SEM Observations on Vestured Pits in Some Yunnan Hardwoods*

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雲南材数種のベスチャード壁孔のSEM観察*

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Abstract

The micromorphology of vestured pits in 11 species of indigenous Yunnan hardwoods was observed using SEM. Considerable variation in the location and extent of vesturing and the morphology of vestures in the vessel pits is noted and illustrated with scanning electron micrographs.

All the intervascular pits of the 11 species were vestured. They were divided into four types on the basis of the location and extent of vesturing within a pit. Vessel to ray and vessel to axial parenchyma pits were always found to be vestured in 7 species but to be both vestured and non-vestured in the remaining species. Vessel to fiber pits were vestured in the 5 species.

Vestured fiber tracheid pits were found in only 2 species.

Key words: SEM, vestured pit, Yunnan hardwoods, vessel wall.

Introduction

Vestured pits are known to occur as normal structures in the vessel members, tracheids and fiber tracheids of the secondary xylem of a limited numbers of dicotyledonous species.

The scanning electron microscope (SEM) is the most suitable microscope for observing the three-dimensional structure of vestures, because their small size and complicated shape cannot be clearly observed using light microscopy. Over the last few years, the occurrence

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and micromorphology of vestured pits have been observed in a wide variety of dicotyledonous woods using SEM (SCURFIELD et al., 1970 ; MEYLAN and BUTTERFIELD, 1974 ; OHTANI and ISHIDA, 1976 ; van VLIET, 1978).

The wood structure of the indigenous hardwood species grown in Yunnan province which is situated in southwest China has been recorded at light microscopic level (TANG, 1973 ; CHENG, 1980, 1985), but not at electron microscopic level. No information about the micromorphology of vestured pits in Yunnan hardwoods has yet been reported.

In the course of SEM observations on wood structure of Yunnan hardwoods, we found vestured pits to exist in 11 species. The present study describes SEM observations of their micromorphology.

Materials and Methods

The following species were selected for this study.

Alstonia scholaris (Apocynaceae), *Cassia siamea* (Caesalpiniaceae), *Terminalia bellericoides* (Combretaceae), *Terminalia myriocarpa* (Combretaceae), *Cleistanthus saichikii* (Euphorbiaceae), *Syzygium szemaoense* (Myrtaceae), *Dalbergia szemaoensis* (Papilionaceae), *Erythrina arborescens* (Papilionaceae), *Erythrina lithosperma* (Papilionaceae), *Anthocephalus chinensis* (Rubiaceae), *Duabanga grandiflora* (Sonneratiaceae).

The above species were confirmed to have vestured pits, during the course of SEM observations on the wood structure of Yunnan hardwoods (36 species, 34 genera, 23 families).

Wood specimens were obtained from wood collections from Kunming Botanical Institute, Yunnan Institute of Forestry and Xinan Forest College. Longitudinal, radial and tangential surfaces to be observed were prepared by splitting and cutting. Final cuts were done with a new steel blade attached to a sliding microtome. Specimens were finished in the form of ca. 6 mm × 6 mm × 1 mm and dried at room conditions. They were then stuck on brass standard stubs with electrically conductive paste. The surfaces to be observed were coated with carbon and gold while being rotated in a high vacuum evaporation unit fitted with two evaporating sources and specimen rotation to provide a coating layer of uniform thickness. Observations were made with a JSM-35CFII SEM at 15 kV.

Results

During our observations on the wood structure of 36 species from 34 genera belonging to 23 families, vestured pits were found in the vessels of 11 species and in the fiber tracheids of 2 species. Families to which the 11 species belong have already been recorded in the list of families with vestured pits published by BAILEY (1933) and METCALFE and CHALK (1983).

Species in which vestured pits were not found are as follows. *Alnus nepalensis, Betula alnoides* (Betulaceae), *Catalpa duclouxii, Stereospermum tetragonum* (Bignoniaceae), *Gossampinus malabarica* (Bombacaceae), *Garuga pinnate* (Burseraceae), *Baccaurea ramiflora, Macaranga denticulata, Mallotus philippinensis* (Euphorbiaceae), *Quercus acutissima* (Fagaceae), *Cinnamomum camphora, Litsea glutinosa* (Lauraceae), *Magnolia heptapeta, Paramichelia baillonii, Talauma gitingensis* (Magnoliaceae), *Chukrasia tabularis var. velutina, Melia azedarach, Toona ciliata* (Meliaceae), *Populus yunnanensis* (Salicaceae), *Arytera littoralis* (Sapindaceae), *Pouteria grandifolia* (Sapotaceae), *Pterospermum lanceaefolium* (Sterculiaceae), *Tetracentron sinensis* (Tetracentraceae), *Gmelina arborea, Vitex quinata* (Verbenaceae).

1. Vessel pits.

Considerable variation in the location and extent of vesturing and the morphology of vestures, both among and within the species examined, was evident. The variability of vessel pits within a species was found among all the pit types (i.e., intervascular pits, vessel to ray parenchyma pits, vessel to axial parenchyma pits and vessel to wood fiber pits). Observations on each pit type are separately described below.

1-1. Intervascular pits.

All the intervascular pits in the 11 species were vestured. They were divided into the following four types on the basis of the location and extent of vesturing within the pit.

Type A……Pits of slight vesturing. Vestures arise from the margin of the outer and inner pit apertures on the pit border. They also arise from the vicinity of the outer aperture on the pit chamber wall. They do not occlude either aperture.

Type B……Pits of moderate vesturing. Vestures arise from the margin of the outer and inner apertures on the pit border and the pit chamber wall. They occlude the outer aperture, but not the inner aperture.

Type C……Pits of remarkable vesturing. Vestures arise from the margin of the outer and inner apertures on the pit border and the pit chamber wall. They occlude both apertures.

Type D……Pits of moderate vesturing. Vestures arise from the margin of the outer aperture and the pit chamber wall, but not from the margin of the inner aperture on the pit border. They occlude the outer aperture.

Diagrammatic representation illustrating the four types of vestured intervascular pits is shown in Fig. 1.

1-1-1. Species having vestured pits of type A.

Vestured pits of type A were found in *Cassia siamea* and *Erythrina lithosperma*.

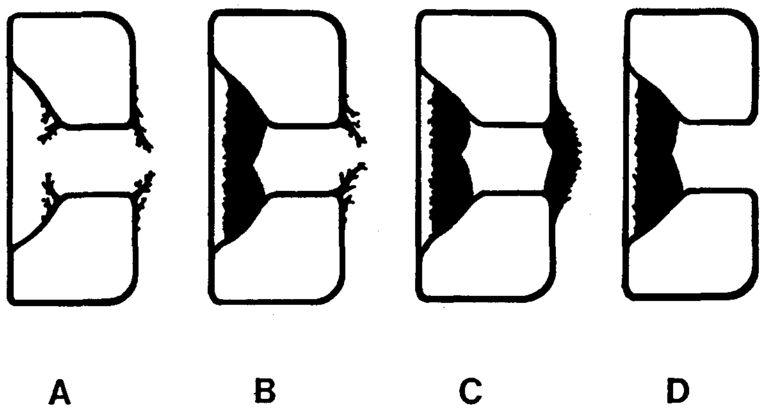

Fig.1. Diagrammatic representation illustrating the different types of vesturing.

Photos 1, 2 and 3 show vestured pits of *Cassia siamea*. Photo 1 shows vestured pits in the wall of a vessel member viewed from the lumen side. Coalescent pit apertures were often found in this species as shown in Photo 1. Branched vestures arise from the margin of the apertures which they do not occlude. Small unbranched vestures are also found. Photo 2 shows vestured pits in the wall of a vessel member viewed from the outer surface. Branched vestures arise from the margin of the outer apertures which they do not occlude. Smaller unbranched vestures occur near the base of larger branched ones on the pit chamber wall. Photo 3 shows a vestured intervascular pit in a cut surface. This shows clearly that the occurrence of vestures is confined to the margin of both the outer and inner apertures and to the pit chamber wall in the vicinity of the outer aperture and that vestures do not occur in the pit canal. Photo 4 shows vestured pits viewed from the outer surface in *Erythrina lithosperma*. In most intervascular pits in this species, larger branched vestures arise from the margin of the outer apertures and do not occlude the apertures. Branched and unbranched vestures occur in the vicinity of the outer aperture on the pit chamber wall.

1-1-2. Species having vestured pits of type B.

Vestured pits of type B were found in *Erythrina arborescens* and *Erythrina lithosperma*. Photos 5 and 6 show vestured pits of *Erythrina arborescens* viewed from the pit membrane and the vessel lumen, respectively. Photo 5 shows vesturing in pit chambers viewed from the outer surface. The pit chambers are almost completely occupied by vestures. Branched vestures are very complicated in appearance and are often anastomosed with each other. Photo 6 shows various forms of vestures arising from the margin of coalescent pit apertures. They do not occlude the apertures.

