CALLIPTERIDS OF THE DUNKARD GROUP OF THE APPALACHIAN BASIN: THEIR IDENTITY AND PALEOENVIRONMENTAL SIGNIFICANCE

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INTRODUCTION

The Dunkard Group, which contains the youngest sedimentary rocks in the Appalachian Basin, is a >340 m (1,116 ft)-thick erosional remnant sited hundreds of kilometers from its nearest correlative. With the exception of rare *Lingula* in the Washington coal zone (Cross and Schemel, 1956), the Dunkard is considered non-marine, therefore lacking definitive index fossils. The geological age of these strata has been a matter of intense debate since the publication of Fontaine and White's (1880) monograph on the Dunkard Group's macrofloras. The age of the Dunkard has turned strongly on the presence of callipterids, a wholly extinct group of peltaspermous plants, in the lower third of the Group, and especially in the 10-20 m (33-66 ft) of strata above the Washington coal in the Washington Formation. Aside from these plants, which globally became abundant and widely distributed beginning near the Pennsylvanian-Permian boundary and through much of the Permian (Kerp, 1988), the Dunkard flora is overwhelmingly characterized by typically Pennsylvanian plant species (Fontaine and White, 1880; Clendening, 1972, 1974, 1975; Clendening and Gillespie, 1972; Gillespie et al., 1975; Cross et al., 1996; Blake et al., 2002; Blake and Gillespie, 2011a, b). Other groups of organisms have been brought to bear on the question of the age of the Dunkard (see summaries in Barlow and Burkhammer, 1975), but none seem to have been emphasized like the callipterids to point both paleobotanists and others toward a Permian interpretation.

Many paleobotanists have collected plant fossils from Dunkard strata. To our knowledge, however, the only illustrations of the callipterids are the original engravings of Fontaine and White (1880, Plate XI, Figures 1-4) and photographs in Darrah (1975, Figures 1-3) and Gillespie et al. (1975, Plate I A and Plate VIII A; refigured in Blake et al., 2002, Plate XXXV, Figures 1-2, 6) and Gillespie and Pfefferkorn (1979, Plate 3, figures 6-8; refigured in Blake et al., 2002, Plate XXXV, Figures 5, 7). Herein we describe and illustrate callipterids from two, previously unillustrated collections. These were made by David White in the summer of 1902, during which time he visited I.C. White in Morgantown, West Virginia, and collected regionally in the Dunkard (though he never published an illustrated flora, see White, 1904, 1936), and from the collections of Aureal T. Cross, now housed at the Field Museum of Natural History, who also worked extensively in the Dunkard in the late 1940s and early 1950s (Cross et al., 1950; Cross, 1954, 1958). Both White and Cross expanded greatly the known stratigraphic range of callipterid occurrence, White high into the Greene Formation.

Four species of callipterid characterize known Dunkard collections. Two are attributable to the genus *Autunia*, a seed plant belonging to the Peltaspermales (Kerp, 1988), a likely descendant of the pteridosperms so common to Pennsylvanian wetlands. These include *A.*

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conferta (a larger and a smaller form) at three of the localities considered here and *A. naumannii*, from one locality. In addition specimens attributable to *Lodevia oxydata* (Goeppert) Kerp and Haubold (*Sphenopteris coreacea* Fontaine and White, identified by Darrah, 1969 as *Callipteris lyratifolia*) occur at one locality. Gillespie et al. (1975) illustrated (Plate VIII a) a specimen that appears much like *Rhachiphyllum schenkii* Kerp.

GEOLOGICAL CONTEXT

The Dunkard Group has been divided traditionally into the Washington Formation, encompassing those rocks between the top of the Waynesburg coal and the top of the Upper Washington Limestone, and the Greene Formation, for the rock sequence above the Upper Washington Limestone (Berryhill, 1963). The U.S. Geological Survey recognizes three formations, dividing the rocks below the Greene into a lower Waynesburg Fm, defined as encompassing those rocks between the bottom of the Waynesburg coal and the bottom of the Washington coal, and an upper Washington Formation, encompassing the Washington coal to the top of the Upper Washington Limestone. This nomenclature was based on mapping done in Washington County, Pennsylvania (Berryhill and Swanson, 1962; Berryhill et al., 1971). The Greene Formation is thicker than the Waynesburg and Washington Formations combined. Dunkard rocks crop out in Pennsylvania, West Virginia, Ohio and Maryland and reach their maximum thickness in SW Pennsylvania, in Greene County, and adjacent parts of Wetzel County, West Virginia where the Dunkard exceeds 340 m (1,116 ft). In the northern part of the Dunkard Basin, in the adjacent areas of northern West Virginia, NE Ohio, and SW Pennsylvania, the Dunkard consists of cyclic successions of coal, limestone, shale and sandstone (Beerbower, 1961). The clastic strata are primarily buff and gray in color, but red beds are present higher in the section, beginning near the top of the Washington Formation, and, and occurring in conjunction with decreased abundances of coal. To the S and SW the Dunkard section becomes increasingly red and is mostly a sequence of stacked paleosols interbedded with channel-form sandstone bodies (Berryhill, 1963; Martin, 1998; Fedorko and Skema, 2011a, b; Cecil et al., 2011a, b).

The Little Washington coal horizon marks the base of the Washington coal complex (Skema et al., 2011), which straddles the Waynesburg-Washington Formation contact. This coal complex is one of the most persistent units in the section and the Little Washington coal at its base, which has a distinctive underclay paleosol (Hennen, 1911), can be traced through much of the basin (Fedorko and Skema, 2011a, b; Skema et al., 2011). The Washington coal complex consists of two to four separate coals separated by shale and or sandstone. In the northwestern part of the basin (Belmont County, Ohio and the western edge of Marshall County, WV) the coal complex consists of two benches separated by a gray shale wedge up to 2 m (7 ft) or more thick. In this clastic parting, brackish water fauna have been found, including linguloid brachiopods and myalinid pelecypods (Cross and Schemel, 1956; Berryhill, 1963). This brackish-water fauna is the highest occurrence of any evidence of marine influence in the Appalachian Basin and may correlate with a global marine highstand pulse identified by Davydov et al. (2010) just below the Pennsylvanian-Permian boundary.

Throughout the Dunkard, if plant fossils are encountered they are almost always typical Pennsylvanian wetland flora, dominated by the tree fern *Pecopteris*, but including Middle Pennsylvanian holdovers, such as the pteridosperms *Neuropteris ovata* and *Macroneuropteris scheuchzeri*, in addition to a wide variety of other plants (Gillespie et al., 1975; Blake et al.,

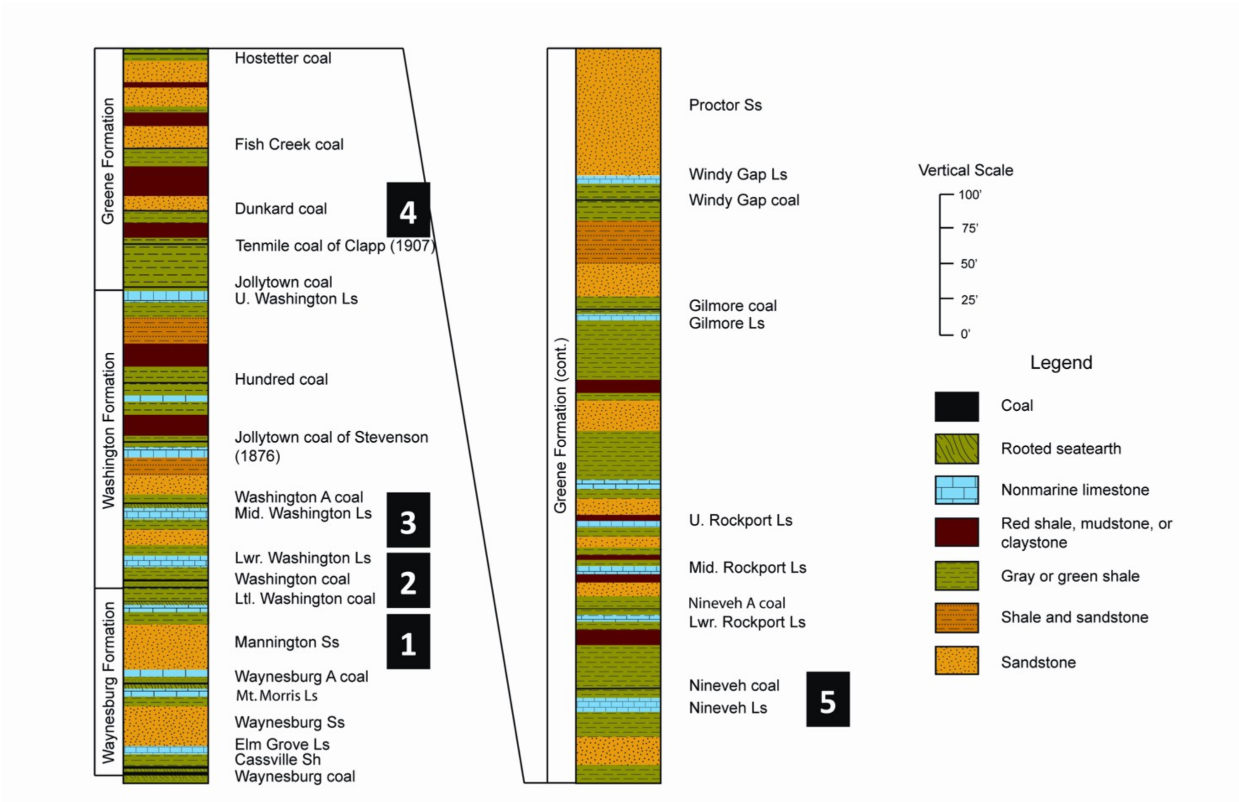

Figure 1. Dunkard Stratigraphy, after Fedorko (this guidebook). Numbers indicate horizons from which callipterids have been positively identified: 1— Between the Waynesburg A and Washington coals; 2—Within or above the Washington coal zone; 3—Within or proximate to the Lower and Middle Washington limestones; 4— Proximate to/above the Dunkard coal; 5—Above the Nineveh coal.

