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SPORE ASSEMBLAGES FROM THE SILURIAN-LOWER DEVONIAN 'LOWER OLD RED SANDSTONE' DEPOSITS OF THE LANARK BASIN OF THE MIDLAND VALLEY OF SCOTLAND

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Abstract: The Lanark Basin is situated along the southern Margin of the Midland Valley of Scotland. It contains a series of Silurian inliers whose transitional marine to brackish to terrestrial sequences are unconformably overlain by Lower Devonian 'Lower Old Red Sandstone' deposits. Dispersed spore assemblages have been reported from terrestrial deposits towards the top of the Silurian sequences and are of early Wenlock age. Those from the Hagshaw Hills inlier have been reinvestigated and updated records reported herein. The first dispersed spore assemblage recovered from the 'Lower Old Red Sandstone' deposits that unconformably overlie the Silurian sequences is described. It is from the Greywacke Conglomerate Formation and is interpreted as being of Early Devonian (Lochkovian) age. This is concordant with previous radiometric age dates reported from associated volcanic rocks.

Key words: Hagshaw Hills inlier, Fish Bed Formation, Greywacke Conglomerate Formation

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Introduction

The continental Silurian-Lower Devonian 'Lower Old Red Sandstone' (LORS) deposits of Scotland are difficult to interpret because biostratigraphical tie points are rare and they are tectonically complex (Bluck 2002, Trewin and Thirlwall 2002). Deposition began during the Caledonian Orogeny as Avalonia, Baltica and Laurentia collided, the terranes that make up Scotland assembled, and the Caledonian Mountains were uplifted and began to be denuded. The Midland Valley of Scotland terrane (MVOS) contains a southern Lanark Basin and northern Strathmore Basin. In the former there are a series of Silurian inliers where early Silurian marine deposits transition into late Silurian continental deposits (Text-fig. 1). These are unconformably overlain by probable Early Devonian LORS deposits. Invertebrate macrofaunas from the Silurian marine deposits indicate that they are of late Llandovery age. However, age constraining the overlying continental deposits is more problematic due to a paucity of fossils. Occasional fish-arthropod biotas are of some use, but are potentially facies specific and therefore of uncertain biostratigraphical value. Of more utility are dispersed spore floras, but these are rare. The Silurian continental deposits contain fish beds that yield fish-arthropod remains in addition to dispersed spore assemblages of early Wenlock age (Wellman and Richardson 1993). The unconformably overlying LORS deposits have not hitherto yielded biostratigraphically useful fossils. Here we review the dispersed spore assemblages from the late Silurian continental deposits and describe a new assemblage from the overlying LORS deposits. Any fossils recovered from these LORS deposits are significant as they shed light on the earliest continental biota at a critical time during the invasion of the land by plants, fungi and animals.

Geology

A series of Silurian inliers are present along the southern margin of the Lanark Basin in the MVOS (Paterson et al. 1998, Bluck 2002; Text-figs 1, 2). They all have similar sequences with early Silurian (late Llandovery) marine deposits shallowing upwards into brackish water deposits that are succeeded by continental (terrestrial-fluviatile-lacustrine) deposits (Paterson et al. 1998, Bluck 2002). Productive palynological samples recovered from fish beds in these continental deposits were previously described by Wellman and Richardson (1993) and indicate an early Wenlock age. The deposits of the inliers are succeeded, either unconformably or paraconformably, by typical LORS

