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THE EOCENE AND EARLY OLIGOCENE FLORAS OF THE RUSSIAN PLAIN AND THEIR RELATION TO THE PALAEOFLORAS OF CENTRAL EUROPE

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ABSTRACT. The floras of Tim and Pasekovo in Central Russia, the Stare Sedlo formation (Bohemia) in the Czech Republic and the Zeitz complex in Germany link the paratropical Middle Eocene floras of the Ukraine, Russia, Kazakhstan and Germany with the Early Oligocene Haselbach – like floras of the Weisselster "Bezirk Leipzig" basin and Svetlogorsk (=former Rauschen) in Kaliningrad oblast of western Russia (=Zamland). The Pasekovo flora (Voronezh oblast) in the Central Russian Upland reveals the first definite inclusion of a temperate (= "arctotertiary" or "turgaic") floristic element. The floristic connections with the Central European palaeofloras of Czech Republic and Germany are discussed. A late Terminal Eocene age for both the Pasekovo and Tim palaeofloras is proposed in preference to the Early Oligocene age suggested by previous authors.

KEY WORDS: Palaeogene, Russia, Central Europe, leaf compression and impression, stomata, epidermis

INTRODUCTION

Between 1986 and 1999 I contributed to a number of papers describing the Palaeogene floras from the European part of the former Soviet Union (currently divided between the Ukraine and Russia) (Vikulin 1986, 1987a, b, c, 1990, 1996a, b, c, 1999, Vikulin & Pneva 1986, Vikulin & Bobrov 1987, Vikulin & Yakovleva 1998, Vikulin *et al.* 1986, Proskurin & Vikulin 1990, Zhilin & Vikulin 1986). In all of these I considered both the sandstone Tim flora near the Russian town of Kursk (containing *Steinhauera subglobosa* C. Presl and *Quercus pseudoneriifolia* Vikulin) and the brown coal Pasekovo flora (in the south of Voronezh oblast (with *Rhodomyrtophyllum pasekovicum* Vikulin, *Laurophyllum hypolanatum* Rüffle, *Apocynophyllum helveticum* Heer and *Epacridicarpum rossicum* Proskurin & Vikulin) as belonging to the terminal Upper Eocene (in contrast with older opinions which had considered it to be Oligocene, or even Early Miocene). In Western and Eastern Europe species of such thermophilous taxa as *Rhodomyrtophyllum* and *Steinhauera* belong to the stratigraphical interval delimiting the terminal Eocene and are index taxa for the interval defining the middle to late Eocene (Mai 1996, Walther 1994).

DISCUSSION

Recent investigations in Central Europe, mainly in the Czech Republic (Bohemia) and Germany (Haselbach and Zeitz-complex) have afforded much palaeobotanical data. In particular may be cited Sokolov and Karlovy Vary- the so-called Stare Sedlo Formation – Upper Eocene (Knobloch 1963, 1988, Knobloch *et al*. 1996, Kvaček & Walther 1988), 2) Geiseltal-Middle Eocene (Mai 1976, Mai 1996, Rüffle 1976, Rüffle & Jänichen 1976, Rüffle *et al*. 1976, Walther 1994), 3) the Weisselster basin, the so-called "Zeitz floristic complex" – Upper Eocene (Mai & Walther 1985, Walther 1994), and 4) the Weisselster basin, the so- called "Haselbach floristic complex" – Lower-Middle Oligocene (Mai 1996, Mai & Walther 1978, Walther 1994).

The papers mentioned above make it possible to indicate the biostratigraphical relations between the Palaeogene floras of Germany, Bohemia and Central Russia. The identifications of *Juglans*, *Salix*, *Cornus*, *Echitonium*, *Rhamnus*, *Cassia*, *Betula*, *Corylus*, *Carpinus*, and some other leaf remains with an entire margin were very debatable both for Tim as well as for Stare Sedlo, and were responsible for earlier researchers making a Miocene-Oligocene estimation of the age of the floras concerned. It now appears that all of these leaves are representatives of the Fagaceae and Lauraceae, although the systematic position of some of them is still open to question (Kvaček & Walther 1988, Vikulin 1977a, b, c, 1990, Vikulin 1999). Prevalent in the floras of the Tim formation in Central Russia and the Stare Sedlo Formation in Bohemia are such entire margined leaves, as e. g. *Quercus pseudoneriifolia* Vikulin (Pl. 1, fig. 2; Pl. 2,

fig. 3) and *Trygonobalanopsis rhamnoides* (Rossm.) Kvaček et Walther. Floras of the Tim and Pasekovo Formations are known from 4 major regions of the Central Russian Upland and Northern Ukraine: 1) in the area east of Kursk (Tim, Bukreevy Barmy, Solntsevo, Lesch' Plota localities); 2) north of Kursk: Molotychi and allied localities, close to Ponyri railway station on the border with Orel oblast); 3) northern Volyn': Karpicha, Tochilnitsa and Kochetyn in the district of Zhitomir (at present in the Ukraine) and adjoining the western part of Kursk region; 4) in the south of Voronezh oblast: in Pasekovo brown coal lignite.