2002). This is true regardless of the facies sampled (Blake and Gillespie, this guidebook). *Pecopteris* foliage has been found in all lithologies sampled from the bottom of sands deposited in channels, to buff and red mudstones presumably deposited in alluvial floodplain or delta plain (alluvial plain) environments, in association with coals or not, and rarely even within limestones.

Dunkard callipterids, on the other hand, have been reported to occur mainly in shales within the Washington Formation (in the more traditional two formation scheme, as used by the West Virginia Geological and Economic Survey), beginning at the approximate horizon of the Washington coal complex through the Lower and perhaps Middle Washington Limestone. These fossils occur in a variety of lithologies, from dark, micaceous finely laminated shales, to buff and red mudstones with poor fissility. At one location, on Robert's Ridge Road near Moundsville, West Virginia, specimens were found in a shale parting within the uppermost portion of a limestone sequence, either the Lower or Middle Washington LS (not differentiable at the site). The stratigraphy of this part of the Dunkard section is complex and the strata are highly variable laterally. The callipterids appear to occur at a number of different stratigraphic horizons within the above mentioned interval. Darrah (1975, in the captions to his Figures 1 and 3 on page 95) provides the only report of callipterids from below the level of the Washington coal. He attributes the collections to James Barlow of the West Virginia Geological Survey, purportedly collected from between the Waynesburg A and Washington

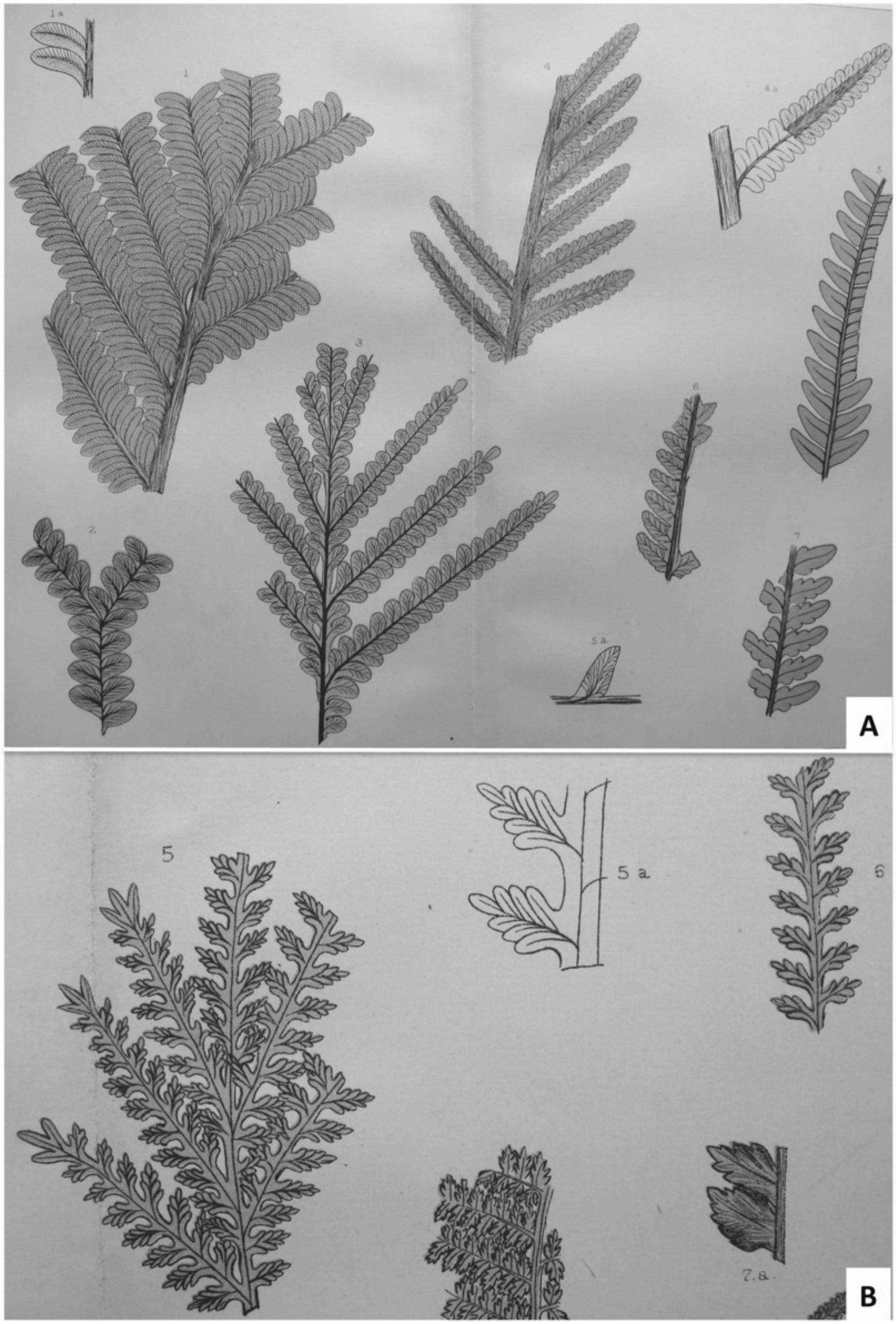

Figure 2. Original illustrations of callipterids by Fontaine and White (1880), from Brown's Bridge, WV: A—*Callipteris conferta*. Original Pl. XI, Fig. 1-4; B—*Sphenopteris coreacea*. Original Pl. V, Fig. 5.

coals near Williamstown, in Wood County, West Virginia. However, coals are very poorly developed in the Dunkard Group in Wood County, and Darrah provides no detailed information on the location of the collecting locality or on the ultimate disposition of the samples, so, at present, we treat this report with reservation. In no instances have callipterids been documented in the immediate roof shales of any coal bed or coaly facies.

There are reports of other kinds of plants uncommon in Pennsylvanian floras, but common in the Permian, such as *Taeniopteris*, *Plagiozamites*, and conifers, from various horizons in the Dunkard Group, including the Cassville Shale, at the base of the Dunkard Group (Fontaine and White, 1880; D. White, 1904, 1936; Darrah, 1975). Such occurrences led some to conclude that the entire Dunkard Group is of Permian age, including David White at the end of his professional career (D. White, 1936). However, callipterids have not been reported from such a low stratigraphic position.

STRATIGRAPHIC AND LITHOLOGICAL OCCURRENCES OF CALLIPTERIDS

We report and illustrate callipterids from three sites investigated by David White in 1902: "Browns Bridge" (also known as Browns Mills or Worley), West Virginia, "Railroad Cut West of Littleton", West Virginia, and "Pleasant Hill Gap", Pennsylvania, and one collected by Aureal Cross, on August 27, 1948: "Winklers Mill", Ohio. We also note and comment on other illustrated callipterids from the Dunkard, including those of Darrah (1975), Gillespie et al. (1975), and Gillespie and Pfefferkorn (1979). The stratigraphic position of these callipterid beds, if securely known, is shown in Figure 1.

Brown's Bridge

Brown's Bridge was the original callipterid discovery site of Fontaine and White (1880) and their illustrated specimens come from that site. To our knowledge, this is the only site from which callipterids have been collected more than once (four times in fact). The location lies on the south side of a bend in Dunkard Creek (NW quadrant of the Blacksville 15' Quadrangle map/NE quadrant of the Blacksville 7.5' Quadrangle map, opposite the town of Worley) along present-day West Virginia Route 7, probably close to the grade of a former railroad at that location.

Fontaine and White's specimens are lost, unfortunately, with a single exception, discussed below. In addition, the bed from which they were collected has never been accurately reidentified or described in the literature or in extant field notes of collectors, so neither the exact stratigraphic nor paleoenvironmental context is known. Their original illustrations are reproduced here as Figure 2. The exception to the lost callipterid specimens is a single specimen US National Museum of Natural History collections from the Brown's Bridge locality, identified as *Callipteris conferta* by Leo Lesquereux (USNM Specimen Number 27141 – Figure 3). This specimen presumably was supplied to Lesquereux for identification by Fontaine and White or perhaps by R.D. Lacoe (see note in Darrah, 1969, p. 153). It is possible that this specimen was part of a suite of typical Dunkard specimens donated by Fontaine and White to the well known private collector R.D. Lacoe, which later came to the U.S. National Museum when Lacoe donated his entire collection to that institution in the late 1800s. Fontaine and White (1880, p. 54) describe their plants as coming from a "calcareous iron ore" that occurs in the roof of the Washington coal (page 54). The specimen identified by Lesquereux (USNM

