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Palynological Analysis and Correlation of wells Barney Brook-1, Camden-100, Creelman Hill-1, Devon Cheverie-1, Kennetcook-1, N-14-A and O-61-C, Onshore Nova Scotia

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	REPORT NUMBER: ECB0937	**REPORT TITLE:** Palynological Analysis and correlation of wells Barney Brook-1, Camden 100, Creelman Hill-1, Devon Cheverie-1, Kennetcook-1, N-14-A and O-61-C, Onshore Nova Scotia	
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A. ADDENDUM TO SUMMARY

1. Horton Group sediments analysed from wells from the Windsor Basin (Creelman Hill-1, Devon Cheverie-1, Kennetcook-1, N-14-A and O-61-C) yield palynofloras indicative of the *S. pretiosus* to *V. vallatus* palynomorph zones of the Ivorian Stage of the Early Carboniferous/Tournaisian.
2. The section in the Creelman Hill-1 well was cored throughout and the sediments at the T.D. of this well are no older than the upper part of the *V. vallatus* zone (*S. cabotii* subzone). The geological report indicates that the Creelman Hill-1 well reached T.D. a few hundred metres above basement.
3. Correlation of palynological events between the Creelman Hill-1 well and the Kennetcook-1 well (based on cuttings samples) suggests that the majority of the Horton Bluff Formation in the Kennetcook-1 well is also no older than the upper part of the *V. vallatus* zone (*S. cabotii* subzone). However, it is possible that a thin interval of sediments equivalent to the older *U. abstrusus-U. distinctus* subzone of the *V. vallatus* zone may be present overlying the basement at the base this well.
4. Palynological evidence from the cuttings samples selected from the Horton Group in the O-61-C well also imply that sediments to the T.D. of this well are no older than the *S. cabotii* subzone of the *V. vallatus* zone. Once again, though, the deepest sample analysed from this section is a few hundred metres above the basement at this well location.
5. The Devon Cheverie-1 well only penetrates the top of sediments equivalent in age to the *V. vallatus* zone at the T.D. of this well section, while it is not possible to determine the exact age of the sediments within the *V. vallatus* zone from the data recovered from the samples analysed from the N-14-A well.
6. The two wells from the Shubenacadie Basin (Barney Brook-1 and Camden-100) yield palynomorph assemblages consistent with an Early Carboniferous/ Tournaisian age. The palynofloras recovered from the Camden-100 well are poorly preserved and carbonised, making palynomorph determination difficult. However, there is sufficient evidence to suggest that the samples analysed from this well are equivalent in age to the undifferentiated *S. pretiosus* to *V. vallatus* zones of the Ivorian Stage of the Early Carboniferous/Tournaisian.
7. The few samples analysed from the Coldstream Formation of the Barney Brook-1 well yield palynomorph evidence for an age equivalent to the *V. vallatus* zone. This is broadly comparable in age to the Horton Bluff Formation in the Windsor Basin, but it has not been possible to determine whether these sediments are equivalent to the *S. cabotii* or the *U. abstrusus-U. distinctus* subzones of this palynomorph zone. These samples may therefore be equivalent to, or slightly older than, the well sections sampled from the Horton Bluff Formation in the Windsor Basin in this study.
8. The fault at 1489m in the N-14-A well could have thickened/repeated section within the top of the *V. vallatus* zone, as the 'Base common *Cyclogranisporites*' palynomorph event is notably deeper below the top of the *V. vallatus* zone in this well than in the other wells studied. The fault at 755m lies within a rather large sample gap (between 700m and 1060m), and it is not possible to determine any effect of this upper fault.

1. SUMMARY

This report presents the results of the palynological analysis of the non marine sediments of the Horton Group from onshore Nova Scotia. A total of 101 core and cuttings samples were analysed from 7 wells: Creelman Hill-1, Devon Cheverie-1, Kennetcook-1, N-14-A and O-61-C located within the Windsor Basin and Barney Brook-1 and Camden 100 from within the Shubenacadie Basin (Figure 1).

The sections analysed are all interpreted as Early Carboniferous/Tournaisian in age, and fall within two palynological zones (the *S. pretiosus* and *V. vallatus* zones) of the Ivorian Stage. The palynomorph assemblages from the Creelman Hill-1 and O-61-C (and possibly in Kennetcook-1) wells in the Windsor Basin suggest an age no older than the upper part of the *V. vallatus* miospore zone, within the *Spelaeotriletes cabotii* subzone. The two wells from the Shubenacadie Basin (Barney Brook-1 and Camden-100) yield poorer palynological data, so it is impossible to determine if these samples are exactly the same age as those from the wells in the Windsor Basin. However, they appear broadly comparable in age.

Those wells with the most complete sampling (Kennetcook-1 and Creelman Hill-1) show excellent palynological correlation. This indicates that both core and cuttings samples yield good data (Enclosure 1), even though cuttings samples typically represented composites from material within several samples over a depth interval up to ~50m. Some of the correlative events identified in these wells can also been seen in the other wells, where there is sparser sampling (Enclosure 2).

Lithological information and lithostratigraphic nomenclature given on Enclosures 1-9 is taken from summary information provided by NS Dept of Energy in the form of geological well reports and/or striplogs. No new lithological descriptions have been undertaken. The sampled sections of wells analysed generally comprised sediments of the Horton Group; the Cheverie and Horton Bluff Formations. Typically the Cheverie Formation proved to be equivalent in age to the *S. pretiosus* miospore zone, while the Horton Bluff Formation typically comprised sediments of the lower part of the *S. pretiosus* zone to the *V. vallatus* zone (?*S. cabotii* subzone). In the Devon Cheverie-1 well, sediments of the Windsor Group (between 833m and 885m) are emplaced within the Horton Group by thrust faulting, but these evaporitic sediments were not sampled for biostratigraphy. Sediments of the Horton Group sampled above and below the thrust faults yielded palynomorph assemblages indicative of the *S. pretiosus* miospore zone. Evidence for penetration of sediments equivalent in age to the older *V. vallatus* zone is recorded only in the deepest sample analysed from the Devon Cheverie-1 well at 1410m.

Range charts of all the taxa recorded are provided as Enclosures 3-9. All depths quoted are measured depth in metres.

Abbreviations used routinely in the text of this report are defined in Appendix A.

Personnel involved in this study are:

Sarah Froom	Graphic displays;
Dave Shaw	Palynology, interpretation and reporting;
Janice Weston	Project management and interpretation.

2. INTRODUCTION

2.1 Analysed Samples

A total of 101 samples from 7 wells were chosen by Janice Weston (RPSE) and Helen Cen (NS DoE) for palynological analysis. The locations of the study wells are presented in Figure 1 and the sampling is summarised in Table 1 and detailed in Appendix B. Samples range from individual core chips to composite cuttings samples. The samples were collected by Helen Cen (NS DoE) during March 2013 and they were processed for palynology at the Global Geolab laboratories in Medecine Hat, Alberta during April 2013.

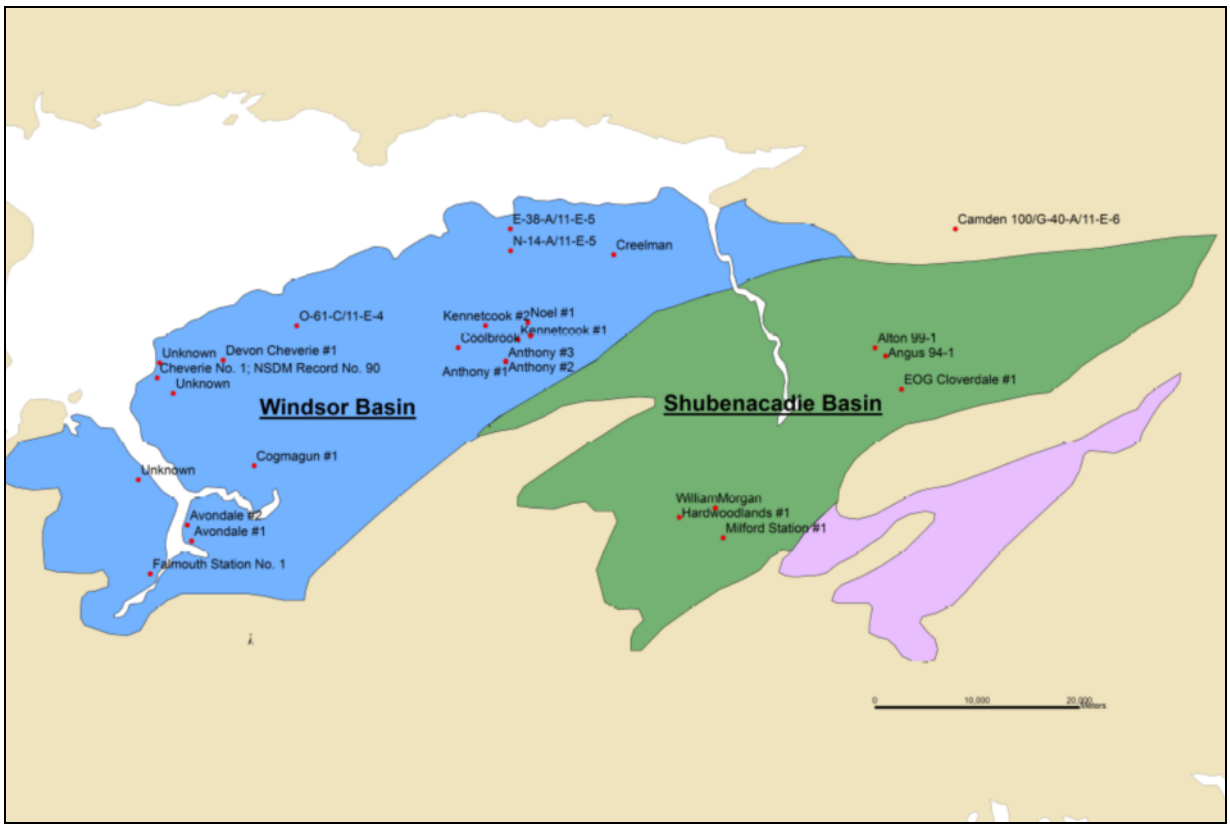

Figure 1 – Location of the Study Wells

Well	Samples	Interval
Barney Brook-1	1 core and 1 cuttings	665.9m - 685m
Camden-100	11 core	29m – 1434m
Creelman Hill-1	40 core	27.5m – 1405.5m
Devon Cheverie-1	11 cuttings	140m – 1410m
Kennetcook-1	19 cuttings	500m – 1340m
N-14-A	8 cuttings	530m – 2460m
O-61-C	10 cuttings	1505m – 2760m

Table 1 – Sample Intervals

2.2 Palynomorph Ranges and Zones

The palynomorph assemblages recorded in the present study can be favourably compared to the published accounts of Playford (1963), Utting & Giles (2004) and Utting *et al.* (1989) from the Early Carboniferous of Nova Scotia. The spore zones described by these authors are also directly applicable to the present study. The spore ranges and miospore zones and subzones are illustrated in Figure 2.

