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POLLEN MORPHOLOGY OF *CARYOPHYLLACEAE* SPECIES FROM TURKEY

KEMAL YILDIZ

Department of Biology, Faculty of Science and Letters, Celal Bayar University, 45040 Muradiye-Manisa-TURKEY. Fax: 90 0236 2412158

Abstract

The pollen morphology of 45 species, 11 of which are endemic, belonging to 15 genera of *Caryophyllaceae* was investigated by light (LM) and scanning electron microscopy (SEM). On the basis of exine structure, ornamentation and morphological data, 10 distinct pollen types viz., 1. *Arenaria* type, 2. *Stellaria holostea* L., 3. *Cerastium* type, 4. *Dianthus* type, 5. *Gypsophila repens* type, 6. *Lychnis viscaria* type, 7. *Silene vulgaris* type, 8. *Silene caryophylloides* subsp. *subulata* (Poiret) Otth, 9. *Silene conica* type and 10. *Agrostemma githago* L., were recognized. Pollen grains are tectate, spheroidal, polypantoporate, microechinate (spinulose), perforate, microperforate (punctate tubuliferous), reticulate and semireticulate. Significant differences in grain size and pore number are also found in all the species. The biggest grains are in *Silene* L., and *Agrostemma* L., species, whereas the smallest grains are in *Petrorhagia* (Ser.) Link. The most advanced species of *Caryophyllaceae* regarding evolution are found in *Silene* and *Agrostemma*.

Introduction

Caryophyllaceae, which is a large cosmopolitan family, is represented by 80 genera and c. 2000 species and is distributed mainly in the Northern hemisphere (Heywood, 1978). It is represented in Turkey by 32 genera and c. 470 native species (Davis, 1967, 1988).

The pollen morphology is an important character used by systematists for the families of the *Centrospermae*. Skvarla (1975), Skvarla & Nowicke (1976) and Nowicke & Skvarla (1977) studied the pollen morphology of the families of the *Centrospermae* and concluded that there was a close and natural association with the presence of spinulose or tubuliferous and punctate sexine (ektexine) in *Caryophyllaceae*, *Molluginaceae* and the betalianian families. They also suggested that in atleast 5 families of this order viz., *Amaranthaceae, Basellaceae, Cactaceae, Caryophyllaceae* and *Nyctaginaceae*, the development of a reticulate sexine had occured and that reticulate sexine was more often associated with sporophytically advanced taxa. Skvarla & Nowicke (1976), in their palynological study of 11 families of *Centrospermae*, compared the species of 8 genera belonging to *Caryophyllaceae* and tried to find phylogenetical links. The most important common feature was that the sexine sculpture was spinulose-tubuliferous/punctate. Pollen type of *Silene noctiflora* was termed pantoporate, reticulate.

Nilsson *et al.*, (1977) studied pollen morphology of *Stellaria media* (L.) Vill., which has spinulose and perforate exine surface and which is pantoporate. Ghazanfar (1984), in her palynogical investigation of 44 taxa representing in the sections *Siphonomorpha* Otth., and *Auriculatae* Boiss., demonstrated that the ectexine sculpture of *Silene italica* (L.) Pers, *Silene viridiflora* L. and *Silene rhynchocarpa* Boiss., was punctate. Sculpture of

sexine of *Silene caryophylloides* subsp. *subulata* (Boiss.) Coode & Cullen was recognized as semireticulate. Prentice *et al.*, (1984) after examination of 32 samples of *Silene latifolia* Poiret collected from several regions of Europe, observed the geographic variations of the pollen grains. Prentice (1987) underlined reticulate and microechinate characteristics in 130 specimens of *Silene* species which were distributed in Europe and Asia. On the other hand, morphological and biochemical studies were conducted on 30 populations of European *Silene latifolia* grown in greenhouse by Mastenbroek *et al.*, (1984). Romanova & Bezus'ko (1987) studied palynology of 7 weed species of the *Caryophyllaceae* and compared morphological features of the *Caryophyllaceae* with c. 200 species of this family in the Ukranian flora. Arkan & İnceoğlu (1992) investigated 18 taxa of the genus *Saponaria* L. (*Caryophyllaceae*). Pollen of 16 taxa were examined by LM and 15 taxa using SEM. In addition to these, fine structures of the exines of 7 taxa were examined with transmission electron microscopy (TEM). Romanova (1992) studied pollen morphology of 192 species from 37 genera growing in Ukraine by light and electron microscopy. Parent & Richard (1993) studied pollen grains of 38 species belonging to 12 genera of *Caryophyllaceae* from the Nordic Querbec adjacent territories and from the Canadian Arctic Archipelago using light microscopy and recognized 13 pollen forms, 11 of which are pantoporate and 2 others are colpate.

Yıldız (1996a; 2001) studied 19 *Silene* taxa from Turkey using LM and SEM, and demonstrated the presence of various type of exine such as spinulose spinulose-microperforate and semireticulate. Yıldız (1996b) also investigated pollen of 3 *Silene* species (endemic for Turkey) with LM and SEM. All examined pollen grains were periporate and spheroidal, tectate, spinulose, microperforate (tubuliferous). The present report describes the pollen morphology of *Caryophyllaceae* species from Turkey.

Materials and Methods

The polleniferous material was obtained from the Marmara University Ataturk Education Faculty Herbarium (MARA) and from the field as shown in Table 1. Map of investigation area is given in Fig. 1.

The pollen grains were prepared for light (LM) and scanning electron microscopy (SEM) using the method of Erdtman (1960). For LM, the pollen grains were mounted in glycerine-jelly-fuchsine mixture and observations were made with a Nikon type trinocular microscope under oil immersion. For SEM studies, pollen grains suspended in a drop of 96% Ethyl alcohol and directly transferred with a fine pipette to a metallic stub using double sided adhesive tape and coated with gold in a sputtering chamber. The SEM examination was carried out under a Jeol microscope (JSM 5400 and JSM 5200). Pollen diameter, pore diameter, distance between two pori and exine thickness were measured. In addition, arithmetic means (M) and standard deviations (S) were calculated. Data on size, is based on the measurements of 50 pollen grains for each species. Slides are deposited in Celal Bayar University, Faculty of Science and Letters, Department of Biology for future reference. Terminology followed here is that of Kremp (1968), Erdtman (1969), Faegri & Iversen (1975), and Moore *et al.*, (1997). Morphological enumerations of the examined pollens, alongwith mean values of measurements and standard deviations, are given in Table 2.

Table 1. Source of *Caryophyllaceae* pollen.
(MARA: Marmara University Ataturk Education Faculty Herbarium.,
A: A Square of Flora of Turkey, E: Endemic for Turkey, Y: Yildiz, Kemal)

SPECIES	LOCALITY	NUMBER
Arenaria serpyllifolia	A3 Kocaeli, Keltepe, 17 km from Masukiye to Izmit 1550 m.	MARA 2311
Arenaria ledebouriana var. *ledebouriana* (E)	A7 Giresun, 21 km from Sebinkarahisar to Giresun, banks, rocky places, 1200 m.	Y 33
Minuartia juniperina	A6 Tokat, Çamlibel radar station, rocky places, 1900 m.	Y 18
Minuartia verna	A8 Bayburt, Soganli mountain, 2300 m.	Y 150
Stellaria media subsp. *pallida*	A6 Tokat, near Gaziosmanpasa University, 700 m.	Y 2
Stellaria nemorum	A8 Rize, Kaçkar mountain, Çamlihemsin, above Ayder hot springs, 2500 m.	Y 120
Stellaria holostea	A6 Tokat, near Güzelce village, 1100 m.	Y 3
Myosoton aquiticum	A3 Kocaeli, near Keltepe-Çesme, under forest, 300 m.	MARA 1817
Cerastium chlorifolium	A6 Tokat, Kizilinis-Tekneli village, field, 1200 m.	Y 23
Cerastium fontanum subsp. *triviala*	A7 Gümüshane, Zigana under way, 2000 m.	Y 116
Cerastium purpurascens	A8 Rize, Çamlihemsin, herbs, 2200-2700 m.	Y 151
Moenchia mantica var. *mantica*	A6 Tokat, 13 km from Gökdere to Erbaa, banks, 900 m.	Y 30
Dianthus eldivenus (E)	A6 Tokat, 1 km from Basçiftlik to Niksar, slopes, 1200 m.	Y 43
Dianthus leptopetalus	A5 Amasya, Akdag, rocky places, 2000 m.	Y 39
Dianthus balansae (E)	A4 Çankiri, near Ilgaz TV station, rocky places, 2100 m.	Y 68
Dianthus crinitus var. *crinitus* (E)	A5 Çorum, 25 km from Sungurlu to Çorum, banks, slopes, 1000 m.	Y 69
Dianthus orientalis	A6 Tokat, near Gaziosmanpasa University, 700 m.	Y 71
Dianthus masmenaus var. *glabrascens* (E)	A4 Kastamonu, Inebolu-Kastamonu, Çataltepe mountain pass, 1250m.	Y 67
Dianthus erinaceus var. *alpinus* (E)	A4 Kastamonu, Inebolu-Kastamonu, Egribel mountain pass, 1200 m.	Y155
Dianthus carmelitarum (E)	A7 Giresun, 37 km from Sebinkarahisar to Giresun, Tamdere, 600 m	Y 60
Dianthus carthusianorum	A3 Kocaeli, near Keltepe, 1600 m.	MARA 2520

Table 1. (Cont'd.)

SPECIES	LOCALITY	NUMBER
Dianthus celocephalus	A6 Tokat, 1 km from Basçiftlik to Niksar, slopes, 1200 m.	Y 44
Petrorhagia alpina subsp. *alpina*	A6 Tokat, 20 km from Gökdere to Erbaa, Canbolat dam, 1400 m.	Y 40
Petrorhagia saxifraga	A5 Amasya, 7 km from Ladik to Akdag, above dam, 900m.	Y 46
Petrorhagia prolifera	A6 Tokat, 13 km from Gökdere to Erbaa, 1000 m.	Y 27
Velezia rigida	A6 Ordu, 14 km from Akkus to Niksar, Quercus forest, 1100 m.	Y 132
Saponaria glutinosa	A6 Tokat, 13 km from Gökdere to Erbaa, 1000 m.	Y 25
Saponaria orientalis	A5 Samsun, 20 km from Ladik to Tasova, 500 m.	Y 41
Saponaria prostata subsp. *prostata* (E)	A6 Tokat, 13 km from Gökdere to Erbaa, 1000 m.	Y 26
Gypsophila elegans	A8 Rize, Çamlihemsin, above Ayder hot spring, 2500 m.	Y 128
Gypsophila venusta	A6 Tokat, Güzelce village, field, 1100 m.	Y 72
Vaccaria pyramidata var. *grandiflora*	A6 Tokat, near Ogulcuk village, field, 700 m.	Y 11
Silene lasiantha	A8 Rize, Kaçkar mountain, above Ayder hot spring, 2500 m.	Y 131
Silene bupleroides	A7 Giresun, 21 km from Sebinkarahisar to Giresun, rocky places, 1200 m.	Y 55
Silene muradica (E)	A6 Tokat, Tokat -Sivas Çamlibel mountain pass, 1600 m.	Y 21
Silene montbretiana	A6 Tokat, Çamlibel radar station, rocky places, 1900 m.	Y 17
Silene dianthoides	A6 Tokat, Akdag, 1900 m.	Y 16
Silene odontopetala	A6 Tokat, 10 km from Pazar to Akdag, rocky places, 1600 m.	Y 13
Silene cserei subsp. *aeoniopsis* (E)	A4 Çankiri, 10 km from Ilgaz to Kastamonu, banks, 900 m.	Y 70
Silene caryophylloides subsp. *subulata*	A6 Tokat, Akdag, rocky places, 1700 m.	Y 36
Silene muncupanda (E)	A6 Tokat, Akdag, 1800-1900 m.	Y 84
Silene conica	A5 Amasya, Akdag, 900 m.	Y 87
Silene conoidea	A6 Tokat, City center, Yesilirmak banks, 550 m.	Y 6
Lychnis coronaria	A3 Bolu, Abant lake, 1300 m.	Y 152
Agrostemma githago	A6 Tokat, City center, near Yesilirmak, 550 m.	Y 29