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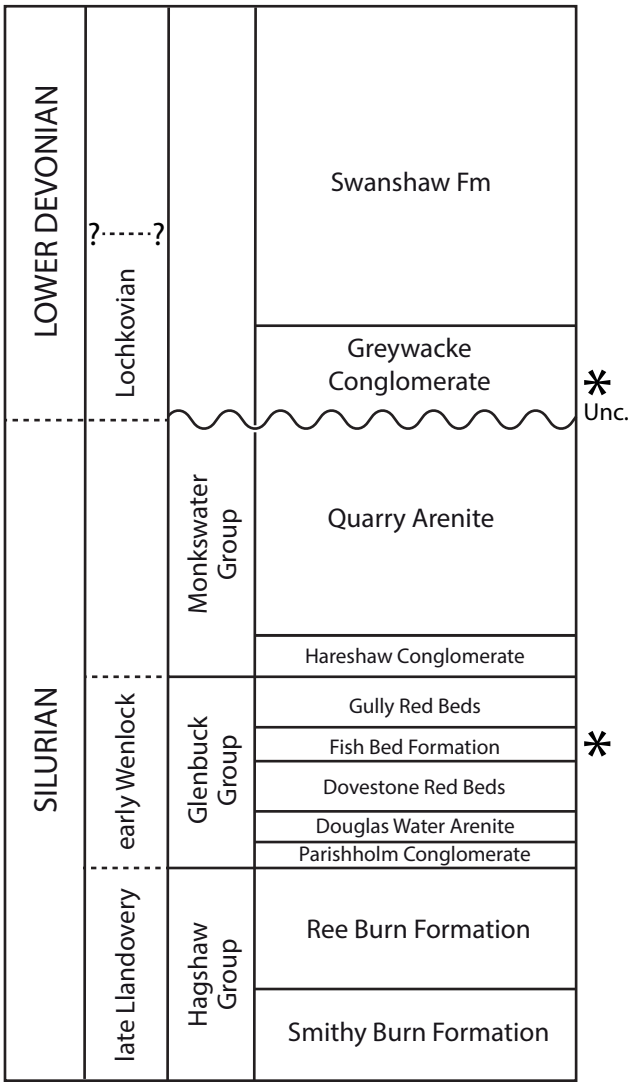
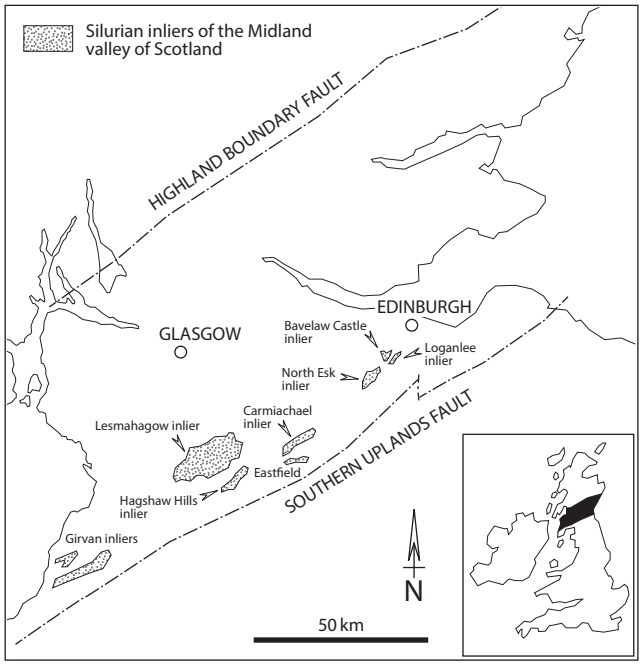


Text-fig. 1. Stratigraphical column showing the sequence of the Hagshaw Hills inlier and unconformably overlying 'Lower Old Red Sandstone' (LORS). The position of recovered dispersed spore assemblages is indicated by the asterisks.



Text-fig. 2. Location map of the Silurian inliers of the Midland Valley of Scotland including the Hagshaw Hills inlier (modified after Wellman and Richardson 1993).

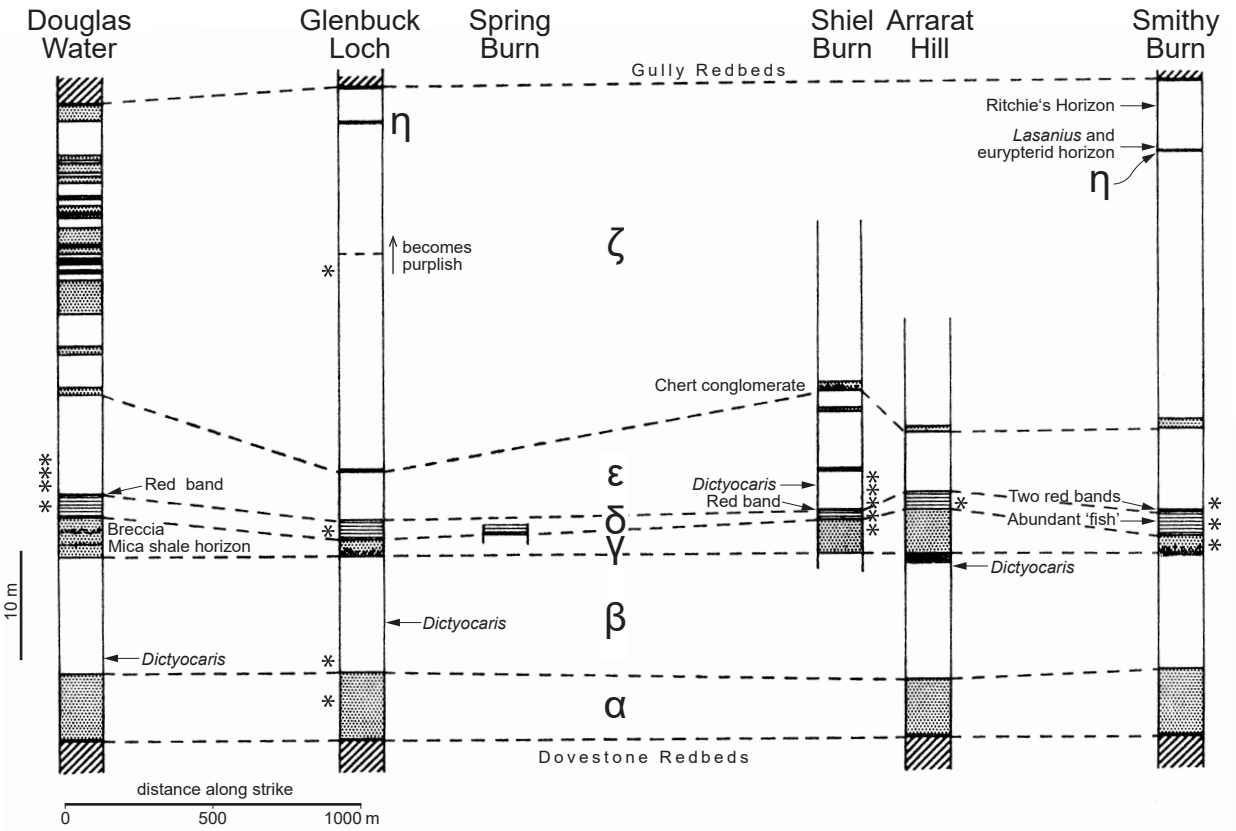
deposits (Smith 1995, Paterson et al. 1998, Browne et al. 2002, Phillips et al. 2004, Smith et al. 2006). These are poorly dated due to a lack of fossil evidence. They have not previously yielded spore assemblages, only rare fish including *Cephalaspis lyelli*, *C. powriei*? and *C. traquairi* (Waterston 1965, Mykura 1983, Browne et al. 2002), millipedes (Brade-Birks 1923) and trace fossils (Smith 1909, Pollard and Walker 1984, Walker 1985). However, radiometric dating by Thirlwall (1988) for the Pentland Hills Volcanic Fm provided a Rb/Sr phenocryst biotite age of 412.6 ± 5.7 Ma and for the Tinto Felsite intrusion a Sm-Nd garnet age of ca. 411.9 ± 1.9 Ma and a Rb-Sr biotite age of 407.2 ± 6.7 Ma. These dates suggest a Lochkovian (410.8–419.2) to Pragian (407.6–410.8) age.