The assemblages also exhibit some comparison to the assemblages described from the Tournaisian of Ireland of Higgs *et al.* (1988) and Van Der Zwan (1980).

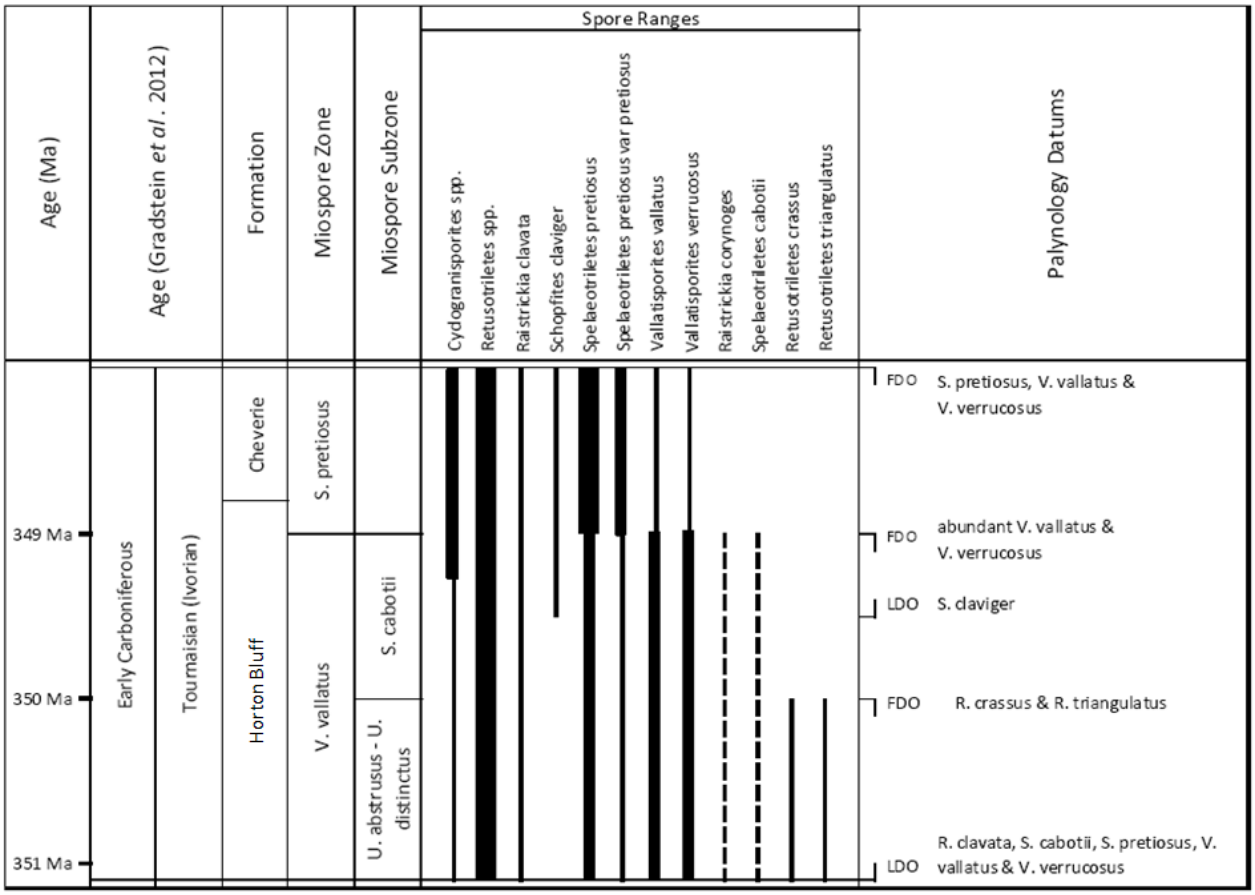

Figure 2 – Spore Ranges and Miospore Zones for the Horton Group

The miospores recorded from the present study indicate that the analysed sections are all of Early Carboniferous age, within the Ivorian Stage of the Tournaisian, and further that the assemblages can be directly related to the *Spelaeotriletes pretiosus* and *Vallatisporites vallatus* miospore zones of Utting & Giles (2004) and Utting *et al.* (1989). These miospore zones and miospore ranges are discussed in detail in Utting *et al.* (1989). The main age diagnostic taxa and miospore zones which are most relevant to the present study are illustrated in Figure 2. The significant points of this figure are as follows:

- The FDO of *Spelaeotriletes pretiosus*, *Vallatisporites vallatus* and *V. verrucosus* mark the top of the *S. pretiosus* zone. These taxa range no younger than this zone, and *S. pretiosus* has its highest abundance within the zone.
- The FDO of abundant *Vallatisporites vallatus* and *V. verrucosus* mark the top of the *V. vallatus* zone. The FDO of *Raistrickia corynoges* and *Spelaeotriletes cabotii* are also at the top of this zone, although these taxa have only been recorded sporadically in this study.

- The LDO of *Schopfites claviger* occurs within the *S. cabotii* subzone.
- The FDO of *Retusotriletes crassus* and *R. triangulatus* define the top of the *U. abstrusus – U. distinctus* subzone. In the present study, these taxa have been recorded rarely and interpreted to be reworked, and the subzone has not been recognised.
- The LDO of a number of taxa (*Raistrickia clavata*, *Schopfites claviger*, *Spelaeotriletes cabotii*, *Spelaeotriletes pretiosus*, *Vallatisporites vallatus* and *V. verrucosus*) mark the base of the *V. vallatus* zone. None of these taxa range below the zone or below the Ivorian Stage.

2.3 Palynomorph Recovery and Preservation

The palynomorph recovery from the studied samples is very variable, from low to relatively high to very high. Where possible counts of 200 specimens were made. Counts less than 200 represent the entire palynomorph recovery.

The preservation of the palynomorphs is also variable, and can be reasonably good to poor and very poor, with a body colour varying from brown to black (see the illustrations of palynomorphs in Appendix B). This is a function of “cooking” and carbonisation of the palynomorphs due to heat and pressure. Palynomorphs can be fragmented and it is considered likely in some of the more poorly preserved assemblages that the more fragile taxa have been almost entirely destroyed. The identification of the more poorly preserved palynomorphs can be difficult, but is aided by comparison with the better preserved assemblages.

The assemblages themselves are almost totally dominated by terrestrially derived spores. Marine acritarchs are rare, and well preserved specimens of *Veryhachium* identified in a sample in the Cheverie Formation in Kennetcook-1 are considered to be caved from marine sediments of the overlying Windsor Group.

3. SUMMARY OF RESULTS

3.1 Barney Brook-1 (Enclosure 3)

SAMPLING – One core chip and one composite cuttings sample.

DIAGNOSTIC CRITERIA:

- Occurrence of the miospores *Vallatisporites vallatus* and *V. verrucosus* at 665.9m (core) suggests the *V. vallatus* miospore zone;
- Occurrence of common specimens of *Vallatisporites vallatus* and rare *V. verrucosus* at 685m = *V. vallatus* miospore zone.

INTERVAL 665.9M (CORE) AND 685M

Age and Miospore Zone – Tournaisian, most likely the *V. vallatus* miospore zone.

Palynology – The palynomorph recovery from the core sample at 665.9m is low, but the assemblage does include rare specimens of *Vallatisporites vallatus*, *V. verrucosus* and ?*Spelaeotriletes pretiosus*, which implies equivalence to the *V. vallatus* miospore zone.

A relatively high abundance assemblage was recorded from the cuttings sample at 685m, which includes relatively common *Retusotriletes* spp. and *Vallatisporites vallatus*, with rare *V. verrucosus* and ?*Spelaeotriletes pretiosus*. This association of taxa indicates derivation from the *V. vallatus* miospore zone.

Kerogen – Rare/relatively common inertinite and structured inertinite, with rare structured dark vitrinite.

3.2 Camden-100 (Enclosure 4)

SAMPLING – Eleven core chips.

DIAGNOSTIC CRITERIA:

- Occurrence of questionable specimens of the miospore *Vallatisporites vallatus* at 192.5m (core) suggests the *S. pretiosus* miospore zone;
- Occurrence of common (but questionable) specimens of *Spelaeotriletes pretiosus* at 348m (core) suggests the *S. pretiosus* miospore zone;
- Occurrence of positive specimens of *Spelaeotriletes pretiosus* and *Vallatisporites vallatus* at 725m (core) = *S. pretiosus* – *V. vallatus* miospore zones;
- LDO of common (but questionable) specimens of *Spelaeotriletes pretiosus* at 1434m (core) suggests an age no older than the *V. vallatus* miospore zone.

INTERVAL 29M (CORE) - 1434M (CORE)

Age and Miospore Zone – Tournaisian, most likely within the *S. pretiosus* – *V. vallatus* miospore zones.

Palynology – The core samples analysed from this interval are widely spaced. Palynomorph recovery is of variable abundance, from low to occasionally high. The preservation of the palynomorphs is generally very poor, and for the most part identification is difficult. This is well illustrated in the high abundance assemblage at 348m, in which most of the taxa can only be identified as undifferentiated trilete spores, and the remainder of the taxa are questionable.

Taking this poor preservation into account, some identifications can be made. In particular, common (but questionable) specimens of *Spelaeotriletes pretiosus* are recorded at 348m (core) and 1434m (core), with positive specimens recorded at 725m (core). In addition, questionable specimens of *Vallatisporites vallatus* are recorded at 192.5m (core), with a positive specimen at 725m (core). A questionable specimen of *Vallatisporites verrucosus* is also recorded at 725m.

Despite the poor preservation of the palynomorphs recorded from this well, these occurrences do provide evidence for a Tournaisian/Ivorian age equivalent to the *S. pretiosus* – *V. vallatus* miospore zones.