Although the Tim flora has been known since the first half of the 19th century, the systematic position of most of the leaf impressions did not become clear until the recent revision of the Tim and Pasekovo floras (Vikulin 1987a, b, c, 1990, 1999). The flora, discovered in the 1920s, at the brown coal pit locality at Pasekovo (49°45´N, and 39°48´E), in the Central Russian Upland, Mikhailovsky district, Voronezh oblast, Western (=European) Russia (Fig. 1) of terminal Upper Eocene age in the upper part of the Kasianovskaya formation (Semenov 1965, 1972), together with the Late Eocene-?Early Oligocene flora in the vicinity of Pasekovo village (near Lebediv hamlet in Voronezh oblast, had been monographically described earlier by S.V. Vikulin as a part of his Ph D (Candidate Nauk) research (Vikulin 1987a, b, c, Vikulin, Gromyko & Proskurin 1986, Vikulin & Pneva 1986, Vikulin & Yakovleva 1998, Proskurin & Vikulin 1990). The Pasekovo flora is characterized by leaf imprints with "a mummified leaf adjustment" (=compression) in an excellent state of preservation revealing their micromorphology, i. e. stomata (Pl. 6, figs 25, 27, 28) and such epidermal features as papillae (Pl. 6, figs 21–24) and trichome bases (Pl. 4, fig. 14; Pl. 5, figs 15–20; Pl. 6, figs 21–28) as well as an exceptionally well-preserved ultra-

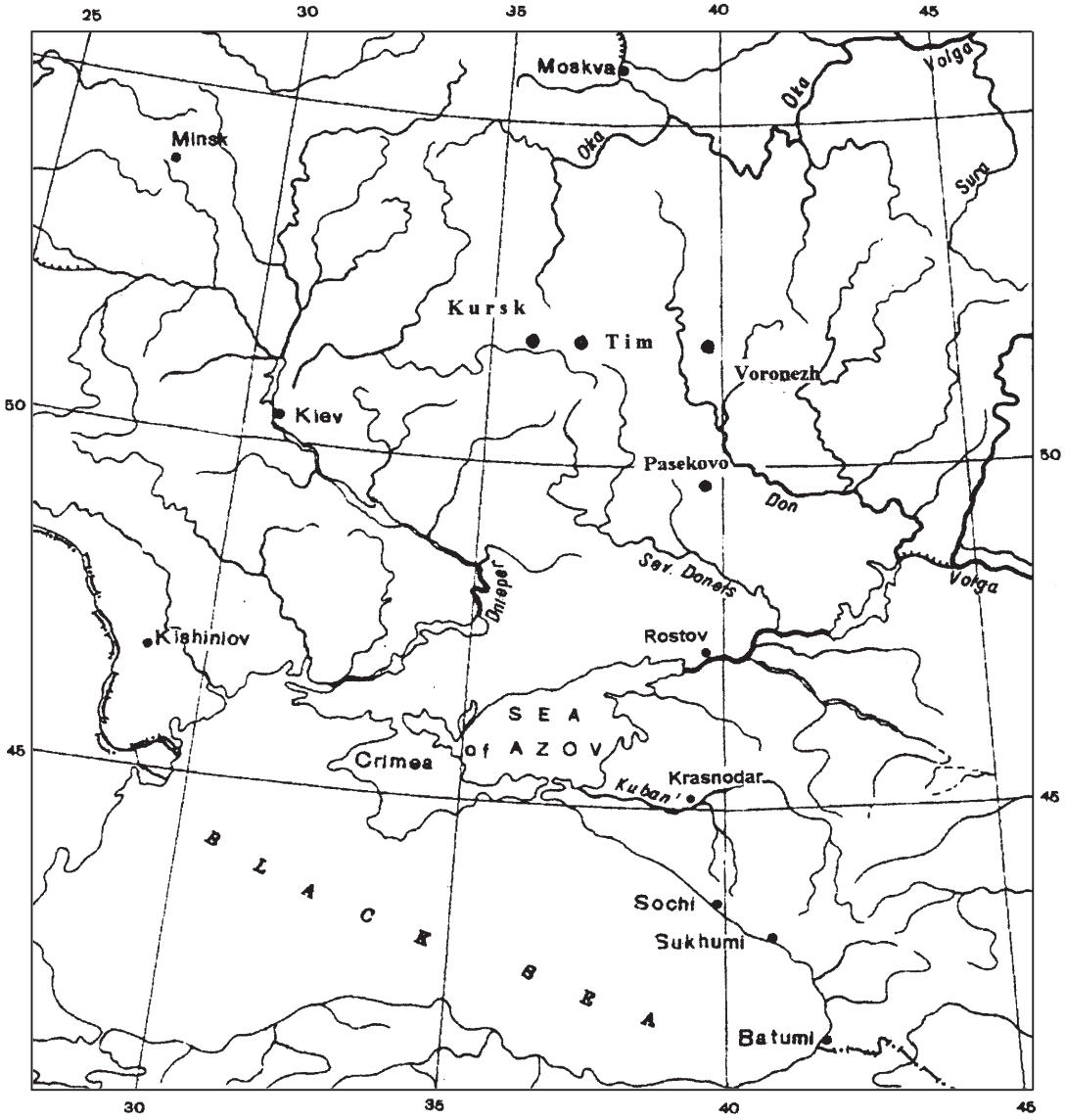

Fig. 1. Geographical location of Tim sandstone (Kursk region) and Pasekovo (Voronezh region) brown coal occurrences of Russia

