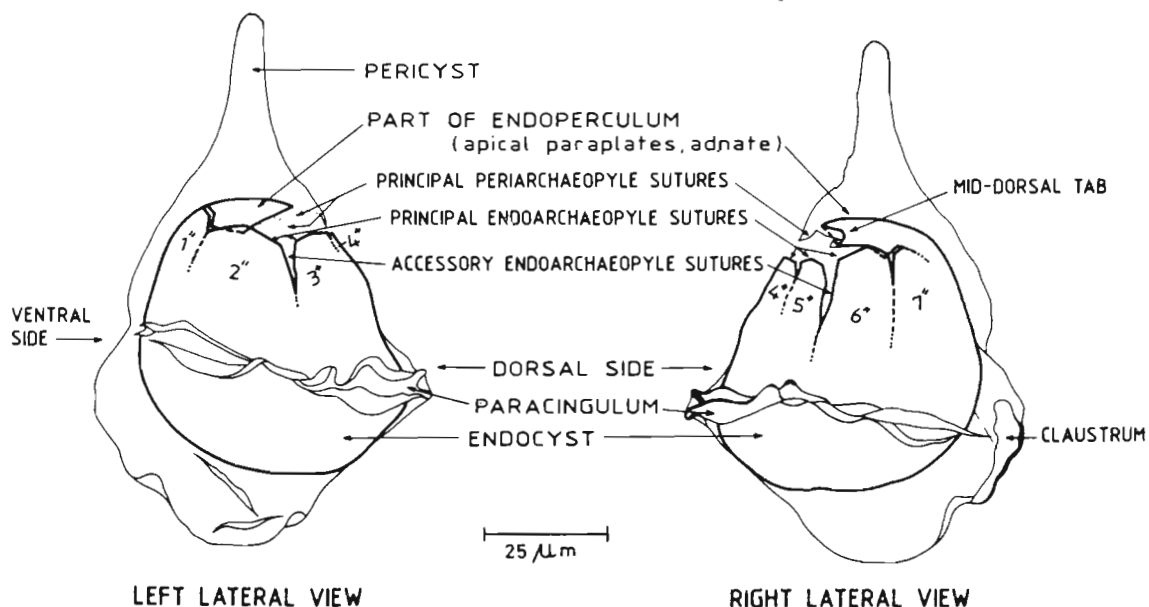
**Endoarthaeopyle**

The endoarthaeopyle, in contrast to periarthaeopyle, can be better interpreted because

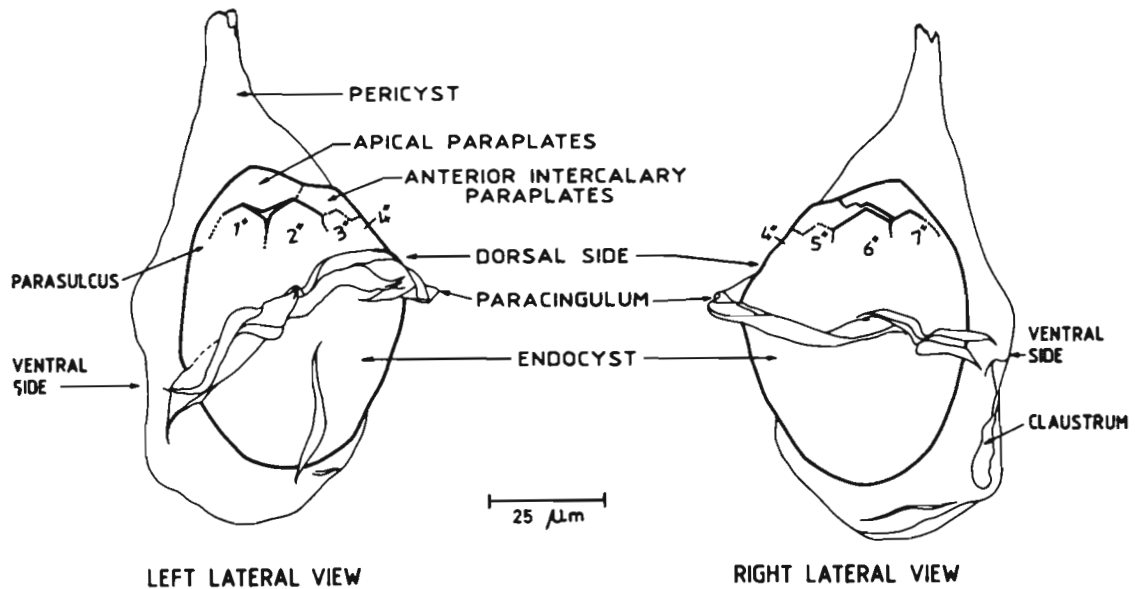
of the distinctive paratabulation of epiendocyst. The paratabulation on epiendocyst is marked by tabular ornamentation, adcingular and adapical margins of the apical and precingular paraplate series respectively and the occasional faint parasutural markings usually present between precingular paraplates.