Kerogen – The kerogen is generally dominated by an abundance of inertinite and structured inertinite. Any recorded structured vitrinite is very dark and grades to inertinite.

3.3 Creelman Hill-1 (Enclosure 5)

SAMPLING – Forty core chips.

DIAGNOSTIC CRITERIA:

- FDO of *Spelaeotriletes pretiosus* and *Vallatisporites verrucosus* at 64.6m (core) = *S. pretiosus* miospore zone;
- FDO of abundant *Vallatisporites vallatus* and *V. verrucosus* at 458.2m (core) = *V. vallatus* miospore zone.
- LDO of *Schopfites claviger* at 1385m (core) = no older than the upper part of the *S. cabotii* subzone;
- LDO of *Spelaeotriletes pretiosus*, *Vallatisporites vallatus* and *V. verrucosus* at 1405.5m (core) = an age no older than the *V. vallatus* miospore zone.

SAMPLE 27.5M (CORE)

The core sample at 27.5m is barren of palynomorphs.

INTERVAL 64.6M (CORE) - 427.0M (CORE)

Age and Miospore Zone – Tournaisian, *S. pretiosus* miospore zone.

Palynology – The studied interval is well represented by relatively closely spaced core samples. The palynomorph recovery is very variable, from low to moderately high, but with generally moderate recovery. There is variable, low to high, species diversity.

The interval 64.6m core – 427m core is characterised by low numbers of *Vallatisporites vallatus* and *V. verrucosus*, with rare *Spelaeotriletes pretiosus* at 64.6m (core). This association of taxa indicates the *S. pretiosus* miospore zone.

The background spore assemblage mainly comprises relatively common *Leiotriletes* spp. and *Retusotriletes* spp. (including *R. avonensis*). Additional taxa include *Cyclogranisporites* spp., *Densosporites* spp., *Punctatisporites* spp., *Radiizonates* spp., with occasional *Auroraspora macra*.

Kerogen – The kerogen is highly variable, often with an abundance of inertinite and structured inertinite, with structured vitrinite, which may be very dark and grading to inertinite. Plant cuticle is also identified.

INTERVAL 458.2M (CORE) – 1405.5M (CORE)

Age and Miospore Zone – Tournaisian, *V. vallatus* miospore zone, upper part of the *S. cabotii* subzone.

Palynology – The studied interval is well represented by relatively closely spaced core samples. The palynomorph recovery is variable, from low to moderately high, but is generally high. There is also a high species diversity.

Assemblages from the interval 458.2m core – 1405.5m core tend to be dominated by an abundance of *Vallatisporites* spp., mainly *V. vallatus* and *V. verrucosus*. In addition, *Spelaeotriletes pretiosus* occurs relatively consistently through the interval in low numbers (the exception being an abundance at 458.2m core), and *Spelaeotriletes cabotii* is recorded occasionally. Specimens of *Raistrickia clavata* are recorded consistently from 1094m (core) – 1405.5m (core), and *Schopfites claviger* is recorded consistently from 1167m (core) – 1385m (core). The abundance of *Vallatisporites* spp. indicates and age equivalent to the *V. vallatus* miospore zone, whilst the occurrences of *Schopfites claviger* in the lower part of the interval further suggests that this section is no older than the upper part of the *S. cabotii* subzone.

The background spore assemblage recovered from this interval mainly comprises an abundance of *Retusotriletes* spp. (including *R. avonensis* and occasional *R. coniferus*), rare

to abundant *Leiotriletes* spp., with occasional high abundances of *Auroraspora macra*. Additional taxa include *Cyclogranisporites* spp. (common down to 552m core), *Densosporites* spp., *Granulatisporites* spp., *Punctatisporites* spp., *Radiizonates* spp., *Raistrickia* spp., *Spinozonotriletes* spp. and *Verrucosisporites* spp., with occasional and rare *Knoxisporites literatus* and *Lophozonotriletes* spp.

Kerogen – The kerogen is generally dominated by an abundance of inertinite and structured inertinite, with structured vitrinite, which may be very dark and grading to inertinite. Plant cuticle is also identified, although this is generally rare.

3.4 Devon Cheverie-1 (Enclosure 6)

SAMPLING – Eleven composite cuttings samples.

DIAGNOSTIC CRITERIA:

- FDO of *Spelaeotriletes pretiosus* and *Vallatisporites vallatus* at 140m = *S. pretiosus* miospore zone;
- Peak abundance of *Spelaeotriletes pretiosus* at 1070m = *S. pretiosus* miospore zone;
- FDO of abundant *Vallatisporites vallatus* and *V. verrucosus* at 1410m = *V. vallatus* miospore zone.

INTERVAL 140M - 1390M

Age and Miospore Zone – Tournaisian, *S. pretiosus* miospore zone.

Palynology – The samples are widely spaced through much of the section, but more closely spaced in the lower part of the interval below 1210m.

The assemblages recorded from this interval are of generally high abundance and are of high species diversity. They are characterised throughout by the occurrence of *Spelaeotriletes pretiosus* (abundant at 1070m and very common at 305m and 1210m), together with *Spelaeotriletes pretiosus* var. *pretiosus* (also abundant at 1070m). In addition, *Vallatisporites vallatus* and *V. verrucosus* are recorded throughout the interval. This association of taxa implies an age equivalent to the *S. pretiosus* miospore zone for most of the studied section from the Devon Cheverie well.

The background spore assemblages mainly comprise *Leiotriletes* spp. and *Retusotriletes* spp. (including *R. avonensis* and occasional *R. coniferus*), with lower numbers (rare/ common) of *Auroraspora macra*, *Cyclogranisporites* spp., *Densosporites* spp., *Dictyotriletes* spp., *Punctatisporites* spp., *Radiizonates* spp., *Raistrickia* spp., *Schopfites* spp. (including occasional *S. augustus* and *S. claviger*), *Spinozonotriletes* spp. and *Verrucosisporites* spp., with occasional and rare *Discernisporites* spp. and *Knoxisporites* spp.

Kerogen – The kerogen is generally dominated by an abundance of inertinite and structured inertinite, with structured vitrinite which may be very dark and grading to inertinite. Plant cuticle is also identified, although this is generally rare.

SAMPLE 1410M

Age and Miospore Zone – Tournaisian, *V. vallatus* miospore zone.

Palynology – The assemblage is of high abundance and diversity. The palynomorph assemblage at 1410m is characterised by an abundance of *Vallatisporites vallatus* and *V. verrucosus*. This implies an age equivalent to the *V. vallatus* miospore zone in this lowest sample analysed from the Devon Cheverie well.

The background spore assemblage is characterised by an abundance of *Retusotriletes* spp. (including abundant *R. avonensis* and common *R. coniferus*), with abundant *Vallatisporites* spp. and lower numbers of *Auroraspora macra*, *Cyclogranisporites* spp., *Densosporites* spp., *Radiizonates* spp. and *Spelaeotriletes* spp.

Kerogen – The kerogen comprises abundant inertinite and structured inertinite, with plant cuticle and tracheids.

3.5 Kennetcook-1 (Enclosure 7)

SAMPLING – Nineteen composite cuttings samples.

DIAGNOSTIC CRITERIA:

- FDO of *Spelaeotriletes pretiosus*, *Vallatisporites vallatus* and *V. verrucosus* at 500m = *S. pretiosus* miospore zone;
- FDO of abundant *Vallatisporites vallatus* and *V. verrucosus* at 720m = *V. vallatus* miospore zone;
- LDO of *Spelaeotriletes pretiosus*, *Vallatisporites vallatus* and *V. verrucosus* at 1340m = no older than the *V. vallatus* miospore zone.

INTERVAL 500m – 675m

Age and Miospore Zone – Tournaisian, *S. pretiosus* miospore zone.

Palynology – The studied interval comprises three composite cuttings samples, covering intervals of 40-55m. Palynomorph recovery is variable, from moderate to high, and there is a relatively high species diversity.

The palynomorph assemblages include *Spelaeotriletes pretiosus* and *S. pretiosus* var. *pretiosus*, an abundance of which is recorded at 675m, together with low numbers of *Vallatisporites vallatus* and *V. verrucosus*. This association of taxa indicates an age equivalent to the *S. pretiosus* miospore zone.

The background spore assemblage mainly comprises *Leiotriletes* spp., *Punctatisporites* spp. and *Retusotriletes* spp. (including *R. avonensis*), with rarer *Auroraspora macra*, *Cyclogranisporites* spp., *Densosporites* spp., *Raistrickia* spp. and *Verrucosisporites* spp., with occasional *Discernisporites* spp., *Granulatisporites* spp., *Radiizonates* spp. and *Schopfites* spp.

Kerogen – The kerogen is dominated by an abundance of inertinite and structured inertinite, locally with structured vitrinite which may be very dark and grading to inertinite. Plant cuticle is persistent but rarer.

INTERVAL 720m – 1340m

Age and Miospore Zone – Tournaisian, *V. vallatus* miospore zone.

Palynology – The studied interval is well represented by relatively closely spaced cuttings samples. Palynomorph recovery is variable, from moderately high to high, and there is a high species diversity.

Palynomorph assemblages are characterised by an abundance of *Vallatisporites vallatus* and *V. verrucosus*, with generally common *Spelaeotriletes pretiosus*. Specimens of *Raistrickia clavata* occur occasionally and sporadically, with the lowest recorded occurrence at 1315m. A single specimen of *Spelaeotriletes cabotii* was recorded at 1200m. The abundance of *Vallatisporites* spp. indicates equivalence to the *V. vallatus* miospore zone.

The background spore assemblage mainly comprises *Retusotriletes* spp. (including *R. avonensis* and occasional *R. coniferus*), with lower numbers of *Auroraspora macra*, *Densosporites* spp., *Leiotriletes* spp., *Punctatisporites* spp. and *Verrucosisporites* spp., with occasional *Cyclogranisporites* spp. (common down to 720m), *Dictyotriletes* spp., *Discernisporites* spp., *Granulatisporites* spp., *Knoxisporites* spp., *Lophozonotriletes* spp., *Raistrickia* spp., *Radiizonates* spp. and *Schopfites* spp.

Kerogen – The kerogen is generally dominated by an abundance of inertinite and structured inertinite, with structured vitrinite which may be very dark and grading to inertinite. Plant cuticle is sporadic and rare.

3.6 N-14-A (Enclosure 8)

SAMPLING – Eight composite cuttings samples.