Some intervascular vestured pits of *Erythrina lithosperma* were similar to those shown in Photos 5 and 6.

1-1-3. Species having vestured pits of type C.

Vestured pits of type C were found in *Cleistanthus saichikii* (Photos 7 and 8), *Anthocephalus chinensis* (Photos 9 and 10), *Syzygium szemaoense* (Photos 11, 12 and 13) and *Alstonia scholaris* (Photos 14 and 15). Although both the inner and outer apertures in these species were occluded by vestures, the form of the vestures was found to differ among the four species. Photo 7 shows that branched vestures arising from the margin of the inner apertures almost occlude the inner apertures and that unbranched ones also occur densely on the inner surface wall near the inner apertures. Photo 8 shows the vestures, viewed from the outer surface, filling the pit chambers. Some of them are massive coralloid structures. In *Anthocephalus chinensis* it can be seen from Photos 9 and 10 that the vestures densely occlude the inner aperture and the pit chamber. They are minutely branched and their appearance is bead-like. Such vesturing in the inner apertures is similar to that in the same species grown in Western Samoa (DONALDSON, 1984). Vestures in *Syzygium szemaoense* have complicated branching in both the inner apertures (Photo 11) and the pit chamber (Photo 12). Their branches are anastomosed to each other. Photos 11 and 12 show that they are also net-like in appearance. Photo 13 shows a longitudinal cut surface of the intervascular pit pairs. It can be seen from this photo that vestures do not occur in the pit canal though they occlude both the inner and outer apertures.

Photos 14 and 15 show vesturing in the inner apertures and pit chambers of *Alstonia scholaris*, respectively. Vesturing in this species was confined to the margin of both the inner and outer apertures and, only in the vicinity of the outer apertures, on the pit chamber wall. They loosely occluded both the inner and outer apertures. They are branched and some of the branches are anastomosed. Some of the vestures arising from the margin of the inner apertures are unique in their form (arrows in Photo 14). They are very elongated, reaching to ca. 3 μm in length. Their diameter from base to tip is almost constant.

1-1-4. Species having vestured pits of type D.

Vestured pits of type D were found in *Terminalia belericoides* (Photos 16 and 17), *Terminalia myriocarpa* (Photo 18), *Duabanga grandiflora* (Photos 19, 20 and 21), *Dalbergia szemaoensis* (Photos 22 and 23) and *Erythrina arborescens*. In the 2 species examined belonging to *Terminalia*, no vestures occur in the margin of the inner aperture (Photo 16). Vestures in both species are bead-like in appearance when they are viewed from the outer surface (Photos 17 and 18). However, vesturing in the pit chamber of *Terminalia belericoides* tends to be more remarkable than that of *T. myriocarpa* (Photos 17 and 18). That is, the vestures fill the entire pit chamber in *T. belericoides* (Photo 17), while they do not arise from the pit chamber wall near the pit annulus in *T. myriocarpa* (Photo 18).

In *Duabanga grandiflora*, vestures do not occur in the margin of the inner aperture and the pit canal (Photo 19), while vesturing is most remarkable in the pit chamber (Photo 20). It can be seen in Photo 20 that vestures fill the pit chamber and they are bead-like in appearance. Such vesturing is also clearly illustrated in Photo 21 which shows a longitudinal cut section through the intervascular pit pairs. Vestures arising from the pit chamber wall have complicated branching. Vesturing in the pit chamber of this species is similar to that of *Duabanga moluccana* which has been reported by BAILEY (1933) using light microscopy. The extent of vesturing in *Dalbergia szemaoensis* (Photos 22 and 23) was similar to that in *Duabanga grandiflora* (Photos 19, 20 and 21). Vestures in the pit chamber have minute branches which are often anastomosed as shown in Photo 23.

Although almost of the pits in *Erythrina arborescens* were of type B as shown in Photos

Table 1. Types of vesturing in the intervascular pits of the species examined

Types	Species	
A	*Cassia siamea*	(Caesalpiniaceae)
	Erythrina lithosperma	(Papilionaceae)
B	*Erythrina arborescens*	(Papilionaceae)
	Erythrina lithosperma	(Papilionaceae)
C	*Alstonia scholaris*	(Apocynaceae)
	Cleistanthus saichikii	(Euphorbiaceae)
	Syzygium szemaoense	(Myrtaceae)
	Anthocephalus chinensis	(Rubiaceae)
D	*Terminalia belericoides*	(Combretaceae)
	Terminalia myriocarpa	(Combretaceae)
	Dalbergia szemaoensis	(Papilionaceae)
	Erythrina arborescens	(Papilionaceae)
	Duabanga grandiflora	(Sonneratiaceae)

5 and 6, rarely, pits of type D were also found.

The results described above on the intervascular pits of the 11 species examined are summarized in Table 1.

1-2. Vessel to ray parenchyma pits.

All the vessel to ray pits were vestured in the following 7 species: *Cassia siamea, Erythrina lithosperma, Erythrina arborescens, Cleistanthus saichikii, Anthocephalus chinensis, Alstonia scholaris, Dalbergia szemaoensis*. Except for *Dalbergia szemaoensis*, the extent of vesturing and the form of vestures in each of these species were similar to those of the intervascular pits. Some examples from these species are shown in Photo 24 (*Cassia siamea*), Photo 25 (*Cleistanthus saichikii*), Photo 26 (*Anthocephalus chinensis*) and Photo 27 (*Alstonia scholaris*).

In *Dalbergia szemaoensis*, the extent of vesturing in the inner apertures was found to vary considerably. Although vestures did not occur in the inner apertures in the intervascular pits (Photo 22), they occluded the inner apertures in some vessel to ray pits as shown in Photo 28.

Vestured and non-vestured pits were found in *Syzygium szemaoense, Duabanga grandiflora, Terminalia myriocarpa* and *Terminalia belericoides*. Except for *Duabanga grandiflora* vestures in these species tended not to occur in those pits having large apertures and slight borders.

Photos 29, 30 and 31 show vessel to ray pits in *Syzygium szemaoense* viewed from the lumen and the pit membrane sides, respectively. The dimensions and form of vessel to ray pits vary considerably (Photo 29). Vestures are found in smaller pits having a prominent border, but not in larger ones having a slight border (Photos 29, 30 and 31). This fact was also found in the 2 species belonging to *Terminalia*. An example in *Terminalia belericoides* is shown in Photo 32. In *Duabanga grandiflora*, however, vestures were also found in some larger pits. Photos 33 and 34 show the vessel to ray pits viewed from the lumen side of *Duabanga grandiflora*. As shown in these photos, vestures are found even in the larger pits having slight borders. Many of these pits were partially vestured (Photo 34). Vestures adhering to the pit membranes (arrowed in Photo 34) are found in the larger pits. They are not connected to the pit border.

1-3. Vessel to axial parenchyma pits.

Both vesturing and form of the vestures in the vessel to axial parenchyma pits were basically similar to that of the vessel to ray pits in all the species examined. Some examples of the vestured vessel to axial parenchyma pits are shown in Photos 35 and 36 (*Cassia siamea*), Photo 37 (*Anthocephalus chinensis*), Photo 38 (*Alstonia scholaris*), Photo 39 (*Dalbergia szemaoensis*) and Photo 40 (*Terminalia belericoides*).

1-4. Vessel to wood fiber pits.

Vasicentric parenchyma was usually found around the vessels of *Cassia siamea, Erythrina lithosperma* and *Erythrina arborescens*. Although paratracheal parenchyma was found in *Anthocephalus chinensis, Dalbergia szemaoensis* and *Duabanga grandiflora* and some vessels were confirmed to be contiguous to wood fibers, vessel to wood fiber pits could not be found in these species in the present study.

All the vessel to fiber tracheid pits were vestured in *Cleistanthus saichikii, Alstonia scholaris, Syzygium szemaoense, Terminalia myriocarpa* and *Terminalia belericoides*. The extent of vesturing and the morphology of vestures in the vessel to fiber tracheid pits were similar to that of the intervascular ones in each species as shown in Photos 41 and 42 (*Cleistanthus saichikii*) and Photos 43 and 44 (*Alstonia scholaris*).

The observations described above on the occurrence of vestures on vessel pits of the species examined is summarized in Table 2.

