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Some morphological changes of the *Potamogeton* endocarps during its fossilization

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ABSTRACT. Both contemporary and fossil endocarps of the *Potamogeton* genus were examined. During the fossilization process large differences in the structure and size of the examined *Potamogeton* endocarps were found. The largest loss of surface, in contemporary endocarps as compared with fossil ones, were found in *P. natans* and *P. crispus*, and a relatively small one in *P. filiformis*. By comparing shape factors, the type of losses of endocarp tissues in examined species was determined. The pericarp structure of the *Potamogeton* fruit determines the degree of the tissue loss in the fossilization process. The proportion between the lid and the rest of the endocarp is maintained in the process. The research conducted has confirmed the usability of the method applied for removal of soft tissue of *Potamogeton* fruit in taxonomy. The usefulness of the Met-Ilo 8 program has been proved for analysing both fossil and contemporary *Potamogeton* endocarps. The method can be applicable in future for examining the remains of other components of fossil floras.

KEY WORDS: endocarp, fruit, fossil, morphology, *Potamogeton*, SEM

INTODUCTION

The *Potamogeton* fruit is composed of a pericarp which includes: a thin-walled exocarp and a soft and spongy mesocarp as well as an endocarp, as the most sclerified. Inside the fruit, there is one seed in the shape of letter C. In the fossilization process, *Potamogeton* fruits are subject to physical changes. They are trans-located in the substratum and mechanically stripped, they change their hydration degree and are saturated with various substances, which results in changes of endocarps that can be observed in the fossilized material. The scale and quickness of changes occurring in fossilized endocarps, as compared with contemporary fruit, is very interesting. Such studies are significant since in morphological descriptions of fossil *Potamogeton* endocarps, the endocarp dimensions are among the most important diagnostic characteristics. Any deviations from medium sizes raise doubts as to the affiliation of the endocarp under examination to a particular species. The *Potamogeton* genus has been selected for the research since its numerous species occur in floras of various Quaternary interglacial periods. The taxonomy of contemporary *Potamogeton* endocarps were studied by Mądalski (1949), Jessen (1955), Aalto (1970), and Cappers (1993); whereas the development of some morphological features of *Potamogeton* fruit was examined by the author of this paper (Toma 2002, 2002a,b). The taxonomy for the whole genus was worked out in detail by Dorofeev (1986). A scheme of morphological features for fossil *Potamogeton* endocarps from Polish and Belarusian floras were calculated, while taking into consideration their significance (Velichkevich & Lesiak 1996). In recent years, research of fossil *Potamogeton* endocarps from Poland and neighbouring countries were carried out by Velichkevich and Granoszewski (1996), Velichkevich and Lesiak (1999), and Velichkevich and Mamakowa (1999).

The results of the SEM method applied in

botanical and palaeobotanical research require the correct interpretation so as to understand properly the changes in the morphological features of endocarps in the fossilization process as well as to demonstrate the most important diagnostic features. A limited number of species of the genus were analysed to obtain the basis for further research. The methods applied here will be used for working out a SEM-Atlas of contemporary species of *Potamogeton*. Another aspect to be used in future is the comparison of endocarps of the same species of *Potamogeton* from different interglacial periods as well as an assessment of changes in endocarp morphology in various climatic conditions. Species common in the ancient/glacial zone of Europe have been selected for the research to enable, in future, the continuation of comparisons of fossil and contemporary *Potamogeton* endocarps of different age and from different areas of Europe. The KRAM-P collection of the Palaeobotanical Museum, W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków, includes a very rich material of Quaternary floras of Poland and neighbouring countries, which can be used as the basis for larger scale research.

The purpose of the study was 1) to demonstrate differences in the structure of contemporary and fossil endocarps of the *Potamogeton* genus using the SEM method, 2) to determine the scale of losses of endocarp surfaces in the fossilization process, 3) to determine the usability of the method of removal of soft tissue of contemporary fruit for taxonomy requirements, 4) to determine the usability of the image analyser for demonstrating changes in the shape and surface of endocarps.