This report considers palynological analysis of the succession of the Hagshaw Hills inlier (Rolfe 1961) and overlying LORS in its vicinity (as illustrated in Text-fig. 1). This work was prompted by the recent exposure of the unconformity at the base of the LORS during roadworks that enabled Mitten et al. (2022) to undertake a detailed sedimentological analysis of the LORS Greywacke Conglomerate Fm. These deposits represent alluvial fans, sourced from the Southern Uplands, and deposited in an arid-semi arid environment.

Material and methods

Since 1988 numerous samples have been collected from the Fish Bed Fm of the Hagshaw Hills inlier (details provided in Text-fig. 3 and Appendix). Many of these have yielded rich palynomorph assemblages. Recently the A70 road near Glenbuck Loch was straightened cutting a continuous section through the upper part of the sequence of the Hagshaw Hills inlier (Rolfe 1961). The cutting also exposed the contact between the Late Silurian Quarry Arenite Fm and Lower Devonian LORS Greywacke Conglomerate Fm (Mitten et al. 2022). The latter consist predominantly of conglomerate and subsidiary coarse sandstones. However, a thin impersistent dark green shale unit is present in a coarse sandstone layer in the Greywacke Conglomerate immediately above the contact with the Quarry Arenite. The shale at Grid Reference: HS75514/28543 was sampled for palynological analysis (sample 21CW053-21SCOT08).

For all samples fresh rock was cleaned and demineralised using standard palynological HCl-HF acid maceration techniques. Sieving was undertaken using a 20 µm mesh. The residue was then subjected to heavy mineral separation, using zinc chloride, to remove any remaining mineral matter. The palynological preparation yields only dispersed spores and phytodebris (cuticle-like sheets and tubular structures) (Wellman and Ball 2021). The spores are moderately abundant, moderately well preserved and of moderate thermal maturity (translucent orange-brown and T.A.I. 3 on the colour scheme of Traverse 2007). Residues were oxidised for up to 30 minutes in fresh Schultz solution until translucent orange-yellow. The residue was strew mounted onto glass coverslips



Text-fig. 3. Sections of the Fish Bed Formation of the Hagshaw Hills inlier with the position of recovered dispersed spore assemblages indicated by the asterisks (modified after Rolfe 1961 using the bed terminology utilised in this publication).

and attached to glass slides using Epoxy resin for light microscope analysis. All materials are curated in the Centre for Palynology of the University of Sheffield, UK.

Spore assemblages from the Fish Bed Formation

The Fish Bed Fm of the Hagshaw Hills inlier yields rich palynological assemblages (Text-figs 4, 5). Wellman and Richardson (1993) described the dispersed spore assemblages and Wellman (1995) described the dispersed phytodebris. The euglenid *Moyeria* is also common (Wellman and Richardson 1993, Strother et al. 2020). Arthropod cuticle and fish denticles have also been recovered with the latter illustrated for the first time herein. The Appendix lists the location of all samples collected and Table 1 lists the taxa recovered from the palynological preparations. A selection of these are illustrated in Text-figs 4, 5 including previously

Table 1. Palynomorphs and phytodebris recovered recovered from the Fish Bed Fm of the Hagshaw Hills inlier (Text-figs 4–5).

