POLLEN MORPHOLOGY OF IRANIAN BORAGINACEAE FAMILY AND ITS TAXONOMIC SIGNIFICANCE

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The pollen morphology of 42 species belonging to 32 genera of *Boraginaceae* have been investigated by SEM and sometimes by LM. The results confirm the eurypalinous character of this family, in which a large number of species can be recognized by their pollen characters. The palynological result revealed that pollen grains of the family posses tricolporate aperture and other types derived from it and are primarily divided into two groups by having and lacking pseudocolpi. The taxonomic implications of the pollen morphological features are discussed.

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Key words. Pollen, *Boraginaceae*, taxonomy, Iran.

ریخت‌شناسی دانه گرده گونه‌های ایرانی تیره گاوزبان و ارزش آنها در رده‌بندی گونه‌ها

محبوبه خاتم‌ساز

ویژگیهای دانه گرده ۴۳ گونه متعلق به ۳۲ جنس از تیره گاوزبان با استفاده از میکروسکوپ الکترونی اسکن و بعضی مواقع با میکروسکوپ نوری مورد بررسی قرار گرفته است. نتایج حاصله نشان می‌دهد که تعداد زیادی از گونه‌ها با صفات گرده‌شناسی از یکدیگر تشخیص داده می‌شوند (eurypalinous). نتایج دیرینه‌شناسی مشخص می‌کند که دانه گرده از شکل ۳ شیار - روزنی شروع و سایر اشکال از آن مشتق می‌شوند و در مراحل اولیه به دو گروه با شیار کاذب و فاقد شیار کاذب تقسیم می‌شوند. مفهوم رده‌بندی صفات دانه گرده نیز شرح داده شده است.

Introduction

The *Boraginaceae* family in Iran was revised as a project for the Flora of Iran in Farsi from 1989. The studies are based on visiting different herbaria of Iran and some ohter herbaria in the world (G, W, E, K). This work were completed with field obsertvation and various micromorphological investigations (Khatamsaz, 1992, 1994, 1999, 2000, 2001; Kazempour Osallo and Khatamsaz 1994; Khatamsaz and Joharchi 1996 and Azizian, Khatamsaz & Kasaian 2000).

The family has been variously divided into groups. Thus De Candolle (1845) recognized six subtribes in the tribe *Borageae* (=subfamily *Boraginoideae*), while Gürke (1897) separated seven tribes within *Boraginoideae*, Johnston (1924) only four and Riedl in Rechinger (1967) recognized three subfamily and seven tribes within *Boraginoideae* subfamily.

As far as the palynology of the group is concerned, Erdtman et al. (1961) claimed that the *Boraginaceae* is a stenopalynous family. However, the studies by Avertisian (1956), Clarke (1977), Sahay (1979), DÈiez (1984, 1991 & 1994), Ahn & Lee (1986), Popova (1995), Bigazzi (1998) and others have demonstrated that the family is one of the most eurypalynous, in which a large proporation of the species can be individully recognized by their palynological characters.

The persent study aimed to describe the pollen morphology of the Iranian *Boraginaceae*, to find out the inter-generic and specific relationships, and to solve some taxonomic problems.

Materials and Methods

Pollen material was obtained from the Central Herbarium of Iran (TARI), voucher specimens examined are given in table 1. The survey is based on light and scanning electron microscopy. The material was acetolysed conventionally (Erdtman, 1960) and all pollen samples were prepared for SEM according to Lynch et al. (1975) and they were sputtercoated with gold, then observed in SEM Leica S360. Thirty measurments for pollen size (P and E) were made for each sample. In general, the terminology follows the "Glossary" of Punt et al. (1994).

Results

General descriptions of the pollen

Pollen grains minute or small, occasionally medium-sized; 3 to 8 or 10 and poly heterocolpate; isopolar or heteropolar radiosymmetric; elliptic, rectangular or rectangular-elliptic, occasionally circular in equatorial outline, with or without constriction at the equator, and more or less circular in polar outline; prolate or perprolate, sometimes prolate-shperoidal. Pseudocolpus in general longer than colporus. Apertures are characteristic to each of the three subfamilies, i. e. in the *Ehretioideae* tricolporate, in the *Heliotropioideae* 6-heterocolporate, in the *Boraginoideae* 3-10 colporate and tricolporate with 3 alternating pseudocolpi in tribes *Eritricheae* and *Cynogloseae*, especially the length and width of colpi and pseudocolpi are variable. The surface patterns are mostly psilate, foveolate, scabrate and gemmate, sometimes sparsely reticulate at the poles or with granules around the apertures and the mesocolpium.

Based on palynological results, the morpholgy of each species is described below and their relevant measurments are presented in table 2.

Ehretia obtusifolia Hochst. ex DC.

Pollen grains shperoidal, P×E= 15.6-20.0×15.6-19.5 µm, mesocolpia slightly concave, 3-colporate. The tectum foveolate but coarsly rugulate in the central zone of the mesoclpia.

Table 1. Origin of the species used in pollen studies.