structure of fossil chloroplasts in the leaf tissue remains, i.e. in the partly preserved mesophyll cells (Pl. 4, fig. 13). These uniquely well preserved features of cell ultrastructure are comparable with those of the famous well-preserved *Clarkia* leaf flora from Miocene lake deposits in eastern Washington and adjacent Idaho, USA (Smiley & Rember 1985 a, b). The Pasekovo flora is still awaiting publication as a monograph, with the exeption of *Quercus pseudoalexeevii* Vikulin*, Nyssa zhilinii* Vikulin et Pneva*, Epacridicarpum rossicum* Proskurin et Vikulin (Vikulin 1987a, b, c, d, 1990, 1991, 1996a, b, c, Vikulin & Pneva 1986, Vikulin & Yakovleva 1998, Vikulin *et al*. 1986, Proskurin & Vikulin 1990). There are many species which allow us to compare the Tim formation floras with the Early Oligocene ones of Kazakhstan, Azerbaijan and the Ukraine. One of them is the controversial "*Quercus neriifolia*". There is a gap during the Early-Middle Miocene during which this species is absent. Earlier I had suggested that a fossil bearing this name might represent one of two species: a Neogene one, whose holotype derives from Oeningen, western Germany, and an undescribed Palaeogene species, dominant in the Tim and Molotychi palaeofloras of the Kursk area (Pl. 1, fig 2; Pl. 2, fig. 5) and of some terminal Eocene Volynian floras from northern Ukraine (Zhitomir oblast). I had substantiated this suggestion by describing the Palaeogene species as *Q. pseudoneriifolia* Vikulin (Vikulin 1987). This species is an index species for the terminal Late Eocene-Early Oligocene interval. The Upper Miocene type of *Q. neriifolia* is actually a species of *Persea*. Furthermore, some Neogene specimens given this name belong to *Myrica* (Vikulin 1987a, b). But there are exceptionally strong links connecting the Pasekovo and Tim-like floras of Russia with the Stare Sedlo and Zeitz floristic complexes of the Upper Eocene on the one hand, and the Haselbach floristic complex of the Early Oligocene on the other. Amongst the Eocene elements are *Steinhauerea subglobosa* C. Presl, *Rhodomyrtophyllum pasekovicum* Vikulin (Pl. 4, figs 12–14, Pl. 5, figs 15–20, *Laurophyllum hypolanatum* Rüffle (Pl. 6, figs 21–28). *R. pasekovicum* provides a first record of Tertiary mummified leaves of the Myrtaceae in the former Soviet Union (Vikulin 1999). The fossil genus *Rhodomyrtophyllum* is a typical Palaeotropical thermophilous evergreen element of the Late Eocene assemblage of Central Europe: the Zeitz complex, Central Germany with its 48 rich localities (Walther 1994, Wilde 1989: 73, Mai & Walther 1985: 102–107, Rüffle & Jähnichen 1976: 306–336). It is evident from the lists below that the Tim Formation shows very close agreement with the Stare Sedlo floristic complex of the Upper Eocene (7 identical and 6 closely related species), whereas in the Zeitz Mid-Eocene floristic complex, as well as in the Early Oligocene Haselbach floristic complex, only 3 identical and 5 very closely related species were recorded. The identical and closely related species of the above-mentioned floras may be divided as follows**:**

TIM–STARE SEDLO COMPARISON

Identical species: 1) *Pinus stroboides* (Rossm.) Mai, 2) *Sequoia abietina* (Brongn.) E. Knobloch, 3) *S. couttsiae* Heer, 4) *Taxodium* cf. *balticum* Sveshn. et Budants, 5) *Steinhauera* (= ? *Altingia*) *subglobosa* C. Presl. 6) *Quercus pseudoneriifolia* Vikulin (Pl. 1, fig. 2; Pl. 2, fig. 5), 7) and *Trigonobalanopsis rhamnoides* (Rossm.) Kvaček et Walther. Closely related species: 1) *Paracyclea populifolia* (Krasn.) Vikulin, fam. Menispermaceae cf. *Menispermophyllum* from Stare Sedlo, 2) *Castanopsis* sp., 3) *Castanopsis timensis* (Palib.) Iljinskaja (Pl. 3, fig. 8), 4) *Ficus sokolovii* Palib. cf. *Ficophyllum* from Stare Sedlo, 5) *Cinnamimum lartetii* Watel., 6) *Neolitsea kryshtofovichii* Baik. (Pl. 1, fig. 1).

TIM–ZEITZ-COMPLEX
(Upper Eocene floristic complex comparison)

Identical species: *Steinhauera subglobosa* C. Presl, 2) *Sequoia abietina* (Brongn.) E. Knobloch, 3) *S. couttsiae* Heer.

b) Closely related species (Tim taxa only): 1) *Castanopsis* sp. (Pl. 3, figs 8, 9), 2) *Q. pseudoneriifolia* Vikulin, 3) *Cinnamomum lartetii* Watel., 4) *Litsea primigenia* (Ung.) Takht., 5) *Taxodium* cf. *balticum* Sveshn. et Budants.

TIM–HASELBACH COMPLEX
(Early Oligocene floristic complex comparison).

Identical species: 1) *Sequoia abietina*, 2) *S. couttsiae*, 3) *Populus germanica* (Menzel) Walther (Pl. 1, fig 1; Pl. 2, figs 6, 7). Related species (Tim taxa only): 1) *Taxodium* cf. *balticum,* 2) *Cinnamomum lartetii*, 3) Castanopsis sp., 4) *Acer tricuspidatum* A.Br. et Agass., cf. *A. haselbachensis*, 5) *Populus eichwaldii* (Palib.) Vikulin, cf. *P. germanica.*