Table 2. Presence or absence of vestures in the vessel pits of the species examined

Species		V-V pit	V-R pit	V-P pit	V-F pit
Alstonia scholaris	(Apocynaceae)	○	○	○	○
Cassia siamea	(Caesalpiniaceae)	○	○	○	–
Cleistanthus saichikii	(Euphorbiaceae)	○	○	○	○
Dalbergia szemaoensis	(Papilionaceae)	○	○	○	–
Erythrina arborescens	(Papilionaceae)	○	○	○	–
Erythrina lithosperma	(Papilionaceae)	○	○	○	–
Anthocephalus chinensis	(Rubiaceae)	○	○	○	–
Terminalia belericoides	(Combretaceae)	○	○×	○×	○
Terminalia myriocarpa	(Combretaceae)	○	○×	○×	○
Syzygium szemaoense	(Myrtaceae)	○	○×	○×	○
Duabanga grandiflora	(Sonneratiaceae)	○	○×	○×	–

○ : vestured pit   × : non-vestured pit
– : V-F pits were not found
V-V pit : intervascular pit
V-R pit : vessel to ray parenchyma pit
V-P pit : vessel to axial parenchyma pit
V-F pit : vessel to fiber tracheid pit

2. Presence or absence of vestures in wood fiber pits.

Except for *Alstonia scholaris* and *Syzygium szemaoense*, all the wood fiber pits were non-vestured in the examined species.

All the pits of fiber tracheids were vestured in *Alstonia scholaris* (Photos 45 and 46). Photo 45 shows vestured pits on the wall of a fiber tracheid viewed from the lumen side. Vestures occlude the pit apertures and have complicated branching. They form mounds projecting into the lumen. Such vesturing agrees with the observation in the same species by SCURFIELD et al. (1970). The elongated vestures occurring in vessel pits, as shown in Photos 14, 38 and 43, were not found in fiber tracheid pits. Photo 46 shows vesturing in the pit chambers viewed from the outer surface. Vestures arise from the margin of the outer apertures but not from the pit chamber wall. Vesturing in the pit chamber was slight compared with that in intervascular pits.

Most of the pits of fiber tracheids were non-vestured in *Syzygium szemaoense*. However, very rarely, vestured pits were also found. Photo 47 shows a vestured pit viewed from the lumen side. Small branched and unbranched vestures (arrowed in Photo 47) arise from the margin of the slit-like inner aperture.

Discussion and Conclusion

Considerable variation in vesturing within a pit was found both among and within a species. In 5 of the 11 species examined, this variation was found among the pit types in the vessel wall within a species. In the present study, vestured intervascular pits have been divided into the 4 types on the basis of their location and extent of vesturing. Other types however will almost certainly be found if more extensive SEM observations on vestured pits of Yunnan hardwoods are carried out.

The location and extent of vesturing in the intervascular pits were almost constant within each species except for *Erythrina lithosperma* where vestured pits of types A and B were found and *E. arborescence* where types B and D were found. In each of these two species, different types of vestured pits were often found in adjacent vessel members but not within one vessel member.

Vestured, partially vestured and non-vestured pits were all found in vessel to ray and vessel to axial parenchyma pits in the vessel wall in *Syzygium szemaoense, Duabanga grandiflora, Terminalia myriocarpa* and *Terminalia beleriocoides*. Such a variation in vesturing has already been reported in the vessel to ray pits of some other species (ISHIDA and OHTANI, 1970 ; SCURFIELD and SILVA, 1970 ; MEYLAN and BUTTERFIELD, 1974 ; OHTANI and ISHIDA, 1976 ; van VLIET, 1978). In the four species above vessel to ray and vessel to axial parenchyma pits varied considerably in their size and form. The extent of vesturing was found to be closely associated with the size of the aperture and the extent of the border. Vestures tend to occur in the prominently bordered pits having smaller apertures, but not in the slightly bordered pits having larger apertures. These evidences suggest that development of vestures depends on the morphology of the pits if the functional differences are not found between these pits.

Several types of vestures based on their form have already been reported by BAILEY (1933), CÔTÉ and DAY (1962), MEYLAN and BUTTERFIELD (1974), OHTANI and ISHIDA (1976) and van VLIET (1978). Various forms of vestures were also found in the present study. Most of them coincided with various forms of the vestures which have been previously reported. However, a unique form of elongated vestures which was found in *Alstonia scholaris* has not been previously recorded. Although SCURFIELD et al. (1970) observed the vestured pits of the same species, they did not report the elongated form of vestures shown (arrowed) in Photos 14, 38 and 43. In order to determine whether such unique elongated vestures are inherent feature in *Alstonia scholaris* or not, further observations on vestured pits in these species from the ecological aspect are necessary.

Vestures in the intervascular pits were confined to the pit apertures and pit chambers. They were scarcely found in the pit canal of pits having both inner and outer pit apertures, though it has been reported (SCHMID, 1965) that they may occur in this region. All vestures arose from the pit border. However, in *Syzygium szemaoense* whose vessel to ray pits have large apertures vestures adhering to the pit membranes were observed (arrows in Photo 34). They were clearly not connected to the pit border. Such vestures adhering to the pit membranes have already been observed in *Alstonia scholaris, Coprosma lucida* and *Lespedeza bicolor* forma *acutifolia* (SCURFIELD et al. ; 1970, MEYLAN and BUTTERFIELD ; 1974, OHTANI and ISHIDA ; 1976). Judging from the published photographs showing them, however, they are considered to be separated tips of vestures arising from the pit border which have been ruptured during specimen preparation. On the other hand, vestures on the pit membranes shown in Photo 34 are not such artifacts because the vessel to ray pits with them were observed from the lumen side in the intact vessel wall which was not split during the specimen preparation.

The present SEM observation on vestured pits in Yunnan hardwoods revealed the micromorphology of the vestured pits not only in the 6 species in which occurrence of vestured pits has already been recorded by TANG (1973) and CHENG (1980, 1985) at light microscope level but also in 5 species in which their occurrence has not been previously recorded.

The micromorphology of vestured pits may be obviously utilized as diagnostic criteria in the systematic study and classification of hardwoods (BAILEY, 1933 ; OHTANI and ISHIDA, 1976). Therefore, more detailed and extensive SEM observations on vestured pits in Yunnan hardwoods should be carried out.

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要　　約

中国雲南省原産広葉樹材11種のベスチャード壁孔の微細形態を走査電子顕微鏡(SEM)を用いて観察した。得られた結果を要約すれば，次のとおりである。

1．道管壁の壁孔内のベスチャーの有無・分布・形態は，樹種間で差異が認められた。それらは同一樹種内でも壁孔の種類により差異が認められる場合があった。したがって，供試樹種の道管壁孔内のベスチャーの有無・分布・形態を道管壁孔の種類別に観察し，記載した。

2．11樹種のすべての道管相互壁孔はベスチャード壁孔であった(Photo 1～23)。それらは壁孔内のベスチャーの発生部位と発達程度により四つのタイプに分けられた(Fig. 1, Table 1)。7樹種のすべての道管放射柔細胞間壁孔と道管軸方向柔細胞間壁孔はベスチャード壁孔であったが (Photo 24～28, Photo 35～39)，4樹種のそれらはベスチャーが存在するものとしないものが認められた(Photo 29～34, Photo 40)。これらの4樹種でのベスチャーの発達程度は，壁孔口の大きさ及び壁孔縁の有縁の程度と密接な関係があることが認められた。すなわち，壁孔縁が顕著に有縁であり孔口が小さい壁孔にはベスチャーが存在するが，壁孔縁がわずかに有縁であり孔口が大きな壁孔にはベスチャーは存在しない。道管木部繊維間壁孔は5樹種に認められたが，それらはすべてベスチャード壁孔であった(photo 41～44)。供試樹種の道管壁孔のベスチャーの有無はTable 2に要約されている。

3．*Alstonia scholaris*, *Syzygium szemaoense* 以外の供試樹種の木部繊維の壁孔にはベスチャーは存在しなかった。*Alstonia scholaris* の繊維状仮道管のすべての壁孔はベスチャード壁孔であった (Photo 45, 46)。*Syzygium szemaoense* の繊維状仮道管の大部分の壁孔にはベスチャーは存在しなかったが，まれにベスチャード壁孔も認められた (Photo 47)。

4．本研究で観察されたほとんどすべてのベスチャーの形は，今まで報告されているものとおおむね一致していた。しかし，*Alstonia scholaris* に認められた細長く伸びたベスチャー (Photo 14, 38, 43) は未報告のものである。このような形状のベスチャーがこの樹種の固有の特徴であるかどうかを明らかにするにはさらに今後の研究が必要である。

5．壁孔内のベスチャーの発生部位は壁孔縁であることが確認されたが，*Syzygium szemaoense* の道管放射柔細胞間壁孔には道管側の壁孔壁上から生じているとみなされるベスチャーも観察された (Photo 34)。

6．本研究では，ベスチャード壁孔の存在が光学顕微鏡によりすでにわかっていた6樹種のみならずそれらの存在が未知であった5樹種のベスチャード壁孔の微細形態を明らかにした。ベスチャード壁孔は広葉樹材の樹種的特徴を示す構造の一つである。雲南産広葉樹材の微細構造の基礎的知見を得るために更に多くの樹種についてのこの種の研究が必要である。

Explanation of photographs

Photo 1. *Cassia siamea.* Vestured intervascular pits in the wall of a vessel member viewed from the lumen side.