MATERIAL AND METHODS

Fossil endocarps of *Potamogeton crispus* L. and *P. filiformis* Pers. from Krukenichi in Ukraine as well as *P. natans* from Minichi in Belarus from the Mazovian interglacial (KRAM-P-KW = collection of F.Yu. Velichkevich), and contemporary endocarps of *P. filiformis* from UAM POZ herbarium as well as *P. natans* and *P. crispus* ones from the author's collection have been studied. Five endocarps from each sample were examined. In the case of each species, the following endocarps were examined: 1) unprepared fossil endocarps, 2) prepared fossil endocarps, 3) unprepared contemporary endocarps and 4) prepared contemporary ones. The preparation consisted in placing endocarps in beakers (100 ml) with water for the period of 3 weeks, boiling them for 6 hours for 3 subsequent days. Then the endocarps were deprived of soft pericarp tissues and dried in the room temperature for 30 days. Endocarps were observed in SEM upon previous coating them with carbon. The images obtained were saved as graphic files.

Changes in endocarp shapes were analysed with the use of a program for image analysis Met-Ilo 8. The analysed pictures were inserted into Met-Ilo 8 analyser then the scales were calibrated to adequate magnifications. The decimal to binary conversion of endocarp and fruit pictures designed for one to one scale analyses was carried out and measurements were taken. The following concepts were applied: the endocarp area (in pixels) as related to the orthogonal projection of the endocarp shape on the plane (Zieliński & Strzelecki 2002); the shape factor that defines a change in the endocarp shape with reference to the circle. Sizes of fossil and contemporary endocarps were compared as measured in pixels, the percentage of the area loss of analysed endocarps was calculated and morphological changes with reference to the beak and the lid were described. Endocarp dimensions were measured in accordance with markings applied for *Potamogeton* remains (Velichkevich & Lesiak 1996), where the endocarp length is measured without the beak.

MORPHOLOGICAL DESCRIPTION

Potamogeton crispus L.

Recent material. Coll. Dr C. Toma, 10. 06. 1997, recreational pond, Three Lakes Valley, Katowice.

Description of recent endocarps. (Pl. 1, figs 1, 4, Pl. 2, figs 1, 4)

The specific area of herbarium fruit is 53 201 pixels, that of endocarps after removal of soft tissues is 29 654 pixels. Herbarium fruit dimensions: width 2.31 mm, length 2.32 mm, after preparation: width 1.81 mm, length 2.11 mm. The beak is long, massive, its edges are almost parallel to each other, the top is truncated sharply. Beak dimensions: width near a base 0.92 mm, length 1.97 mm. The lid is markedly crest-shaped, with a wavy external surface and in basal part of lid is basal wart. In the plan projection of the endocarp, in its middle part, the lid accounts for 77% in relation to the whole width of the endocarp. Width of the lid: 0.69 mm.

Fossil material. Coll. KRAM-P- KW-4

Description of endocarps. (Pl. 1, figs 7, 10; Pl. 2, figs 7, 10)

The specific area of fossil endocarps is 24 934 pixels. Endocarp dimensions: width

1.49 mm, length 1.85 mm. The beak is massive, triangular-shaped, with two sides longer and the third one short, blunt at the end. Beak dimensions: width 0.55 mm, length 0.86 mm. The lid surface is slightly wavy, without outgrowths. The lid ending is smooth, narrow and oval. The arm is situated in the lid plane. The lid edges are parallel to each other at its greater part. In the plan projection of the endocarp, in its middle part, the lid accounts for 64.2% in relation to the whole width of the endocarp. Width of the lid 0.57 mm.

Comparison. The loss of surface of the prepared *Potamogeton crispus* endocarp as against the fossil one is 19%. The fruit area is by 113% larger than that of the fossil endocarp (Fig. 1). Owing to the long beak of the *P. crispus* fruit, the shape factor value is below 0.5, since such a shape considerably differs from the circular one. The shape factor of the fossil endocarp is higher since the beak has become smaller and smoother (Fig. 2).

Potamogeton filiformis Pers.

Recent material. Coll. I. Dąmbska UAM POZ. O5. 08. 1952, Gorzyńskie Lake, Międzychód district.