For the Haselbach floristic complex as well as for those of Svetlogorsk (=Rauschen) and Pasekovo in Central Russian Upland (Voronezh area) the first definite inclusion of a mesophytic floristic element (arctotertiary, temperate or the so called "turgaic") in Central and Eastern Europe was demonstrated by Mai and Walther (1978), Budantsev & Sveshnikova (1964) and Vikulin (1987a, b, c). My new data (on the same lines as that of S.G. Zhilin for Kazakhstan) shows for the first time the somewhat earlier appearance of *Populus*, *Acer* and *Sorbus* in the history of Eastern Europe in the terminal Late Eocene, compared with that in Central Germany dated as Early Rupelian sensu stricto by Mai & Walther (1978). Nonetheless, such truly arctotertiary genera as *Liquidam-*

bar, *Alnus*, *Carpinus*, *Betula*, *Carya* and *Salix* are totally lacking in the Tim and Pasekovo Formations, as well as that of Stare Sedlo. But the position of the Tim Formation flora is in some ways intermediate between the terminal Eocene Stare Sedlo Formation and the Early Oligocene Haselbach floristic complex, as well as between the Late Eocene or Early Oligocene Svetlogorsk and the Late Eocene of Pasekovo (Vikulin 1999). Biostratigraphically, the Pasekovo floristic complex seems to be younger than the Middle/Upper Eocene Zeitz floristic complex, but older than the Lower/Early Middle Oligocene Haselbach floristic complex (Germany). The age of the Tim flora (sensu stricto) is Uppermost Upper Eocene (Vikulin 1990). Such floristic elements of Tim as *Populus germanica* (Pl. 1, fig. 1; Pl. 2, figs 6, 7) and *Platanus timensis* Vikulin, as well as *P.* cf. *fraxinifolia* (Johnson et Gilmore) Walther from Stare Sedlo, are of uncertain systematic position, possessing some archaic Cretaceous leaf features (Vikulin 1987c, 1990, Knobloch 1988). Recent palaeobotanical investigations in Germany (Mai 1996, Mai & Walther 1978, 1985, Walther 1994, Wilde 1989), the Czech Republic (Bohemia) (Knobloch 1963, 1988, Kvaček & Walther 1988) and Russia (Central Russian Upland) (Vikulin 1987a, b, c, 1990, 1996a, b, c, 1999) have revealed many new palaeobotanical and stratigraphical facts which have allowed us to stratify the Stare Sedlo, Tim and Pasekovo formations as Upper Eocene (Knobloch 1988, Kvaček & Walther 1988, Vikulin 1987a, b, c, 1990, 1999).

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PLATES

Plate 1

1. *Neolitsea kryshtofovichii* Baik. (specimen 41a) and *Populus germanica* (Menzel) Walther (specimen 41b), coll. BIN RAS 41/1393 of S.V. Vikulin: Tim town, Kursk region, Central Russia, scale bar = 1 cm
2. *Quercus pseudoneriifolia* Vikulin. Leaf apex, coll. BIN RAS 100/1393 of S.V. Vikulin, scale bar = 1 cm


1
2

Plate 2

3, 4. *Eugenia vidaliana* Elmer (BIN RAS Herbarium: LE – Philippines), note brochidodromous pattern of venation and base of lamina gradually tapering to the short petiole, which is attached to the branchlet, cf. Pl. 4, fig. 2

3. Magnified detail of marginal venation: intramarginal vein is absent, scale bar = 1 cm

4. Whole leaf, scale bar = 1 cm

5, 7. Coll. 1393 of S.V. Vikulin: Tim town, Kursk region, terminal Upper Eocene

5. foliage of *Quercus pseudoneriifolia* Vikulin: two leaf impressions (specimen 221a, b), scale bar = 1 cm

6. Coll. of A.N. Krasnov from Tim (BIN RAS, No. 60), specimen 12/60, scale bar = 1 cm

7. Specimen 193/1393 – polymorphic species, *Populus germanica* (Menzel) Walther, scale bar = 1 cm

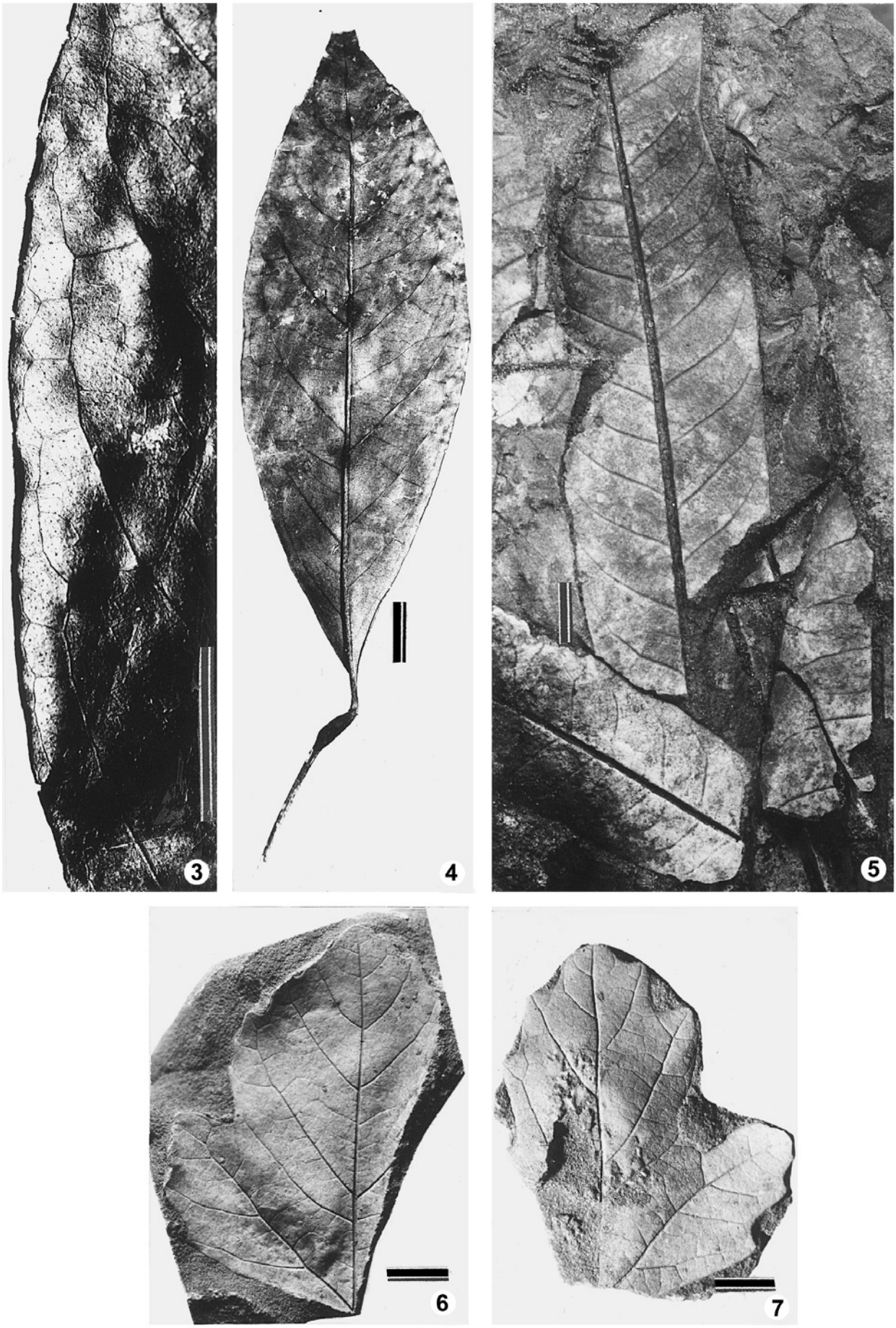
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Plate 3