Photo 2. *Cassia siamea.* Vestured intervascular pits in the wall of a vessel member viewed from the outer surface.

Photo 3. *Cassia siamea.* A longitudinal cut through a vestured intervascular pit.

Photo 4. *Erythrina lithosperma.* Vestured intervascular pits in the wall of a vessel member viewed from the outer surface.

Photo 5. *Erythrina lithosperma.* Vestured intervascular pits in the wall of a vessel member viewed from the outer surface.

Photo 6. *Erythrina arborescens.* Vestured intervascular pits in the wall of a vessel member viewed from the lumen side.

Photo 7. *Cleistanthus saichikii.* Vestured intervascular pits in the wall of a vessel member viewed from the lumen side.

Photo 8. *Cleistanthus saichikii.* Vestured intervascular pits in the wall of a vessel member viewed from the outer surface.

Photo 9. *Anthocephalus chinensis.* Vestured intervascular pits in the wall of a vessel member viewed from the lumen side.

Photo 10. *Anthocephalus chinensis.* Vestured intervascular pits in the wall of a vessel member viewed from the outer surface.

Photo 11. *Syzygium szemaoense.* Vestured intervascular pits in the wall of a vessel member viewed from the lumem side.

Photo 12. *Syzygium szemaoense.* A vestured intervascular pit in the wall of a vessel member viewed from the outer surface.

Photo 13. *Syzygium szemaoense.* A longitudinal cut through the walls of two adjacent vessel members showing the position of the vestures within intervascular pits.

Photo 14. *Alstonia scholaris.* Vestured intervascular pits in the wall of a vessel member viewed from the lumen side. Arrows show elongated vestures.

Photo 15. *Alstonia scholaris.* Vestured intervascular pits in the wall of a vessel member viewed from the outer surface.

Photo 16. *Terminalia belericoides.* Vestured intervascular pits in the wall of a vessel member viewed from the lumem side.

Photo 17. *Terminalia belericoides.* Vestured intervascular pits in the wall of a vessel member viewed from the outer surface. PM : pit membrane.

Photo 18. *Terminalia myriocarpa.* Vestured intervascular pits in the wall of a vessel member viewed from the outer surface.

Photo 19. *Duabanga grandiflora.* Vestured intervascular pits in the wall of a vessel member viewed from the lumen side.

Photo 20. *Duabanga grandiflora.* Vestured intervascular pits in the wall of a vessel member viewed from the outer surface.

Photo 21. *Duabanga grandiflora.* A longitudinal cut through the walls of two adjacent vessel members showing the position of the vestures within intervascular pits.

Photo 22. *Dalbergia szemaoensis.* Vestured intervascular pits in the wall of a vessel member viewed from the lumen side.

Photo 23. *Darbergia szemaoensis.* Vestured intervascular pits in the wall of a vessel member viewed from the outer surface.

Photo 24. *Cassia siamea.* Vestured vessel to ray parenchyma pits in the wall of a vessel member viewed from the lumen side.

Photo 25. *Cleistanthus saichikii.* Vestured vessel to ray parenchyma pits in the wall of vessel member viewed from the lumen side.

Photo 26. *Anthocephalus chinensis.* Vestured vessel to ray parenchyma pits in the wall of a vessel member viewed from the lumen side.

Photo 27. *Alstonia scholaris.* Vestured vessel to ray parenchyma pits in the wall of a vessel member viewed from the lumen side.

Photo 28. *Dalbergia szemaoensis.* Vestured vessel to ray parenchyma pits in the wall of a vessel member viewed from the lumen side.

Photo 29. *Syzygium szemaoense.* Vessel to ray parenchyma pits in the wall of a vessel member viewed from the lumen side.

Photo 30. *Syzygium szemaoense.* Vessel to ray parenchyma pits in the wall of a vessel member viewed from the lumen side.

Photo 31. *Syzygium szemaoense.* Vessel to ray parenchyma pits in the wall of a vessel member viewed from the outer surface.

Photo 32. *Terminalia belericoides.* Vessel to ray parenchyma pits in the wall of a vessel member viewed from the lumen side.

Photo 33. *Duabanga grandiflora.* Vestured vessel to ray parenchyma pits in the wall of a vessel member viewed from the lumen side.

Photo 34. *Duabanga grandiflora.* Vestured vessel to ray parenchyma pits in the wall of a vessel member viewed from the lumen side. Arrows show the vestures adhering to the membranes.

Photo 35. *Cassia siamea.* Vestured vessel to axial parenchyma pits in the wall of a vessel member viewed from the lumen side.

Photo 36. *Cassia siamea.* A longitudinal cut showing the position of the vestures within vessel to axial parenchyma pits in the wall of a vessel member.
AP : axial parenchyma cell. V : vessel member.

Photo 37. *Anthocephalus chinensis.* Vestured vessel to axial parenchyma pits in the wall of a vessel member viewed from the lumn side.

Photo 38. *Alstonia scholaris.* Vestured vessel to axial parenchyma pits in the wall of a vessel member viewed from the lumen side. Arrows show elongated vestures.

Photo 39. *Dalbergia szemaoensis.* Vestured vessel to axial parenchyma pits in the wall of a vessel member viewed from the lumen side.

Photo 40. *Terminalia belericoides.* Vestured vessel to axial parenchyma pits in the wall of a vessel member viewed from the lumen side.

Photo 41. *Cleistanthus saichikii.* Vestured vessel to fiber pits in the wall of a vessel member viewed from the lumen side.

Photo 42. *Cleistanthus saichikii.* Vestured vessel to fiber pits in the wall of a vessel member viewed from the outer surface.

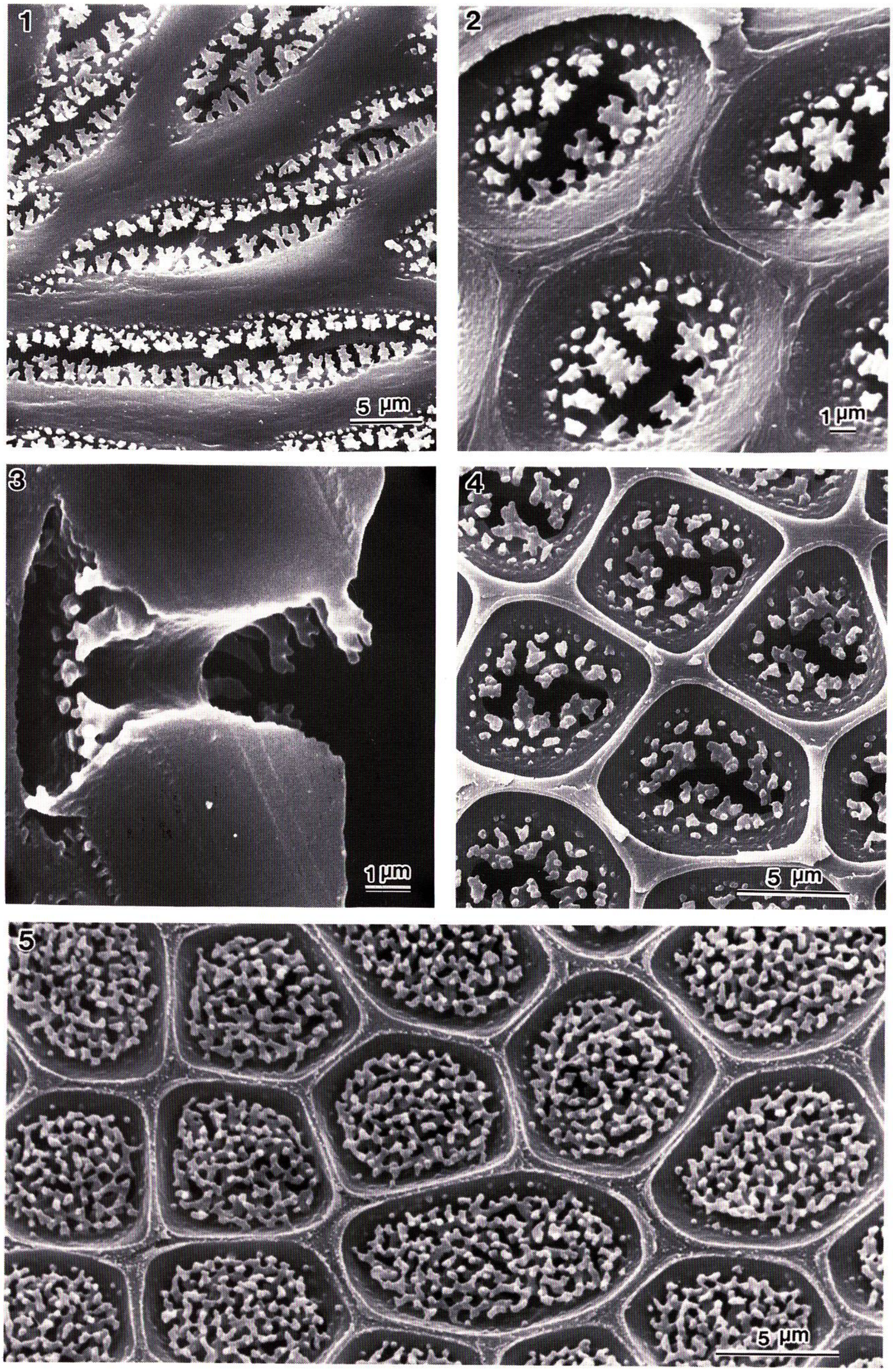
Photo 43. *Alstonia scholaris.* Vestured vessel to fiber pits in the wall of a vessel member viewed from the lumen side. Arrows show elongated vestures.