Species	Locality	Voucher no.
Alkanna orientalis	Azerbaijan: Sabalan mont. 2900 m.	13854
Alkanna bracteosa	Tehran: Abe-Ali, near Rude-hen, 2050 m.	12424
Anchusa strigosa	Kurdestan: Sanandaj, Khuroseh, 1650 m	1502
Arnebia fimbriopetala	Fars: 54 km Firouzabad to Shiraz, 1600 m.	41247
Arnebia linierfolia	Gorgan: 42 km moraveh Tape, Inchehbroun pass, 180 m.	55415
Arnebia decumbens	Hormuzgan: Bandar-abbas to Minab pass, rudan, 100 m.	68055
Arnebia grandiflora	Gorgan: between Golidaghi and Gonbad-Kavous, 600 m.	3634
Arnebia tubata	Khuzistan: 39 km. Ramhormuz to Darvishan. 790 m.	30951
Asperugo procumbens	Fars: Shiraz, Saadatabad, 1850 m.	9118
Buglossoides arvensis	Mazandaran: Siah-Bisheh, 39 km to Mazandaran, 2050 m.	69238
Caccinia strigosa	Mazandaran: Haraz road, Abegarm, 2250 m.	33137
Cerinthe minor	Azerbaijan: Sahand mont., between ligvan and Esparkhan, 2600 m.	30621
Cynoglossum creticum	Mazandaran: 5 km Alamdeh to Kojur, 110 m.	28125
Echiochilon persicum	Hormuzgan: Bandarabas, Geno mont., 280-700 m.	15324
Echium amoenum	Mazandaran: 2 km to kelardasht, 700 m.	69244
Ehretia obtusifolia	Balouchestan: Iranshahr, Sarbaz pass, Ahuran riverside. 1000 m.	70154
Heliocarya monandra	Esfahan: 10 km S. of Esfahan, Pinart, 1550-1800 m.	6539
Heliotropium europeaum	Gorgan: Between Almeh & Behkadeh, 1300 m.	14234
Heterocaryum laevigatum	Khorassan; 25 km SW. of Darreh-Gaz, Chehelmehr, 2000 m.	50844
Hormuzakia aggregata	Khuzistan: Aghajari, 180 m.	3295
Huyhia pulchra	Gilan: Asalem to Khalkhal, 1900 m.	27792
Lappula spinocarpos	Esfahan: Maymeh, 2000 m.	72910
Lepechiniella wendelboi	Mazandaran: 30 km S. of Ramsar, kuh-e Sefid, 3100 m.	51278
Lithospermum officinale	Khorassan: 25 km Sw. Dare -Gaz, Tandoureh, 1200 m.	50774
Microparacaryum intermedium	Tehran: Kavir protected Area, Siah-kuh, 1700 m.	17179
Moltkia coerulea	Semnan: 15 km Semnan to Firuzkuh, 1400 m.	58956
Moltkiopsis ciliata	Hormuzgan: Minab to Jask, km. 50, Ziarat, 100 m.	44038
Myosotis ramosissima	Azerbaijan: SW of Khalkhal, 1800 m.	27822
Nonea caspica	Gorgan: Golestan National park, Almeh, 1200 m.	10968
Nonea pulla	Azerbaijan: Arasbaran protected area, between Kharil & Makidi, 1800 m.	24985
Nonea persica	Fars: Shiraz, 150 km to Abadeh, 2040 m.	9036
Omphaldoes luciliae	Bakhtiari: Zardkuh, Tunel Kuhrang, 2600-3200 m.	57688
Onosma rostellatum	Fars: S. of Shiraz, 1650 m.	17794
Onosma orientalis	Kuhgilouyeh & Boyrahmad: Dogonbadan, near Abrigoon, 800 m.	38540
Onosma elwendicum	Tehran: Tehran, Garmdarreh, 1500 m.	27521
Paracaryum persicum	Fars: Shiraz, Hossein-abad, 1850 m.	46671
Paracaryum luristanicum	Luristan: Khorramabad, 1400 m.	25133
Phyllocara aucheri	Azerbaijan: 30 km S. of Khalkhal, 1500 m.	36274
Rochelia peduncularis	Tehran: Karaj, Palangabad, 1250 m.	8364
Solenanthus stamineus	Gilan: between Kushan and Amarlou, Jirandeh, 2000 m.	1682
Symphytum kurdicum	Kurdestan: 50 km Sardasht to Marivan, 1580 m.	29122
Trichodesma aucheri	Bakhtiari; Shahrkurd, Tang-e Said, Pirkuh, 2000 m.	62125

Table 2. Pollen characters of *Boraginaceae* species examined. Pollen shape (S), aperture number (AN), measurements (µm) of the polar (P) and equatorial (E) axes, shape index (P/E) and ornamentation (O).

Species	S	AN	P	E	P/E	O
Ehretia obtusifolia	Spheroidal	3-colporate	15.6-20.0	15.6-19.5	1-1.03	Foveolate
Heliotropium europaeum	Prolate	6-heterocoprate	26.5-34.0	19.0-26.5	1.0-1.3	psilate
Echiochilon persicum	Subprolate -spheroidal	3-colpate	14.60-17.40	9.61-13.3	1.3-1.5	Psilate-perforate
Arnebia fimbriopetala	Prolate	5-colporate	33.3-34.8	17.0-17.8	1.9-2.0	Psilate
Arnebia decumbens	Prolate	5-colporate	34.7-35.0	14.0-15.8	2.4-2.5	Psilate
Arnebia grandiflora	Prolate	5-colporate	35.3-36.0	18.3-19.5	1.8-1.93	Psilate
Arnebia tubata	Prolate	5-colporate	40.0-40.5	21.0-21.5	1.8-1.9	Psilate
Huynhia pulchra	Prolate	Polycolpate	32.3-32.5	18.0-18.5	1.7-1.8	Gemmate
Lithospermum officinale	Prolate	4-colporate	8.0-13.5	5.5-7.0	1.4-1.9	Psilate
Buglossoides arvensis	Prolate	5-colporate	14.5-18.0	8.5-13.0	1.4-1.7	Psilate
Moltkiopsis ciliata	Prolate	6-colporate	17.5-20.3	13.0-15.0	1.3-1.35	Psilate
Onsoma rostellatum	Prolate	3-colporate	12.15-14.3	7.83-10.5	1.35-1.55	Psilate
Onosma orientalis	Triangular	3-colporate	9.7-11.8	8.4-10.8	1.09-1.15	Psilate-gemmate
Onosma elwendicum	Triangular	3-colporate	10.3-12.15	8.1-9.9	1.0-1.23	Psilate-gemmate
Moltkia coerulea	Triangular	10-colporate	15.5-20.3	12.5-16.4	1.2-1.3	Psilate
Alkanna orientalis	Triangular	3-colporate	11.3-15.8	9.5-11.0	1.18-1.37	Psilate
Alkanna bracteosa	Triangular	3-colprate	13.2-14.0	9.0-10.2	1.3-1.5	Psilate
Cerinthe minor	Prolate	8-colporate	14.8-15.5	10.0-11.0	1.4-1.5	Gemmate
Echium amoenum	Triangular	3-coloporate	15.08-16.1	13-13.2	1.2-1.25	Gemmate
Nonea caspica	Prolate	4-6-colporate	24.4-25.0	21.0-21.6	1.2-1.6	Foveolate
Nonea pulla	Prolate	4-colporate	23.4-23.8	15.3-15.8	1.5-1.53	Psilate
Nonea persica	Prolate	4-colporate	23.6-24.1	18.2-18.5	1.2-1.3	Psilate
Symphytum kurdicum	Prolate	8-colporate	31.7-32.1	18.5-18.7	1.70-1.75	Psilate
Anchusa strigosa	Prolate	4-colporate	39.5-41.9	28.6-30.7	1.36-1.38	Psilate
Phyllocara aucheri	Prolate	3-colporate	35.6-39.0	26.0-29.5	1.3-1.4	Psilate
Hormuzakia aggregata	Prolate	6-colporate	25.8-27.5	23.5-24.8	1.0-1.1	Psilate
Asperugo procombens	Prolate	6-heterocolpate	9.16-11.0	3.7-6.0	1.83-2.58	Psilate
Myosotis ramosissima	Prolate	8-heterocolpate	10.8-13.5	6.6-8.8	1.53-1.66	Psilate
Heterocaryum laevigatum	Prolate	6-heterocopate	8.8-9.8	4.8-5.7	1.7-1.8	Psilate
Rochelia peduncularis	Prolate	6- heterocopate	14.2-16.8	5.5-9.2	1.8-2.5	Psilate
Lappula spinocarpos	Prolate	6- heterocopate	13.5-16.7	5.4-9.2	1.8-2.5	Psilate
Lepechiniella wendelboi	Prolate	6- heterocopate	8.2-13.5	3.6-5.3	2.3-2.5	Psilate
Trichodesma aucheri	Prolate	3-colporate	15.8-16.5	12.1-12.7-1.2-1.3	1.2-1.3	Psilate
Omphalodes luciliae	Prolate	6- heterocopate	7.5-14.8	4.5-8.2	1.6-1.8	Psilate
Cynoglossum creticum	Prolate	6- heterocopate	8.5-16.2	5.0-10.5	1.5-1.7	Psilate
Solenanthus stamineus	Prolate	6- heterocopate	11.5-13.8	9.5-10.5	1.2-1.3	Psilate
Paracaryum persicum	Prolate	6- heterocopate	15.3-17.0	8.9-11.6	1.4-1.7	Psilate-foveolate

