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East–West European Middle Pleistocene correlation – the contribution of the first British record of *Aracites interglacialis* Wieliczk.

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ABSTRACT. Reported here is the first record of the extinct *Aracites interglacialis* Wieliczk. (possibly in the family Araceae) from the British Pleistocene at Gilson, Warwickshire in the English Midlands.

The palynological assemblages from the *Aracites interglacialis* seed-bearing sediments at Gilson support a correlation with those from the Hoxnian stratotype at Hoxne, Suffolk, England (Middle Pleistocene). The data indicate correlation with the middle and latter part of the Hoxnian Stage (correlated with the Holsteinian Stage). Like at Hoxne, the organic sediments at Gilson occur in a small depression (probably a kettle hole) on Anglian cold Stage (correlated with the Elsterian Stage) outwash sands and gravels, showing that they were deposited after this glaciation ended.

Velichkevich et al. (2004) stated that *Aracites interglacialis* "is characteristic only of the Mazovian interglacial and is abundant in fossil floras in Poland, Belarus and Russia". Using the presence of *Aracites interglacialis* as a biostratigraphic marker therefore allows the correlation of the British Hoxnian Stage with the Belarussian Alexandrian Stage, Polish Mazovian Stage and the Russian Likhvinian Stage.

KEYWORDS: *Aracites interglacialis* Wieliczk., Middle Pleistocene, biostratigraphic correlation, Europe

INTRODUCTION

The Gilson site occurs north-east of Coleshill in Warwickshire, England (Ordnance Survey grid reference SP19321 90324), at an elevation of 93 m O.D., on an interfluve between the rivers Cole, Tame and Blythe (Fig. 1). The site has been known for some time. Brown (1980) described a 19.8 m thick sequence here which included organic sediments within a shallow depression. The British Geological Survey map of the area (Powell et al. 2000) indicates that the underlying geology is Triassic Mercia Mudstone overlain by a series of Quaternary deposits comprising glacial clay underlying a series of sands and gravels with some organic sediments. The modern Tame, Cole and Blythe rivers subsequently incised into the Quaternary deposits forming the interfluve at Gilson.

More recently, a new borehole, named Gilson BH14-02(A), was put down in September 2014 with a view to reassessing the previous work (Gibson 2017). The core obtained reached a depth of 3.5 m and its lithological character is described in Table 1. The new borehole was situated 60 m down-slope from Brown's (1980) original boring. A ground-penetrating radar investigation of the site showed that the organic sediments occur in a depression which probably originated as a kettle hole (Gibson 2017).

A plant macrofossil investigation of the organic sediments from the Gilson BH14-02(A) core yielded seeds of *Aracites interglacialis* Wieliczk. This extinct species was formerly known only in Middle Pleistocene sediments from central and eastern Europe (Velichkevich