DIAGNOSTIC CRITERIA:

- FDO of *Spelaeotriletes pretiosus* and *Vallatisporites vallatus* at 530m = *S. pretiosus* miospore zone;
- FDO of abundant *Vallatisporites vallatus* at 1060m = *V. vallatus* miospore zone;
- LDO of *Spelaeotriletes pretiosus* and *Vallatisporites vallatus* at 2460m = no older than the *V. vallatus* miospore zone.

INTERVAL 530m – 700m

Age and Miospore Zone – Tournaisian, *S. pretiosus* miospore zone.

Palynology – The two samples analysed from this interval are relatively widely spaced and represent composites of material over 30m interval. Palynomorph recovery is moderate to high, and species diversity is moderate.

The palynomorph assemblages recorded include very common *Spelaeotriletes pretiosus* and relatively common *S. pretiosus* var. *pretiosus*, with low numbers of *Vallatisporites vallatus* at 530m and a specimen of *V. verrucosus* at 700m. This association of taxa provides good evidence for equivalence to the *S. pretiosus* miospore zone.

The background spore assemblage includes an abundance of *Leiotriletes* spp. and *Retusotriletes* spp. (including *R. avonensis* and occasional *R. coniferus*), with occasional *Auroraspora macra*, *Cyclogranisporites* spp., *Knoxisporites* spp., *Punctatisporites* spp. and *Schopfites* spp. and persistent *Radiizonates* spp.

Kerogen – The kerogen is dominated by an abundance of inertinite and structured inertinite, with structured vitrinite which may be very dark and grading to inertinite. Plant cuticle is rare.

INTERVAL 1060m – 2460m

Age and Miospore Zone – Tournaisian, *V. vallatus* miospore zone.

Palynology – The samples analysed from this interval are widely spaced and represent composites of material over 25-30m. Palynomorph recovery is generally high, although species diversity is moderate.

The palynomorph assemblages are characterised by an abundance of *Vallatisporites vallatus*, with rare to common *Spelaeotriletes pretiosus* and *Vallatisporites verrucosus*. A single specimen of *Raistrickia clavata* was recorded at 2460m, with *Raistrickia corynoges* at 2370m and 2460m (with a questionable specimen at 1330m). This association of taxa provides good evidence for an age equivalent to the *V. vallatus* miospore zone.

The background spore assemblage includes an abundance of *Retusotriletes* spp. (including *R. avonensis*), with occasionally abundant *Leiotriletes* spp. and lower numbers of *Auroraspora macra*, *Cyclogranisporites* spp. (relatively common down to 1560m), *Punctatisporites* spp. and *Radiizonates* spp. There are also sporadic rare occurrences of *Dictyotriletes* spp., *Discernisporites* spp., *Knoxisporites* spp., *Lophozonotriletes* spp. and *Schopfites* spp.

Kerogen – The kerogen is dominated by an abundance of inertinite and structured inertinite, with some structured vitrinite which may be very dark and grading to inertinite. Plant cuticle is generally rare.

3.7 O-61-C (Enclosure 9)

SAMPLING – Eight composite cuttings samples.

DIAGNOSTIC CRITERIA:

- FDO of *Spelaeotriletes pretiosus* and *Vallatisporites vallatus* at 1505m = *S. pretiosus* miospore zone;
- FDO of common *Vallatisporites vallatus* at 1795m = *V. vallatus* miospore zone;
- LDO of *Spelaeotriletes pretiosus* and *Vallatisporites vallatus* at 2760m = no older than the *V. vallatus* miospore zone;
- LDO of *Schopfites claviger* at 2760m suggests an age no older than the upper part of the *S. cabotii* subzone;

INTERVAL 1505m – 1630m

Age and Miospore Zone – Tournaisian, *S. pretiosus* miospore zone.

Palynology – The samples analysed are relatively widely spaced, and represent composites of material from 20-35m. The palynomorph recovery from this interval is high, although species diversity is only moderately high.

Assemblages are characterised by *Spelaeotriletes pretiosus* (common at 1550m and abundant at 1630m), with common to rare *S. pretiosus* var. *pretiosus*, and occasional rare *Vallatisporites vallatus*. This association of taxa provides good evidence for equivalence to the *S. pretiosus* miospore zone.

The background spore assemblage tends to be dominated by an abundance of *Leiotriletes* spp. and *Retusotriletes* spp. (including *R. avonensis* and *R. coniferus*). Additional taxa include persistent low numbers of *Densosporites* spp., *Knoxisporites literatus* and *Radiizonates* spp. with occasional rare *Auroraspora macra*, *Dictyotriletes* spp., *Discernisporites* spp., *Punctatisporites* spp., *Spinozonotriletes* spp., *Cyclogranisporites* spp. and *Verrucosisporites* spp.

Kerogen – The kerogen is dominated by an abundance of inertinite and structured inertinite. Plant cuticle is generally rare.

INTERVAL 1795m – 2760m

Age and Miospore Zone – Tournaisian, *V. vallatus* miospore zone, upper part of the *S. cabotii* subzone.

Palynology – The samples analysed are relatively widely spaced, and represent composites of material from 25-50m. The palynomorph recovery from this interval is generally high, although species diversity is only moderately high.

The assemblages are characterised by the abundance of *Vallatisporites vallatus* (common at 1795m and abundant at and below 1895m). In addition, *Spelaeotriletes pretiosus* and *Vallatisporites verrucosus* are generally common throughout the interval. *Raistrickia clavata* was recorded at 2145m, 2270m and 2760m, and *Spelaeotriletes cabotii* at 2145m and 2270m. *Schopfites claviger* is common at 1795m and rare at 2760m. This association of taxa provides good evidence for equivalence to the *V. vallatus* miospore zone, whilst the occurrence of *Schopfites claviger* further implies that these sediments are no older than the upper part of the *S. cabotii* subzone of the *V. vallatus* zone.

The background spore assemblage tends to be dominated by an abundance of *Leiotriletes* spp. and *Retusotriletes* spp. (including *R. avonensis* with occasional *R. coniferus*). Additional taxa include rare to common *Auroraspora macra*, *Cyclogranisporites* spp. and *Punctatisporites* spp. and occasional low numbers of *Densosporites* spp., *Dictyotriletes* spp., *Discernisporites* spp., *Radiizonates* spp., *Spinozonotriletes* spp. and *Verrucosisporites* spp.

Kerogen – The kerogen is dominated by an abundance of inertinite and structured inertinite, with structured vitrinite which may be very dark and grading to inertinite. Plant cuticle is generally rare.

4. CORRELATION

The correlation of the study wells is presented in Enclosures 1 and 2.

Those wells with the most complete sampling (Kennetcook-1 and Creelman Hill-1) show excellent palynological correlation, showing that both core and cuttings samples yield good data (Enclosure 1). Some of the correlative events can also been seen in the other wells with sparser sampling (Enclosure 2).

4.1 Miospore Zonal Correlation

The *Spelaeotriletes pretiosus* miospore zone is well defined in the Creelman Hill-1, Devon Cheverie-1, Kennetcook-1, N-14-A and O-61-C wells. The majority of the section analysed from the Horton Group in the Devon Cheverie-1 well appears to be equivalent to the *S. pretiosus* miospore zone, which is different from the sections analysed from the other wells in this study in which only the upper parts of the analysed sections were equivalent to this biozone.

The *Vallatisporites vallatus* miospore zone is very well defined in Creelman Hill-1, Kennetcook-1, N-14-A and O-61-C, and the top of this zone is just penetrated at the base of the analysed section in Devon Cheverie-1. The FDO of abundant specimens of *Vallatisporites* spp. is an excellent correlative marker. The zonal definition can be further refined in Creelman Hill-1 and O-61-C (and possibly in Kennetcook-1), where the assemblages suggest an age within the upper part of this biozone, the *Spelaeotriletes cabotii* subzone.

Only two samples were analysed from the Barney Brook-1 well. The assemblages recovered are poor, but there is enough data to suggest that the sediments analysed are derived from Tournaisian sediments equivalent to the *V. vallatus* zone.

The widely spaced samples that yield poorly preserved palynomorph assemblages from Camden-100 also contain enough evidence to indicate that the assemblages are also equivalent in age to the *Spelaeotriletes pretiosus* to *Vallatisporites vallatus* miospore zones.

4.2 Intra-Zonal Correlation

Aside from the broad zonal correlation of the wells, a number of palynological events can be recognised. These are best observed in the Kennetcook-1 and Creelman Hill-1 wells where sampling was most extensive. These are illustrated on Enclosure 1 and the individual events are:–

- Peak *Spelaeotriletes pretiosus*
- Base common *Cyclogranisporites* spp.
- Peak in *Vallatisporites* spp.
- Decrease in palynofloral recovery
- Second peak in *Vallatisporites* spp.
- Increase in *Schopfites* spp.
- Third peak in *Vallatisporites* spp.

Of these events observed in Kennetcook-1 and Creelman Hill-1, the peak abundance of *Spelaeotriletes pretiosus* and the base of common *Cyclogranisporites* spp. can be correlated with varying degrees of certainty within other wells (Enclosure 2).

