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Palynology of samples from the Ballagan Formation of the Blairmulloch Borehole

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Palynology of samples from the Ballagan Formation of the Blairmulloch Borehole

M. H. Stephenson

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Maclean Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB

✍ 01491-838800 Fax 01491-692345

Parent Body

Natural Environment Research Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1EU

✍ 01793-411500 Fax 01793-411501
www.nerc.ac.uk

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Summary

The results of palynological analysis of 30 samples from the Ballagan Formation in the Blairmulloch Borehole (NS 56050 28200), and 9 samples from outcrop of the same formation in Murroch Glen, Dumbartonshire (415 785) are reported. The samples were collected by Elwaleid Abbas Abusham of the University of Sheffield as part of PhD project.

CM Biozone (Tournaisian Tn3c) assemblages are present between 200.17m and 53.90m of the Blairmulloch Borehole. No specimens of *Lycospora pusilla* were recorded in this interval. The highest sample studied, from 5.75m, yielded a very poorly preserved assemblage consisting almost entirely of *Densosporites* spp., suggesting a possible Viséan or younger age. The samples from Murroch Glen are almost barren and contain no age-diagnostic taxa.

The findings of the study are very much at variance with those of Abusham (2000) who reported CM Biozone assemblages between 212.0 and 124.65m in the Blairmulloch Borehole, Pu Biozone assemblages between 123.3 and 23.90 m, and TS Biozone assemblages from 5.75m.

There are qualitative similarities between the 'upper Ballagan' assemblages at the Heads of Ayr (Stephenson et al., in press) and the section in Blairmulloch between 184.25 and 53.90m in that *Acanthotriletes* cf. *macrogaleatus*, *Radiizonates mirabilis*, and taxa similar to *Dictyotriletes sagenoformis*, *L. malevkensis* and *S. microspinosus* occur in both. On the basis of these qualitative similarities, a new updated correlation of Ballagan Formation sections across the MVS is presented in Fig. 2.

1 Introduction

This report records the results of palynological analysis of 30 samples from the Ballagan Formation in Blairmulloch Borehole, (NS 56050 28200) and 9 samples from outcrop of the same formation in Murroch Glen, Dumbartonshire (415 785). The samples were collected by Elwaleid Abbas Abusham of the University of Sheffield as part of PhD project. The slides were made at the University of Sheffield and have been donated to BGS by Prof. B. Owens.

The objective of the study is to record the palynostratigraphy of the Blairmulloch Borehole and integrate this with correlations for the Ballagan Formation in the Midland Valley of Scotland, reported in BGS Reports IR/02/040 and I/02/004 and by Stephenson et al. (in press, *Scottish Journal of Geology*).

Slides do not at present have an MPA number, but will be registered as a priority.

2 Description of Blairmulloch assemblages

2.1 SAMPLE 5.75

Depth 5.75m

The sample yielded a sparse organic residue consisting mainly of black equant woody fragments and poorly preserved dark brown spores. The assemblage is dominated by species of *Densosporites*, though *Leiotriletes* and *Punctatisporites* are present. A poorly preserved zonate spore is also present.

2.1.1 Interpretation

In the absence of age diagnostic taxa, this assemblage cannot be dated, however, the presence of common *Densosporites* spp. suggests a Viséan or younger age.

2.2 SAMPLE 23.90

Depth 23.9m

The sample yielded a sparse organic residue consisting mainly of light brown and grey amorphous organic matter (AOM). No palynomorphs are present.

2.2.1 Interpretation

No age determination possible.

2.3 SAMPLE 49.65

Depth 49.65m

The sample yielded a sparse organic residue consisting mainly of light brown degraded sheet cellular or AOM and very rare palynomorphs including *Leiosphaeridia* sp. A (of BGS Report IR/01/11)

2.3.1 Interpretation

No age determination is possible. This assemblage is similar to a type 1 ‘aquatic algal assemblage of BGS Report IR/02/004.

2.4 SAMPLE 53.90

Depth 53.9m

The sample yielded a rich organic residue consisting mainly of light brown degraded sheet cellular material, AOM and elongate and equant black fragments. Well preserved light brown palynomorphs are common. The assemblage contains:

Apiculiretusispora spp.
Auroraspora cf. *macra* (narrow margin)
Auroraspora macra
Auroraspora sp.
Calamospora spp.
Colaitsporites spp.,
Convolutispora spp.
Grandispora echinata
Leiosphaeridia sp. B
Leiosphaeridia spp.
Punctatisporites spp.
Retusotriletes incohatus
Retusotruiletes spp.
Rugospora minuta
Rugospora polyptycha
Schopfites claviger
Spelaeotriletes cf. *pretiosus*
Stenozonotriletes spp.
Verrucosisporites nitidus

2.4.1 Interpretation

CM Biozone, Tournaisian (Tn3c); see Clayton et al. (1977).

2.5 SAMPLE 57.40

Depth 57.4m

The sample yielded a rich organic residue consisting mainly of light brown degraded sheet cellular material, AOM and elongate and equant black fragments. Moderately preserved light brown palynomorphs are common. The assemblage contains:

?Reduviasporonites chalastus
?Remysporites sp.
Acanthotriletes cf. *macrogaleatus*
Anaplanisporites baccatus
Auroraspora cf. *macra* (narrow margin)
Auroraspora macra
Baculatisporites fusticulus
Colatisporites spp.,
Convolutispora spp.
Dictyotriletes cf. *sagenoformis*
Grandispora echinata
Knoxisporites spp.

Leiosphaeridia spp.
Plicatispora scolecophora
Radiizonates mirabilis
Retusotriletes incohatus
Retusotriletes spp.
Retusotriletes spp.
Rugospora minuta
Schopfites claviger
Spelaeotriletes cf. *microspinosus*
Stenozonotriletes spp.

2.5.1 Interpretation

CM Biozone, Tn3c.

2.6 SAMPLE 83.75

Depth 83.75m

The sample yielded a rich organic residue consisting mainly of light brown degraded sheet cellular material, AOM and elongate and equant black fragments. Moderately preserved light brown palynomorphs are common. The assemblage contains

Acanthotriletes cf. *macrogaleatus*
Apiculiretusispora spp.
Auroraspora cf. *macra* (narrow margin)
Auroraspora cf. *macra*
Auroraspora macra
Botryococcus spp.
Colatisporites spp.
Convolutispora spp.
Cristatisporites spp.
Discernisporites micromanifestus
Knoxisporites spp.
Large ?algal palynomorph
Leiosphaeridia sp. A
Leiosphaeridia sp. B
Leiosphaeridia spp.
Plicatispora scolecophora
Retusotriletes incohatus monolete form
Retusotriletes spp.
Rugospora minuta
Rugospora polyptycha
Schopfites claviger
Stenozonotriletes spp.