Table 2. (Continued)

Paracaryum luristanicum	Prolate	6- heterocopate	11.0-12.1	7.15-8.4	1.4-1.5	Psilate
Microparacaryum intermedium	Prolate	6- heterocopate	8.35-9.76	4.0-5.37	1.8-2.07	Psilate
Caccinia strigosa	Subprolate-spheroidal	3-colpate	16.8-18.8	16.3-17	1.03-1.10	
Heliocarya monandra	Prolate	3-colpate	30.2-31.0	15.0-15.8	1.96-2.0	Gemmate

Heliotropium europaeum L.
Pollen grains elliptical (prolate), P×E=26.5-34.0×19.0-26.5 µm, isopolar, 6-heterocolporate (tricolporate with three alternating pseudocolpi); pseudocolpus narrower and longer than colpus. Tectum psilate or slightly perforate.

Echiochilon persicum (Burm. f.) Jonhnst. (Fig. 1)
Pollen grins subprolate-spheroidal, P×E= 14.60-17.40×9.61-13.30 µm, 3-colpate. Tectum psilate-perforate with granules around the colpi.

Arnebia fimbriopetala Stock (Fig. 2)
Pollen grains prolate concave, P×E=33.3-34.8×17.0-17.8 µm, 5-colporate; ectoapertures fairly long with tapering ends, broadest in the middle, membrane faintly granular. Tectum psilate.

Arnebia linearifolia DC. (Fig. 3)
Pollen grains prolate, slightly concave, P×E=33.5-34.0×18.5-19.4 µm, 5-colporate; ectoapertures fairly long with tapering ends, broadest in the middle, membrane faintly granular. Tectum psilate.

Arnebia decumbens (Vent.) Coss. & Kral. (Fig. 4)
Pollen grains prolate, slightly constricted, P×E=34.7-35.0×14.0-15.8 µm, aperture 5-colporate, ectoapertures long with tapering ends, broadest in the middle, membrane faintly granular. Tectum psilate.

Arnebia grandiflora (Trautv.) M. Pop. (Fig. 5)
Pollen grains very slightly constricted oval cirular prolate, P×E=35.3-36.0×18.3-19.5 µm, 5 colporate, ectoapertures long with tapering ends, broadest in the middle, membrane faintly granular. Tectum psilate.

Arnebia tubata (Bertol.) Samuelss. (Fig. 6)
Pollen grains oval circular prolate, P×E= 40.0-40.5×21.0-21.5 µm, 5-colporate, ectoapertures long with tapering ends, broadest in the middle, membrane faintly granular. Tectum psilate.

Huynhia pulchra (Roemer & Schultes) Greuter & Burdet (Fig. 7)
Pollen grains isopolar, prolate, P×E= 32.3-32.5 × 18.0-18.5 µm, 8 to 10 colporate, colpus 25.8 µm long. Tectum gemmate.

Lithospermum officinale L.
Pollen grains subisopolar-heteropolar, rectangular with the long sides constricted at the equator, P×E= 8-13 × 5-7 µm, 4-colporate, ectoapertures fairly long, with tapering ends, broadest in the middle, membrane faintly granular. Tectum psilate.

Buglossoides arvensis (L.) Johnston
Pollen grains isopolar, outline in equatorial view rectangular or elliptic, P×E=14.5-18.0× 8.5-13.0 µm, (4-)5(-6)-colporate, ectoapertures rather short, membrane regularly granular. Tectum psilate.

Moltkiopsis ciliata (Forsk.) Johnston (Fig. 8)
Pollen grains prolate, P×E= 17.5-20-3×13.0-15.0 µm; 6- colporate, colpi 13.0-14.8 µm long, ectoapertures long with tapering ends,

broadest in the middle, membranae faintly granular. Tectum psilate.

Onosma rostellatum Leahm.
Pollen grains prolate, isopolar, rectangular-ellitic in equatorial view, P×E=12.15-14.31 ×7.78-10.53 µm, 3-colporate. Tectum psilate.

Onosma orientalis L.
Pollen grains triangular, heteropolar, outline in equatorial view ovate, in polar view circular-triangular, P×E=9.7-11.8×8.4-10.8 µm, 3-colporate, ectoapertures long with tapering ends in larger pole. Tectum psilate-gemmate.

Onosma elwendicum Wettst.
Pollen grains triangular, heteropolar, outline in equatorial view ovate, in polar view cirular-triangular, P×E=10.3-12.15×8.1-9.9 µm, 3-colporate, ectoapertures long with tapering ends in larger pole. Tectum psilate-gemmate.

Moltkia coerulea (Willd.) Lehm. (Figs. 9-10)
Pollen grains heteropolar, triangular concave, obtuse, P×E= 15.5-20.3×12.5-16.4 µm; 10-colporate, ectoapertures long, broadest in the middle, membrane granular. Tectum psilate.