Description of recent endocarps. (Pl. 1, figs 2, 5, Pl. 2, figs 2, 5)

The specific area of herbarium fruit is 24 611 pixels., that of endocarps after removal of soft tissues is 18 915 pixels. Herbarium fruit dimensions: width 1.58 mm, length 2.06 mm, endocarp after preparation width 1.33 mm, length 1.94 mm. The beak of the herbarium fruit is cylindroid and small, width 0.49 mm, length 0.14 mm. The lid is smooth, without outgrowths. The lid ending is smooth, narrow and oval. A long false arm is visible over the lid end. In the plan projection of the endocarp, in its middle part, the lid accounts for 67% in relation to the whole width of the endocarp. Width of the lid 0.61 mm.

Fossil material. Coll. KRAM-P-KW-4

Description of fossil endocarps. (Pl. 1, figs 8, 11, Pl. 2, figs 8, 11)

The specific area of fossil endocarps is 16 040 pixels. The endocarp shape is more oval as compared with the contemporary one. Endocarp dimensions: width 1.29 mm, length 1.68 mm. The beak is small, width 0.17 mm,

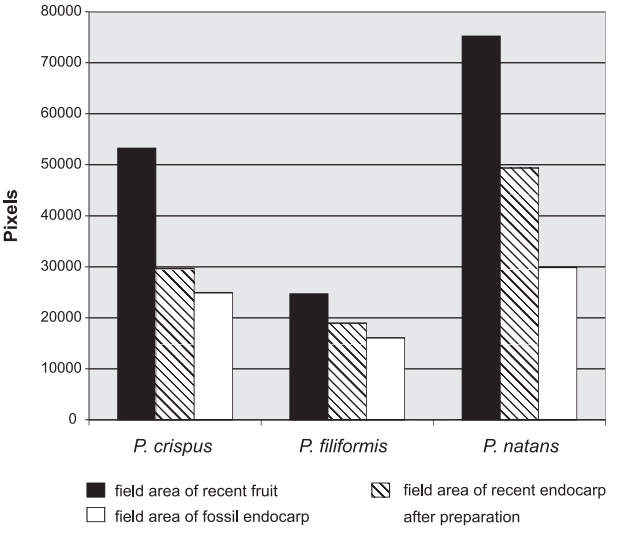

Fig. 1. Comparison of areas of recent and fossil *Potamogeton* endocarps in pixels

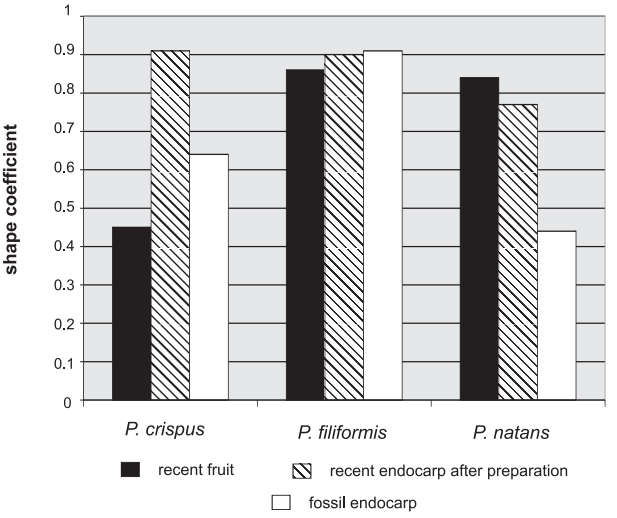

Fig. 2. Comparison of shape coefficients of recent and fossil *Potamogeton* endocarps

length 0.06 mm. The lid surface is smooth, without a crista or a keel. The lid ending is smooth, narrow and oval. A long false arm is visible, situated in the lid plane. In the plan projection of the endocarp, in its middle part, the lid accounts for 62.7% in relation to the whole width of the endocarp. Width of the lid 0.38 mm.

Comparison. The 17% loss of the endocarp surface of the prepared *Potamogeton filiformis* in relation to the fossil endocarp is not too large. The *P. filiformis* fruit area is larger than that of the fossil endocarp by 53% (Fig. 1). A more elongated shape of the contemporary endocarp is evident in relation to the fossil one. The shape factor of the *P. filiformis* fruit

is high due to its streamlined shape. The fossil endocarp of the species has an even higher shape factor value since it has become rounded in the fossilization process (Fig. 2).

