A new species of *Lepidostrobus* from the Early Westphalian of South Joggins, Nova Scotia, Canada

BARRY A. THOMAS, JIŘÍ BEK & STANISLAV OPLUŠTIL

A new species *Lepidostrobus dawsonii* sp. nov., from Langsetttian-Duckmantian strata at Joggins section, Nova Scotia, Canada is proposed based on palaeobotanical and palynological study. The new species represents gently tapering, narrow and nearly cylindrical cone fragments the base and apical parts of which are missing. *In situ* spores are trilete, cingulizonate and of the *Lycospora aber*-type. This is the first description of a lycopsid fructifications and its *in situ* spores from the Canadian Carboniferous. Morphology of the cones and spores resembles those of the Czech species *Lepidostrobus thomasii* Bek & Opluštil from the Intra-Studetic Basin, which is of the same age but represents a less robust and more cylindrical cone. • Key words: Lycopsids, *in situ* spores, *Lepidostrobus, Lycospora*, Pennsylvanian.


Barry A. Thomas, Aberystwyth University, Aberystwyth, Ceredigion, SY23 3AL, UK; bat@aber.ac.uk • Jiří Bek, Institute of Geology v.v.i., Academy of Sciences, Rovnojová 269, 165 00 Prague 6, Czech Republic; mrbek@gli.cas.cz • Stanislav Opluštil, Faculty of Sciences, Charles University, Albertov 6, 128 43 Prague 1, Czech Republic; oplustil@natur.cuni.cz

Reproductive organs of arborescent lycopsids are usually found as fragments or rarely as the entire cone specimens. Scarce are those organically connected to branches of their parent plants. Some types of cones (*e.g.* sigillarian) have never been found attached to the parent plant; others (*e.g.* *Lepidocarpon*-type) are usually found disintegrated into very small fragments, such as sporophylls etc. Arborescent lycopsid cones of the *Lepidostrobus*-type are commonly found in Carboniferous plant assemblages and many have been studied (*e.g.* Brongniart 1828–1838; Binney 1870–1875; Crookall 1964, 1966; Němejc 1954; Chaloner *in Boureau et al.* 1967; Thomas 1965, 1978; Bek & Opluštil 2004, 2006). The generic and specific classification of cones of the *Lepidostrobus/Flemingites*-types sometimes can be difficult or even impossible especially if they are poorly preserved compression specimens. Therefore, a very important criterion is the study of *in situ* spores, *i.e.* spores isolated directly from reproductive organs of plants. The importance of combining macrofossils and palynological approaches to study of lycopsid cone holotype in order to determine affinity accurately was demonstrated by Brack-Hanes & Thomas (1983), who revised the genera *Lepidostrobus* (Brongniart) Brack-Hanes & Thomas and *Flemingites* (Binney) Brack-Hanes & Thomas. The records of *in situ* spores of arborescent lycopsid fructifications are not abundant (*e.g.* Lix 1954; Abbott 1963; Chaloner *in Boureau et al.* 1967; Balbach 1967; Brack 1970; Brack-Hanes & Thomas 1983; Thomas 1978, 1988; Willard 1989a, b) but today descriptions, classifications and illustrations of *in situ* spores are accepted as parts of diagnoses, and descriptions of fructifications or parent plants. Significant progress in the study of lycopsid fructifications and their *in situ* spores have been made recently by Czech palaeobotanists and palynologists (Bek *et al.* 2001, 2008, 2009a, b; Drábková *et al.* 2005; Libertín & Bek 2005), including study *Lepidostrobus strobili* (Bek & Opluštil 1998, 2004, 2006; Opluštil & Bek 2009).

North American specimens have been described from the USA but not, as yet, from Canada. There are records and descriptions of Canadian lycopsid cones by Bunbury (1847), Bell (*e.g.* 1938, 1940, 1962, 1966), Dawson (1866) and Zodrow & McCandlish (1980), but this is the first one to be described in detail with its *in situ* spores.