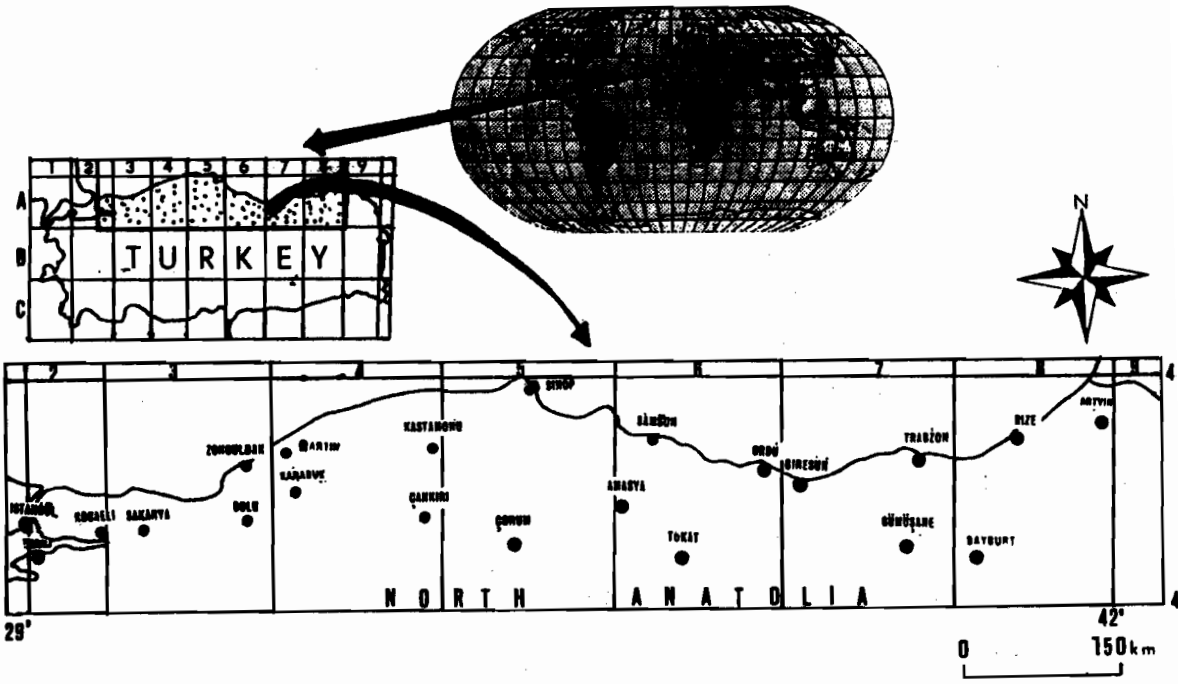


Fig. 1. Map of the investigation area.

Results

General pollen characters of *Caryophyllaceae* (Table 2, Figs. 2-145)

Pollen grains of the *Caryophyllaceae* are ± spheroidal, isopolar, radially symmetrical and pantoporate. Exine generally thinner at the pori edge than in the mesoporium. At least some of the columellae are coarse. Tectum is generally perforate-microperforate (punctate tubuliferous) with minute echinae (microechinate), echinae between the perforation, sometimes reticulate and semireticulate. Grains are generally medium-sized, 20.68±2.38 μm (*Petrorhagia alpina* subsp.*alpina*) to 56.14±2.43 μm (*Silene conoidea*) in diameter. The exines ranges 1.92±0.32 μm (*Petrorhagia alpina* subsp.*alpina*) to 5.59±1.26 μm (*Stellaria holostea*) in thickness. Pore diameter ranges from 2.21±0.40 μm (*Petrorhagia alpina* subsp.*alpina*) to 6.63±1.14 μm (*Silene bupleroides*) in diameter. The distance between two pori is from 4.43±0.84 μm (*Silene muradica*) to 14.73±1.64 μm (*Saponaria glutinosa*). The pore numbers vary considerably. The number of pores varies from 9 (*Minuartia verna*), to 42 (*Agrostemma githago*). Each pore has an operculum and the spinules on the operculum are often longer, stronger and better in shape than those on the exine surface. On the basis of exine ornamentation types 4 distinct pollen groups are recognized viz., 1. Microperforate (punctate tubuliferous) pollen grains: 39 species. 2. Perforate (punctate tubuliferous) pollen grains: *Silene montbretiana, Dianthus crinitus* subsp. *crinitus*. 3. Semireticulate pollen grains: *Silene caryophylloides* subsp. *subulata, Silene conica, Silene conoidea.* 4. Reticulate pollen grains: *Dianthus leptopetalus*.

On the basis of exine structure, ornamentation and morphological measurements 10 distinct pollen types were recognized, viz., 1. *Arenaria* type: *Arenaria* and *Minuartia* species, 2. *Stellaria holostea*, 3. *Cerastium* type: *Cerastium* species, *Stellaria media* subsp. *pallida*, *Stellaria nemorum*, *Myosoton aquiticum*, *Moenchia mantica* var. *mantica*, 4. *Dianthus* type: *Dianthus* species, *Petrorhagia alpina* subsp. *alpina*, *Velezia rigida*, *Saponaria species*, *Vaccaria pyramidata* var. *grandiflora*, 5. *Gypsophila repens* type: *Gypsophila elegans*, *Gypsophila venusta*, 6. *Lychnis viscaria* type: *Lychnis coronaria*, 7. *Silene vulgaris* type: *Silene lasiantha*, *Silene bupleroides*, *Silene muradica*, *Silene montbretiana*, *Silene dianthoides*, *Silene odontopetala*, *Silene cserei* subsp. *aeoniopsis*, *Silene nuncupanda*, 8. *Silene caryophylloides* subsp. *subulata*, 9. *Silene conica* type: *Silene conica*, *Silene conoidea* and 10. *Agrostemma githago* (Faegri & Iversen, 1975; Moore *et al.*, 1997).

Pollen types (M: Means, S: Standard deviation):

Type-1. *Arenaria* type (Figs. 2-9; 92-93): Columellae are irregularly distributed throughout the mesoporium, occasionally in a faintly infrareticulate pattern. Tectum microperforate. Grains with 9-11 pori. Grain size ranges from 27.83 (M) ± 1.52 (S) to 29.72 (M) ± 2.40 (S) μm.

Type-2. *Stellaria holostea* (Figs. 14-15; 94-95): Grain outline obtusely angular with 5-6 sides due to the mesoporium rising up into a pattern of ridges between the pori. Columellae longest and coarsest under the ridges. Tectum microperforate microechinae prominent on the ridges. Grains with 13-18 pori. Grain size ranges from 41.28±1.72 μm to 29.72±2.40 μm.

Type-3. *Cerastium* type (Figs. 10-13; 16-25; 98, 101): Pollen grains with more clearly defined pore that are relatively larger in relation to pollen diameter. Columellae irregularly distributed, slimmer and more densely arranged ones in the region nearest the pore (may appear to be aggregated around the pore), *Stellaria media* subsp. *pallida* and *Stellaria nemorum* appear slightly angular. Microechinae most distinct in *Cerastium* species with several granules on operculum. Tectum microperforate. Grains with 10-25 pori. Grain size ranges from 36.38±2.31 μm to 40.01±3.38 μm. Pore diameter ranges from 3.81±0.93 μm to 5.96±0.86 μm.

Type-4. *Dianthus* type (Figs. 26-59; 64-65; 102-121; 124-125): Perforations rather sparse. Columellae irregular, thinning towards the base. Tectum microperforate, reticulate. Grains with 11-20 (generally 11-16) pori. Grain size ranges from 20.68±2.42 μm to 45.35±3.57 μm.

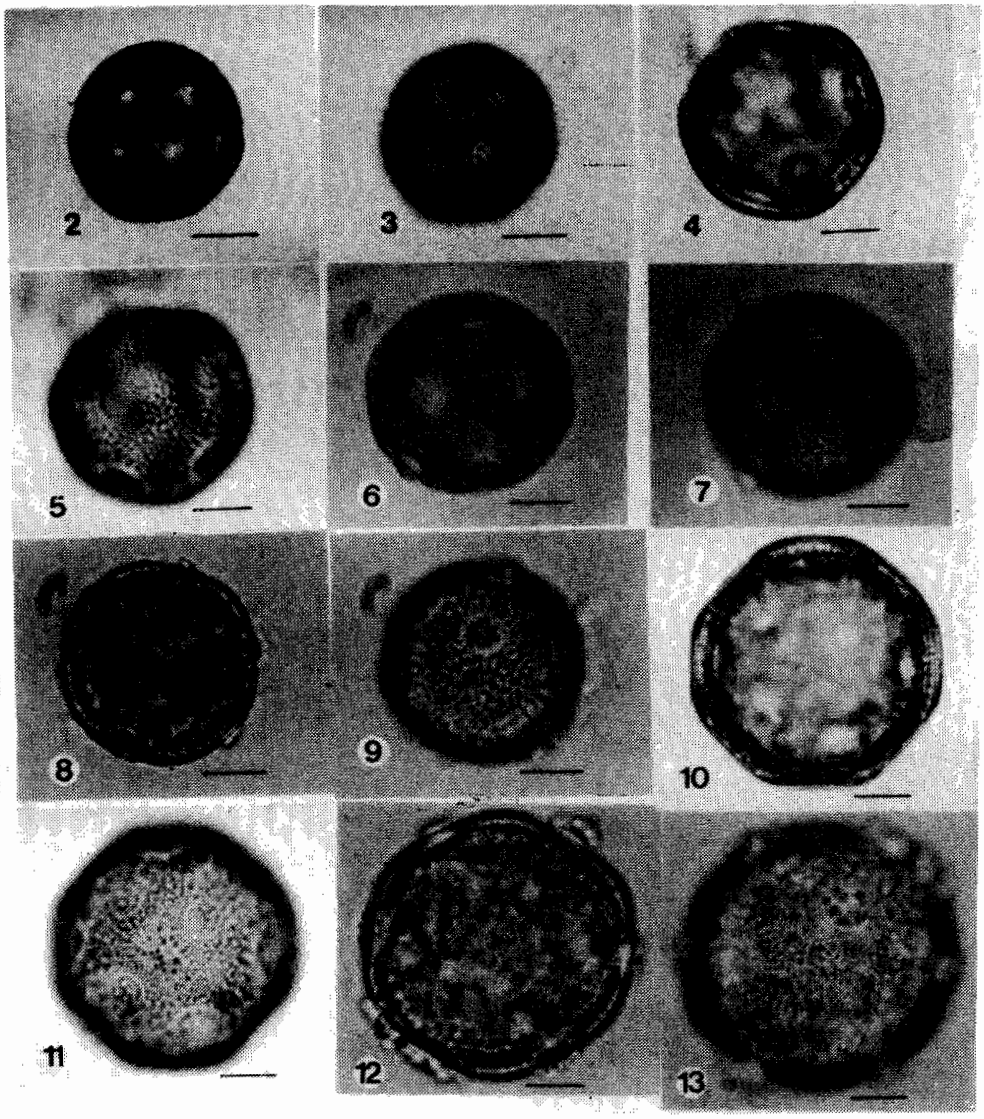
Type-5. *Gypsophila repens* type (Figs. 60-65; 122-123): Pollen grain outline obtusely angular with 5-6 sides due to the mesoporium rising up into a pattern of ridges between the pori. Each pore edged by a broad solid ring or band. Tectum microperforate. Grains with 9-14 pori. Grain size ranges from 28.11±1.68 μm to 31.34±1.68 μm.

Table 2. Morphological data of *Caryophylaceae* pollen grains (M: Average diameter of pollen, S: Standard deviation, E: Endemic for Turkey).