8. *Castanopsis timensis* (Palib.) Iljinskaja, holotype, coll. of I.V. Palibin 55/1343 of the Central Geol. Museum (VSEGEI, St Petersburg), Palibin 1901: Table 3, sub nom. *Quercus timensis* Palib., scale bar = 1 cm

9. Castanopsis sp. coll. of S.V. Vikulin: BIN RAS 34/1343, scale bar = 1 cm, cf. *Phyllites furcinervis* Rossmäsler 1840: Table 7, Fig. 26

10, 11. *Quercus pseudoalexeevii* Vikulin

10. Coll. of S.V. Vikulin BIN RAS 11/1392 (detail), scale bar = 0.5 cm

11. Coll. of S.V. Vikulin BIN RAS 10/1392 (holotype), scale bar = 1 cm


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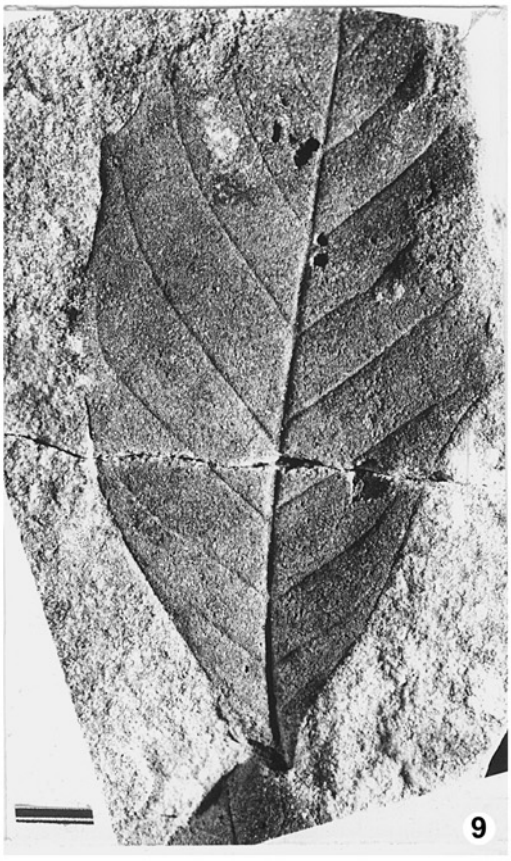
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Plate 4

12–14. *Rhodomyrtophyllum pasekovicum* Vikulin, coll. of S.V. Vikulin from Pasekovo (Voronezh region, southern Russia: BIN RAS 116/1392)

12. Basal portion of preserved leaf impression with adjusted mummified leaf tissue (compression). Note lamina gradually tapering to the slender point of the short petiole, and the tiny net of tertiary microvenation, scale bar = 1 cm

13. The high level of cell organelle fidelity is confirmed by Transmission Electron Microscopy (TEM, Scale bar = 0.5 μm), revealing fossil chloroplast (41 Myr) with preserved grana and membrane lamellae (1); extraction from the preserved mummified leaf mesophyll of *R. pasekovicum.* Rounded bodies (r b) inside (plastoglobuli) can be compared with starch granulae (ultrastructural preparations of chloroplast were made through the courtesy of Dr. O.V. YAKOVLEVA from the Department of the Plant Anatomy, BIN RAS)

14. LM micromorphology of the cuticle. Note the dense groups of stomatal sets, undulation of the main epidermal cells (m c), and the dark coloured hair bases (h b) scattered on the leaf surface, attached to the vein (v). Giant solitary stomata (=sometimes called "water" stomata) – G S, scale bar = 100 μm