Alkanna orientalis (L.) Boiss. (Fig. 11)
Pollen grains heteropolar, triangular concave, obtuse, P×E=11.3-15.8×9.5-11.0 µm, 3-colporate, colpus 4.9-6.2 µm long. Tectum psilate.

Alkanna bracteosa Boiss. (Fig. 12)
Pollen grains heteropolar, triangular concave, obtuse, P×E= 13.2-14.0×9.0-10.2 µm; 3-colporate, colpus 8.0-10.5 µm long. Tectum psilate.

Cerinthe minor L.
Pollen grains isopolar, prolate, P×E=14.8-15.5×10.0-11.0 µm; 8-colporate, colpus 7.5-8 µm long, widest at the equator, abruptly tapering to the poles and cross-shaped, the side tips of them connected with each other. Tectum gemmate.

Echium amoenum Fisch. & Mey. (Fig. 13)
Pollen grains heteropolar, triangular, obtuse, P×E= 15.8-16.1×13-13.2 µm; 3-colporate, colpus 9.29 µm long. Tectum gemmate.

Nonea caspica (Willd.) G. Don (Fig. 14)
Pollen grains isopolar, prolate, obtuse, P×E= 24.4-25.0×21.0-21.6 µm; 4 to 6- colporate, colpus 15.7 µm long. Tectum psilate, but foveolate in equator.

Nonea pulla (L.) DC. (Fig. 15)
Pollen grains isopolar, prolate, obtuse, P×E= 23.4-23.8×15.3-15.8 µm; 4-colporate, colpus 14.2-14.7 µm long, connected with each other at the equator. Tectum psilate.

Nonea persica Boiss. (Fig. 16)
Pollen grains isopolar, prolate obtuse, P×E= 23.6-24.1×18.2-18.5 µm, 4-colporate, colpus 10-10.5 µm long. Tectum psilate, foveolate in equator.

Symphytum kurdicum Boiss. (Fig. 17)
Pollen grains isopolar, prolate or subprolate, situated at the equator, obtuse, P×E=31.7-32.1×18.5-18.7 µm, 8-colporate, rarely 9 or 10-colporate; colpus relatively short and narrow, 12.7-12.9 µm long,pore protruded, costa prominent. Tectum psilate to subgemmate.

Anchusa strigosa Labill. (Fig. 18)
Pollen grains large, isopolar, prolate, obtuse, P×E=39.5-41.9×28.6-30.7 µm, 4-colporate, zonocolporate; colpus 18.1-18.5 µm long, endoaperture lalongate. Tectum thick at the mesocolpium but thinner at the poles, ornamentation psilate with equatorial reticulum.

Phyllocara aucheri (DC.) Gusuleac
Pollen grains isopolar, prolate, obtuse, P×E= 35.6-39.0 × 26.0-29.5 µm, 3- colporate; colpus short. Tectum psilate with equatorial reticulum.

Hormuzakia aggregata (Lehm.) Gusuleac
Pollen grains isopolar, prolate, obtuse, P×E=25.8-27.5×23.5-24.8 µm, 6-colporate,

zonocolporate. Tectum psilate but reticulate at the equator.

Asperugo procumbens L. (Fig. 19)
Pollen grains minute, isopolar, prolate, slightly constricted at the equator, P×E= 9.16-11.0×3.7-6.0 µm, 6-heterocolpate, subterminal and narrow single ectocolpus, and shorter and rhombic in compound ectocolpi, endoapertures lalongate and situated at the equator. Tectum psilate with granules around the colpi.

Myosotis ramosissima Rochel ex Schultes
Pollen grains minute, isopolar, prolate, P×E= 10.8-13.5×6.5-8.8 µm, 8- hetercolpate, terminal or subterminal and narrow simple colpi and shorter and wider compound ectocolpi. Tectum psilate with granules around the colpi.

Heterocaryum laevigatum (Kar. & Kir.) DC. (Fig. 20)
Pollen grains minute, ispoloar, prolate, P×E= 8.8-9.8×4.8-5.7 µm, 6- heterocolpate; terminal or subterminal and narrow simple colpi, 7.51-8.82 µm; and shorter and wider compound ectocolpi, 4.55-5.37 µm, long. Tectum psilate with few granules around the colpi.

Rochelia peduncularis Boiss. (Fig. 21)
Pollen grains small, prolate, P×E=14.2-16.8×5.5-9.2 µm, 6- heterocolpate, outline elliptic and constricted at the equatorial view and circular-hexagonal in polar view; terminal 3 ectoaperture with 11.62-13.0 µm long and 3 subterminal endoapertures with 8.5-9.8 µm long. Tectum psilate, with granules around the colpi.

Lappula spinocarpos (Forssk.) Ascherson & O. Kuntze (Fig. 22)
Pollen grains minute, prolate, P×E=13.5-16.7×5.4-9.2 µm, outline rectangular-elliptic and very constricted at the equator in equatorial view and circular-hexagonal in polar view, 6-heterocolpate, 3 terminal and narrow simple ectocolpi and 3 subterminal and wider compound ectocolpi. Tectum psilate, with granules around the colpi.

Lepechiniella wendelboi Riedl (Fig. 23)
Pollen grains minute, prolate, P×E= 8.2-13.5 ×3.6-5.3 µm, outline rectangular-elliptic and constricted at the equator and circular in polar view. 6-heterocolpate, 3 terminal and narrow simple ectocolpi and 3 subterminal and wider compound ectocolpi. Tectum psilate, with few granules around the colpi.

Trichodesma aucheri DC. (Fig. 24)
Pollen grains prolate, P×E=15.8-16.5×12.1-12.7 µm, obtuse, 3-colporate; colpus subterminal, 13-13.5 µm long. Tectum psilate.

Omphalodes luciliae Boiss.
Pollen grains minute, prolate, P×E=7.5-14.8×4.5-8.2 µm, outline rectangular-elliptic and more or less constricted at the equator. 6-heterocolpate, 3 terminal and narrow simple ectocolpi and 3 shorter and wider compound ectocolpi. Tectum psilate, with one line of granules around the colpi.

Cynoglossum creticum Miller
Pollen grains minute, prolate, P×E=8.5-16.2×5.0-10.5 µm, outline elliptic or rectangular-elliptic in equatorial view and circular-hexagonal in polar view. 6-heterocolpate, 3 subterminal and narrow simple ectocolpi and wider and shorter compound ectocolpi with endoapertures lalongate. Tectum psilate, with granules around the colpi.