Photo 44. *Alstonia scholaris.* Vestured vessel to fiber pits in the wall of a vessel member viewed from the outer surface.

Photo 45. *Alstonia scholaris.* Vestured pits in the wall of a fiber tracheid viewed from the lumen side.

Photo 46. *Alstonia scholaris.* Vestured pits in the wall of a fiber tracheid viewed from the outer surface.

Photo 47. *Syzygium szemaoense.* A vestured pit in the wall of a fiber tracheid viewed from the lumen side. Arrows show vestures arising from the margin of the slit-like inner aperture.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3
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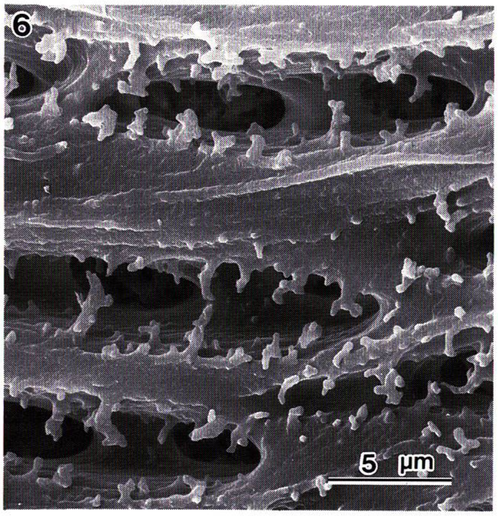
4
5 μm
5
5 μm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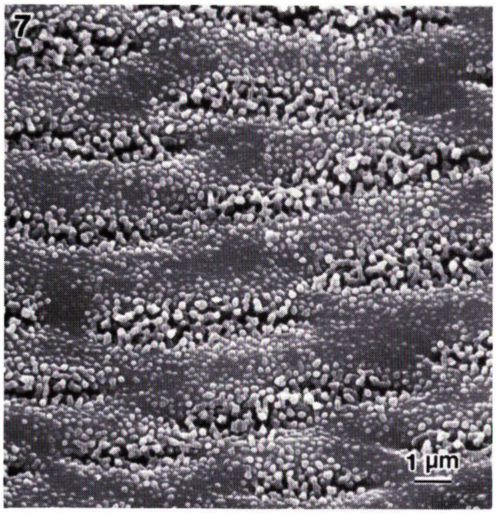
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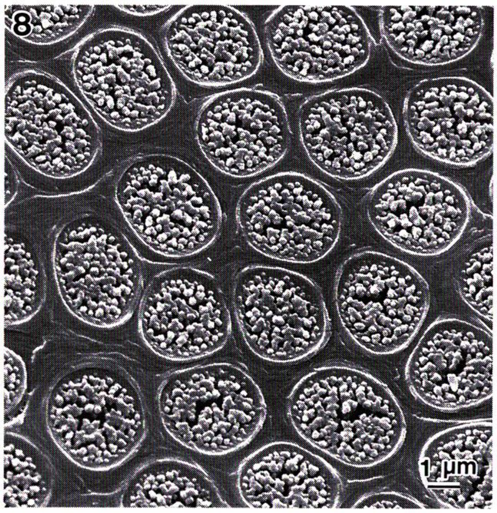