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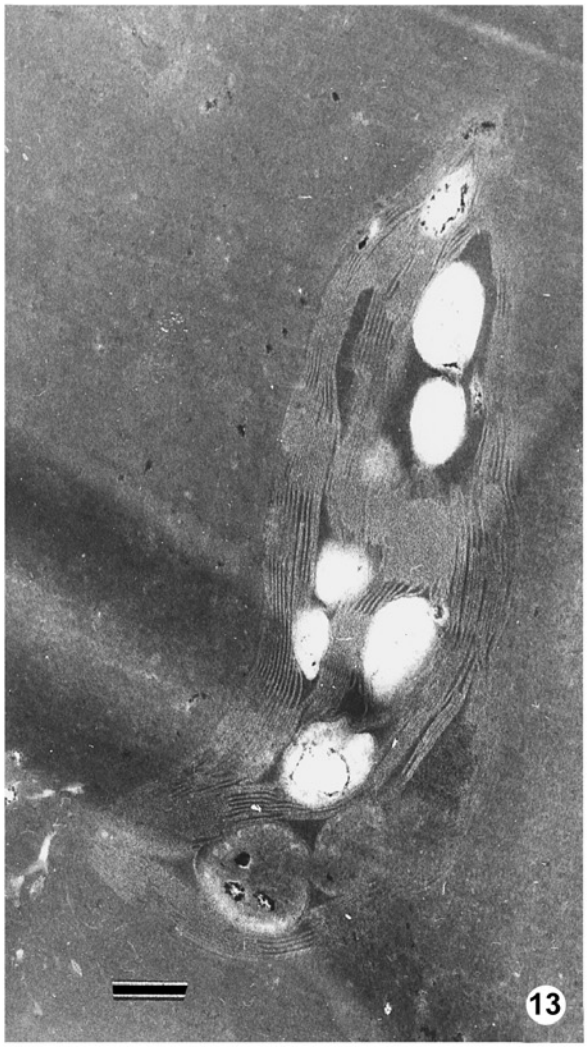
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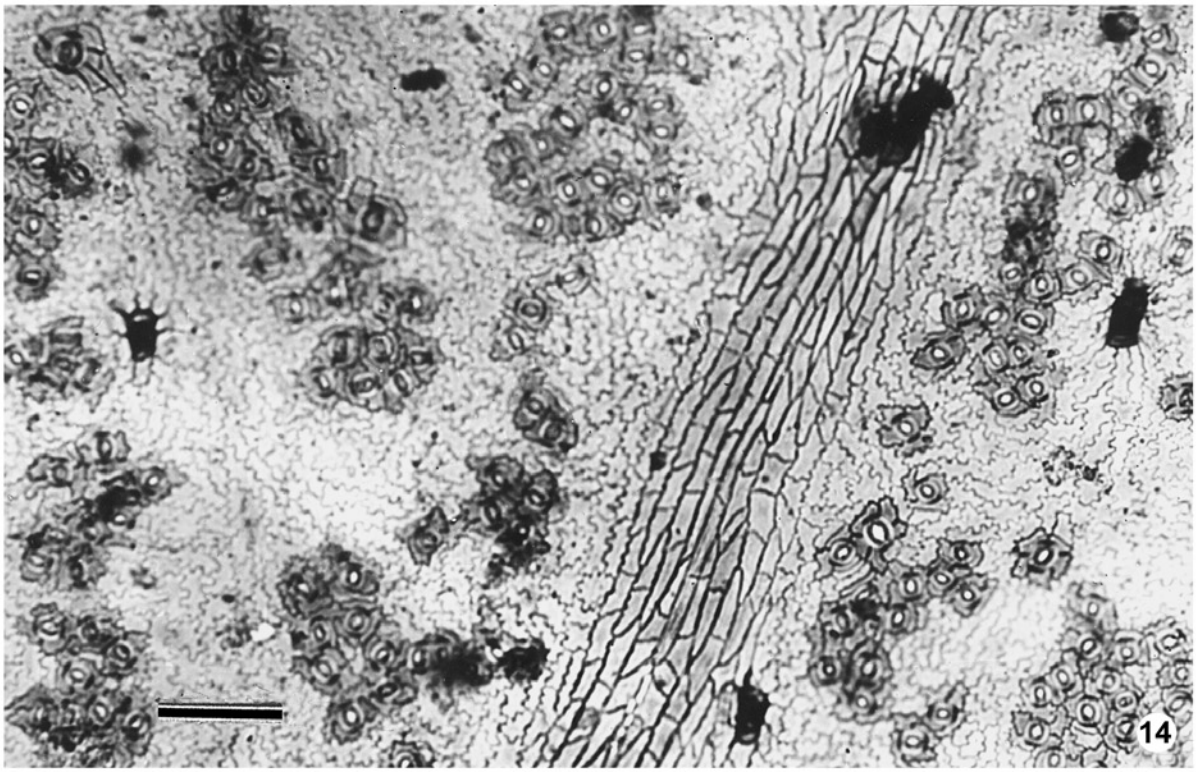
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Plate 5

15, 16. *Laurophyllum hypolanatum* Rüffle. Lower leaf surface under Light Microscopy (LM), coll. BIN RAS 50/1392

15. General view of lower leaf cuticle, note numerous strongly differentiated papillae, scattered all across the epidermal surface, scale bar = 100 μm

16. Close-up of the stomatal sets (mainly paracytic), scale bar = 10 μm

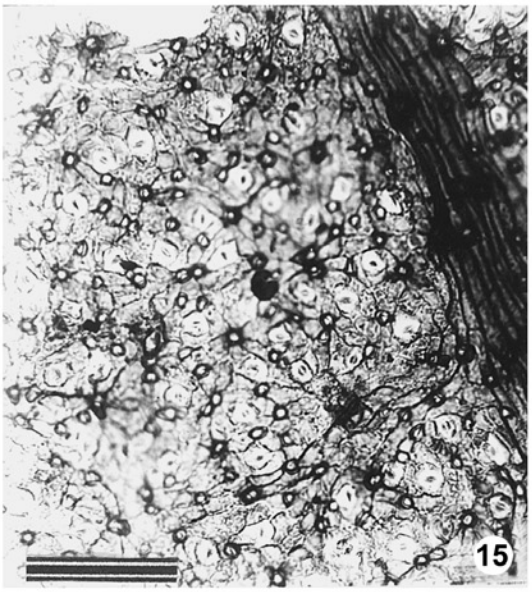
17–20. *Rhodomyrtophyllum pasekovicum* Vikulin. LM and SEM of the lower surface of the leaf cuticle, coll. BIN RAS 116/1392