Solenantuhs stamineus (Dest.) Wettst.
Pollen grains minute, prolate, P×E=11.5-13.8×9.5-1.5 µm, outline at the equatorial view and more or less hexagonal in polar view. 6-heterocolpate, 3 subterminal and narrow ectoapertures with ectocingulum, and 3 shorter endoapertures lalongate. Tectum psilate with granules around the colpi.

Paracaryum persicum (Boiss.) Boiss. (Figs. 25-26)

Pollen grains minute, prolate, P×E=15.3-17×8.9-11.6 µm, outline elliptic in equatorial view and hexagonal in polar view. 6-heterocolpate, 3 subterminal and narrow ectoapertures wider at the equator, and 3 shorter endoapertures lanlongate. Tectum psilate-foveolate, thick around the apertures.

Paracarym luristanicum Nab. (Figs. 27-28)

Pollen grains minute, P×E=11.0-12.1×7.15-8.4 µm, outline elliptic in equatorial view and hexagonal in polar view. 6-heterocolpate, 3 subterminal and narrow ectoapertures wider at the equator, and 3 shorter endoapertures lalongate. Tectum psilate, thick and with granules around the apertures.

Microparacaryum intermedium (Fresen.) Hilger & Podlech (Figs. 29-30)

Pollen grains minute, P×E=8.35-9.76×4.0-5.37 µm, prolate, slightly constricted at the equator. 6-heterocolpate, 3 subterminal and narrow ectoapertures and 3 endoapertures lalongate. Tectum psilate.

Caccinia strigosa Boiss. (Fig. 31)

Pollen grains minute, P×E=16.8-18.8×16.3-17.0, subprolate-spheroidal, circular, in equatorial and polar views. 3-colpate; colpus jointed at the polar. Tectum psilate.

Heliocarya monandra Bge. (Fig. 32)

Pollen grains prolate, isopolar, P×E=30.2-31.0×15.0-15.8 µm, 3-colpate, colpus 26.7 µm long. Tectum gemmate.

Discussion

The tricolporate condition of *Ehretia obtusifolia* is the most primitive in the Iranian *Boraginaceae*. These studies improve Sahay (1979) view, that the pollen grains shape in *Heliotropioideae* is similar to that of the *Ehretioideae* and pseudocolpus appears such as in *Boraginoideae* seems to be at an intermediate position between the two subfamilies.

From the tricolporate type two lines of palynological phylogeny are presumed: one is the pseudocolpate line in which the tricolporate aperture remained unchanged and three pseudocolpi were interpolated between the adjacent colpi or at the mesocolpia. This line includes the subfamily *Heliotropioideae* and the tribes *Eritrichieae* and *Cynoglosseae* of subfamily *Boraginoideae*. Another is non-pseudocolpate line in which the number of aperture increased and gave rise to 4, 6, 8 or 10 -colporate types. This line includes the tribes Lithospermeae and *Anchuseae* of the *Boraginoideae* (Ahn & Lee 1986).

According to Johnston (1924), the *Lithospermeae* apperas to be evolved from some primitive members of *Heliotropioideae* or some specialized members of *Ehretioideae*, the present study supports the latter view.

The pollen morphology supports transfer of *Echiochilon* from *Eritrichieae* (Riedl in Rechinger 1967) to *Lithospermeae* and transfer of *Myosotis* to *Eritrichieae*.

According to the present study *Mattiastrum* and *Paracaryum* are synonymus and also the seperation of *Microparacaryum* from them is supported. (Hilger et al. 1985).

On the basis of corolla structure, Johnston (1954) suggested a position of *Buglossoides* distant from *Lithospermum* and Clark (1977) accepted Johnston's treatment, this study supports this view.

Pollen morphology suggests that the genera *Hormuzakia* and *Phyllocara* and *Anchusa* are justified (Diez 1994). The present study confirm Gruter's (1981) separation of *Huynhia* from *Arnebia*.

Pollen morphology of 42 species from 32 genera suppors Popova (1995), which the tribe *Lithospermeae* was investigated most extensively, and the diversity of palynomorphological types of the species in this tribe. It also shows intrageneric differences in the pollen grains of the members of *Arnebia*, *Onosma*, *Echium*, and *Symphytum*. However the palynomorphological data support the Popova's idea (1995) that the tribes *Echieae* and *Cerintheae* are distinct and can not be included in the tribe *Lithospermeae*.

References

Ahn, young Mee & Lee, Sangtae 1986: A palynotaxonomical study of the Korean Boraginaceae. -Kor. J. Plant Tax. 16 (3): 199-215.

Avertisian, E. M. 1956: Morphologie des micospores de Boraginaceae. -Tr. Botan. Inst. Akad. Nauk. Arm. SS. R. 10: 7-66.

Azizian, D., Khatamsaz, M. & Kasaian, J. 2000: The taxonomic significance of leaf anatomy in the genus Onosma L. (Boraginaceae) in Iran. -Iran. Journ. Bot. 8(2): 167-180.

Bigazzi, M. & Selvi, F. 1998: Pollen morphology in the Boraginaceae. -Plant. Syst. and Evol. 213: 121-151.

Clarke, G. C. S. 1977: The northwest European pollen flora. 10. Boraginaceae. -Rev. Palaeobot. Palynol. 24: 50-101.

De Candolle, A. P. 1845: Prodromus Sytematis Naturalis Regni Vegetabilis, vol. 9 -Paris.

Diez, M. J. 1984: Contribution al Atlas polinico de Andalucia Occidental, I. Boraginaceae. -Lagoscalia 13: 147-171.

— & Valdés, B: 1991: Pollen morphology of the tribes Eritrichieae and Cynoglosseae (Boraginaceae) in the Iberian Peninsula and its taxonomic significance. -Bot. Jour. Linnean Soci. 107: 49-66.

— — 1994: A general survey of pollen types in Anchusa L. (Boraginaceae) in relation to taxonomy. -Acta Bot. Gallica 141 (2): 233-242.

Erdtman, G. 1960: The acetolysis method. A revised description. -Sven. Bot. Tidskr. 54: 561-564.

— , Berglund, B. & Praglowski, J. 1961: An introduction to a Scandinavian pollen flora. -Grana palynologica: an international Journ. Palynol. 2: 3-92.

Gretur, W. & Burdet, 1981: Med-checklist Notulae 3. -Willdenowia 11: 37.

Gïrke, M. 1897: Boraginaceae in Engler & Prantl, Die Naturelichen Pflanzenfamilien IV: 71-131.

