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Identification of a population of *Ranunculus* achenes extracted from Middle Pleistocene sediments exposed at Belhus Park, Essex, UK

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ABSTRACT. A plant macrofossil assemblage extracted from Middle Pleistocene fluvial organic sediments collected from Belhus Park, Aveley, Essex, UK contained a number of tuberculate (verrucose) achenes attributed to the genus *Ranunculus*, one of which had two short spines preserved on its surface. The identification of these achenes is discussed here. This is worthy of note because *Ranunculus* tuberculate or spinose fossil achenes can be difficult to determine to species as they can have similar features, some *Ranunculus* species produce achenes in several morphological forms, and during fossilization delicate structures maybe destroyed (e.g. spines). After careful morphological consideration it is concluded that the fossil achenes from Belhus Park are *Ranunculus parviflorus* L., indicating that dry grassland or disturbed ground existed in the river catchment. The plant macrofossil assemblages that included the *Ranunculus parviflorus* achenes were dominated by waterside, damp ground, and aquatic taxa. It is probable that flowing water transported the achenes from further afield before their incorporation into the fluvial sediments. The identification of these fossils illustrates the importance of considering the morphological characteristics of the achene only and not to make a determination on the nature of the predominant palaeoenvironmental signal from an assemblage.

KEYWORDS: *Ranunculus*, fossil tuberculate/spinose achenes, Middle Pleistocene, Belhus Park site, identification

INTRODUCTION

A recent investigation recovered *Ranunculus* achenes from interglacial silty clays of fluvial origin that were sampled in 1979 at Belhus Park, Aveley, Essex, UK during the construction of the M25 motorway that encircles London (OS Grid Reference TQ 575810) (Gibbard 1994). This paper focuses on the problem of identifying these fossils. Most of the fossil achenes had a tuberculate (verrucose) surface, but one specimen had two spines preserved.

The fossiliferous sediments were originally thought to have been deposited in the first half of the Ipswichian Stage (the last interglaciation) based on a palynological study (Gibbard 1994). However, the presence of the heterosporous pteridophyte *Azolla filiculoides* in the plant macrofossil assemblages indicates an older age in the Middle Pleistocene. Amino acid racemization data from the opercula of *Bithynia* recovered from the sediments allow correlation with MIS 9 (Penkman et al. 2011).

MATERIAL AND METHODOLOGY

Three sediment samples from Belhus Park (BP11C, BP11B and BP AB45-65) yielded tuberculate achenes that could be attributed to the genus *Ranunculus*, one having two short spines preserved on its surface. A number of *Ranunculus* species produce tuberculate or short spiny achenes and some species produce achenes in several morphological forms (e.g. lacking any tubercles or spines, having tubercles located in certain positions, being covered in tubercles or spines, or having a ribbed-reticulate surface). For this reason the identification of the fossils from Belhus Park was difficult and required comparison of the fossils with

modern reference material. In addition, an assessment of the degree to which the fossils were modified during fossilization was also required. The following methodology was employed leading to the identification of the Belhus Park fossil achenes.

First, published descriptions and images of achenes from extant *Ranunculus* species were studied (for example in Berggren 1981, Bojňanský & Fargašová 2007, d'Olivat & Pals 1974, Tutin et al. 1993, Stace 1997) to determine which were most like the fossil specimens from Belhus Park. Achenes from five extant species were selected for comparison with the fossils because of their broad similarity to the Belhus Park fossils. These were *Ranunculus arvensis*, *Ranunculus lateriflorus*, *Ranunculus marginatus*, *Ranunculus parviflorus* and *Ranunculus sardous*. Other species can have tubercules or spines on their achenes but were not morphologically similar enough or not in a comparable size range to be described here. For example, *Ranunculus ophioglossifolius* achenes are tuberculate but minutely so and the spiny achenes of *Ranunculus muricatus* are much too large (up to 8 mm in length).

Secondly, modern achenes were examined from the *Ranunculus* species that were short-listed for comparision. Modern reference material was studied from Nationaal Herbarium Nederland (Leiden), the Faculty of Archaeology (Leiden University) seed and fruit collection, and the author's own seed and fruit collection. A minimum of 50 achenes were measured from each species. The number of specimens varied according to the material available. Whenever possible the population examined was composed of a number of achenes collected from different sites. Analysis of achenes on plant specimens attached to herbarium sheets was done, whenever possible, without removing the achenes from the pressed plant.