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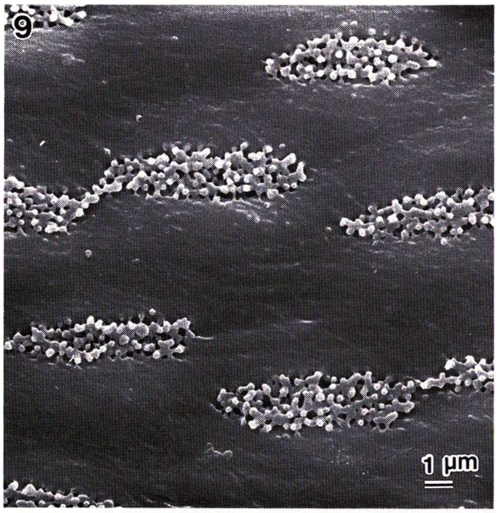
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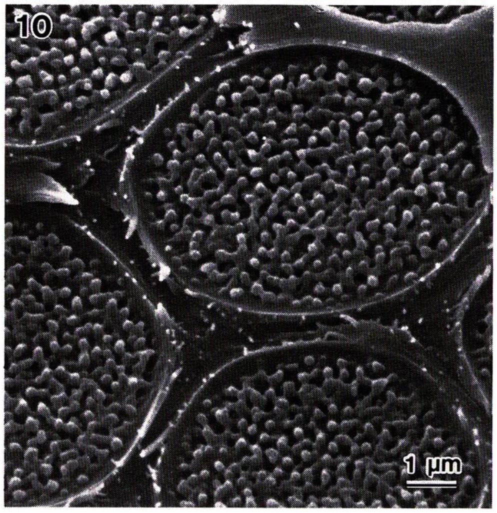
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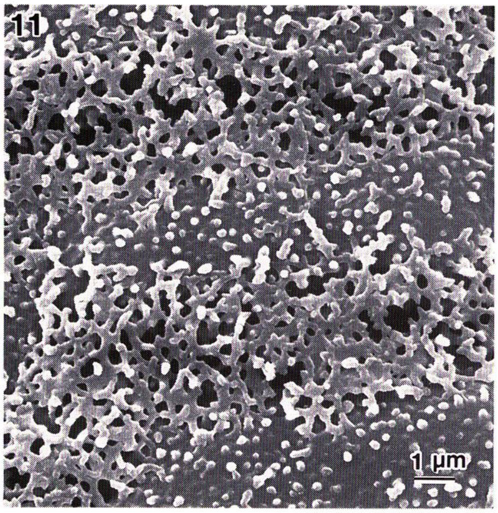
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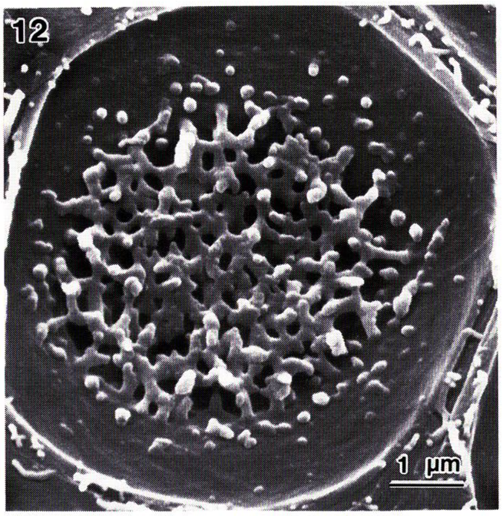
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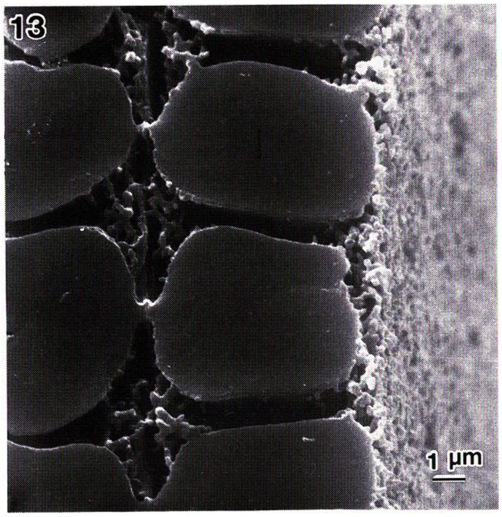
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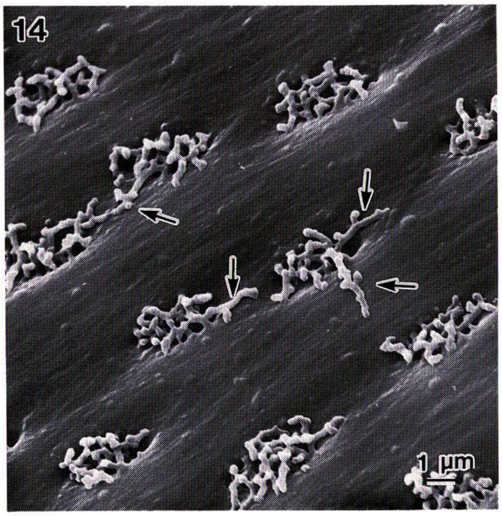
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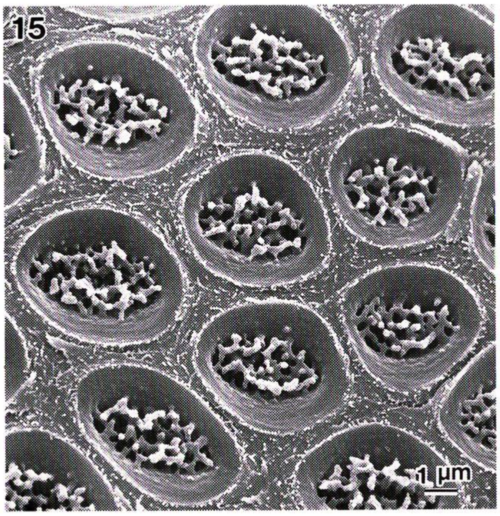
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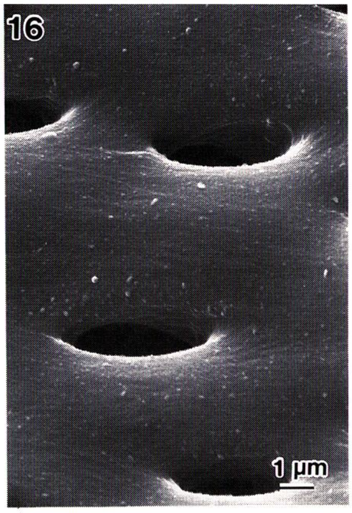
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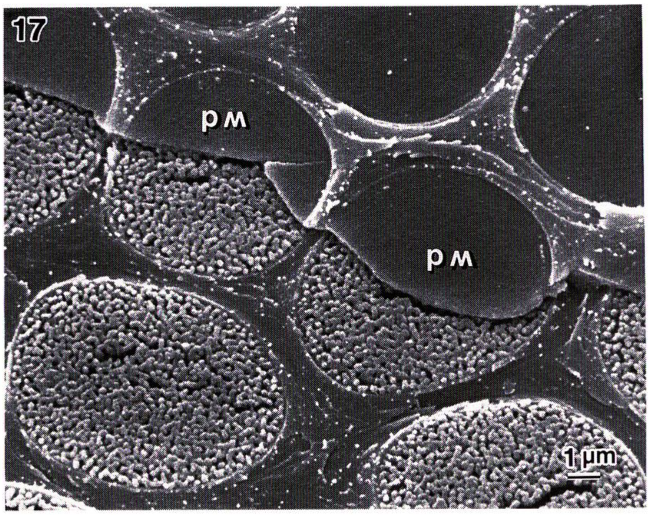