Hilger, H., Balzer, M., Frey, W. & Podlech, D. 1985: Heteromerikarpie und Fruchtpolymorphismus bei Microparacaryum, gen. nov. (Boraginaceae). -Pl. Syst. Evol. 148: 291-312.

Johnston, I. M. 1924: Studies in the Boraginaceae. 2. A Synopsis of the American native and immigrant borages of the subfamily Boraginaceae. -Cont. Gray Herb. Harv. 70: 1-61.

— 1954: Studies in the Boraginaceae 27, some general observations concerning the Lithospermeae. -J. Arn. Arb. 35: 158-166.

Kazempour Osallo. Sh. & Khatamsaz, M. 1994: Pollen morphology of the genus Echiochilon (Boraginaceae) in Iran. -Iran. Journ. Bot. 6 (2): 247-249.

Khahtamsaz, M. 1992: Onosma strausii as a new combination and some new plant records in Iran. -Iran. Journ. Bot. 5 (2): 75-82.

— 1994: A new taxon and new records of the genus Paracaryum (Boraginaceae) from Iran. -Iran. Journ. Bot. 6 (2): 227-233.

— 1999: Three new species from Boraginaceae in Iran. -Iran. Journ. Bot. 8(1): 1-8

— 2000: Two new species from Rosaceae and Boraginaceae in Iran. -Iran. Journ. Bot. 8 (2): 181-186.

— 2001: Flora of Iran, Boraginaceae (in press).

— & Joharchi, M. 1996: Some new records of Boraginaceae from Iran. -Iran. Journ. Bot. 7 (1): 11-14.

Lynch, S. P. & Webster, G. L. 1975: A new technique of preparing pollen for Scaning Electron Microscopy. -Grana 15: 127-136.

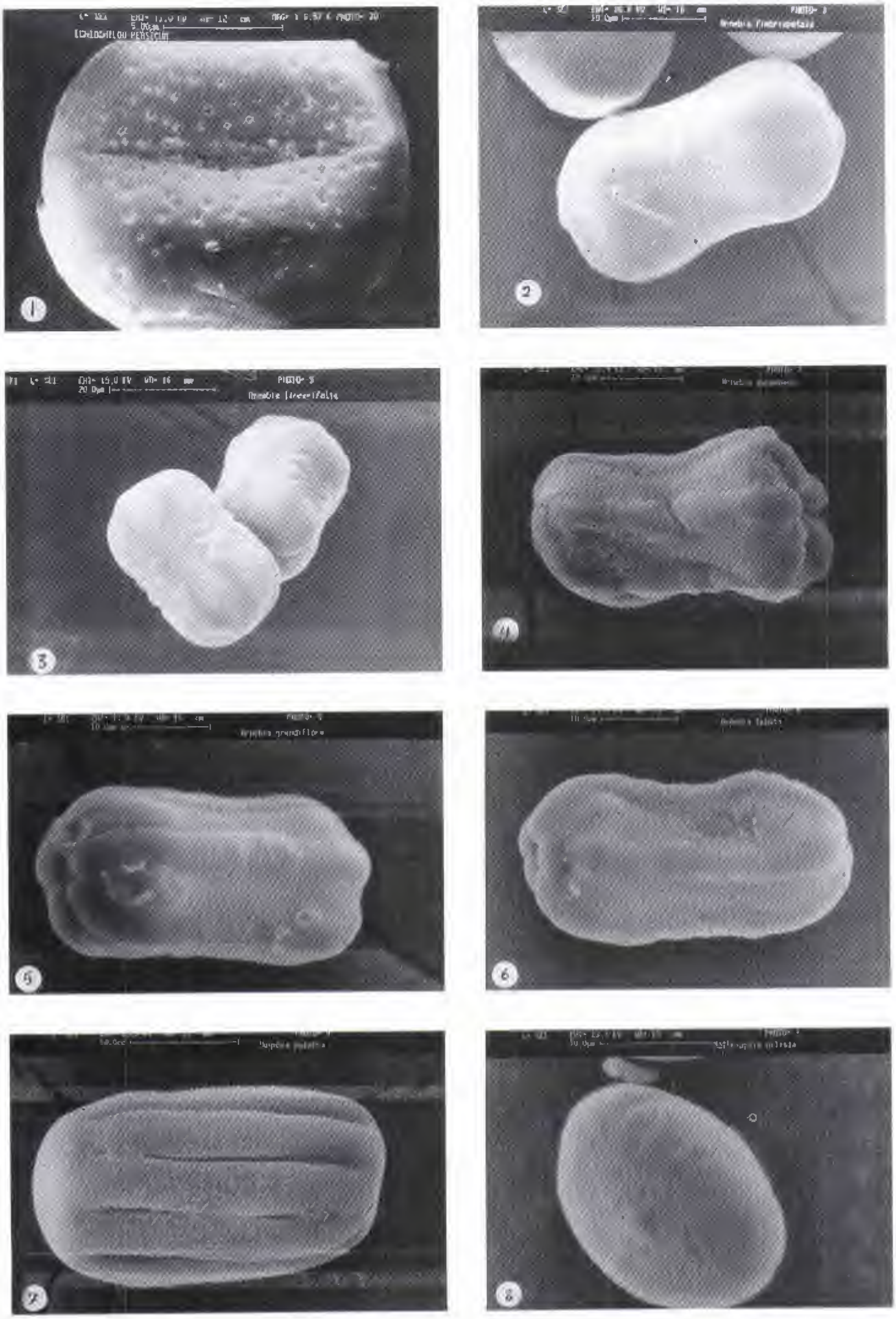
Popova, T. N. & Zemskova, E. A. 1995: Palynomorpholgy study of some species of Boraginaceae. -Bot. Zhur. st. Petressb. 80 (10): 1-13.