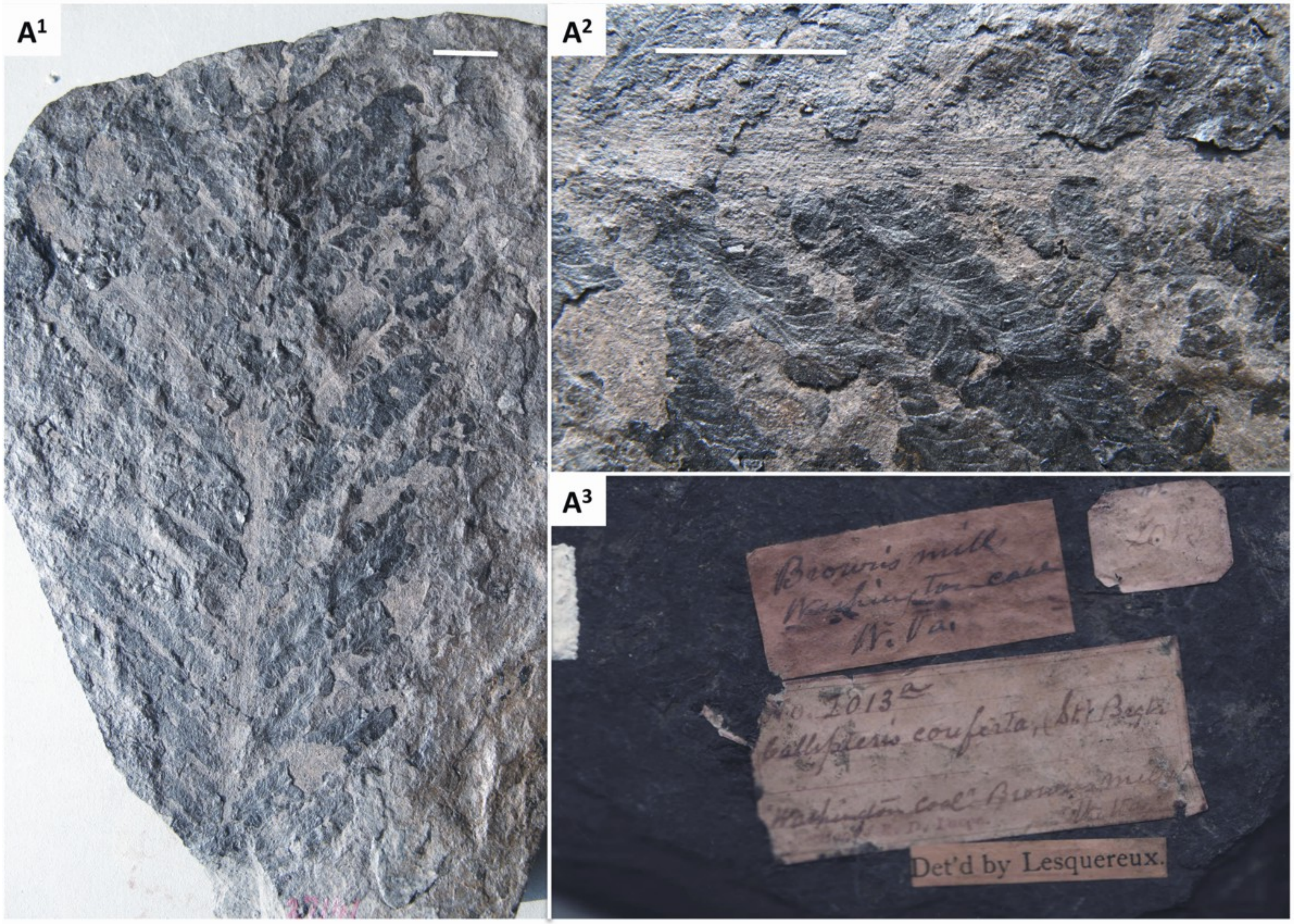

Figure 3. Brown's Mill (Brown's Bridge), WV. *Autunia conferta* from original collecting locality of Fontaine and White (1880). USNM specimen number 27141: A1—Specimen. Typical small-pinnule form of *Autunia conferta*; A2—Close up of pinnae to show the blunt apices of the pinnules and upswept midvein; A3—Reverse side of specimen showing original Lesquereux identification label (as *Callipteris conferta*) and locality identifier label. 2013a is the original Lacoe specimen number. Scale bars = 1 cm.

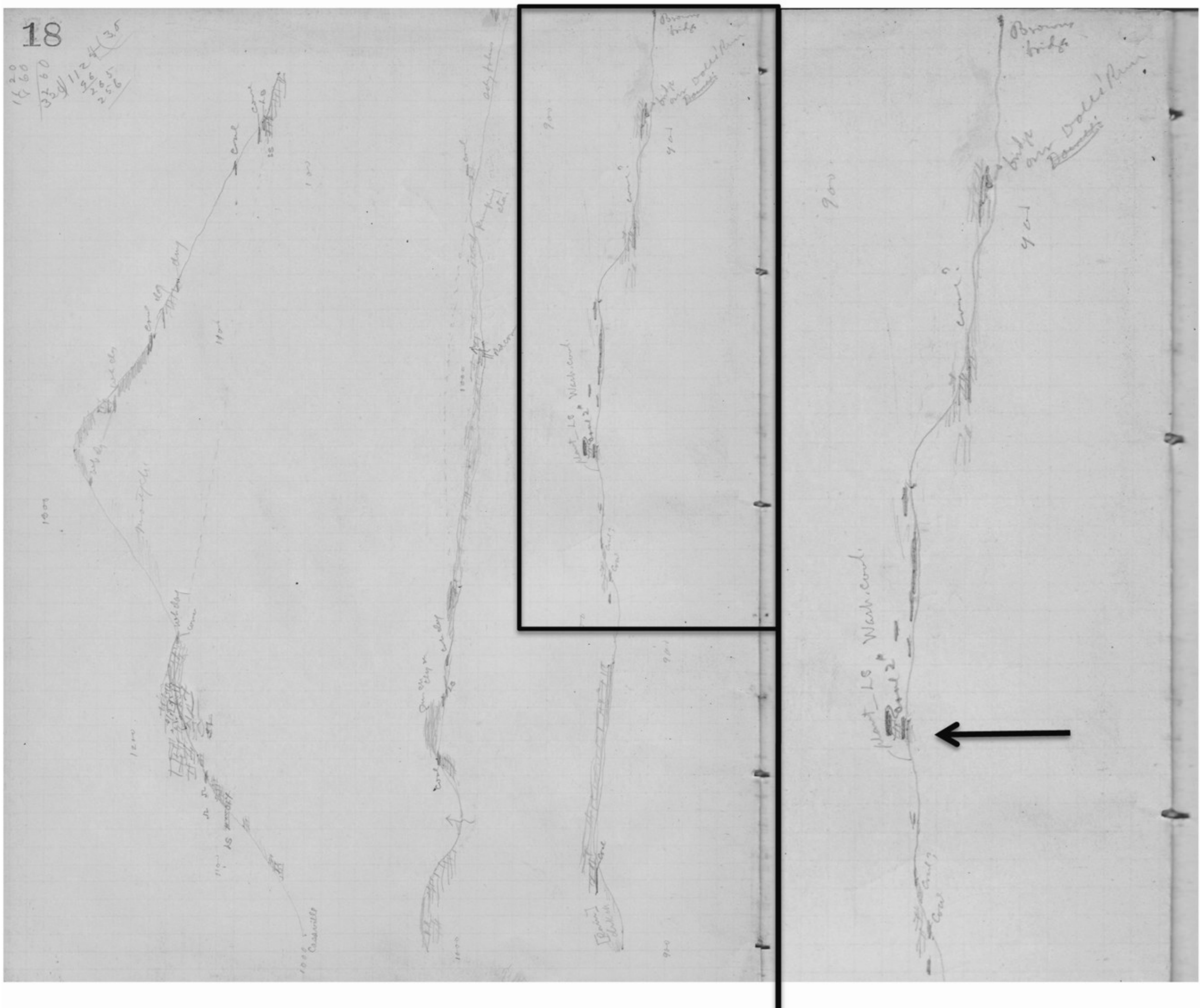

Figure 4. David White's 1902 field notes for Brown's Bridge, WV. Area in black box on left side of figure is enlarged on right side. "Brown's Bridge" noted in lower right hand corner of notebook page. Notation of plants, but not callipterids, at arrow, placing a plant-bearing bed ambiguously in the vicinity of the Washington coal or an overlying limestone.

Specimen Number 27141) is in a heavy, thin bedded, dark gray shale that, from its weight, must indeed contain considerable siderite, but is not what one would describe as an ironstone.

David White visited this site in 1902, during extended fieldwork in the Dunkard, and collected plants from a very dark shale, described below (see White, 1936). Darrah (1975) reports collecting callipterids from this site in the 1930s, from a brown iron stone layer above the Washington coal, which seems similar to the beds from which Fontaine and White collected. Gillespie et al. (1975, p. 229) also report finding callipterids at this site more than once (one time by opening up the site with dynamite), but the fossils were taxonomically indeterminate due to poor preservation in a coarse, sandy matrix, which is quite distinct from the lithology collected by Fontaine and White. The diversity of lithologies from which callipterids have been identified at this site strongly suggests that they were widespread and occurred across the landscape for an extended period perhaps both before and after deposition of the Washington coal.