Dispersed spores	**Phytodebris: Tubular structures**
Tetrahedraletes medinensis P.K.Strother et Traverse, 1979 emend. Wellman and Richardson (1993)	*Laevitubulus crassus* N.D.Burgess et D.Edwards, 1991
Rimosotetras problematica N.D.Burgess, 1991	*Laevitubulus laxus* N.D.Burgess et D.Edwards, 1991
Cheilotetras caledonica C.H.Wellman et J.B.Richardson, 1993	*Laevitubulus plicatus* N.D.Burgess et D.Edwards, 1991
Dyadospora murusdensa P.K.Strother et Traverse, 1979 emend. Burgess and Richardson (1991)	*Laevitubulus tenuis* N.D.Burgess et D.Edwards, 1991
Dyadospora murusattenuata P.K.Strother et Traverse, 1979 emend. Burgess and Richardson (1991)	*Porcatitubulus annulatus* N.D.Burgess et D.Edwards, 1991
Pseudodyadospora petasus C.H.Wellman et J.B.Richardson, 1993	*Porcatitubulus microannulatus* C.H.Wellman, 1995
Laevolancis divellomedium (Chibrikova) N.D.Burgess et J.B.Richardson, 1991	*Porcatitubulus microspiralis* C.H.Wellman, 1995
Laevolancis plicata N.D.Burgess et J.B.Richardson, 1991	*Porcatitubulus spiralis* N.D.Burgess et D.Edwards, 1991
Ambitisporites avitus W.S.Hoffmeister, 1959	*Porcatitubulus strupus* C.H.Wellman, 1995
Ambitisporites dilutus (W.S.Hoffmeister) J.B.Richardson et T.R.Lister, 1969	*Ornatifilum* sp.
	Prototaxites sp.
Freshwater phytoplankton	**Phytodebris: Cuticle-like sheets**
Moyeria sp.	
Sphaeromorph (small)	**Arthropod cuticle**
Sphaeromorph (medium)	
Sphaeromorph (large)	**Fish denticles**
Sphaeromorph with spot	**Fish plates**

Text-fig. 4. Fish Bed Formation palynoflora. a: ***Tetrahedraletes medinensis*** **[Slide BH4/3, E.F.no (X42/3)]; b:** ***Tetrahedraletes medinensis*** **[Slide 18DH01/1, E.F.no (R23)]; c:** ***Cheilotetras caledonica*** **[Slide 19SCOT08/1, E.F.no (V43/2)]; d:** ***Rimosotetras problematica*** **[Slide 23SCOT04/1, E.F.no (L31)]; e:** ***Dyadospora murusattenuata*** **[Slide 23SCOT04/1, E.F.no (N32/3)]; f:** ***Dyadospora murusdensa*** **[Slide 23SCOT03/1, E.F.no (L48/2)]; g:** ***Pseudodyadospora petasus*** **[Slide 18DH02/1, E.F.no. (K43/2)]; h:** ***Ambitisporites avitus*** **[Slide 23SCOT04/1, E.F.no (H49)]; i:** ***Ambitisporites dilutus*** **[Slide BH4/3, E.F.no (W54/3)]; j:** ***Laevolancis plicata*** **[Slide BH8/2,**

Table 2. Spores recovered from the Greywacke Conglomerate Fm (Text-figs 6–7).

Retusotriletes triangulatus (Streel) Streel, 1967	*Granulatisporites* sp.
Retusotriletes spp.	Large verrucate-rugulate trilete spore (86–98 µm)
Apiculiretusispora plicata (K.C.Allen) Streel, 1967	Reticulate spore
Apiculiretusispora spp.	*Verrucosisporites* sp.
Dibolisporites sp. A in Lavender and Wellman (2002)	*Archaeozonotriletes chulus* (H.F.Cramer) J.B.Richardson et T.R.Lister, 1969
Dibolisporites sp. D in Lavender and Wellman (2002)	Zonate spores
Ambitisporites avitus W.S.Hoffmeister, 1959	*Laevolancis divellomedium* (Chibrikova) N.D.Burgess et J.B.Richardson, 1991
Emphanisporites sp.	*Pseudodyadospora petasus* C.H.Wellman et J.B.Richardson, 1993

unpublished images of fish remains and the non-spore 'sphaeromorph' component (that probably represents in the main the resting cysts of freshwater aquatic phytoplankton). The spore assemblages belong with the CN *chulus-nanus* Spore Assemblage Biozone indicating an early Wenlock (Sheinwoodian) age (Richardson and McGregor 1986, Burgess and Richardson 1991, 1995).

Spore Assemblage from the Greywacke Conglomerate Formation

The spore assemblage is depauperate, consisting of only 16 types (Table 2). Many of the specimens are relatively large (>100 µm) suggesting that size sorting may have occurred with the smaller elements winnowed away. This is not unexpected given the coarse nature of the sediment from which they were recovered. The preparation contains abundant phytodebris in the form of cuticle-like sheets and tubular structures, including banded tubes. A list of taxa is provided in Table 2 and illustrations of the palynomorphs in Text-figs 6, 7.

The dispersed spore assemblage is difficult to age constrain due to the paucity of taxa recovered. However, it most likely belongs to the *micrornatus-newportensis* Spore Assemblage Biozone (MN SAB) (Richardson and McGregor 1986, Streel et al. 1987) given that:

1. *Emphanisporites* ?*micrornatus* J.B.Richardson et T.R.Lister is reported (albeit a single specimen).
2. Large specimens of *Dibolisporites* sp. A (Lavender and Wellman 2002) and *Dibolisporites* sp. D (Lavender and Wellman 2002) are present that are identical to those described from MN SAB spore assemblages from the Arbuthnott Group of Scotland (Richardson et al. 1984, Lavender and Wellman 2002).
3. Large spores (>100 µm) are present.
4. Zonate spores are present.