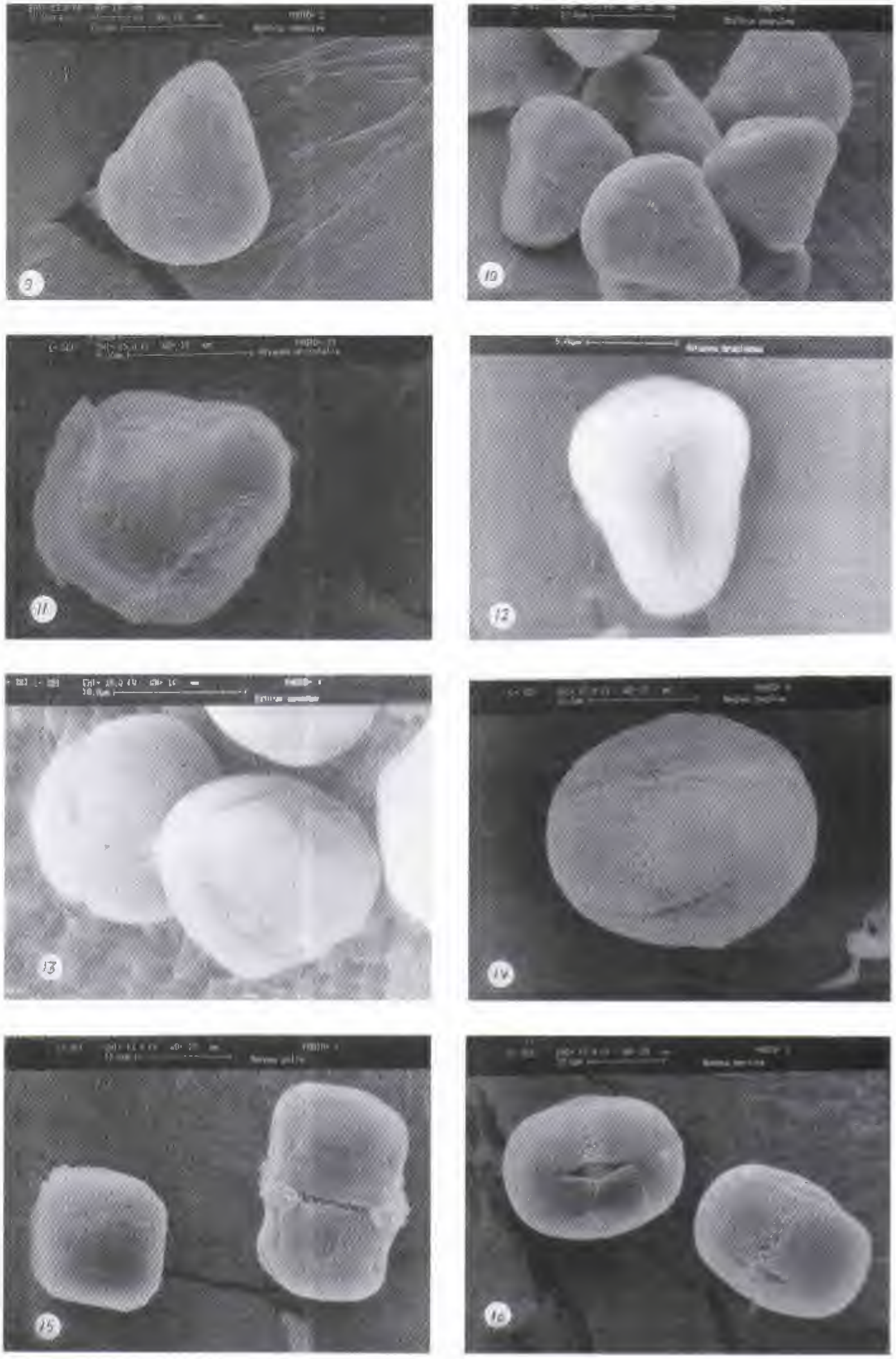
Punt, W., Blackmore, S., Nilsson, S. & Thomas, A. 1994: Glossary of pollen and spore terminology, Lab. Palaebt. Palynol. Contr. ser I. Lpp. Foundation, -Utrect.

Riedl, H. in Rechinger, K. H. (ed.) 1967: Flora Iranica no. 48. Boraginaceae. -Graz.

Sahay, S. K. 1979: Palynotaxonomy of Boraginaceae and some other families of Tubiflorae. -Biol. Mem 4: 117-250.

Figs. 1-32: Scaning electron microscopic photographs of the Boraginaceous pollen grains. -Fig. 1. *Echiochilon persicum*; Fig. 2. *Arnebia fimberiopetala*; Fig. 3. *Arnebia linarifolia*; Fig. 4. *Arenbia decumbens*; Fig. 5. *Arnebia grandiflora*; Fig. 6. *Arnebia tubata*; Fig. 7. *Huynhia pulchra*; Fig. 8. *Moltkiopsis ciliata*; Fig. 9-10. *Moltkia coerulea*; Fig. 11. *Alkanna orientalis*; Fig. 12. *Alkanna bracteosa*; Fig. 13. *Echium amoenum*; Fig. 14. *Nonea caspica*; Fig. 15. *Nonea pulla*; Fig. 16. *Nonea persica*; Fig. 17. *Symphytum kurdicum*; Fig. 18. *Anchusa strigosa*; Fig. 19. *Asperugo procumbens*; Fig. 20. *Heterocaryum laevigatum*; Fig. 21. *Rochelia peduncularis*; Fig. 22. *Lappula spinocarpos*; Fig. 23. *Lepechiniella wendelboi*; Fig. 24. *Trichodesma aucheri*; Fig. 25-26. *Paracaryum persicum*; Fig. 27-28. *Paracaryum luristranicum*; Fig. 29-30. *Microparacaryum intermedium*; Fig. 31. *Caccinia strigosa*; Fig. 32. *Heliocarya monandra.*