Potamogeton natans L.

Recent material. Coll. Dr C. Toma, 10. 08. 1994, recreational pond, Three Lakes Valley, Katowice.

Description of recent endocarps. (Pl. 1, figs 3, 6, Pl. 2, figs 3, 6)

The specific area of herbarium fruit is 75 169 pixels, that of endocarps after removal of soft tissues is 49 368 pixels. Herbarium fruit dimensions: width 2.86 mm, length 3.97 mm, endocarp after preparation: width 2.41 mm, length 2.67 mm. The beak is wide at the base, short, 0.43 mm in width and 0.29 mm in length. The lid has a smooth back, without a crista, with a poorly developed keel and a wide and oval ending. In the plan projection of the endocarp, in its middle part, the lid accounts for 56.7% in relation to the whole width of the endocarp. Width of the lid 0.84 mm.

Fossil material. Coll. KRAM-P-KW-1.

Description of fossil endocarps. (Pl. 1, figs 9, 12, Pl. 2, figs 9, 12)

The specific area of fossil endocarps is 29 878 pixels. Endocarp dimensions: width 1.65 mm, length 2.24 mm. The beak is narrow, long, club-like, jagged, 0.19 mm in width and 0.93 mm in length. The lid, with a frayed back, has a spine of lid in its apical part, 0.33 mm in length. The back is more jagged in the apical part of the endocarp. The lid ending is smooth, narrow and oval. The arm is situated at the angle of 135° in relation to the lid. In the plan projection of the endocarp, in its middle part, the lid accounts for 53.2% in relation to the whole width of the endocarp. Width of the lid 0.51 mm.

Comparison. A loss of 65% has occurred in the surface of the prepared *Potamogeton natans* endocarp with respect to the fossil one. The fruit area is larger by 151% than the fossil endocarp area (Fig. 1). Owing to the lack of a long beak as in case of *P. crispus*, the shape factor value of the *P. natans* fruit is high, whereas that of the fossil endocarp is below 0.5 due to the jagged upper part of the lid (Fig. 2).

CONCLUSION

Large differences in the structure and size of the examined *Potamogeton* endocarps were found. Endocarps area and losses of tissue were determined with the use of the Met-Ilo 8 program. The largest loss of surface, in contemporary endocarps as compared with fossil ones, were found in *P. natans and P. crispus*, and a relatively small one in *P. filiformis*. By comparing shape factors, the type of losses of endocarp tissues in examined species was determined. Fossilization of *P. crispus* endocarps results in a significant reduction of the beak size, which increases the shape factor value of fossil endocarps. In case of *P. natans*, the endocarp is irregularly destroyed and the resulting structure significantly decreases the shape factor value of fossil endocarps. In case of *P. filiformis*, the fossilization has resulted in relatively slight changes of the shape factor, and the endocarp is destroyed regularly. The pericarp structure of the *Potamogeton* fruit determines the degree of the tissue loss in the fossilization process. *P. natans* has large cellular spaces in the pericarp and this species reveals the largest reduction of the area in the fossilization process. The fruit of *P. filiformis*, with a small number of cellular spaces, reveals slight changes in the endocarp surface area. The proportion between the lid and the rest of the endocarp is maintained in the fossilization process. The research conducted has confirmed the usability of the method applied for removal of soft tissue of *Potamogeton* fruit in taxonomy. The usefulness of the Met-Ilo 8 program has been proved for analysing both fossil and contemporary *Potamogeton* endocarps. The method can be applicable in future for examining the remains of other components of fossil floras.

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REFERENCES

AALTO M. 1970. Potamogetonaceae fruits I. Recent and subfossil endocarps of the Fennoscandian species. Acta Bot. Fenn., 88: 1–85.

CAPPERS R.T. 1993. The identification of Potamogetonaceae fruits found in the Netherlands. Acta Bot. Neerl., 42(4): 447–460.

DOROFEEV P. 1986. Iskopaemye *Potamogeton*. Nauka, Leningrad.

