ABSTRACT

Plant Community Change Across the Paleocene-Eocene Boundary in the Gulf Coastal Plain, Central Texas

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During the early Paleogene (~58-53 million years ago), the earth experienced long-term global warming punctuated by several short-term 'hyperthermal' events, the largest of which is the Paleocene-Eocene Thermal Maximum (PETM). During this time, tropical climates expanded into extra-tropical areas and it is likely that this created a wide band of 'paratropical' forests, which may have expanded into the mid-latitude Northern Great Plains during the PETM. Relatively little is known about these 'paratropical' floras, which would have occurred across the Gulf Coastal Plain (GCP) during this time. This study is focused on assessing the floras of the GCP in Central Texas from before, during, and after the PETM. The Paleocene-Eocene floras of the central Texas GCP suggest a high turnover rate, change in plant community composition, and similar plant communities across the GCP at the Paleocene-Eocene boundary.

Plant Community Change Across the Paleocene-Eocene Boundary
in the Gulf Coastal Plain, Central Texas

by

Jennifer D. Wagner, B.S.

A Thesis

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# DEDICATION

To my father: thank you for inspiring my fondness of the natural world.
Luv ya.

# CHAPTER ONE

## Introduction

Since the early 1900s, fossil microfloras and macrofloras have been collected and described from localities throughout the Gulf Coastal Plain (GCP) (Berry, 1916; Crepet et al., 1975; Potter, 1976; Crepet et al., 1980; Dilcher and Manchester, 1986; Taylor, 1988; Harrington et al., 2003; Jardine et al., 2012; Denison et al., 2017; Gardner et al., 2017; Stephenson et al., 2018). The GCP is rich in early Paleogene deposits, mostly late Paleocene and early Eocene in age. During the early Paleogene (~58 - 50 million years ago, Ma), the Earth experienced a long-term trend of increasing temperatures, allowing latitudinal expansion of sub-tropical habitats (Bowen et al., 2001; Zachos et al., 2001).The warming of the early Paleogene has been suggested to have caused tropical climates to expand into extra-tropical areas, which in turn allowed a wide band of 'paratropical' forests to extend throughout the mid-latitudes (Wing et al. 2005; Fine and Ree, 2006; Jaramillo et al., 2006; Jardine et al.,2012; Wing and Currano, 2013). The long-term warming of the early Paleogene was punctuated by several abrupt and short-term rapid increases in temperature known as 'hyperthermal' events. The best known of these hyperthermals is the Paleocene-Eocene Thermal Maximum (PETM), which occurs at ~56.3 Ma and demarcates the beginning of the Eocene (e.g., Slotnick, et al., 2012).

During the PETM, the Earth experienced a significant increase in atmospheric $CO_2$ due to the release of 2,300 to 83,000 Pg C, which occurred over less than 20,000 years (Bowen et al., 2001; Zachos et al., 2006). This rapid release in $^{13}C$ depleted carbon

caused a major perturbation to the global carbon cycle, which is recorded in marine and terrestrial records by a negative carbon isotope excursion (CIE) of 3-6 ‰ (Zachos et al., 2005). Contemporaneous with the rise in $CO_2$ is a dramatic increase in global temperatures of ~5 °C. The warming associated with the PETM likely persisted between 100,000 to 200,000 years (McInerney and Wing, 2011; Bender, 2013; Zeebe, 2013). The rapid increase in $CO_2$ and increase in temperature changed weathering rates, hydrologic cycles, and created a feedback loop that altered the global carbon cycle (Slotnick et al., 2012). The warming and associated environmental changes led to changes in the distribution of biota and quick evolutionary turnover rates in both marine and terrestrial environments, including shifts in the latitudinal range and species occurrences of marine plankton, a mass extinction of benthic foraminifera in marine environments, an alteration in the trophic structure and taxonomic composition of terrestrial faunas, major changes in the composition of mid-latitude floral communities, and a major diversification of tropical plant groups (e.g., Zachos et al., 2005; Wing et al., 2005; Takeda and Kaiho, 2007; Woodburne et al., 2009; Jaramillo et al., 2010; McInerney and Wing, 2011).

The best-studied floras from the PETM occur in the Bighorn Basin in Wyoming and document significant changes through the interval. Species present during the Paleocene were almost completely replaced by new, "thermophilic" taxa, which are thought to have migrated from southern latitudes (Wing et al., 2005; McInerney and Wing, 2011; Wing and Currano, 2013). The Bighorn Basin PETM floras contain a distinctive leaf, "*Artocarpus*" *lessigiana*, which is present in Late Cretaceous and Paleocene deposits of the southern Rocky Mountains and GCP but is essentially absent in the Paleocene flora of the Bighorn Basin (Berry, 1916; Ellis et al., 2003). Other low-

latitude taxa are present during the PETM (Wing and Currano, 2013), suggesting a northward expansion of species of between 4 and 20 degrees north (Wing et al., 2005). The most logical source for many of these species is the Gulf Coastal Plain (GCP). Interestingly, during the recovery from the PETM, many of the Paleocene taxa that were replaced during the PETM return to the Bighorn Basin but are then replaced again about two million years later by the same "thermophilic" taxa during the Early Eocene Climatic Optimum (Wing et al., 2005; McInerney and Wing, 2011). This rapid transition suggests the presence of high-elevation refugia for cool-climate taxa and isolated low-elevation refugia for warm-climate taxa.

Despite suggestions that paratropical forests existed in mid-latitudes during the early Paleogene and that taxa from southern North America migrated into the Northern Great Plains (NGP) during warm times (Wing et al., 2005; McInerney and Wing, 2011; Jardine et al., 2012), relatively little is known about early Paleogene floras from southern North America, limiting our ability to test these hypotheses. Floras collected from Paleogene GCP deposits present an excellent opportunity to examine the floral record from southern North America during the early Paleogene. Macrofloras and microfloras are common in the upper Wilcox Group and lower Claiborne Group in Central Texas (Berry, 1916; Yancey et al., 2010; Dickey and Yancey, 2010; Gardner et al., 2017; Stephenson et al., 2018), and are thus ideal floras to study. Here, I use macrofloras collected from central Texas to describe and assess the floral composition and paleoecology of Gulf Coastal Plain floras across the Paleocene-Eocene boundary. These trends and characteristics are then compared to other GCP floras, and to the NGP flora of the Bighorn Basin to test the hypothesis that paratropical forest communities migrated

north from the GCP during hyperthermal events and contracted back to the GCP during cool periods.

*Geologic Framework*

The GCP of Texas is comprised of approximately 100 stratigraphic units that span much of the Mesozoic and Cenozoic (Baker, Jr., 1995). The stratigraphic nomenclature of the geologic units in the GCP of Texas is very complex and is generally separated into three regions: east coastal plain, central coastal plain, and south coastal plain (Fig. 1.1; Baker, 1995). The formations that are the focus of this study are in the Wilcox and Claiborne Groups, which are present across the entire GCP (Fig. 1.1; Baker, 1995; Weems and Edwards, 2004;).

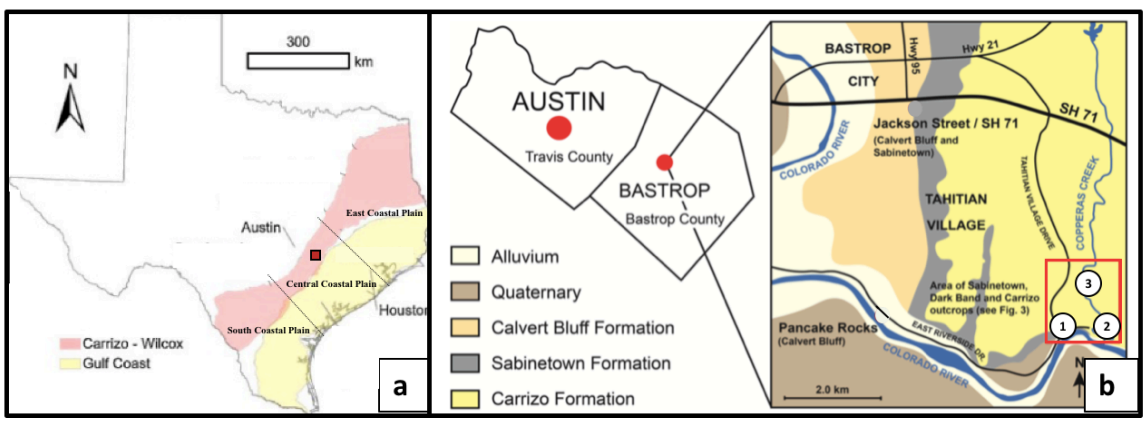


Figure 1.1 a) Location of the collection sites within the Gulf Coastal Plain, specifically the Carrizo-Wilcox Group location, in Texas. Bastrop, TX is represented by the red box to the south-east of Austin. b) stratigraphic map of the collection sites with each census location indicated within the red box (Denison et al., 2017: used with permission).

The Wilcox Group is composed of siliciclastic sediments that were deposited in the Gulf of Mexico during the Paleocene (Fisher and McGowen, 1967; Galloway et al., 2000; Wahl et al., 2016; Olariu and Zeng, 2018). Initially, the Wilcox Group outcrops of

Texas were interpreted as fluvial deposits (e.g., Fisher and McGowen, 1967; Baker, 1995); however, this has recently been challenged due to the presence of tidal heterolithic strata (Breyer and McCabe, 1986; O'Keefe et al., 2005; Denison et al., 2017), marine trace fossils, and sedimentary structures indicative of open-marine deposition (Dickey and Yancey, 2010; Yancey et al., 2010, 2012; Denison et al., 2017), and are now inferred to represent tidal to open marine environments (e.g., Denison et al., 2017). The shoreface to tidal deposits of the Claiborne Group unconformably overlie the Wilcox Group and are Eocene in age (Fisher and McGowen, 1967; Baker, 1995).

*Paleogene Gulf Coastal Plain deposits in Central Texas.* There are several locations in Bastrop, TX where sections of the Wilcox Group and lower Claiborne Group are exposed (Fig. 1.1). The stratigraphic succession present in Bastrop in ascending order is the Calvert Bluff and Sabinetown Formations of the upper Wilcox Group, a 'Dark Band' section, and the Carrizo Sands of the Claiborne Group (Fig. 1.2; Denison et al., 2017). The 'Dark Band' has not been formally defined or placed into a stratigraphic formation or group, although it is presently thought to be the uppermost unit of the Wilcox Group and to have been deposited during the PETM making it early Eocene in age (e.g., Denison et al., 2017; Gardner et al., 2017; Demchuk et al., 2018; Stephenson et al., 2018).

The uppermost Calvert Bluff Formation consists of coarsening-upward sequences that begin with marine mudstones and progress upward into sand-dominated tidal flats that are cut by tidal channels with layers of silt and occasional trace fossils (*Skolithos*, *Planolites*, *Ophiomorpha*) (Yancey et al., 2010; Denison et al., 2017). The tidal channels contain cross-bedded and oscillation-rippled sandstones. The depositional environment is more marine-influenced than fluvial. The uppermost Calvert Bluff Formation is exposed

across from the Buc'ees gas station in Bastrop, TX to the northwest of the study area and at the 'Pancake Rocks' exposure to the west of the Golf Course exposure. It does not occur in the study area.

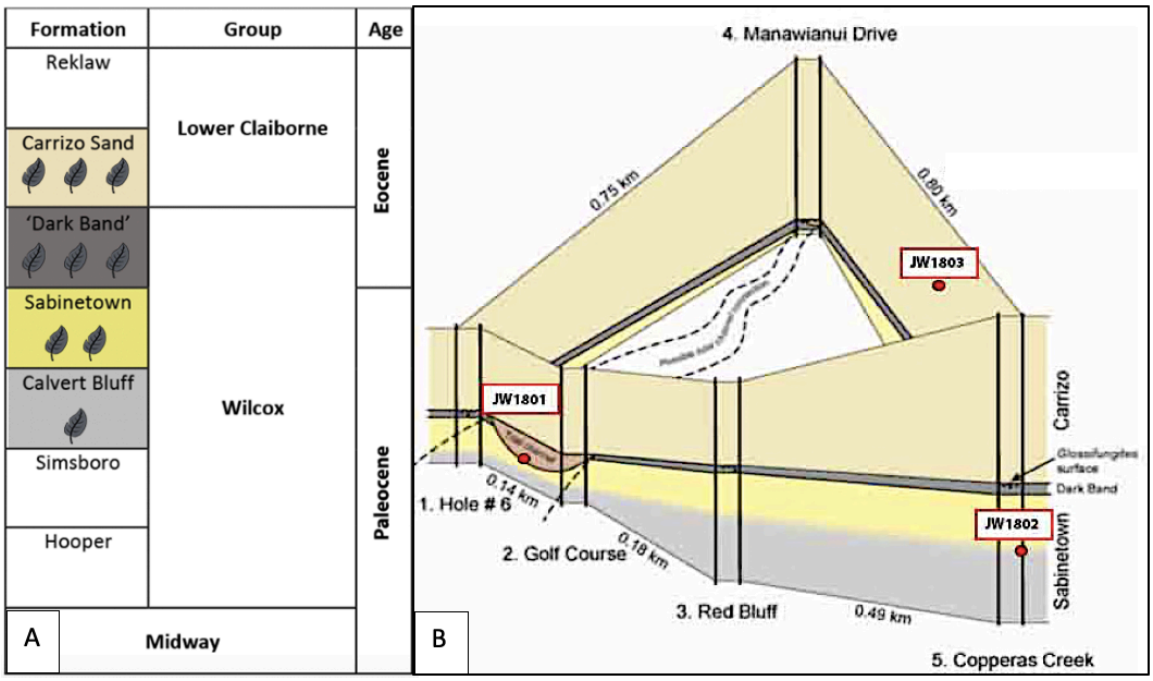


Figure 1.2. A) the nomenclature and age of the formations from the Wilcox Group and Lower Claiborne Group. Leaves show fossil leaf presence and abundance. Stratigraphic column is not drawn to scale; B) the formations present in Bastrop, TX in reference to each other and the channel deposits (Fence diagram is edited from Denison et al., 2017, with permission). Approximate geographic and stratigraphic location of the three fossil leaf sites (JW1801, JW1802, and JW1803) are indicated by red circles.

The Sabinetown Formation, which is well exposed at Copperas Creek and at the base of the Pine Forest Golf Course (Fig. 1.2B), is a progradational parasequence that is capped by the Carrizo Sand (Dickey and Yancey, 2010; Yancey et al., 2010, 2012; Denison et al., 2017). The Sabinetown consists of silt-dominated, muddy tidal deposits that become more heterolithic upwards with well-developed muddy tidal flats and a quick transition to sandy tidal flats. There is a distinct silt-dominated unit present (the "Dark

Band") between the top of the Sabinetown and the base of the Carrizo Sand. The contact between the Sabinetown, "Dark Band", and base of the Carrizo sand suggests an unconformity. Within the Sabinetown Formation fossil leaves are common, though poorly preserved and never found in high abundance in one location.

Between the uppermost Sabinetown Formation and the base of the Carrizo Sand is the "Dark Band" (Fig. 1.2B; Denison et al., 2017) which, due to presence of marine trace fossils, suggests a very shallow marine transgression. The Dark Band has been eroded in all three locations by channels (Fig. 1.2B). Tidal channel-fill deposits consist of sand and mud and commonly end with a subbituminous coal of varying thicknesses. The channel deposits contain abundant fossil leaves.

Above the Dark Band and the channel deposits is the Carrizo Sand (Fig. 1.2). It unconformably overlies the Dark Band, and *Thalassinoides* burrows from a Glossifungites surface extend down into the Dark Band (Denison et al., 2017). The Carrizo Formation is composed of fine-grained cross-bedded sands that contain abundant large-scale *Ophiomorpha* burrows, indicating deposition on an open marine shelf. Upsection, mud laminae become increasingly abundant indicating a small-scale regression, then decrease and the sands become better sorted, indicating renewed transgression and a return to open shelf conditions. Within these sand deposits, usually in the mud layers, there are pieces of wood debris and occasional well-preserved fossil leaves (Yancey et al., 2010).

Palynological analyses of these deposits indicate that the PETM is likely within the dark band or near the contact of the Claiborne Group, where it hasn't been cut out by erosion prior to deposition of the Carrizo Sand (Yancey et al., 2010; Dickey and Yancey,

2010; Gardner et al., 2017; Demchuk et al., 2018). The palynological analyses show a spike in *Cicatricosisporites sp*. fern spores, the last occurrence of *Spinaepollis* sp. angiosperm pollen, a spike in the abundance of *Apectodinium homomorphum* within the dinocyst assemblage, and a lack of Eocene-restricted taxa (Denison et al., 2017; Gardner et al., 2017; Demchuk et al., 2018; Stephenson et al., 2018).

Assessment of the palynoecology using fungi and non-pollen palynomorphs suggests deposition at the base of the Sabinetown Formation took place on a shallow shelf offshore from a tidal marsh surrounded by an onshore hardwood wetland and fern savannah and the upper section deposition took place in a tidal lagoon or shallow shelf adjacent to a fire-prone fern-dominated savannah (Stephenson et al., 2018). The palynoecology of the coal deposits within the uppermost Sabinetown suggest a transition from mangrove swamps to hardwood hammocks, followed by a transition to sawgrass marshes (Stephenson et al., 2018). The palynoecology from the Carrizo Sand suggests an abrupt change in depositional environment which consisted of a shallow shelf offshore from a brackish tidal marsh bordered by a palm savannah (Stephenson et al., 2018).

Additionally, preliminary results of compound-specific isotope analyses of widely-spaced samples from the dark band show a weak negative excursion in $\delta\ ^{13}C$, which is suggestive of a carbon isotope excursion (Demchuk et al., 2018). Importantly, fossil leaves are abundant within this interval (Fig.1.2A), making it an ideal location to assess the southern North American floral record of the early Paleogene.

CHAPTER TWO

Methods

Fossil leaves were collected from the late Paleocene and early Eocene upper Wilcox Group and early Eocene lower Claiborne Group deposits along the Colorado River, near Bastrop, TX (Fig. 1.2 and 2.1). Voucher collections were made at three localities: late Paleocene (JW1802), PETM (JW1801), and early Eocene (JW1803). Two census collections were made, JW1801 (PETM) and JW1803 (early Eocene), to assess the species richness and diversity of the flora. Fossil leaf preservation was not good enough to make a census collection at JW1802 (late Paleocene).