Materials and methods

The principal study specimen bears a label in J.W. Dawson’s handwriting stating it was recorded from South Joggins, Nova Scotia, Canada and to have been collected in 1888 (Fig. 1). The age of the specimen is therefore most...
likely to be Langsettian or Duckmantian. The holotype is deposited in the Kidston Collection of the British Geological Survey at Keyworth, England (No. 7318). This lycopsid cone is preserved as a longitudinally split compression on brown and grey fined grained sandstone. A second specimen, almost identical in appearance to the one in the British Geological Survey, was collected more recently by D. Reid and is now in the collections of the Joggins Fossil Centre, Joggins, Nova Scotia, Canada (No. NSM008 GF031.011). It is also a fragment of a cone approximately 55 mm long. Even though we have not prepared spores from this cone we believe it is sufficiently alike to be included the same species.

Portions of the cone were removed and macerated with concentrated nitric acid, followed by dilute ammonia solution. Some of the liberated microspores were mounted in glycerine jelly, while others were coated with gold for study with a CAMECA SX100 scanning electron microscope. Slides with in situ spores and digital photomicrographs are stored in the Geological Institute v.v.i., Academy of Sciences, Prague, Czech Republic. The terms used for the descriptions of spores are those of the ‘Glossary of pollen and spore terminology’ of Punt et al. (2007).

Systematic part

Class Lycopsida Scott, 1909
Order Lepidocarpales Thomas & Brack-Hanes, 1984
Genus Lepidostrobus (Brongniart) Brack-Hanes & Thomas, 1983

Type species. – Lepidostrobus ornatus Brongniart, 1828.

Lepidostrobus dawsonii sp. nov.
Figures 2, 3

Holotype. – Specimen No. 7318, Kidston’s collection, British Geological Survey, UK.

Type locality. – South Joggins, Nova Scotia, Canada.

Type horizon. – Langsettian–Duckmantian.

Derivation of name. – In honour of J.W. Dawson, the noted palaeobotanist who found this specimen.


Diagnosis. – Cone at least 120 mm long, 24 mm wide basally but gradually tapering to 22 mm. Cone axis narrow, at least 3.6 mm wide. Sporophyll pedicels in vertices of ca 30°, basally ca 1.4 mm wide, orientated ca 5–15° up from the horizontal with an indistinct heel. Sporangia ca 2 mm high, attached along the pedicels. Trilete cingulizonate microspores, amb circular to subcircular. Proximal surface laevigate, distal sculpture finely scabrate, microgranulate to micro verrucate.

Description. – Both cones are split longitudinally revealing the axis and the sporangia in lateral view. Unfortunately they appear to have been abraded prior to fossilisation, presumably during transport and subsequent deposition. As a result, the cones have neither apex nor base and the distal parts, the laminae, of the sporophylls are also mostly missing (Fig. 2A). The remaining of the larger cone is approximately 120 mm in length and 24 mm in width at its base but gradually tapers upwards to a width of 22 mm. The cone axis appears to be comparatively narrow, but fragments revealed through missing sporangia show that it was at least 3.6 mm wide (Fig. 2B). The sporophyll pedicels are angled upwards from the axis at about 80–85° and scars of their bases on the pedicel show them to depart in verticals of about 30° (Fig. 2B–E). The pedicels are about 1.4 mm wide at their base and about 12 mm long. The length of sporangia, however, slightly decreases to the upper part of the fragment where they are only 9–10 mm long. Few of them appear to end with an indistinct heel (Fig. 2C, E). The sporangia appear to be attached along the pedicels and about 2 mm high. A few sporophyll laminae can be seen at the apical part of the cone and attached to isolated sporangia near the apical part of the cone. These isolated sporangia probably separated from the cone as it was settling into the sediment, similar to those illustrated by Thomas (1981). The only other plant debris on the surface of the rock is a piece of stem that is also badly worn and it is impossible to identify.
In situ microspores are all of the same type and differ only in diameter and width of cingulum and zona. The diameter is 31 (41.2) 46 μm. The laesurae is straight and simple, sometimes elevated (Fig. 3G). Microspores have an obvious cingulum 3–6 μm wide and a zona 2–6 μm wide (Fig. 3A–G). These spores are similar to the dispersed species *Lycospora uber* (Hoffmeister et al.).

Neither cone has any distinguishing feature that would permit us to refer them to a known species or to establish a new species. The *in situ* spores, however, are another matter, as their features are distinctive enough to characterise them and, therefore, the cone.