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APPENDIX A: GLOSSARY OF TERMS AND ABBREVIATIONS

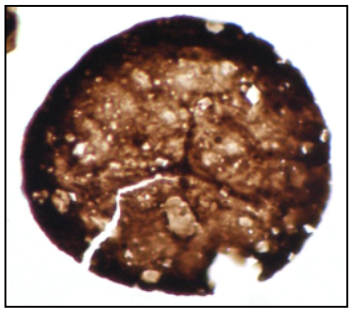
FDO	First Downhole Occurrence
LDO	Last Downhole Occurrence
Ma	Million Years
MD	Measured Depth
MFS	Maximum Flooding Surface
RPSE	RPS Energy
SB	Sequence Boundary
TVD	Total Vertical Depth

APPENDIX B: SAMPLE PROGRAMME

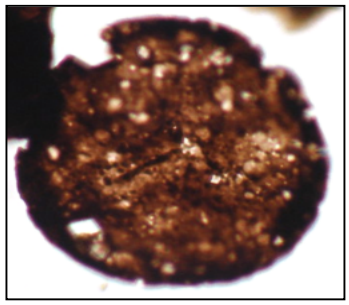
Creelman Hill (co)	Kennetcook-1 (cu)	Barney Brook (co+cu)	Camden 100 (co)	Devon Cheverie (cu)	O-61-C (cu)	N-14-A (cu)
27.5	460-500	660-685 (cu)	29	94-140	1475-1505	500-530
64.6	545-600	665.9	192.5	270-305	1530-1550	670-700
125	635-675		348	435-455	1595-1630	1040-1060
218.6	685-720		465	695-725	1745-1795	1295-1330
241	720-745		725	1000-1070	1835-1885	1530-1560
284	770-810		827.6	1150-1210	1955-1995	1990-2020
339	850-900		1129.4	1220-1255	2080-2105	2350-2370
393.7	905-945		1203.7	1295-1320	2110-2145	2435-2460
427	950-985		1259	1340-1365	2245-2270	
458.2	990-1025		1278.7	1365-1390	2725-2760	
480	1030-1050		1434	1395-1410		
533.4	1055-1085					
552	1130-1155					
594	1175-1200					
633	1205-1230					
672	1235-1260					
690	1265-1290					
741	1295-1315					
787	1320-1340					
822						
849						
889.5						
936						
963						
987						
1002.5						
1021						
1056						
1094						
1107						
1167						
1206						
1229						
1243						
1262						
1296.5						
1335						
1370						
1385						
1405.5						
40	19	2	11	11	10	8
Total: 101						

APPENDIX C: PLATES OF SELECTED PALYNOMORPHS

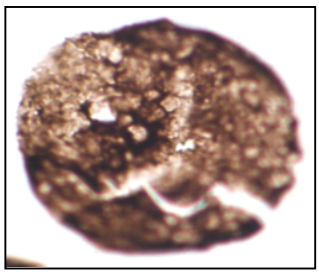
Plate 1
Early Carboniferous (Tournaisian) Horton Group - Spores



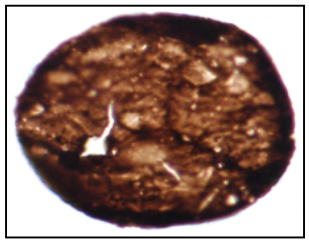
Punctatisporites sp.
Creelman Hill 458.2m core (K35)
65µm x 68µm



Punctatisporites sp.
Creelman Hill 458.2m core (N41)
62µm x 67µm

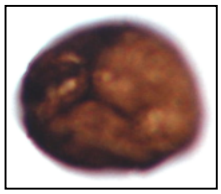


Punctatisporites sp.
Creelman Hill 1405.5m core (T58/1)
57µm x 62µm



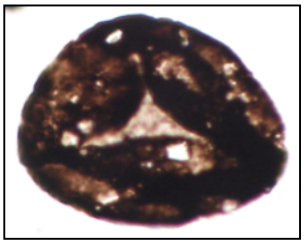
Punctatisporites sp.
Creelman Hill
458.2m core (E39/1)
47µm x 60µm

Punctatisporites minutus
Creelman Hill
125m core (O58/2)
30µm x 35µm

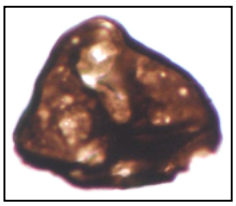


Punctatisporites minutus
Kennetcook-1
500m (N33)
32µm x 37µm

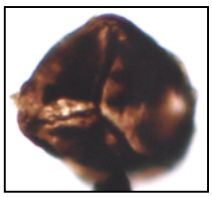
Punctatisporites glaber
Kennetcook
600m (F38/1) 50µm x 50µm



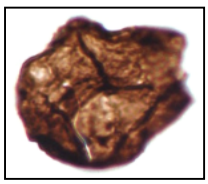
Leiotriletes sp.
Creelman Hill
1094m core (F44/3)
45µm x 50µm



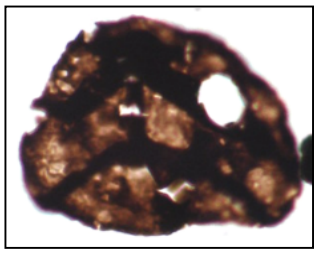
Leiotriletes sp.
Creelman Hill
64.6m core (D44/4)
37µm x 40µm



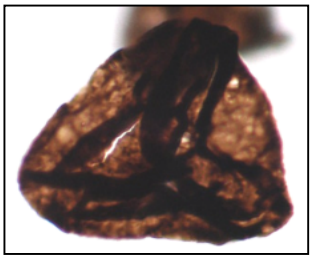
Leiotriletes sp.
Creelman Hill
64.6m core (R50)
32µm x 35µm



Leiotriletes sp.
Creelman Hill
64.6m core (T61/3)
35µm x 38µm

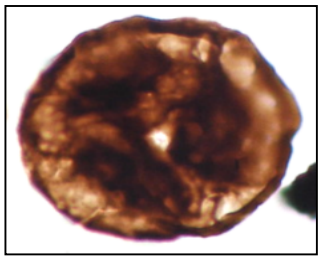


Leiotriletes ornatus
Creelman Hill
1002.5m core (H47)
50µm x 60µm

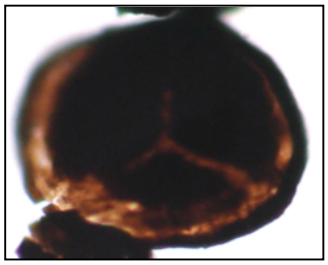


Leiotriletes ornatus
Creelman Hill
284m core (F44/3)
55µm x 62µm

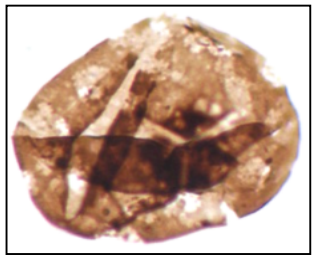
Plate 2
Early Carboniferous (Tournaisian) Horton Group - Spores



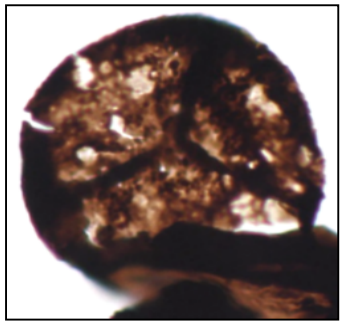
Retusotriletes crassus
Cheverie 305m (O31/3)
42µm x 50µm



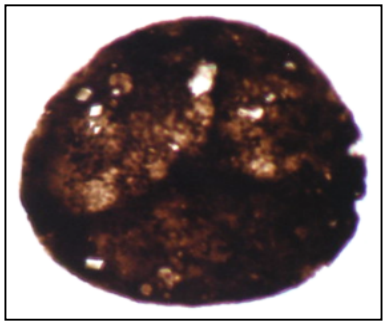
Retusotriletes crassus
Cheverie 305m (S43)
45µm x 55µm



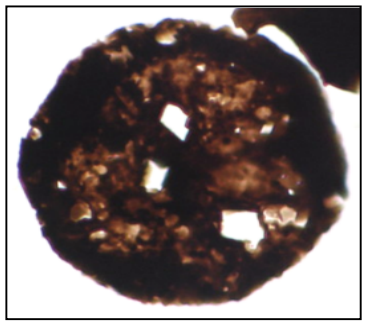
Retusotriletes triangulatus
Kennetcook 677m (F33)
40µm x 50µm



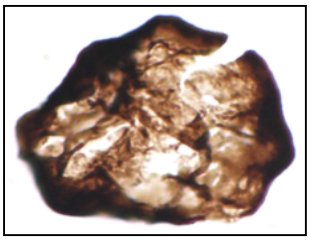
Retusotriletes coniferus
Creelman Hill
522.4m core (K53/2)
57µm x 60µm



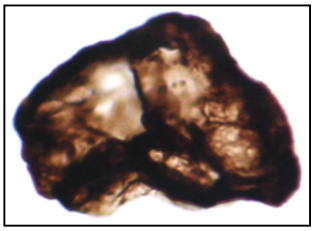
Retusotriletes coniferus
Creelman Hill
522.4m core (O50/3)
57µm x 62µm



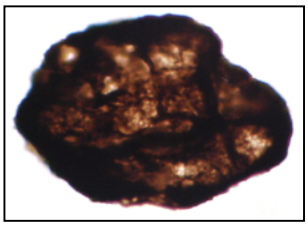
Retusotriletes coniferus
Creelman Hill
522.4m core (M40)
60µm x 65µm



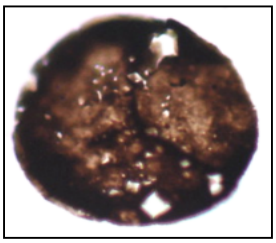
Retusotriletes avonensis
Creelman Hill
64.6m core (S58)
45µm x 50µm



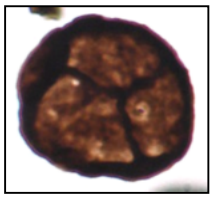
Retusotriletes avonensis
Creelman Hill
64.6m core (E65/1)
40µm x 50µm



Retusotriletes avonensis
Creelman Hill
64.6m core (R66/3)
50µm x 65µm

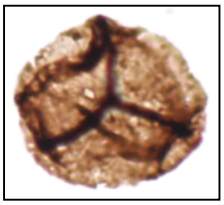


Retusotriletes sp.
Creelman Hill
1056m core (Q42)
45µm x 50µm

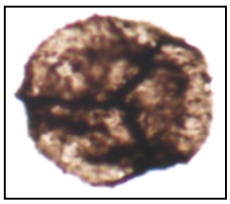


Retusotriletes sp.
Creelman Hill
1002.5m core (T51/3)
30µm x 32µm

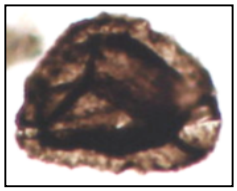
Plate 3
Early Carboniferous (Tournaisian) Horton Group - Spores



Auroraspora macra
Creelman Hill
458.2m core (P32/2)
30µm x 32µm

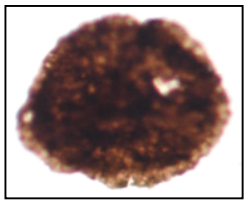


Auroraspora macra
Creelman Hill
1405.5m core (F62/4)
30µm x 30µm

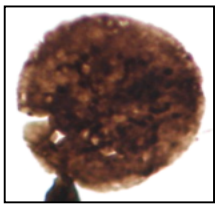


Auroraspora macra
Creelman Hill
1405.5m core (T43)
25µm x 32µm

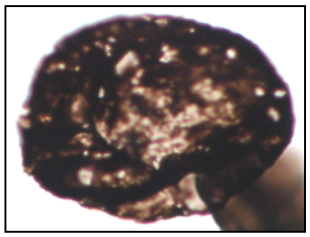
Auroraspora macra
Creelman Hill
1405.5m core (S48)
28µm x 35µm