Assignment to the MN SAB suggests an Early Devonian Lochkovian age (early, but not earliest to late, but not latest Lochkovian).

Discussion

The biostratigraphical age-constraint for the Greywacke Conglomerate Fm, based on the new dispersed spore assemblages, is concordant with radiometric age constraint that indicate an Early Devonian (Lochkovian) age. Palynofacies analysis reveals that the palynomorph assemblages comprises entirely land-derived forms (spores and phytodebris). This is to be expected from a deposit interpreted as an alluvial fan (i.e., typical continental LORS). The dispersed spore assemblage has limited implications regarding the contemporary flora as it is clearly depauperate, due to the low yield and probable size sorting as a consequence of the high energy environment in which it was deposited. However, it is clearly much more evolved than spore assemblages from the Fish Bed Fm of the Hagshaw Hills inlier and is probably in the region of 15–20 million years younger. Taxa similar to other MN SAB dispersed spore assemblages from the MVOS, such as those from the northern Strathmore Basin are present (Richardson et al. 1984, Wellman 1993, Lavender and Wellman 2002). MN SAB spore assemblages show distinct local differences related to palaeoenvironment, for example between the lowland, floodplain deposits of the Anglo-Welsh Basin and inland, upland deposits of the Scottish Caledonides (Wellman 1993, Lavender and Wellman 2002), as well as larger scale palaeophytogeographical variation (e.g., Wellman et al. 2022). The presence of cuticle-like sheets and banded tubes indicates the presence of nematophytes as would be expected (Wellman and Ball 2021).

Acknowledgements

This paper is dedicated to the memory of Cedric Schute. As a young Ph.D. student Cedric's encyclopaedic knowledge of the William Lang collection and willingness to guide me through it was invaluable. I will also never forget the rebuke I received when he caught me examining Rhynie chert thin

E.F.no (P60/3)]; k: *Laevolancis divellomedium* [Slide 23SCOT03/1, E.F.no (G33)]; l: Parallel filaments with multiple septae [Slide 19SCOT05/1, E.F.no (P41/3)]; m: Filament with multiple septae [Slide 23SCOT04/1, E.F.no (X37/4)]; n: Parallel-arranged *Laevitubulus laxus* [Slide 19SCOT08/1, E.F.no (P29/3)]; o: Branching *Laevitubulus laxus* [Slide 23SCOT04/1, E.F.no (E39/4)]; p: *Laevitubulus crassus* [Slide 19SCOT01/1, E.F.no (H36)]; q: Bundle of *Laevitubulus crassus* [Slide BH4/3, E.F.no (W49)]; r: *Laevitubulus plicatus* [Slide BH8/2, E.F.no (K45/1)]; s: *Laevitubulis tenuis* [Slide 23SCOT03/1, E.F.no (O35)]; t: Branching multi-layered tubular structure (*Ornatifilum*) [Slide 23SCOT04/1, E.F.no (L43/3)]; u: *Porcatitubulus strupus* [Slide 19SCOT08/1, E.F.no (C44/3)]; v: *Porcatitubulus annulatus* [Slide 23SCOT04/1, E.F.no (T48)]; w: *Porcatitubulus spiralis* [Slide BH8/2, E.F.no (Q51)]; x: *Porcatitubulus microspiralis* [Slide 18DH02/1, E.F.no (V44)]; y: Cuticle-like sheet with strutting [Slide BH4/3, E.F.no (X55/4)]; z: Cuticle-like sheet with holes [Slide 19SCOT08/1, E.F.no (F40/2)]; aa: Cuticle-like sheet with cells with central thickening [Slide 18DH01/1, E.F.no (P30/2)]; ab: Cuticle-like sheet [Slide 25SCOT03/1, E.F.no (T49)]. Scale bar = 150 µm (l–u, x), 120 µm (y–ab), 60 µm (v–w), 30 µm (a–k).

Text-fig. 5. Fish Bed Formation palynoflora. a: Small sphaeromorph [Slide 19SCOT08/1, E.F.no. (B43/4)]; b: Medium sized sphaeromorph [Slide 23SCOT03/1, E.F.no. (M40/3)]; c: Large sphaeromorph [Slide 23SCOT04/1, E.F.no. (D49)]; d: Large shagrinate sphaeromorph [Slide 23SCOT04/1, E.F.no. (Q42/2)]; e: Ellipsoidal sphaeromorph [Slide 23SCOT04/1, E.F.no. (M46/4)]; f: Sphaeromorph enclosed in leavigate envelope [Slide 23SCOT04/1, E.F.no. (K33/3)]; g: Reticulate 'sphaeromorph' [Slide 19SCOT02/1, E.F.no. (H34/4)]; h: Verrucate 'sphaeromorph' [Slide 19SCOT08/1, E.F.no. (M49/1)]; i: *Moyeria* (thicker-walled *Chomo-*

sections with an incorrectly set up microscope – and the subsequent kindness he showed in spending time to teach me how to properly adjust it. This research was funded by NERC grant NE/R001324/1.