2.6.1 Interpretation

CM Biozone, Tn3c

2.7 SAMPLE 87.50

Depth 87.5m

The sample yielded a rich organic residue consisting mainly of light brown degraded sheet cellular material, AOM and elongate and equant black fragments. Moderately preserved light brown palynomorphs are common. The assemblage contains

Acanthotriletes cf. *macrogaleatus*
Apiculiretusispora sp.
Auroraspora cf. macra (narrow margin)
Auroraspora macra
Auroraspora sp.
Calamospora spp.
Cf. *Acanthotriletes* cf. *macrogaleatus*
Colatisporites spp.
Convolutispora spp.
Discernisporites cf. *micromanifestus*
Leiosphaeridia spp.
Retusotrilete spp.
Rugospora minuta

2.7.1 Interpretation

CM Biozone, Tn3c

2.8 SAMPLE 103.75

Depth 103.75m

The sample yielded a rich organic residue consisting mainly of equant black fragments. Moderately preserved brown-dark brown palynomorphs are common. The assemblage contains:

Apiculiretusispora spp.
Auroraspora cf. *macra*
Auroraspora macra
Calamospora spp.
Colatisporites spp.
Convolutispora spp.
Plicatispora scolecophora
Retusotriletes spp.
Schopfites claviger
Spelaeotriletes cf. *pretiosus*
Spelaeotriletes tuberosus

2.8.1 Interpretation

CM Biozone, Tn3c

2.9 SAMPLE 123.3

Depth 123.3m

The sample yielded a rich organic residue consisting mainly of equant black fragments. Moderately preserved brown-dark brown palynomorphs are common. The assemblage contains:

?Murospora sp.
Auroraspora cf. *macra*
Auroraspora cf. macra (narrow margin)
Auroraspora macra
Calamospora spp.

Colatisporites spp.
Convolutispora spp.
Discernisporites micromanifestus
Latosporites sp.
Plicatispora scolecophora
Punctatisporites spp.
Retusotriletes spp.
Rugospora minuta
Rugospora polyptycha
Schopfites claviger
Spelaeotriletes tuberosus
Stenozonotriletes spp.

2.9.1 Interpretation

CM Biozone, Tn3c

2.10 SAMPLE 125.6

Depth 125.6m

The sample yielded a rich organic residue consisting mainly of equant black fragments. Moderately preserved brown-dark brown palynomorphs are common. The assemblage contains:

Apiculiretusispora spp.
Auroraspora cf. *macra*
Auroraspora macra
Calamospora spp.
Colatisporites spp.
Convolutispora spp.
Leiosphaeridia spp.
Plicatispora scolecophora
Punctatisporites spp.
Retusotriletes incohatus
Retusotriletes spp.
Rugospora minuta
Schopfites claviger

2.10.1 Interpretation

CM Biozone, Tn3c

2.11 SAMPLE 131.88

Depth 131.88m

The sample yielded a rich organic residue consisting mainly of light brown degraded sheet cellular material, AOM and elongate and equant black fragments. Moderately preserved light brown palynomorphs are common. The assemblage contains

Lophozonotriletes bellus
Auroraspora cf. *macra*
Auroraspora macra
Calamospra spp.
Colatisporites spp.
Convolutispora spp.
Discernisporites micromanifestus

Grandispora echinata
Lophozonotriletes sp.
Punctatisporites spp.
Retusotriletes incohatus
Retusotriletes spp.
Rugospora polyptycha
Schopfites claviger
Spelaeotriletes cf. *microspinosus*
Vallatisporites sp.
Verrucosisporites nitidus

2.11.1 Interpretation

CM Biozone, Tn3c

2.12 SAMPLE 137.63

Depth 137.63m

The sample yielded an extremely sparse organic residue containing no palynomorphs.

2.12.1 Interpretation

No age determination possible.

2.13 SAMPLE 143.3

Depth 143.3m

The sample yielded an extremely sparse organic residue containing no palynomorphs.

2.13.1 Interpretation

No age determination possible.

2.14 SAMPLE 150.70

Depth 150.7m

The sample yielded a rich organic residue consisting mainly of light brown degraded sheet cellular material, AOM and elongate and equant black fragments. Well-preserved light brown palynomorphs are common. The assemblage contains:

Apiculiretusispora spp.
Auroraspora cf. *macra*
Auroraspora macra
Baculatisporites fusticulus
Calamospora spp.
Colatisporites spp.
Convolutispora spp.
Densosporites sp.
Discernisporites micromanifestus
Grandispora cf. *echinata (with pila)*
Grandispora echinata
Laevigatosporites sp.
Leiosphaeridia spp.
Lophozonotriletes sp.

Plicatispora scolecophora
Retusotriletes incohatus
Retusotriletes spp.
Rugospora polyptycha
Schopfites claviger
Stenozonotriletes sp.
Verrucosisporites nitidus

2.14.1 Interpretation

CM Biozone, Tn3c

2.15 SAMPLE 155.14

Depth 155.14m

The sample yielded a relatively sparse organic residue consisting mainly of equant black fragments. Relatively few, poorly preserved yellow to dark brown palynomorphs are present. The assemblage contains

Auroraspora cf. *macra*
Auroraspora macra
Botryococcus spp.
Colatisporites spp.
Convolutispora spp.
Leiosphaeridia sp. A
Leiosphaeridia spp.
Retusotriletes spp.

2.15.1 Interpretation

CM Biozone, Tn3c

2.16 SAMPLE 158.02

Depth 158.02m

The sample yielded a sparse organic residue consisting mainly of equant black fragments. Relatively few, poorly preserved yellow to dark brown palynomorphs are present. The assemblage contains

Baculatisporites fusticulus
Large spongeous leiosphere
Leiosphaeridia sp. A
Leiosphaeridia spp.

2.16.1 Interpretation

No age determination possible. This assemblage is similar to a type 1 ‘aquatic algal assemblage of BGS Report IR/02/004.