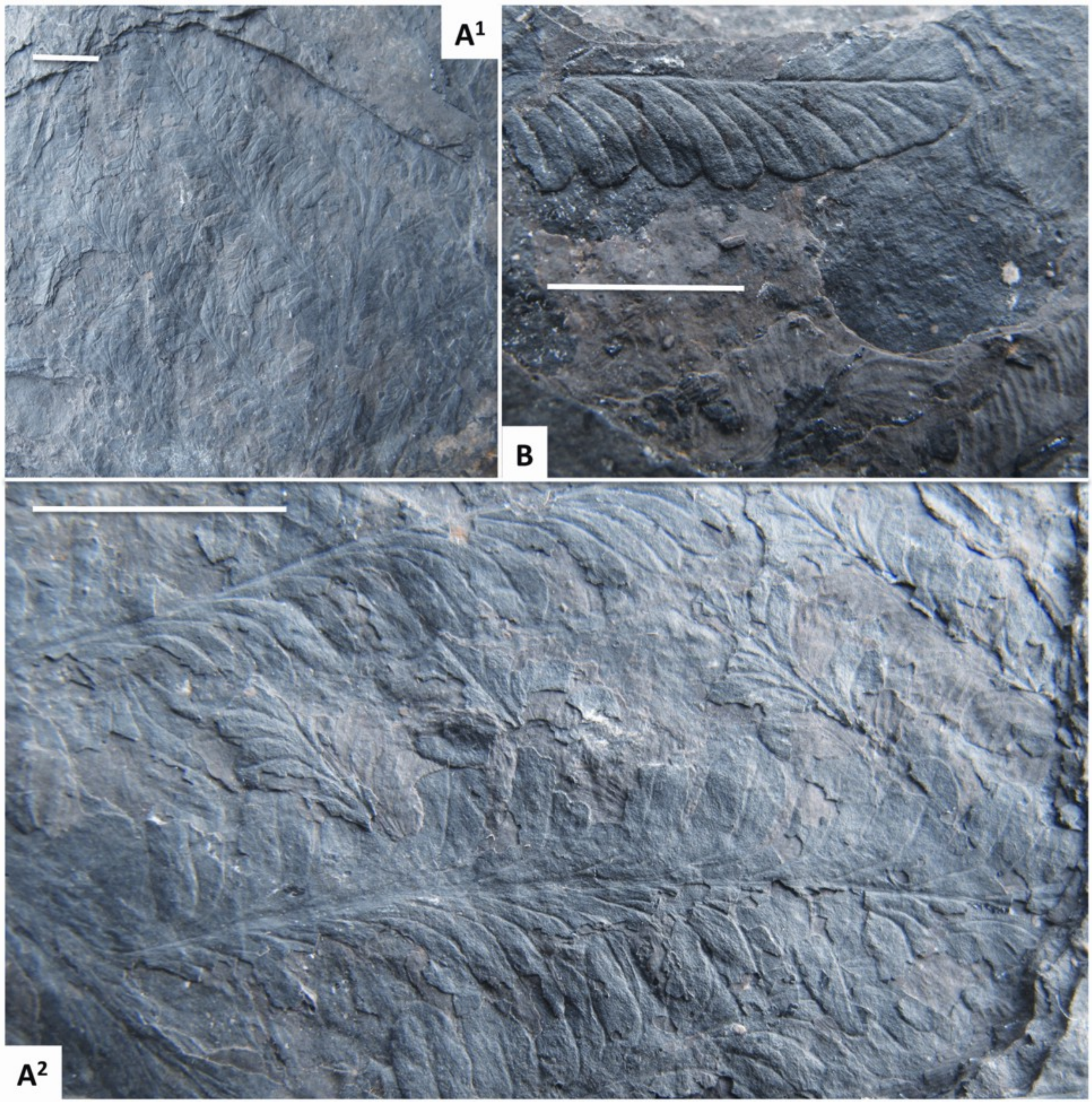

Figure 5. ***Autunia conferta*** **from David White's Brown's Bridge, WV, collecting location. USGS locality number 2926: A1—Fragmentary frond with several pinnae attached to a rachis; A2—3X enlargement of A1 illustrating the shape of the pinnules, which is the same as that of the Lacoe/Lesquereux specimen from the original Fontaine and White (1880) collecting site. Note the thickness of the pinnules, such that the steeply ascending lateral veins are mostly obscure; B—Specimen illustrating the shape of the pinna tip, pinnules gradually fused acroscopically and the steeply ascending lateral veins. Scale bars = 1 cm.**

The lithological matrix of the 1902 collections of David White (USGS Locality Number 2926) is not identical to the single specimen of Fontaine and White that resides in the Smithsonian collections, mainly in being less sideritic and somewhat more distinctly laminated, but both are very dark shales with considerable siderite content, so they may represent the same bed. Darrah recollected from the general site in 1932, but does not illustrate it or provide a geological interpretive section of the site; he described the plant bed as a thin, dense,

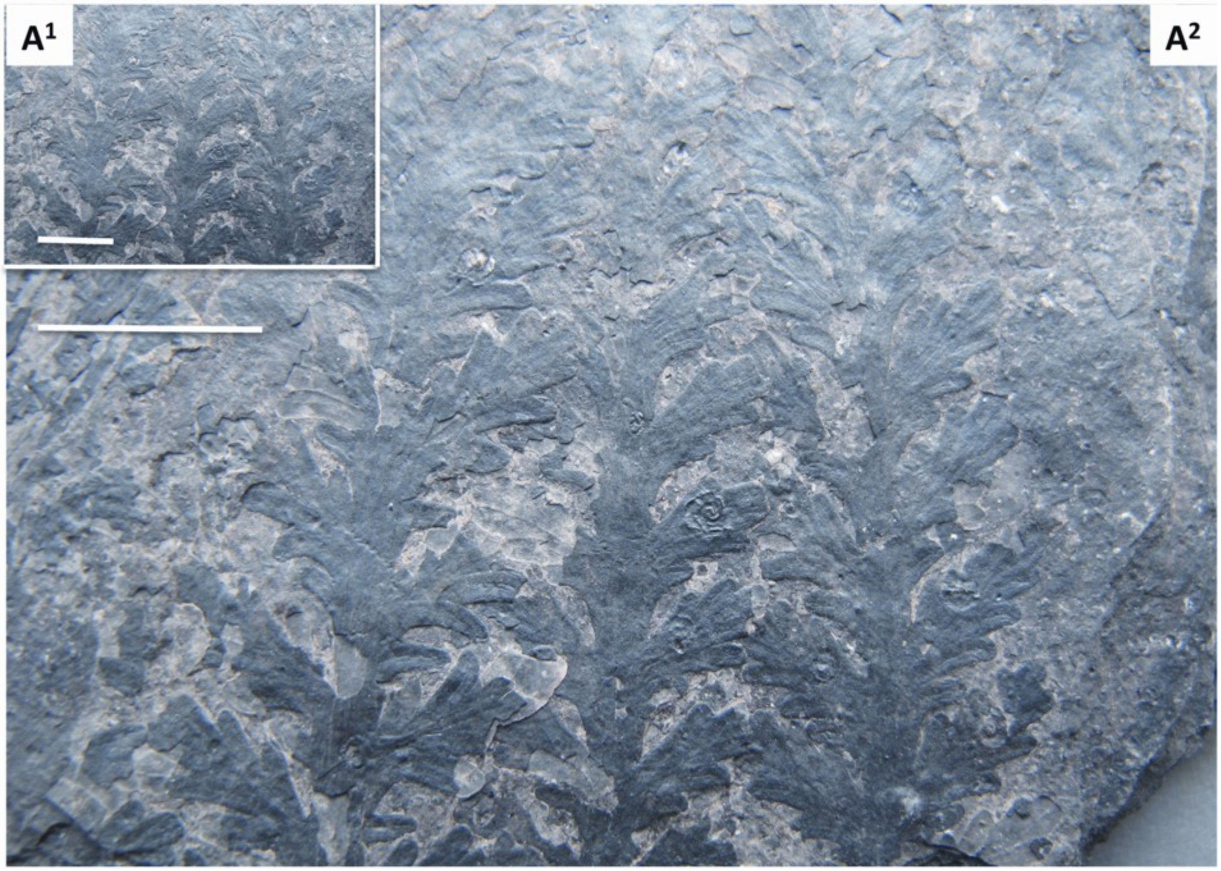

Figure 6. *Lodevia oxydata* from David White's Brown's Bridge, WV, collecting location. USGS locality number 2926. Note spirorbids attached to the foliage: A1—Three pinnae with typical flabellate, lobed pinnules; A2—3X enlargement of A1 illustrating pinnule shape, steeply ascending lateral venation, and thick pinnule aspect. Scale bars = 1 cm.

arenaceous shale, which broadly fits the other known collections, though he does not mention the conspicuously dark color.

As to the physical position of the callipterid bearing beds, David White, whose 1902 field notes are the only known record of this locality by someone who collected callipterids there, barely mentions the site. In the White notes, page 18, upper right corner (Figure 4), the collecting location is shown without comment. He notes a questionable coal near the grade of Brown's Bridge and "plants" below a 5-cm (2-in) thick coal and thin limestone, 12 m (40 ft) above the base of the exposure. It is this thin coal that he identified as the Washington. The callipterid-bearing shale White collected contains non-marine ostracodes, snails, and spirorbids (Tibert et al., in press), and thus may have come from a clastic interbed facies of the Lower Washington Limestone. We recently identified three discontinuous, thin benches of limestone at this location from above what may be a bench of the Washington coal, above the level of the railroad grade in about the position specified in White's field notes. Plants were present, but not callipterids. However, we also have noted many discontinuous siderite layers below the railroad grade at the site and there is evidence of in situ coal below the grade also, which may be another bench of the Washington coal. If the callipterid beds were at this level, they are no longer accessible without major excavation. Modern cover at the location makes it difficult to sort out these relationships.

The Brown's Bridge callipterids are of two types. One we tentatively identify as a small pinnuled form of *Autunia conferta* (Figure 5), consistent with the identification of Fontaine and White (1880), who called these specimens *Callipteris conferta* (F & W Plate XI, Figures 1-4, Figure 2 of this paper). The other we identify as *Lodevia oxydata* (Goeppert) Kerp and Haubold (1988) (Figure 6), originally identified as *Sphenopteris coreacea* Fontaine and White (F & W Plate 5, Figure 5, Figure 2 of this paper). Notably, they compared the species to *Sphenopteris oxydata* Goeppert and *S. lyratifolia* Weiss. Darrah (1969) identified this material as *Callipteris lyratifolia*.

Pleasant Hill Gap

Pleasant Hill Gap is located between New Freeport and Jollytown, Pennsylvania, in the southeast corner of the New Freeport 7.5' Quadrangle map. Here White found callipterids in association with the Nineveh coal bed, high up into the Greene Formation (White 1902, Dunkard Field Notes, page 27) (Figure 7), though he does not indicate the position of the callipterid-bearing rocks in relationship to that coal (i.e., roof shale or some distance above the