17. LM close-up of the cuticle, note anomo- and anomostaurocytic stomatal types and distinct cuticular rims (c r), similar to those of living Central American species of *Eugenia*, scale bar = 20 μm

18. LM general view, scale bar = 20 μm

19. SEM (Jeol 35c: BIN RAS) of the outer cuticular surface revealing prominent cuticular rims (c r), scale bar = 100 μm

20. SEM of the inner cuticular surface revealing several stomatal types: anomo-, anomostauro-, latero-, para- cytic and intermediates, scale bar 10 μm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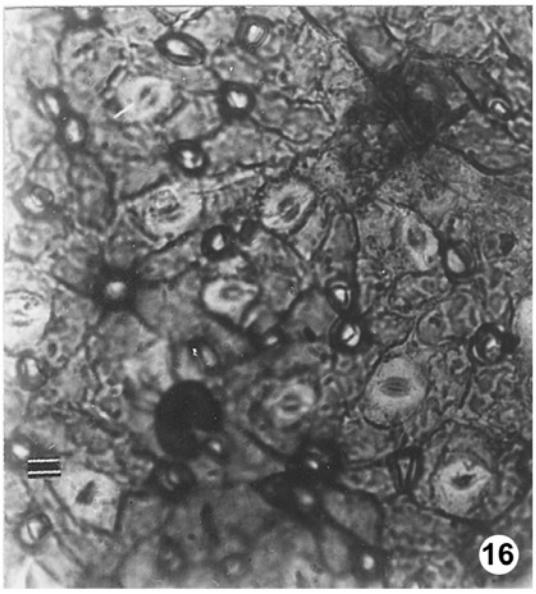
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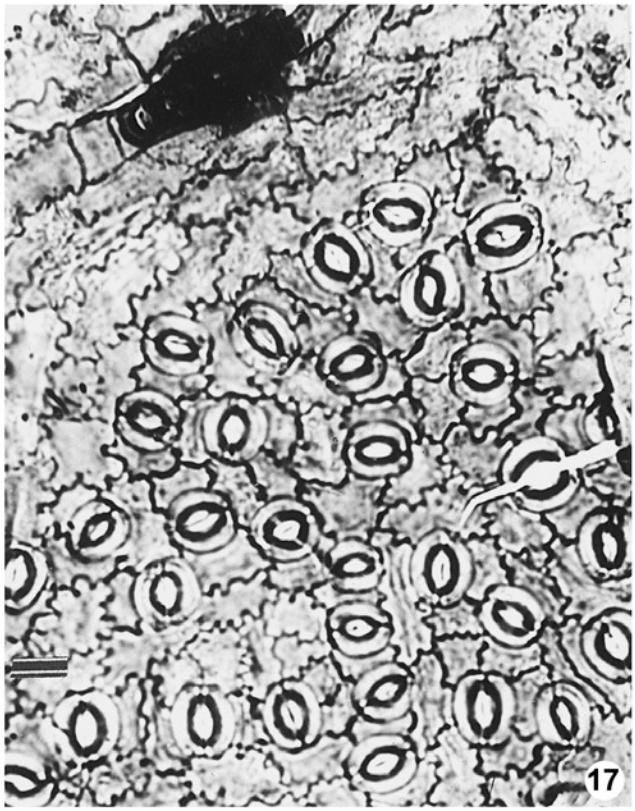
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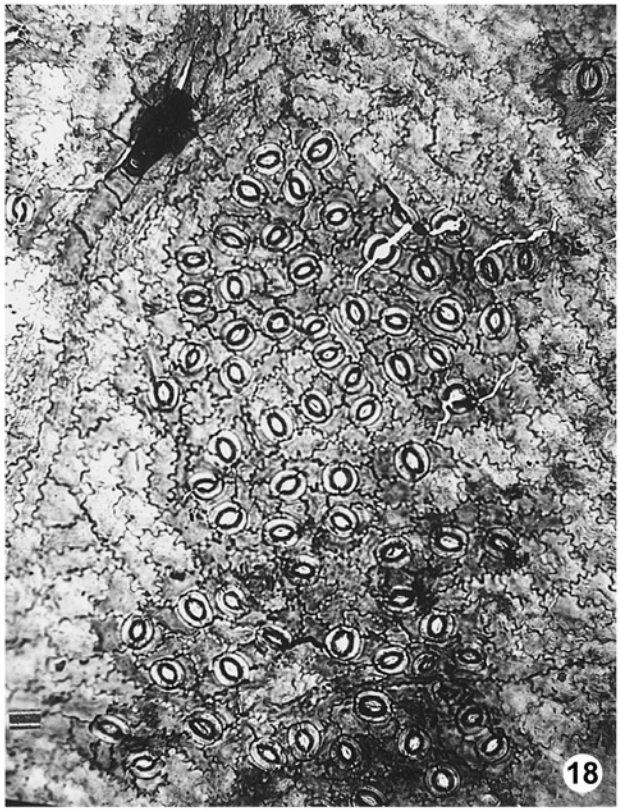
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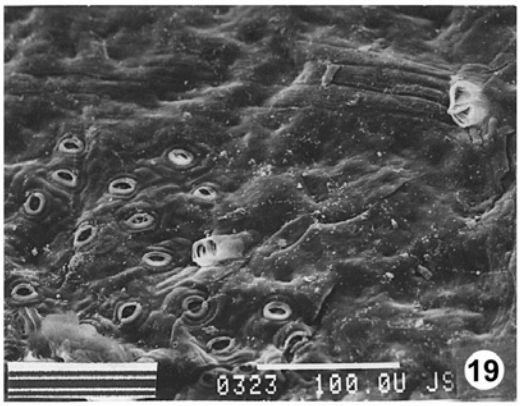