2.17 SAMPLE 160.7

Depth 160.7m

The sample yielded a rich organic residue consisting mainly of light brown degraded sheet cellular material, AOM and elongate and equant black fragments. Well-preserved light brown palynomorphs are common. The assemblage contains:

?Monolete spore of McLean & Neves 2001
?Vallatisporites sp.
Apiculiretusispora spp.
Auroraspora cf. *macra*
Calamospora spp.
Colatisporites spp.
Convolutispora spp.
Discernisporites cf. *sullivanii*
Discernisporites micromanifestus
Grandispora cf. *echinata*
Grandispora echinata
Knoxisporites spp.
Leiosphaeridia spp.
Punctatisporites spp.
Raistrickia sp.
Retusotriletes spp.
Spelaeotriletes cf. *arenaceus*
Spinozonotriletes uncatus/impensus

2.17.1 Interpretation

CM Biozone, Tn3c

2.18 SAMPLE 162.02

Depth 162.02m

The sample yielded a rich organic residue made up of black equant and elongate fragments and brown to dark brown moderately preserved palynomorphs. The assemblage contains:

Auroraspora cf. *macra*
Auroraspora macra
Colatisporites spp.
Convolutispora spp.
Knoxisporites spp.
Leiosphaeridia sp. B
Leiosphaeridia spp.
Plicatispora scolecophora
Raistrickia corynoges
Retusotriletes spp.
Rugospora polyptycha
Schopfites claviger
Stenozonotriletes sp.
Tetraporina spp.

2.18.1 Interpretation

CM Biozone, Tn3c

2.19 SAMPLE 163.43

Depth 163.43m

The sample yielded a sparse organic residue consisting mainly of equant black fragments. Relatively few, poorly preserved yellow to dark brown palynomorphs are present. The assemblage contains:

Auroraspora cf. *macra*
Colatisporites sp.
Leiosphaeridia sp. B
Leiosphaeridia spp.

2.19.1 Interpretation

No age determination possible. This assemblage is similar to a type 1 ‘aquatic algal assemblage of BGS Report IR/02/004.

2.20 SAMPLE 169.68

Depth 169.68m

The sample yielded a rich organic residue made up of black equant and elongate fragments and brown to dark brown well preserved palynomorphs. The assemblage contains

?Aratrisporites sp.
Auroraspora cf. *macra*
Auroraspora macra
Auroraspora sp.
Baculatisporites fusticulus
Botryococcus spp.
Calamospora spp.
Colatisporites spp.
Convolutispora sp.
Discernisporites micromanifestus
Grandispora echinata
Large spongeous leiosphere
Leiosphaeridia sp. A
Leiosphaeridia sp. B
Leiosphaeridia spp.
Lophozonoptriletes sp.
Lophozonotriletes cf. *malevkensis*
Punctatisporites spp.
Raistrickia corynoges
Retusotriletes incohatus
Retusotriletes spp.
Rugospora polyptycha
Schopfites claviger
Schopfites delicatus
Spelaeotriletes tuberosus
Stenozonotriletes sp.

2.20.1 Interpretation

CM Biozone, Tn3c

2.21 SAMPLE 174.52

Depth 174.52m

The sample yielded a relatively sparse organic residue made up of black equant fragments and brown to dark brown well preserved palynomorphs. The assemblage contains

Apiculiretusispora sp.
Auroraspora cf. *macra*

Auroraspora macra
Calamospora spp.
Colatisporites spp.
Convolutispora spp.
Discernisporites micromanifestus
Leiosphaeridia spp.
Punctatisporites spp.
Retusotriletes incohatus
Retusotriletes spp.
Rugospora polyptycha
Schopfites claviger
Stenozonotriletes sp.

2.21.1 Interpretation

CM Biozone, Tn3c

2.22 SAMPLE 175.80

Depth 175.8m

The sample yielded a sparse organic residue made up of black equant fragments and rare yellow-brown palynomorphs. The assemblage contains

Leiosphaeridia sp. A
Leiosphaeridia spp.

2.22.1 Interpretation

No age determination possible. This assemblage is similar to a type 1 ‘aquatic algal assemblage of BGS Report IR/02/004.

2.23 SAMPLE 180.44

Depth 180.44m

The sample yielded a relatively sparse organic residue made up of black equant and elongate fragments and brown to dark brown well-preserved palynomorphs. The assemblage contains:

?Ahrensisporites sp.
Apiculiretusispora spp.
Auroraspora cf. *macra*
Auroraspora macra
Baculatisporites fusticulus
Cf. *Dictyotriletes submarginatus*
Colatisporites spp.
Convolutispora spp.
Dibolisporites distinctus
Grandispora echinata
Knoxisporites spp.
Large ?algal palynomorph
Leiosphaeridia spp.
Lophozonotriletes cf. *malevkensis*
Lophozonotriletes sp.
Plicatispora scolecophora
Raistrickia cf. *corynoges*
Raistrickia corynoges

Retusotriletes incohatus
Retusotriletes incohatus (monolete form)
Retusotriletes spp.
Rugospora polyptycha
Schopfites claviger
Stenozonotriletes spp.
Vallatisporites cf. *vallatus*
Verrucosisporites nitidus

2.23.1 Interpretation

CM Biozone, Tn3c

2.24 SAMPLE 184.25

Depth 184.25m

The sample yielded a rich organic residue made up of black equant and elongate fragments and yellow to brown well preserved palynomorphs. The assemblage contains:

Acanthotriletes cf. *macrogaleatus*
Anaplanisporites baccatus
Auroraspora macra
Baculatisporites fusticulus
Calamospora spp.
Colatisporites sp.
Convolutispora spp.
Grandispora echinata
Knoxisporites spp.
Raistrickia corynoges
Retusotriletes incohatus
Schopfites claviger
Schopfites delicatus
Verrucosisporites cf. *nitidus*
Verrucosisporites nitidus

2.24.1 Interpretation

CM Biozone, Tn3c

2.25 SAMPLE 191.52

Depth 191.52m

The sample yielded a sparse organic residue made up of black equant fragments and rare yellow-brown palynomorph material. The assemblage contains no recognisable palynomorphs.