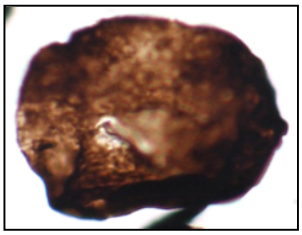
Colatisporites decorus
Creelman Hill
552m core (P38)
37µm x 42µm



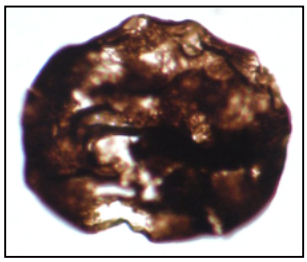
Colatisporites decorus
Creelman Hill
741m core (O34)
37µm x 37µm



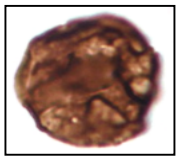
large alete spore
Creelman Hill
1405.5m core (J44/1)
48µm x 57µm



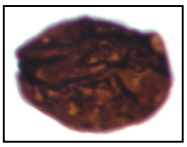
large alete spore
Creelman Hill
125m core (K35/1)
45µm x 52µm



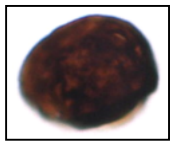
large alete spore
Creelman Hill
125m core (F45/1)
52µm x 58µm



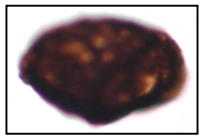
small alete spore
Creelman Hill
125m core (N61/4)
27µm x 27µm



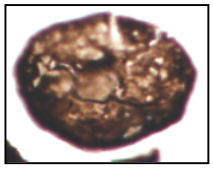
small alete spore
Creelman Hill
125m core (J41)
25µm x 30µm



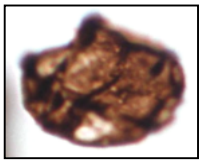
small alete spore
Creelman Hill
125m core (N48/2)
22µm x 27µm



small alete spore
Creelman Hill
125m core (X59/3)
25µm x 35µm

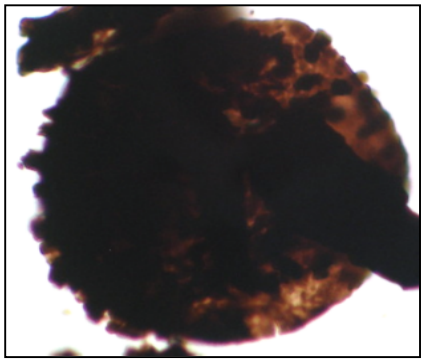


small alete spore
Creelman Hill
1405.5m core (T43)
27µm x 27µm

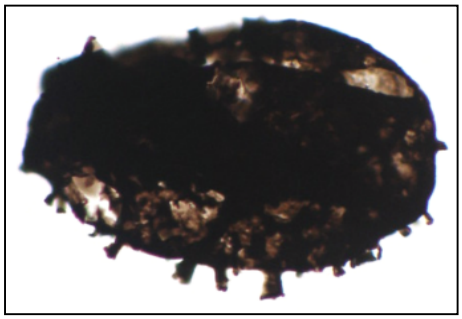


small alete spore
Creelman Hill
284m core (R43/2)
25µm x 32µm

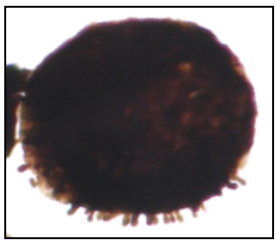
Plate 4
Early Carboniferous (Tournaisian) Horton Group - Spores



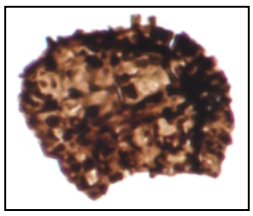
Schopfites augustus
Kennetcook 1315m (J37/3)
70µm x 70µm



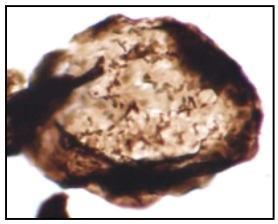
Schopfites augustus
Creelman Hill 1385m core (K46)
70µm x 100µm



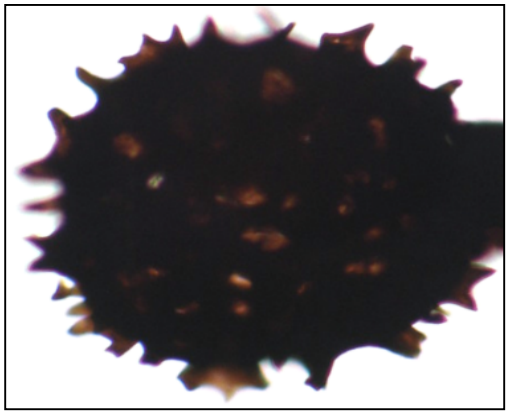
Schopfites claviger
O-61-C 1550m (N39/4)
35µm x 38µm



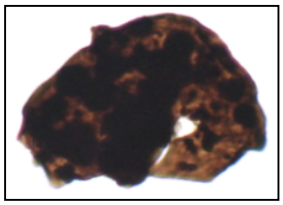
Raistrickia baculosa
Creelman Hill
787m core (V44/4)
37µm x 40µm



Umbonatisporites abstrusus
Creelman Hill
64.6m core (W46)
45µm x 50µm

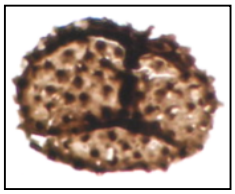


Raistrickia spathulata
N-14-A 1060m (S35) 65µm x 74µm

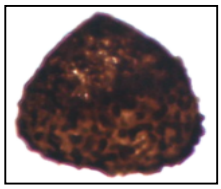


Tumulispora variverrucata
Creelman Hill
533.4m core (M40/2)
35µm x 45µm

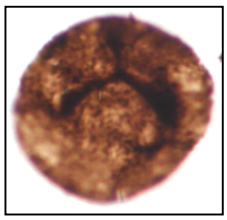
Plate 5
Early Carboniferous (Tournaisian) Horton Group - Spores



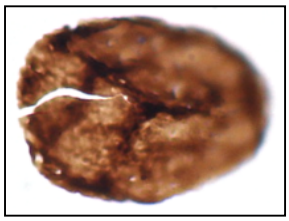
Apiculatisporis sp.
Creelman Hill
741m core (H58/3)
30µm x 35µm



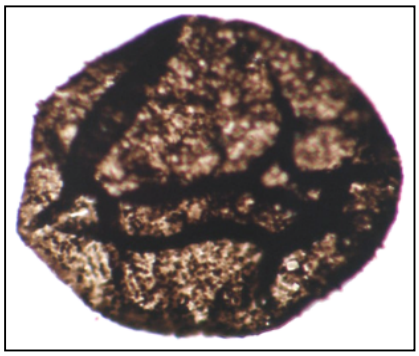
Granulatisporites sp.
Creelman Hill
125m core (U30/2)
32µm x 35µm



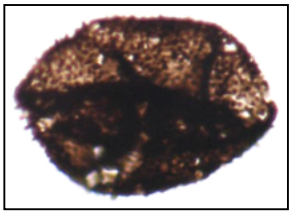
Cyclogranisporites sp.
Kennetcook
1025m core (U58/1)
37µm x 40µm



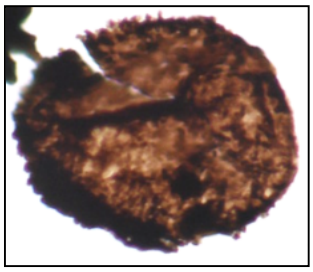
Cyclogranisporites sp.
Creelman Hill
458.2m core (M30)
42µm x 52µm



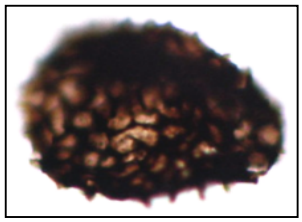
Baculatisporites fusticulus
Creelman Hill 1405.5m core (Y33)
82µm x 90µm



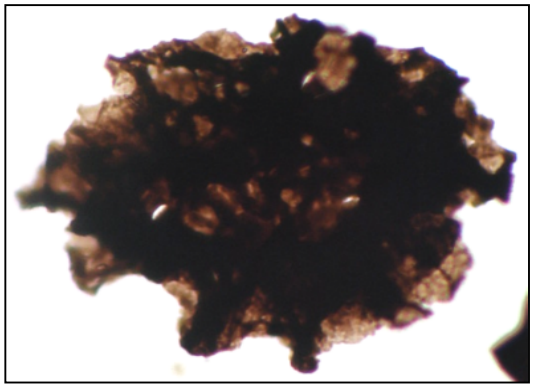
Baculatisporites sp.
Creelman Hill
1107m core (G44/2)
35µm x 47µm



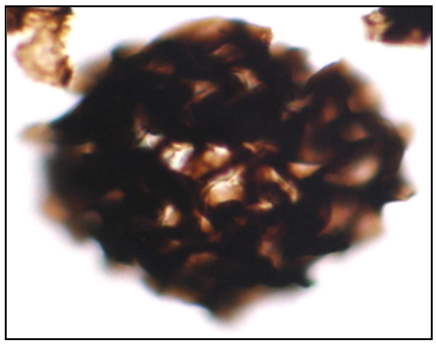
Crassispora sp.
N-14-A 700m (L40/3)
50µm x 55µm



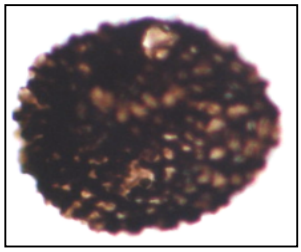
Dictyotriletes sp.
Creelman Hill 787m core (O35)
35µm x 50µm



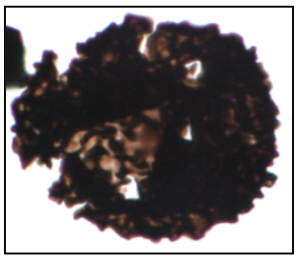
Dictyotriletes trivialis O-61-C 1885m (U45/3)
75µm x 100µm