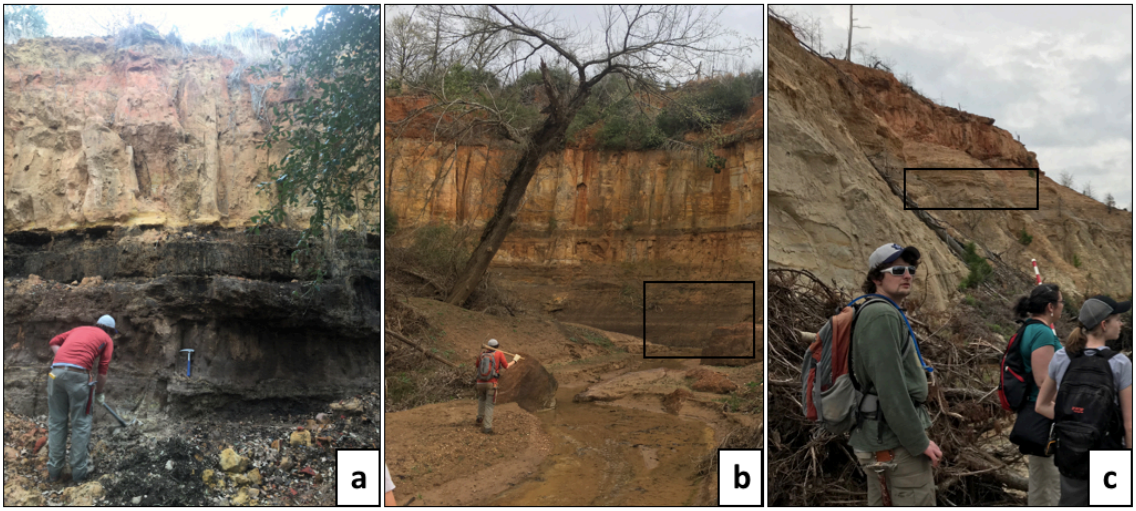


Figure 2.1. The locations of the three systematic census collections in Bastrop, TX; a) the channel fill below the lignite and Carrizo at the Pine Forest Golf Course; b) the upper Sabinetown formation at Copperas Creek; c) the Carrizo Sand at Manawianui Drive. The boxes in b and c are roughly the location of the collection in the outcrop.

*Fossil Collection and Description*

Locality JW1802, here forward referred to as 'late Paleocene', was collected from the Sabinetown Formation of the Wilcox Group and was located within an outcrop exposed at Copperas Creek, which is a small tributary of the Colorado River (Fig 2.1B). Locality JW1801, referred to as 'PETM', was located in an outcrop exposed on the Pine Forest Golf Club course along the Colorado River in Bastrop, TX (Fig 2.1A). Locality JW1803, referred to as 'early Eocene', was located at an outcrop exposed at the end of Manawianui Dr. in Bastrop, Texas (Fig. 2.1A). Voucher collections, in which the best-preserved specimens and specimens of any unknown morphotypes were collected, were made at all three sites. Census collections of fossil leaves, in which at least 300 specimens were examined, identified, and tallied, were made from the upper Wilcox Group (JW1801) and lower Claiborne Group (JW1803) sites that sample the PETM and the early Eocene. The tallied specimens made during these collections comprise the "field census". Representative samples of each morphotype, all unknown specimens, and well-preserved specimens that document that variability of morphotypes were collected during the census collections. All specimens collected as part of this work have been given lab identification numbers and are housed at Baylor University. In the lab, all morphotypes from the field census and voucher collections were tallied, to make the "lab census".

Fossil dicotyledonous angiosperm (dicot) leaves were described using the Manual of Leaf Architecture (Ellis et al., 2009). Monocotyledonous angiosperms (monocots) and ferns were described primarily using venation characteristics. Based on the features observed when making these descriptions, the fossils from each locality were divided into

morphotypes (e.g., Ellis et al., 2009; Peppe et al., 2008). See Appendix for descriptions and illustrations of all morphotypes identified in this study.

In addition to comparing the morphotypes across the Bastrop localities, late Paleocene and early Eocene fossil leaves housed at the Florida Museum of Natural History from GCP localities from north eastern Texas, Tennessee, Arkansas, and Kentucky (Fig. 2.2) were assessed and photographed for comparison with the Bastrop, TX morphotypes.

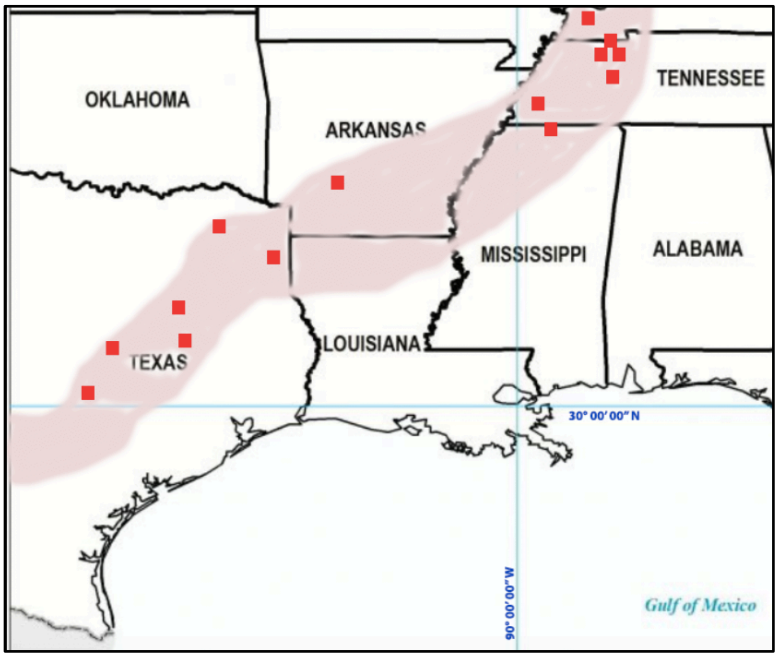


Figure 2.2. Gulf Coastal Plain Wilcox and Claiborne Group fossil localities. Gulf Coastal Plain deposits indicated by pink shading. Fossil sites indicated by red squares. Fossils and data are for these localities are stored at the University of Florida Museum of Natural History.

*Vein Density*

Photographs of all morphotypes were taken using a high-resolution camera (Nikon D330, DX-VR,18-55 mm). All photographs included a scale bar, locality, and morphotype ID. Vein density was measured on all specimens with well-preserved

secondary veins. Secondary veins (2°) were identified using the definition of Ellis et al. (2009) and included all regular, inter-, interior, and minor secondaries. Four or more rectangular boxes were placed on the photographs of preserved leaf fragments using Adobe Photoshop CC 2019. These boxes were located on the basal, middle (2), and apical thirds of the leaf following the protocols of Sack et al. (2012) and Merkhofer et al. (2015). If those locations were not available, the boxes were fit on the available preserved area. Vein density is defined as the total vein length divided by the area of the rectangle (Sack et al. 2012). The area of each rectangle was sized to include at least two $2^o$ veins. After measuring and recording the area of each box, the lengths of all secondary veins were measured and recorded. All measurements were made in Image J. After calculating the average vein length density ($mm/mm^2$) for all specimens, the estimated area of each leaf was scaled using the regression method of Sack et. al (2012):

$$\log_{10}(\text{leaf area cm}^2) = 1.96 - 2.04 \times \log_{10}(\text{subsampled } 2^o \text{ vein density cm/cm}^2) \quad \text{(Eq.1)}$$

The estimated leaf area was recorded in $mm^2$ and the natural log of the estimated leaf area was used to categorize each leaf into the following leaf sizes: leptophyll, nanophyll, microphyll, notophyll, mesophyll, and megaphyll; which are defined as greater than 2.12 $mm^2$, 4.32 $mm^2$, 6.51 $mm^2$, 8.01 $mm^2$, 9.11 $mm^2$, and 11.42 $mm^2$, respectively (Webb, 1959).

*Leaf Mass per Area*

In order to calculate leaf mass per area ($g/m^2$), the vein-scaled areas were used in combination with petiole widths using the woody dicot regression from Royer et al. (2007):

$$\log[LMA] = 0.3820 \times \log[PW^2/A] + 3.070 \qquad \text{(Eq.2)}$$

If the area could be determined via direct measurement (i.e. the fossil leaf was complete enough to measure the entire area), this area was used instead of the vein scaled area. All leaves measured were non-sessile with observable petioles. If the entire petiole was not present, the width of the exposed primary vein merging with the uppermost section of the petiole was measured following the protocol of Royer et al. (2007; 2012). The leaf mass per area was then compared to modern sites (Royer et al., 2012; Peppe et al., 2011) to assess the ecological habitat.

*Diversity Analyses*

Floral diversity was assessed using PAST (Hammer et al. 2001) from quantitative (census) collections. Abundance counts from JW1801 and JW1803 (PETM and early Eocene, respectively) were used to determine the diversity (Shannon, Simpson, and Equitability Indices), dominance (Berger-Parker Dominance), and evenness of the flora (Shannon index divided by the natural log of species richness) (Harper, 1999; Morris et al., 2014). Bray Curtis Dissimilarity (Legendre and Legendre, 1998) and Jaccard's Index of Similarity (Real and Vargas, 1996) were used to compare the composition of the communities.

# CHAPTER THREE

## Results

### *Flora Composition Characteristics*

The megaflora fossils collected from the late Paleocene deposit (Sabinetown Formation, locality JW1802) were poorly preserved and commonly occurred in mats between mudstone deposits. A total of 11 morphotypes consisting of 91% dicots and 9% monocots were identified and described (Table 3.1, Fig. 3.1A). Out of the 10 dicots, 63% had toothed margins. The megaflora fossils from the PETM deposit were better preserved and had a total of 26 morphotypes. The morphotypes were 84% dicot, 8% monocot, and 8% fern (Table 3.1, Fig. 3.1B), with 39% of the dicots having toothed margins. The early Eocene megaflora fossils' preservation was comparable to the PETM's and consisted of 13 morphotypes. The megaflora fossils were 77% dicot, 15% monocot, and 8% fern (Table 3.1, Fig. 3.1C), with 60% of dicots having a toothed margin.

Table 3.1. The Central Texas Paleocene-Eocene boundary fossil flora characteristics. The number of morphotypes, composition, and margin characteristics of the flora collected at the Paleocene-Eocene boundary in the GCP of central Texas.

| Locality | # morphotypes | % dicot | % monocot | % fern | Margin (% |
|---|---|---|---|---|---|
| early Eocene flora | 13 | 77 | 15 | 8 | 60 |
| PETM flora | 26 | 84 | 8 | 8 | 39 |
| late Paleocene flora | 11 | 91 | 9 | 0 | 63 |

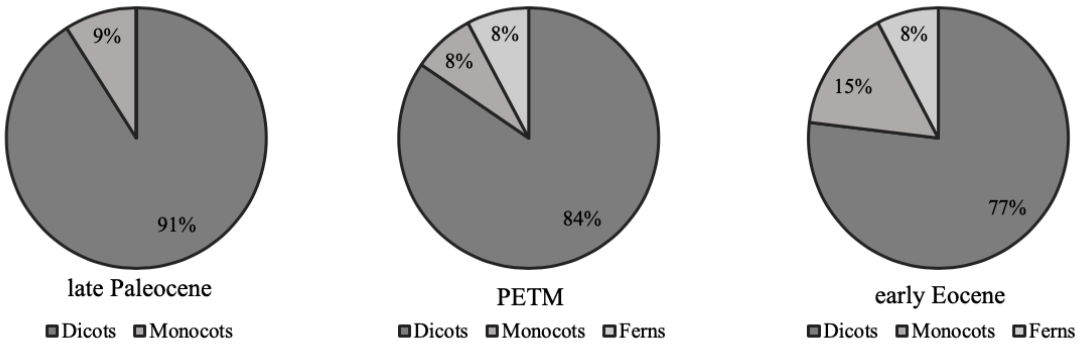


Figure 3.1. Composition of the late Paleocene, PETM, and early Eocene flora from the Gulf Coastal Plain, central Texas. (A)The late Paleocene flora comprised 10 dicots and 1 monocot; (B) the PETM flora comprised 22 dicots, 2 monocots, and 2 ferns; (C) the early Eocene flora comprised 10 dicots, 2 monocots, and 1 fern. These compositions included fossil leaves and reproductive material.

The field census collection at the PETM locality (JW1801) yielded 310 specimens composed of 10 morphotypes. Morphotypes BT-01 and BT-02 made up >50% of the collection (Table 3.2). The PETM lab collection had 200 specimens composed of 23 morphotypes (Table 3.2). BT-01 and BT-02 were also the most abundant morphotypes (~40% of the collection) in this collection. The field census collection at the early Eocene locality (JW1803) yielded 344 specimens composed of 13 morphotypes. BT-30, a monocot, made up >40% of the collection (Table 3.3). The early Eocene lab collection had 108 specimens composed of 13 morphotypes. The most abundant morphotypes were BT-23 (palm) and BT-34 (dicot/laurel) (Table 3.3). The late Paleocene locality (JW1802) lab collection had 54 specimens composed of 12 morphotypes. Dicots BT-02 and BT-15 were the two most abundant morphotypes (Table 3.4).

Several morphotypes were shared among the localities. Two morphotypes, BT-02 and BT-28, were present in all three localities (Table 3.5, Appendix). BT-01 and BT-29 are present in the PETM and the early Eocene, BT-21 is present in the late Paleocene and

PETM intervals, and BT-34 is present in the late Paleocene and early Eocene (Table 3.5). The fossil leaves observed from other localities within the Gulf Coastal Plain share morphotypes in common with those found at Bastrop, Texas, including BT-02, BT-05, BT-06, BT-09, BT-12, BT-14, BT-20, BT-23, BT-30, BT-34, BT-35 and BT-37 (Table 3.6., Fig. 2.2).

Table 3.2. Field and lab census data for locality JW1801 (PETM) collected in Bastrop, Texas.

| JW1801 | Field Census | Lab Census | Total |
|---|---|---|---|
| BT-01 | 81 | 51 | 132 |
| BT-02 | 105 | 36 | 141 |
| BT-03 | 0 | 5 | 5 |
| BT-04 | 0 | 1 | 1 |
| BT-05 | 3 | 1 | 4 |
| BT-06 | 0 | 2 | 2 |
| BT-07 | 0 | 1 | 1 |
| BT-08 | 0 | 1 | 1 |
| BT-09 | 10 | 8 | 18 |
| BT-11 | 3 | 2 | 5 |
| BT-12 | 0 | 1 | 1 |
| BT-13 | 5 | 3 | 8 |
| BT-14 | 17 | 16 | 33 |
| BT-16 | 9 | 17 | 26 |
| BT-19 | 0 | 1 | 1 |
| BT-20 | 40 | 27 | 67 |
| BT-21 | 37 | 17 | 54 |
| BT-29 | 0 | 1 | 1 |
| BT-31 | 0 | 2 | 2 |
| BT-32 | 0 | 2 | 2 |
| BT-33 | 0 | 2 | 2 |
| BT-38 | 0 | 2 | 2 |
| BT-39 | 0 | 1 | 1 |
| Total Specimens: | 310 | 200 | 510 |

Table 3.3. Field and lab census data for locality JW1803 (early Eocene) collected in Bastrop, Texas.

| JW1803 | Field Census | Lab Census | Total |
|---|---|---|---|
| BT-01 | 3 | 4 | 7 |
| BT-02 | 8 | 7 | 15 |
| BT-22 | 22 | 4 | |
| BT-23 | 45 | 20 | 65 |
| BT-24 | 20 | 8 | 28 |
| BT-25 | 7 | 2 | 9 |
| BT-27 | 3 | 2 | 5 |
| BT-28 | 21 | 17 | 38 |
| BT-29 | 2 | 1 | 3 |
| BT-30 | 143 | 15 | 158 |
| BT-34 | 48 | 19 | 67 |
| BT-35 | 7 | 5 | 12 |
| BT-44 | 15 | 4 | 19 |
| Total Specimens: | 344 | 108 | 426 |

Table 3.4. Lab census data for locality JW1802 (late Paleocene) collected in Bastrop, Texas (GPS).

| JW1802 | Lab Census |
|---|---|
| BT-02 | 10 |
| BT-10 | 1 |
| BT-15 | 23 |
| BT-17 | 1 |
| BT-21 | 9 |
| BT-28 | 1 |
| BT-34 | 1 |
| BT-36 | 1 |
| BT-37 | 1 |
| BT-40 | 1 |
| BT-41 | 2 |
| BT-42 | 2 |
| Total Specimens: | 53 |

Table 3.5. Presence/absence data for the late Paleocene, PETM, and early Eocene flora. The 'X' indicates presence in each locality.

| Morphotype | late Paleocene | PETM | early Eocene | Type |
|---|---|---|---|---|
| BT-01 | | X | X | Dicot |
| BT-02 | X | X | X | Dicot |
| BT-03 | | X | | Dicot |
| BT-04 | | X | | Dicot |
| BT-05 | | X | | Dicot |
| BT-06 | | X | | Dicot |
| BT-07 | | X | | Dicot |
| BT-08 | | X | | Dicot |
| BT-09 | | X | | Dicot |
| BT-10 | X | | | Dicot |
| BT-11 | | X | | Dicot |
| BT-12 | | X | | Dicot |
| BT-13 | | X | | Dicot |
| BT-14 | | X | | Dicot |
| BT-15 | X | | | Dicot |
| BT-16 | | X | | Dicot |
| BT-17 | X | | | Dicot |
| BT-18 | | X | | Dicot |
| BT-19 | | X | | Dicot |
| BT-20 | | X | | Monocot |
| BT-21 | X | X | | Monocot |
| BT-22 | | | X | Dicot |
| BT-23 | | | X | Monocot |
| BT-24 | | | X | Dicot |
| BT-25 | | | X | Dicot |
| BT-26 | | X | | Dicot |
| BT-27 | | | X | Fern |
| BT-28 | X | | X | Dicot |
| BT-29 | | X | X | Dicot |
| BT-30 | | | X | Monocot |
| BT-31 | | X | | Dicot |
| BT-32 | | X | | Fern |
| BT-33 | | X | | Dicot |
| BT-34 | X | | X | Dicot |
| BT-35 | | | X | Dicot |
| BT-36 | X | | | Dicot |
| BT-37 | X | | | Dicot |
| BT-38 | | X | | Dicot |
| BT-39 | | X | | Fern |
| BT-40 | X | | | Dicot |
| BT-41 | X | | | Dicot |
| BT-43 | X | | | Dicot |
| BT-44 | | X | X | Dicot |

Table 3.6. Morphotype localities throughout the GCP in the Wilcox and Claiborne groups. All reference and collection data were taken from the fossil specimen labels. References and collection information for fossil localities are: Warman Clay Pit, Steve Manchester (1989) and Zhenbo Sun (1989); Somerville, Puryear Clay Pit, Miller Clay pit, F.W. Potter Jr. (1976); Calvert Lignite Mine, R. S. Irving & T.F. Stuessy (1971); Jewitt Coal Mine, collected by N. Frisbee, J. Wolfe, and David Dilcher in 1996 (no publication); Hope, Arkansas, collected by David Dilcher in 1976 (no publication); Marshall, Texas, collected by T. Delevoryas (no publication).