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pm
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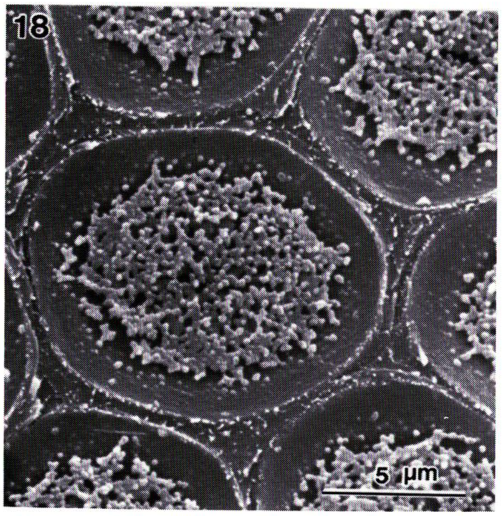
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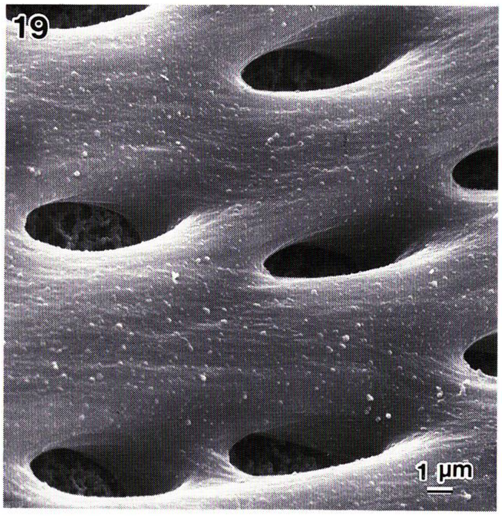
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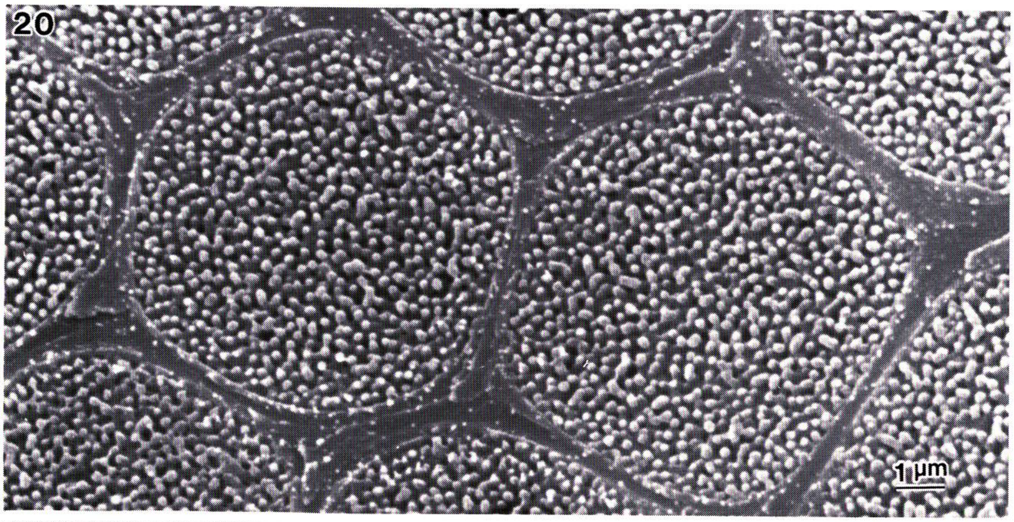
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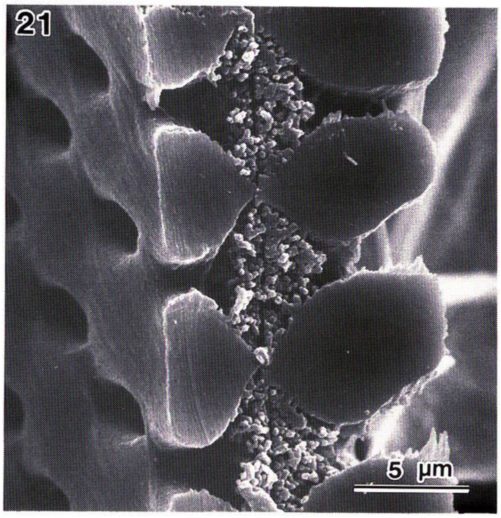
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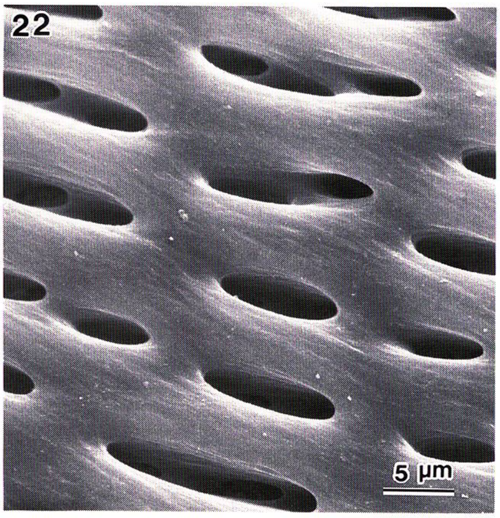
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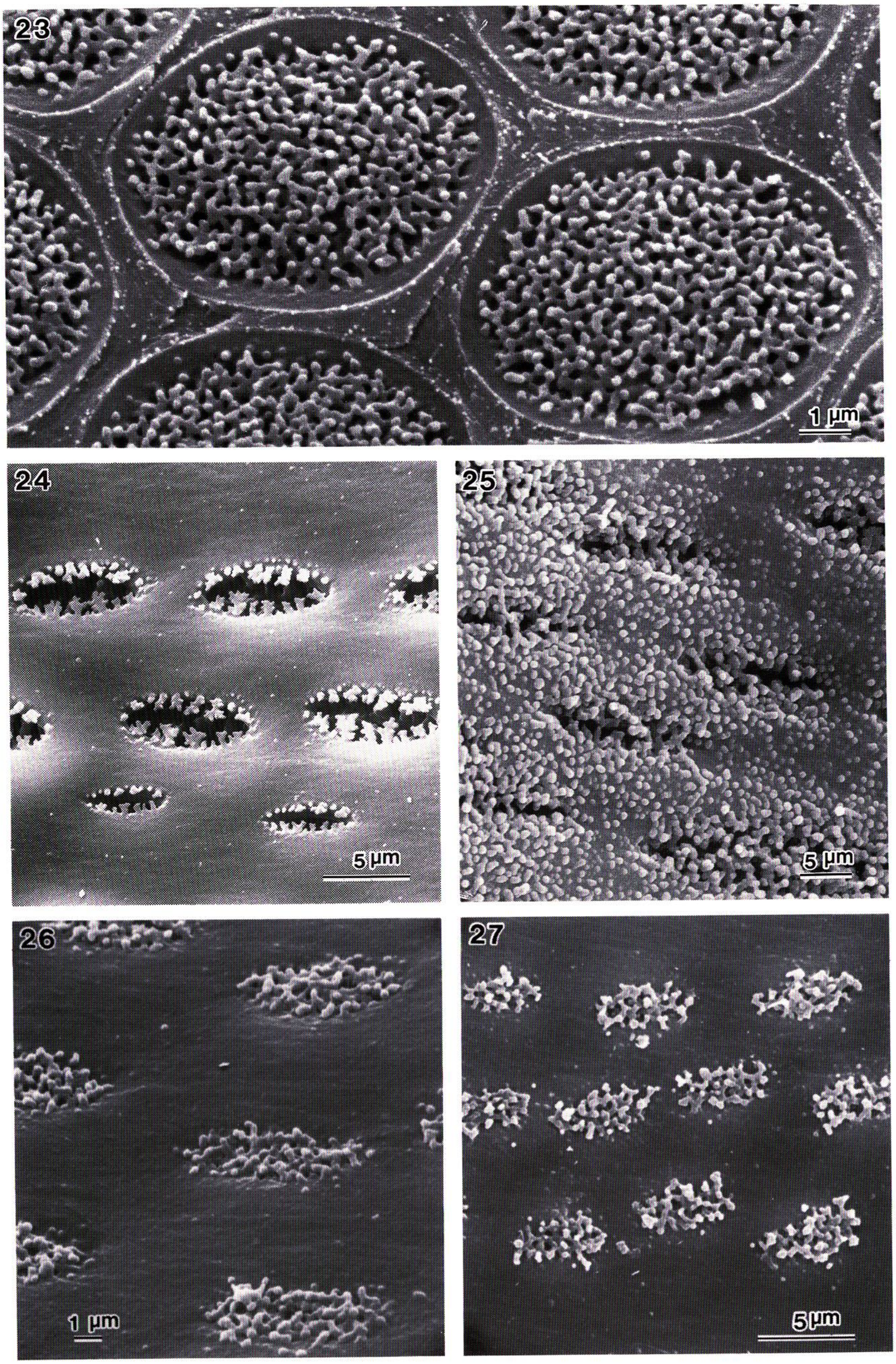
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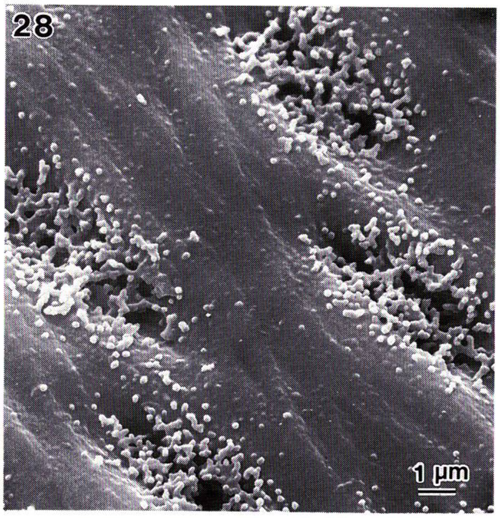
5 μm
25
5 μm
26
1 μm
27
5 μm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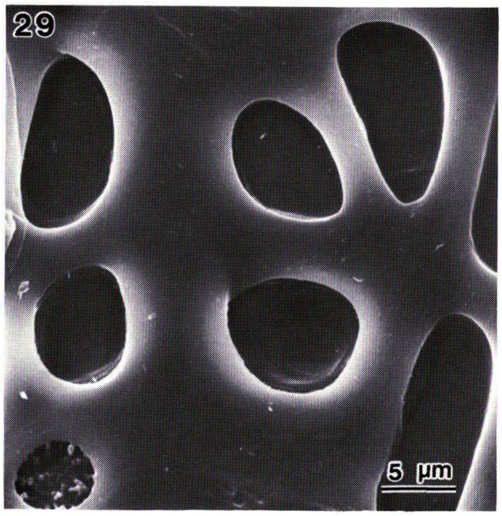