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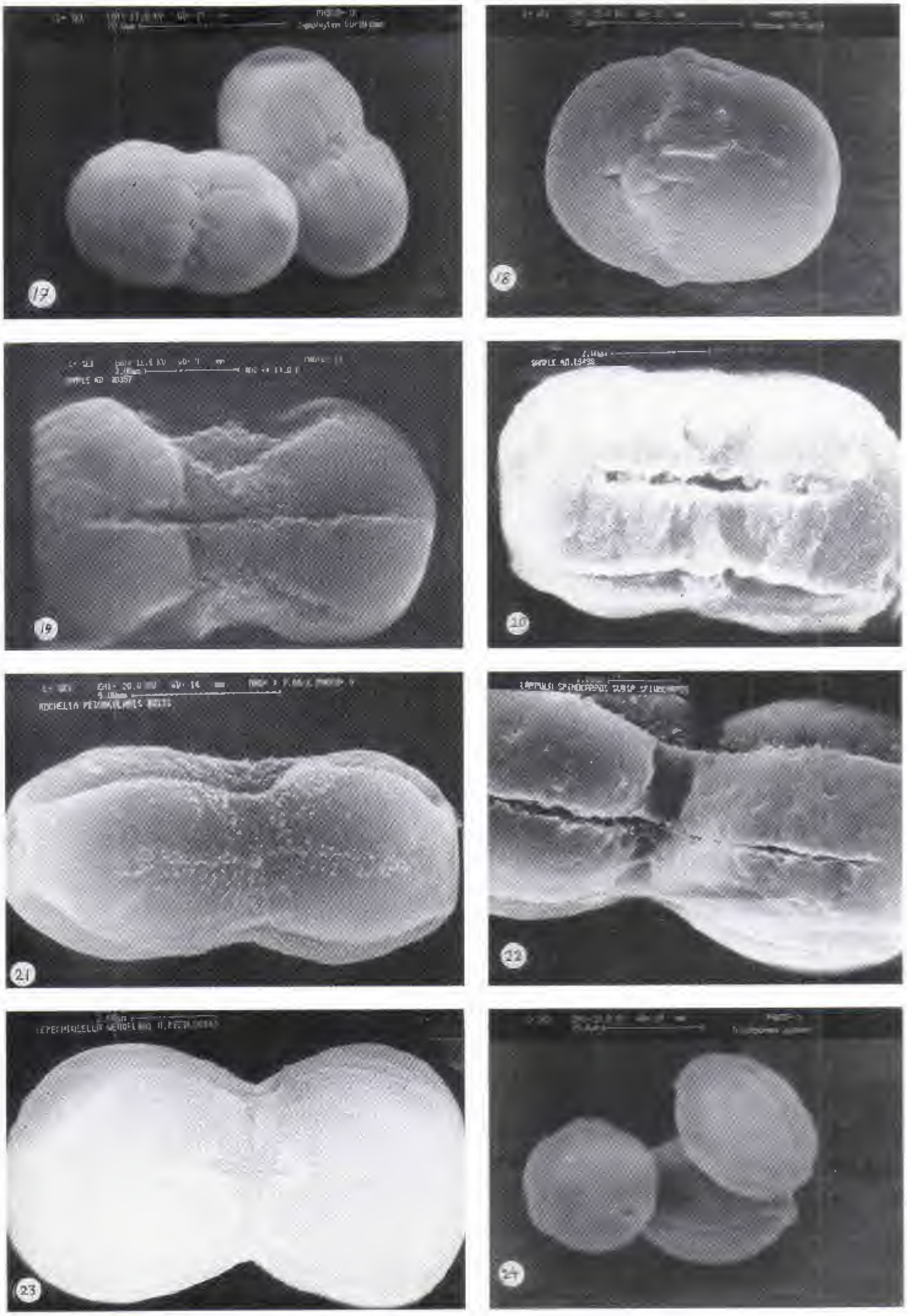
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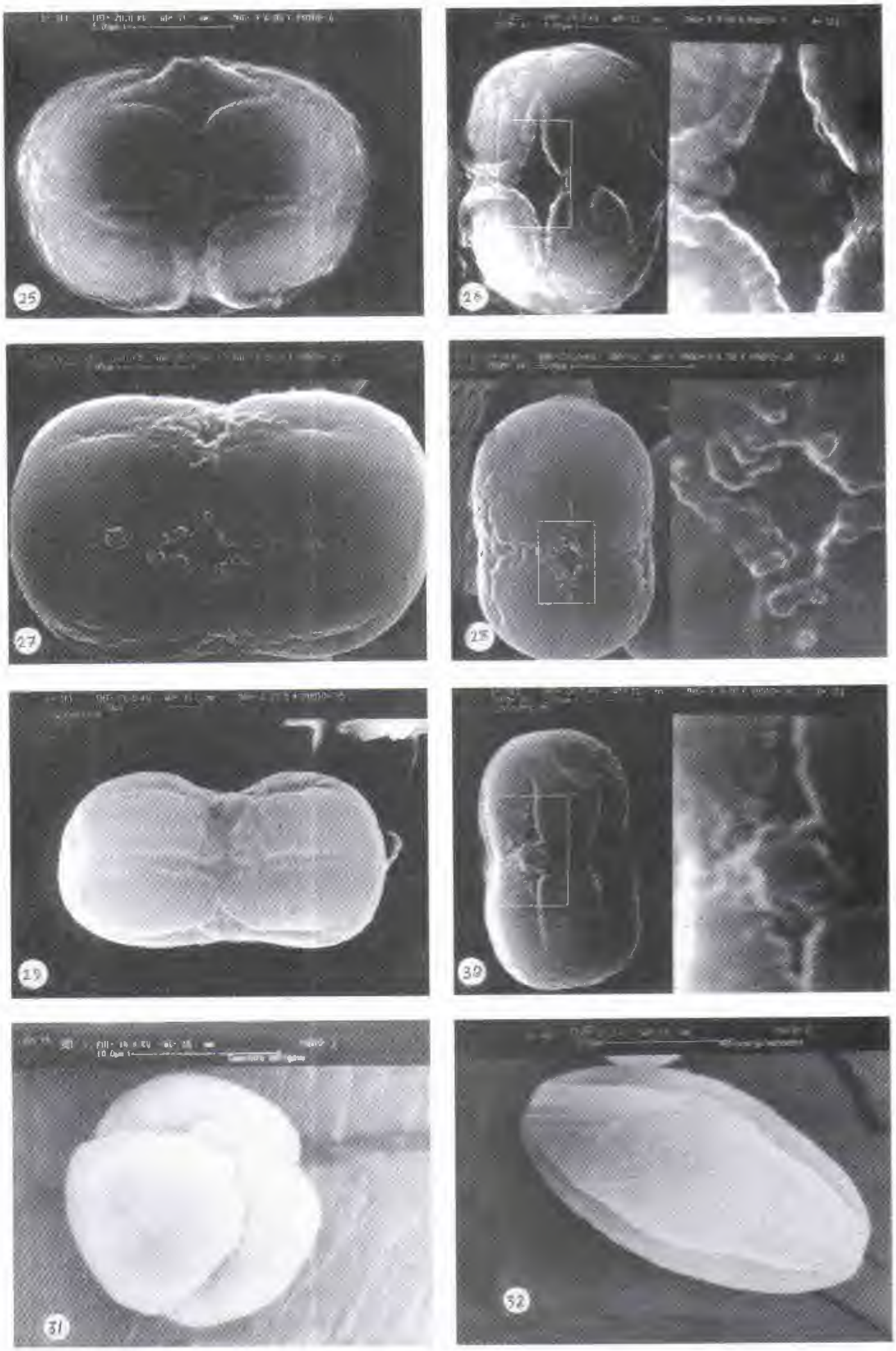
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