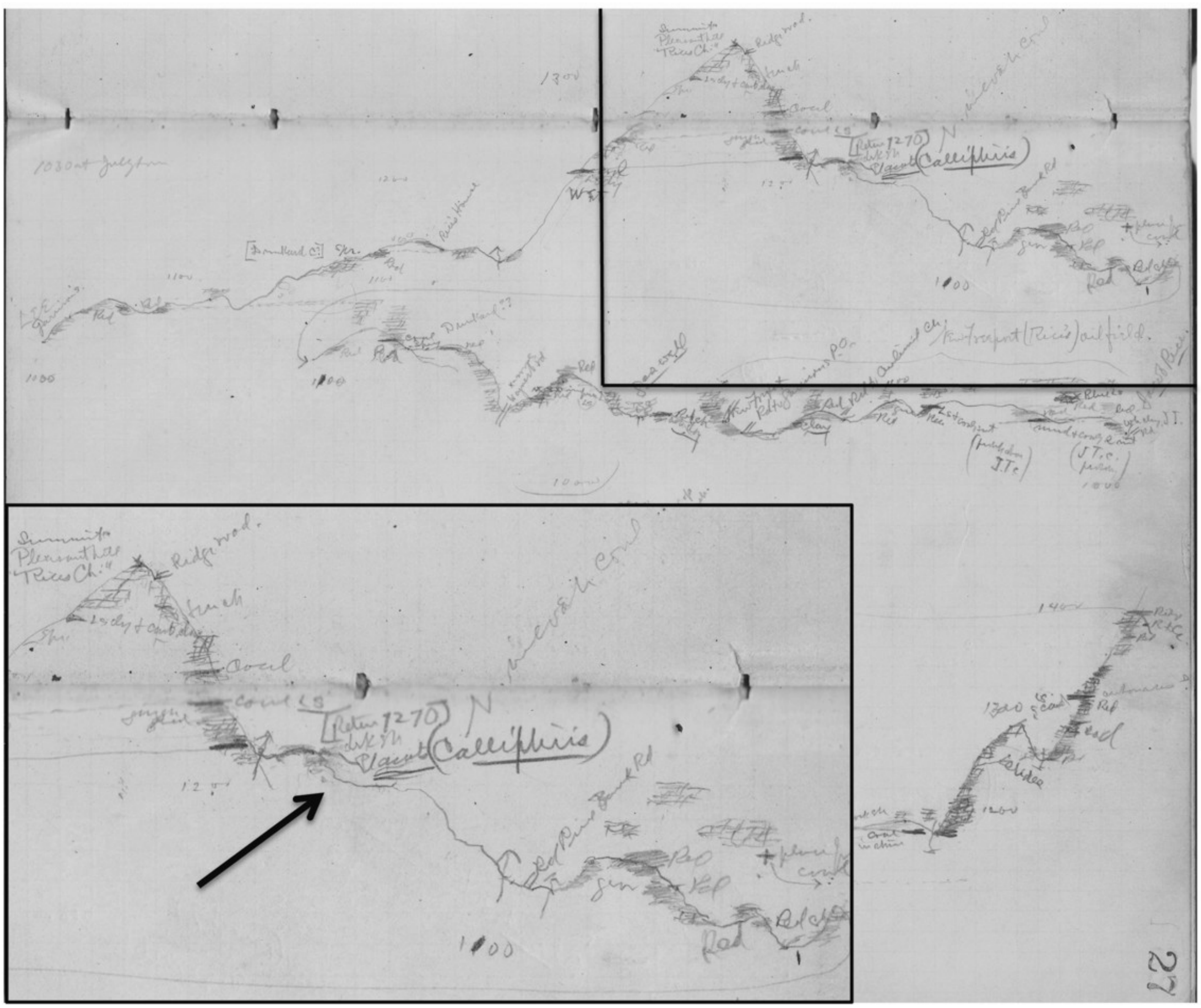

Figure 7. David White's 1902 field notes for Pleasant Hill Gap, PA, USGS Locality Number 2915. Page is rotated 90 degrees clockwise. Area in black box in upper right of image is enlarged in lower left. The occurrence of *Callipteris* is noted in proximity to the Nineveh coal (at arrow).

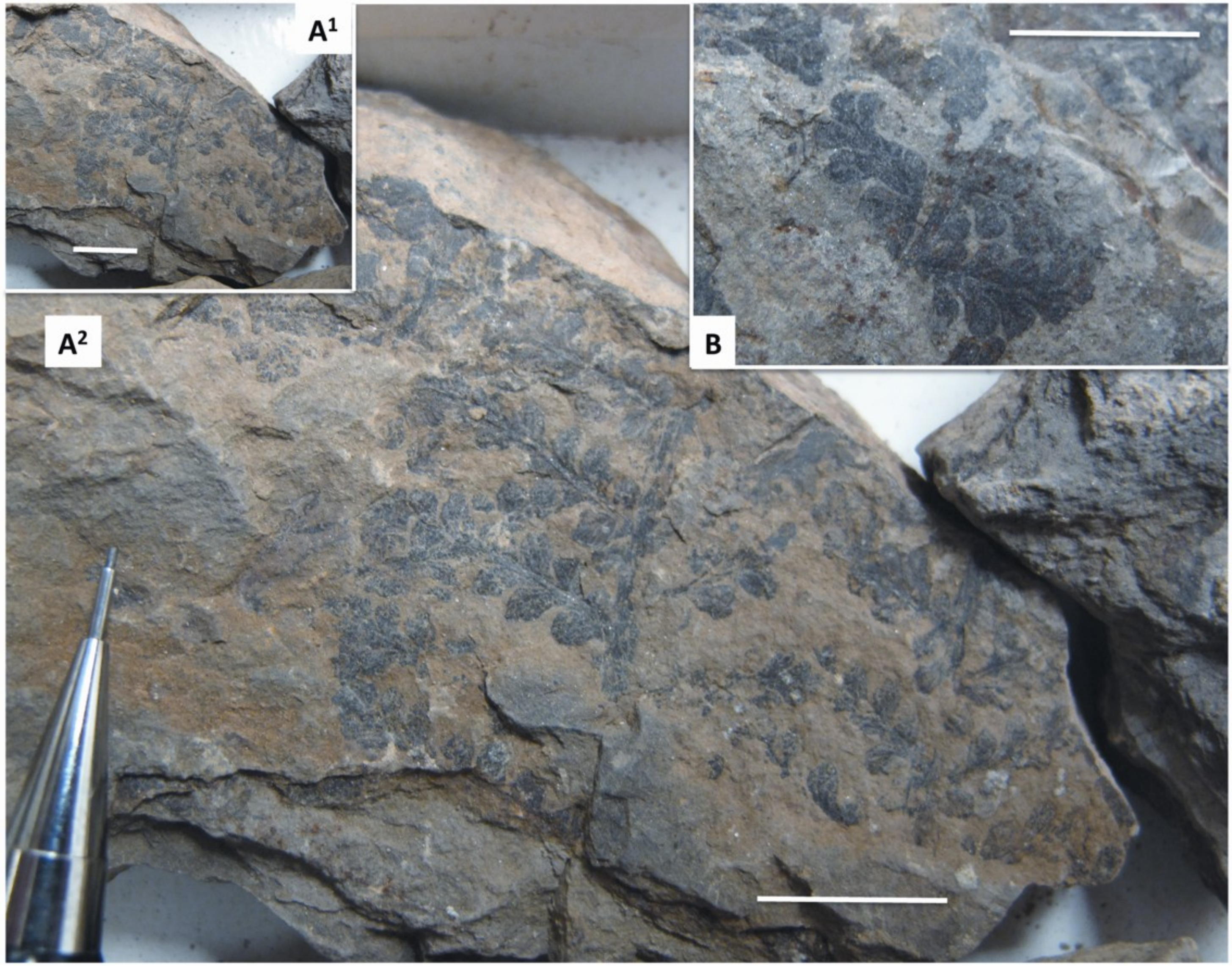

Figure 8. *Autunia naumannii* from David White's Pleasant Hill Gap, Pennsylvania collecting locality, USGS Locality Number 2915. A1. Specimen showing the general aspect and relatively delicate nature of the frond. A2. 3X enlargement of specimen illustrated in A1. Note weakly lobed nature of the pinnule margins and steeply ascending venation. B. Specimen illustrating the rounded to weakly lobed pinnule shape and steeply ascending venation. Scale bars = 1 cm.

coal). This is USGS Locality Number 2915, also known as “Rice’s Gap” and noted by White as occurring on the west side of the gap, 2.4 km (1.5 mi) east of New Freeport. The 1904 road configuration (refer to the Rogersville 15’ Quadrangle map, southwest quadrant) appears to be only slightly different from today, and a church is located at the gap as today. However, the area is now heavily vegetated and we were not able to locate the exact beds from which White collected. Although poorly exposed, the section does not appear to contain continuous beds of limestone and the fossil collection was made from a brown siltstone. Darrah (1969) reported relocating this site after discussions with David White in the 1930s. Darrah reports the fossiliferous beds in claystones above the Nineveh coal, with reservation due to the inability to identify any limestones in the section in this section.

We determine the callipterids from this site to be *Autunia naumannii* (Figure 8). Darrah (1969, p. 17) reported additionally finding *Autunia conferta* at this locality.

West of Littleton

The collecting locality West of Littleton is described by David White in his 1902 field notes, page 28 (August 22nd 1902) (Figure. 9). A note in the collection drawer at the museum

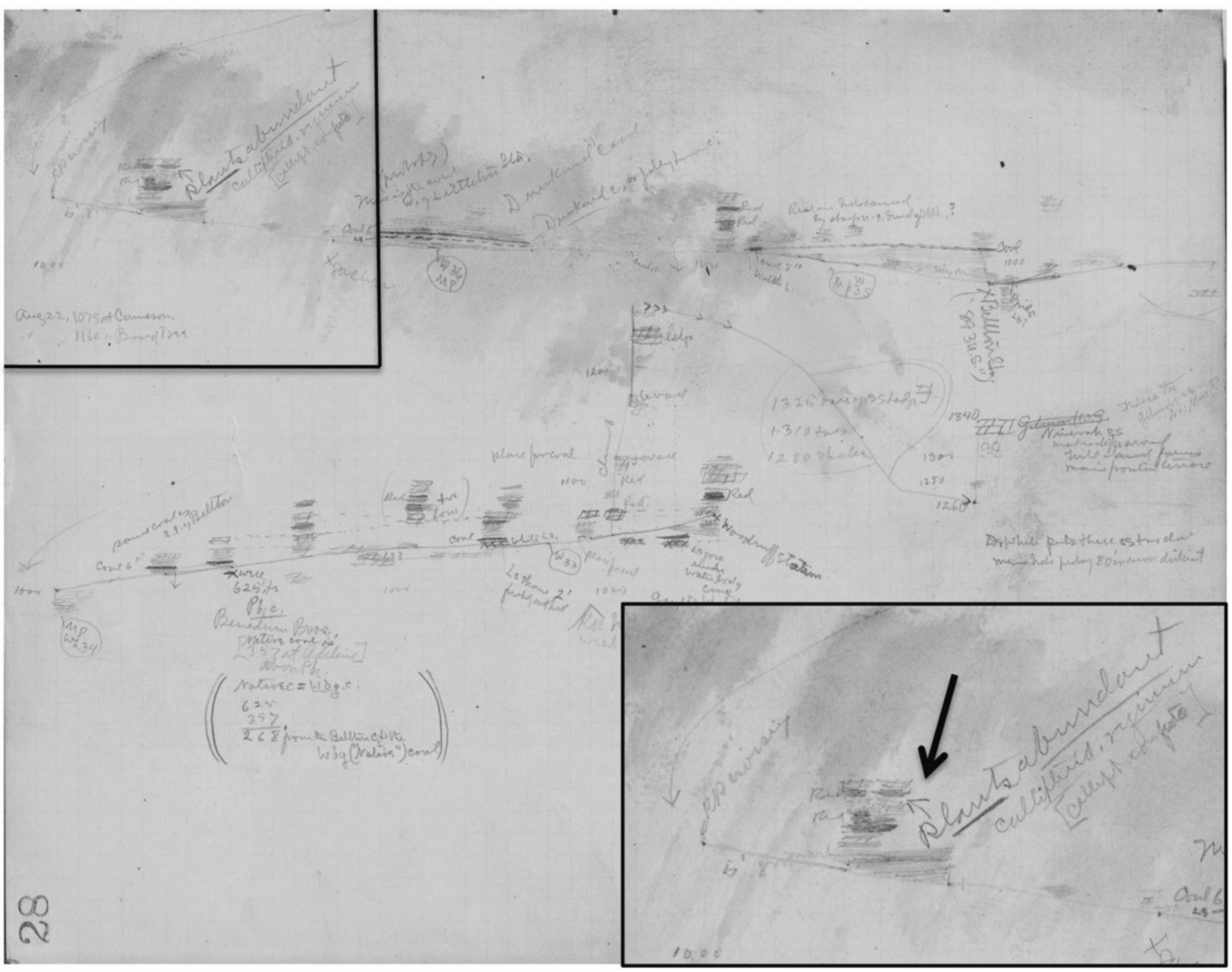

Figure 9. David White’s 1902 field notes for Railroad Cut West of Littleton, WV. Page is rotated 90 degrees counter clockwise. Area in black box in upper left of image is enlarged in lower right. Note (at arrow) the