In the case of *Ranunculus* species that produce polymorphic achenes only the achenes that are tuberculate or spinose were studied and compared to the Belhus Park fossil achenes. Maximum length and width of each achene was measured (Fig. 1) and the number of tubercles or spines on each side of the achene were counted. The same measurements were collected from the Belhus Park fossils. To illustrate certain details scanning electron microscopy was undertaken on representative specimens from the modern and fossil material.

Nomenclature follows Flora Europaea (1964–1993).

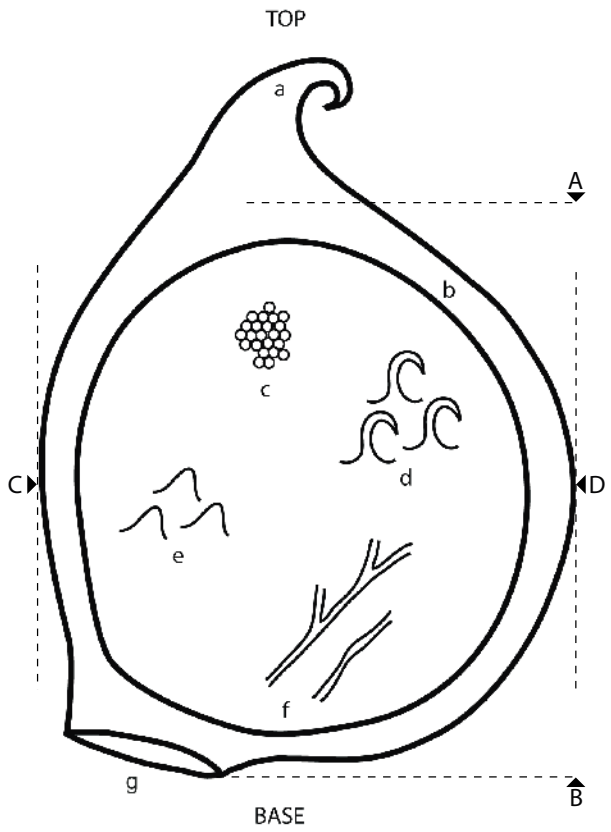

Fig. 1. The terms applied to the morphological features found on a *Ranunculus* achene (**a** – beak, **b** – marginal rim, **c** – cells, **d** – recurved spines, **e** – tubercles, **f** – ribs, **g** – funicular scar). A – B shows the where the maximum length was measured and C – D where the maximum width was measured

RESULTS

A description of the fossil *Ranunculus* achenes from Belhus Park is followed by descriptions of the modern *Ranunculus* achenes of extant species that were regarded to most closely resemble the fossils.

THE BELHUS PARK *RANUNCULUS* ACHENES

Six whole *Ranunculus* achenes and one achene fragment with a tuberculate surface were preserved. The terms applied to the morphological features of the achenes are shown in Figure 1. The achenes are nearly orbiculate (Pl. 1a) except one which is more obovate (Pl. 1b). The achenes are slightly asymmetrical with the funicular scar and beak both off-centre. The one side of the achene is more curved than the other in side view. The maximum length (measured from the funicular scar to the base of the beak) is 2.84 mm, the average length is 2.69 mm and the minimum length is 2.52 mm. The maximum width is 2.29 mm, the average width is 2.18 mm and the minimum width is 1.91 mm. In transverse section the achenes are flat, but this may be a product of fossilization. One specimen has the beak (part of the style) well preserved while the others only have the base of the beak present. At the base of the achenes is a wide funicular scar (Pl. 1a). Only one specimen does not show this feature (Pl. 1b), but there appears to be some damage in the basal area on this achene. All the achenes have a wider marginal rim on the less curved edge. Sculpturing on the achene surface consists of tubercles. However, one specimen has two spines preserved in an upper

dorsal position (Pl. 1b). It is possible that originally the tubercles on the other fossil achenes were in fact the base of the short spines and during incorporation into the fossil assemblage the short spines were destroyed. The density of the tubercles varies from 31 to 58 each side of an achene. Epidermal cells are very conspicuous on the surface of the achenes.