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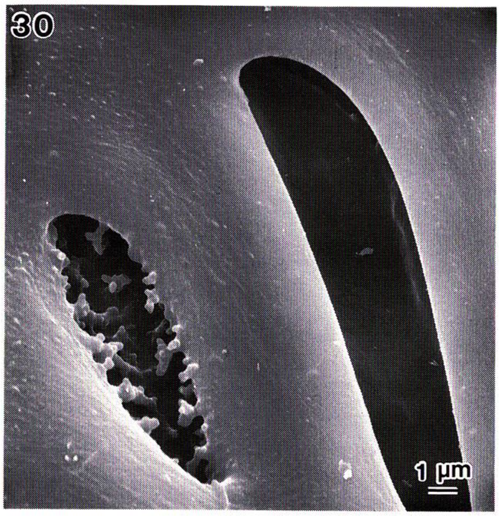
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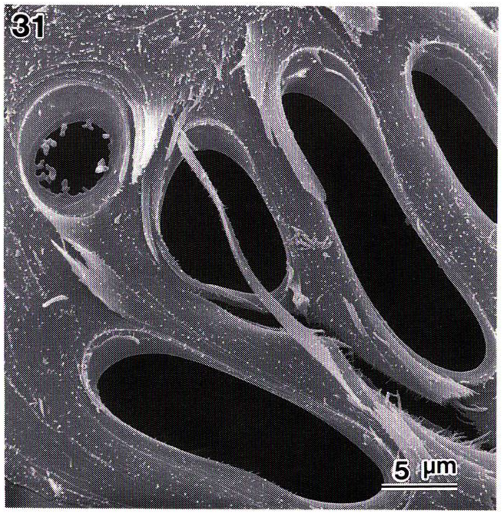
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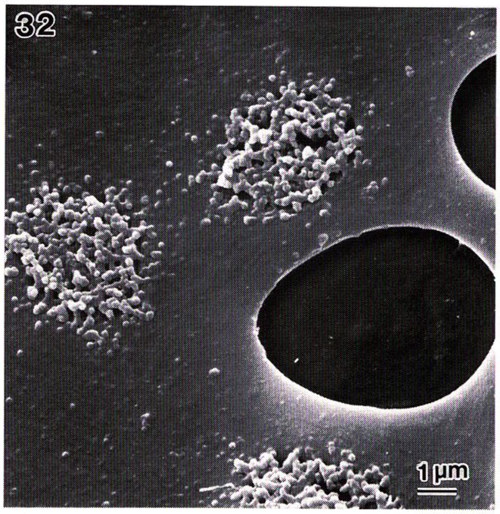
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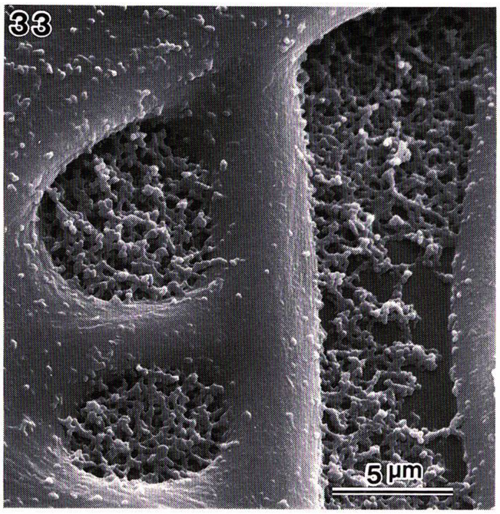
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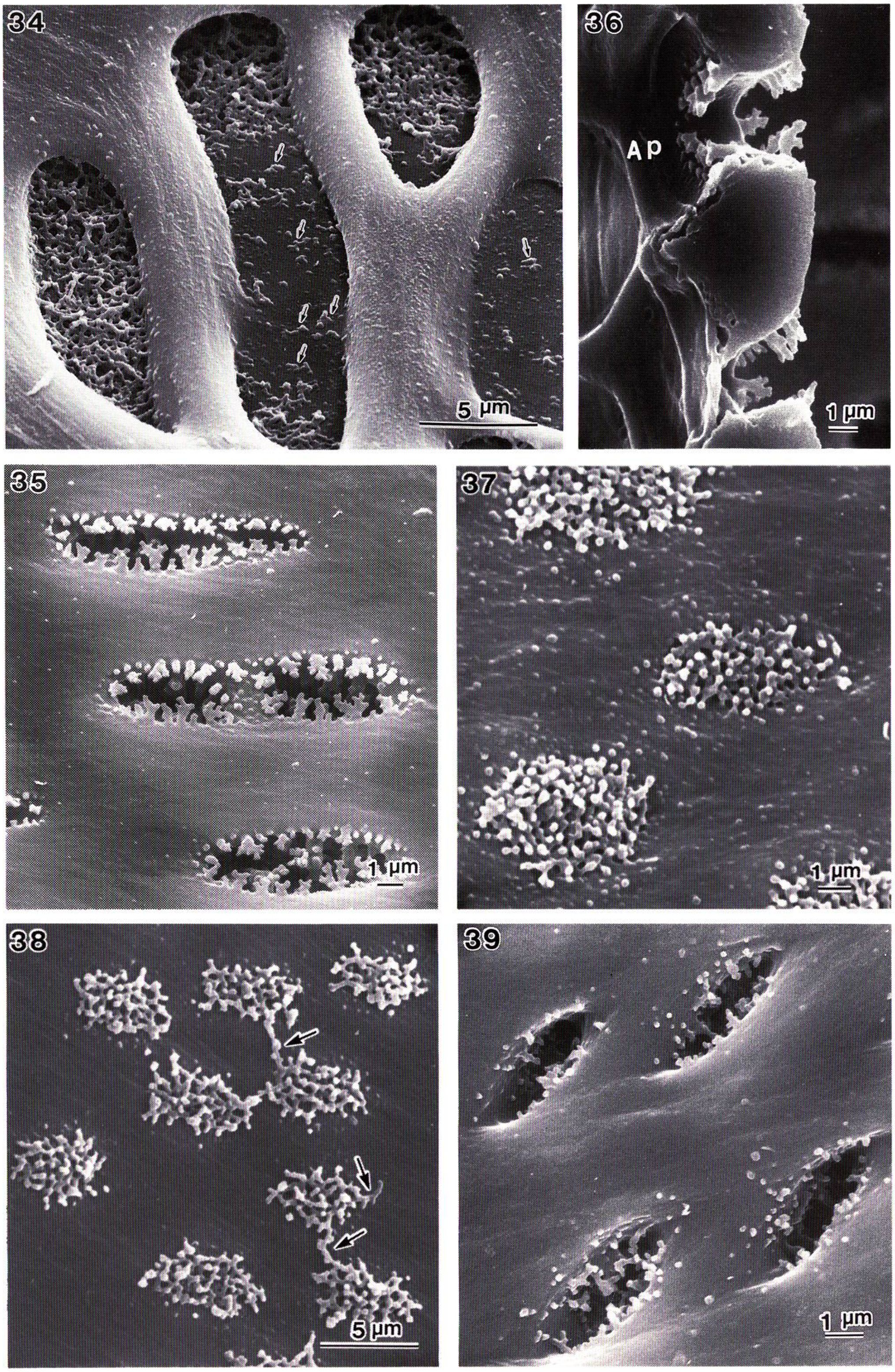
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Ap
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1 µm
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1 µm
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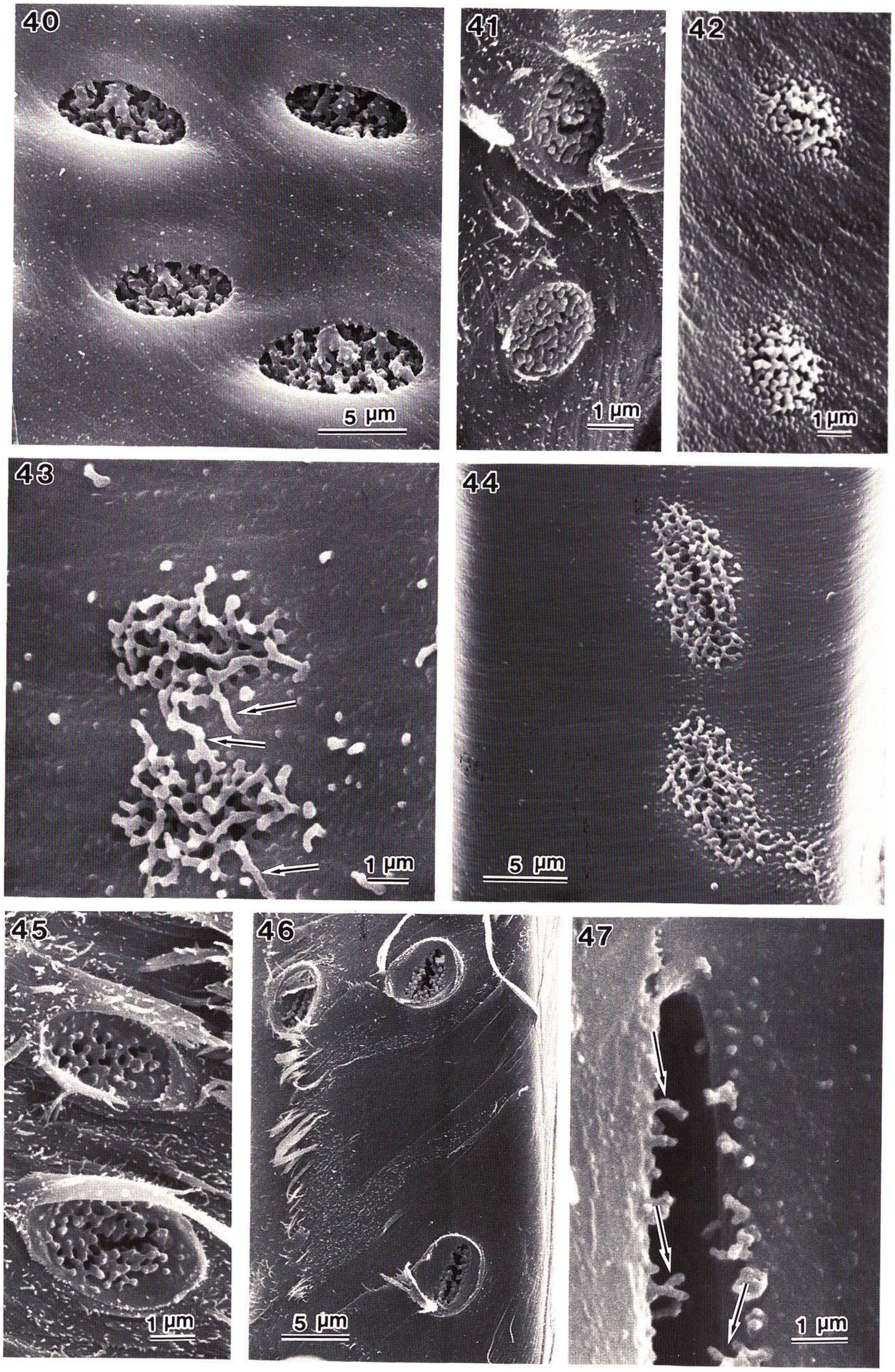
5 µm
39
1 µm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