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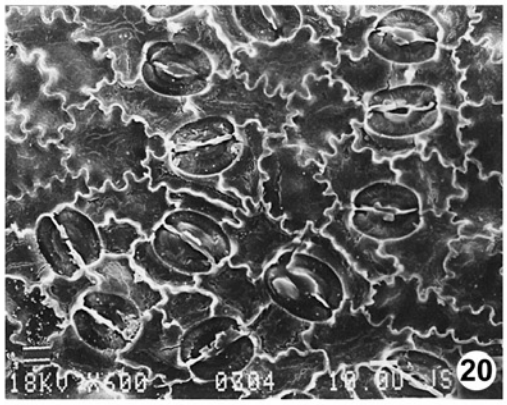
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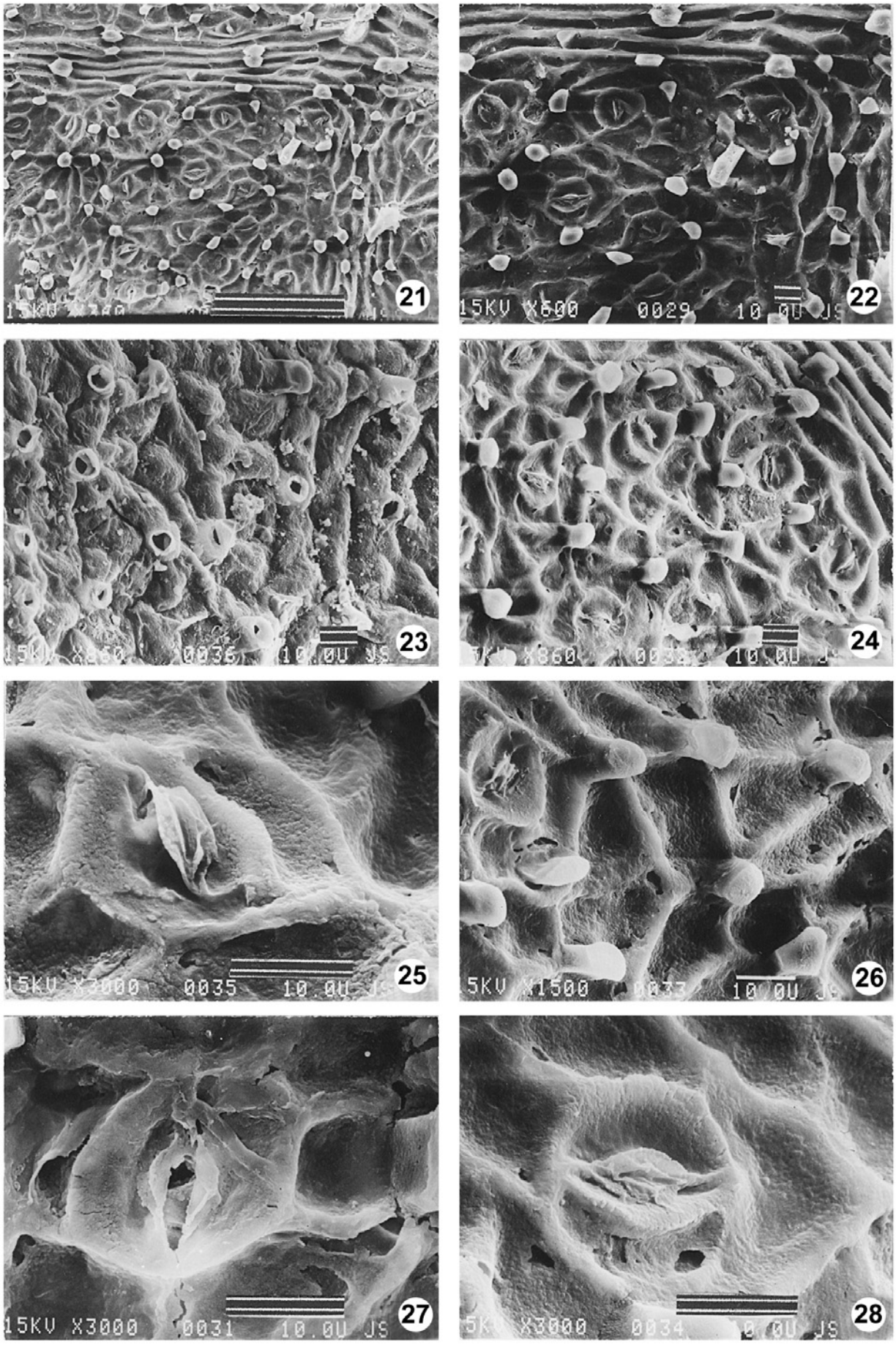
Plate 6

21–28. *Laurophyllum hypolanatum* Rüffle. Scanning Electron microscopy (SEM Jeol 35c: BIN RAS) of the cuticle. Various views of epidermal surface revealing numerous papillae scatterd either on the veinlets (v) or all over the epidermal surface; note the randomly oriented stomata. Views of stomata: paracytic, brachyparacytic and laterocytic stomatal types are represented (fig. 21, scale bar = 100 μm; fig. 22, scale bar = 10 μm; fig. 24, 10 μm; fig. 25, scale bar = 10 μm; fig. 27, scale bar = 10 μm; fig. 28, scale bar = 10 μm). Papillae, detail (figs 24, 26, scale bar = 10 μm). fig. 23 – Collapsed papillae looking like bubble projections with a hole, scale bar = 10 μm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