RANUNCULUS ARVENSIS L. ACHENES

The achenes of this species are relatively large and almost orbiculate with the funicular scar and beak positioned off-centre (Pl. 1c). *Ranunculus arvensis* produces several types of achene which have distinct morphological features. A rare form of achene has a reticulate ribbed surface. More commonly plants produce achenes with long spines. The length of the spines can vary and often the spines in a marginal position are longest. This type of achene does not resemble the Belhus Park fossils. The tuberculate achenes were examined to determine if shorter spines existed on the end of the tubercles and therefore could be compared with the Belhus Park specimens. The maximum length if this type is 5.30 mm, the average length is 5.05 mm and the minimum length is 4.84 mm. The maximum width is 3.88 mm, the average width is 3.62 mm and the minimum width is 3.31 mm. The beak is located well off-centre and curves back towards the centre line of the achene (Pl. 1c). The basal funicular scar is positioned on the same side of the achene as the beak and is narrow (just over 0.5 mm across). The density of tubercles on each side of the achene is between 25 and 38. The marginal rim is thick and has tubercles that are slightly angled to face towards the centre of the achene. None of the tubercles had a small spine extending from its tip. Epidermal cells are not conspicuous on the surface (Pl. 1c).

RANUNCULUS LATERIFLORUS L. ACHENES

Achenes of *Ranunculus lateriflorus* are distinctive because they are relatively small compared to the other *Ranunculus* achenes described here and obovate in shape with a long straight or very slightly curved beak which is located in a central position and is almost as long as the achene (Pl. 1d). The maximum length of this species achenes is 1.77 mm, the average length is 1.64 mm and the minimum length is 1.52 mm. The maximum width is 1.09 mm, the average width is 0.98 mm and the minimum width is 0.93 mm. The funicular scar is located slightly off-centre. The density of tubercles is low (12–23 per side of achene). The achene is surrounded by a narrow marginal rim.

RANUNCULUS MARGINATUS D'URV. ACHENES

This species produces relatively large achenes (maximum length of the achenes is 3.11 mm, the average length is 2.86 mm and the minimum length is 2.72 mm. The maximum width is 2.43 mm, the average width is 2.27 mm and the minimum width is 2.11 mm) which are orbiculate and possess a wide marginal rim (Pl. 2a). Both the beak and funicular scar are found slightly off-centre. The surface of the achene is covered in a combination of short recurved spines or pointed tubercles that number between 22 to 25.

RANUNCULUS PARVIFLORUS L. ACHENES

The achenes are nearly orbiculate (Pl. 2b). The achenes are slightly asymmetrical in shape. The maximum length is 2.71 mm, the average length is 2.40 mm and the minimum length is 2.16 mm. The maximum width is 2.43 mm, the average width is 2.29 mm and the minimum width is 2.16 mm. In transverse section the achenes are flat. The beak is located in an off-centre position, has a wide base and a short recurved tip. At the base of the achenes on the same side as the beak is a wide funicular scar (Pl. 2b). All the achenes possess a marginal rim. Sculpturing on the achene surface consists of spines which are recurved. Recurved spines also are located on the marginal rim particularly towards the base of the achene. The density of the spines varies from 42 to 53 each side of an achene. Epidermal cells are very conspicuous on the surface of the achenes.

RANUNCULUS SARDOUS CRANTZ ACHENES

Like *Ranunculus arvensis* plants of this species produce a range of achene morphological types; the surface of the achenes can be smooth, can have tubercles arranged near the edge, or can be covered in tubercles. The latter form most closely matches the Belhus Park fossil achenes and is described here. The tuberculate achenes are orbicular to obovate (Pl. 2c). The maximum length of this type of achene is

2.86 mm, the average length is 2.55 mm and the minimum length is 2.31 mm. The maximum width is 2.75 mm, the average width is 2.16 mm and the minimum width is 1.70 mm. The beak is located off-centre and is short. The marginal rim is wide and has a characteristic narrow ridge on the inner edge. The density of tubercles is relatively low (16–21 per side of achene). Some of the tubercles are connected by fine ridges (Pl. 2d).

DISCUSSION

An accurate identification of the Belhus Park fossils is essential to contribute to a precise reconstruction of the vegetation and environmental conditions at the time of deposition of the fluvial sediments. The extant species that produce achenes that resemble the fossils have different ecological tolerances and different biogeographical ranges. For example, *Ranunculus parviflorus* is native to Britain today (Stace 1997) and grows on dry grassland and disturbed ground (Stewart et al. 1994), whereas *Ranunculus marginatus* is not a British native (Stace 1997) but has a southern European and eastern Mediterranean distribution where it prefers moist conditions (Boulos 1999). Therefore, mis-identification of the fossils could possibly lead to incorrect conclusions about the environmental conditions at the time of deposition.