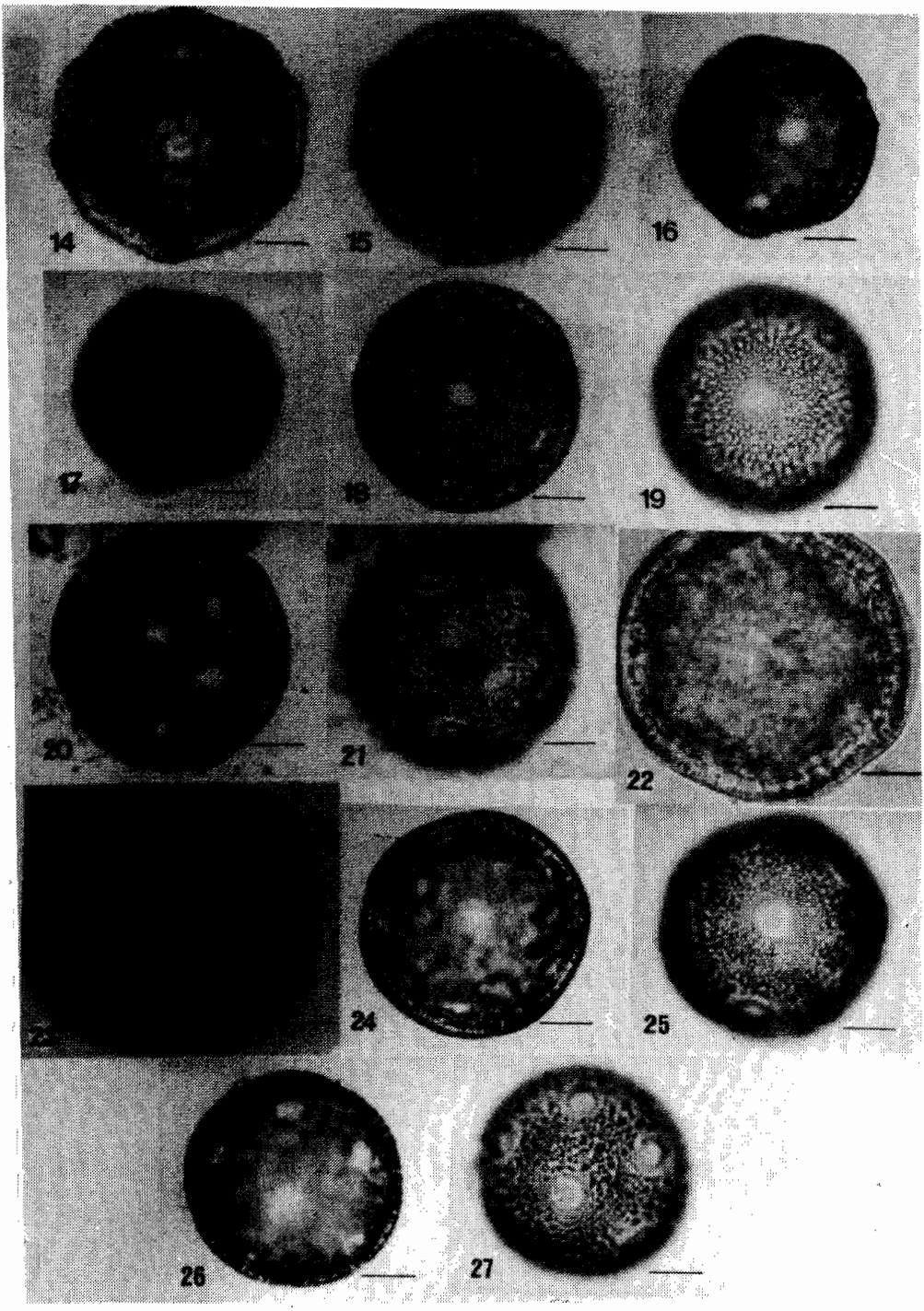
Species	Diameter of Pollen (μm)		Diameter of pore (μm)		Distance between two pores (μm)		Exine thickness (μm)		Number of pores
	M	S(±)	M	S(±)	M	S(±)	M	S(±)	
Arenaria serpyllifolia	27.83	1.52	3.70	0.73	5.49	0.53	2.58	0.51	16-21
Arenaria ledebouiriana var. *ledebouiriana* (E)	29.19	1.46	4.09	0.41	10.03	1.27	2.87	0.41	10-14
Minuartia juniperina	28.61	1.59	4.28	0.88	6.58	1.71	2.14	0.74	12-16
Minuartia verna	29.72	2.40	5.20	0.83	10.60	1.92	2.89	0.42	9-12
Stellaria media subsp. *pallida*	37.09	3.42	5.54	0.80	10.00	1.29	3.48	0.86	16-19
Stellaria nemorum	36.96	1.73	5.50	0.48	11.40	1.82	3.57	0.53	13-18
Stellaria holostea	41.28	1.72	6.00	0.44	11.00	1.42	5.99	1.26	14-19
Myosoton aquiticum	36.38	2.31	5.31	0.66	11.05	1.51	3.02	0.76	13-16
Cerastium chlorifolium	38.65	2.36	5.96	0.86	11.93	0.91	3.79	0.55	12-14
Cerastium fontanum subsp. *triviala*	39.20	2.83	3.81	0.93	7.86	1.12	3.00	0.66	23-28
Cerastium purpurascens	40.01	3.38	5.68	0.42	12.83	2.17	3.88	1.22	10-15
Moenchia mantica var. *mantica*	38.19	1.89	5.45	0.63	11.58	0.84	3.60	0.62	11-15
Dianthus eldivenus (E)	35.58	2.44	4.48	0.62	10.00	0.93	3.06	0.41	11-16
Dianthus leptopetalus	34.69	2.59	4.77	0.86	11.33	1.29	2.94	0.59	10-13
Dianthus balansae (E)	42.00	2.95	6.00	0.87	11.55	2.18	4.44	0.96	16-20
Dianthus crinitus var. *crinitus* (E)	45.35	3.57	6.61	1.23	14.64	1.34	4.52	0.95	13-17
Dianthus orientalis	37.17	2.14	4.56	0.96	10.97	1.39	2.98	0.64	14-17
Dianthus masmenaus var. *glabrascens* (E)	37.61	3.05	5.23	0.84	10.00	1.71	3.21	0.43	15-19
Dianthus erinaceus var. *alpinus* (E)	37.92	1.28	4.93	0.46	10.75	1.80	3.00	0.50	14-18
Dianthus carmelitarum (E)	37.08	2.15	5.54	0.98	10.00	1.69	2.88	0.79	11-15
Dianthuscarthusianorum	36.72	4.88	5.11	0.58	10.18	2.44	3.17	0.99	11-14
Dianthus celocephalus	42.50	2.61	6.00	0.99	13.25	2.36	3.27	0.52	12-15
Petrorhagia alpina subsp. *alpina*	20.68	2.42	2.21	0.43	5.00	0.93	1.92	0.32	12-14

Table 2. (Cont'd.)

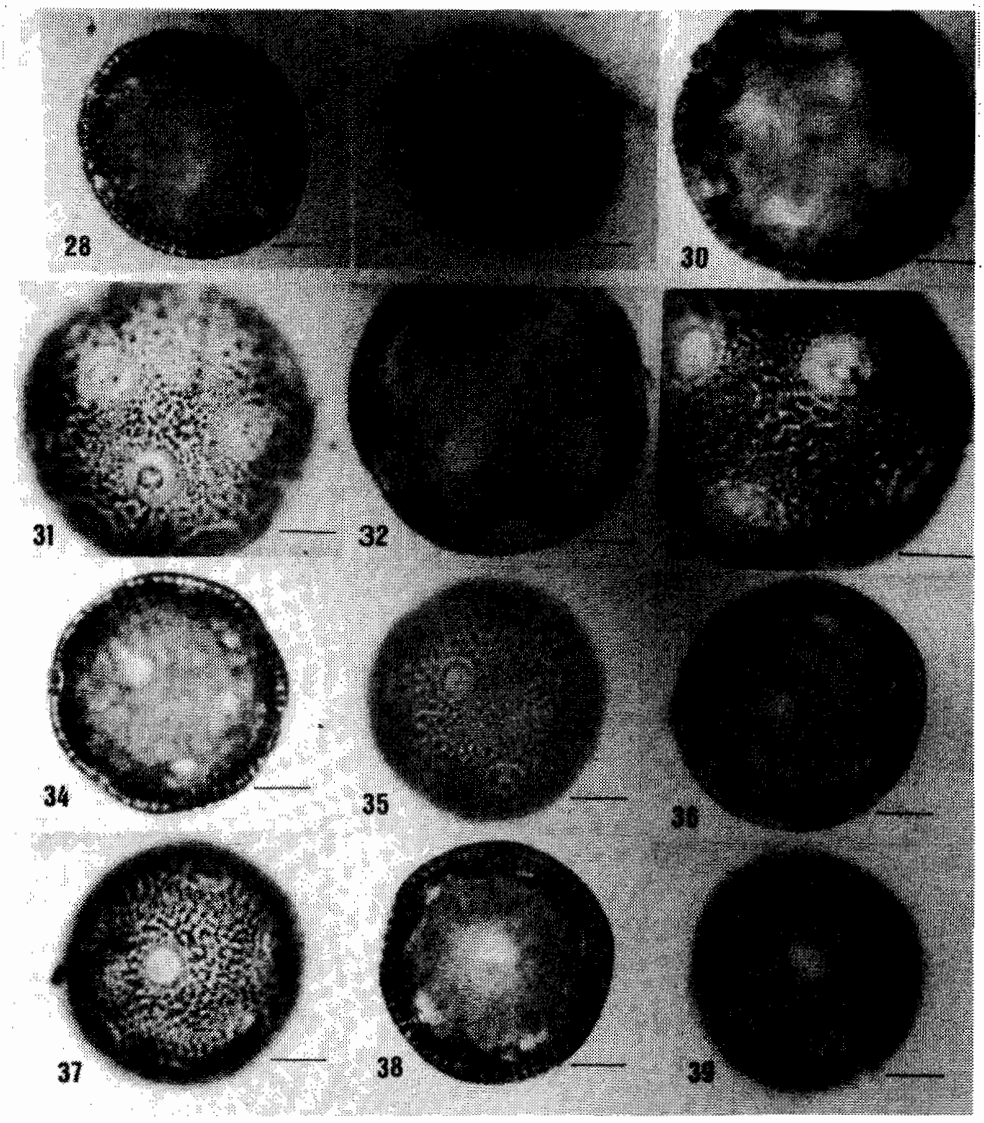
Species	Diameter of Pollen (μm)		Diameter of pore (μm)		Distance between two pores (μm)		Exine thickness (μm)		Number of pores
	M	S(±)	M	S(±)	M	S(±)	M	S(±)	
Petrorhagia saxifraga	26.32	2.38	3.90	0.88	7.88	1.43	2.42	0.59	12-15
Petrorhagia prolifera	40.92	2.68	5.73	1.12	10.22	1.33	3.45	0.84	13-16
Velezia rigida	34.25	1.30	5.25	0.39	6.05	2.30	2.48	0.54	13-16
Saponaria glutinosa	40.85	3.15	6.11	0.77	12.06	3.75	3.38	0.65	10-12
Saponaria orientalis	29.95	2.53	4.29	0.92	8.61	1.49	2.60	0.61	13-17
Saponaria prostata subsp. *prostata* **(E)**	33.69	2.74	5.94	0.94	11.67	1.54	2.77	0.48	10-12
Gypsophila elegans	31.34	1.68	4.49	0.82	11.10	0.96	2.92	0.72	9-14
Gypsophila venusta	28.11	1.68	5.38	1.09	8.20	0.85	2.78	0.48	10-13
Vaccaria pyramidata var. *grandiflora*	38.48	3.05	5.86	0.81	11.89	1.73	3.05	0.55	11-14
Silene lasiantha	35.44	2.97	4.75	0.43	8.87	1.77	3.40	1.21	24-30
Silene bupleroides	38.00	2.87	6.63	1.14	5.95	2.05	2.84	0.61	16-22
Silene muradica **(E)**	28.60	2.35	4.23	1.09	4.43	0.84	1.83	0.41	15-20
Silene montbretiana	28.26	2.32	4.36	0.59	4.63	0.91	2.56	0.47	24-27
Silene dianthoides	30.70	2.08	5.23	0.32	5.44	1.09	2.25	0.49	20-24
Silene odontopetala	34.10	2.28	5.58	0.66	5.25	0.89	2.64	0.51	18-22
Silene cserei subsp. *aeoniopsis* **(E)**	42.31	2.11	6.41	0.80	7.78	1.34	3.39	0.52	18-24
Silene caryophylloides subsp. *subulata*	44.57	2.71	5.93	0.80	5.29	1.06	3.00	0.37	34-40
Silene nuncupanda **(E)**	39.91	3.32	6.13	1.71	5.34	0.96	3.67	1.01	18-22
Silene conica	38.14	1.82	4.57	0.59	4.77	0.84	2.67	0.51	32-40
Silene conoidea	47.44	1.52	6.16	0.50	5.25	0.91	3.11	0.48	30-34
Lychnis coronaria	30.34	1.21	3.08	0.76	6.07	0.82	2.95	0.30	18-25
Agrostemma githago	50.35	2.46	6.22	0.69	7.53	1.29	4.98	0.60	35-42