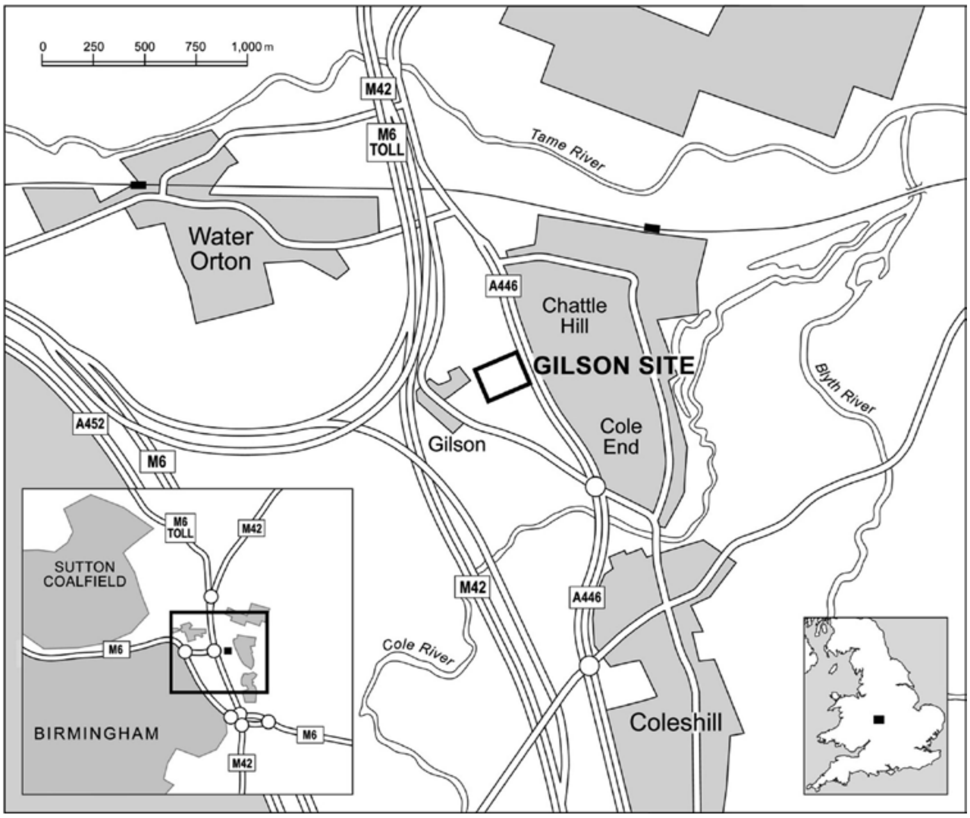

Fig. 1. The location of the Gilson site in Warwickshire, England

& Zastawniak 2006). Therefore, this is the first British record of *Aracites interglacialis*. Velichkevich & Zastawniak (2006) suggest that it belongs in the family Araceae. However, Bogner (2009) states that it does not belong in the Araceae but is of uncertain affinity. Unfortunately, Bogner (2009) does not give a reason for this statement. One argument for its exclusion from the Araceae family may be that the seed coats of Araceae members often contain idioblasts with raphide bundles (crystals), which are absent from the Gilson specimens and not referred to in the literature on *Aracites* (Ferry Bouman, personal communication).

This paper describes the fossil *Aracites interglacialis* seeds from Gilson, discusses the environment in which they were deposited, speculates about the ecological requirements of *Aracites interglacialis*, and comments on the stratigraphic implications of this discovery for east–west European Middle Pleistocene correlation.

Table 1. Description of the sediments from the Gilson BH14-02(A) core

Depth (m)	Description
0.00–0.15	Topsoil
0.15–0.35	Sand and gravel, massive, medium sand and sub-angular to sub-rounded gravel
0.35–1.35	Sandy silty clay, massive
1.35–1.54	Sandy silty clay, massive, with gravel
1.54–3.33	Organic clayey peat With wood between 1.97–2.02 m and 2.18–2.19 m With clay, massive, between 2.96–2.99 m, 3.09–3.12 m, and 3.19–3.22 m
3.33–3.36	Sand, massive
3.36–3.48	Silty peat, massive
3.48–3.50	Silt, massive

It appears that units from 3.33 m have unconformable basal contact, disturbed by the drilling technique.

THE FOSSIL *ARACITES INTERGLACIALIS* WIELICZK. SPECIMENS FROM GILSON

Mamakowa & Velichkevich (1993) and Velichkevich & Zastawniak (2006) briefly discuss the occurrence of fossil seeds with a similar morphology that have been found from the late Tertiary onwards in central and eastern Europe. A number of taxonomists have attempted to classify these fossil seeds. For example, Bennike (1990) described all morphologically similar fossils from the late Tertiary to the Middle Pleistocene as one taxon: *Aracites globosa* (Reid & Reid) Bennike. Aalto et al. (1992) argue that it is possible to separate Tertiary from Middle Pleistocene taxa and determine Middle Pleistocene fossils from Naakenavaara, Finnish Lapland, as *Aracites interglacialis*. Velichkevich (1977, 1982) formally described a new extinct fossil species, *Aracites interglacialis* Wieliczk., from interglacial sediments found in Ruba on the West Dvina river in Belarus correlated with the Likhvinian Stage. The Gilson specimens were identified as *Aracites interglacialis* by using descriptions and photographs in Mamakowa & Velichkevich (1993) and Velichkevich & Zastawniak (2006), and by comparison with fossil reference material of *Aracites interglacialis* seeds from Minichi, southwest of Minsk, Belarus (material kindly given to M.H. Field by F.Yu. Velichkevich in 1999). The Gilson specimens matched those of *Aracites interglacialis* from central and eastern Europe. In their conclusion to the discussion on *Aracites interglacialis*, Velichkevich & Zastawniak (2006) remark that "this taxon needs further investigation". This paper concentrates on announcing this new record for Britain and does not pretend to act as a revision of this taxon.