2.25.1 Interpretation

No age determination possible

2.26 SAMPLE 196.10

Depth 196.1m

The sample yielded a sparse organic residue made up of black equant fragments and rare brown to dark brown, poorly preserved palynomorphs. The assemblage contains:

Auroraspora macra
Baculatisporites cf. *fusticulus*
Calamospora spp.
Colatisporites spp.
Leiosphaeridia spp.
Punctatisporites spp.
Retusotriletes incohatus
Retusotriletes spp.
Schopfites claviger

2.26.1 Interpretation

CM Biozone, Tn3c

2.27 SAMPLE 198.0

Depth 198.0m

The sample yielded a relatively sparse organic residue made up of black equant and elongate fragments and brown to dark brown, moderately preserved palynomorphs. The assemblage contains

Auroraspora cf. macra
Auroraspora macra
Colatisporites spp.
Convolutispora spp.
Grandispora echinata
Knoxisporites spp.
Leiosphaeridia sp. A
Leiosphaeridia spp.
Punctatisporites spp.
Retusotriletes spp.
Rugospora polyptycha
Schopfites claviger
Spelaeotriletes tubersosus

2.27.1 Interpretation

CM Biozone, Tn3c

2.28 SAMPLE 200.17

Depth 200.17m

The sample yielded a rich organic residue made up of black equant and elongate fragments and yellow to brown, well preserved palynomorphs. The assemblage contains

Auroraspora macra
Baculatisporites fusticulus
Colatisporites spp.
Convolutispora spp.
Discernisporites micromanifestus
Grandispora cf. *echinata*
Grandispora echinata
Knoxisporites literatus
Knoxisporites spp.
Retusotriletes incohatus

Retusotriletes spp.
Rugospora polyptycha
Schopfites claviger
Spelaeotriletes tuberosus
Verrucosisporites gibberosus
Verrucosisporites nitidus

2.28.1 Interpretation

CM Biozone, Tn3c

2.29 TAXONOMIC NOTES

The upper part of the studied section (87.5-53.9m) contained common specimens of a small spore similar in construction and appearance to *Auroraspora macra*, and in this study temporarily recorded as *Auroraspora* cf. *macra* (narrow margin) (see Plates 1 and 2). The specimens are superficially similar to *Discernisporites crenulatus* (Playford) Clayton 1970 but more closely related to *Auroraspora asperella* (Kedo) Van der Zwan 1980. The specimens have not been assigned to that taxon because they lack minute distal grana, the exoexine being spongeous with no surface ornamentation.

2.30 DISCUSSION

Abusham (2000) reported CM Biozone assemblages between 212.0-124.65m in the Blairmulloch Borehole, Pu Biozone assemblages between 123.3-23.90 m and TS Biozone assemblages from 5.75m. The basis for correlation with the Pu Biozone was the putative presence of *Lycospora pusilla* at a percentage of 6.5% in 123.30m. It was also recorded by Abusham (2000), in samples from 53.90m, 57.40m, 83.70m, 87.50m and 103.75m. Abusham (2000) also recorded a 'well preserved' assemblage from 5.75m in which *Knoxisporites triradiatus* and *K. stephanephorus* were present in abundances of 6.3% and 5.7% respectively. On this basis he assigned this sample to the late Arundian-early Holkerian TS Biozone of Clayton (1985).

The findings of the present study are very much at variance with those of Abusham (2000). CM Biozones assemblages are present between 200.17m and 53.90m. No specimens of *Lycospora pusilla* are present in this interval. The highest sample studied, from 5.75m, yielded a very poorly preserved assemblage consisting almost entirely of *Densosporites* spp., though a possible of specimen of *L. pusilla* is present. No specimens of *Knoxisporites triradiatus* and *K. stephanephorus* are present in the sample from 5.75m.

On the basis of the latter zonal assignments, the section 200.17m and 53.90m is Tournaisian (Tn3c) in age, while the presence of common *Densosporites* suggests a possible Viséan or younger age for the section above 5.75m in the borehole.

There are qualitative similarities between the 'upper Ballagan' assemblages at the Heads of Ayr (Stephenson et al., in press) and the section in Blairmulloch between 184.25 and 53.90m. in that *Acanthotriletes* cf. *macrogaleatus*, *Radiizonates mirabilis*, and taxa similar to *Dictyotriletes sagenoformis*, *L. malevkensis* and *S. microspinosus* occur in both. There are two hypotheses which may explain this similarity:

1. The upper parts of the Ballagan Formation in the Ayrshire/Cumnock district (i.e. Heads of Ayr and Blairmulloch) contain spores produced by a localised flora present in 'upper Ballagan times' and not present at the same time in eastern parts part of the MVS, for example, in the vicinity of the East Dron and Glenrothes boreholes.
2. The 'upper Ballagan' assemblages of the Ayrshire/Cumnock area are younger than the highest preserved parts of the Ballagan Formation in the East Dron and Glenrothes boreholes.

At present the second possibility is favoured because there appears to be supporting ostracod evidence for younger Ballagan sediments in Ayrshire (Williams 2001), and because the 'Upper Ballagan assemblages' are in part characterised by a lycopsid spores indicative of relatively wet climatic conditions, and such conditions would be expected to affect all areas of the MVS simultaneously.

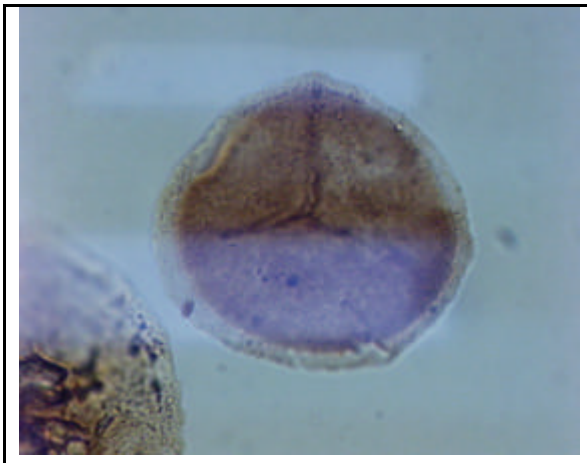
On the basis of this second suggestion a new updated correlation of Ballagan Formation sections across the MVS is presented in Fig. 2.

