

Note

A fossil beech fern (cf. *Phegopteris* (C. Presl) Fée) from Driftwood Canyon Provincial Park, British Columbia

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Abstract

Ferns are important components of the biodiversity of wet forests across Canada, and the fossil record offers insights into the origins of fern diversity and biogeography. In 1967, Driftwood Canyon Provincial Park in north-central British Columbia was declared an Eocene Epoch plant, insect, fish, bird, and mammal fossil site of national scientific significance to preserve the Driftwood Creek fossil beds. The fossil plants from this important fossil site remain largely unknown. Here, a first record of a beech fern from the Eocene of British Columbia—morphologically comparable to the *Phegopteris connectilis* group—is illustrated, further revealing the past biodiversity of ancient British Columbia. The absence of sori and other key anatomical characters prevents definitive identification. Today, the circumpolar to temperate species Northern Beech Fern (*Phegopteris connectilis*) is widespread across British Columbia, occurring in wet coniferous forests; other members of the *P. connectilis* group also occur in temperate climates.

Key words: Beech fern; *Phegopteris*; fossil; Eocene; British Columbia; diversity

Today, British Columbia (BC) has ~60 species of native ferns (class Polypodiopsida, subclass Polypodiidae), excluding horsetails (*Equisetum* spp.) and the grape ferns and adders tongue ferns (subclass Ophioglossidae). They encompass ~10 families and ~23 genera, including the beech ferns (*Phegopteris* (C. Presl) Fée, Thelypteridaceae; Douglas *et al.* 2000, 2002; PPG I 2016). One tool for exploring the origins of fern diversity in BC and across North America is the fossil record (Arnold 1955; Rothwell and Stockey 1991; Stockey *et al.* 1999, 2006; Collinson 2001; Smith *et al.* 2006; Collinson *et al.* 2017; Pigg *et al.* 2021). A few fossil sites from BC dated to the Eocene Epoch (55–36 million years ago [Mya]) include fossil ferns, principally near Princeton and near Falkland in south-central BC, around metropolitan Vancouver, and in Driftwood Canyon Provincial Park (Figure 1) east of Smithers in north-central BC (Greenwood *et al.* 2005, 2016; Pigg *et al.* 2021). In 1967, Driftwood Canyon Provincial Park was declared to preserve the Driftwood Creek fossil beds, an Eocene Epoch plant, insect, fish, bird, and mammal fossil site of national scientific significance (Wilson 1977; Stockey 1984; Archibald *et al.* 2011; Eberle *et al.* 2014; Archibald

and Makarkin 2017; Mayr *et al.* 2019), which are dated as 51.77 ± 0.34 Mya (Greenwood *et al.* 2016).

Here, I illustrate a small fossil fern from Driftwood Canyon Provincial Park as an exemplar of the, as yet, poorly documented diversity of the ancient Eocene forests of north-central BC. It is a close morphological match for extant beech ferns of the genus *Phegopteris* (Thelypteridaceae; Figure 2). The specimen is part of a public education display mounted on a wooden board housed in the BC Parks Smithers office and is lacquered, preventing detailed examination of the micromorphology of the specimen. Its date of collection and collector are unknown.

The Thelypteridaceae contains two subfamilies, Phegopteridoideae and Thelypteridoideae, with the former containing three genera, including *Phegopteris*, with seven species (PPG I 2016; Patel *et al.* 2019; Fujiwara *et al.* 2021). Laminal wings at the base of most pinnae are characteristic of *Phegopteris* and are present on the fossil fern leaf from Driftwood Canyon. *Phegopteris* is separable into two groups: the *Phegopteris connectilis* group—*Phegopteris connectilis* (Michaux) Watt (Northern Beech Fern), *Phegopteris excelsior* N.R. Patel & A.V. Gilman (Tall Beech

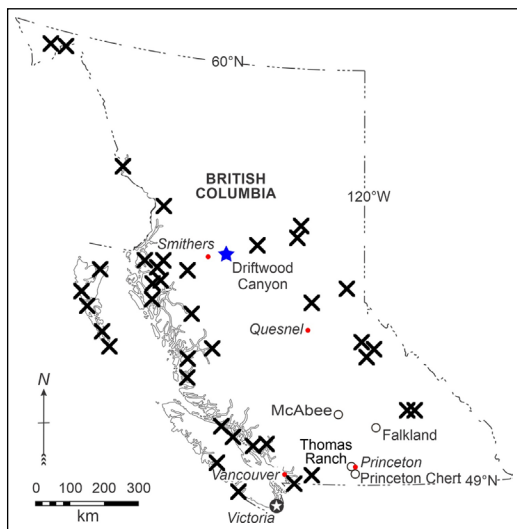


FIGURE 1. Map of British Columbia with overlay of current distribution (×) of Northern Beech Fern (*Phegopteris connectilis*; Klinkenberg 2020). Blue star indicates location of Driftwood Provincial Park. Other fossil localities mentioned in the text shown by open circles, and nearby cities and towns by red dots. Base map adapted from Greenwood *et al.* (2016).