The seeds from Gilson (Figs 2 & 3) are well preserved, occur in high concentrations (e.g. 65 cm^3 of sample 166–176 yielded 46 whole seeds and 14 seed fragments), and most are whole, being 1.40 mm to 1.84 mm in length and between 1.02 mm and 1.31 mm wide. The seed wall (testa) is thick, and more so in the apical and basal areas than in the middle part of the seed (Figs 3a & 3e). The seed wall cells are round (Figs 3d & 3h), but towards the surface of the seed they become more compressed (Figs 3c & 3g). This sclerotic tissue is seen in seeds and fruits of many plants that live in or near water (Ferry Bouman, personal communication). It is often suberized or air-filled, enabling the propagules to float and disperse in water.

The whole seeds have the same shape Velichkevich & Zastawniak (2006) described, being "obovate to cordate or almost oval in outline, circular in cross-section" (Fig. 2a–d). Some of the seeds were a little flattened or had slight depressions on their sides, probably as a result of the fossilization process. The base of the seed tapers to a point in some specimens, while on others it is more rounded. Mamakowa & Velichkevich (1993) show specimens of *Aracites interglacialis* with a short pedicle (or stalk), but none are preserved on the Gilson specimens. The top of the seed has a broad funnel-shaped opening in which an operculum (or plug) is visible on some specimens (Fig. 2e–h). Velichkevich & Zastawniak (2006) suggest that the opening is a micropyle (a minute opening in the ovule of a seed plant through which the pollen tube usually enters). Figure 3a, b, e & f shows a small pore or canal on the side of the funnel-shaped opening whose function is not certain. In all the seeds that were split open this small pore was observed only on one side of the larger funnel-shaped opening. The funnel-shaped opening is either in a central position or just off centre. The opening leads to a pear-shaped (pyriform) cavity (Figs 3a & 3e) which is lined by a characteristic layer of cells that can be seen in cross section in Figure 3c & 3g. The top of the seed is truncate in some specimens, sometimes obliquely giving them an asymmetrical appearance. If the cuticle is preserved, as it is on many specimens (Figs 3c & 3g), it is smooth, lustrous, olive brown in colour, and on some specimens a faint epidermal cell pattern can be observed through the cuticle (Figs 2a–d).

THE DEPOSITIONAL ENVIRONMENT OF THE ORGANIC SEDIMENTS FROM THE GILSON BH14-02(A) CORE (RECONSTRUCTED FROM THE PLANT MACROFOSSILS RECOVERED)

The plant macrofossil assemblages recovered from the Gilson BH14-02(A) core sediments are not diverse in composition. The lack of aquatic and waterside taxa represented in the assemblages containing the seeds of *Aracites interglacialis* suggests that the basin in which sediment deposition took place had a high water table but was not often, if at all, filled with any depth of water – it was probably a swamp and never a lake with large areas of open water. Aalto et al. (1992) agreed with this conclusion by remarking that it was a peat-forming species. This also may explain the absence of *Azolla filiculoides*, whose megasporangia are regularly recovered from sites of Hoxnian age in the British Isles. No other marginal Hoxnian plant macrofossil record of this type exists from Britain. Most of the British Hoxnian palaeobotanical records come from lacustrine situations (West 1980).

Extremely high concentrations of bisaccate pollen grains of *Abies* were observed when picking the residues, produced by wet-sieving the sediment samples for plant macrofossils under a low power microscope. Blocks of sediment were observed composed entirely of *Abies* pollen before wet sieving (Fig. 4). In addition, the occurrence of *Abies* male cones scales, *Abies* leaf fragments and *Pinus* subgenus *Dipoxylon* leaves indicates that the basin was surrounded by coniferous trees whose canopies, in places, probably overhung the swamp. It is likely that the high concentrations of *Abies* pollen reflect grains falling directly onto the swamp surface from the canopies above. At times whole male cones dropped into the sediments. The coniferous woodland in the vicinity of the basin lead to the development of nutrient-poor, acidic edaphic conditions. Peat bog existed in more open areas, indicated by the presence of sclereids (or vascular sclerenchyma) of *Eriophorum vaginatum* and the occurrence of the opercula of *Sphagnum* capsules, as well as heath supported by the record of seeds and leaves of *Calluna vulgaris*. Aalto et al.'s (1992) Finnish investigation also noted that the *Aracites*-bearing sediment was of an oligotrophic *Sphagnum* peat character.