3 Samples from the Ballagan Formation in Murroch Glen

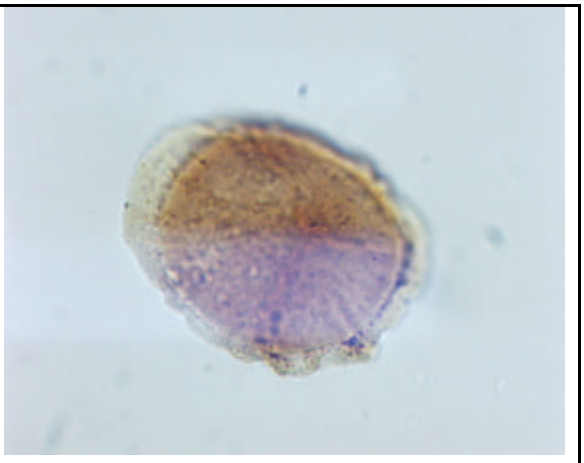
Nine slides made from samples from a well-exposed section of the Ballagan Formation in Murroch Glen, Dumbarton (415 785) were donated by Prof. B. Owens to allow study. The samples were taken from the lower part of the section.

All the slides displayed very sparse organic residue consisting mainly of equant black fragments and very rare, fragmentary palynomorphs. Amongst palynomorph taxa recorded are: *Leiosphaeridia* spp., *Leiosphaeridia* sp. A (of Stephenson et al., in press) and ?*Colatisporites* spp.. These assemblages do not allow age determination and their sparseness also prevents deductions about palaeoenvironment.

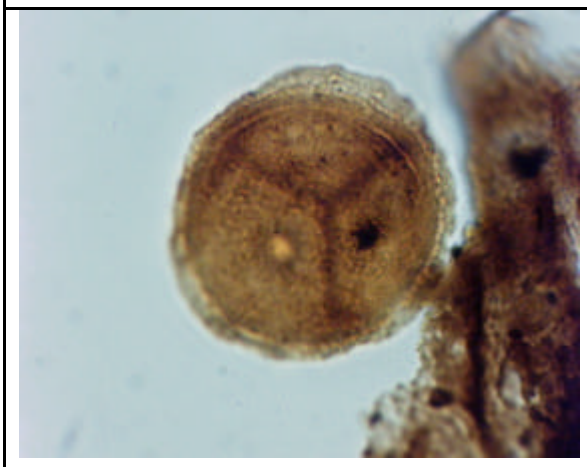
Appendix 1 Plates



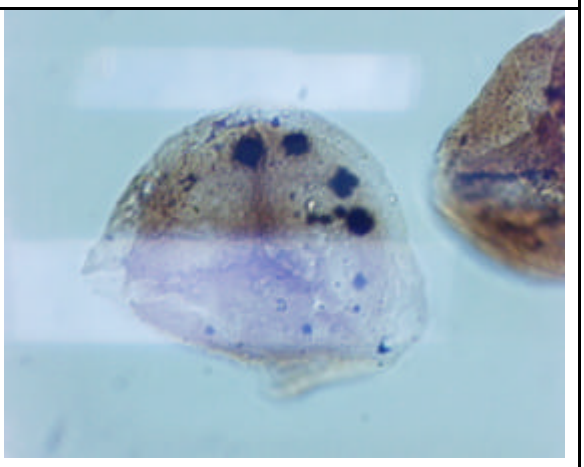
A. cf. macra (narrow margin), E25/2, 57.4