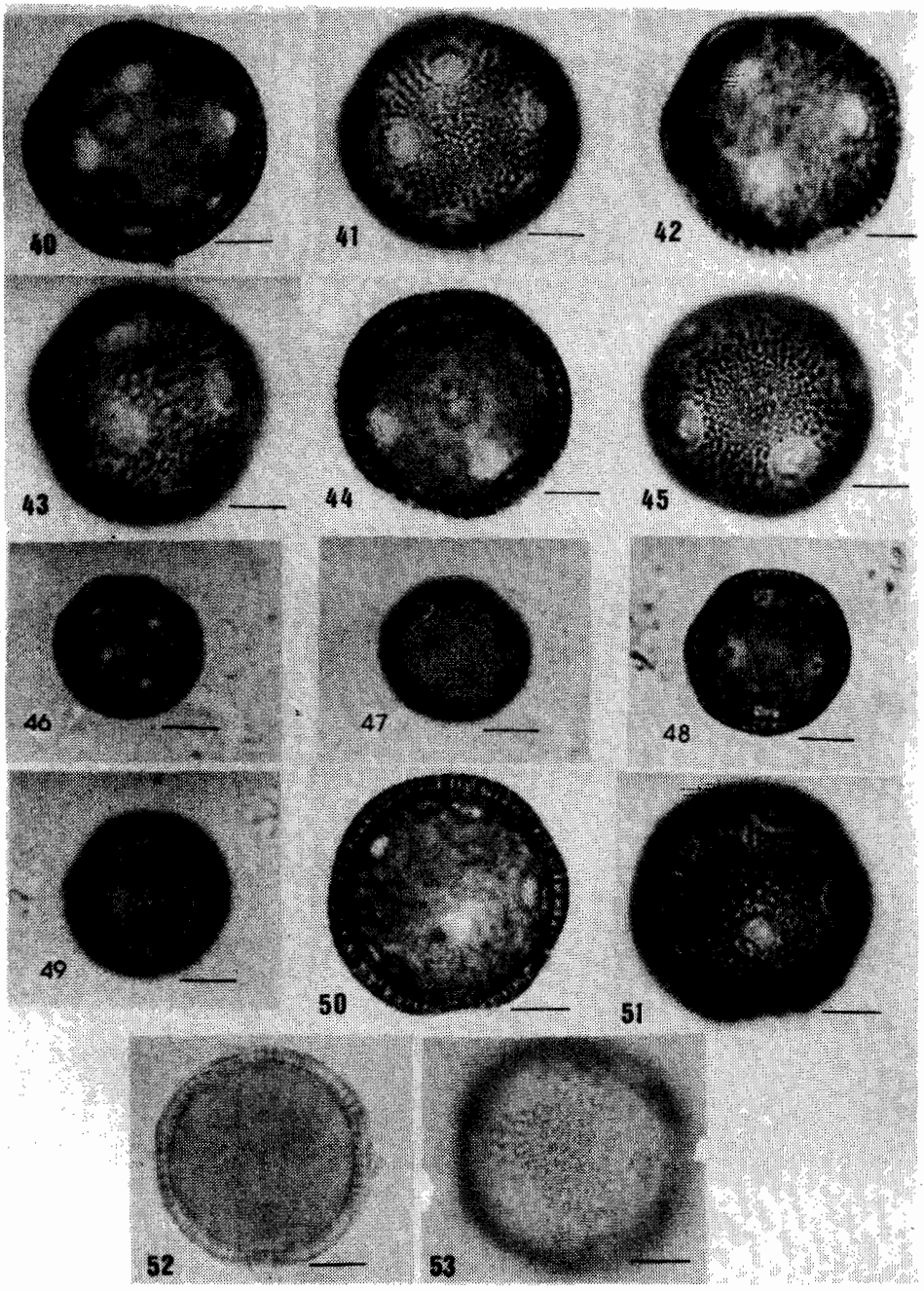
Figs. 2-27. Light micrographs of *Arenaria, Minuartia, Stellaria, Myosoton Cerastium, Moenchia* and *Dianthus* pollen (The scale equals 10 μm).
Figs. 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26,: Optical section.
Figs. 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27: Surface view.
Figs. 2-3. *Arenaria serpyllifolia,* Figs. 4-5. *Arenaria ledebouiriana* var. *ledebouiriana,* Figs. 6-7. *Minuartia juniperina,* Figs. 8-9. *Minuartia verna,* Figs. 10-11. *Stellaria media* subsp. *pallida,* Figs. 12-13. *Stellaria nemorum.*



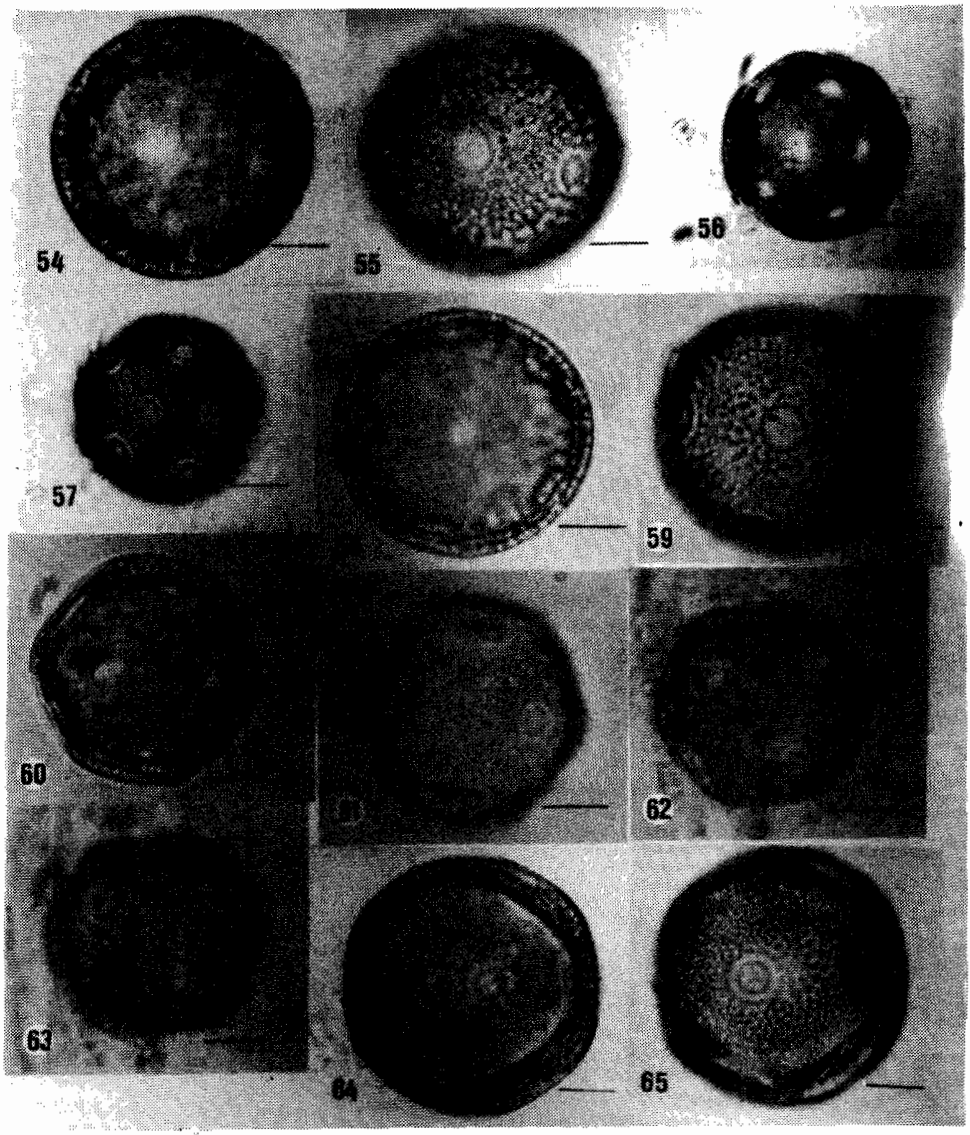
Figs. 14-15. *Stellaria holostea*, Figs. 16-17. *Myosoton aquiticum*. Figs. 18-19. *Cerastium chlorifolium*, Figs. 20-21. *Cerastium fontanum* subsp. *triviala*, Figs. 22-23. *Cerastium purpurascens*, Figs. 24-25. *Moenchia mantica* var. *mantica*, Figs. 26-27. *Dianthus eldivenus*.



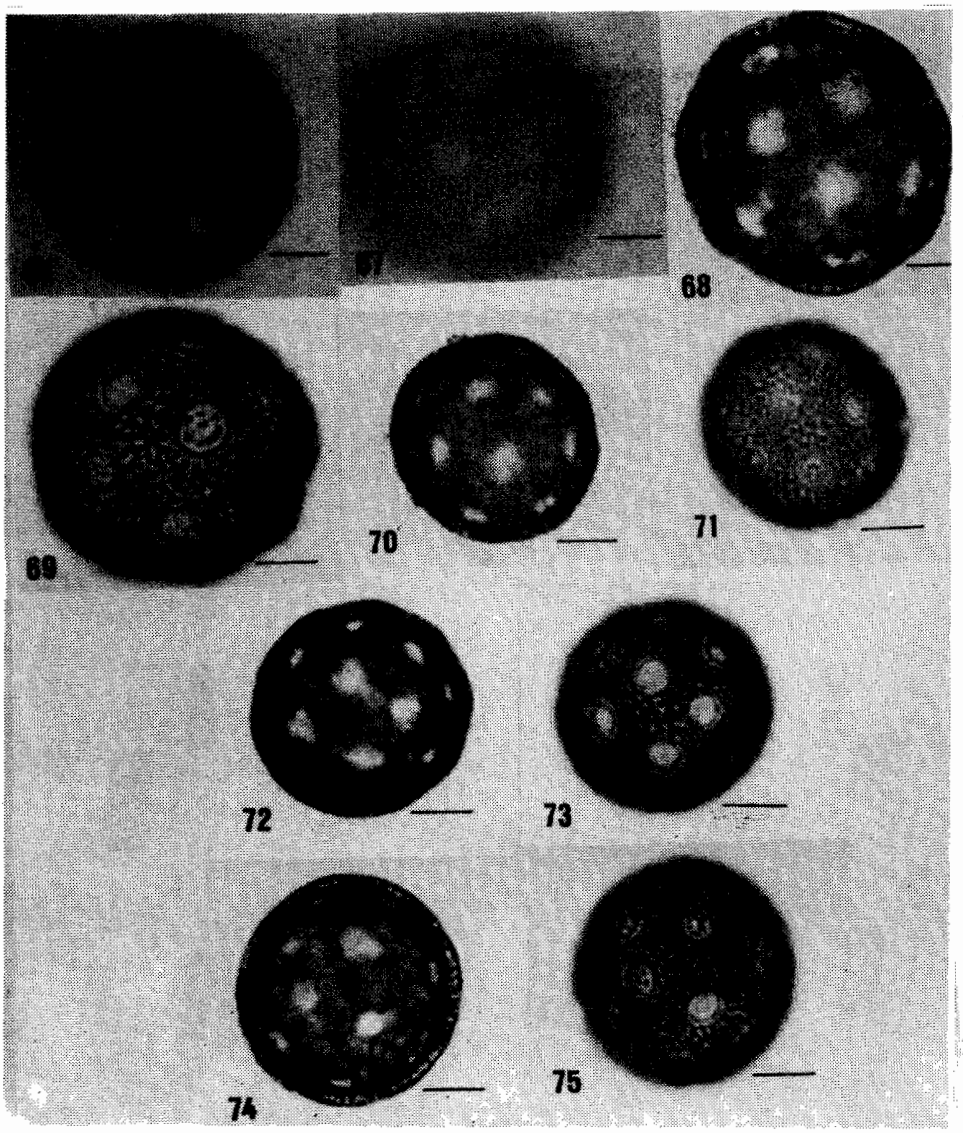
Figs. 28-53. Light micrographs of *Dianthus, Petrorhagia* and *Velezia* pollen (The scale equals 10μm).
Figs. 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52: Optical section.
Figs. 29, 31, 33, 35, 37, 39, 41, 43, 45, 47, 49, 51, 53: Surface view.
Figs. 28-29. *Dianthus leptopetalus,* Figs. 30-31. *Dianthus balansae,* Figs. 32-33. *Dianthus crinitus* var. *crinitus.* Figs. 34-35. *Dianthus orientalis,* Figs. 36-37. *Dianthus masmenaus* var. *glabrascens,* Figs. 38-39. *Dianthus erinaceus* var. *alpinus.*



Figs. 40-41. *Dianthus carmelitarum*, **Figs. 42-43.** *Dianthus carthusianorum*, **Figs. 44-45.** *Dianthus celocephalus*, **Figs. 46-47.** *Petrorhagia alpina* subsp. *alpina*, **Figs. 48-49.** *Petrorhagia saxifraga*, **Figs. 50-51.** *Petrorhagia prolifera*. **Figs. 52-53.** *Velezia rigida*.