It is possible to divide *in situ* and dispersed lycospores into several morphological groups (Bek & Opluštil 2006). One cingulizone with a relatively broad cingulum and zona, *i.e.* the same type as those from *L. dawsonii*, whereas others have a relatively narrow cingulum and zona, lack a zona, or possesses different sculpture. Thomas (1970), and Thomas & Dytko (1980) suggested that microsporangiate cones produced lycospores with a cingulum and zona, whereas bisporangiate cones contained lycospores with a narrow cingulum lacking a zona. The type of *Lepidostrobus*, *i.e.* *L. ornatus*, was later shown to contain microspores with a broad cingulum and zona so the genus was re-diagnosed to contain only microsporangiate cones with cingulizone lycospores. Bisporangiate cones were assigned to the genus *Flemingites*. The Canadian cone, having cingulizone lycospores of the microsporangiate type is therefore referred to *Lepidostrobus*.

Dispersed lycospores with a relatively broad cingulum and zona are included in *Lycospora noctuina* Butterworth & Williams, *L. nitida* Artüz, *L. paulula* Butterworth & Williams, *L. uzunmehmedii* Artüz, *L. tenuireticulatus* Artüz, *L. uber* and possibly *L. pellucida* (Wicher) Schopf et al. The spores of *L. dawsonii* fit roughly into the parameters of *Lycospora uber*. However, since they differ from the

### Comparison

![Figure 2](image_url)

**Figure 2.** A – holotype of *Lepidostrobus dawsonii* sp. nov. preserved in very fine grained sandstone. Scale bar 10 mm. • B – detail of pedicels bearing sporangia and cone axis in upper part of the preserved cone fragment. Scale bar 5 mm. • C – detail of pedicels with sporangia from the middle part of cone. Scale bar 5 mm. • D, E – details of pedicels and cone axis in lower part of the cone fragment. k – keel, h – heel, s – sporangium. Scale bar 5 mm.
Table 1. Lepidostrobus species that have yielded cingulizone lycospores with a relatively broad cingulum and zona together with characteristics of their in situ spores.

<table>
<thead>
<tr>
<th>Cone species</th>
<th>Lycospore species (as previously identified)</th>
<th>Diameter (μm)</th>
<th>Cingulum width (μm)</th>
<th>Zona width (μm)</th>
<th>sculpture of proximal surface</th>
<th>sculpture of distal surface</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>L. haslingdenensis</td>
<td>L. noctuina</td>
<td>24–44.5</td>
<td>0.6–4.8</td>
<td>1.8–4.2</td>
<td>Scabrate to finely granulate</td>
<td>Microspinate</td>
<td>Thomas &amp; Dytko 1980</td>
</tr>
<tr>
<td>L. haslingdenensis</td>
<td>L. noctuina</td>
<td>30–39</td>
<td>4.5</td>
<td>5.8</td>
<td>Granulate</td>
<td>Verrucate to regulare</td>
<td>Willard 1989b</td>
</tr>
<tr>
<td>L. cf. haslingdenensis</td>
<td>L. uber</td>
<td>30(39)</td>
<td>2(2.57)</td>
<td>2(4.39)</td>
<td>Laevigate to finely scabrate</td>
<td>Microgranulate to microspinate</td>
<td>Bek &amp; Opluštíl 2006</td>
</tr>
<tr>
<td>L. kohoutii</td>
<td>L. uzunmehmedii</td>
<td>31(36.2)</td>
<td>2(3.34)</td>
<td>3(4.5)</td>
<td>Laevigate to finely scabrate</td>
<td>Finely scabrate</td>
<td>Bek &amp; Opluštíl 2006</td>
</tr>
<tr>
<td>L. thomasii</td>
<td>L. cf. uzunmehmedii</td>
<td>27(35.4)</td>
<td>1.5(2.86)</td>
<td>1.5(3.88)</td>
<td>Laevigate</td>
<td>Finely microgranulate</td>
<td>Bek &amp; Opluštíl 2004</td>
</tr>
<tr>
<td>L. dawsonii sp. nov.</td>
<td>L. cf. uber</td>
<td>31(41.2)</td>
<td>3–6</td>
<td>2–6</td>
<td>Laevigate to scabrate</td>
<td>Microgranulate to microverrucate</td>
<td>Herein</td>
</tr>
</tbody>
</table>

original diagnosis given by Hoffmeister et al. (1955) is being slightly smaller in diameter and in having a slightly narrower cingulum and zona, they are best regarded as Lycospora cf. L. uber.