The fossil *Ranunculus* achenes from Belhus Park come from an assemblage dominated by waterside, damp ground and aquatic taxa. This could lead to a bias when decisions are made about their specific identity with a species preferring moist conditions more likely to be considered. However, identification must only be made on the morphological features observed and comparison of these with modern reference material even if the determination provides a different ecological message to the rest of the taxa in the assemblage. Any possible morphological changes that occurred during fossilization must also be considered.

On size alone *Ranunculus arvensis* and *Ranunculus lateriflorus* can be discounted as being the identity of the fossils; *Ranunculus arvensis* is too large and *Ranunculus lateriflorus* is too small. *Ranunculus marginatus* has achenes that are slightly larger than the fossils, they have lower spine or tubercle densities on the achene sides, and no distinctive cell pattern was observed on their surface. Therefore, this species too can be disregarded as a candidate. None of the modern *Ranunculus sardous* achenes possessed spines on their sides. This trait together with the fact that the density of tubercles on the achene sides is too low (on *Ranunculus sardous* achenes that are covered in tubercles) means that the fossils did not originate from this species. Allowing for fossilization the fossil achenes are remarkably similar to modern *Ranunculus parviflorus* achenes in being the same shape and similar size, having very similar density of projections (spines and/or tubercles) on the achene sides, possessing the same shape and position of the funicular scar, and exhibiting the same characteristic surface cell pattern (compare Pl. 1a with Pl. 2b). One of the fossil achenes has two spines preserved on its surface. If all the tubercles on the fossil achenes are assumed to be the bases of spines which were lost during incorporation into the fossil assemblages then it can be concluded that the identity of the fossil achenes is *Ranunculus parviflorus*. The morphological similarities between the fossils and the modern *Ranunculus parviflorus* achenes discounts the need for a *Ranunculus* cf. *parviflorus* identification or the consideration that the fossils may originate from an extinct species.

This determination has implications for the palaeoenvironmental reconstruction made from the plant macrofossil assemblages. Overrepresentation of waterside, damp ground and aquatic taxa occurs in the Belhus Park plant macrofossil assemblages. The presence of *Ranunculus parviflorus* in the vegetation at the time of deposition of the fluvial sediments indicates that well drained, dry grassland or disturbed ground also existed in the river catchment. However, no other strictly non riparian herbaceous taxa were recorded in the Belhus Park assemblages. Therefore, the *Ranunculus parviflorus* achenes were most likely transported by flowing water in the channel from elsewhere in the catchment to the point of deposition.

CONCLUSIONS

Fossil *Ranunculus* achenes with tubercles or spines can be difficult to determine to species level. Middle Pleistocene fluvial sediments

from Belhus Park, Essex, UK yielded a small population of *Ranunculus* achenes with tubercles with one specimen having two spines preserved on its side. Detailed morphological comparison with modern reference material from species which most closely match the fossils and a consideration of the morphological changes that could have taken place during fossilization allow the fossils to be determined as *Ranunculus parviflorus*; a species that prefers dry grassland and disturbed ground. The plant macrofossil assemblages that included the *Ranunculus parviflorus* achenes were dominated by waterside, damp ground, and aquatic taxa. Probably the fossil achenes were transported by flowing water in the channel from elsewhere in the catchment before deposition. The identification of the Belhus Park fossils illustrates the importance of considering the morphological characteristics and possible modification of the achene only and not to make a determination based on the nature of the predominant palaeoenvironmental signal from an assemblage.

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PLATES

Plate 1

1a & 1b. Fossil *Ranunculus* achenes from the Belhus Park fluvial sediments (sample BP11C). The achene in plate 1b has two spines preserved on the upper right-hand side

1c. An achene of *Ranunculus arvensis* L. (from the Nationaal Herbarium Nederland – J.Wiesbaur. Kalksburg near Wien, Austria. 15/6/1882. Herb. Lugd. Bat. No. 908.182-1358)

1d. An achene of *Ranunculus lateriflorus* L. (from the Utrecht Herbarium – ex Joannes Wagner. June 1917)