| Morphotype | Location | Formation |
|---|---|---|
| BT-01 | Warman Clay Pit; Como, TN Quadrangle; 36° 17' 15" N, 88° 31' 49" W | Upper Claiborne |
| BT-01 | Lamkin Clay Pit; Kentucky, US; 36.8638111000, -88.6980556000 | Claiborne |
| BT-02 | Somerville, TN; 35° 15' 47" N, 89° 21' 15" W; | Claiborne |
| BT-02 | Puryear Clay Pit; Henry County, TN; 36° 26' 17" N 88° 20' 15" W | Claiborne |
| BT-02 | Miller Clay Pit; Henry, TN; 36° 13' 15" N 88° 28' 46" | Claiborne |
| BT-02 | Hope, Arkansas; 30°40'01" N, 93°35'09" W | Claiborne |
| BT-02 | Marshall, TX; Harrison County; Marshall Clay Company | Wilcox |
| BT-02 | Warman Clay Pit; Como, TN Quadrangle; 36° 17' 15" N, 88° 31' 49" W | Upper Claiborne |
| BT-04 | Marshall, TX; Harrison County; Marshall Clay Company | Wilcox |
| BT-05 | Marshall, TX; Harrison County; Marshall Clay Company | Wilcox |
| BT-06 | Marshall, TX; Harrison County; Marshall Clay Company | Wilcox |
| BT-09 | Warman Clay Pit; Como, TN Quadrangle; 36° 17' 15" N, 88° 31' 49" W | Claiborne |
| BT-09 | Marshall, TX; Harrison County; Marshall Clay Company | Wilcox |
| BT-10 | Puryear Clay Pit; Henry County, TN; 36° 26' 17" N 88° 20' 15" W | Claiborne |
| BT-12 | Warman Clay Pit; Como, TN Quadrangle; 36° 17' 15" N, 88° 31' 49" W | Claiborne |
| BT-14 | Marshall, TX; Harrison County; Marshall Clay Company | Wilcox |
| BT-20/23 | Warman Clay Pit; Como, TN Quadrangle; 36° 17' 15" N, 88° 31' 49" W | Upper Claiborne |
| BT-20/23 | Calvert Lignite Mine; Robertson County, TX; 31° 06' 06" N, 96° 39' 58" W | Wilcox |
| BT-20/23 | Jewett Coal Mine; Freestone County, TX; 31° 28.23 N 96° 09.64 W | Claiborne |
| BT-30 | Marshall, TX; Harrison County; Marshall Clay Company | Wilcox |
| BT-34 | Puryear Clay Pit; Henry County, TX; 36° 26' 17" N 88° 20' 15" W | Claiborne |
| BT-34 | Calvert Lignite Mine; Robertson County, TX; 31° 06' 06" N, 96° 39' 58" W | Wilcox |
| BT-35 | Warman Clay Pit; Como, TN Quadrangle | Upper Claiborne |
| BT-37 | Marshall, TX; Harrison County; Marshall Clay Company | Wilcox |

*Diversity*

The rarefaction curves for both the PETM and early Eocene specimens' display similar species richness (10 and 13 morphotypes, respectively) and plateau, which indicates that the sites have been well sampled (Fig. 3.2). The floras also had very similar levels of diversity and dominance (Table 3.7). However, despite having similar levels of

species richness and diversity, the floras had markedly different floral compositions demonstrated by the Bray Curtis Dissimilarity value of 0.966 and a Jaccard's Index of Similarity of 0.095 (Table 3.8).

*Paleoecology*

All of the floras had similar site mean and median leaf mass per area and were comprised primarily by taxa reconstructed to be deciduous, though there was a small component of evergreen taxa in each flora. For the late Paleocene locality, the mean and median leaf mass per area was 93 $g/m^2$ (uncertainty: upper 213 $g/m^2$ and lower 41 $g/m^2$) (Fig. 3.3), and 2 of the 6 morphotypes (BT-36, BT-37) had LMA values indicating that they were likely evergreen. The mean leaf mass per area for the PETM locality was 93 $g/m^2$ (uncertainty: upper 177 $g/m^2$ and lower 51 $g/m^2$) (Fig. 3.3), and four morphotypes (BT-04, BT-05, BT-06, and BT-12) were likely evergreen. The early Eocene locality had one morphotype (BT-35) that was likely evergreen, and the mean and median leaf mass per area was 84 (uncertainty: upper 134 $g/m^2$ and lower 53 $g/m^2$) (Fig. 3.3). Although the mean and median leaf mass per area was similar between the sites, the distributions of leaf mass per area at each locality are considerably different (Fig. 3.4). In particular, the PETM had a much wider distribution of leaf mass per areas than the late Paleocene and early Eocene sites (Fig. 3.4), suggesting differences in the paleoecology of the PETM flora from the other sites.

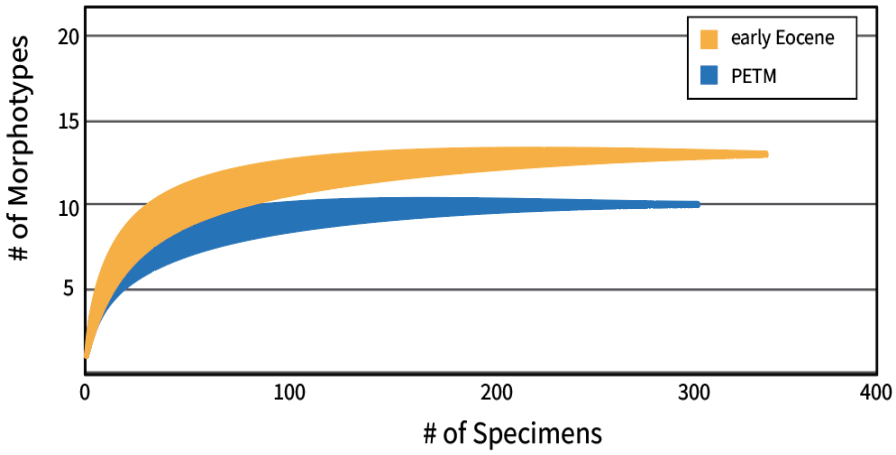


Figure 3.2. Rarefaction curves for the PETM (JW1801) and early Eocene (JW1803) field census collection data. The PETM and early Eocene census data consists of 310 specimens, 10 morphotypes and 347 specimens, 11 morphotypes, respectively.

Table 3.7. Diversity values for 'PETM' and late Eocene flora from Bastrop, Texas. Floral diversity was assessed using PAST (Hammer et al. 2001) from quantitative (census) collections.

| Locality | Shannon Index | Simpson Index (1-D) | Equitability (Evenness) | Berger-Parker Dominance |
|---|---|---|---|---|
| early Eocene | 1.913 | 0.776 | 0.746 | 0.416 |
| PETM | 1.764 | 0.781 | 0.766 | 0.339 |

Table 3.8. Diversity comparisons of the PETM and early Eocene census collections. See methods for equations.

| Communities | Bray Curtis Dissimilarity | Jaccard's Index of Similarity |
|---|---|---|
| PETM vs early Eocene | 0.966 | 0.095 |

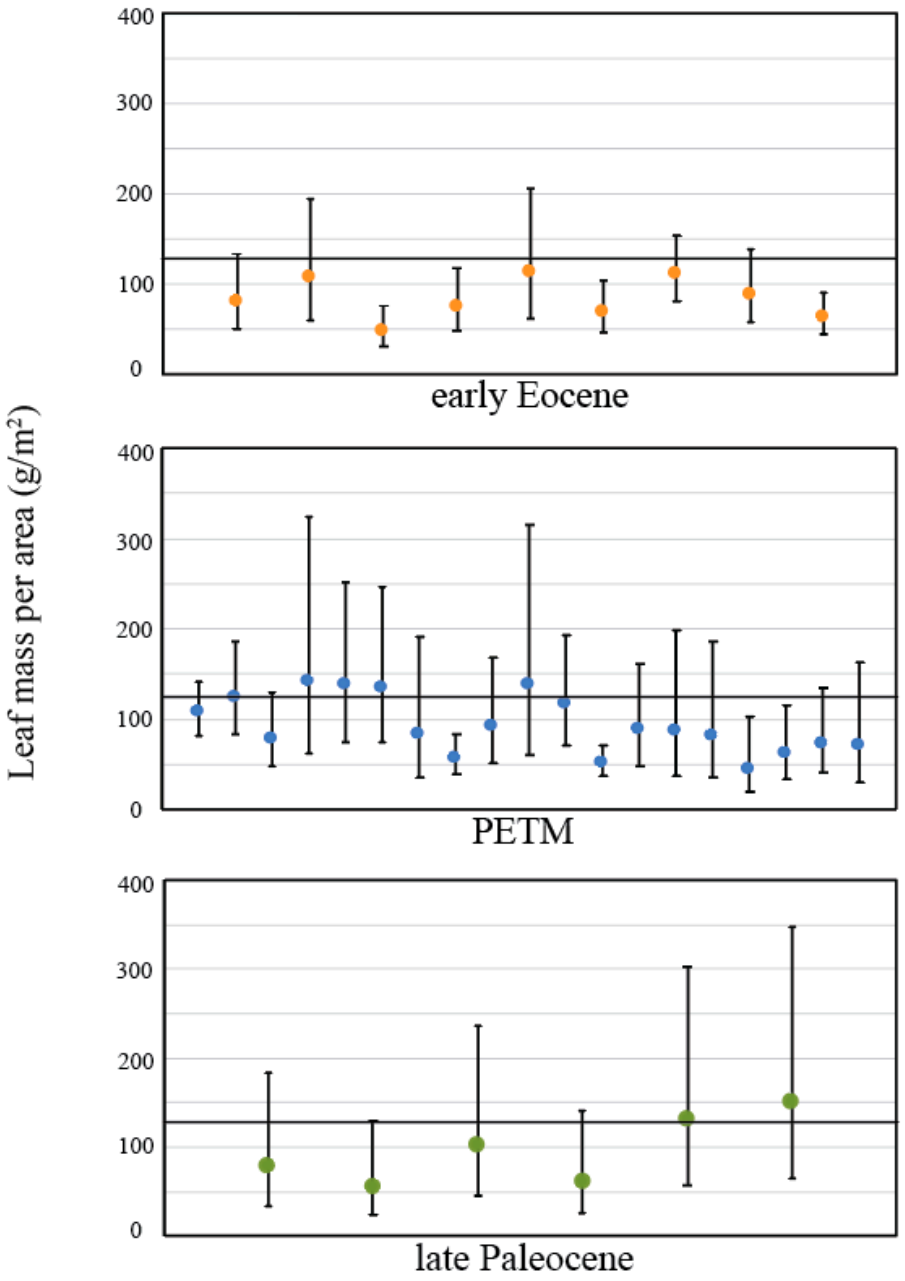


Figure 3.3. LMA values with standard error bars for the late Paleocene, PETM, and early Eocene GCP central Texas flora. The horizontal scale represents the deciduous/evergreen 'threshold' of 129 g/m$^2$. Values >129 g/m$^2$ are suggested to be evergreen and <129 g/m$^2$ are suggested to be deciduous. Average LMA values for the Late Paleocene, PETM, and early Eocene localities are 93, 93, and 84 g/m$^2$, respectively. All values were calculated using vein-density scaled leaf area and the Royer et al. (2012) method.

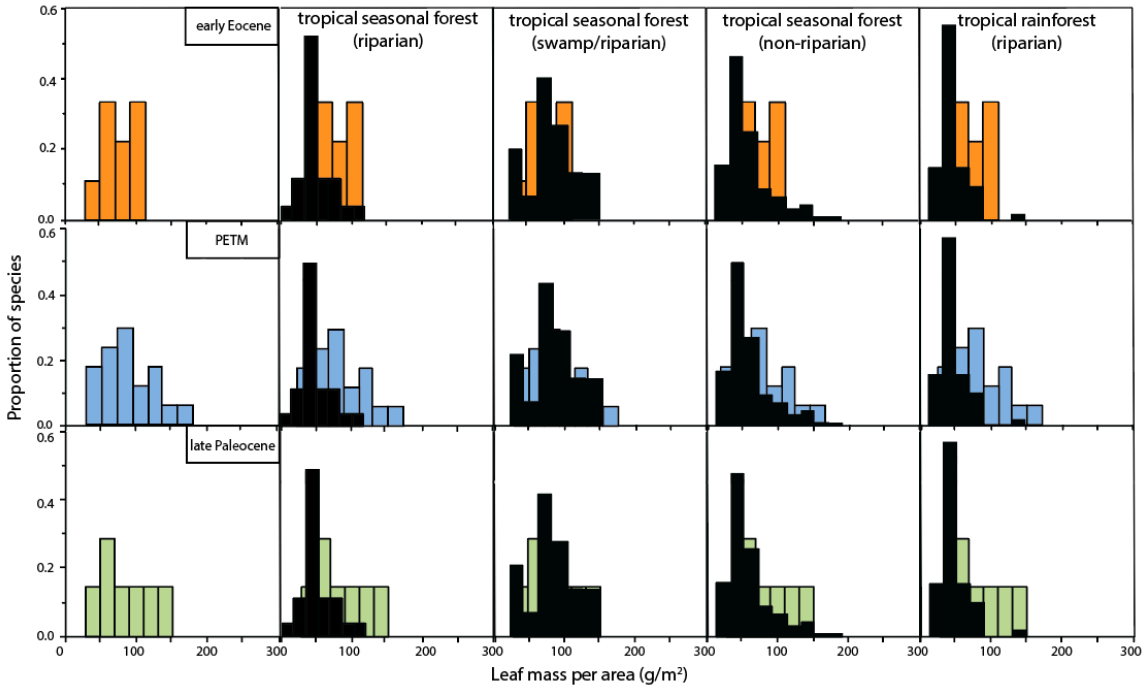


Figure 3.4. Distribution of LMA values for the late Paleocene, PETM, and early Eocene localities in central Texas. The black bars in each column represent modern day tropical LMA distributions, from Peppe et al. (2011). The late Paleocene distribution is most similar to the modern swamp/riparian tropical seasonal forest, the PETM is most similar to the non-riparian tropical seasonal forest, and the early Eocene distribution is an overall poor fit for the modern-day tropical forest LMA distributions.

# CHAPTER FOUR

## Discussion

### *Composition and Diversity of Central Texas Gulf Coastal Plain Floras*

An overall change in floral composition from the Paleocene to the Eocene was observed. The late Paleocene flora was dominated by dicots. Monocots were present, but much less abundant in number of morphotypes and abundance of specimens when compared to the younger localities. Further, unlike the other two sites, ferns and gymnosperms were not present. Two dicots dominated the assemblage and legume-like fruits were relatively common. Given the composition of the flora and the dominance of a few taxa in the total assemblage, the flora was probably low in species richness and diversity. This could not be tested further because the flora was relatively poorly preserved and not amenable to systematic collecting. However, the flora was sufficiently well preserved to compare the taxonomic composition of the flora with the other two sites.

The PETM flora contained approximately twice the number of morphotypes than either the late Paleocene or the early Eocene floras (Table 3.1). With a total of 23 morphotypes, the flora was dominated by 4 taxa (3 dicots, 1 palm) with the other morphotypes being relatively rare. Despite the relatively high richness in the voucher collection, the census collection yielded only 10 morphotypes, suggesting that extensive voucher sampling yielded rare morphotypes that were not observed in the census collection. Interestingly, despite the marked difference in species richness between the

voucher and census collections, rarefaction analysis for the census collection suggests the site was well sampled (Fig. 3.2). The presence and increased abundance of palms and ferns in the PETM deposit suggests a change in the flora composition, which is complemented by the presence of dicot morphotypes which were not present in the late Paleocene (Table 3.5). There are only two morphotypes that persist from the late Paleocene into the PETM (BT-02 and BT-01), both of which are more abundant in the PETM than the late Paleocene.

The early Eocene flora was dominated by palms and a laurel-like morphotype (BT-34) (Table 3.3). The voucher and census collections yielded 13 distinct morphotypes and rarefaction suggested the collection was well-sampled (Fig. 3.2). Of the 11 Paleocene morphotypes that were apparently extirpated during the PETM (Table 3.5), only 2 return and are present in the early Eocene flora (BT-28 and BT-34). Morphotype BT-02 (mentioned above, high in abundance during the PETM) decreased in abundance during the early Eocene, returning to an abundance similar to what was observed in the late Paleocene locality. The diversity of the PETM and early Eocene floras were similar (Table 3.7), but the Berger-Parker Dominance value was greater in the early Eocene (Table 3.8), indicating the site was more dominated by a few taxa. Though the diversity indices are similar between the PETM and Eocene sites are similar, the floral composition is significantly different (Table 3.8) suggesting that the high turnover in floral composition had little effect on the overall diversity of the flora.

### *Gulf Coastal Plain Early Paleogene Floras*

The Wilcox and Claiborne Group fossils housed by the University of Florida Natural History Museum were collected along the Gulf Coastal Plain stretching from Bastrop,

Texas to the southwest corner of Kentucky during many prior field campaigns (Fig. 2.2). The localities across the GCP and southeastern United States share ~15 morphotypes (Table 3.6). The most common morphotypes to appear in the other GCP localities are BT-02, BT-20, BT-23, and BT-34. It appears these morphotypes belong to the Juglandaceae, Arecaceae, and Lauraceae families, respectively.

BT-02, the lanceolate, usually entire, Juglandaceous-type leaf, was the most common morphotype throughout the observed GCP floras. Berry (1916) described several fossil leaf morphotypes similar to BT-02. In addition, Dilcher and Manchester (1986) created a new genus for a fossil leaf with characteristics very similar to BT-02, *Oreoroa,* to accommodate leaves similar to *Oreomunnea* and *Alfaroa*. Extant *Oreomunnea* and *Alfaroa* are genera of evergreen trees that grow in montane/sub-montane tropical rain forests in Central America. They typically have pinnately compound leaves with lanceoloate leaflets.

The *Oreoroa* described by Dilcher and Manchester (1986) ranges from Middle Eocene to the Upper Miocene in Europe and is very common in the Eocene of south eastern North America. Furthermore, they described one particular species of *Oreoroa*, *O. claibornensis*, based on its locality in the Claiborne Formation in Mississippi, Tennessee, and Kentucky. Similar morphotypes across the GCP, possibly either *O. claibornensis* or other species of *Oreoroa*, were present in the GCP floras access, with primary difference being the margin type with some specimens have a serrated margin and others an entire margin. In addition to the fossil leaves of *Oreoroa*, abundant *Momipites*-type pollen have been described from the same setting as the Bastrop, TX GCP flora (Stephenson et al., 2018) as well as being described in other locations across

the GCP (Elsik and Grabaugh, 2001; Dickey and Yancey, 2010), and it is thought that *Oreoroa sp.* likely produced this pollen type.