The precingular series consists of seven paraplates which are larger than others on epiendocyst and are longitudinally elongate (higher than broad), differing in shape with unequal adapical margins (Pl. 1, figs 4-6; Pl. 2, figs 1-3, 6; Text-figs 1, 3). Paraplates 1", 2", 6" and 7" are longer than paraplates 3", 4" and 5". Of these, paraplates 2" and 6" are comparatively broad occupying major areas on the left and right lateral sides respectively. The paraplate 4" is characteristically four sided and flat topped (planate) whereas the rest are five sided (camerate) (Pl. 1, figs 4-6; Pl. 2, figs 1-3, 6; Text-figs 1, 3).

The apical series consists of four paraplates which in excysted specimens remain attached with the parasulcus through 1', forming a hood like structure over precingular series. The paraplates 2' and 4' superimpose each other lying on left and right lateral sides respectively (Pl. 1, figs 1-3; Pl. 2, figs 1-3; Text-figs 1, 2). The most significant paraplate of the apical series is 3' which projects into the broad endoarthaeopyle opening, forming a mid-dorsal tab (Pl. 1, figs 1-6; Text-figs 2, 3). This opening extends all along the adapical margin of the precingular paraplates. The principal endoarthaeopyle sutures and the accessory



**Text-figure 3**—*Dingodinium cerviculum* Cookson & Eisenack 1958: Camera lucida sketch of an excysted specimen showing disposition of precingular paraplates, mid-dorsal tab and planate 4" in epiendocyst, principal endoarthaeopyle sutures and accessory endoarthaeopyle sutures, slide no. 10150; Coordinates: 16.9 × 131.8.



**Text-figure 4**—*Dingodinium cerviculum* Cookson & Eisenack 1958: Camera lucida sketch of an unopened cyst showing presence of anterior intercalary paraplates forming a hump-like structure on anterodorsal side of epiendocyst, slide no. BSIP 8092; Coordinates: 12.9 × 137.9.

endoarchaeopyle sutures are distinctly marked. The latter are characteristically developed, sometimes extending deep, between the precingular paraplates 1''-2'', 2''-3'', 5''-6'' and 6''-7''

The relationship of apical and precingular paraplate series in the excysted specimens indicates close proximity between precingular paraplates 1'', 7'' and in part 2'', 6'' and the apical paraplates 1' and in part 2', 4' only. The remaining adapical margin of the precingular paraplates 3'', 4'', 5'' and in part 2'', 6'' and adcingular margin of apical paraplates 3' and in part 2', 4' remain separated apart leaving a broad gap on anterodorsal side (Pl. 1, figs 1-6; Pl. 2, figs 1-3, 6; Text-figs 1, 3). This gap with reference to paraplates involved obviously indicates the loss of some anterior intercalary paraplates which are seen intact in a few complete unexcysted specimens in the form of a hump like structure (Pl. 2, figs 4, 5; Text-fig. 4).

In view of the above observations with special reference to the presence of seven precingular paraplates, the mid-dorsal tab and planate 4'' precisely suggest displacement of three anterior intercalary paraplates, of which 2a should be of hexa type.

In one of the specimens the anterior intercalary paraplates could be seen marked by faint accessory sutures suggesting that the three intercalary paraplates might have separated independently and paraplate 2a is of standard hexa type (Pl. 1, fig. 7). This observation, for the time being, is kept open till more data is available.