Fern), *Phegopteris hexagonoptera* (Michaux) Fée (Broad Beech Fern), and *Phegopteris tibetica* Ching (no English common name; Patel *et al.* 2019), characterized by creeping rhizomes and deltoid (triangular) leaf blades; and the *Phegopteris decursive-pinnata* group with three species, *Phegopteris decursive-pinnata* (H.C. Hall) Fée (Japanese Beech Fern), *Phegopteris koreana* B.Y. Sun & C.H. Kim (no English common name), and *Phegopteris taiwaniana* T. Fujiw., Ogiso & Seriz. (no English common name), characterized by erect rhizomes and lanceolate leaf blades (Fujiwara *et al.* 2021). The fossil fern from Driftwood Canyon is deltoid and bipinnate–pinnatifid, consistent with the *P. connectilis* group.

The fossil beech fern shares with the Canadian species of *Phegopteris* (*P. connectilis*, *P. excelsior*, and *P. hexagonoptera*; Patel *et al.* 2019) a triangular pinnate–pinnatifid to bipinnate–pinnatifid frond (Figure 2a), with pinnae in the lower two thirds that are winged with the rachis both basiscopically and acroscopically, i.e., extending from the lower and upper edges of the pinna junction with the rachis (Figure 2b–d). The fossil has nine lanceolate, free, pinnae pairs on an incompletely preserved fossil leaf blade with the lowermost preserved pair also incomplete versus *P. connectilis*, *P. excelsior*, and *P. hexagonoptera* with 12–15 pairs. The distal portion of the fern blade in *P. connectilis* (Figure 2a), and less so

in *P. excelsior*, narrows abruptly to a pinnatifid tip, whereas, in *P. hexagonoptera*, the blade narrows evenly toward the tip as seen in the fossil (Figure 2b). Patel *et al.* (2019) separated *P. connectilis* from *P. excelsior* on the basis of the “tear-shaped” outline of the whole blade versus the broadly deltoid shape of *P. excelsior* and from *P. hexagonoptera* by the prominent basiscopically (downward) pointing and asymmetric lowermost pair of pinnae in that species, with *P. connectilis* pinnae symmetrical and *P. excelsior* intermediate between these states. It is unclear whether the lowermost pair of pinnae is present on the fossil beech fern, and the attachment of the lowermost pinna to the rachis is poorly preserved (Figure 2b). However, if the lowermost pinna is interpreted as part of the lowermost pinna pair, it is symmetrical, as seen in *P. connectilis* (Patel *et al.* 2019), but lacks the basiscopical orientation (Figure 2a,b) typical of the *P. connectilis* group. It is unclear whether laminal wings joined this pinna to the one above it or whether the rachis was unwinged, as seen in *P. connectilis* and *P. excelsior* (Patel *et al.* 2019). Marginal exindusiate sori—diagnostic of *Phegopteris*—are absent on the specimen, preventing definitive assignment of the specimen to *Phegopteris* and to a species (e.g., Stockey *et al.* 2006). The presence of free dichotomously branching veins that extend to the pinnule margins in the fossil, however, is consistent with *Phegopteris*, as are the crenate margins of the pinnules and wings at the juncture of narrowly lanceolate pinnatifid pinnae with the rachis (Figure 2c,d). The overall size of the fossil, at 3.4 cm length × 1.9 cm width, is very small compared with fully developed fronds in all three extant Canadian species (e.g., *P. excelsior* 17–44 cm long × 14–29 cm wide; Patel *et al.* 2019) and may reflect a frond from a young or stunted plant.