Figs. 54-75. Light micrographs of *Saponaria, Gypsohila, Vacccaria* and *Silene* pollen (The scale equals 10 μm).
Figs. 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74: Optical section.
Figs. 53, 55, 57, 59, 61, 63, 65, 67, 69, 71, 73, 75: Surface view.
Figs. 54-55. *Saponaria glutinosa,* Figs. 56-57. *Saponaria orientalis,* Figs. 58-59. *Saponaria prostata* subsp. *prostata,* Figs. 60-61. *Gypsophila elegans,* Figs. 62-63. *Gypsophila venusta,* Figs. 64-65. *Vaccaria pyramidata* var. *grandiflora.*



Figs. 66-67. ***Silene lasiantha,*** **Figs. 68-69.** ***Silene bupleroides,*** Figs. 70-71. ***Silene muradica,*** Figs. 72-73. ***Silene montbretiana,*** Figs. 74-75. ***Silene dianthoides.***

Type- 6. ***Lychnis viscaria*** type (Figs. 88-89; 142-143): With more slender columellae. Tectum microperforate microechinae may or may not be prominent. This type is very similar to ***Arenaria*** type, but Arenaria type pollen grains small and low pore number. Grains with 18-25 pori. Grain size 30.34±1.21 μm.

Type-7. *Silene vulgaris* type (Figs. 66-83; 126-139): Perforations rather more densely spaced, often not directly over the lumina of the obscure infrareticulum. Tectum microperforate with coarse, usually sparse, columellae and prominent microechinae. Grains with 15-30 pori. Grain size ranges from 28.26±2.35 μm to 42.31±2.11 μm.

Type-8. *Silene caryophylloides* subsp. *subulata* (Figs. 80-81; 136-137): Operculum ovoid and pore circular margin. Tectum semireticulate. Grains with numerous (34-40) pori. Grain size 44.57±2.71 μm.

Type-9. *Silene conica* type (Figs. 84-87; 140-141): Columellae inordinately arranged, with coarse, usually sparse, columellae. Tectum semireticulate. These species may be distinguished by the ornamentation (semireticulate) of their operculum which take the form of a ring shape enclosing one or more islands (5-30 granules). Grains with numerous (30-40) pori. Grain size ranges from 28.11±1.68 μm to 31.34±1.68 μm.

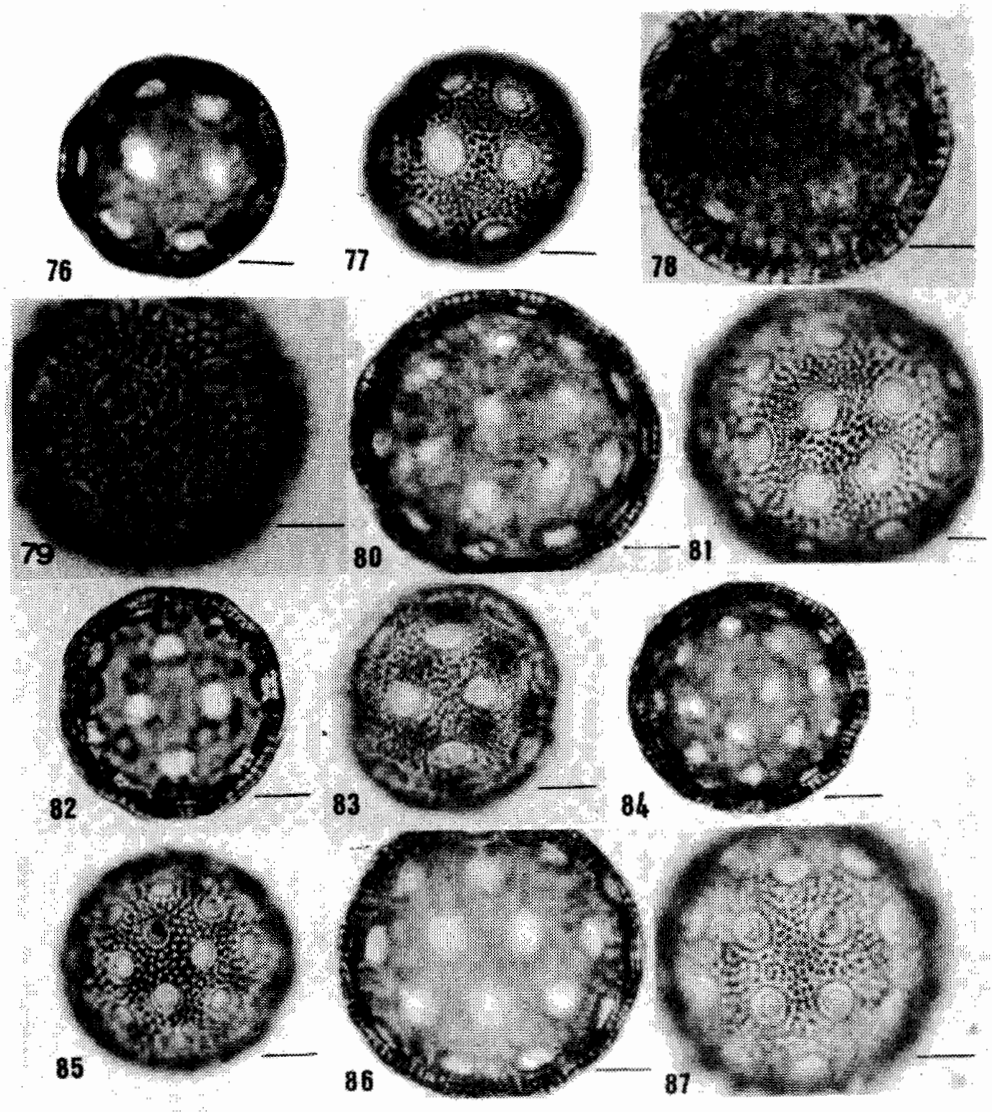
Type-10. *Agrostemma githago* (Figs. 90-91; 144-145): Perforations of equal frequency to columellae or less frequent than columellae in mesoporium. Columellae always rather crowded in the mesoporium. Tectum microperforate. Grains with 35-42 pori. Grain size 50.35±2.46 μm.

Discussion

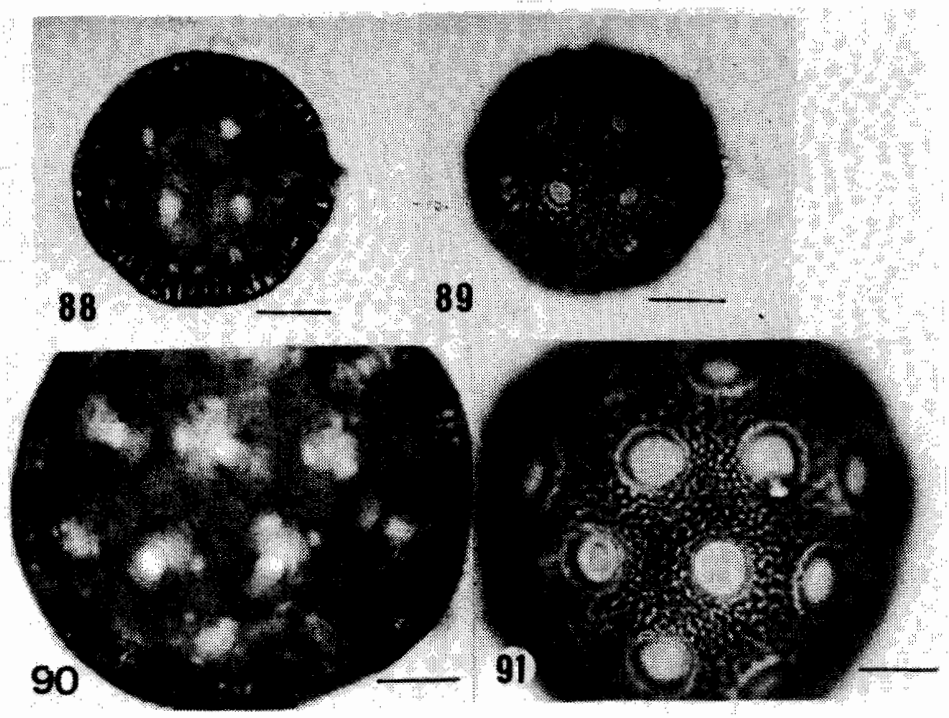
Most of the species i.e., 41 out of 45 are microperforate, whereas 3 species are semireticulate (*Silene caryophylloides* subsp. *subulata*, Figs. 80, 81, 136, 137; *Silene conica*, Figs. 84, 85, 140, 141; *Silene conoidea*, Figs. 86, 87). *Dianthus leptopetalus* (Figs. 28, 29) is the only species with reticulate tectum. Perforation diameters of *Silene montbretiana* and *Dianthus crinitus* var. *crinitus* are longer than other species.

The pori in *Arenaria ledebouiriana* var. *ledebouiriana* (Figs. 3, 92, 93), *Cerastium chlorifolium* (Figs. 19, 9, 99), *Moenchia mantica* var. *mantica* (Figs. 25, 100, 101), *Dianthus erinaceus* var. *alpinus* (Figs. 39, 110, 111), *Dianthus carmelitarum* (Figs. 41, 112, 113), *Dianthus celocephalus* (Figs. 45, 114, 115), *Velezia rigida* (Figs. 53, 118, 119), *Saponaria prostata* subsp. *prostata* (Figs. 59, 120, 121), *Silene lasiantha* (Figs. 67, 126, 127), *Silene muradica* (Figs. 71, 128, 129), *Silene montbretiana* (Figs. 73, 130, 131), *Silene odontopetala* (Figs. 77, 132, 133), *Silene cserei* subsp. *aeoniopsis* (Figs. 79, 134, 135), *Silene caryophylloides* subsp. *subulata* (Figs. 81, 136, 137), are protruding and their delimitations are distinct.

Microperforates of all *Dianthus* specimens are shown in Figs. 26–45, 102–115. Perforations of *Dianthus eldivenus, Dianthus balansae, Dianthus crinitus* var. *crinitus, Dianthus orientalis, Dianthus masmenaus* var. *glabrascens, Dianthus erinaceus* var. *alpinus, Dianthus carmelitarum* are c. 1 μm. Moreover, tectal spinules of *Dianthus eldivenus, Dianthus balansae, Dianthus crinitus* var. *crinitus, Dianthus orientalis, Dianthus masmenaus* var. *glabrascens, Dianthus erinaceus* var. *alpinus, Dianthus carmelitarum* are quite distinct. The longest and biggest tectal spinules are observed in *Dianthus balansae*.