THOUGHTS ON THE ECOLOGY OF *ARACITES INTERGLACIALIS* WIELICZK.

Because *Aracites interglacialis* is an extinct species, it is only possible to speculate about its ecological preferences. The plant macrofossil investigation at Gilson suggests that this plant preferred damp, nutrient-poor, acidic conditions. It is possible that it could also tolerate low levels of light as a result of the shading effect of the coniferous woodland canopy. The seeds of *Aracites interglacialis* are well represented at Gilson, showing it was successfully reproducing sexually. The low taxa diversity in the plant macrofossil assemblages suggests that it was a competitive and successful plant under the right ecological conditions, and that at the time of sediment deposition may have formed monospecific vegetation in places in the swamp.

A combination of a number of abiotic (e.g. a lack of suitable hydrological and edaphic conditions, and climate change) and biotic (e.g. pressures related to changes in distribution at the end of the interglacial stage and competition) factors probably led to the extinction of *Aracites interglacialis* at the end of the Hoxnian Stage in the British Isles.

AGE, CORRELATION AND STRATIGRAPHIC IMPLICATIONS OF THE *ARACITES INTERGLACIALIS* WIEICZK. BEARING SEDIMENTS

The character of the palynological assemblages from the *Aracites interglacialis* seed-bearing organic sediments at Gilson supports a correlation with those from the Hoxnian stratotype at Hoxne, Suffolk, England (West 1956). This evidence allows a correlation with the middle and latter part of the Hoxnian Stage (Brown 1980). Brown's (1980) palynological data from Gilson have been reinterpreted by Gibson (2017), with three regional pollen assemblage biozones being identified in the profile. The pollen assemblages identified are correlated with Hoxnian regional substage biozones established for eastern England described by Turner and West (1968) and Turner (1970).

The basal Ho IIIa biozone (5.5–4.1 m depth in Brown's pollen diagram) is characterized by a poor representation of *Abies* and a high frequency of *Corylus* pollen. A decline in *Pinus* pollen contrasts to a rise in *Betula* and *Alnus* pollen through the biozone. *Tilia* and *Carpinus* pollen are notably present through the biozone. Aquatic plants are not well presented, but *Sphagnum* spores are present throughout.

The second biozone is Ho IIIb (4.1–3.15 m depth in Brown's pollen diagram), the base of which is placed at the point where *Abies* pollen, the main characteristic element of the biozone, markedly increases. At this point *Corylus* pollen also markedly decreases. The pollen of other major tree components occurring in this interval include *Picea*, *Quercus*, *Betula*, *Pinus* and *Alnus*. A rise in *Pinus* pollen contrasts with a decline of that of *Betula*. *Ulmus* pollen is a notable feature of the biozone. The lower boundary is marked by a sharp rise in aquatic plants, together with *Sphagnum* spores and the pollen of Gramineae and *Cyperaceae* herbs, which are well represented.

The uppermost biozone recognised is correlated with Ho IVa (3.15–2.90 m depth in Brown's pollen diagram), the basal boundary of which is placed at a pronounced decrease in the *Abies* pollen, accompanied by rising numbers of *Picea* pollen. Other tree taxa that are represented throughout the biozone include *Quercus*, *Betula*, *Pinus* and *Alnus*. The basal boundary of the biozone is characterised by a low frequency of *Corylus* pollen, rising