Dictyotriletes sp.
Cheverie 305m (T58) 60µm x 70µm

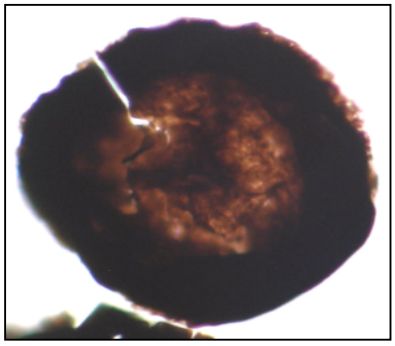


Convolutispora permixta
O-61-C
1885m (S49)
42µm x 50µm

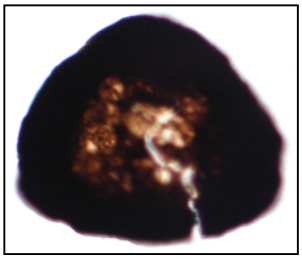


Convolutispora permixta
Creelman Hill
1206m core (P32)
48µm x 52µm

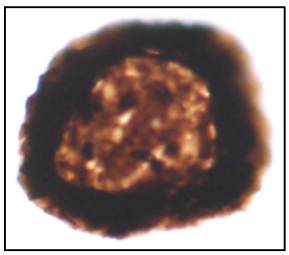
Plate 6
Early Carboniferous (Tournaisian) Horton Group - Spores



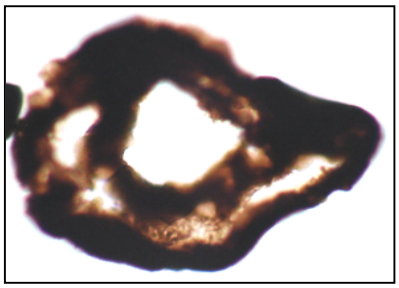
Densosporites sp.
O-61-C 1550m (E47)
65µm x 72µm



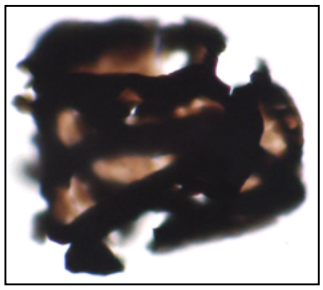
Densosporites sp.
Creelman Hill
64.6m core (V37/4)
62µm x 68µm



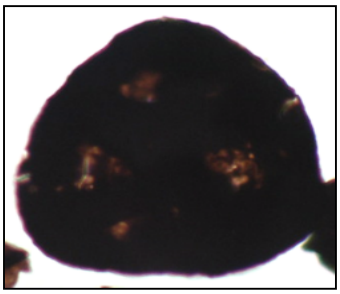
Densosporites spitsbergensis
Kennetcook
600m (M53/3)
42µm x 47µm



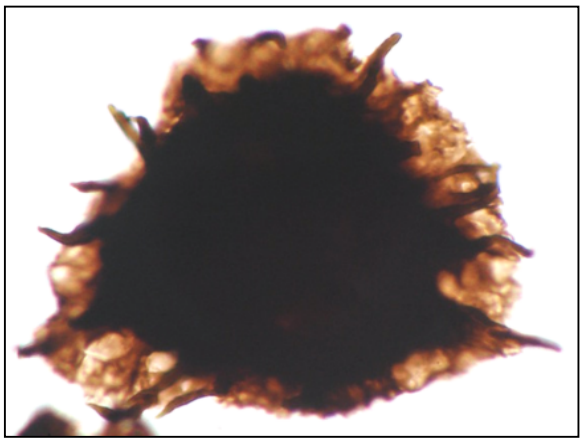
Knoxisporites literatus
Creelman Hill
64.6m core (G41/3)
62µm x 87µm



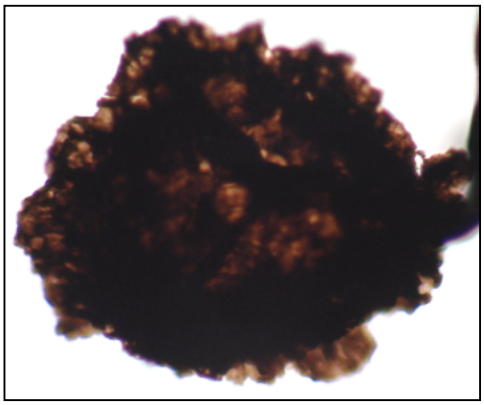
Knoxisporites literatus
Creelman Hill
1002.5m core (D47)
65µm x 70µm



Knoxisporites sp.
Creelman Hill
1167m core (J54/1)
57µm x 62µm

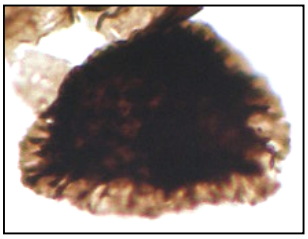


Spinozonotriletes sp.
Cheverie 305m (F35) 80µm x 80µm, spines <15µm

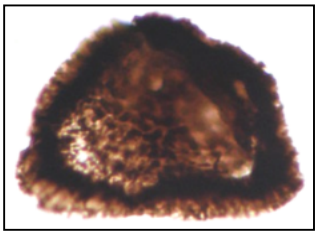


Cristatisporites aculeatus
Creelman Hill 787m core (G53/2)
85µm x 90µm

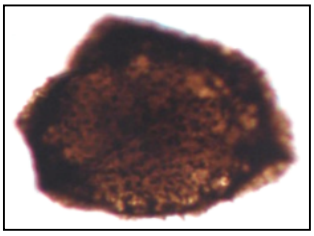
Plate 7
Early Carboniferous (Tournaisian) Horton Group - Spores



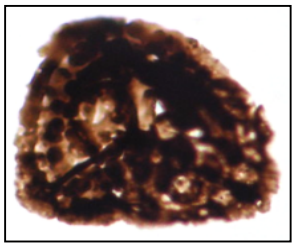
Vallatisporites vallatus
Creelman Hill
125m core (T59/1)
32µm x 40µm



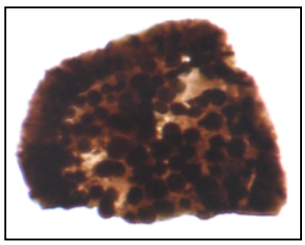
Vallatisporites vallatus
Creelman Hill
125m core (W57/2)
40µm x 52µm



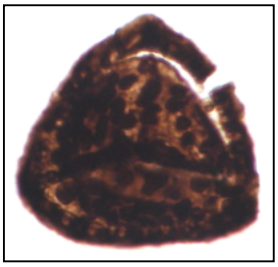
Vallatisporites vallatus
Creelman Hill
125m core (O48/2)
37µm x 45µm



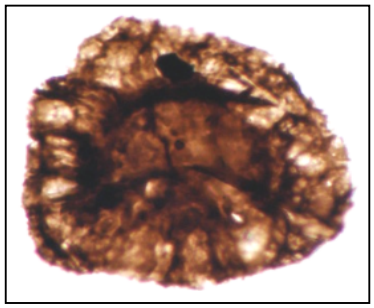
Vallatisporites verrucosus
Creelman Hill
458.2m core (E30/1)
45µm x 55µm



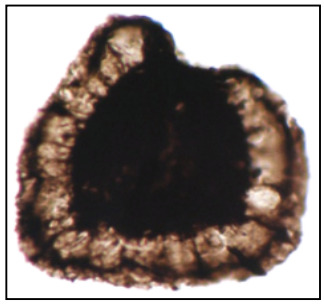
Vallatisporites verrucosus
Creelman Hill
125m core (S53/4)
40µm x 50µm



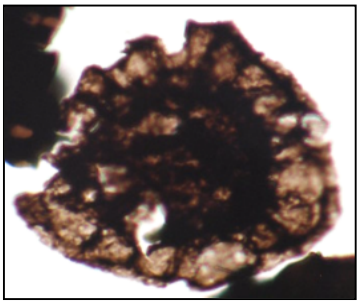
Vallatisporites verrucosus
Creelman Hill
284m core (N34/4)
50µm x 50µm



Radiizonates sp.
Kennetcook 677m (R61/1)
58µm x 68µm

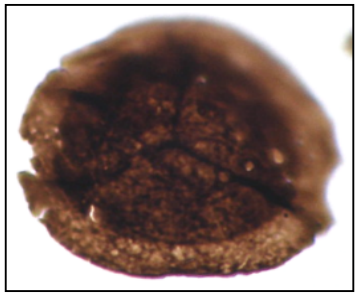


Radiizonates sp.
Creelman Hill
1167m core (N43)
62µm x 62µm

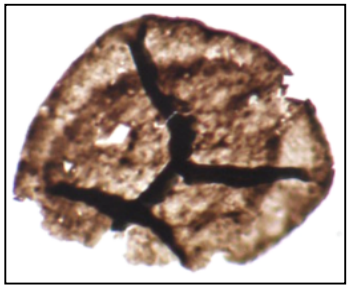


Radiizonates algerans
Creelman Hill
1002.5m core (U42)
58µm x 65µm

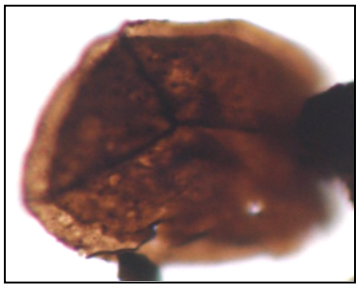
Plate 8
Early Carboniferous (Tournaisian) Horton Group - Spores



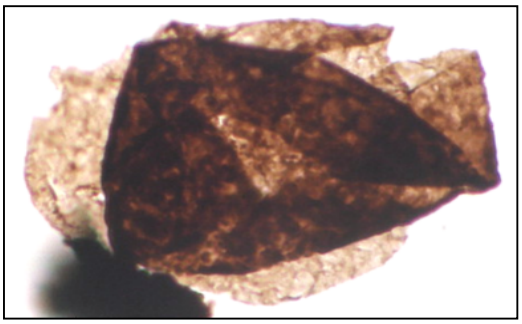
Discernisporites sullivani
Creelman Hill 741m core (J46/1)
55µm x 65µm