Figs. 76-91. Light micrographs of *Silene, Lychnis* and *Agrostemma* pollen (The scale equals 10μm).
Figs. 76, 78, 80, 82, 84, 86, 88, 90: Optical section.
Figs. 77, 79, 81, 83, 85, 87, 89, 91: Surface view.
Figs. 76-77. *Silene odontopetala,* Figs. 78-79. *Silene cserei* subsp. *aeoniopsis,* Figs. 80-81. *Silene caryophylloides* subsp. *subulata,* Figs. 82-83. *Silene nuncupanda,* Figs. 84-85. *Silene conica,* Figs. 86-87. *Silene conoidea.*



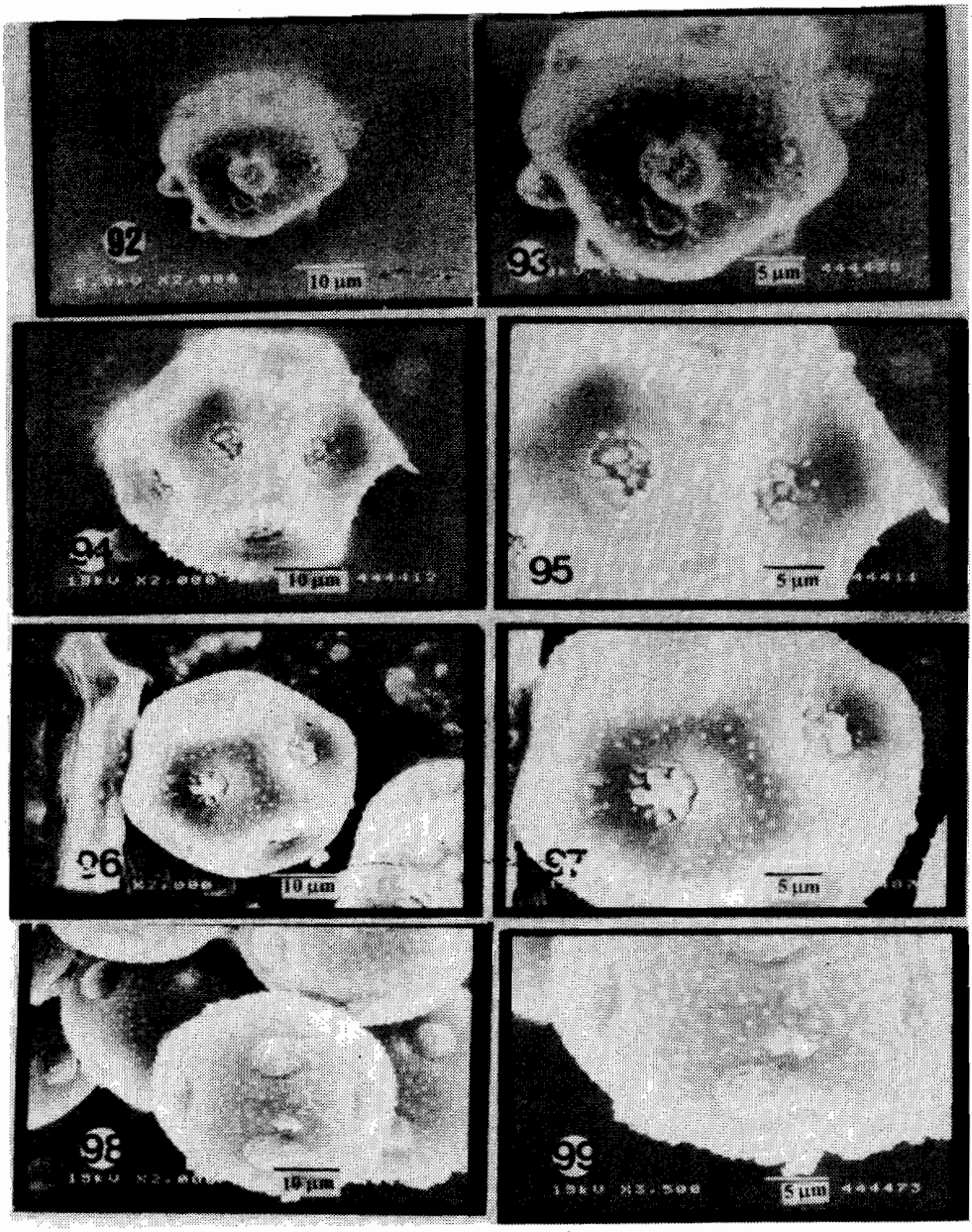
Figs. 88-89. *Lychnis coronaria*, Figs. 90-91. *Agrostemma githago*.

Perforations of *Silene montbretiana* are much clearer than other *Silene* species. Pollen grains of *Silene conica, Silene conoidea* and *Silene caryophylloides* subsp. *subulata* are semireticulate which seperate them from the other studied species.

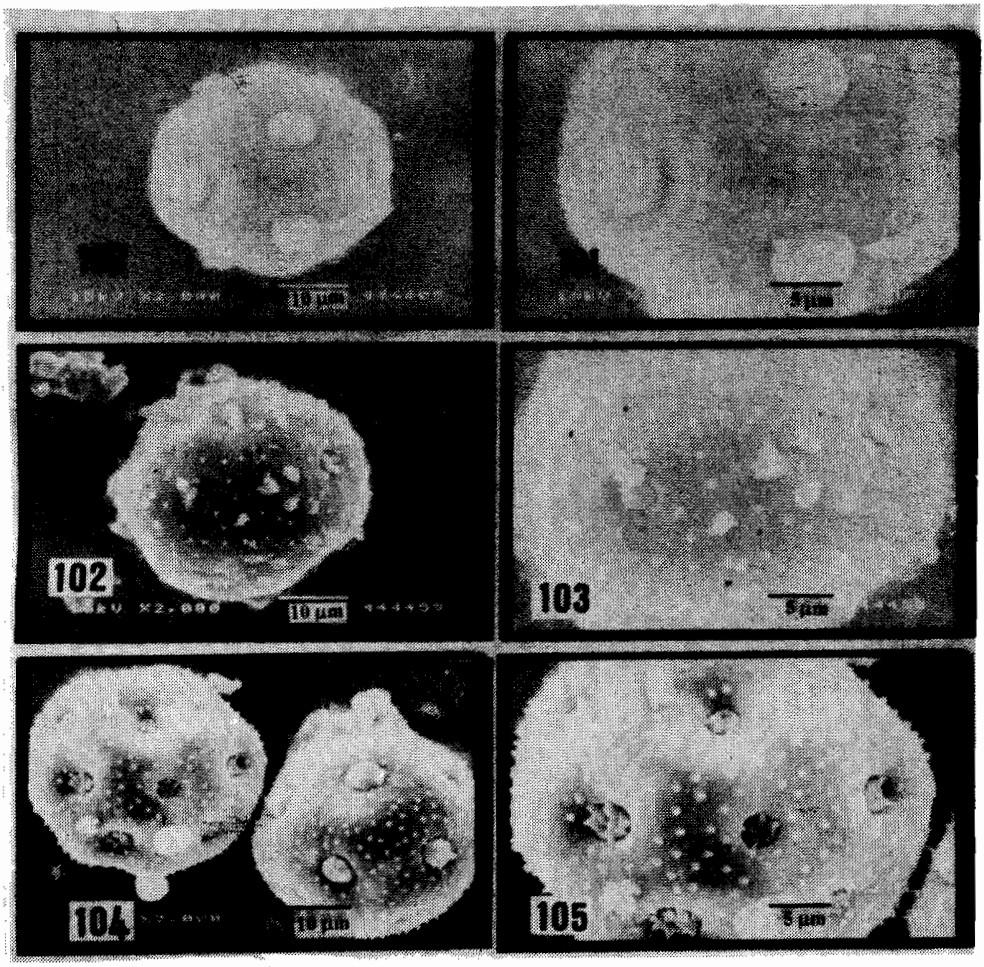
In studies on the pollen morphology of *Caryophyllaceae* Skvarla, (1975), Skvarla & Nowicke, (1976), Nowicke & Skvarla, (1977), Ghanzanfar, (1984), Arkan & İnceoğlu, (1992) and Yıldız, (1996a, 1996b, 2001) demonstrated that the pollen are usually of medium size ranging from 25 to 50 μm. The present studies are also in agreement with their contention. Pollen of 43 species are of medium size. However, few exceptions have also been observed. The pollen of *Petrorhagia alpina* are small (20.68±2.42 μm), in contrast *Agrostemma githago* has large pollens (50.35±2.46 μm).

Silene noctiflora L., *Dianthus barbatus* L., *Lychnis alba* L., subsp. *superbus* L., are characterized by a thick tectum and sharp spines (Skvarla & Nowicke, 1976). Pore numbers 7-50 have been reported in many studies (Skvarla & Nowicke 1976; Nowicke & Skvarla, 1977; Ghanzanfar, 1984; Arkan & İnceoğlu, 1992; Yıldız, 1996a; 1996b; 2000). In the present study, number of pore is from 9 to 42, and many of the species have 10-20 pores.

Pollen developmental studies on *Silene* (Heslop-Harrison, 1963, 1968) as well as morphological observations in the present study confirm columellae-foot layer attachment. In these genera the foot layer is notably thin and only slightly thicker than the endexine. Exine morphology of *Silene* is quite similar to *Dianthus, Saponaria, Velezia, Gypsophila, Vaccaria* and *Agrostemma* with the exception that the tectum is discontinuous and reticulate.

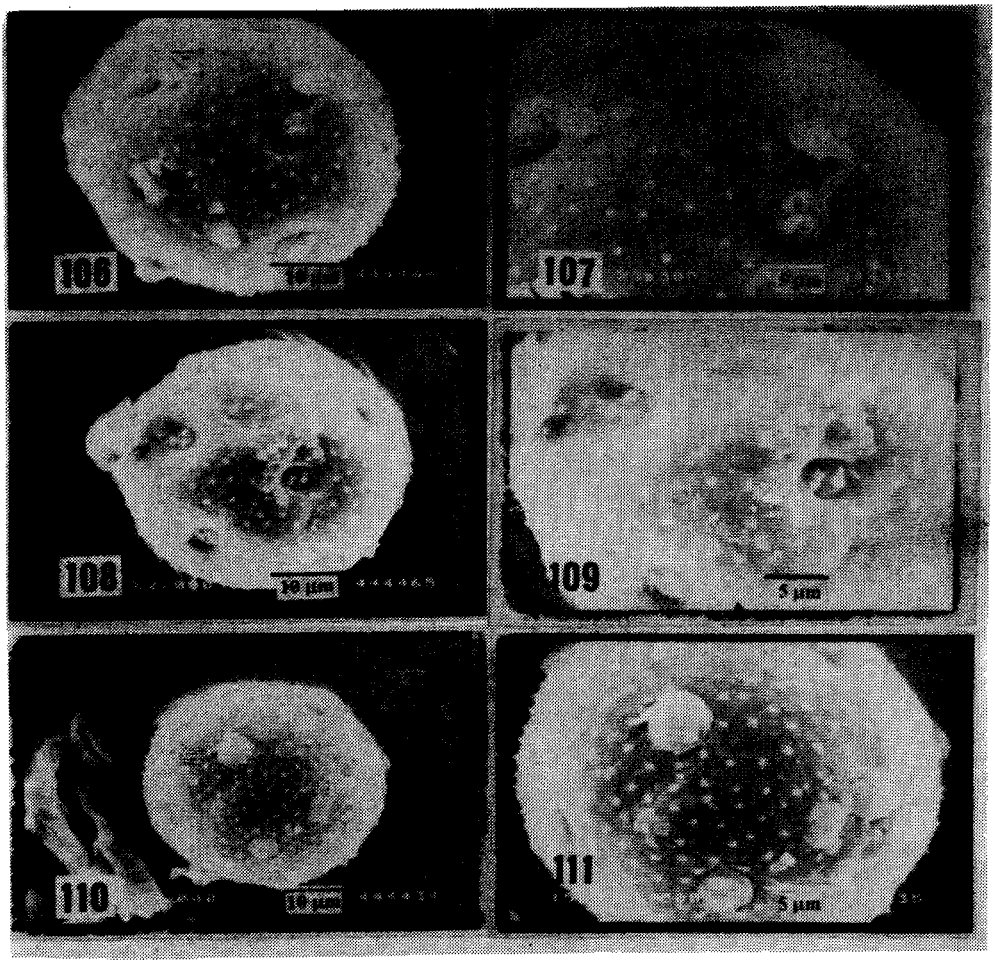


Figs. 92-105. SEM micrographs of *Arenaria, Stellaria, Myosoton, Cerastium Moenchia* and *Dianthus* pollen.
Figs. 92, 94, 96, 98, 100, 102, 104: General view.
Figs. 93, 95, 97, 99, 101,103, 105: Surface view.
Figs. 92-93. *Arenaria ledebouiriana* var. *ledebouiriana*,Figs. 94-95. *Stellaria holostea*, Figs. 96-97. *Myosoton aquiticum*, Figs. 98-99. *Cerastium chlorifolium*.