This type of in situ lycospore with relatively broad cingulum and zona has rarely been reported from Lepidostrobus cones. Thomas & Dytko (1980) isolated similar lycospores from compression specimens of Lepidostrobus haslingdenensis Thomas & Dytko from the uppermost Namurian of the Millstone Grit Series of Great Britain. These lycospores differ from those described here in having a differently sculptured distal surface and a narrower cingulum and zona. Thomas & Dytko (1980) compared them with the dispersed species Lycospora noctuina. Willard (1989b) described similar lycospores from compression specimens that she also referred to as Lepidostrobus haslingdenensis from the Namurian B/C of Illinois, USA and compared them with the same dispersed species as Thomas & Dytko (1980), i.e. Lycospora noctuina. However, the British and American in situ lycospores differ from another in the sculpture of both surfaces. The distal surfaces of the British spores are densely microspinate, while the American ones possess microverrucate to regulare sculpture (Willard 1989b). The proximal surfaces of the British spores are scabrate while the American ones have microgranulate exines. Although both sets of in situ spores were closely compared with the same dispersed species, Lycospora noctuina, we now interpret as belonging to different natural species. The American spores recovered by Willard (1989b) correspond more closely with the original diagnosis of this species, as the densely microspinate distal surface of the British lycospores is not mentioned in original diagnosis of L. noctuina (Butterworth & Williams 1958, p. 376).

Three similar morphological types of in situ lycospores have been described from three compressed species of Lepidostrobus cones from the Carboniferous of the Czech Republic. Lycospores isolated from a specimen of Lepidostrobus cf. L. haslingdenensis by Bek & Opluštíl (2006) from the Bolsovian of the Kladno-Rakovník Basin are compared with the dispersed species Lycospora uber. These lycospores have more densely microgranulate sculpture on the distal surface than the Lepidostrobus dawsonii spores although both lycospores correspond well in all other characteristics. Also, L. cf. haslingdenensis is most probably a different and generally larger type of cone. Lycospores isolated from Lepidostrobus kohoutii Bek & Opluštíl (Bek & Opluštíl 2006) from the Bolsovian of the Kladno-Rakovník Basin were compared with the dispersed species Lycospora uzunmehmedii Artúz. They differ mainly in perforations of the zona and its width.

The greatest similarity is seen between Lepidostrobus dawsonii and L. thomasii Bek & Opluštíl (Bek & Opluštíl 2004) from the Langsettian/lower Duckmantian of the Intra-Sudetic Basin, Czech Republic. Cones of both species are relatively long and narrow, more (in case of L. thomasii) or less (L. dawsonii) cylindrical. Furthermore both species are found in strata of the same age. In situ spores of L. thomasii, named as Lycospora cf. L. uzunmehmedii, are similar in some respects to those of our Canadian cone. The main difference between the two species is in the slightly tapering character of the cone of L. dawsonii, whereas the largest known fragment of L. thomasii, about 300 mm long, is a cylindrical cone about 18–20 mm wide. Also, pedicels of L. thomasii are generally smaller, only 6–7 mm long compared to 10–12 mm in L. dawsonii. The axis of these cone species is of comparable width, varying between 3 and 4 mm. The length of
cones is not useful because only fragments of each species are preserved. Nevertheless, it seems that L. dawsonii represents a slightly more robust, less cylindrical cone than L. thomasii. However, both could be born on similar type of lepidodendrid lycopsid. The cones of L. thomasii are often associated with remains of Lepidophloios sp. (Bek & Opluštil 2004).

No similar lycospores have been reported from petrified, *i.e.* coal-ball specimens of Lepidostrobus.

**Conclusion**

Comparison of these lepidodendrid cone fragments from the Joggins section in eastern Maritime Canada indicates that they are similar to other Lepidostrobus species from Euramerican coalfields. In detail, however, there are differences either in morphology and/or type of *in situ* microspores, which warrants placing these specimens as a new Lepidostrobus species (L. dawsonii). This is the first Lepidostrobus cone species from the Canadian Carboniferous the diagnosis of which is based on cone morphology and *in situ* spores.

**Acknowledgements**

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