BT-20 and BT-23, fan palms from the Arecaceae family, possibly subfamily Coryphoideae (Gomez-Navarro et al. 2009), appear throughout the GCP in the Wilcox and Claiborne Groups in Tennessee and Texas (Table 3.6). The macrofossil palms appear to be very similar in morphology between GCP sites, but more analysis is needed to determine if they are the same species. Multiple palm pollen types have been identified in the same setting in Bastrop, including *Arecipites*, *Pandanus*, and *Butia* types (Stephenson et al., 2018). Interestingly, one of the taxa that appears in the body of the negative CIE in the Bighorn Basin was a palm (Wing et al., 2006), and perhaps the GCP palms were the source of the NGP palm taxa. During the Paleocene and Eocene, palms experienced a significant radiation event (Gomez-Navarro et al. 2009), which coincides with the long-term global warming of the early Paleogene (e.g., Zachos et al., 2007;). The trend observed in the central TX early Paleogene flora is an increased palm abundance from the late Paleocene into the early/mid Eocene, which coincides with this radiation event (Harley 2006; Dranfield et al., 2008). The hyperthermal events could have acted as catalyst moments, providing opportunities for palm species to increase in abundance in subtropical areas (e.g. the GCP) and appear in high latitudes during the 'hyperthermal' events (e.g. the PETM).

BT-34 is a species within the Lauraceae family that is present in Texas and Tennessee Claiborne Group localities. It is likely an evergreen tree or shrub, possibly in the genus *Cinnamomum*. This morphotype was not present in the central TX PETM locality, but appeared in the late Paleocene and early Eocene localities (Table 3.5).

The GCP would have been composed of a variety of coastal and offshore environments during the early Paleogene, as the ocean transgressed repeatedly into North America. This is complemented by the location of the Wilcox and Claiborne Groups in the GCP, in addition to the sedimentary structures present in the studied sections (Fig. 1.1, 2.2). The decrease in the temperature latitudinal gradient between the lower and upper latitudes due to the rapid warming of the early Paleogene (Zachos et al., 2001; Wing et al., 2005; McInerney and Wing, 2011) would have created a sub-tropical/tropical coastal environment composed of similar taxa throughout the GCP. The presence of shared morphotypes along the GCP early Paleogene deposits suggests that a 'paratropical belt' consisting of similar taxa was likely present across the region during the Early Paleogene.

*Paleogene Floras Across the PETM*

In central Texas, the morphotypes present before, during, and after the PETM are distinctly different with only one morphotype persisting for the entire interval. This is similar to what is observed in the Bighorn Basin (Wing & Currano 2013) between the Paleocene and the PETM where extirpation is high and eighty-eight percent of plant taxa from the latest Paleocene are not recorded during the PETM interval, and only two Paleocene taxa persisted through the onset, body and recovery of the CIE. During the recovery period of the CIE and further into the early Eocene in the Bighorn Basin, 22 of the locally extirpated taxa from the late Paleocene return and 5 'immigration' taxa remain (McInerney & Wing, 2011). The GCP flora in central Texas shows a markedly different pattern; the Eocene flora does not return to its previous Paleocene composition and relatively few taxa persist from the PETM into the Eocene. Rather, 2 morphotypes return (BT-28, BT-34), 4 morphotypes from the PETM interval remain (including BT-02, the

only persistent taxa), and 7 new morphotypes appear. This suggests that the floral recovery following the PETM in the GCP was very different from that in the NGP.

The rarefaction curves of the Bighorn Basin PETM flora (Wing et al., 2005) suggest a standing species richness between 15-30 morphotypes which is greater than the standing species richness of the PETM and early Eocene flora of the GCP (10 and 13 taxa, respectively)(Fig. 4.1). The greater species richness of the Bighorn Basin flora suggests there may have been higher turnover rates or opportunities for greater diversification. It is interesting that the GCP PETM flora have a lower standing richness than the Bighorn Basin flora, given that it is at a lower latitude and typically richness and diversity decrease with increasing latitude (Stevens, 1989). The higher standing richness could be attributed to the difference in environments; the flora of the GCP was marine influenced while the NGP flora was terrestrial. The tidally influenced, marsh-like environment of the GCP flora may have limited the niche space available for current and immigrating taxa (i.e. flora adapted to coastal, marsh-like environments). However, despite the differences in species richness, the percent of dicots, monocots, and ferns in the Bighorn Basin ruing the PETM is comparable to that of the GCP PETM and early Eocene (Fig. 4.1).

The turnover and extirpation of the flora of the mid-latitude Bighorn Basin (~44 °N) during the onset, body, and recovery of the PETM has been associated with higher temperatures and increased water stress (Secord et al. 2012; Kraus et al. 2013; Wing & Currano 2013). Once the temperatures and precipitation returned to pre-PETM conditions, the PETM taxa were likely pushed out and the taxa with an affinity for cooler temperatures and low water-stress environments returned (McInerney & Wing, 2011;

Wing & Currano, 2013). In higher latitudes (Arctic, 70-80°N), the PETM flora is characterized by a decrease in conifer abundance and an increase in angiosperm abundance (Sluijs et al. 2006) and is associated with high water availability and runoff. In the tropics, there is a significant increase in diversity from the late Paleocene into the Eocene, suggesting that water stress and high temperatures during the PETM did not exceed the tolerance of the tropical vegetation (Jaramillo et al. 2010). While there is noticeable turnover in floral composition, there is no change in species richness or diversity between the PETM and Eocene in the relatively low latitude (~30 °N) GCP floras in central Texas.

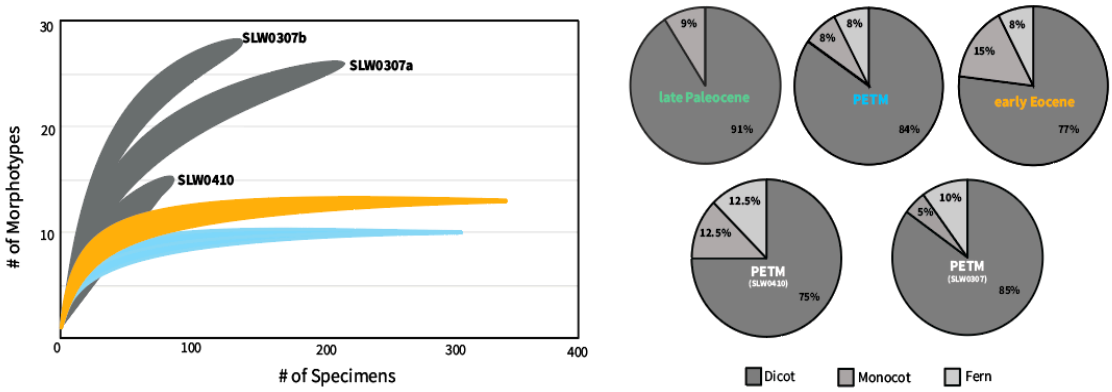


Figure 4.1. Rarefaction curves and plant composition for the Bighorn Basin in Wyoming PETM (Wing et al., 2008; SI) in relation to the GCP Paleocene-Eocene rarefaction and plant composition. The localities are SLW0410 and SLW0307ab, 3 and 37 meters above the base of the CIE, respectively. PETM and early Eocene rarefaction represented by the blue and orange curves, respectively.

The lack of diversity and species richness change suggests that as turnover was occurring in central Texas, the flora's threshold for tolerating higher temperatures and increased seasonality was not breached, rather it allowed for immigration of taxa from the tropics while the local taxa either remained and were out competed or dispersed to more

northern latitudes. This would explain the increased turn-over at the Paleocene-Eocene boundary with little change in diversity and species richness.

As emphasized by Wing and Currano (2013), plant community response to the rapid warming and change in seasonality varied depending on latitudinal location. In the Arctic where there was increased runoff and precipitation, conifer abundance decreased, and angiosperm abundance increased. In the mid-latitudes of North America, higher temperatures and water-stress coincided with extirpation of local NGP flora which were replaced by thermophilic, mimosoid-like flora. In the lower latitudes of North America, the GCP flora of the Paleocene-Eocene boundary had a high turnover rate, with little change in diversity and species richness. In the tropics of South America where the heat tolerance threshold was likely not reached, flora diversity increased during the Paleocene-Eocene transition.

In summary, fossil evidence from North America, Europe, and South America suggests that the warming of the PETM increased turnover rates in low, middle, and high latitudes, increased diversity near the equator (i.e. tropical regions), and created a 'paratropical belt' that extended into the mid-latitudes where the flora turnover and diversity would have been more likely to be influenced by heat-tolerance thresholds and increased aridity (Jaramillo et al., 2010; McInerney and Wing, 2011; Wing and Currano, 2013). Understanding the variation and dynamics of flora and fauna response to rapid global warming will be essential for current and future climate change, as farmlands and food production are likely to be affected.

*Paleoecology*

Leaf mass per area can be used to assess the leaf economics for fossil taxa and their correlated habitat (Royer et al. 2007). The threshold for the woody dicot calibration is 129 g/m$^2$ with deciduous taxa being <129 g/m$^2$ and evergreen taxa being >129 g/m$^2$. Because vein density was used to scale and estimate the complete size of the incomplete fossil leaves, it is important to mention there are already assumptions underway when the LMA was estimated. The late Paleocene, PETM, and early Eocene leaf mass per area distributions have similar averages (93, 93, and 84 g/m$^2$, respectively) and do not exactly resemble the modern-day tropical seasonal and rain forest distributions, although there are some commonalities.

The distribution of the late Paleocene flora is most similar to distributions seen in modern swamp/riparian tropical seasonal forests (Fig. 3.4). The width of the distribution (40- 150 g/m$^2$) is very similar to the modern tropical seasonal forest (swamp/riparian) distribution, but the proportion of morphotypes is different; 30% of the flora in the late Paleocene were 50-60 g/m$^2$ and only 10% of the modern tropical seasonal forest (swamp/riparian) flora were in the same category. Bastrop's Wilcox and Claiborne Groups have recently been re-described as coastal marine and just onshore, based on the lithology, ichnology, and palynology (Denison et al., 2017). The environment of deposition was probably within and offshore from a tide-dominated deltaic system, including tidal lagoons, tidal channels and bars, tidal marshes, and peat-producing topogenous mires, as indicated by the sedimentology, organic petrography, palynology, and ichnofossils. (Denison et al. 2017; O'Keefe et al., 2017; Stephenson et al., 2018). Thus, the plants inhabiting this region at the time would have needed to be tolerant of salt

spray, tidal changes, brackish water, and possibly winds. These plant communities are often low in diversity due to such harsh, changing environments (Mitsch and Gosselink, 2015).

The PETM distribution was most similar to the tropical seasonal forest (non-riparian) (Fig. 3.4). The leaves deposited in the channel fill were likely sourced from the surrounding area which complements the non-riparian characteristic of the PETM flora. Most of the leaves are well preserved with ≥50% of the leaf being present, suggesting relatively limited transport. Because the PETM flora composition is significantly different from the pre and post PETM flora, the wide distribution may be the result of new taxa establishing territory in the GCP while the previous taxa were being 'extirpated'. The number of morphotypes during the PETM, particularly the morphotypes that were not present in the field census collection, could represent species diversification as new niche spaces were created during the Paleocene-Eocene flora turnover. This difference could also be attributed to the depositional environment, as the channel fill was composed of multiple splays and the census collection may have sampled a single splay, while the voucher collection may have comprised multiple splays. In addition, the ecosystem suggested by the palynology is a peat-producing sawgrass marsh near a hardwood hammock (Stephenson et al., 2018). Hardwood hammocks typically comprise a mixture of diverse evergreen and semi-deciduous tree and shrub species and are often closed canopy. The LMA distribution of the central Texas PETM macroflora suggests a mixture of evergreen, semi-deciduous, and deciduous taxa, supporting the hypothesis of a hardwood hammock ecosystem.

The early Eocene distribution did not resemble any of the modern-day tropical rainforest and tropical seasonal forest distributions (Fig. 3.4). The distribution of the flora is primarily deciduous with ~30% of the flora being between 100-120 g/m$^2$, suggesting these floras may have been semi-deciduous. The increase in palm abundance observed in the early Eocene flora and the heterolithic coarsening upwards with well-developed muddy tidal flat deposits of the early Eocene locality suggest an offshore coastal environment, possibly surrounding a tidal marsh, rich in palms, deciduous to semi-deciduous shrubs, and scattered ferns. The palynology described from the same locality in the Carrizo Sand at Manawanui Drive suggests a shallow shelf environment offshore from a brackish tidal marsh with low pollen diversity and the presence of fungi (Stephenson et al., 2018). The Shannon and Simpson (1-D) Index values for the early Eocene macroflora suggests a low diversity with moderately high evenness. Salt marshes are typically low in diversity with a variety of plant compositions depending on the salinity gradient (Mitsch and Gosselink, 2015).

Comparisons of the LMA distributions of the central Texas flora and the Bighorn Basin (Currano et al., 2008) suggest the central Texas GCP late Paleocene flora and the NGP Bighorn Basin PETM flora have similar deciduous/evergreen distributions (Fig. 4.2). The GCP late Paleocene distributions range from 56-151 g/m$^2$ and the NGP PETM distributions range from 53-156 g/m$^2$ with average LMAs of 93 and 89 g/m$^2$, respectively. This suggests similar ecological habitats and supports the hypothesis of the expansion of a 'paratropical' belt during the PETM into the NGP. However, only a few morphotypes present in the late Paleocene of the central Texas GCP resemble the flora of the Bighorn Basin (BT-20, BT-23, BT-24, BT-28, and BT-41; 2 palms, a laurel, an

unidentified dicot leaf, and a legume-like fruit, respectively). The legume-like fruits (specifically of the morphology of BT-41, see Appendix) were solely observed in the late Paleocene flora of the central Texas GCP, which is interesting considering the thermophilic taxa present in the NGP PETM flora were rich in mimosoid-like legumes which would have produced fruit similar to the fruit present in the late Paleocene.

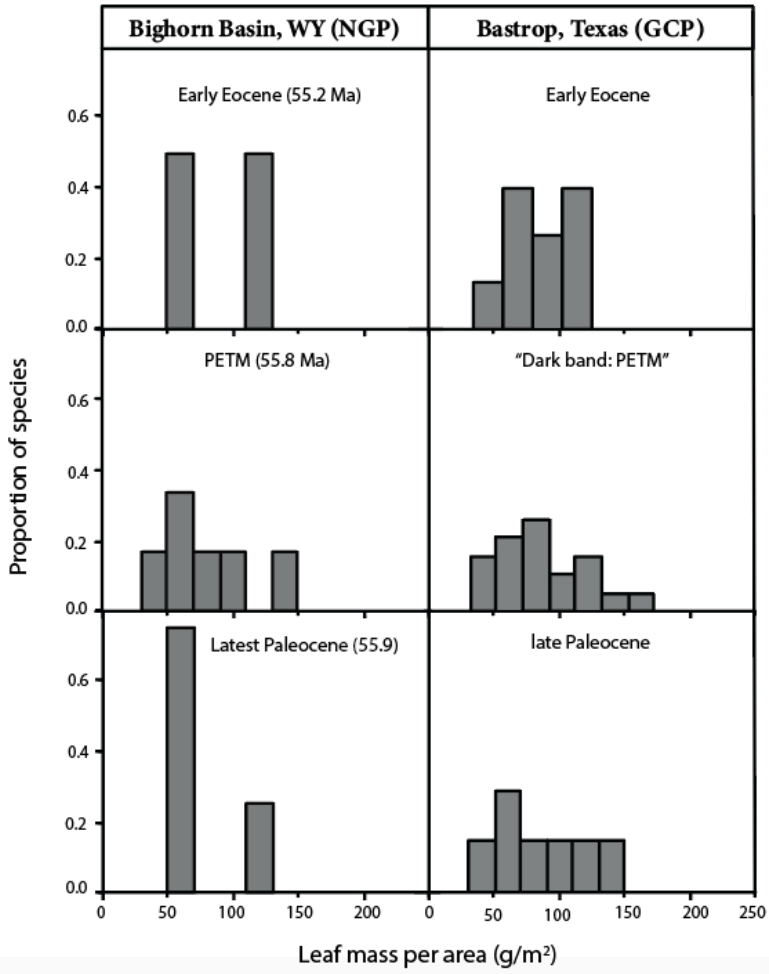


Figure 4.2. Estimated LMA distributions of fossil flora from Bighorn Basin in WY and GCP central TX. Bighorn Basin data taken from Currano et al. (2008) supplemental data. Latest Paleocene: USNM 416413, 'Clarkforkian 3' (55.9 Ma); PETM: USNM 42384, 'Wasatchian 0' (55.8 Ma); early Eocene: USNM 42395-42399, 'Wasatchian 2' (55.2 Ma). The Royer et al. (2007) method was used to estimate all LMA values.

Data suggest the environments of the late Paleocene, PETM, and early Eocene flora of the central Texas GCP were coastal, tidally influenced lagoons or marshes, which transitioned to an offshore shallow-shelf environment abundant with palms and moderately diverse dicots. All floras in this study would have been strongly influenced by and adapted to coastal, marine environments. A variety of microhabitats develop along coastal areas in response to tidal influences and salinity gradients (Sternberg et al., 1991). Plant community composition can change due to changes in sea level as a result of a change in salinity; this is observed in lower, middle, and upper marsh habitats due to varying salinity gradients (Gough and Grace, 1998). Eustatic sea level rise was occurring during the PETM and dinoflagellate cyst composition suggests this rise in sea level would have shifted the deposition of terrigenous material landward (Sluijs et al., 2014). This coincides with the change in depositional environments observed across the Paleocene-Eocene boundary in central Texas and along the GCP (i.e. transitioning from the progradational parasequence of muddy tidal flats of the Sabinetown to the shallow marine transgression of the 'Dark Band' and ultimately to the cross-bedded sandstone with herringbone crossbedding deposits within the Carrizo Sand formation) (Yancey et al., 2010; Yancey et al., 2012; Sluijs et al.,2014; Denison et al., 2017).

Microfossil studies show that seasonal euxinic photic zone conditions developed along the GCP at the Paleocene-Eocene boundary (Sluijs et al., 2014) and it has been suggested that this led to shelf eutrophication, which facilitated carbon burial along continental margins, ultimately acting as negative feedbacks to carbon input and global warming (Sluijs et al., 2014). Coastal habitats (submerged or partially submerged) often reduce the flow of turbulence and dampen wave energy while their roots trap sediment

and prevent resuspension of sediment (Duarte et al.,2013). As a result, these coastal regions act as large carbon deposits, influence basin accommodation space, regulate nutrient fluxes, and provide a form of climatic regulation (Duarte et al., 2013). If this is the case, coastal plant communities within the GCP, specifically those with tidal marsh, mangrove, and hardwood hammock characteristics, may have played an essential role in sediment accumulation during the PETM.

Flora compositions within the GCP would have been changing in response to sea level rise and salinity change during the PETM, in addition to the expansion of 'paratropical' belt ecosystems and immigration of topical or subtropical plants. This is important to consider when evaluating the source of the NGP flora and possible immigration of the GCP flora, as well as when comparing the response of coastal and inland floral communities and composition to rapid climate change. Certain taxa found in central Texas may have been restricted to the coast and unlikely to be found inland in areas such as the NGP. Taxa with similar ecological niches that are not restricted to coastal areas (i.e. morphotypes present further inland in places like TN, AR, and KY) may more likely be the source of the flora, but more descriptions and accurate dating along other areas of the GCP are necessary to test this hypothesis.