Figs. 100-101. *Moenchia mantica* var. *mantica*, Figs. 102-103. *Dianthus eldivenus*, Figs. 104-105. *Dianthus balansae*.

Moore *et al.*, (1997) examined exines by SEM of *Stellaria holostea, Myosoton aquiticum, Dianthus carthusianorum, Gypsophila fastigiata, Silene latifolia* subsp. *alba, Lychnis flos-cuculi* and by LM of *Silene noctiflora, Stellaria holostea, Silene dioica, Silene conica, Agrostemma githago, Gypsophyla repens, Dianthus armeria, Silene vulgaris* subsp. *maritima, Cerastium fontanum, Minuartia sedoides, Lychnis flos-cuculi, Lychnis viscaria.* Their findings, are in accordance with the present studies. Moore *et al.*, (1997), included *Caryophyllaceae* in polypantoporate group. In this group some of the species belong to *Caryophyllaceae* have maximum number of pori i.e. upto 40. They divided *Caryophyllaceae* into 8 types. Viz., *Silene dioica* type, *Gypsophila repens* type, *Cerastium* type, *Arenaria* type, *Dianthus* type, *Silene vulgaris* type, *Silene conica* type



Figs. 106-119. SEM micrographs of *Dianthus, Petrorhagia* and *Velezia* pollen.
Figs. 106, 108, 110, 112, 114, 116, 118: General view.
Figs. 107, 109, 111,113, 115, 117, 119: Surface view.
Figs. 106-107. *Dianthus crinitus* var. *crinitus*, Figs. 108-109. *Dianthus masmenaus* var. *glabrascens*, Figs. 110-111. *Dianthus erinaceus* var. *alpinus*.

and *Lychnis viscaria* type. The present studies are also in agreement with the classification that all the species studied belong to one of these 8 groups, except *Silene dioica* type.

Ghazanfar (1984) reported that the sexine sculpture of *Silene italica* (L.) Pers, *Silene viridiflora* L., and *Silene rhynchocarpa* Boiss., was punctate. In *Silene caryophylloides* subsp. *subulata* collected from Turkey by Ghazanfar (1984), the diameter of pollen 35-44 µm; diameter of pore 4-5 µm; distance between two pori 4-5

μm; number of pore 45-49; sculpture of ektexine semireticulate are recognized. Average of pollen diameter of some species mentioned are 44.57±2.71 μm, pore diameter 5.93±0.80 μm, distance between two pores 5.29±1.06 μm, number of pore 34-40, ornamentation of exine (sexine) semireticulate are recognized. However, in the present study pollen diameter, pore diameter and distance among pori is comparatively greater also the number of pori are slightly more in number. Since, there are not any major differences between two studies, we can say that observations of both studies are compatible to each other.

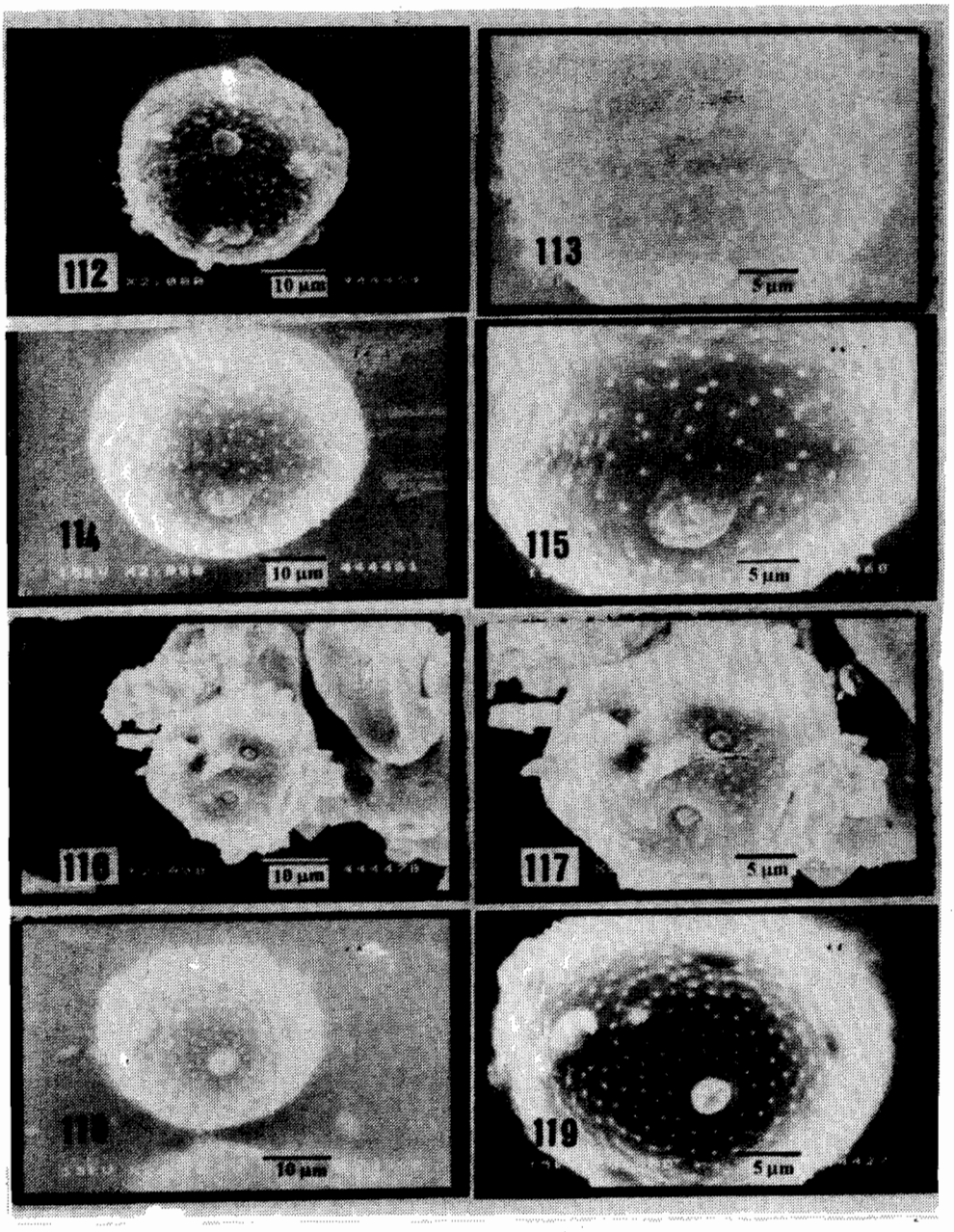
The palynological studies of Arkan & Inceoğlu (1992) on *Saponaria*, the diameter of pollen, diameter of pore, distance between two pori, exine thickness and number of pore values of *Saponaria glutinosa, Saponaria orientalis* and *Saponaria glutinosa* subsp. *prostata* species, are similar to the present study.

Parent & Richard (1993) in their studies on 12 genera and 38 species of *Caryophyllaceae* which are distributed in Canada indicate that 2 species of *Spergula* are colpate; 36 species of *Arenaria, Cerastium, Honckaya, Stellaria, Lychnis, Melandrium, Minuartia, Moenchringia, Sagina* and *Silene* polypantoporate which is similar to the present report.

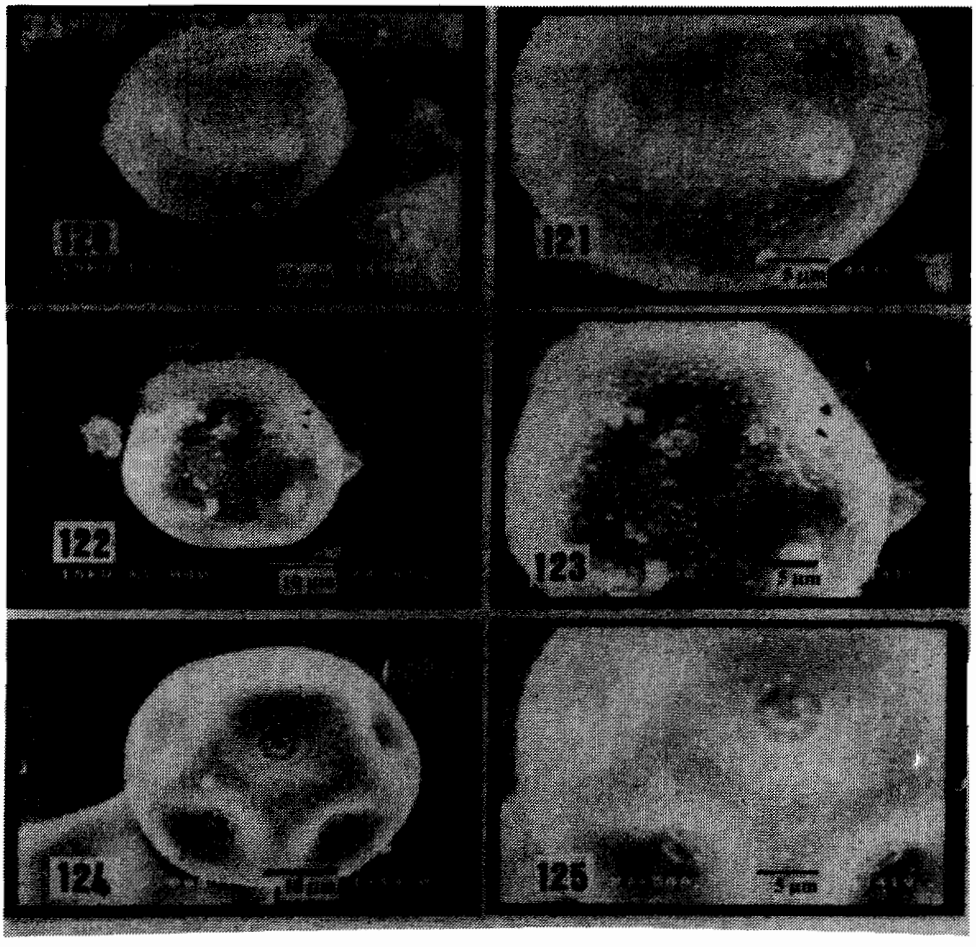
Palynological studies of a total of 19 *Silene* (*Caryophyllaceae*) species (Yıldız, 1996a, 1996b, 2000) revealed that pollens are spheroidal, periporate, tectate-semitectate, spinulose-microperforate and semireticulate. Yıldız (1996a) in his palynological studies of 6 taxa represented in the sect. *Siphonomorpha* Otth., sect. *Elisanthe* (Fenzl) Fenzl, sect. *Silene* described the exine sculpture of *Silene italica* (L.) Pers., *S.viridiflora* L., *S.alba* (Miller) Krause subsp. *eriocalycina* (Boiss.) Walters, *S.noctiflora*, *S.gallica*, *S.bellidifolia* Jacp. as spinulose, spinulose-microperforate and semireticulate recording respective measurements. Since there has not been any palynological data available on *Silene* in Turkey, this investigation is attempted to measure average diameter of pollen grains and of pori, thickness of exine, distance between two pori, the number of pore and diameter of spinule base and sexine sculpture of *Silene* to understand taxonomical positions. Similarly in this study, 11 *Silene* species were investigated which showed similar results.

The presence of semireticulate and reticulate sexines in *Dianthus leptopetalus*, *Silene caryophylloides* subsp. *subulata, Silene conica, Silene conoidea* and their total absence in other species suggest a relationship between sexines and phylogenetically advanced species. *Dianthus leptopetalus*, *Silene caryophylloides* subsp. *subulata, Silene conica, Silene conoidea* are regarded phylogenetically higher than other species, primarily on the basis of inflorescence.