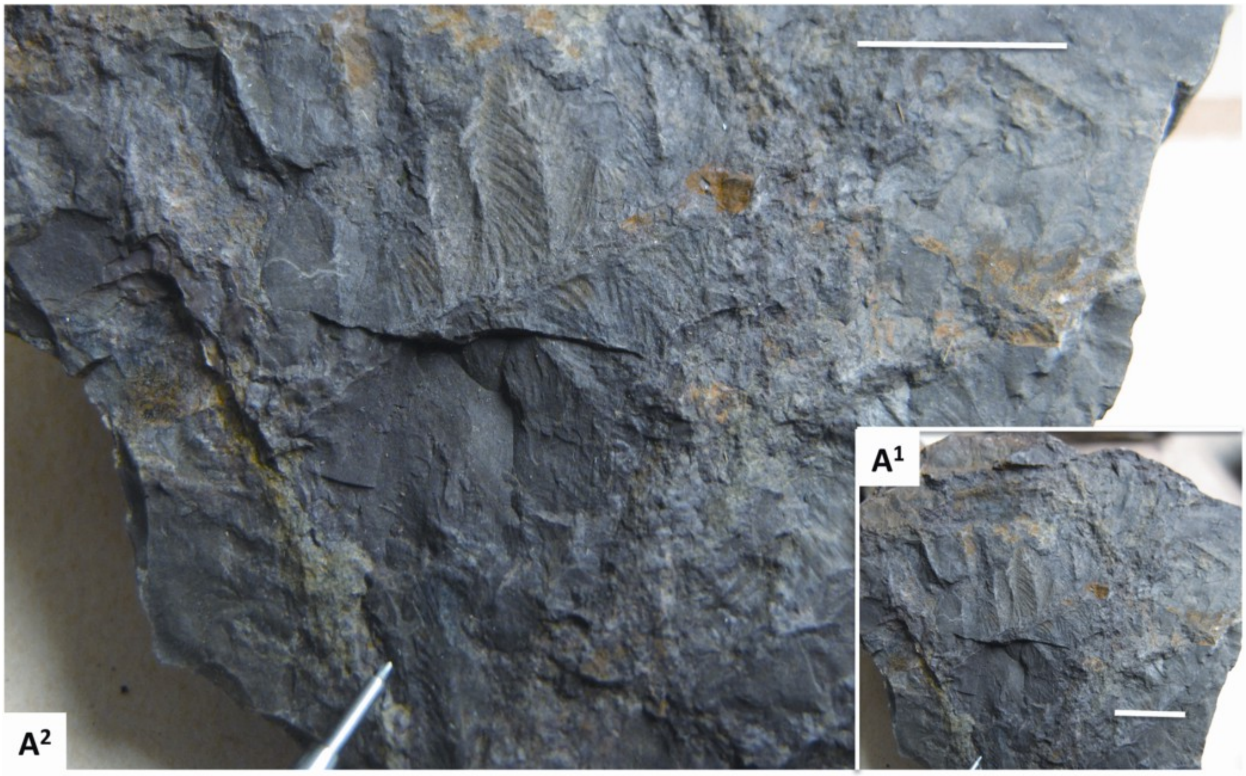

Figure 10. ***Autunia conferta*** **from David White's Railroad Cut West of Littleton, West Virginia, collecting locality USGS Locality Number 2909x. A1. The single callipterid specimen collected from this site, the flora from which is dominated by wetland plants. This plant may have been collected from a different bed, given the distinct locality number (2909x rather than 2909). A2. 3X enlargement of specimen illustrated in A1, showing the bluntly acute pinnule apices, nearly centrally located pinnule midvein, and steeply ascending but convexly arched lateral veins. These pinnules do not appear to be as thick as those from Brown's Bridge. They resemble the larger form of** ***Autunia conferta*** **reported elsewhere in the Dunkard and in the Permian of North America (see text).**

(written on the back of an envelope from the "Hotel Creed, Cameron, West Virginia") describes the collection locality more accurately as occurring at the west end of the first railroad cut west of Littleton. The fossils occur in red shales above what White identified as the "Dunkard (or perhaps the Jollytown)" coal, a bed 6" thick, in the Greene Formation. He notes the presence of "*Callipteris reginum*", which either he or someone else has annotated in brackets as "[Callipteris conferta]". There appear to be other annotations in the notebook referring to "D. White" in the third person, taking exception with a stratigraphic determination. However, those describing this West of Littleton site seem to be in White's own handwriting.

The West of Littleton plant collection (USGS Locality Number 2909) consists mainly of typically wetland plants, including tree fern foliage and possibly *Callipteridium,* in red shales. However, there is a single specimen, segregated from the others, labeled USGS Locality Number 2909x, identified on a note as *Callipteris*, with an illegible species name (David White's handwriting is often nearly illegible). We determine the plant from this site to be the typically larger form of *Autunia conferta* (Figure 10), although the lateral veins are somewhat more flexuous than is typical for most specimens of that species.

Rinehart Tunnel Station

On the last field day (August 23rd) of his 1902 summer field season White (field notes page 34) stopped near a newly excavated railroad tunnel on the West Virginia Shortline Railroad. He called the site "Tunnel Sta." (?Tunnel Station) located, according to his description, "…in SE corner of Wetzel County in Centerpoint 15' quad and Folsom 7 1/2 ' quad. It is between Rinehart and Folsom." Again, the fossils seem to come from the Greene Formation, located approximiately 373 m (1,225 ft) above the Pittsburgh coal and about 91-122 m (300-400 ft) below the top of the hill.

White explicitly notes "*Callipteris* in plenty at the tunnel in the **** [illegible] dump and in dump at the w. end of switch below tunnel sta." We were able to relocate and reach the eastern portal the tunnel, but could find no evidence of waste rock dumps from tunnel excavation, the presumed source of the callipterid fossils. It is probable that the excavated rock was hauled off and perhaps was used locally as fill in the construction of the railroad bed. Unfortunately, no collections appear to have been made from this site, at least as far as we can tell from an examination of the USGS locality records or from a survey of the Smithsonian collections.

Winkler's Mill

Winkler's Mill is a site collected by Aureal Cross on August 27, 1948. It is in the NW quarter of New Martinsville 15' Quadrangle, approximately due west of New Martinsville WV. Cross et al. (1950) describe the general area, though not this specific site, in Stop 12 of the Day 1 road log and as Geological Sections 8C, 8D, and 8E on Bares Run, which is the drainage to the immediate east of Winklers Mill. The area exposes the highest Greene Formation rocks in Ohio. A fossiliferous horizon containing callipterids is not noted in the geological sections or road log of that field guide. Only the plant containing beds noted in Section 8E are not from shales immediately above coaly horizons, making these the most likely candidates for the bed from which the callipterids were obtained. However, the descriptions of the beds note that they are gray-green to purple in color (purple is often used, however, for red beds with hematitic inclusions, so red coloration is not ruled out by this description).

The Winklers Mill collection is presently held by the Field Museum of Natural History in Chicago, Illinois, and bears A.T. Cross' original locality number C-339(2) and B-3667. We identify the callipterid in this collection as the larger form of *Autunia conferta* (Figure 11). The flora of that collection contains other, more typically wetland elements, in the same matrix as *A. conferta*, including an *Alethopteris* similar to *A. zeilleri* and *Annularia carinata*.

Other collections

Darrah (1975) illustrates three callipterid specimens, all of which he identified as *Callipteris conferta*. We are in agreement with this identification for his Figures 1 and 2, which appear to be the small pinnuled form of *Autunia conferta* (Figures 12 A and B). Darrah's Figure 3 is much more fragmentary and appears to be lobed. It may be the small form of *A. conferta*, but the lobes are not separated adequately to be described as pinnules. Ultimately, the specimen, as photographed, is too small for a positive identification. The specimens illustrated in Darrah's Figure 1 (Figure 12B) and Figure 3 were collected by J.A. Barlow on Williams Run