Onoclea L. and *Woodwardia* Smith, genera known from the western Canadian Paleocene and Eocene (Rothwell and Stockey 1991; Greenwood *et al.* 2016; Pigg *et al.* 2021), share with the Driftwood fern a winged rachis, but unlike the fossil, these genera have netted venation. The Paleocene fossil, *Speirseopteris orbiculata* Stockey, Lantz & Rothwell (Thelypteridaceae), from Alberta shares with the Driftwood Canyon specimen a deltoid pinnate–pinnatifid lamina and pinnules with free branched venation, although Stockey *et al.* (2006) note key differences between their fossil species and *Phegopteris*. *Speirseopteris orbiculata*, however, is much larger (ca. 16 cm) than the Driftwood Canyon specimen, lacks laminal wings basal to the pinnae, has pinnules with narrowly triangular apices rather than rounded in the Driftwood Canyon specimen, and has preserved sori, so I do not consider these fossils congeneric. Collinson (2001) and Stockey *et al.* (2006) caution against assigning fossil

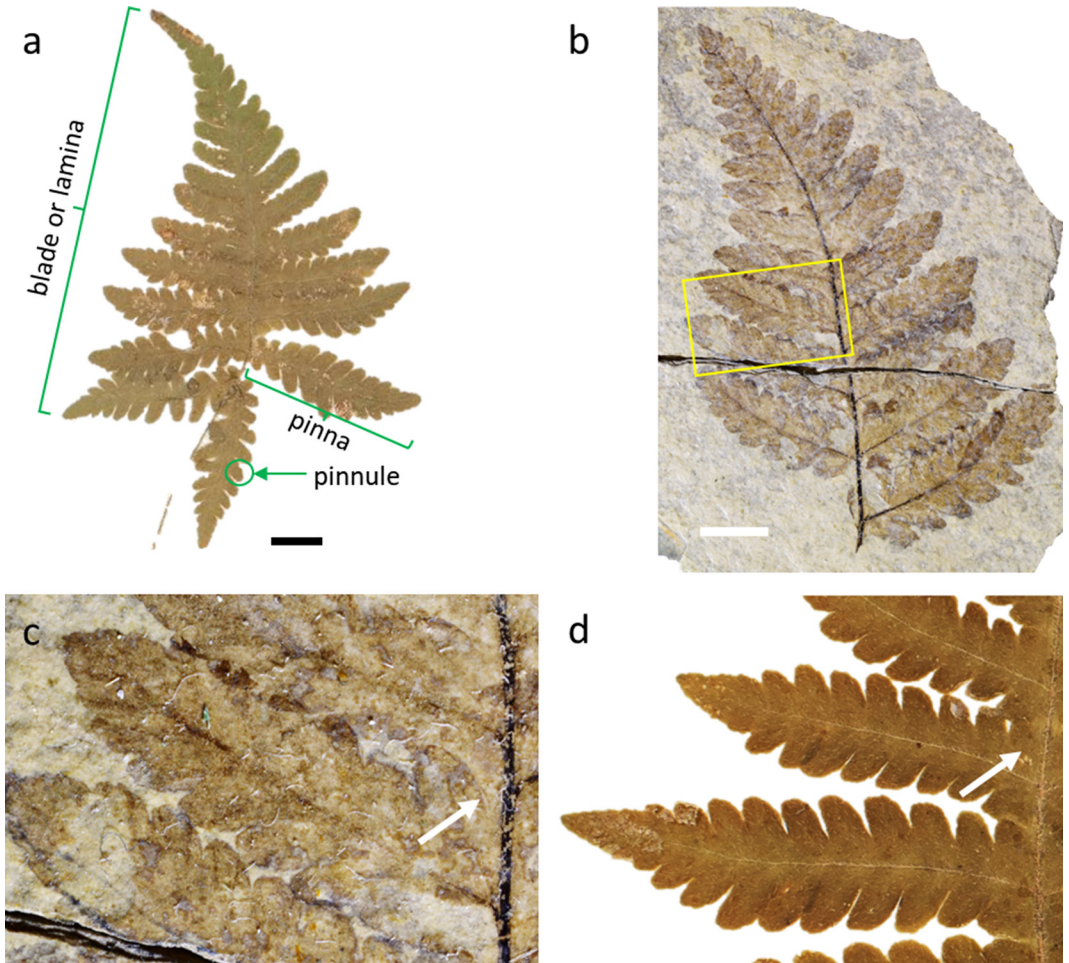


FIGURE 2. a. Whole leaf of Northern Beech Fern (*Phegopteris connectilis*; 1 cm scale bar) versus b. whole leaf of the fossil (0.5 cm scale bar). c. Close-up of fossil showing winged rachis (arrow) and pinnae with free, branching venation. d. Close-up of extant *P. connectilis* showing winged rachis characteristic of *Phegopteris*. Images have been digitally brightened by 20% to better show pinnae features. Photos a and d: used under CC BY-SA from the Carnegie Museum Herbarium, specimen CM007315 (Mid-Atlantic Herbaria Consortium 2022). Photos b and c: D.R. Greenwood.

ferns to extant families and genera in the absence of key characters, including those associated with sori. Therefore, while the Driftwood Canyon specimen is a close morphological match to members of the *P. connectilis* group, assignment to the family Thelypteridaceae and genus *Phegopteris* is tentative.