A. cf. macra (narrow margin), E45/3, 57.4



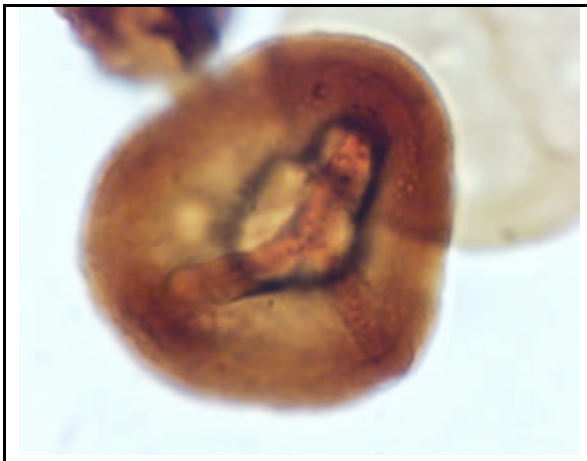
A. cf. macra (narrow margin), G30, 57.4



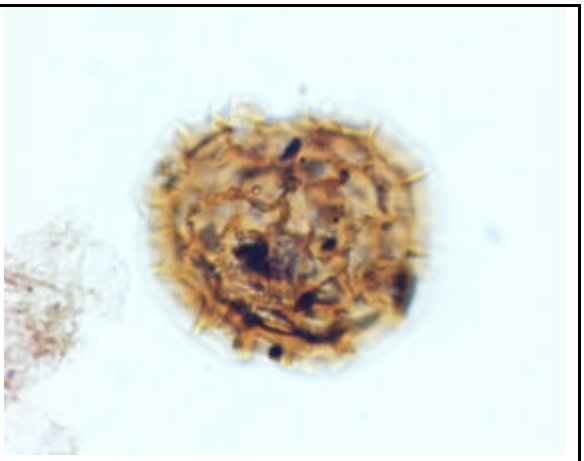
A. cf. macra (narrow margin), M30, 57.4

A. cf. macra (narrow margin), T53, 57.4

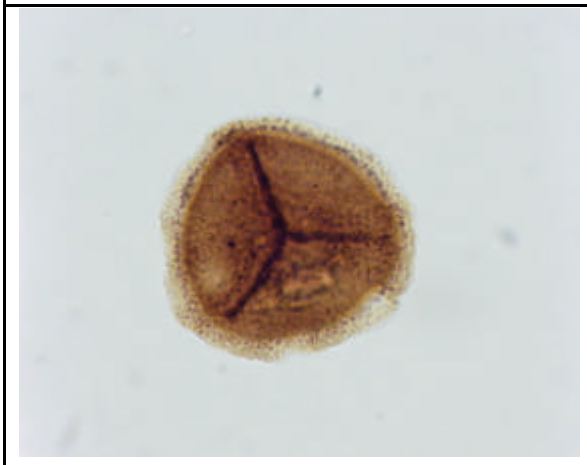
R. cf. mirabilis, E41/3, 57.4



R. famenensis, E50/4, 57.4

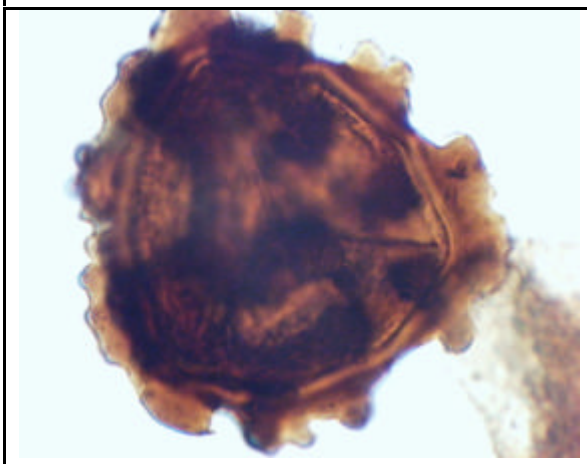


D. cf. sagenoformis, L38/3, 57.4



A. cf. macra (narrow margin), G47/1, 83.75

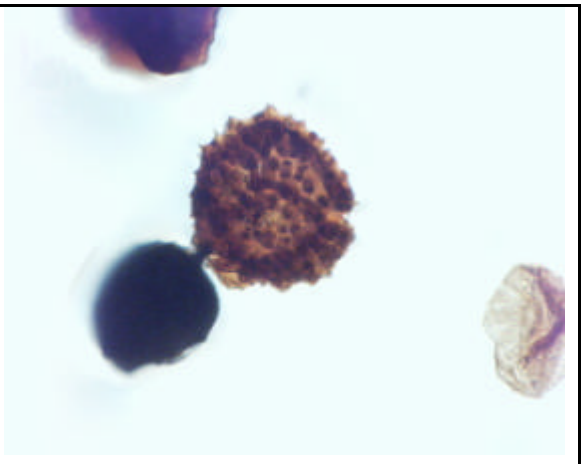
A. cf. macra (narrow margin), H45/1, 83.75