Ongoing destruction of coastal environments (salt marshes, tidal lagoons, hardwood hammocks, mangrove forests) has been well documented and studied (Watson and Byrne, 2009) because of the recognized ecological and biogeochemical importance of such habitats. Current global warming is occurring at a faster rate than what is observed at the Paleocene-Eocene boundary. If these habitats play an important role in carbon sequestration and they are already being destroyed due to anthropogenic effects

(Watson and Byrne, 2009), they may not be able to keep up with the pace of current climate change and essential carbon sinks could be lost.

### *Conclusions and Future Work*

The Paleocene-Eocene macrofossil flora of the central Texas GCP suggest a high turnover rate and change in plant community composition at the Paleocene-Eocene boundary in response to rapid global warming. The response of flora and fauna during the onset, body, and recovery of the PETM is important for understanding how biota will respond to current and future global warming. Coastal plant compositions and distributions will likely depend on sediment accumulation, keeping pace with rising sea levels (Watson and Burne, 2009), heat tolerance thresholds (Wing and Currano, 2013), and immigration of new or invasive species (Dukes and Mooney, 1999). Environments such as marshes, swamps, and coastal lagoons are not only important ecological habitats, but also act as carbon sinks. As global temperatures continue to rise at an alarming rate, important ecological habitats are increasingly threatened due to adaptation and evolution limiting the rate at which these habitats can respond to the fast rate of global warming.

The high turnover of flora observed in the GCP suggests continuous response to the changing environment and the lack of change in diversity suggests the plant communities were not limited by heat tolerance thresholds but were influenced by changes within the environment such as salinity, sea level, and the introduction of new thermophilic taxa. The similar morphotypes throughout the Wilcox and Claiborne Groups of the southeastern U.S. GCP support the hypothesis of an expanded ‘paratropical’ belt composed of thermophilic taxa. Several of the morphotypes described in the central Texas GCP late Paleocene flora may be present in the NGP PETM flora, though more

descriptions and comparisons are necessary to confirm this hypothesis. The similarity in the LMA distributions of the GCP late Paleocene flora and the NGP PETM flora suggests an environment comparable to that of the late Paleocene flora, supporting the hypothesis of an expansion of paratropical environments into northern latitudes. More descriptions and better age constraint of the GCP flora are necessary to further evaluate the composition and transition of flora at the Paleocene-Eocene boundary across the southeastern USA and the relationship between the GCP and NGP floras.

APPENDIX

# APPENDIX

*Supplemental Data and Morphotype Descriptions*

This appendix consists of the raw leaf mass per area (LMA) data, a table summarizing all morphotypes in this study, and descriptions and images for each morphotype described in localities JW1802, JW1801, and JW1803. These represent the time periods before, during, and after the Paleocene-Eocene Thermal Maximum, respectively. Fossil dicotyledonous angiosperm (dicot) leaves were described using the Manual of Leaf Architecture (Ellis et al., 2009). Monocotyledonous angiosperms (monocots) and ferns were described primarily using venation characteristics. Based on the features observed when making these descriptions, the fossils from each locality were divided into morphotypes (Ellis et al., 2009; Peppe et al., 2008).

Each morphotype is represented by a description of the leaf architecture followed by images of the morphotypes with a figure caption listing the specimen labels, exemplars, and classification when possible. All scale bars are 5 cm long and each box is 1 cm in length. Dicots are listed first, followed by monocots, ferns, and ending with fruits, seeds, and reproductive material. Monocot, fern, and fruit descriptions are contained within the figure captions. All fossils from this study are housed at Baylor University Department of Geosciences in the Terrestrial Paleoclimatology Research Lab.

Table A.1. Average leaf mass per area values for JW1802 with standard error (95% confidence interval).

| Morphotype | Average | SE+ | SE- |
|---|---|---|---|
| BT-02 | 80.00 | 103.51 | 45.12 |
| BT-10 | 56.75 | 73.47 | 32.02 |
| BT-15 | 103.05 | 133.35 | 58.13 |
| BT-17 | 61.28 | 79.32 | 34.57 |
| BT-36 | 132.26 | 171.30 | 74.63 |
| BT-37 | 151.30 | 196.10 | 85.40 |
| BT-40 | 68.13 | 88.17 | 38.43 |

Table A.2. Average leaf mass per area values for JW1801 with standard error (95% confidence interval).

| Morphotype | Average | SE+ | SE- |
|---|---|---|---|
| BT-01 | 107.54 | 33.68 | 25.65 |
| BT-02 | 124.71 | 61.94 | 41.38 |
| BT-03 | 78.11 | 50.64 | 30.72 |
| BT-04 | 141.37 | 183.17 | 79.79 |
| BT-05 | 137.77 | 113.43 | 62.21 |
| BT-06 | 135.65 | 111.67 | 61.25 |
| BT-08 | 83.83 | 108.46 | 47.28 |
| BT-09 | 57.41 | 26.11 | 17.95 |
| BT-11 | 93.00 | 76.41 | 41.95 |
| BT-12 | 137.78 | 178.48 | 77.75 |
| BT-13 | 117.71 | 76.41 | 46.33 |
| BT-14 | 51.65 | 19.69 | 14.25 |
| BT-16 | 88.40 | 72.62 | 39.87 |
| BT-19 | 86.53 | 111.95 | 48.81 |
| BT-26 | 81.51 | 105.46 | 45.98 |
| BT-31 | 44.60 | 57.82 | 25.18 |
| BT-33 | 62.91 | 51.72 | 28.38 |
| BT-38 | 73.81 | 60.65 | 33.29 |
| BT-44 | 71.14 | 92.05 | 40.13 |

Table A.3. Average leaf mass per area values for JW1803 with standard error (95% confidence interval).

| Morphotype | Average | SE+ | SE- |
|---|---|---|---|
| BT-01 | 80.41 | 52.13 | 31.63 |
| BT-02 | 106.81 | 87.79 | 48.19 |
| BT-22 | 47.79 | 26.64 | 17.10 |
| BT-24 | 75.18 | 41.72 | 26.83 |
| BT-25 | 112.40 | 92.41 | 50.71 |
| BT-28 | 69.62 | 34.50 | 23.07 |
| BT-34 | 110.97 | 42.14 | 30.54 |
| BT-35 | 88.78 | 49.26 | 31.68 |
| BT-44 | 63.48 | 26.86 | 18.87 |

Table A.4. List of all morphotypes with type, classification, margin characteristics, and leaf size category. For margin, entire is expressed by '1' and toothed is expressed by '0'. The estimated leaf area was recorded in $mm^2$ and the natural log of the estimated leaf area was used to categorize each leaf into the following leaf sizes: leptophyll, nanophyll, microphyll, notophyll, mesophyll, and megaphyll; which are defined as greater than 2.12 $mm^2$, 4.32 $mm^2$, 6.51 $mm^2$, 8.01 $mm^2$, 9.11 $mm^2$, and 11.42 $mm^2$, respectively (Webb, 1959).

| Morphotype | Type | Classification | Margin | Leaf Size Category |
|---|---|---|---|---|
| BT-01 | Dicot | Theaceae: cf. *Ternstroemites sp*. | 0 | Microphyll |
| BT-02 | Dicot | Juglandaceae; *Oreoroa claibornensis* | 1 | Mircophyll |
| BT-03 | Dicot | | 1 | Microphyll |
| BT-04 | Dicot | | N/O | Notophyll |
| BT-05 | Dicot | | 1 | Microphyll |
| BT-06 | Dicot | Cf. Lauraceae | 1 | Microphyll |
| BT-07 | Dicot | | 1 | Mesophyll |
| BT-08 | Dicot | | 1 | Mesophyll |
| BT-09 | Dicot | | 0 | Mesophyll |
| BT-10 | Dicot | | 0 | Microphyll |
| BT-11 | Dicot | | 0 | Micro/Notophyll |
| BT-12 | Dicot | Juglandaceae: cf. *Oreoroa* sp. | 1 | Notophyll |
| BT-13 | Dicot | | 1 | Microphyll |
| BT-14 | Dicot | Cf. Fagaceae | 0 | Mesophyll |
| BT-15 | Dicot | | 1 | Notophyll |
| BT-16 | Dicot | | 1 | Notophyll |
| BT-17 | Dicot | | 0 | Notophyll |
| BT-18 | Seed | | N/A | N/A |
| BT-19 | Dicot | | 1 | Mesophyll |
| BT-20 | Monocot | Palmaceae | N/A | N/A |
| BT-21 | Monocot | Araceae: cf. *Orontium* sp. ? | N/A | N/A |
| BT-22 | Dicot | Juglandaceae; *Oreoroa sp.* | 0 | Notophyll |
| BT-23 | Monocot | Arecaceae; cf. *Sabalite*s | N/A | N/A |
| BT-24 | Dicot | | 0 | Notophyll |
| BT-25 | Dicot | | 1 | Mesophyll |
| BT-26 | Dicot | | 0 | Mesophyll |
| BT-27 | Fern | | N/A | N/A |
| BT-28 | Dicot | | 0 | Mesophyll |
| BT-29 | Dicot | | 1 | ? |
| BT-30 | Monocot | | N/A | N/A |
| BT-31 | Dicot | | N/O | Megaphyll |
| BT-32 | Fern | | N/A | N/A |
| BT-33 | Dicot | | 0 | Notophyll |
| BT-34 | Dicot | Lauraceae*;* cf. *Cinnamomum sp.* | 1 | Notophyll |
| BT-35 | Dicot | | 0 | Notophyll |
| BT-36 | Dicot | | 0 | Notophyll |
| BT-37 | Dicot | | N/O | Notophyll |
| BT-38 | Dicot | | 0 | Nanophyll |
| BT-39 | Fern | *Eostangeria pseudopteris* | N/A | N/A |
| BT-40 | Dicot | | 0 | Notophyll |
| BT-41 | Seed | | N/A | N/A |
| BT-43 | Repro. | Juglandaceae; cf. *Platycarya sp*. | N/A | N/A |
| BT-44 | Dicot | | 0 | Mesophyll |

Table A.5. Morphotype BT-01 leaf architecture description. Present in locality JW1801 and JW1803.

| Section I. Leaf Characters | Description |
|---|---|
| Leaf attachment | petiolate |
| leaf arrangement | not visible |
| leaf organization | simple |
| leaflet organization | not visible |
| Leaflet attachment | not visible |
| Petiole features | alate |
| **Features of the blade:** | |
| Position of lamina attachment | marginal |
| Laminar size | noto-meso |
| laminar L:W ratio | 4:1 |
| laminar shape | linear-elliptic |
| medial symmetry | asymmetrical |
| base symmetry | asymmetrical |
| base symmetry | not visible |
| lobation | unlobed |
| margin type | serrate |
| special margin features | not visible |
| Apex angle | acute |
| apex shape | straight |
| apex shape | acuminate |
| base angle | acute |
| base shape | straight |
| base shape | not visible |
| Terminal apex features | not visible |

| | Section II. Venation | Description |
|---|---|---|
| **1º** | Primary vein framework | pinnate |
| | naked basal veins | absent |
| | number of basal veins | 1 |
| | agrophic veins | absent |
| **2º** | Major 2º vein framework | semicraspedodromous |
| | Interior secondaries | present |
| | minor secondary course | not applicable |
| | Perimarginal veins | intramarginal |
| | major secondary spacing | irregular |
| | Variation of secondary angle | inconsistent |
| | Major secondaryattachment | decurrent |
| **Inter-2º** | proximal course | parallel to major secondaries |
| | intersecondary length | <50% of subjacent secondary |
| | distal course | parallel to subjacent major secondary |
| | vein frequency | ~ 1 per intercostal area |
| **3º** | Intercostal tertiary vein fabric | irregular reticulate |
| | Intercostal tertiary vein fabric | not applicable |
| | Angle of percurrent tertiaries | not applicable |
| | vein angle variability | inconsistent |
| | Epimedial tertiaries | mixed |
| | proximal course | not visible |
| | distal course | not visible |
| | Exterior tertiary course | looped |
| **4º** | Quaternary vein fabric | irregular reticulate |
| **5º** | Quinternary vein fabric | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | irregular |
| number of orders of teeth | 1 |
| teeth / cm | 5 |
| sinus shape | rounded |
| tooth shapes | CV:CC |
| tooth shapes | |
| tooth shapes | CC:CC |
| tooth shapes | |
| Principal vein | absent |
| principal vein termination | on distal flank of tooth |
| course of accessory vein | looped |
| features of the tooth apex | not applicable |
| non-specific tooth apex | |

**Diagnostic Features:**
Serrated; intersecodaries; semicrapedodromous;

**Text Description:**

Leaf attachment petiolate; leaf arrangement not visible; leaf organization simple. Leaflet attachment not visible; leaflet organization not visible. Blade attachment marginal. Petiole features alate. Laminar size noto-meso; laminar L:W ratio 4:1; laminar shape linear-elliptic with medial asymmetrical and base asymmetrical to not visible. Margin unlobed and serrate with not visible edges. Apex angle acute; apex shape straight to acuminate; base angle acute; base shape straight to not visible. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins absent; 1basal veins; agrophic veins absent. Major secondaries semicraspedodromous, spacing irregular, inconsistent; attachment decurrent. Interior secondaries present; minor secondary course not applicable; intramarginalpresent, proximal course parallel to major secondaries; Intersecondaries <50% of subjacent secondary; distal course parallel to subjacent major secondary; occur at ~ 1 per intercostal area; Intercostal tertiary veins irregular reticulate, to not applicable; not applicableto midvein; vein angle inconsistent. Epimedial tertiaries mixed; proximal course not visible; distal course not visible. Exterior tertiary course looped. Quaternary vein fabric irregular reticulate. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing irregular, with 1 orders of teeth; teeth / cm 5; sinus shape rounded. Tooth shapes CV:CC; ; CC:CC; and . Principal vein absent; terminates absent; accessory vein looped; tooth apex not applicable.

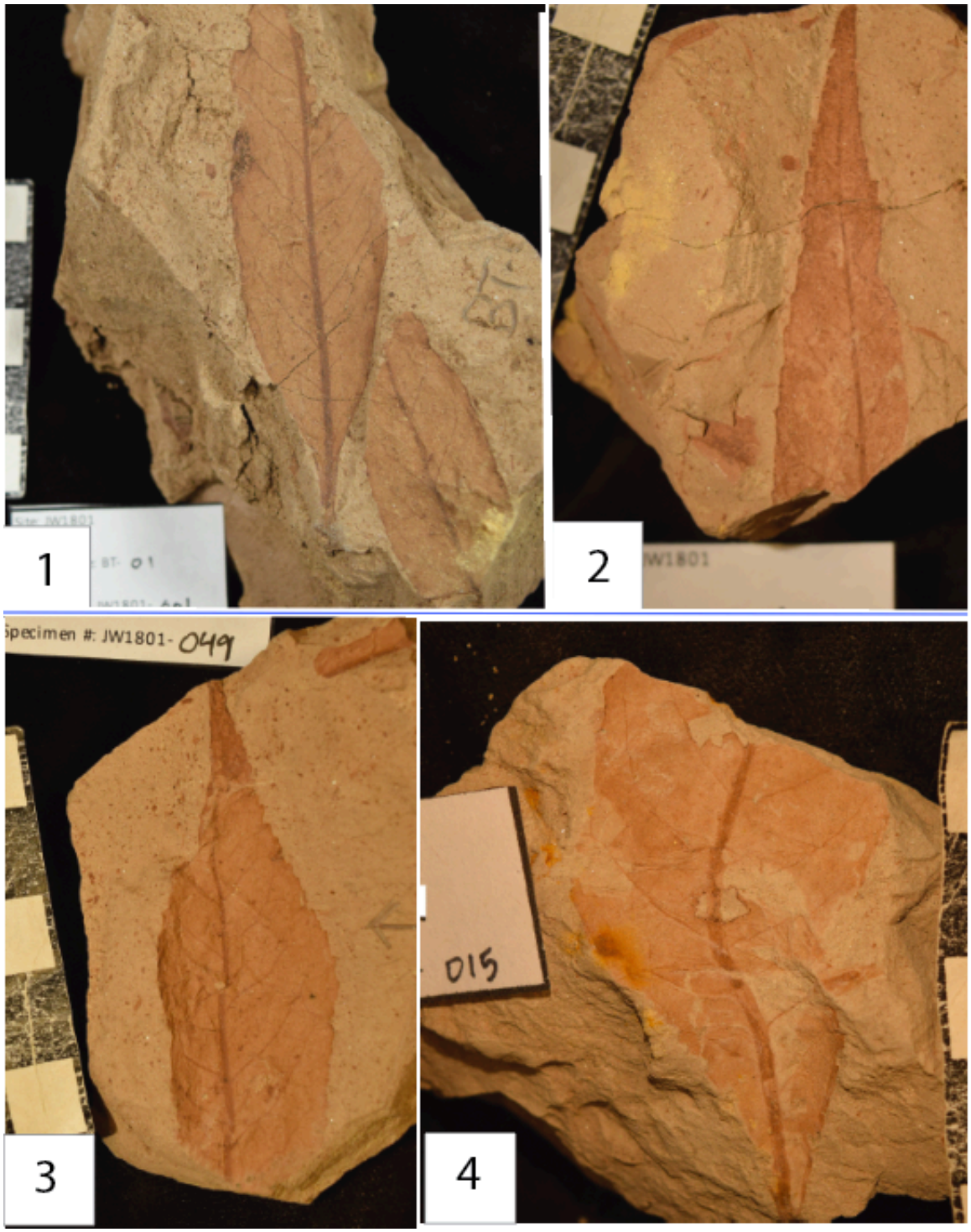


Figure A.1. Morphotype BT-01. Located in locality JW1801 and JW1803. 1. Specimen number JW1801-001, exemplar, 2. JW1801-027, 3. JW1801-049, 4. JW1803-015.