We opine that the endoarchaeopyle is of combination type involving all the four apical and three anterior intercalary paraplates. The endopericulum is compound represented in two parts, the apical part being polyplacoid, simple and adnate while the intercalary part is polyplacoid, free

## PLATE 2

(All photomicrographs in Nomarski Differential Interference Contrast).

1-7. *Dingodinium cerviculum* Cookson & Eisenack 1958.

1-3. Slide no. 10150, Coordinates: 17.0 × 131.5. 1. Complete specimen, ca × 800; 2, 3. Same specimen (portion magnified) in right lateral and left lateral views respectively, ca × 2000.

4-5. Slide no. BSIP 8092, Coordinates: 12.9 × 137.9. 4. Complete specimen, ca × 800; 5. Same specimen (portion magnified) showing presence of intercalary paraplates forming a hump-like structure, ca × 2000.

6. Magnified portion of a specimen in left lateral view showing paraplate disposition on epiendocyst and reduced ornamentation on parasulcus, slide no. BSIP 10149, Coordinates: 22.8 × 135.5, ca × 2000.

7. Complete specimen showing intercalary part of endopericulum in three pieces as well as paraplate 2a to be of standard hexa type, slide no. BSIP 10151; Coordinates: 13.8 × 130.9, ca × 800.

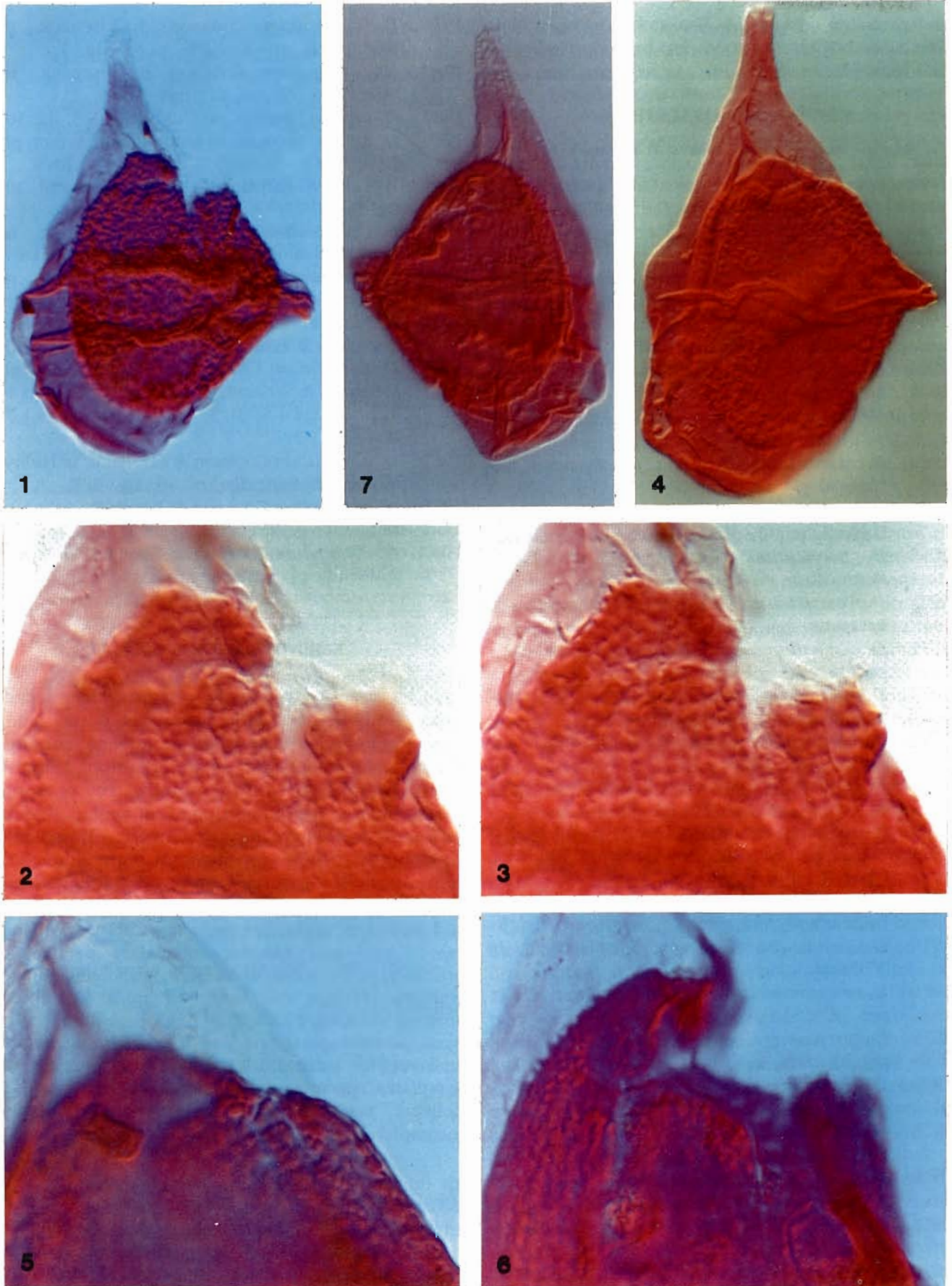


PLATE 2

and probably compound. The archaeopyle formula based on above observations has been derived as ?2-31/(4A)a 31:

### SYSTEMATIC DESCRIPTION

#### Genus—*Dingodinium* Cookson & Eisenack 1958

*Dingodinium cerviculum* Cookson & Eisenack, 1958 emend. Mehrotra & Sarjeant, 1984; emend. herein

Pl. 1, figs 1-7; Pl. 2, figs 1-7; Text-figs 1-4

- 1958 *Dingodinium cerviculum* Cookson & Eisenack, p. 40; pl. 1, figs 12-14.