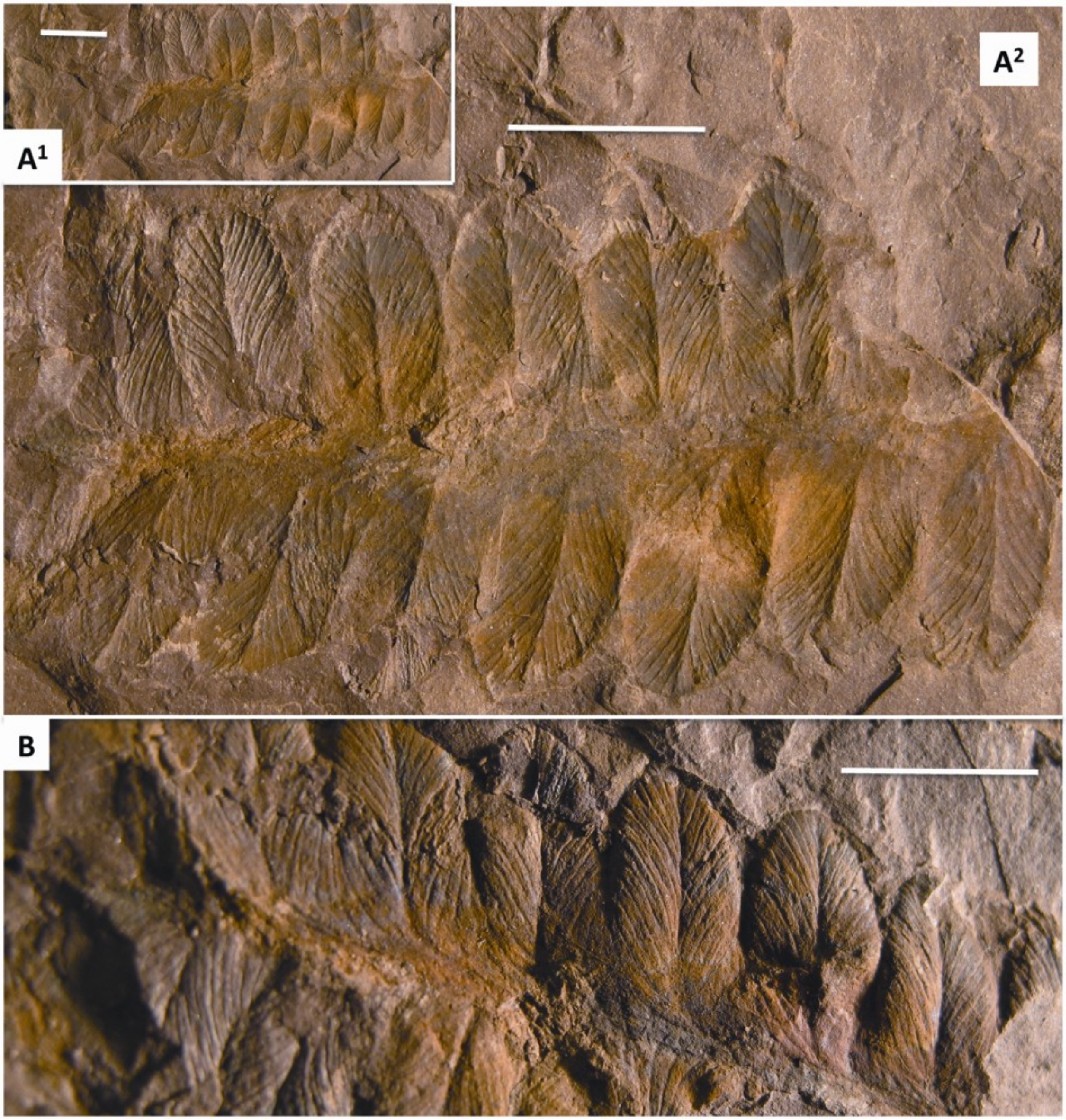

Figure 11. ***Autunia conferta*** **from Aureal Cross' Winkler's Mill, Ohio collecting locality, A.T. Cross collection numbers C-339(2) and B-3667. A1. Specimen showing general aspect of a single pinna. A2. 3X enlargement of specimen illustrated in A1 showing the bluntly acute pinnule apices, nearly centrally located pinnule midvein, and steeply ascending but convexly arched lateral veins. These pinnules, as with those illustrated in Figure 10, do not appear to be as thick as those from Brown's Bridge and resemble the larger form of** ***Autunia conferta*** **reported elsewhere in the Dunkard and in the Permian of North America (see text). B. Specimen illustrating the pinnule shape and venation. Because this is a "positive" specimen, it likely preserves an impression of the underside of the pinna and pinnules. Note the prominence of the veins, as if they were well marked on the lower surface of the leaf, which was pressed into the sediment matrix, leaving a "footprint". Scale bars = 1 cm.**

near Williamstown, West Virginia. The specimen illustrated in Darrah's Figure 2 (Figure 12A) comes from a ravine north of Wolfdale in Canton Township, northwest of Washington, Pennsylvania.

Gillespie et al. (1975) illustrate two callipterid specimens (Figure 13). Both were collected from 1.2 m (4 ft) above the Lower Washington Limestone, approximately 1.6 km (1 mi) east of Waynesburg, Pennsylvania. The first (Gillespie et al., Plate I A, 2/3 X) (Figure 13A) is the larger pinnuled form of *Autunia conferta*, which Gillespie et al. identify as "possibly *C. conferta*". The second specimen (Gillespie et al., Plate VIII A, no scale) (Figure 13B) is also identified as "possibly *C. conferta*", but appears to be *Rhachiphyllum schenkii* Kerp (Kerp, 1988). Pinnules are large, elongate with lobed margins, are strongly decurrent and have distinct lobes on the basiscopic margins near the point of lamina contact with the midrib. The pinnules appear to be thin and non-vaulted, of relatively flat aspect with the midvein and lateral veins flush with the surface of the lamina; details of venation cannot be observed in the photograph of the specimen.

Darrah (1969, p. 17) notes the occurrence of *Autunia* (*Callipteris*) *conferta* at a minimum of 8 sites in Pennsylvania and West Virginia, in addition to Brown's Bridge and Pleasant Hill Gap of David White. Most of these sites he describes as north and northwest of Waynesburg, in both red shales and dark gray sandstones above the Lower Washington Limestone.

Gillespie and Pfefferkorn (1979) report and illustrate several specimens that they attribute to *Callipteris conferta* from red shale, probably from the Washington coal interval, exposed near Liberty, Kanawha County, West Virginia. This locality is in a basin margin setting, over 161 km (100 mi) south of the classic Dunkard area being covered by this field trip, and well outside the area where coals and limestones are best developed in the Dunkard Group. As a consequence these specimens are extremely important indicators of the occurrence of callipterids in areas where soil moisture was likely seasonal in distribution.

DISCUSSION

A diverse group of callipterids has been identified in the Dunkard Group. This diversity was recognized very early in the study of the Dunkard flora, and various names have been applied to these fossils. Our present list includes the following: *Autunia conferta*, both a large and a small form, *Autunia naumannii*, *Lodevia oxydata*, and *Rhachiphyllum schenckii*. The large and small pinnuled forms of *Autunia conferta* may indeed be different species. The small pinnuled form bears a close resemblance to the more traditional European morphotypes attributed to *A. conferta* (see Kerp, 1988). The larger pinnuled form, a very nice specimen of which Gillespie et al. (1975) illustrate in their Plate I A, is quite like large pinnuled callipterids from Kungurian red beds of North-Central Texas (Chaney and DiMichele, 2007) in terms of pinnule shape (ovoid), moderate-to-large size, and the tip shape (varying from sharply to bluntly pointed). There are other names that have been applied to some of the Dunkard callipterid specimens, but nearly all these names seem to swirl around the "*Callipteris conferta*"-like specimens from Brown's Bridge, the commentaries related mainly to the matter of *C. conferta* as a traditional marker species for the bottom of the Permian, thus the import of a correct species identification at the time most of the papers were written. Gillespie et al. (1975, p. 229) note that David White (1933) described the Brown's Bridge fossils by a number of names (*Callipteris lyratifolia*, *C. diabolica*, and *C. currettiensis*) but not as *Callipteris conferta*. They also note that Hans Bode (1958) reports examining the Brown's Bridge material first hand

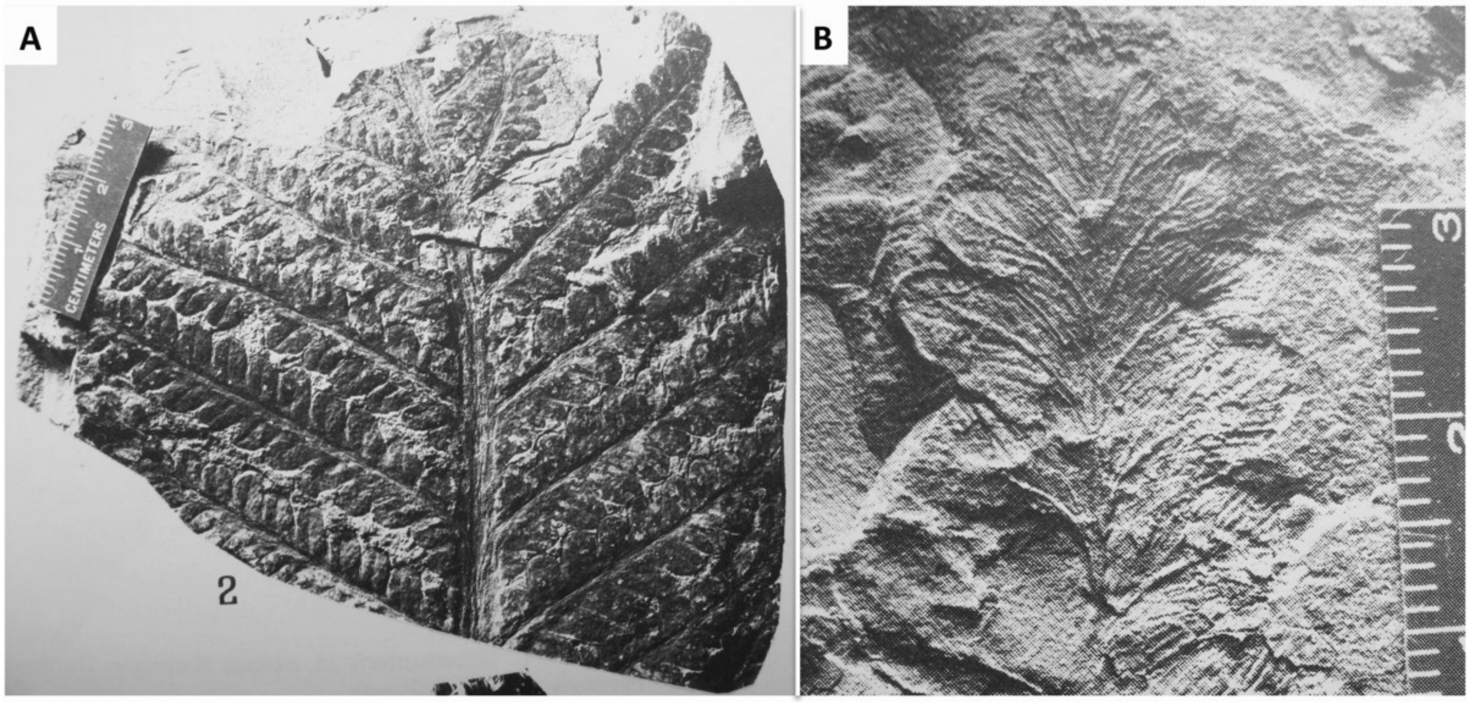

Figure 12. Callipterid specimens originally illustrated by Darrah (1975). A. ***Autunia conferta*** of the large pinnule form. This is Darrah's original Figure 2. B. ***Autunia conferta*** of the large pinnule form. A portion of Darrah's original Figure 1. Note the bluntly acuminate pinnule apices and the steeply ascending, but convexly arching lateral veins, and fused pinnules at the pinna apex.