Table A.6. Morphotype BT-02 leaf architecture description. Family Juglandaceae or Sapindaceae. Present in Localities JW1801, JW1802, and JW1803.

| Section I. Leaf Characters | Description | | Section II. Venation | Description |
|---|---|---|---|---|
| Leaf attachment | petiolate | **1°** | Primary vein framework | pinnate |
| leaf arrangement | not visible | | naked basal veins | absent |
| leaf organization | not visible | | number of basal veins | 1 |
| leaflet organization | not visible | | agrophic veins | absent |
| Leaflet attachment | not visible | **2°** | Major 2° vein framework | simple brochidodromous |
| Petiole features | absent | | Interior secondaries | present |
| | | | minor secondary course | semicraspedodromous |
| **Features of the blade:** | | | Perimarginal veins | intramarginal secondary |
| Position of lamina attachment | marginal | | major secondary spacing | gradually increasing proximally |
| Laminar size | noto-meso | | Variation of secondary angle | uniform |
| laminar L:W ratio | > 6:1 | | Major secondary attachment | decurrent |
| laminar shape | linear | **Inter-2°** | proximal course | parallel to major secondaries |
| medial symmetry | symmetrical | | intersecondary length | >50% of subjacent secondary |
| base symmetry | symmetrical | | distal course | parallel to subjacent major secondary |
| base symmetry | symmetrical | | vein frequency | ~ 1 per intercostal area |
| lobation | unlobed | **3°** | Intercostal tertiary vein fabric | convex opposite percurrent |
| margin type | entire | | Intercostal tertiary vein fabric | not applicable |
| special margin features | undulate (sparse) | | Angle of percurrent tertiaries | acute |
| Apex angle | acute | | vein angle variability | absent |
| apex shape | straight | | Epimedial tertiaries | not visible |
| apex shape | straight | | proximal course | not visible |
| base angle | acute | | distal course | not visible |
| base shape | straight | | Exterior tertiary course | not visible |
| base shape | straight | **4°** | Quaternary vein fabric | irregular reticulate |
| Terminal apex features | absent | **5°** | Quinternary vein fabric | not visible |
| **Section III. Teeth** | | | **Text Description:** | |
| Tooth spacing | not applicable | | | |

**Diagnostic Features:**
Lanceolate, entire, variation in length, >3:1 length to width ratio

Leaf attachment petiolate; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not visible; leaflet organization not visible. Blade attachment marginal. Petiole features absent. Laminar size noto-meso; laminar L:W ratio > 6:1; laminar shape linear with medial symmetrical and base symmetrical to symmetrical. Margin unlobed and entire with undulate (sparse) edges. Apex angle acute; apex shape straight to straight; base angle acute; base shape straight to straight. Termianal apex absent. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins absent; 1basal veins; agrophic veins absent. Major secondaries simple brochidodromous, spacing gradually increasing proximally, uniform; attachment decurrent. Interior secondaries present; minor secondary course semicraspedodromous; intramarginal secondarypresent, proximal course parallel to major secondaries; Intersecondaries >50% of subjacent secondary; distal course parallel to subjacent major secondary; occur at ~ 1 per intercostal area; Intercostal tertiary veins convex opposite percurrent, to not applicable; acuteto midvein; vein angle absent. Epimedial tertiaries not visible; proximal course not visible; distal course not visible. Exterior tertiary course not visible. Quaternary vein fabric irregular reticulate. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing not applicable, with not applicable orders of teeth; teeth / cm ; sinus shape not applicable. Tooth shapes ; ; ; and . Principal vein not applicable; terminates not applicable; accesory vein not applicable; tooth apex not applicable.

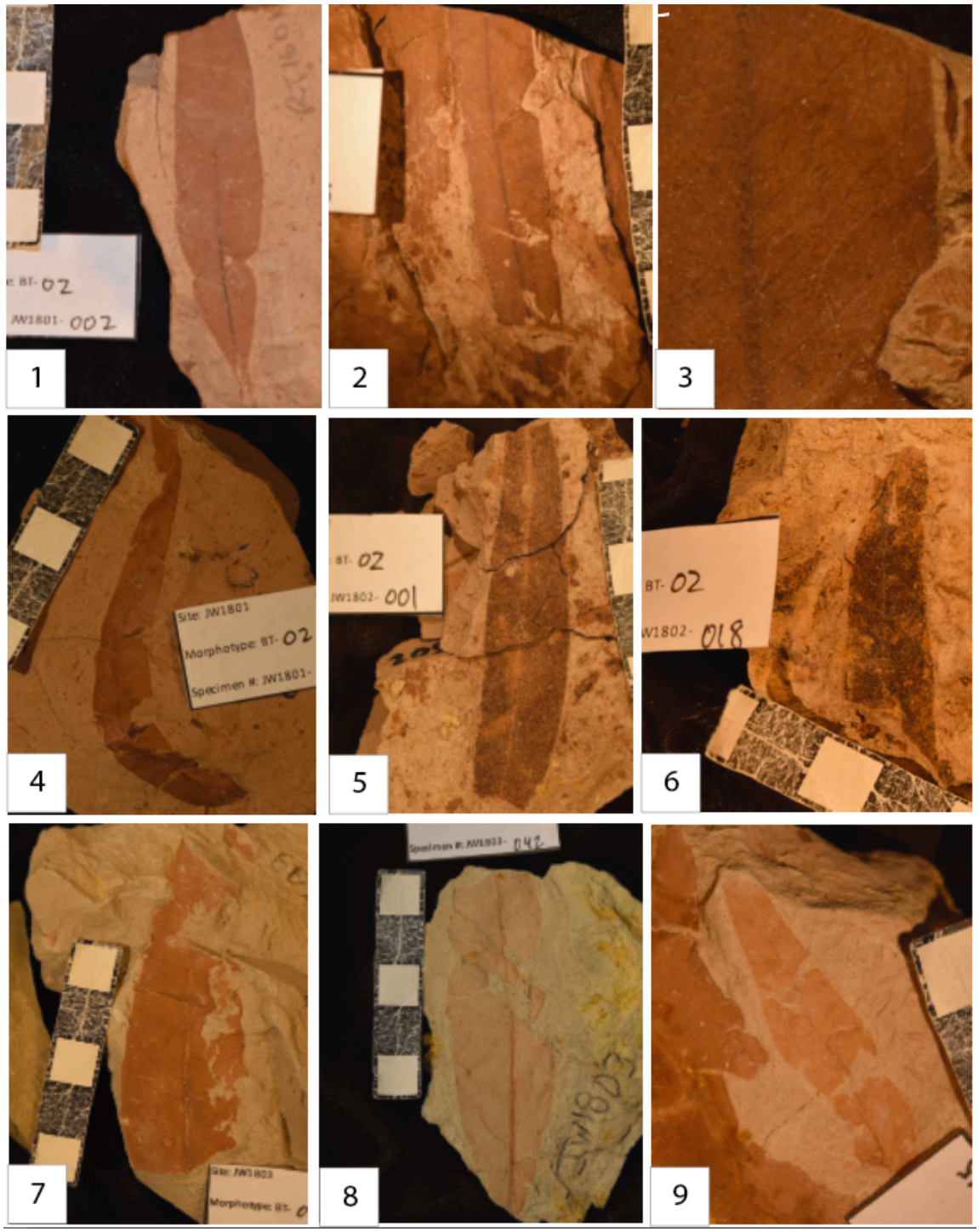


Figure A.2. Morphotype BT-02. Located in localities JW1801, JW1802, and JW1803. 1. Specimen number JW1801-002, exemplar, 2. JW1801-075, 3. JW1801-075 enlarged to show venation, 4. JW1801-084, 5. JW1802-001, exemplar, 6. JW1802-18, 7. JW1803-040, 8. JW1803-042, 9. JW1803-045.

Table A.7. Morphotype BT-03 leaf architecture description. Present in locality JW1801.

| Section I. Leaf Characters | Description | | Section II. Venation | Description |
|---|---|---|---|---|
| Leaf attachment | petiolate | **1º** | Primary vein framework | pinnate |
| leaf arrangement | not visible | | naked basal veins | absent |
| leaf organization | not visible | | number of basal veins | 1 (3?) |
| leaflet organization | not visible | | agrophic veins | absent |
| Leaflet attachment | not visible | **2º** | Major 2º vein framework | festooned brochidodromous |
| Petiole features | not visible | | Interior secondaries | absent |
| | | | minor secondary course | not visible |
| **Features of the blade:** | | | Perimarginal veins | intramarginal secondary |
| Position of lamina attachment | marginal | | major secondary spacing | irregular |
| Laminar size | noto-meso | | Variation of secondary angle | abruptly increasing proximally |
| laminar L:W ratio | > 2:1 | | Major secondary attachment | decurrent |
| laminar shape | oblong-ovate | **Inter-2º** | proximal course | absent |
| medial symmetry | not visible | | intersecondary length | not applicable |
| base symmetry | symmetrical | | distal course | not applicable |
| base symmetry | | | vein frequency | not applicable |
| lobation | unlobed | **3º** | Intercostal tertiary vein fabric | percurrent |
| margin type | entire | | Intercostal tertiary vein fabric | straight opposite percurrent |
| special margin features | not visible | | Angle of percurrent tertiaries | perpendicular |
| Apex angle | not visible | | vein angle variability | consistent |
| apex shape | not visible | | Epimedial tertiaries | opposite percurrent |
| apex shape | not visible | | proximal course | perpendicular to midvein |
| base angle | obtuse | | distal course | parallel to intercostal tertiary |
| base shape | rounded | | Exterior tertiary course | looped |
| base shape | not visible | **4º** | Quaternary vein fabric | alternate percurrent |
| Terminal apex features | not visible | **5º** | Quinternary vein fabric | regular reticulate |
| | | | Areolation | not visible |
| Surface texture | not visible | | FEV branching | not visible |
| Surficial glands | not visible | | FEV termination | not visible |
| | | | Marginal Ultimate venation | incomplete loops |

| **Section III. Teeth** | |
|---|---|
| Tooth spacing | not applicable |
| number of orders of teeth | not applicable |
| teeth / cm | |
| sinus shape | not applicable |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | not applicable |
| principal vein termination | not applicable |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**Diagnostic Features:**
Secondaries festooned brochidodromous, enitre

**Text Description:**

Leaf attachment petiolate; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not visible; leaflet organization not visible. Blade attachment marginal. Petiole features not visible. Laminar size noto-meso; laminar L:W ratio > 2:1; laminar shape oblong-ovate with medial not visible and base symmetrical to . Margin unlobed and entire with not visible edges. Apex angle not visible; apex shape not visible to not visible; base angle obtuse; base shape rounded to not visible. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins absent; 1 (3?)basal veins; agrophic veins absent. Major secondaries festooned brochidodromous, spacing irregular, abruptly increasing proximally; attachment decurrent. Interior secondaries absent; minor secondary course not visible; intramarginal secondarypresent, proximal course absent; Intersecondaries not applicable; distal course not applicable; occur at not applicable; Intercostal tertiary veins percurrent, to straight opposite percurrent; perpendicularto midvein; vein angle consistent. Epimedial tertiaries opposite percurrent; proximal course perpendicular to midvein; distal course parallel to intercostal tertiary. Exterior tertiary course looped. Quaternary vein fabric alternate percurrent. Quinternary vein fabric regular reticulate. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation incomplete loops. Tooth spacing not applicable, with not applicable orders of teeth; teeth / cm ; sinus shape not applicable. Tooth shapes ; ; ; and . Principal vein not applicable; terminates not applicable; accesory vein not apparent



Figure A.3. Morphotype BT-03. Located in locality JW1801. 1. Specimen number JW1801-003, exemplar, 2. JW1801-0102a.

Table A.8. Morphotype BT-04 leaf architecture description. Present in locality JW1801.

| Section I. Leaf Characters | Description |
|---|---|
| Leaf attachment | not visible |
| leaf arrangement | not visible |
| leaf organization | not visible |
| leaflet organization | not visible |
| Leaflet attachment | not visible |
| Petiole features | not visible |
| | |
| **Features of the blade:** | |
| Position of lamina attachment | not visible |
| Laminar size | mesophyll |
| laminar L:W ratio | >2:1 |
| laminar shape | unknown |
| medial symmetry | symmetrical |
| base symmetry | not visible |
| base symmetry | not visible |
| lobation | unlobed |
| margin type | entire |
| special margin features | not visible |
| Apex angle | not visible |
| apex shape | not visible |
| apex shape | not visible |
| base angle | obtuse |
| base shape | not visible |
| base shape | not visible |
| Terminal apex features | not visible |
| | |
| Surface texture | not visible |
| Surficial glands | not visible |

| | Section II. Venation | Description |
|---|---|---|
| 1º | Primary vein framework | pinnate |
| | naked basal veins | not visible |
| | number of basal veins | 1 |
| | agrophic veins | absent |
| 2º | Major 2º vein framework | eucamptodromous |
| | Interior secondaries | not visible |
| | minor secondary course | not visible |
| | Perimarginal veins | not visible |
| | major secondary spacing | irregular |
| | Variation of secondary angle | inconsistent |
| Inter-2º | Major secondary attachment | decurrent/deflect |
| | proximal course | not visible |
| | intersecondary length | not applicable |
| | distal course | not applicable |
| | vein frequency | not applicable |
| 3º | Intercostal tertiary vein fabric | opposite percurrent |
| | Intercostal tertiary vein fabric | straight opposite percurrent |
| | Angle of percurrent tertiaries | obtuse |
| | vein angle variability | not applicable |
| | Epimedial tertiaries | not visible |
| | proximal course | not visible |
| | distal course | not visible |
| | Exterior tertiary course | not visible |
| 4º | Quaternary vein fabric | not visible |
| 5º | Quinternary vein fabric | not visible |
| | Areolation | not visible |
| | FEV branching | not visible |
| | FEV termination | not visible |
| | Marginal Ultimate venation | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | not applicable |
| number of orders of teeth | not applicable |
| teeth / cm | |
| sinus shape | not applicable |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | not applicable |
| principal vein termination | not applicable |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**Diagnostic Features:**
Thick midvein, alternating irregularly spaced and angled secondaries

**Text Description:**

Leaf attachment not visible; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not visible; leaflet organization not visible. Blade attachment not visible. Petiole features not visible. Laminar size mesophyll; laminar L:W ratio >2:1; laminar shape unknown with medial symmetrical and base not visible to not visible. Margin unlobed and entire with not visible edges. Apex angle not visible; apex shape not visible to not visible; base angle obtuse; base shape not visible to not visible. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins not visible; 1basal veins; agrophic veins absent. Major secondaries eucamptodromous, spacing irregular, inconsistent; attachment decurrent/deflect. Interior secondaries not visible; minor secondary course not visible; not visiblepresent, proximal course not visible; Intersecondaries not applicable; distal course not applicable; occur at not applicable; Intercostal tertiary veins opposite percurrent, to straight opposite percurrent; obtuseto midvein; vein angle not applicable. Epimedial tertiaries not visible; proximal course not visible; distal course not visible. Exterior tertiary course not visible. Quaternary vein fabric not visible. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing not applicable, with not applicable orders of teeth; teeth / cm ; sinus shape not applicable. Tooth shapes ; ; ; and . Principal vein not applicable; terminates not applicable; accesory vein not applicable; tooth apex not applicable.

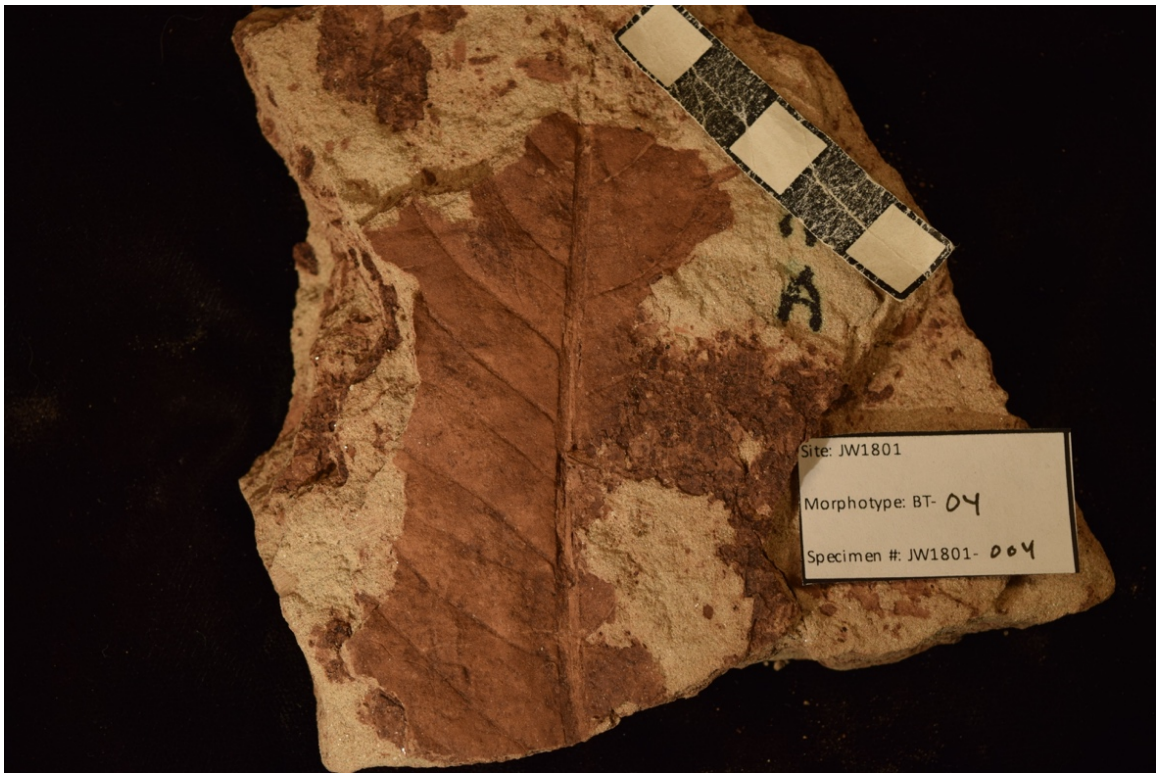


Figure A.4. Morphotype BT-04. Located in locality JW1801. Specimen number JW1801-004

Table A.9. Morphotype BT-05 leaf architecture description. Present in locality JW1801.

| Section I. Leaf Characters | Description |
|---|---|
| Leaf attachment | petiolate |
| leaf arrangement | not visible |
| leaf organization | not visible |
| leaflet organization | not visible |
| Leaflet attachment | not visible |
| Petiole features | absent |
| | |
| **Features of the blade:** | |
| Position of lamina attachment | marginal |
| Laminar size | mesophyll |
| laminar L:W ratio | ? |
| laminar shape | obovate |
| medial symmetry | not visible |
| base symmetry | not visible |
| base symmetry | not visible |
| lobation | unlobed |
| margin type | entire |
| special margin features | not visible |
| Apex angle | not visible |
| apex shape | not visible |
| apex shape | not visible |
| base angle | acute |
| base shape | decurrent |
| base shape | not visible |
| Terminal apex features | not visible |
| | |
| Surface texture | not visible |
| Surficial glands | not visible |

| | Section II. Venation | Description |
|---|---|---|
| **1º** | Primary vein framework | pinnate |
| | naked basal veins | not visible |
| | number of basal veins | 1 |
| | agrophic veins | not visible |
| **2º** | Major 2º vein framework | |
| | Interior secondaries | not visible |
| | minor secondary course | not visible |
| | Perimarginal veins | not visible |
| | major secondary spacing | not visible |
| | Variation of secondary angle | not visible |
| **Inter-2º** | Major secondary attachment | not visible |
| | proximal course | not visible |
| | intersecondary length | not applicable |
| | distal course | not applicable |
| | vein frequency | not applicable |
| **3º** | Intercostal tertiary vein fabric | not applicable |
| | Intercostal tertiary vein fabric | not applicable |
| | Angle of percurrent tertiaries | not applicable |
| | vein angle variability | not applicable |
| | Epimedial tertiaries | not visible |
| | proximal course | not visible |
| | distal course | not visible |
| | Exterior tertiary course | not visible |
| **4º** | Quaternary vein fabric | not visible |
| **5º** | Quinternary vein fabric | not visible |
| | Areolation | not visible |
| | FEV branching | not visible |
| | FEV termination | not visible |
| | Marginal Ultimate venation | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | not applicable |
| number of orders of teeth | not applicable |
| teeth / cm | |
| sinus shape | not applicable |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | not applicable |
| principal vein termination | not applicable |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**Diagnostic Features:**

Thick midvein, maybe entire

**Text Description:**

Leaf attachment petiolate; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not visible; leaflet organization not visible. Blade attachment marginal. Petiole features absent. Laminar size mesophyll; laminar L:W ratio ; laminar shape obovate with medial not visible and base not visible to not visible. Margin unlobed and entire with not visible edges. Apex angle not visible; apex shape not visible to not visible; base angle acute; base shape decurrent to not visible. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins not visible; 1basal veins; agrophic veins not visible. Major secondaries , spacing not visible, not visible; attachment not visible. Interior secondaries not visible; minor secondary course not visible; not visiblepresent, proximal course not visible; Intersecondaries not applicable; distal course not applicable; occur at not applicable; Intercostal tertiary veins not applicable, to not applicable; not applicableto midvein; vein angle not applicable. Epimedial tertiaries not visible; proximal course not visible; distal course not visible. Exterior tertiary course not visible. Quaternary vein fabric not visible. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing not applicable, with not applicable orders of teeth; teeth / cm ; sinus shape not applicable. Tooth shapes ; ; ; and . Principal vein not applicable; terminates not applicable; accesory vein not applicable; tooth apex not applicable.