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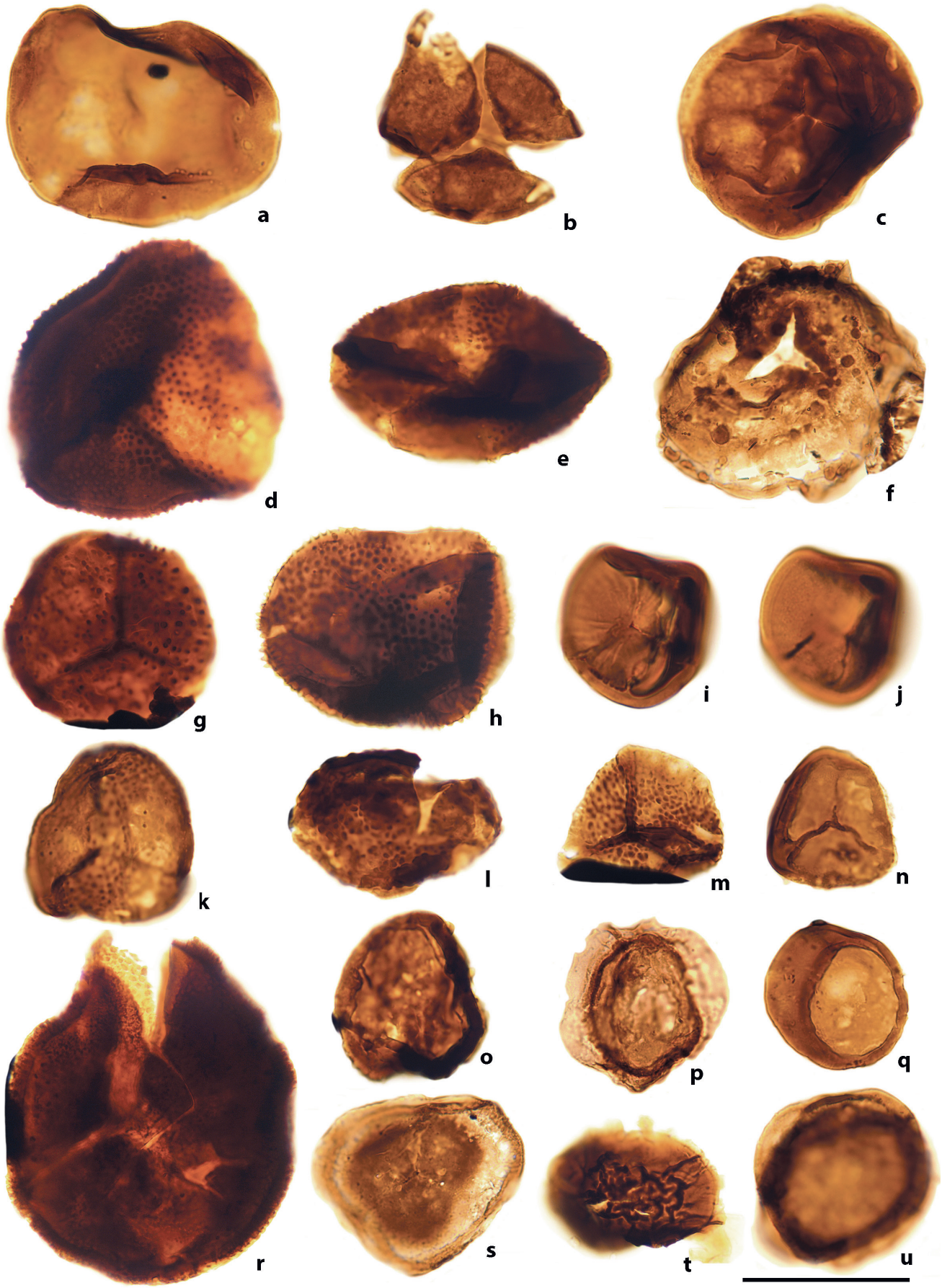
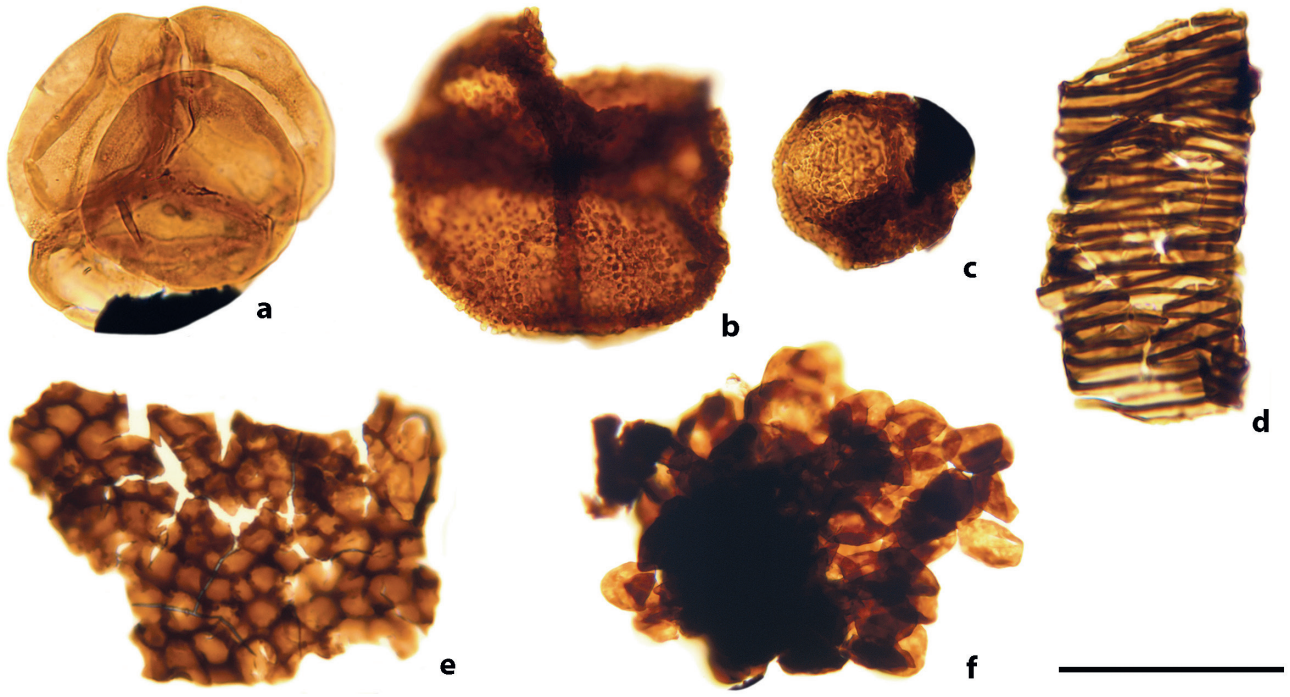
***triletes*-type) [Slide BH8/2, E.F.no. (L55)]; j: *Moyeria* [Slide BH4/3, E.F.no. (P39/2)]; k: Sphaeromorph with spot [Slide 23SCOT03/1, E.F.no. (N40/1)]; l: Apiculate 'sphaeromorph' [Slide BH8/2, E.F.no. (J50/2)]; m: Fish denticle [Slide 21SCOT05/1, E.F.no. (L34)]; n: Fish denticle [Slide 21SCOT05/1, E.F.no. (J43/4)]; o: Fish plate [Slide21SCOT05/1, E.F.no. (S35/4)]; p: ?Arthropod cuticle comprising adjoining segments bearing a hooked spine [Slide 23SCOT03/1, E.F.no. (S34/3)]; q: Arthropod cuticle with serrated edge [Slide 23SCOT04/2, E.F.no. (N32)]; r: Arthropod spine [Slide 23SCOT04/1, E.F.no. (L38)]; s: Arthropod cuticle [Slide BH4/3, E.F.no. (T58/3)]. Scale bar = 150 µm (m–o), 120 µm (p–s), 90 µm (a–e), 30 µm (f–l).**