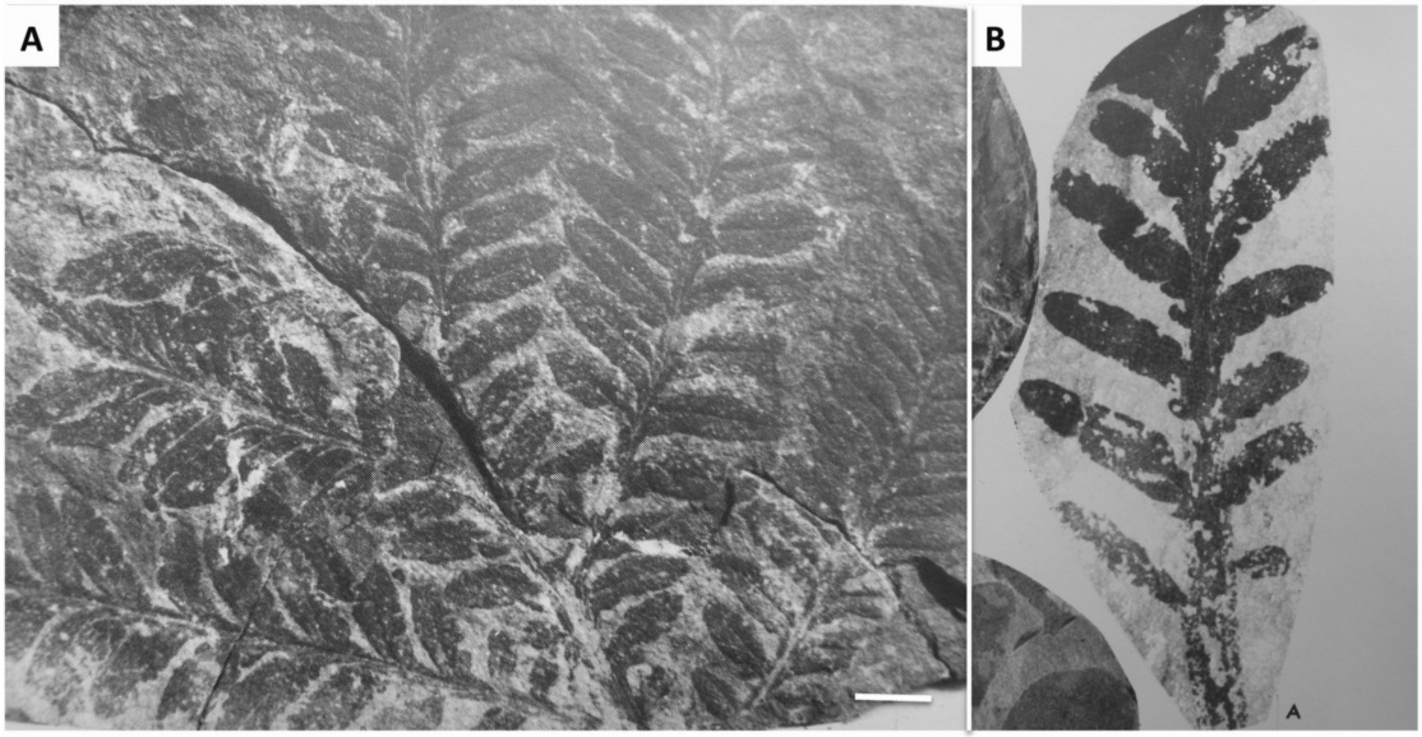

Figure 13. Callipterid specimens originally illustrated by Gillespie et al. (1975). A. *Autunia conferta*. Gillespie et al.'s original Plate IA figure. This is the most extreme example of *Autunia conferta* with large pinnules. In this case the pinnules are distinctly obovate with tapered tips. Intercallary pinnules, characteristic of callipterid fronds, are clearly visible on the main rachis of the specimen, above the first left-side pinna from the base. Scale bar = 1 cm. B. Possible *Rhachiphyllum schenkii*. Gillespie et al.'s original Plate VIIIA, which was identified as "Possible *Callipteris conferta*". Note flat aspect to the pinnules; they are not vaulted and the midvein is not sunken in the lamina surface. Pinnule margins are wavy and the pinnules are distinctly lobed at the base. The terminal pinnule, as far as it can be seen, is free. No scale was given for the original illustration.

in 1956 while the collection was on loan to Aureal Cross at West Virginia University. He also doubted the *C. conferta* identification and attributed the lot to *C. lyratifolia*, noting that they were rather poorly preserved – beauty being in the eye of the beholder.

Callipterids appear, as has been noted before by every author who has looked closely at the matter, in the middle of the Washington Formation (in the two formation scheme) and continue to occur upward, sporadically, into the Greene Formation. Darrah (1969, p. 47) noted that *Callipteris conferta*, *C. lyratifolia*, and *C. naumanni* occur at several horizons in the Dunkard and generally are abundant where found. However, the number of localities at which they have been found are rather few and scattered compared to occurrences of typically wetland plants. Darrah interprets the coriaceous leaves of the Dunkard callipterids to indicate "a facies flora of drier environments. " He notes that he "never found *Callipteris* in fine grained gray or black shales. … but in the upper Dunkard section it always occurs in coarse micaceous sandstone of yellow brown to chocolate brown color." He also notes finding *Lebachia* in association with callipterids above the Nineveh coal (?presumably at the Pleasant Gap locality), which is in keeping with an overall interpretation of these plants as indicative of seasonally dry conditions.

Darrah (1969, p. 154) states: "The occurrence of *Callipteris* is much more sporadic than I had long ago assumed. … When *Callipteris* does occur, however, it is abundant almost to the exclusion of other forms, at many localities." He notes that it occurs from the level of the Washington coal upward into the upper Dunkard.

Interpreting the callipterid growth environment from the patterns of occurrence and the environments of deposition, such as they are known, is not particularly revealing. Callipterids have been found in various kinds of lithologies, from limey zones (such as that at Brown's Mills and on Robert's Ridge Road) to siltstones (Pleasant Gap) and red claystones (Winkler's Mill, East of Littleton). In Darrah's words (1969, p. 68), "…the *Callipteris* Permian flora...appears to be indicative of physiologically xerophytic conditions. It is a biofacies usually associated with a peculiar lithofacies." However, that lithofacies has not been characterized well enough for any generalities to be drawn. Perhaps the most telling occurrences are those that clearly are associated with non-marine limestones, such as David White's Brown's Mills collection or our more recent collection from Robert's Ridge Road. In each of these instances the callipterids occur in close association with invertebrates (the ostracodes and non-marine snails of the Brown's Mills shales) or non-marine limestones themselves (the occurrence of callipterids in a shale parting at the top of the Lower Washington Limestone on Robert's Ridge Road). These occurrences suggest environments of high evapotranspiration, at least seasonally, that led to relatively high concentrations of dissolved solids in lacustrine environments. It is noteworthy biofacies and lithofacies similar to those of the Dunkard occur in the Appalachian section in the older Missourian (Kasimovian) Conemaugh Formation and, to a lesser extent, in the Virgilian (Gzhelian) Monongahela Formation, and conifers have been reported from these rocks (Blake, 1992; Darrah, 1969; Martino and Blake, 2001; Blake et al., 2002). However, no callipterids are known. Callipterids have been reported in association with sabkha facies in Missourian (Kasimovian) age rocks of New Mexico (Falcon-Lang et al., 2011) and the earliest known callipterid has been reported from late Desmoinesian (Westphalian/Moscovian) age rocks of the Illinois Basin (Pšenička et al., 2011), so these plants were "out there" on the landscape someplace much earlier than they appear in the Dunkard Group.

The sense of callipterid rarity may be exaggerated by the limited amount of outcrop, particularly of the non-resistant shales, in the presently humid to moist subhumid, highly vegetated northern Appalachian landscape. Were the Appalachian region to be exposed under a semi-arid to arid climate, such as that of the Permian of Texas or New Mexico, the controversy over this matter might be less conspicuous because callipterid-bearing beds might be better exposed, found to be more numerous, and be better understood depositionally/ sedimentologically. Callipterid-bearing beds seem to be unassociated with the conspicuous coaly facies of the Dunkard Group. Rather they occur in various kinds of shales, even clastic beds within limestones. Most plant sampling, in the Greene Formation, in particular, comes from coaly layers, which certainly tend to produce wetland plants of a type generally considered to be a "Pennsylvanian" flora. Of course, the real issue with plants is fidelity to climatic conditions (e.g., see many references to this in Roscher and Schneider, 2006; DiMichele et al., 2008). There seems to be little controversy surrounding the suggestion that whatever the occurrence of callipterids in the Dunkard may signify about its age, they most certainly indicate subhumid paleoclimates, demonstrated by the return of red Vertisols in the Greene Formation. Within the scope of the Pennsylvanian, such climatic conditions are known to have appeared in the equatorial regions as far back as the Middle Pennsylvanian (Cecil et al., 2003; Falcon-Lang et al., 2009; DiMichele et al., 2010). The interlayering of callipterid-dominated assemblages with those dominated by typically Pennsylvanian wetland floras indicates greater extremes of climatic oscillation than those characterizing the preceding Monongahela Formation and lower Dunkard – part of a longer term drying trend with repeated oscillations back to wetter conditions (Roscher and Schneider, 2006; Tabor and Poulsen, 2008). The overall pattern is typical of many continental basins throughout the US and Europe wherein the Pennsylvanian-Permian boundary, regardless of how it may be defined paleontologically or by absolute age dates, is lithologically gradational, to the point of being described as "indistinct".

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One day, while looking for fossils in the Dunkard Group.