Figure A.5. Morphotype BT-05. Present in locality JW1801. Specimen number JW1801-005.

Table A.10. Morphotype BT-06 leaf architecture description. Present in locality JW1801.

| Section I. Leaf Characters | Description |
|---|---|
| Leaf attachment | petiolate |
| leaf arrangement | not visible |
| leaf organization | not visible |
| leaflet organization | not visible |
| Leaflet attachment | not visible |
| Petiole features | not visible |
| | |
| **Features of the blade:** | |
| Position of lamina attachment | marginal |
| Laminar size | mesophyll |
| laminar L:W ratio | 1:1 to 2:1 |
| laminar shape | ovate? |
| medial symmetry | not visible |
| base symmetry | not visible |
| base symmetry | not visible |
| lobation | possibly lobed |
| margin type | not visible |
| special margin features | not visible |
| Apex angle | not visible |
| apex shape | not visible |
| apex shape | not visible |
| base angle | obtuse |
| base shape | concave |
| base shape | not visible |
| Terminal apex features | not visible |
| | |
| Surface texture | not visible |
| Surficial glands | not visible |

| | Section II. Venation | Description |
|---|---|---|
| **1º** | Primary vein framework | palinactinodromous |
| | naked basal veins | not visible |
| | number of basal veins | 3 |
| | agrophic veins | present |
| **2º** | Major 2º vein framework | semicraspedodromous |
| | Interior secondaries | absent |
| | minor secondary course | not visible |
| | Perimarginal veins | not visible |
| | major secondary spacing | regular |
| | Variation of secondary angle | uniform |
| | Major secondary attachment | deflected |
| **Inter-2º** | proximal course | not visible |
| | intersecondary length | not applicable |
| | distal course | not applicable |
| | vein frequency | not applicable |
| **3º** | Intercostal tertiary vein fabric | straight opposite percurrent |
| | Intercostal tertiary vein fabric | mixed percurrent |
| | Angle of percurrent tertiaries | acute |
| | vein angle variability | consistent |
| | Epimedial tertiaries | mixed percurrent |
| | proximal course | not visible |
| | distal course | not visible |
| | Exterior tertiary course | not visible |
| **4º** | Quaternary vein fabric | not visible |
| **5º** | Quinternary vein fabric | not visible |
| | Areolation | not visible |
| | FEV branching | not visible |
| | FEV termination | not visible |
| | Marginal Ultimate venation | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | not applicable |
| number of orders of teeth | not applicable |
| teeth / cm | |
| sinus shape | not applicable |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | not applicable |
| principal vein termination | not applicable |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**Diagnostic Features:**

3 primary veins, agrophic veins, strongly decurrent secondaries

**Text Description:**

Leaf attachment petiolate; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not visible; leaflet organization not visible. Blade attachment marginal. Petiole features not visible. Laminar size mesophyll; laminar L:W ratio 1:1 to 2:1; laminar shape ovate? with medial not visible and base not visible to not visible. Margin possibly lobed and not visible with not visible edges. Apex angle not visible; apex shape not visible to not visible; base angle obtuse; base shape concave to not visible. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation palinactinodromous; naked basal veins not visible; 3basal veins; agrophic veins present. Major secondaries semicraspedodromous, spacing regular, uniform; attachment deflected. Interior secondaries absent; minor secondary course not visible; not visiblepresent, proximal course not visible; Intersecondaries not applicable; distal course not applicable; occur at not applicable; Intercostal tertiary veins straight opposite percurrent, to mixed percurrent; acuteto midvein; vein angle consistent. Epimedial tertiaries mixed percurrent; proximal course not visible; distal course not visible. Exterior tertiary course not visible. Quaternary vein fabric not visible. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing not applicable, with not applicable orders of teeth; teeth / cm ; sinus shape not applicable. Tooth shapes ; ; ; and . Principal vein not applicable; terminates not applicable; accesory vein not applicable; tooth apex not applicable.


Figure A.6. Morphotype BT-06. Present in locality JW1801. Specimen number: 1. JW1801-006, 2. JW1801-100.

Table A.11. Morphotype BT-07 leaf architecture description. Present in locality JW1801.

| Section I. Leaf Characters | Description |
|---|---|
| Leaf attachment | not visible |
| leaf arrangement | not visible |
| leaf organization | not visible |
| leaflet organization | not visible |
| Leaflet attachment | not visible |
| Petiole features | not visible |
| | |
| **Features of the blade:** | |
| Position of lamina attachment | not visible |
| Laminar size | noto/meso |
| laminar L:W ratio | ~ 2:1 |
| laminar shape | ovate? |
| medial symmetry | symmetrical |
| base symmetry | not visible |
| base symmetry | not visible |
| lobation | unlobed |
| margin type | not visible |
| special margin features | not visible |
| Apex angle | not visible |
| apex shape | not visible |
| apex shape | not visible |
| base angle | obtuse? |
| base shape | not visible |
| base shape | not visible |
| Terminal apex features | not visible |
| | |
| Surface texture | not visible |
| Surficial glands | not visible |

| | Section II. Venation | Description |
|---|---|---|
| **1º** | Primary vein framework | pinnate |
| | naked basal veins | not visible |
| | number of basal veins | 1 |
| | agrophic veins | not visible |
| **2º** | Major 2º vein framework | *looping near margin |
| | Interior secondaries | absent |
| | minor secondary course | not applicable |
| | Perimarginal veins | not visible |
| | major secondary spacing | regular |
| | Variation of secondary angle | uniform |
| | Major secondary attachment | decurrent |
| **Inter-2º** | proximal course | not visible |
| | intersecondary length | not applicable |
| | distal course | not applicable |
| | vein frequency | not applicable |
| **3º** | Intercostal tertiary vein fabric | straight opposite percurrent |
| | Intercostal tertiary vein fabric | |
| | Angle of percurrent tertiaries | perpendicular |
| | vein angle variability | consistent |
| | Epimedial tertiaries | opposite percurrent |
| | proximal course | perpendicular to midvein |
| | distal course | parallel to intercostal tertiary |
| | Exterior tertiary course | not visible |
| **4º** | Quaternary vein fabric | mixed percurrent |
| **5º** | Quinternary vein fabric | not visible |
| | Areolation | not visible |
| | FEV branching | not visible |
| | FEV termination | not visible |
| | Marginal Ultimate venation | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | not applicable |
| number of orders of teeth | not applicable |
| teeth / cm | |
| sinus shape | not applicable |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | not applicable |
| principal vein termination | not applicable |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**Diagnostic Features:**

Strongly deccurent secondaries, well developed venation

**TextDescription:**

Leaf attachment not visible; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not visible; leaflet organization not visible. Blade attachment not visible. Petiole features not visible. Laminar size noto/meso; laminar L:W ratio ~ 2:1; laminar shape ovate? with medial symmetrical and base not visible to not visible. Margin unlobed and not visible with not visible edges. Apex angle not visible; apex shape not visible to not visible; base angle obtuse?; base shape not visible to not visible. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins not visible; 1basal veins; agrophic veins not visible. Major secondaries *looping near margin, spacing regular, uniform; attachment decurrent. Interior secondaries absent; minor secondary course not applicable; not visiblepresent, proximal course not visible; Intersecondaries not applicable; distal course not applicable; occur at not applicable; Intercostal tertiary veins straight opposite percurrent, to ; perpendicularto midvein; vein angle consistent. Epimedial tertiaries opposite percurrent; proximal course perpendicular to midvein; distal course parallel to intercostal tertiary. Exterior tertiary course not visible. Quaternary vein fabric mixed percurrent. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing not applicable, with not applicable orders of teeth; teeth / cm ; sinus shape not applicable. Tooth shapes ; ; ; and . Principal vein not applicable; terminates not applicable; accesory vein not applicable; tooth apex not applicable.


Figure A.7. Morphotype BT-07. Present in locality JW1801. Specimen number JW1801-007.

Table A.12. Morphotype BT-08 leaf architecture description. Present in locality JW1801.

| Section I. Leaf Characters | Description | | Section II. Venation | Description |
|---|---|---|---|---|
| Leaf attachment | petiolate | 1º | Primary vein framework | pinnate |
| leaf arrangement | not visible | | naked basal veins | not visible |
| leaf organization | simple | | number of basal veins | 1 |
| leaflet organization | not visible | | agrophic veins | not visible |
| Leaflet attachment | not visible | 2º | Major 2º vein framework | eucamptodromous |
| Petiole features | not visible | | Interior secondaries | not visible |
| | | | minor secondary course | not visible |
| **Features of the blade:** | | | Perimarginal veins | not visible |
| Position of lamina attachment | marginal | | major secondary spacing | regular |
| Laminar size | mesophyll | | Variation of secondary angle | uniform |
| laminar L:W ratio | | | Major secondary attachment | excurrent |
| laminar shape | unknown | Inter-2º | proximal course | not visible |
| medial symmetry | not visible | | intersecondary length | not applicable |
| base symmetry | not visible | | distal course | not applicable |
| base symmetry | not visible | | vein frequency | not applicable |
| lobation | unlobed | 3º | Intercostal tertiary vein fabric | not applicable |
| margin type | entire | | Intercostal tertiary vein fabric | not applicable |
| special margin features | not visible | | Angle of percurrent tertiaries | not applicable |
| Apex angle | not visible | | vein angle variability | not applicable |
| apex shape | not visible | | Epimedial tertiaries | not visible |
| apex shape | not visible | | proximal course | not visible |
| base angle | acute | | distal course | not visible |
| base shape | concave | | Exterior tertiary course | not visible |
| base shape | not visible | 4º | Quaternary vein fabric | not visible |
| Terminal apex features | not visible | 5º | Quinternary vein fabric | not visible |
| | | | Areolation | not visible |
| Surface texture | not visible | | FEV branching | not visible |
| Surficial glands | not visible | | FEV termination | not visible |
| | | | Marginal Ultimate venation | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | not applicable |
| number of orders of teeth | not applicable |
| teeth / cm | |
| sinus shape | not applicable |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | not applicable |
| principal vein termination | not applicable |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**TextDescription:**

Leaf attachment petiolate; leaf arrangement not visible; leaf organization simple. Leaflet attachment not visible; leaflet organization not visible. Blade attachment marginal. Petiole features not visible. Laminar size mesophyll; laminar L:W ratio ; laminar shape unknown with medial not visible and base not visible to not visible. Margin unlobed and entire with not visible edges. Apex angle not visible; apex shape not visible to not visible; base angle acute; base shape concave to not visible. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins not visible; 1basal veins; agrophic veins not visible. Major secondaries eucamptodromous, spacing regular, uniform; attachment excurrent. Interior secondaries not visible; minor secondary course not visible; not visiblepresent, proximal course not visible; Intersecondaries not applicable; distal course not applicable; occur at not applicable; Intercostal tertiary veins not applicable, to not applicable; not applicableto midvein; vein angle not applicable. Epimedial tertiaries not visible; proximal course not visible; distal course not visible. Exterior tertiary course not visible. Quaternary vein fabric not visible. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing not applicable, with not applicable orders of teeth; teeth / cm ; sinus shape not applicable. Tooth shapes ; ; ; and . Principal vein not applicable; terminates not applicable; accesory vein not applicable; tooth apex not applicable.

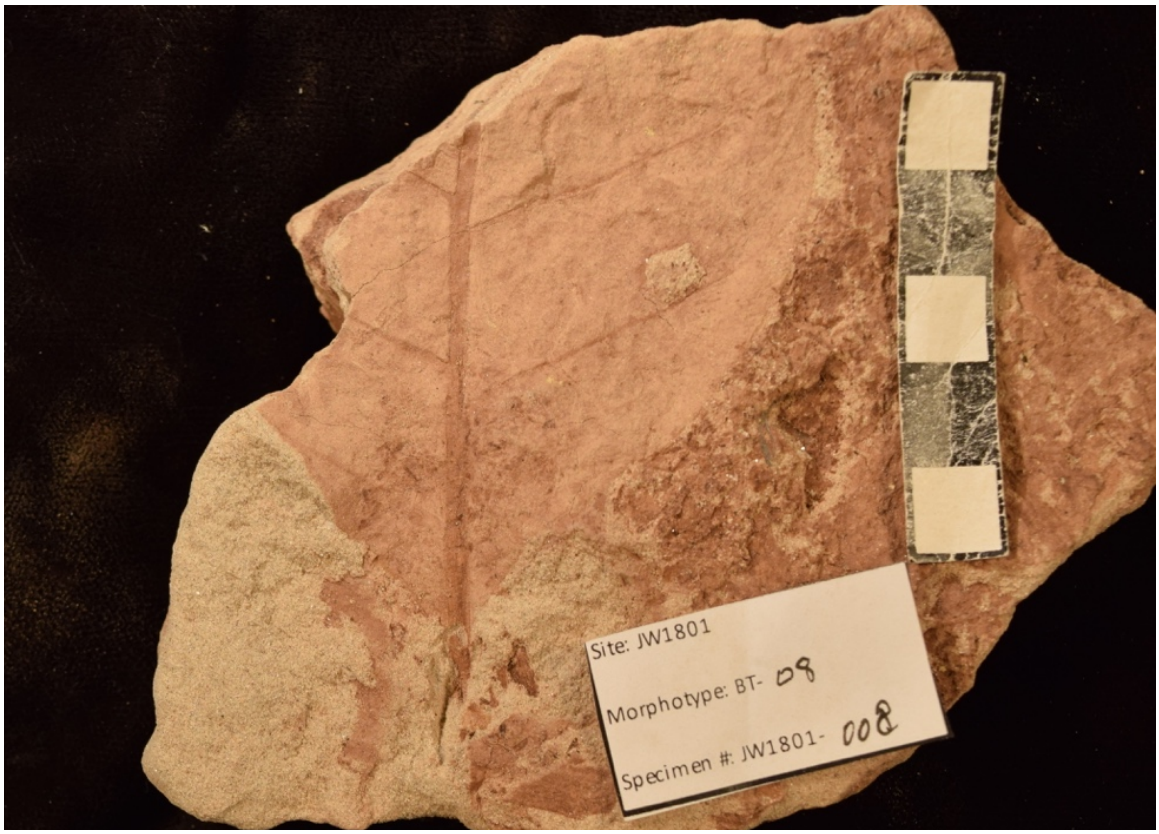


Figure A.8. Morphotype BT-08. Present in locality JW1801. Specimen number JW1801-008.

Table A.13. Morphotype BT-09 leaf architecture description. Present in locality JW1801

| Section I. Leaf Characters | Description |
|---|---|
| Leaf attachment | petiolate |
| leaf arrangement | not visible |
| leaf organization | not visible |
| leaflet organization | not visible |
| Leaflet attachment | not visible |
| Petiole features | not visible |
| **Features of the blade:** | |
| Position of lamina attachment | marginal |
| Laminar size | meso |
| laminar L:W ratio | 2:1 |
| laminar shape | elliptic |
| medial symmetry | symmetrical |
| base symmetry | asymmetrical |
| base symmetry | not visible |
| lobation | unlobed |
| margin type | entire |
| special margin features | not visible |
| Apex angle | **Just barely acute |
| apex shape | rounded OR |
| apex shape | slightly convex |
| base angle | acute |
| base shape | concave |
| base shape | not visible |
| Terminal apex features | not visible |
| Surface texture | not visible |
| Surficial glands | not visible |

| | Section II. Venation | Description |
|---|---|---|
| **1º** | Primary vein framework | pinnate |
| | naked basal veins | not visible |
| | number of basal veins | 1 |
| | agrophic veins | not visible |
| **2º** | Major 2º vein framework | eucamptodromous |
| | Interior secondaries | not visible |
| | minor secondary course | not visible |
| | Perimarginal veins | not visible |
| | major secondary spacing | gradually increasing proximally |
| | Variation of secondary angle | uniform? |
| **Inter-2º** | Major secondary attachment | decurrent |
| | proximal course | not visible |
| | intersecondary length | not applicable |
| | distal course | not applicable |
| | vein frequency | not applicable |
| **3º** | Intercostal tertiary vein fabric | sinuous opposite percurrent |
| | Intercostal tertiary vein fabric | |
| | Angle of percurrent tertiaries | acute |
| | vein angle variability | consistent |
| | Epimedial tertiaries | not visible |
| | proximal course | |
| | distal course | |
| | Exterior tertiary course | not visible |
| **4º** | Quaternary vein fabric | regular reticulate |
| **5º** | Quinternary vein fabric | not visible |
| | Areolation | not visible |
| | FEV branching | not visible |
| | FEV termination | not visible |
| | Marginal Ultimate venation | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | not applicable |
| number of orders of teeth | not applicable |
| teeth / cm | |
| sinus shape | not applicable |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | not applicable |
| principal vein termination | not applicable |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**Diagnostic Features:**

Entire margin; major secondaries eucamptodromous, spacing increases proximally

**Text Description:**

Leaf attachment petiolate; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not visible; leaflet organization not visible. Blade attachment marginal. Petiole features not visible. Laminar size meso; laminar L:W ratio 2:1; laminar shape elliptic with medial symmetrical and base asymmetrical to not visible. Margin unlobed and entire with not visible edges. Apex angle **Just barely acute; apex shape rounded OR to slightly convex; base angle acute; base shape concave to not visible. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins not visible; 1basal veins; agrophic veins not visible. Major secondaries eucamptodromous, spacing gradually increasing proximally, uniform?; attachment decurrent. Interior secondaries not visible; minor secondary course not visible; not visiblepresent, proximal course not visible; Intersecondaries not applicable; distal course not applicable; occur at not applicable; Intercostal tertiary veins sinuous opposite percurrent, to ; acuteto midvein; vein angle consistent. Epimedial tertiaries not visible; proximal course ; distal course . Exterior tertiary course not visible. Quaternary vein fabric regular reticulate. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing not applicable, with not applicable orders of teeth; teeth / cm ; sinus shape not applicable. Tooth shapes ; ; ; and . Principal vein not applicable; terminates not applicable; accesory vein not applicable; tooth apex not applicable.