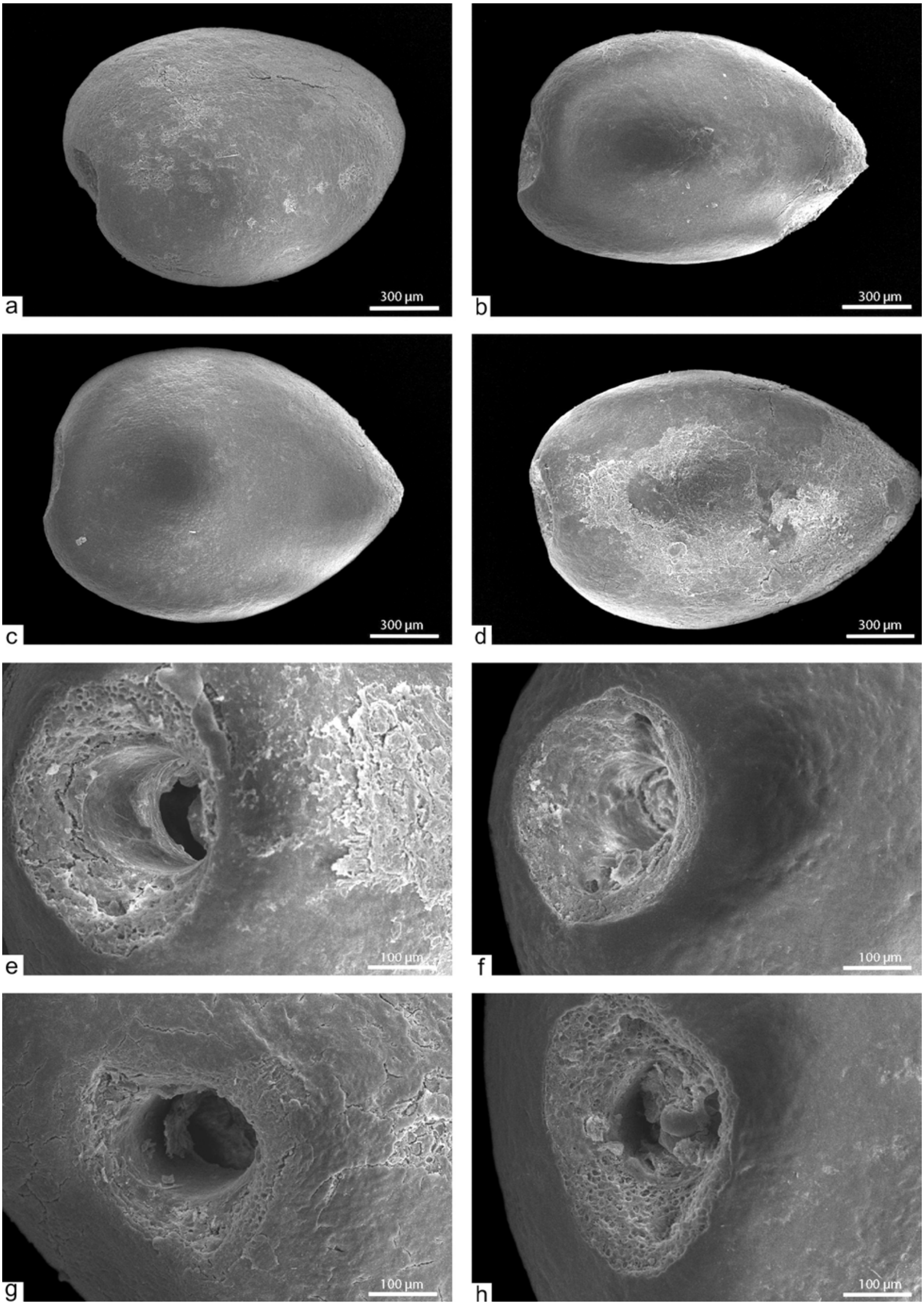

Fig. 2. SEM images of the external morphology of *Aracites interglacialis* Wieliczk. seeds recovered from the Gilson BH14-02(A) core (sample 156–166)