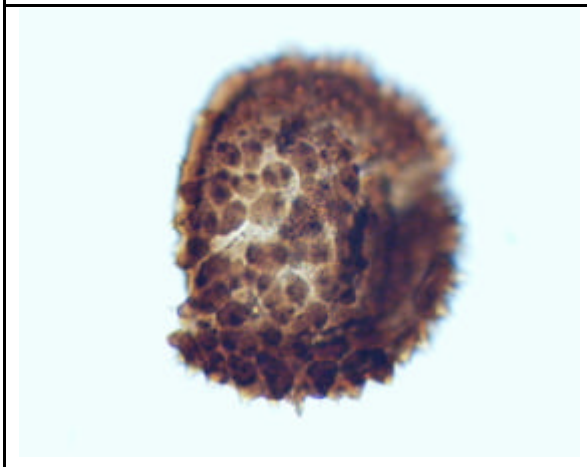
L. bellus, M45/3, 131.88

V. cf. vallatus, D34/1, 180.44

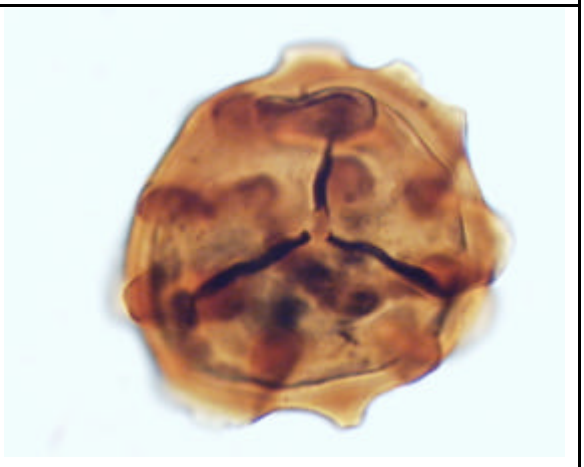
A. cf. macrogaleatus, L45, 184.25



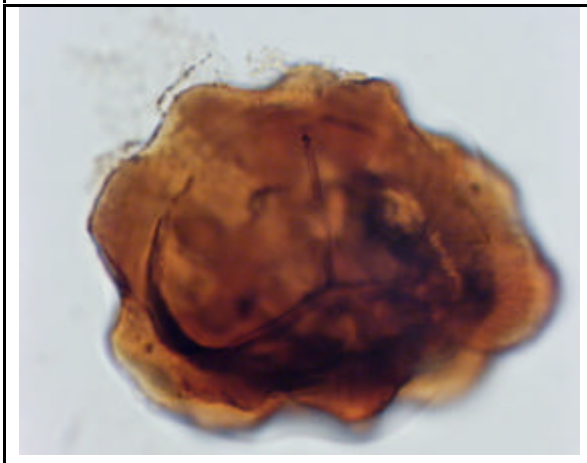
A. cf. macrogaleatus, M34, 83.75



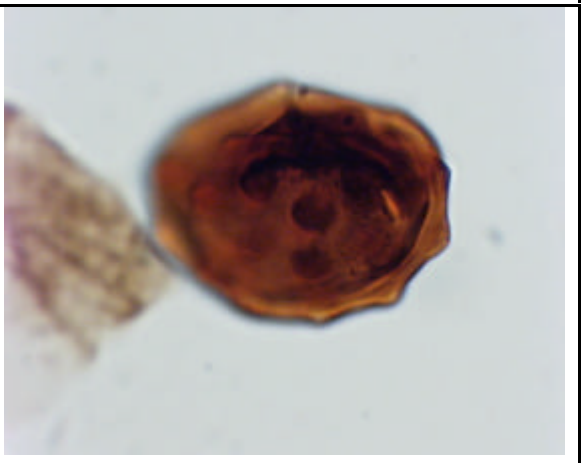
A. cf. macrogaleatus, J51/1, 87.50



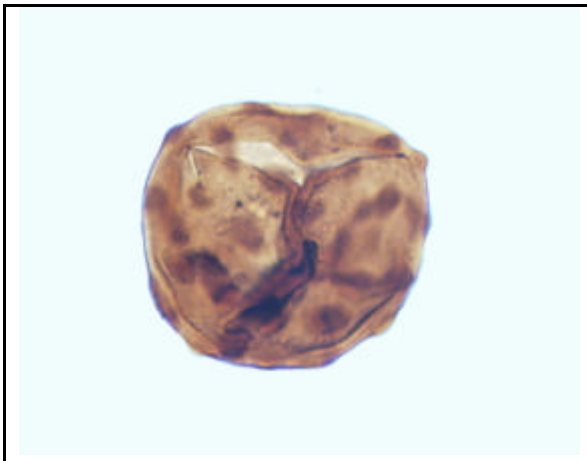
L. cf. malevkensis, H37/3, 180.44



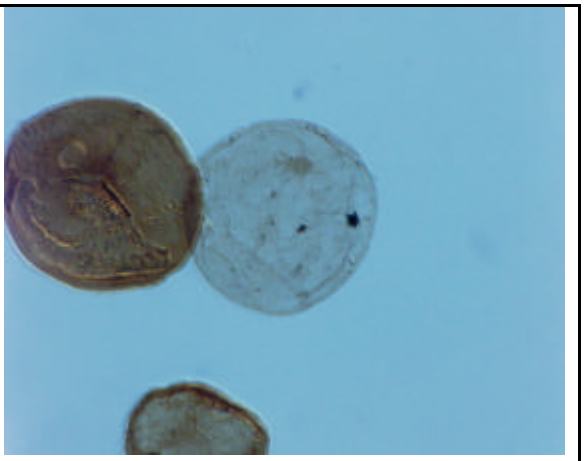
Lophozonotriletes sp. J53/4, 180.44



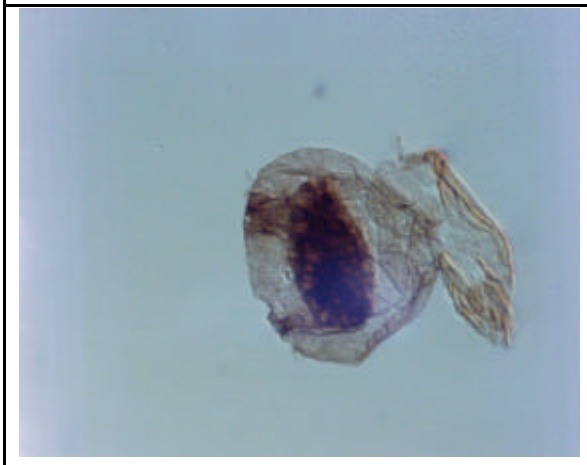
Lophozonotriletes sp., O29, 169.68



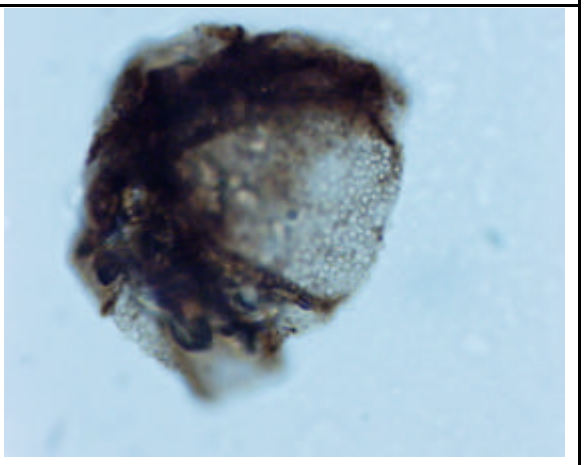
Lophozonotriletes sp., R45, 169.68



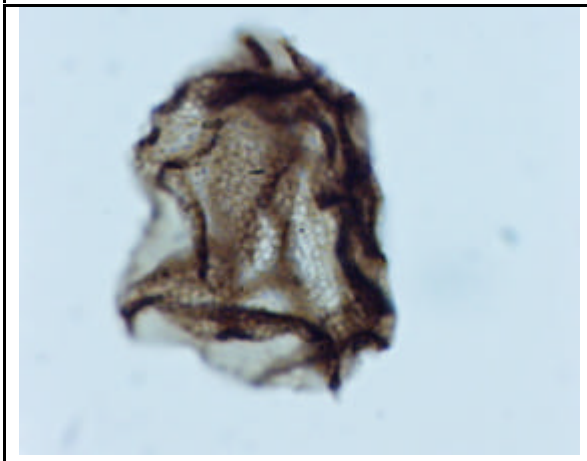
Leiosphaeridia sp., E41, 169.68



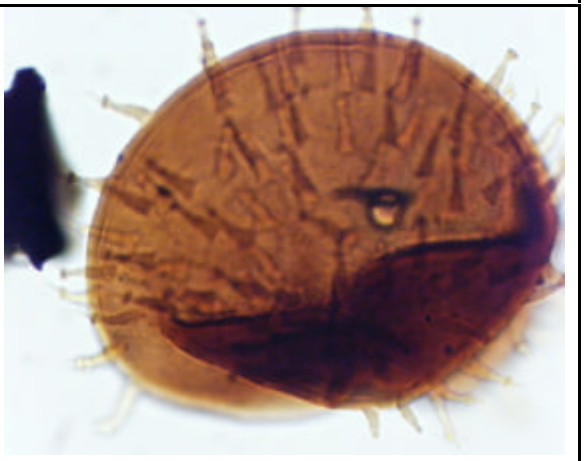
Leiosphaeridia sp. B, V43/2, 169.68



Leiosphaeridia sp. A, K41/3, 158.02



Leiosphaeridia sp. A, Y30, 158.02



D. distinctus, T51/2, 180.44

References

Abusham, E. A. 2000. A palynology and palynofacies investigation of the Lower Carboniferous of the Midland Valley of Scotland. Unpublished PhD thesis, University of Sheffield.

Andrews, J. E. & Nabi, G 1994. Lithostratigraphy of the Dinantian Inverclyde and Strathclyde Groups, Cockburnspath Outlier, East Lothian - North Berwickshire. Scottish Journal of Geology, 30, 105-119.

Clayton, G. 1971 Lower Carboniferous miospore assemblage from the calciferous sandstone measures of the Cockburnspath region of eastern Scotland. Pollen Spores, 12, 577-600.

Clayton, G. 1985. Dinantian miospores and inter-continental correlation. Compte Rendu 10th International Congress on Carboniferous Stratigraphy and Geology (Madrid 1983), 4, 9-23.

Clayton, G., Coquel, R., Doubinger, J., Gueinn, K. J., Loboziak, S., Owens, B. & Streel, M. 1977. Carboniferous miospores of Western Europe: illustration and zonation. Mededilingen Rijks Geologische Dienst, 29, 1-71.