- 1961 *D. cerviculum* Cookson & Eisenack, in Alberti, p. 17; pl. 3, figs 14-15.
- 1961 ?*Dingodinium* sp. A, in Alberti, pp. 17-18; pl. 3, fig. 16.
- 1966 ?*D. albertii* Sarjeant, pp. 210-211; pl. 21, fig. 3; pl. 23, fig. 1.
- 1968 *D. cerviculum* Cookson & Eisenack, in Ingram, p. 103.
- 1969 *D. cerviculum* Cookson & Eisenack, in Haskell, p. 60; pl. 1, figs 1-4.
- 1969 *D. cerviculum* Cookson & Eisenack, in Millioud, p. 428.
- 1971 *D. cerviculum* Cookson & Eisenack, in Brideaux, pp. 101-102; pl. 30, fig. 104.
- 1971 *D. cerviculum* Cookson & Eisenack, in Singh, pp. 361-363; pl. 62, figs 1-4.
- 1972 *D. cerviculum* Cookson & Eisenack, in Habib, p. 379; pl. 12, figs 1-2.
- 1973 *D. cerviculum* Cookson & Eisenack, in Burger, pp. 37-38.
- 1974 *D. cerviculum* Cookson & Eisenack, in Davey & Verdier, p. 632; pl. 91, fig. 6.
- 1974 *D. albertii* Sarjeant, in Davey, p. 49.
- 1974 ?*D. albertii* Sarjeant, in Wiseman & Williams, fig. 5.
- 1975 *D. cerviculum* Cookson & Eisenack, in Brideaux & McIntyre, p. 38; pl. 14, fig. 5.
- 1975 *D. cerviculum* Cookson & Eisenack, in Williams, pl. 14, fig. 11.
- 1976 *D. cerviculum* Cookson & Eisenack, in Habib, pp. 382-383; pl. 1, figs 6-8.
- 1976 *D. cerviculum* Cookson & Eisenack, in Kemp, pp. 33-35.
- 1976 *D. cerviculum* Cookson & Eisenack, in Harris, pl. 21, figs 1-2.
- 1976 *D. cerviculum* Cookson & Eisenack, in Williams & Bujak, p. 472; pl. 5, fig. 6.
- 1976 *D. cf. albertii* Sarjeant, in Ioannides, Stavrinou & Downie, p. 451; pl. 1, figs 10-12.
- 1977 *D. albertii* Sarjeant, in Duxbury, pp. 29-30; pl. 9, fig. 4; Text-fig. 6.
- 1978 *D. albertii* Sarjeant, in Davey, pp. 891-894.