Phegopteris connectilis is a circumboreal species found across Canada. In BC, it is found mostly in the coastal wet forests, but also grows in wet mixed conifer–broadleaf forests of the interior, including areas east of Driftwood Canyon (Figure 1; Douglas *et al.* 2000). Both *P. excelsior* and *P. hexagonoptera* are restricted to northeastern North America, including southern Ontario, New Brunswick, and Nova Scotia in Canada (Patel *et al.* 2019). Schneider *et al.* (2013)

place the evolutionary diversification of *Phegopteris* from other Thelypteridaceae in the Eocene to Oligocene (ca. 43 ± 13 Mya), and they estimate that the temperate-climate *P. connectilis* group originated during the Oligocene, about 30 ± 6 Mya. Multiple studies have constructed dated fern phylogenies using the few well-dated fossil fern taxa (Pigg *et al.* 2021 and references they cite). If the Driftwood fern is a member of the *P. connectilis* group, its early Eocene age (~ 52 Mya) re-dates origination of the *P. connectilis* group as 28–16 Mya older and closer in age to the calculated diversification of *Phegopteris* from other Thelypteridaceae than estimated by Schneider *et al.* (2013).

The original forest community of the cf. *Phegopteris* fossil from the Driftwood Creek fossil beds has

been interpreted as a mixed conifer–broadleaf forest community with cedars and redwoods (Cupressaceae: *Chamaecyparis* and/or *Thuja*, *Metasequoia*, and *Sequoia*), and other conifers including fir (*Abies*), larch (*Larix*), spruce (*Picea*), pines (*Pinus driftwoodensis* Stockey), golden larch (*Pseudolarix*), as well as rare *Ginkgo*, and the broadleaf deciduous angiosperms alder (*Alnus*), birch (*Betula*), *Sassafras* (*Sassafras hesperia* (Berry) Wolfe et Wehr), elms (*Ulmus*), oak family (Fagaceae), and many as yet unidentified plant fossils (Stockey 1984; Greenwood *et al.* 2005, 2016). A diverse insect fauna is known from the Driftwood Creek beds, together with fish, birds, and two mammals, a primitive hedgehog and tapir (Wilson 1977; Archibald *et al.* 2011; Eberle *et al.* 2014; Greenwood *et al.* 2016; Archibald and Makarkin 2017; Mayr *et al.* 2019). The climate was reconstructed as temperate and wet, with mean annual temperature ~10–15°C and mean annual precipitation ~100 cm with little or no winter freezing (Greenwood *et al.* 2005; Eberle *et al.* 2014). The environmental interpretation of the early Eocene forest setting for the cf. *Phegopteris* fossil frond is comparable to that of the present-day southern range of *P. connectilis* (e.g., Vancouver and Ontario and adjoining United States states).

Several BC Eocene fossil sites have recorded the floating fern *Azolla* (Arnold 1955; Greenwood *et al.* 2005, 2016; Collinson *et al.* 2017), a genus occurring today in southern BC but generally considered a subtropical–tropical fern (Douglas *et al.* 2000; Collinson *et al.* 2017; Klinkenberg 2020). Apart from *Azolla*, however, ferns have only rarely been reported from BC Eocene fossil floras (e.g., Driftwood Canyon, Falkland, McAbee, and Thomas Ranch; Greenwood *et al.* 2016; Pigg *et al.* 2021), although five fern taxa have been described from the Princeton chert (Pigg and DeVore 2016). From Falkland (Figure 1), Pigg *et al.* (2021) described the fossil fern *Dennstaedtia christophellii* Pigg, Greenwood, Sundue, & DeVore (Dennstaedtiaceae), a relative of the bracken fern (*Pteridium* spp.) allied to extant Neotropical *Dennstaedtia* species. *Dennstaedtia* has one extant species in eastern Canada, Hay-scented Fern (*Dennstaedtia punctilobula* (Michaux) T. Moore), but this genus is absent from the present-day BC native flora (Douglas *et al.* 2000). The beech fern from Driftwood Canyon occurs within the circumboreal distribution of *P. connectilis* today. Discoveries of past fern diversity from the fossil record highlight past biogeographical linkages between the fern flora of BC and both warmer climate areas to the south (*Azolla*, *Dennstaedtia*) and potentially across the Northern Hemisphere (*P. connectilis* group).

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