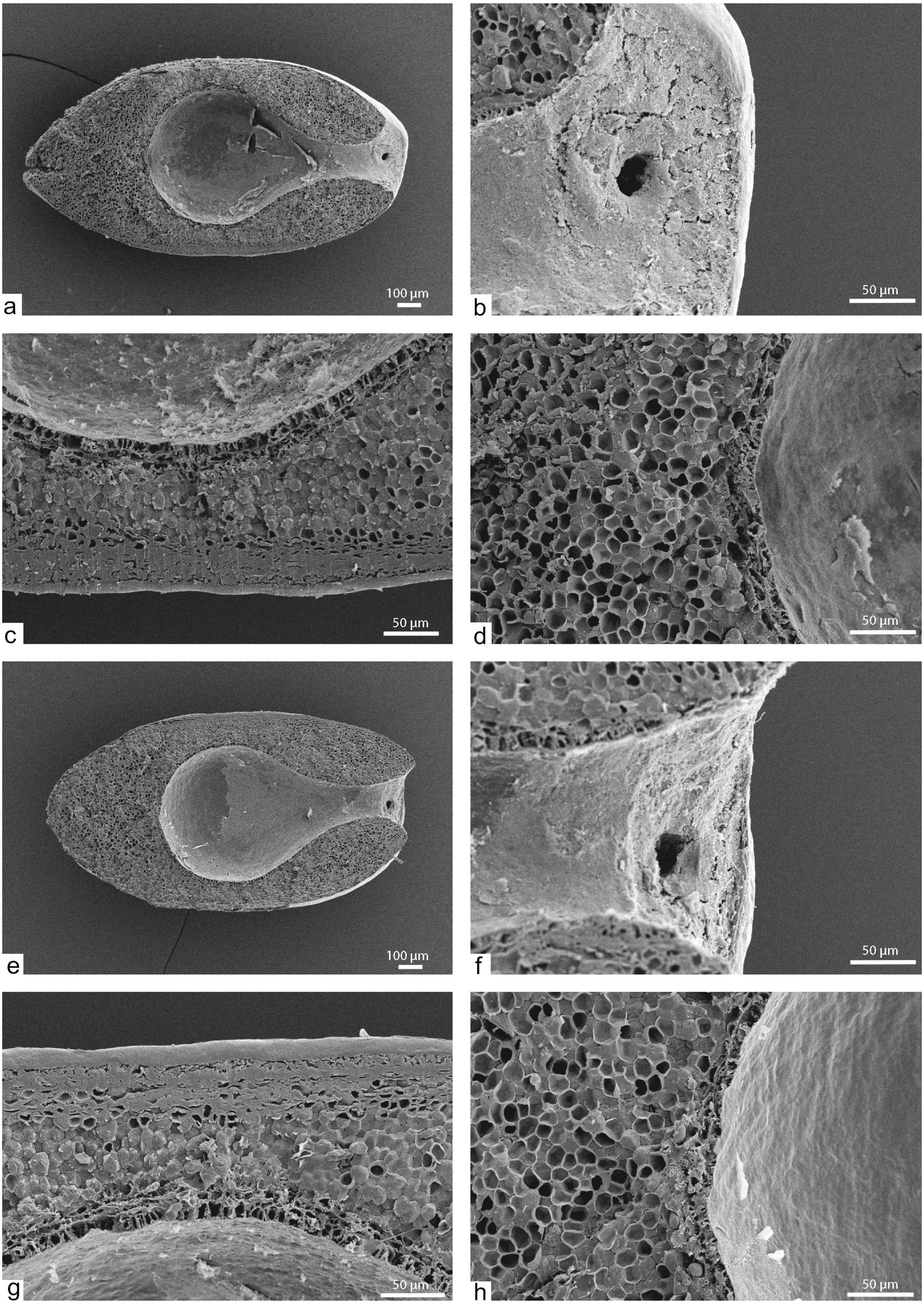

Fig. 3. SEM images of the internal morphology of *Aracites interglacialis* Wieliczk. seeds recovered from the Gilson BH14-02(A) core (sample 156–166). Figs 3a–d show details from one specimen and Figs 3e–h from another

steadily through the remainder of the biozone. The pollen of aquatic plants and the spores of *Sphagnum* decline, this contrasting with an increase in herb pollen and that of Gramineae and *Cyperaceae* at the top of the sequence.

As at Hoxne, the organic sediments at Gilson occur in a depression, probably a kettle hole formed at the end of the Anglian Stage glaciation, the sediments of which immediately underlie the site, indicating that the fill was deposited immediately following this cold period. As already stated, the pollen biozones determined indicate that only the latter half of the temperate event is represented at the Gilson locality. Discontinuous sequences from within shallow depression fills have been discovered at several Hoxnian-age sites, such sequences having been previously identified in southern and eastern England. Gilson is the first such sequence from the English Midlands where a discontinuous sequence has been found. This discontinuous sedimentation has been attributed to water-level changes resulting from groundwater fluctuations (Gibbard & Aalto 1977, Gibbard et al. 1986, Boreham & Gibbard 1995, Boreham et al. 1999). The evidence from a range of sites indicates that at the beginning of the Hoxnian temperate event, water levels were initially low, but that they rose during in the latter half of the period, beginning at the start of Ho III, thereby increasing accommodation space for sediments to accumulate. Whilst this regional pattern possibly results from increased precipitation, it is important to realize that it is likely to have been modified by local hydrological conditions at individual sites.