- 1978 *D. cerviculum* Cookson & Eisenack, in Herngreen, pp. 275-276; pl. 1, fig. 1.
- 1980 *D. cerviculum* Cookson & Eisenack, in Burger, p. 72; pl. 22, figs 5-6.
- 1980 *D. albertii* Sarjeant, in Duxbury, pl. 3, fig. 10.
- 1980 *D. albertii* Sarjeant, in Antonescu & Avram, pl. 9, fig. 4.
- 1981 ?*D. albertii* Sarjeant, in Below, p. 45; pl. 10, fig. 3.
- 1981 *D. cerviculum* Cookson & Eisenack, in Reneville & Raynaud, p. 5; pl. 2, fig. 16.
- 1982 *D. cerviculum* Cookson & Eisenack, in Burger, pl. 2, fig. 4.
- 1982 *D. cerviculum* Cookson & Eisenack, in Cookson & Eisenack, p. 34; pl. 2, figs 8-10.
- 1984 *D. cerviculum* Cookson & Eisenack emend. Mehrotra & Sarjeant, pp. 296-298; pl. 1, figs 1-6; pl. 2, figs 1-5; pl. 3, figs 1-4; pl. 4, figs 1-7; text-figs 1-2.
- 1987 *D. cerviculum* Cookson & Eisenack, in Helby, Morgan & Partridge, p. 46, fig. 28K.
- 1987a *D. cerviculum* Cookson & Eisenack, in Stover & Helby, p. 251; figs 23F-K.
- 1987b *D. cerviculum* Cookson & Eisenack, in Stover & Helby, pp. 281-282; figs 15A-K.

### EMENDED DIAGNOSIS

Cyst camocavate, laterally compressed, endocyst eccentrically placed shifted towards dorsal side, sometimes appressed, pericoel prominent ventrally; pericyst ellipsoidal with a well-developed apical horn, periphragm thin, smooth, an opening (claustrum) generally developed on ventral side at posterior sulcal region; endocyst ellipsoidal, endophragm thick, ornamented with tubercles, verrucae and spines, usually arranged in longitudinal rows; archaeopyle differently developed on epicyst and endocyst, periarchaeopyle intercalary involving more than one anterior intercalary paraplates, probably 3, perioperculum free, endoarchaeopyle combination type involving four apical and three anterior intercalary paraplates, endoperculum in two parts, adnate apical and free intercalary, accessory archaeopyle sutures develop along precingular paraplates, paracingulum distinct on periphragm, helicoid, markedly offset ventrally; paratabulation incompletely discernible.

#### Description :

*Shape*—Cyst laterally compressed, ellipsoidal, epipericycyst prolonged into an apical horn with a bluntly rounded tip, endocyst ellipsoidal.



*Wall relationship*—Cyst camocavate, endocyst eccentrically placed, shifted more towards dorsal side, some times almost appressed dorsally in precingular and post-cingular areas, pericoel well-developed ventrally.

*Wall features*—Periphragm extremely thin, smooth without any parasutural features, an opening (claustrum) invariably present on ventral surface somewhere in the posterior sulcal region, tip of the apical horn generally open, endophragm thick, ornamented with verrucae, tubercles and short spines arranged in longitudinal rows, ornamentation partly tabular, well-defined in endocyst.

*Paracingulum*—Distinct on periphragm, expressed by parallel transverse folds running high over endophragm, markedly offset ventrally.

*Paratabulation*—Incompletely indicated by periarchaeopyle and undivided periparacingulum on pericyst; differently developed on endocyst; complete on epiendocyst indicated by endoarchaeopyle and tabular ornamentation, poorly and incompletely expressed on hypoendocyst; endocyst formula 4', 3a, 7'' Xc, X''', X''''

*Archaeopyle*—Differently developed on periphragm and endophragm; periarchaeopyle intercalary, involving more than one, probably three, anterior intercalary paraplates, operculum free; endoarchaeopyle combination type involving all four apical and three anterior intercalary paraplates; endoperculum compound, represented in two parts; an apical free part which is polyplacoid, simple and adnate while the other part comprising intercalary paraplates is polyplacoid, free and probably compound. Formula ?2-3I/(4A)a3I.