JESSEN K. 1955. Key to subfossil *Potamogeton*. Bot. Tidsskr., 52: 1–7.

MĄDALSKI J. 1949. Cechy morfologiczne pestek europejskich gatunków *Potamogeton* (Tourn.) L. i klucz do oznaczania ich szczątków dyluwialnych. Prace Wroc. Tow. Nauk., Seria B, 24: 1–24.

TOMA C. 2002. Ontogenesis of the *Potamogeton* flower and fruitlet in SEM research. Acta Soc. Bot. Pol., 71(2): 93–100.

TOMA C. 2002a. Fruitlet development in the genus *Potamogeton* (Potamogetonaceae). Acta Biol. Cracov. Ser. Bot., 44: 63–71.

TOMA C. 2002b. Lid formation in the genus *Potamogeton*. Nord. J. Bot., 22(3): 341–347.

VELICHKEVICH F.Yu. & GRANOSZEWSKI W. 1996. *Potamogeton sukaczevii* Wieliczk. in the Neopleistocene flora of Poland, Belarus and Lithuania. Acta Paleobot., 36(1): 97–105.

VELICHKEVICH F.Yu. & LESIAK M.A. 1996. Fossil *Potamogeton* species of Mizerna. Acta Palaeobot., 36(1): 79–95.

VELICHKEVICH F.Yu. & LESIAK M.A. 1999. *Potamogeton* species of the Kholmech flora in Belarus. Acta Palaeobot., 39(1): 15–27.

VELICHKEVICH F.Yu. & MAMAKOWA K. 1999. Taxonomic revision of the collection of plant macrofossils from some localities of Poland now referred to the Vistulian Glaciation. Acta Palaeobot., 39(1): 29–87.

ZIELIŃSKI K.W. & STRZELECKI M. 2002. Komputerowa analiza obrazu biomedycznego. Wstęp do norfometrii i patologii ilościowej. Wydawn. Nauk. PWN, Warszawa-Łódź.

PLATES

Plate 1

1. *Potamogeton crispus*, fruit ×18, KRAM-P-KW-4
2. *Potamogeton filiformis*, fruit ×18, KRAM-P-KW-4
3. *Potamogeton natans*, fruit ×13, KRAM-P-KW-1
4. *Potamogeton crispus*, recent endocarp after preparation ×18, KRAM-P-KW-4
5. *Potamogeton filiformis*, recent endocarp after preparation ×18, KRAM-P-KW-4
6. *Potamogeton natans*, recent endocarp after preparation ×18, KRAM-P-KW-1
7. *Potamogeton crispus*, fossil endocarp ×18, KRAM-P-KW-4
8. *Potamogeton filiformis*, fossil endocarp ×18, KRAM-P-KW-4
9. *Potamogeton natans*, fossil endocarp ×18, KRAM-P-KW-1
10. *Potamogeton crispus*, fossil endocarp after preparation ×18, KRAM-P-KW-4
11. *Potamogeton filiformis*, fossil endocarp after preparation ×18, KRAM-P-KW-4
12. *Potamogeton natans*, fossil endocarp after preparation ×18, KRAM-P-KW-1