Imperforate exine (Walker, 1974a; 1974b) and fewer number of pori (Van Campo, 1966) are generally accepted as primitive. Pore number is low in the genera *Arenaria, Minuartia, Stellaria, Myosoton, Cerastium* and *Moenchia* of the family *Caryophyllaceae* which is accepted primitive phylogenetically in the Flora of Turkey (Davis, 1967). But the pore number of *Silene* and *Agrostemma* species is more than other species (Table 2). The most advanced species of *Caryophyllaceae* regarding evolution are in *Silene* and *Agrostemma*. The phylogeny of flora of Turkey (Davis, 1967) seem true according to this result.



Figs. 112-113. *Dianthus carmelitarum*, Figs. 114-115. *Dianthus celocephalus*, Figs. 116-117. *Petrorhagia saxifraga*, Figs. 118-119. *Velezia rigida*.



Figs. 120-133. SEM micrographs of *Saponaria, Gypsophila, Vaccaria* and *Silene* pollen.
Figs. 120, 122, 124, 126, 128, 130, 132: General view.
Figs. 121, 123, 125, 127, 129, 131, 133: Surface view.
Figs. 120-121. *Saponaria prostata* subsp. *prostata*, Figs. 122-123. *Gypsophila elegans*, Figs. 124-125. *Vaccaria pyramidata* var. *grandiflora*.

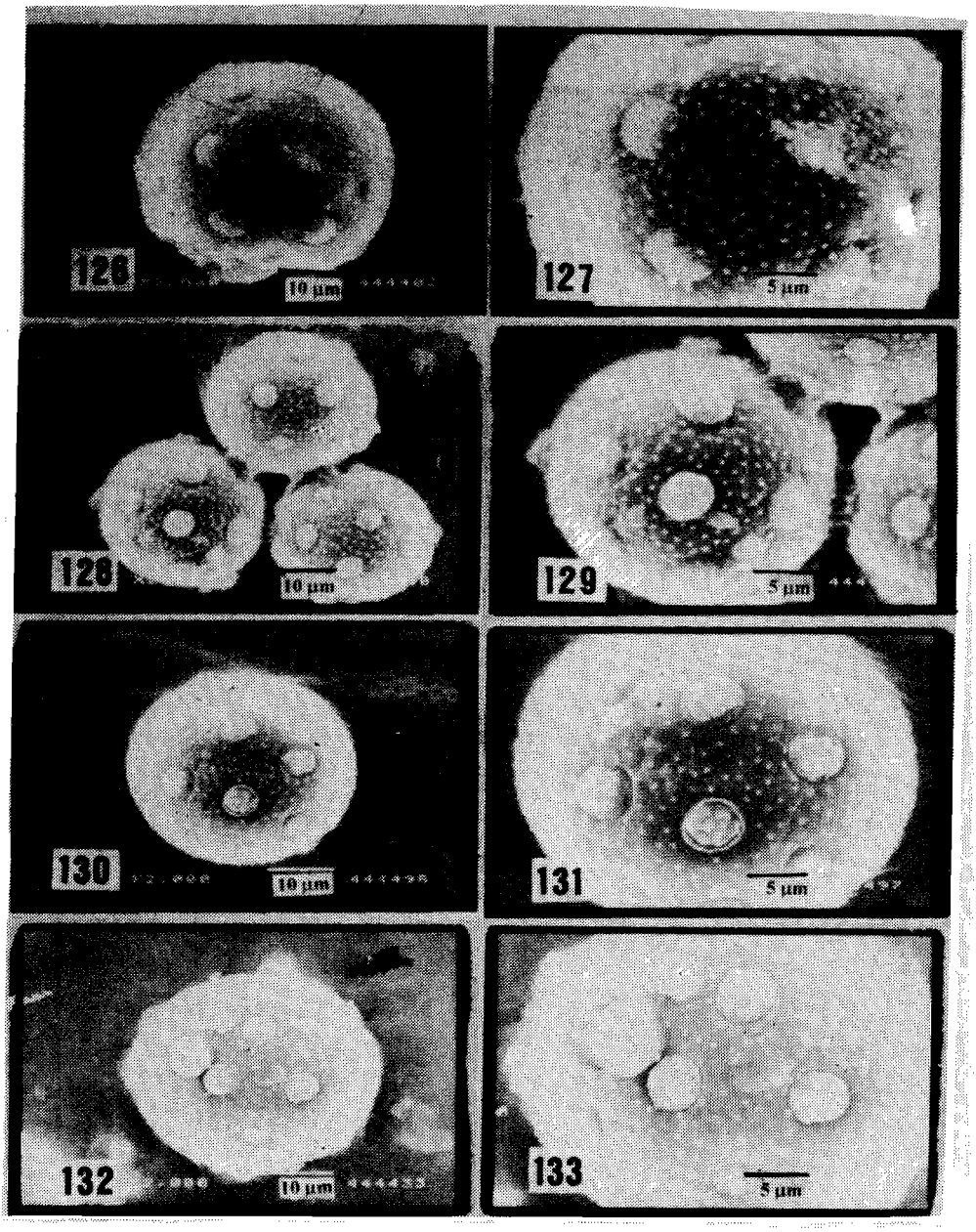
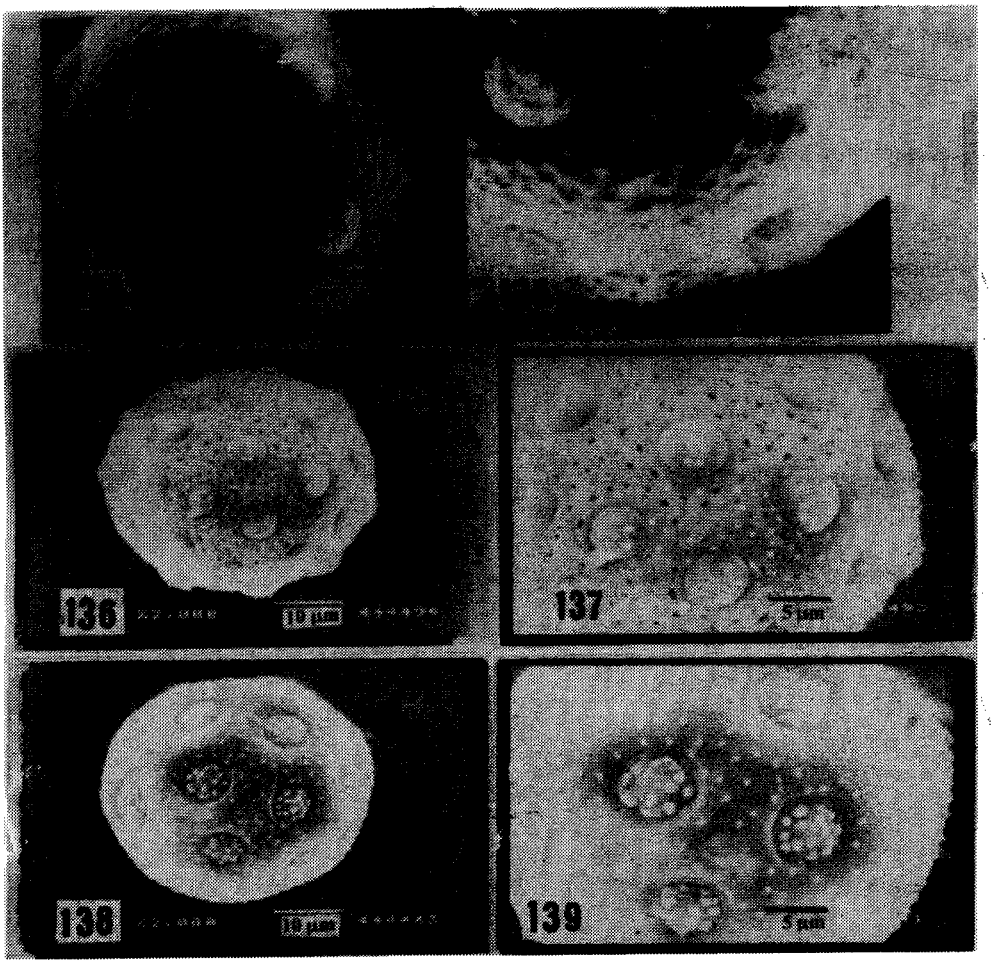
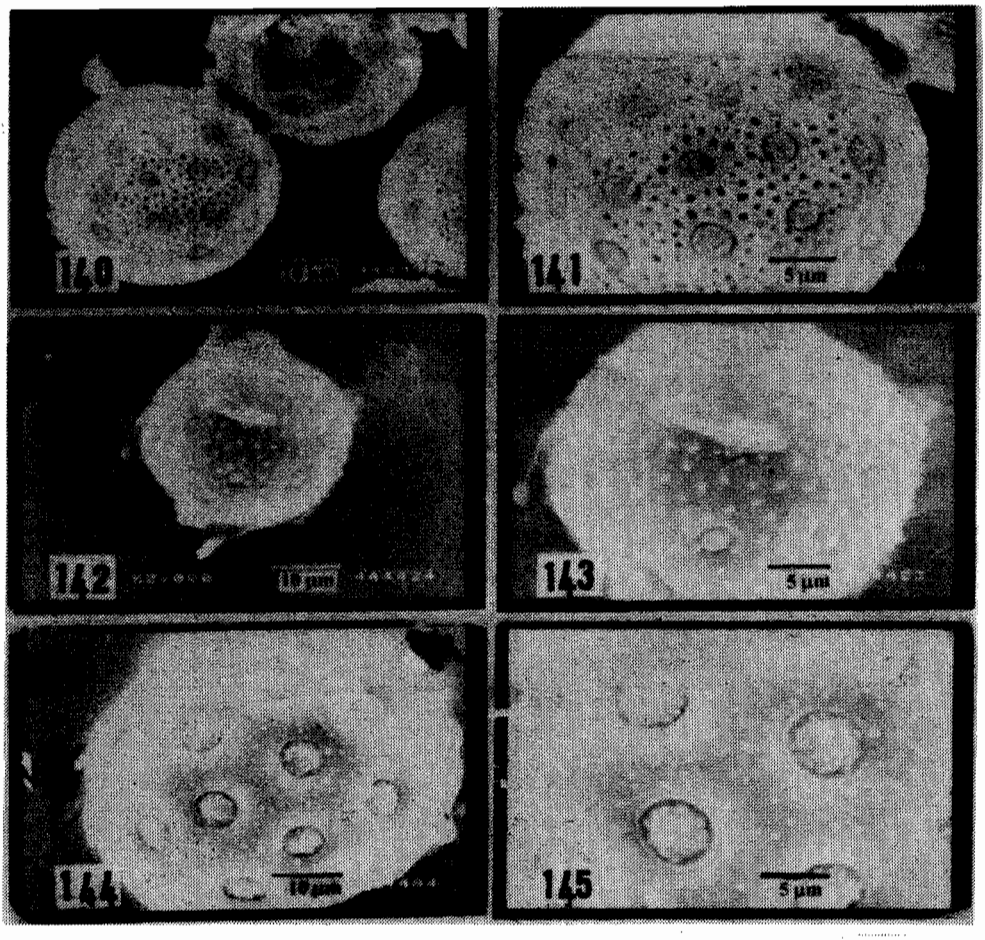


Fig. 126-127. *Silene lasiantha*, Figs. 128-129. *Silene muradica*, Figs. 130-131. *Silene montbretiana*, Figs. 132-133. *Silene odontopetala*.



Figs. 134-145. SEM micrographs of *Silene, Lychnis* and *Agrostemma* pollen.
Figs. 134, 136, 138, 140, 142, 144: General view.
Figs. 135, 137, 139, 141, 143, 145: Surface view.
Figs. 134-135. *Silene cserei* subsp. *aeoniopsis,* Figs. 136-137. *Silene caryophylloides* subsp. *subulata,* Figs. 138-139. *Silene nuncupanda.*



Figs. 140-141. Silene conica, Figs. 142-143. Lychnis coronaria, Figs. 144-145. Agrostemma githago.

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