Text-fig. 6. Greywacke Conglomerate Formation palynoflora. a: ***Apiculiretusispora plicata*** **[Slide 21SCOT08.1, E.F.no. (D48/4)]; b:** ***Retusotriletus triangulatus*** **[Slide 21SCOT08.1, E.F.no. (E35)]; c: Trilete spore with prominent thickening associated with trilete mark [Slide 21SCOT08.2, E.F.no. (E34/1/3)]; d:** ***Dibolisporites*** **sp. A [Slide 21SCOT08.1, E.F.no. (K32/1)]; e:** ***Dibolisporites*** **sp. A [Slide 21SCOT08.1, E.F.no. (D34)]; f:** ***Retusotriletes triangulatus*** **associated with abundant tapetal debris [Slide 21SCOT08.1, E.F.no. (P37/3)]; g:** ***Dibolisporites*** **sp. D [Slide 21SCOT08.2, E.F.no. (T38/1)]; h:** ***Dibolisporites*** **sp. A [Slide 21SCOT08.1, E.F.no.**



Text-fig. 7. Greywacke Conglomerate Formation palynoflora and phytodebris. a: Tetrad of laevigate trilete spores [Slide 21SCOT08.2, E.F.no. (D39)]; b: Tetrad of verrucate trilete spores [Slide 21SCOT08.1, E.F.no. (K36)]; c: Tetrad of regulate trilete spores [Slide 21SCOT08.2, E.F.no. (F45/4)]; d: Banded tube [Slide 21SCOT08.2, E.F.no. (K37)]; e: Cuticle-like sheet [Slide 21SCOT08.1, E.F.no. (Y38/4)]; f: Spore mass [Slide 21SCOT08.1, E.F.no. (G33/3)]. Scale bar = 20µm (a–c), 30 µm (d), 15 µm (e), 10µm (f).