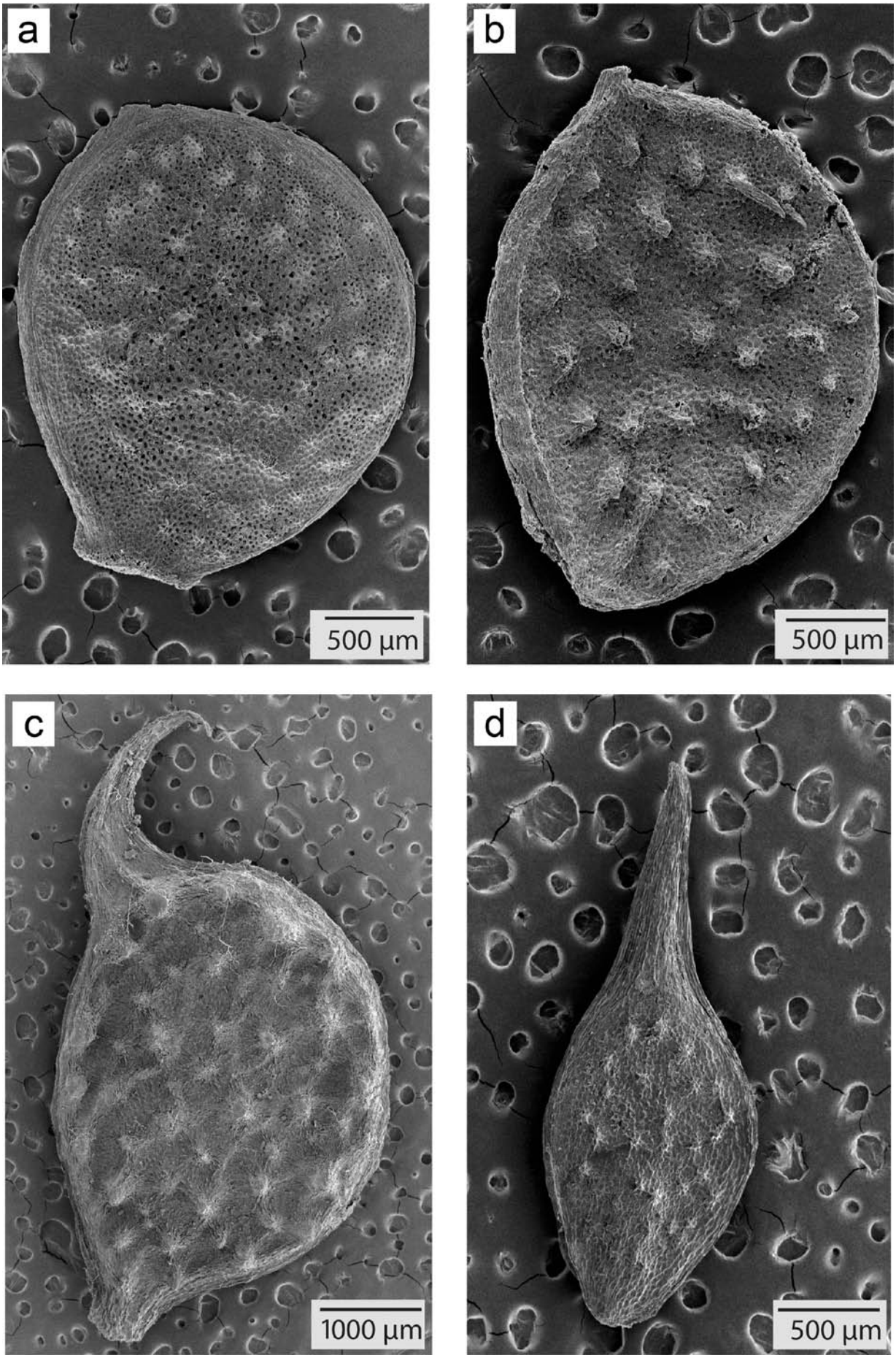
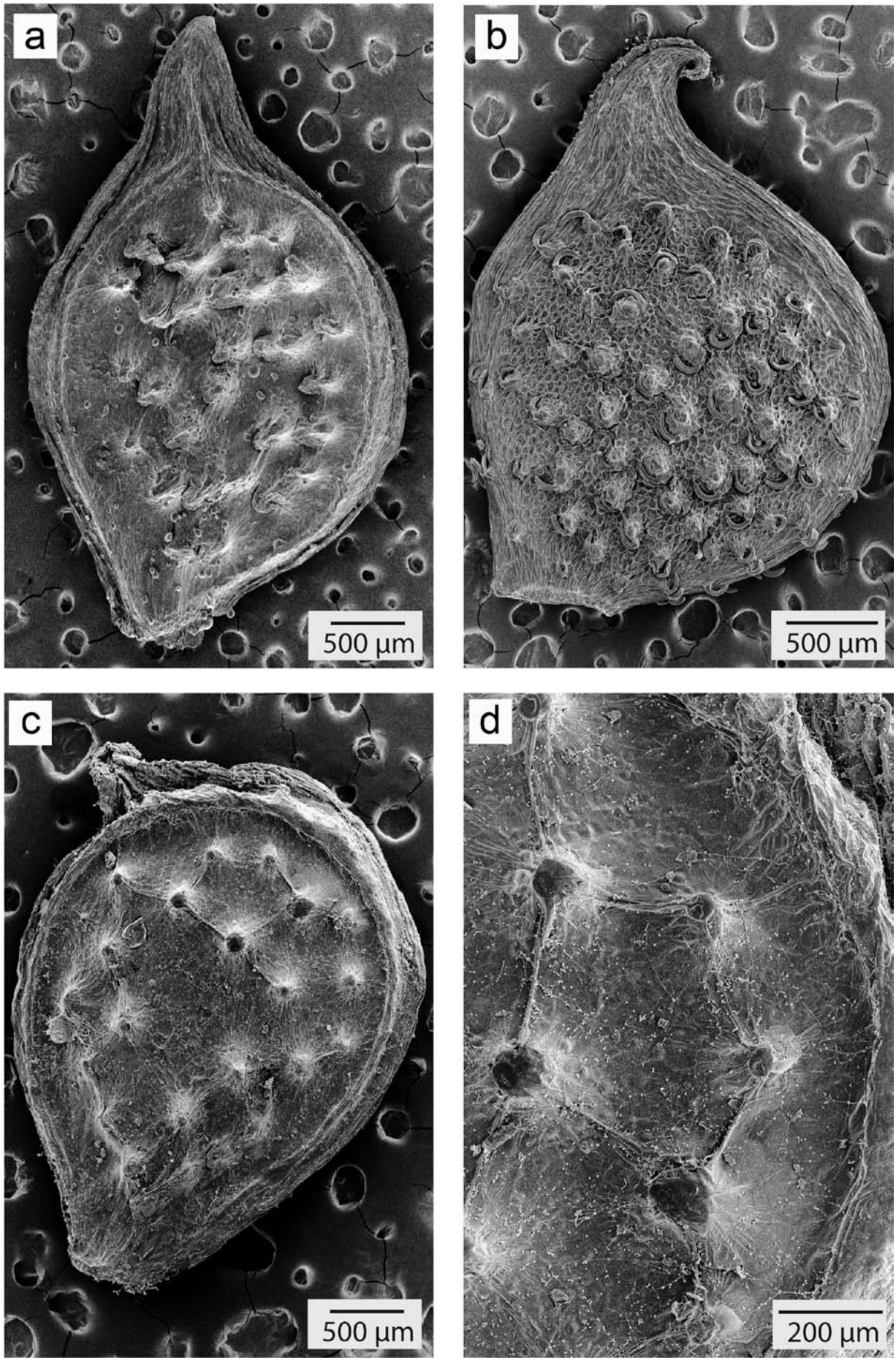

a
500 µm
b
500 µm
c
1000 µm
d
500 µm

Plate 2

2a. An achene of *Ranunculus marginatus* D'Urv. (from the Nationaal Herbarium Nederland – Collected by E.Hennipman et al. Selimiye, 5 km south of Manavgat, Antalya, Turkey. 3/5/1959. No. 848)

2b. An achene of *Ranunculus parviflorus* L. (from the Nationaal Herbarium Nederland – Rijksherbarium, Leiden Bot. Exc. 1983. Malaga, Spain. 17/4/1983. Herb. Lugd. Bat. No. 519627)

2c & 2d. An achene of *Ranunculus sardous* Crantz (from the Nationaal Herbarium Nederland – B.K.Boom Herbarium. Denia, Valencia, Spain. 14/4/1936. Herb. Lugd. Bat. No. 959.278-752). In plate 2d the fine ridges that connect some of the tubercles are shown


a
500 µm
b
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c
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d
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