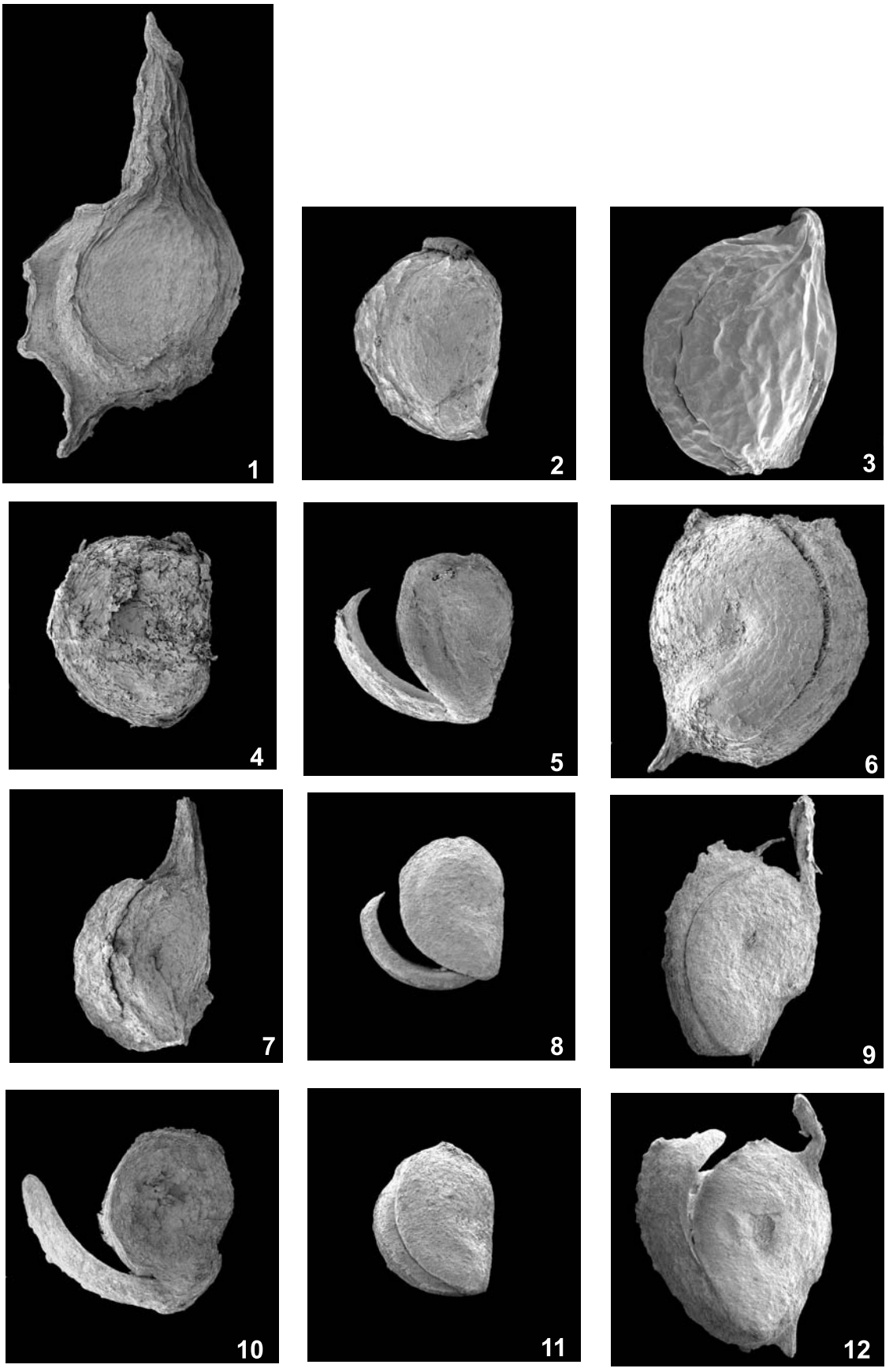
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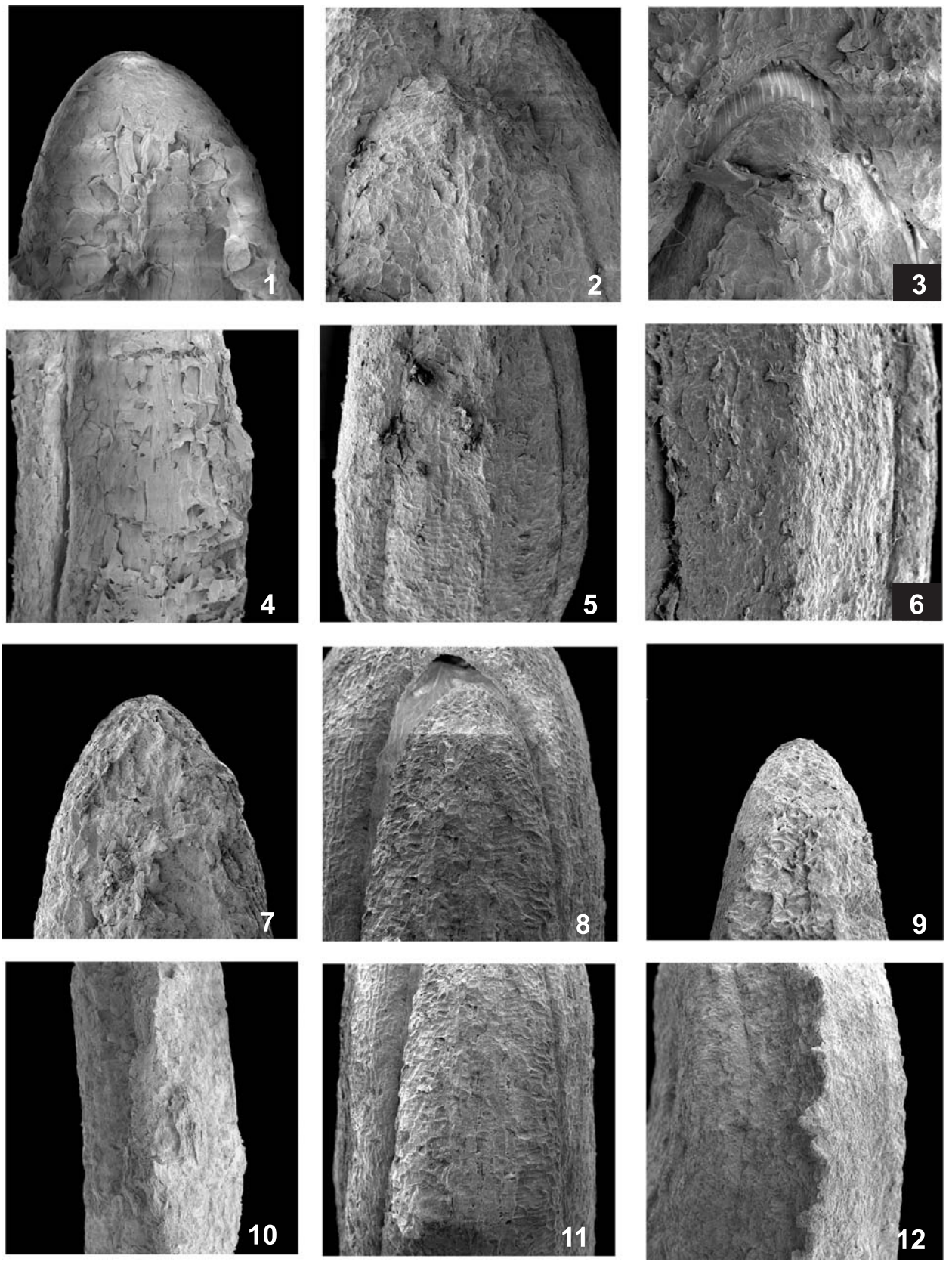
Plate 2