Neves R., Gueinn K.J., Clayton G., Ioannides N.S., Neville R.S.W. and Kruszewska K. 1973. Palynological correlations within the Lower Carboniferous of Scotland and Northern England. Transactions of the Royal Society of Edinburgh, 69, 4-70.

Neves, R. & Ioannides, N. 1974. Palynology of the Lower Carboniferous (Dinantian) of the Spilmersford Borehole, East Lothian, Scotland. Bull. Geol. Surv. Gt. Brit. No. 45, 73-97.

Stephenson, M. H. 2002. Carboniferous palynology of the East Dron Borehole: a preliminary report. BGS Report IR/02/40.

Stephenson, M. H. 2002. Palynology of samples from the Ballagan Formation of the Glenrothes Borehole, Fife. BGS Report IR/02/004.

Stephenson, M. H., Williams, M., Monaghan, A., Arkley, S. & Smith, R. A. (in press). Biostratigraphy and palaeoenvironments of the Ballagan Formation (lower Carboniferous) in Ayrshire, SW Scotland, Scottish Journal of Geology.

Williams, M. 2001. Ostracods form the Ballagan Formation (Tournaisian; lower Carboniferous) of the Glenrothes Borehole. BG Report IR/01/63.

Well Name : Blairmulloch

Interval : 6m - 200m **Fig. 1**

Scale : 1:500

Chart date: 26 June 2002 **Mike Stephenson**

British Geological Survey
Keyworth, UK

Palynology

Samples (metres)

% within discipline (20mm=100%)

Quantitative data

Aurospora macra
Baculatisporites fusticulus
Coletaspontes spp.
Cornutisporia spp.
Discernisporites micromanifestus
Grandspora echinata
Knoxisporites literatus
Retusotriletes incohatus
Retusotriletes spp.
Rugospora polyptycha
Schopfites claviger
Speleotriletes tuberosus
Verrucosisporites globerosus
Verrucosisporites nitidus
Aurospora cf. macra
Leiosphaeridia sp. A
Leiosphaeridia spp.
Punctatisporites spp.
Baculatisporites cf. fusticulus
Calamospora spp.
Acanthotriletes cf. macrogaleatus
Anaplanisporites baccatus
Raistrickia corynges
Schopfites delicatus
Verrucosisporites cf. nitidus
?Ahrensisporites sp.
Apiculatisporis spp.
Cf. Dictyotriletes submarginatus
Dibolisporites distinctus
Large ?algal palynomorph
Lophozonotriletes cf. malevkensis
Lophozonotriletes spp.
Pilatisporis scolecophora
Raistrickia cf. coryngies
Retusotriletes incohatus monolete form
Stenozonotriletes spp.
Valvisporites cf. vallatus
?Axiatrisporites sp.
Botryococcus spp.
Leiosphaeridia sp. B
Teraporina spp.
?Monaletes spore of McLean
?Valvisporites sp.
Discernisporites cf. sullvanii
Speleotriletes cf. aenaceus
Spinozonotriletes uncatus/impensus
Leiosphaeridia sp. E
Densospontes spp.
Leiotriletes sp.
Lophozonotriletes bellus
Vallatisporites sp.
Rugospora minuta
?Murospora sp.
Aurospora cf. macra (narrow margin)
Latosporites spp.
Aurospora sp.
Cf. Acanthotriletes cf. macrogaleatus
Discernisporites cf. micromanifestus
Cristatisporites spp.
?Reduviaspinonates chalastus
?Remysporites sp.
Dictyotriletes cf. sagenoformis
Radizonates mirabilis
Retusotriletes famenensis
Speleotriletes cf. macrosparosus
?Lycospora pusilla
Leiotriletes sp.

Comments

Low yield sample
Low yield sample
Low yield sample
Low yield sample
Low yield sample

Palynology

Palynology

Stratigraphic Range

Range data

Aurospora macra
Baculatisporites fusticulus
Coletaspontes spp.
Cornutisporia spp.
Discernisporites micromanifestus
Grandspora echinata
Knoxisporites literatus
Knoxisporites spp.
Retusotriletes incohatus
Retusotriletes spp.
Rugospora polyptycha
Schopfites claviger
Speleotriletes tuberosus
Verrucosisporites globerosus
Verrucosisporites nitidus
Aurospora cf. macra
Leiosphaeridia sp. A
Leiosphaeridia spp.
Baculatisporites cf. fusticulus
Calamospora spp.
Acanthotriletes cf. macrogaleatus
Anaplanisporites baccatus
Raistrickia corynges
Schopfites delicatus
Verrucosisporites cf. nitidus
Ahrensisporites sp.
Apiculatisporis spp.
Cf. Dictyotriletes submarginatus
Dibolisporites distinctus
Large ?algal palynomorph
Lophozonotriletes cf. malevkensis
Lophozonotriletes spp.
Pilatisporis scolecophora
Raistrickia cf. coryngies
Retusotriletes incohatus monolete form
Stenozonotriletes spp.
Valvisporites cf. vallatus
?Axiatrisporites sp.
Botryococcus spp.
Large spongeous leiosphere
Leiosphaeridia sp. B
Teraporina spp.
?Monaletes spore of McLean
?Valvisporites sp.
Discernisporites cf. sullvanii
Speleotriletes cf. aenaceus
Spinozonotriletes uncatus/impensus
Leiosphaeridia sp. E
Densospontes spp.
Leiotriletes sp.
Lophozonotriletes bellus
Vallatisporites sp.
Rugospora minuta
Aurospora cf. macra (narrow margin)
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Cristatisporites spp.
?Reduviaspinonates chalastus
?Remysporites sp.
Dictyotriletes cf. sagenoformis
Radizonates mirabilis
Retusotriletes famenensis
Speleotriletes cf. macrosparosus
?Lycospora pusilla
Leiotriletes sp.

Chronostrat.

Lithostrat.*

?Visean

?Clyde Sst. Fm.

L. Lst. Fm.

Lst Coal Fm.

?'lower Ballagan' assemblages

'upper Ballagan' assemblages

CM Biozone Tournaisian 3c

Ballagan Formation

*based on M. A. E. Browne pers. comm.

Fig. 2 Correlation of the Ballagan Formation across the MVS, including Cockburnspath, Spilmersford and Blairmulloch. Thicknesses approximate.