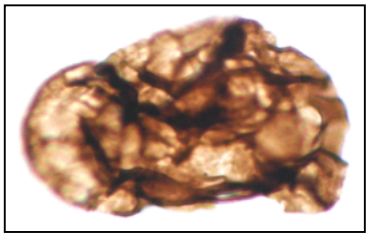
Discernisporites sp.
Creelman Hill 1094m core (Q42)
52µm x 58µm



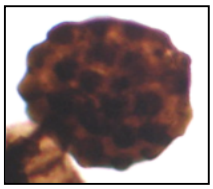
Discernisporites sp.
Cheverie 1210m core (P29)
55µm x 65µm



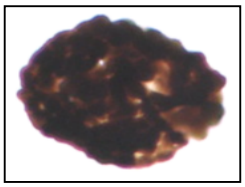
Auroraspora sp.
O-61-C
1505m (R35/3)
55µm x 85µm



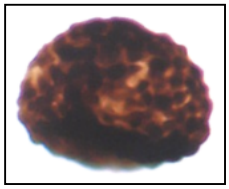
Auroraspora sp.
Cheverie 140m (F60)
37µm x 60µm



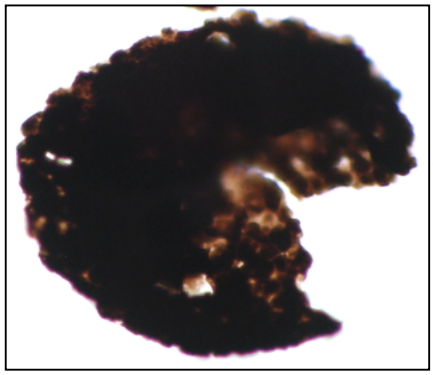
Verrucosisporites congestus
Kennetcook
500m (P47/4)
27µm x 30µm



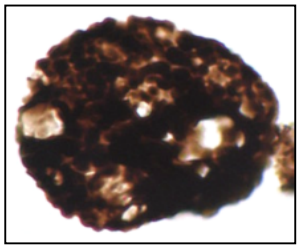
Verrucosisporites nitidus
O-61-C
1505m (F28)
25µm x 32µm



Verrucosisporites nitidus
Kennetcook
500m (J31/4)
27µm x 30µm

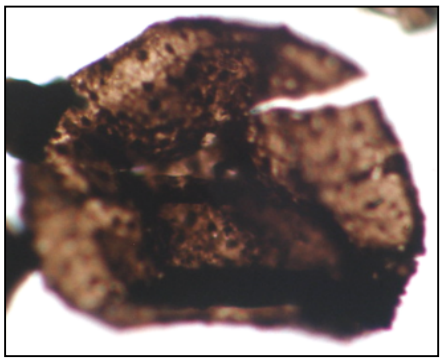


Verrucosisporites sp.
Creelman Hill 533.4m core (S58/3)
80µm x 90µm

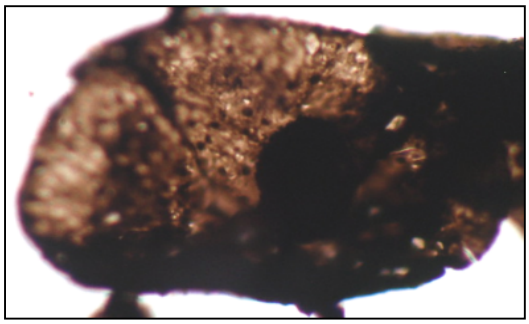


Verrucosisporites sp.
Creelman Hill
427m core (C49)
45µm x 50µm

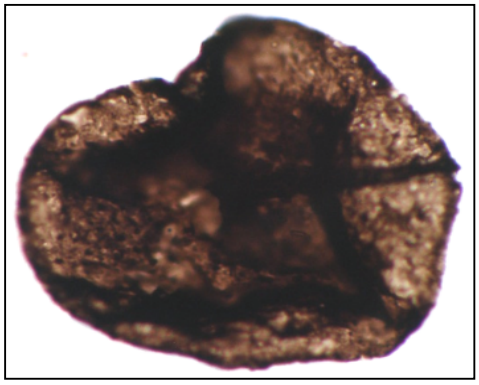
Plate 9
Early Carboniferous (Tournaisian) Horton Group - Spores



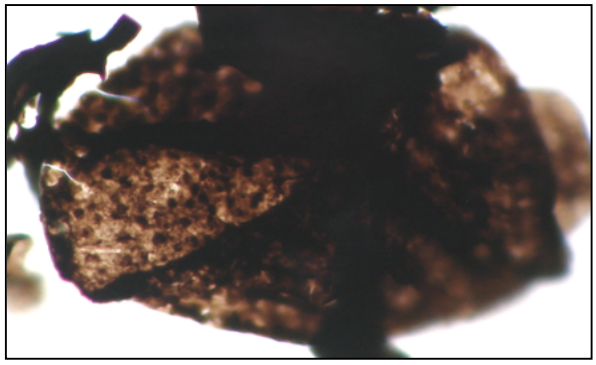
Spelaeotriletes pretiosus
Creelman Hill
1405.5m core (L51) 75µm x 90µm



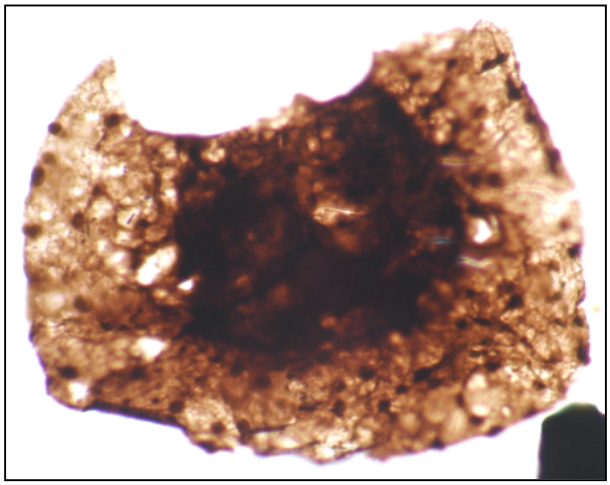
Spelaeotriletes pretiosus
Creelman Hill
1405.5m core (J35) 65µm x 105µm



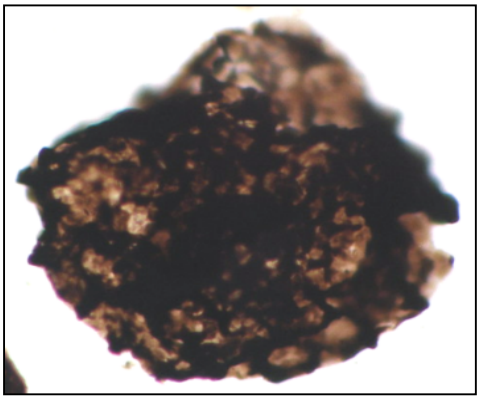
Spelaeotriletes pretiosus
Creelman Hill
1405.5m core (F62) 87µm x 103µm



Spelaeotriletes pretiosus
Creelman Hill
1405.5m core (T40/3) 82µm x 125µm

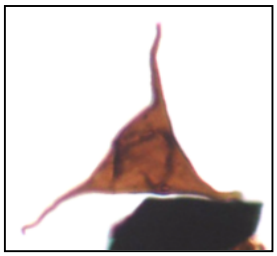


Spelaeotriletes pretiosus var pretiosus
Cheverie 1400m (L52/3) 108µm x 120µm

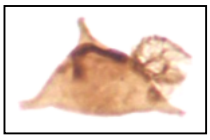


Spelaeotriletes cabotii
O-61-C 2270m (O46) 75µm x 85µm

Plate 10
Early Carboniferous (Tournaisian) Horton Group - Acritarchs & Spores

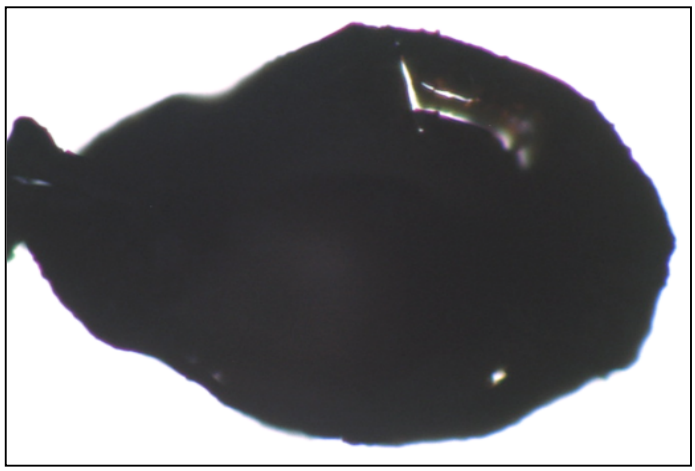


Veryhachium trispinosum
Kennetcook
500m (F38/1)
cyst body 15µm x 17µm, spines <15µm

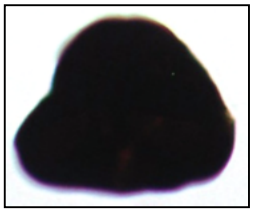


Veryhachium sp.
Kennetcook
500m (Q31/4)
cyst body 12µm x 16µm
spines <5µm

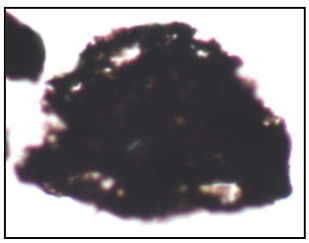
Highly carbonised spores



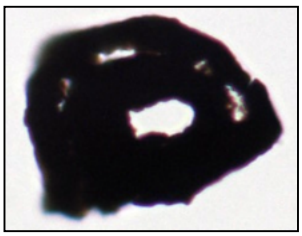
?Spelaeotriletes pretiosus
Camden 348m (G43/4) 90µm x 125µm



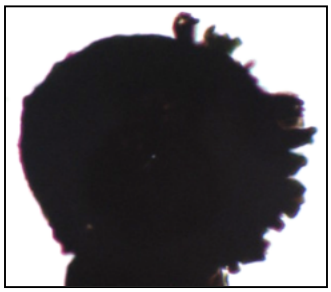
?Leiotriletes sp.
Creelman Hill
125m core (O48/2)
38µm x 38µm



?Vallatisporites vallatus
Camden
192.5m (Q55/1)
38µm x 50µm



?Knoxisporites literatus
Camden
192.5m (E37/3)
35µm x 42µm



Schopfites augustus
Creelman Hill
1262m core (E56/2)
50µm x 52µm