1. *Potamogeton crispus*, apical part of lid from recent endocarp after preparation ×100, KRAM-P-KW-4
2. *Potamogeton filiformis*, apical part of lid from recent endocarp after preparation ×100, KRAM-P-KW-4
3. *Potamogeton natans*, apical part of lid from recent endocarp after preparation ×100, KRAM-P-KW-1
4. *Potamogeton crispus*, middle part of lid from recent endocarp after preparation ×50, KRAM-P-KW-4
5. *Potamogeton filiformis*, middle part of lid from recent endocarp after preparation ×50, KRAM-P-KW-4
6. *Potamogeton natans*, middle part of lid from recent endocarp after preparation ×50, KRAM-P-KW-1
7. *Potamogeton crispus*, apical part of lid from fossil endocarp after preparation ×100, KRAM-P-KW-4
8. *Potamogeton filiformis*, apical part of lid from fossil endocarp after preparation ×100, KRAM-P-KW-4
9. *Potamogeton natans*, apical part of lid from fossil endocarp after preparation ×100, KRAM-P-KW-1
10. *Potamogeton crispus*, middle part of lid from fossil endocarp after preparation ×50, KRAM-P-KW-4
11. *Potamogeton filiformis*, middle part of lid from fossil endocarp after preparation ×80, KRAM-P-KW-4
12. *Potamogeton natans* middle part of lid from fossil endocarp after preparation ×50, KRAM-P-KW-1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