It is worth noting that Velichkevich et al. (2004) comment that *Aracites interglacialis* "is characteristic only of the Mazovian interglacial and is abundant in fossil floras in Poland, Belarus and Russia". Using the presence of *Aracites interglacialis* as a biostratigraphic marker therefore allows the correlation of the British Hoxnian Stage with the Belarussian Alexandrian Stage, Polish Mazovian Stage and Russian Likhvinian Stage.

Mamakowa & Velichkevich (1993) examined the palynological data available from Poland, Belarus, Russia and the Ukraine to conclude that *Aracites interglacialis* occurred mainly in the younger part of the interglacial stage and reached peak most probably in the younger part of the *Abies*-*Carpinus* zone. However, a detailed study of Mazovian sediments from Nowiny Żukowskie, southeast Poland, contradicts Mamakowa & Velichkevich's conclusion and shows that *Aracites interglacialis* increased in the thermal maximum as hydrological changes in the basin allowed swamp areas to expand. By the close of the interglacial stage, swamp (indicated by a large increase in *Aracites interglacialis*) and peat bog communities dominated (Hrynowiecka & Szymczyk 2011). Of course, this story may be site-specific, but it is interesting to note that the timing of the presence of *Aracites interglacialis* at Gilson is also in the latter part of the interglacial cycle. This is shown by palynological data from the Gilson BH14-02(A) core sediments. The seeds of *Aracites interglacialis* occur in sediments that contain high concentrations of *Abies* pollen. Some of the sediment towards the top of the organic sediments in the Gilson BH14-02(A) core was composed mainly of bisaccate pollen grains of *Abies* (Fig. 4).

Plant macrofossil data, as well as palynological data, can contribute to age determination of sediments and to development of a biostratigraphic scheme. Plant macrofossil data, unlike palynological data, provide a local, detailed reconstruction of the vegetation and environment at the time of sediment deposition and therefore can offer the ability to accurately identify parastratotypes (where deposition of sediments at different sites occurs at the same time but in different depositional settings). The sediments at Gilson allow a parastratotype reference locality for the Hoxnian Stage to be described, because such a depositional context for this stage has not been previously found in Britain. The majority of Hoxnian sediments

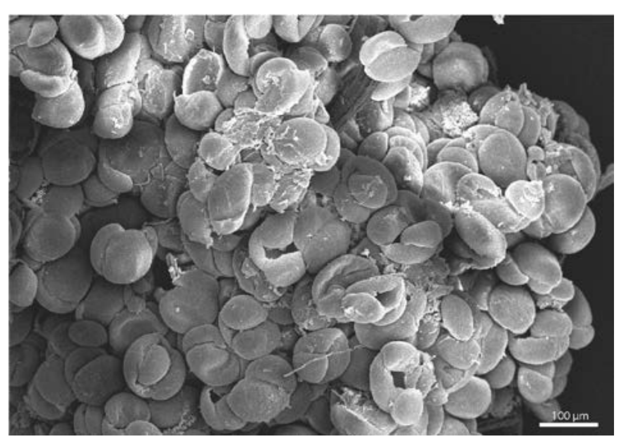

Fig. 4. A SEM image showing a block of sediment from the Gilson BH14-02(A) core (sample 156–166) composed almost entirely of *Abies* bisaccate pollen grains

are of lacustrine origin. Gilson represents the first Hoxnian Stage record from a swamp environment (see above).

CONCLUSION

The first British record of *Aracites interglacialis* extends its palaeobiogeographical range into western Europe. Evidence from eastern Europe shows that it only existed during one interglacial stage – termed the Alexandrian Stage in Belarus, the Mazovian Stage in Poland and the Likhvinian Stage in Russia. Using *Aracites interglacialis* as a biostratigraphic marker it is possible to correlate these with the British Hoxnian Stage. The plant macrofossil data from the *Aracites interglacialis* seed-bearing sediments show that sedimentation occurred in a swamp. Most British Hoxnian Stage sites represent deposition in lacustrine basins which are kettle holes. The Middle Pleistocene sediments at Gilson can therefore be formally described as a parastratotype reference locality for the Hoxnian Stage. A fuller report on the Gilson site will be published later.

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