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(Y43/2)]; i–j: *Emphanisporites ?micrornatus* spp. [Slide 21SCOT08.2, E.F.no. (O29/4)]; k: *Aneurospora* spp. [Slide 21SCOT08.2, E.F.no. (C40/4)]; l: Verrucate spore [Slide 21SCOT08.2, E.F.no. (G43)]; m: Verrucate spore [Slide 21SCOT08.2, E.F.no. (J37)]; n: *Apiculiretusispora* spp. [Slide 21SCOT08.2, E.F.no. (Q34/2)]; o: *Archaeozonotriletes chulus* [Slide 21SCOT08.1, E.F.no. (L45/1)]; p: Zonate spore [Slide 21SCOT08.1, E.F.no. (W47)]; q: *Laevolancis divellomedium* [Slide 21SCOT08.1, E.F.no. (Q32)]; r: Large verrucate-rugulate trilete spore [Slide 21SCOT08.1, E.F.no. (N35)]; s: Zonate spore [Slide 21SCOT08.2, E.F.no. (D40/1/3)]; t: Reticulate ?trilete spore [Slide 21SCOT08.2, E.F.no. (J43/1)]; u: *Pseudodyadospora petasus* [Slide 21SCOT08.1, E.F.no. (U47)]. Scale bar = 30 µm (i, j), 20 µm (a–h, k–u).

Appendix

Location of spore assemblages recovered from the Fish Bed Formation of the Hagshaw Hills inlier. Logged samples in bold.

Douglas Water
23SCOT01 NS7525427192 laminated siltstone 90 cm above breccia [Palynomorphs extremely poorly preserved]
23SCOT02 NS7525427192 laminated siltstone 110 cm above 23SCOT01 (20 cm above red layer) [Palynomorphs extremely poorly preserved]
23SCOT03 NS7525427192 massive mudstone 30 cm above 23SCOT02 [Palynomorphs moderate-well preserved]
23SCOT04 NS7525427192 massive mudstone 30 cm above 23SCOT03 [Palynomorphs well preserved]

Glenbuck Loch
88-AH5 NS76132838 Grey siltstone [Well preserved spore assemblage]
89-BH4 NS76142838 Grey-green mudstone 5m N of junction with Dovestone Red Beds [Well preserved spore assemblage]
89-BH5 NS76142850 Grey siltstone near junction with Gully Red Beds [Barren]
89-BH6 NS76132857 Purple mudstone directly above 89-BH5 [Barren]
89-BH8 NS76142840 Grey-green mudstone 20m from junction with Dovestone Red Beds [Well preserved spore assemblage]
89-BH9 NS76142840 Grey siltstone 20m from junction with Dovestone Red Beds [Well preserved spore assemblage]
00-CH1a [Well preserved spore assemblage]
00-CH1b [Well preserved spore assemblage]
19SCO01 NS7613928374 5m N of red beds [Well preserved spore assemblage]
19SCO02 NS7613728376 Next exposure north of 19SCO01 [Well preserved spore assemblage]
19SCO03 NS7613728376 As above [Well preserved spore assemblage]
19SCO04 NS7613728376 As above [Well preserved spore assemblage]
19SCO05 NS7613728376 As above [Well preserved spore assemblage]
19SCO06 NS7611228397 Next exposure north of 19SCO02-05 [Well preserved spore assemblage]
19SCO07 NS7614428428 Next exposure north of 19SCO06 [Poorly preserved spore assemblage]
19SCO08 NS7614428428 As above [Well preserved spore assemblage]
19SCO09 NS7614428428 As above [Well preserved spore assemblage]

Sheil Burn
89-BH15 NS77702904 ε 170 cm above top of fish bed Grey-green mudstone [Well preserved spore assemblage]
21SCO01 NS7770029038 ε 100cm above fish bed Nodule [Barren]
21SCO02 NS7770029038 ε 100cm above fish bed 2cm laminated horizon [Well preserved spore assemblage]
21SCO03 NS7770029038 ε 100cm above fish bed Grey-green siltstone [Well preserved spore assemblage]
89-BH14 NS77702904 ε 85 cm above fish bed Grey-green mudstone [Well preserved spore assemblage]
88-AH10 NS77722905 ε Immediately above top of fish bed Green siltstone [Well preserved spore assemblage]
89-BH13 NS77702904 ε Immediately above top of fish bed Grey-green siltstone [Well preserved spore assemblage]
88-AH06 NS77722905 δ 5cm below top of fish bed Laminated grey-black shale [Well preserved spore assemblage]
21SCO05 NS7770029038 δ 10cm below top of fish bed Laminated grey-black shale [Barren]
89-BH12 NS77702904 δ 15cm below top of fish bed Grey-green siltstone [Well preserved spore assemblage]
88-AH07 NS77722905 δ 25cm below top of fish bed Grey siltstone [Barren]
88-AH08 NS77722905 δ 90cm below top of fish bed Grey siltstone [Barren]
21SCO04 NS7770029038 δ 90cm below top of fish bed Grey sandy siltstone [Barren]
89-BH11 NS77702904 δ 95 cm below top of fish bed Laminated grey-black shale [Barren]
88-AH09 NS77722905 γ immediately below base of fish bed Grey siltstone [Barren]
89-BH16 NS77702904 γ 15 cm below base of fish bed Green-grey fine sandstone [Barren]
00-CH2 [Barren]

Arrarat Hill
00-CH3 [Barren]

Smithy Burn
89 (BH17) NS78783023 Dark grey siltstone from west bank [Barren]
18CW053 (DH01) NS7878430141 Fish bed [Well preserved spore assemblage]
18CW054 (DH02) NS7878430141 Fish Bed [Well preserved spore assemblage]
18CW055 (DH03) NS7878430141 Below fish bed [Moderately preserved spore assemblage]