*Dimensions*—Overall cyst size : 80-118 × 40-75  
 $\mu\text{m}$   
 Size of endocyst : 40-60 × 37-57  
 $\mu\text{m}$   
 Length of apical : 20-35  $\mu\text{m}$   
 horn

## DISCUSSION

Our observation and interpretation of the archaeopyle type in *Dingodinium cerviculum* should provide taxonomic stability to this morphologically distinctive taxon. Despite its characteristic morphology, the difference of opinion

about the type of archaeopyle is bound to cause ambiguity in precise morphologic identification and taxonomic status of not only *D. cerviculum* but the genus *Dingodinium* itself. Mehrotra and Sarjeant (1984, p. 286), while advocating variability of archaeopyle character in *Dingodinium* species, have remarked that if archaeopyle alone is taken as a differentiating character, *Dingodinium* might be subdivided into as many as four genera. They, however, preferred to maintain *Dingodinium* as a single entity due to its morphological unity and also due to their conviction that involvement of intercalary paraplates is an essential feature in its archaeopyle formation.

Based on comprehensive study of *D. cerviculum* and critical review of earlier records of *Dingodinium* species, Mehrotra and Sarjeant (1984) documented five to seven types of archaeopyle in *Dingodinium* in general and at least three types in *D. cerviculum* and consequently proposed emendations of both. They concluded that in *D. cerviculum*, the periarchaeopyle is apical comprising all apical paraplates (the number of apical paraplates involved may be 3 instead of 4) with usually ventrally attached operculum closing after excystment. Variability is documented primarily in the endoarchaeopyle which is considered to be either single plate intercalary (?1a or 2a) or combination type involving anterior intercalary paraplate and precingular paraplate with simple or compound, free or partly or completely attached endoperculum. However, all these variations are not visible in their illustrations. We observed no variability in archaeopyle character in our studied specimens.

Furthermore, the illustrations as well as the text-figures provided by Mehrotra and Sarjeant (1984, pl. 1, figs 1, 2, 4, 5; pl. 2, figs 4, 5; pl. 3, figs 1-4; text-figs 1, b-b'; 2 a-a') suggest that lateral views of the cyst have been interpreted as dorsal or ventral sides. A careful observation reveals that ventral surface in their specimens is indicated by discontinuity of the helicoid paracingulum while on the dorsal side endocyst is closely appressed to the pericyst with the development of a prominent pericoel along paracingulum; obviously the cysts are laterally compressed and preserved in lateral view. As such their interpretations concerning archaeopyle type and paratabulation in *Dingodinium cerviculum* are not acceptable. Lentin and Williams (1985, p. 109) also remarked that variability in the number of paraplates involved in the formation of archaeopyle as well as the paratabulation and relationship between 3'' and 1a outlined by Mehrotra and Sarjeant is very unusual. Regarding the paratabulation outlined by Mehrotra and Sarjeant, we

are of the opinion that hypocystal paratabulation in the endocyst is inconclusive.

Recently, Stover and Helby (1987b, pp. 281-282) have also studied archaeopyle type of *D. cerviculum* and *D. jurassicum* and concluded that *Dingodinium* possesses type (tA)a apical archaeopyle. They specifically mentioned that no intercalary paraplates are found in their specimens or in any earlier illustrated specimens. While describing the archaeopyle, they referred to the endoarchaeopyle and defined it by generally angular principal endoarchaeopyle sutures, accessory sutures and ventrally attached operculum. As for the periarchoepyle, Stover and Helby (1987b) mentioned that its outline is commonly uncertain owing to folding and tearing of the periphragm. However, at least one of the well preserved and complete specimens illustrated by them (fig. 15D, p. 280) shows small apical paraplate series forming a hood like structure over exceptionally elongate and large precingular paraplates. There is an indication of occurrence of small anterior intercalary paraplates (seen as a hump). A restudy of such specimens should endorse our observations on Indian material.

The archaeopyle controversy in the genus *Dingodinium* primarily resulted from varying interpretations on *D. cerviculum* (including *D. albertii*) by earlier workers. Significantly, archaeopyle has been consistently noted to be apical in the type species *D. jurassicum* and rest of the species assigned to the genus except for *D. cooksoniae* and *D. sanmartinoi* which are described as having 2a intercalary archaeopyle (Table 1). However, archaeopyle type is insufficiently and incompletely documented in all these species, as periarchoepyle and endoarchaeopyle have not been differentiated. It is recommended that restudy of various *Dingodinium* species should be carried out in the light of our observations on *D. cerviculum*.

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