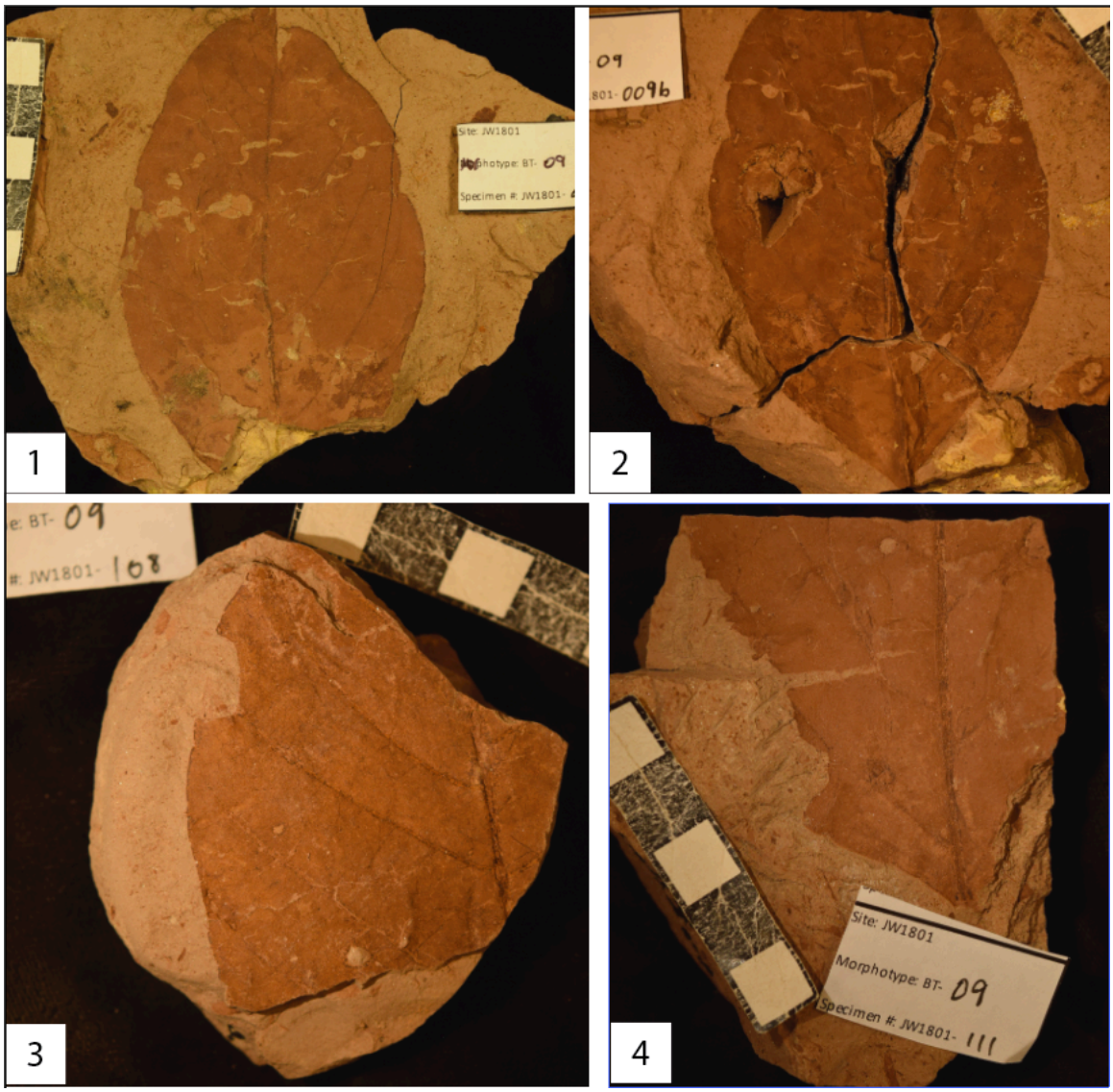


Figure A.9. Morphotype BT-09. Present in locality JW1801; 1. Specimen number JW1801-009a, 2. JW1801-009b, 3. JW1801-108, 4. JW1801-111.

Table A.14. Morphotype BT-10 leaf architecture description. Present in locality JW1802.

| Section I. Leaf Characters | Description |
|---|---|
| Leaf attachment | not visible |
| leaf arrangement | not visible |
| leaf organization | not visible |
| leaflet organization | not visible |
| Leaflet attachment | not visible |
| Petiole features | petiolar |
| **Features of the blade:** | |
| Position of lamina attachment | marginal |
| Laminar size | notophyll |
| laminar L:W ratio | 2:1 |
| laminar shape | unknown |
| medial symmetry | not visible |
| base symmetry | asymmetrical |
| base symmetry | basal width asymmetrical |
| lobation | unlobed |
| margin type | crenate |
| special margin features | |
| Apex angle | obtuse |
| apex shape | rounded |
| apex shape | rounded |
| base angle | maybe acute |
| base shape | not visible |
| base shape | not visible |
| Terminal apex features | retuse |
| Surface texture | not visible |
| Surficial glands | not visible |

| | Section II. Venation | Description |
|---|---|---|
| **1º** | Primary vein framework | pinnate |
| | naked basal veins | not visible |
| | number of basal veins | 1 |
| | agrophic veins | not visible |
| **2º** | Major 2º vein framework | craspedodromous |
| | Interior secondaries | absent |
| | minor secondary course | not visible |
| | Perimarginal veins | not applicable |
| | major secondary spacing | gradually increasing proximally |
| **Inter-2º** | Variation of secondary angle | uniform |
| | Major secondary attachment | excurrent |
| | proximal course | absent |
| | intersecondary length | not applicable |
| | distal course | not applicable |
| | vein frequency | not applicable |
| **3º** | Intercostal tertiary vein fabric | opposite percurrent |
| | Intercostal tertiary vein fabric | opposite percurrent |
| | Angle of percurrent tertiaries | obtuse |
| | vein angle variability | decreasing proximally |
| | Epimedial tertiaries | opposite percurrent |
| | proximal course | Perp to midvein |
| | distal course | parallel to intercostal tertiary |
| | Exterior tertiary course | term at the margin |
| **4º** | Quaternary vein fabric | not visible |
| **5º** | Quinternary vein fabric | not visible |
| | Areolation | not visible |
| | FEV branching | not visible |
| | FEV termination | not visible |
| | Marginal Ultimate venation | not visible |

**Section III. Teeth**

| | |
|---|---|
| Tooth spacing | irregular |
| number of orders of teeth | one |
| teeth / cm | 2-Jan |
| sinus shape | rounded |
| tooth shapes | CC/FL |
| tooth shapes | FL/FL |
| tooth shapes | |
| tooth shapes | |
| Principal vein | present |
| principal vein termination | on distal flank of tooth |
| course of accessory vein | not visible |
| features of the tooth apex | not applicable |

**Diagnostic Features:**

Major secondaries craspedodromous, terminal apex retuse, crenate margin

**Text Description:**

Leaf attachment not visible; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not visible; leaflet organization not visible. Blade attachment marginal. Petiole features petiolar. Laminar size notophyll; laminar L:W ratio 2:1; laminar shape unknown with medial not visible and base asymmetrical to basal width asymmetrical. Margin unlobed and crenate with edges. Apex angle obtuse; apex shape rounded to rounded; base angle maybe acute; base shape not visible to not visible. Termianal apex retuse. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins not visible; 1basal veins; agrophic veins not visible. Major secondaries craspedodromous, spacing gradually increasing proximally, uniform; attachment excurrent. Interior secondaries absent; minor secondary course not visible; not applicablepresent, proximal course absent; Intersecondaries not applicable; distal course not applicable; occur at not applicable; Intercostal tertiary veins opposite percurrent, to opposite percurrent; obtuseto midvein; vein angle decreasing proximally. Epimedial tertiaries opposite percurrent; proximal course perpendicular to midvein; distal course parallel to intercostal tertiary. Exterior tertiary course terminating at the margin. Quaternary vein fabric not visible. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing irregular, with one orders of teeth; teeth / cm 43467; sinus shape rounded. Tooth shapes CC/FL; FL/FL; ; and . Principal vein present; terminates present; accesory vein not visible; tooth apex not applicable.

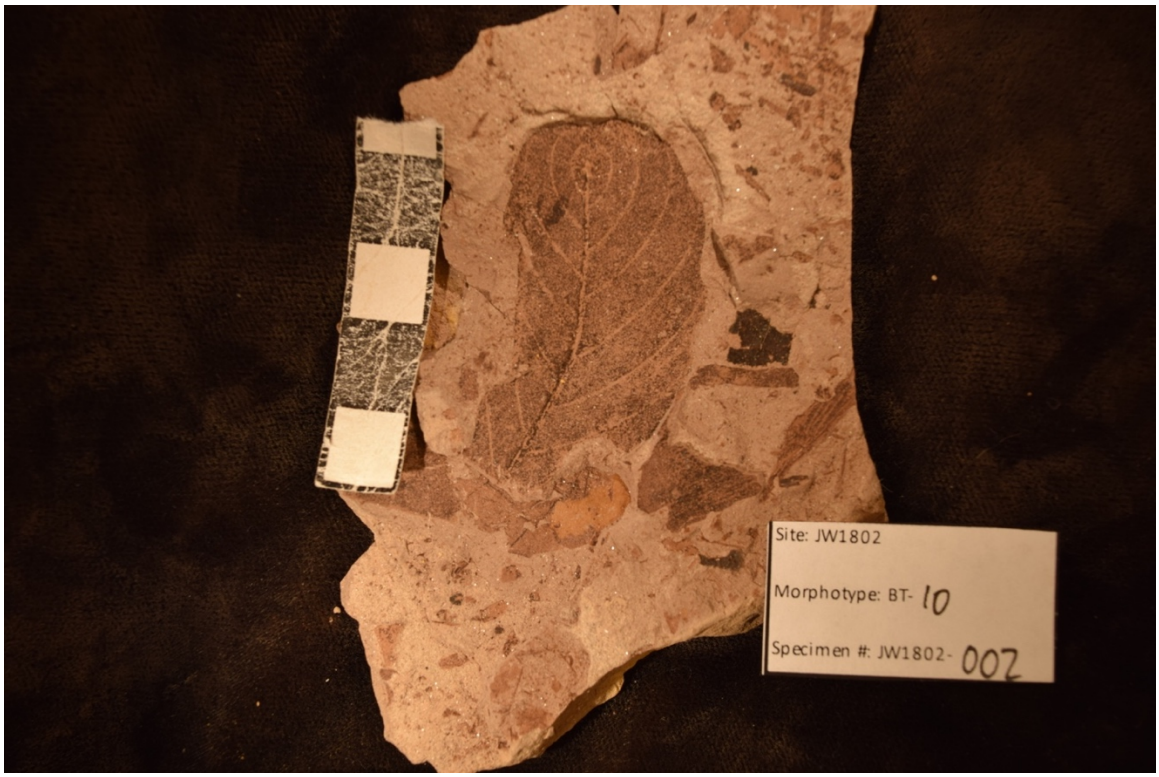


Figure A.10. Morphotype BT-10. Present in locality JW1802. Specimen number JW1802-002.

Table A.15. Morphotype BT-11 leaf architecture description. Present in locality JW1801.

| Section I. Leaf Characters | Description | | Section II. Venation | Description |
|---|---|---|---|---|
| Leaf attachment | petiolate | **1º** | Primary vein framework | pinnate |
| leaf arrangement | not visible | | naked basal veins | absent |
| leaf organization | not visible | | number of basal veins | 1 |
| leaflet organization | not visible | | agrophic veins | absent |
| Leaflet attachment | not applicable | **2º** | Major 2º vein framework | semicraspedodromous |
| Petiole features | not visible | | Interior secondaries | present |
| | | | minor secondary course | not applicable |
| **Features of the blade:** | | | Perimarginal veins | not applicable |
| Position of lamina attachment | marginal | | major secondary spacing | gradually increasing proximally |
| Laminar size | meso/macro | | Variation of secondary angle | uniform |
| laminar L:W ratio | >2:1 | **Inter-2º** | Major secondary attachment | decurrent |
| laminar shape | elliptic/obovate | | proximal course | absent |
| medial symmetry | not visible | | intersecondary length | <50% of subjacent secondary |
| base symmetry | symmetrical | | distal course | reticulating |
| base symmetry | symmetrical | | vein frequency | >1 per intercostal area |
| lobation | lobed | **3º** | Intercostal tertiary vein fabric | irregular reticulate |
| margin type | entire | | Intercostal tertiary vein fabric | irregular reticulate |
| special margin features | sinuous | | Angle of percurrent tertiaries | not applicable |
| Apex angle | not visible | | vein angle variability | inconsistent |
| apex shape | not visible | | Epimedial tertiaries | not visible |
| apex shape | not visible | | proximal course | not visible |
| base angle | acute | | distal course | not visible |
| base shape | straight | | Exterior tertiary course | not visible |
| base shape | straight | **4º** | Quaternary vein fabric | not visible |
| Terminal apex features | absent | **5º** | Quinternary vein fabric | not visible |
| | | | Areolation | not visible |
| Surface texture | not visible | | FEV branching | not visible |
| Surficial glands | not visible | | FEV termination | not visible |
| | | | Marginal Ultimate venation | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | not applicable |
| number of orders of teeth | not applicable |
| teeth / cm | |
| sinus shape | not applicable |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | not applicable |
| principal vein termination | not applicable |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**Diagnostic Features:**

Lobed, major seocndaries semicraspedodromous, decurrent attachment,

**Text Description:**

Leaf attachment petiolate; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not applicable; leaflet organization not visible. Blade attachment marginal. Petiole features not visible. Laminar size meso/macro; laminar L:W ratio >2:1; laminar shape elliptic/obovate with medial not visible and base symmetrical to symmetrical. Margin lobed and entire with sinuous edges. Apex angle not visible; apex shape not visible to not visible; base angle acute; base shape straight to straight. Termianal apex absent. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins absent; 1basal veins; agrophic veins absent. Major secondaries semicraspedodromous, spacing gradually increasing proximally, uniform; attachment decurrent. Interior secondaries present; minor secondary course not applicable; not applicablepresent, proximal course absent; Intersecondaries <50% of subjacent secondary; distal course reticulating; occur at >1 per intercostal area; Intercostal tertiary veins irregular reticulate, to irregular reticulate; not applicableto midvein; vein angle inconsistent. Epimedial tertiaries not visible; proximal course not visible; distal course not visible. Exterior tertiary course not visible. Quaternary vein fabric not visible. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing not applicable, with not applicable orders of teeth; teeth / cm ; sinus shape not applicable. Tooth shapes ; ; ; and . Principal vein not applicable; terminates not applicable; accesory vein not applicable; tooth apex not applicable.


Figure A.11. Morphotype BT-11. Present in locality JW1801. 1. Specimen number JW1801-010, 2. JW1801-105.

Table A.16. Morphotype BT-12 leaf architecture description. Present in locality JW1801.

| Section I. Leaf Characters | Description | | Section II. Venation | Description |
|---|---|---|---|---|
| Leaf attachment | not visible | **1º** | Primary vein framework | pinnate |
| leaf arrangement | not visible | | naked basal veins | not applicable |
| leaf organization | not visible | | number of basal veins | 1 |
| leaflet organization | not visible | | agrophic veins | absent |
| Leaflet attachment | not visible | **2º** | Major 2º vein framework | eucamptodromous |
| Petiole features | not visible | | Interior secondaries | present |
| | | | minor secondary course | not applicable |
| **Features of the blade:** | | | Perimarginal veins | not visible |
| Position of lamina attachment | not visible | | major secondary spacing | irregular |
| Laminar size | unknown | | Variation of secondary angle | uniform |
| laminar L:W ratio | >3:1 | | Major secondary attachment | decurrent |
| laminar shape | unknown | | proximal course | parallel to major secondaries |
| medial symmetry | symmetrical | **Inter-2º** | intersecondary length | <50% of subjacent secondary |
| base symmetry | not visible | | distal course | reticulating |
| base symmetry | not visible | | vein frequency | ~ 1 per intercostal area |
| lobation | unlobed | **3º** | Intercostal tertiary vein fabric | irregular reticulate |
| margin type | entire | | Intercostal tertiary vein fabric | irregular reticulate |
| special margin features | not visible | | Angle of percurrent tertiaries | not applicable |
| Apex angle | not visible | | vein angle variability | inconsistent |
| apex shape | not visible | | Epimedial tertiaries | reticulate |
| apex shape | not visible | | proximal course | acute to midvein |
| base angle | not visible | | distal course | parallel to intercostal tertiary |
| base shape | not visible | | Exterior tertiary course | looped |
| base shape | not visible | **4º** | Quaternary vein fabric | irregular reticulate |
| Terminal apex features | not visible | **5º** | Quinternary vein fabric | irregular reticulate |
| | | | Areolation | moderate development |
| Surface texture | not visible | | FEV branching | mostly one branched |
| Surficial glands | not visible | | FEV termination | simple |
| | | | Marginal Ultimate venation | not visible |

| **Section III. Teeth** | |
|---|---|
| Tooth spacing | not applicable |
| number of orders of teeth | not applicable |
| teeth / cm | |
| sinus shape | not applicable |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | not applicable |
| principal vein termination | not applicable |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**Diagnostic Features:**

Major secondaries eucamptodromous, irregular spacing, many intersecondaries, entire margin

**Text Description:**

Leaf attachment not visible; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not visible; leaflet organization not visible. Blade attachment not visible. Petiole features not visible. Laminar size unknown; laminar L:W ratio >3:1; laminar shape unknown with medial symmetrical and base not visible to not visible. Margin unlobed and entire with not visible edges. Apex angle not visible; apex shape not visible to not visible; base angle not visible; base shape not visible to not visible. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins not applicable; 1basal veins; agrophic veins absent. Major secondaries eucamptodromous, spacing irregular, uniform; attachment decurrent. Interior secondaries present; minor secondary course not applicable; not visiblepresent, proximal course parallel to major secondaries; Intersecondaries <50% of subjacent secondary; distal course reticulating; occur at ~ 1 per intercostal area; Intercostal tertiary veins irregular reticulate, to irregular reticulate; not applicableto midvein; vein angle inconsistent. Epimedial tertiaries reticulate; proximal course acute to midvein; distal course parallel to intercostal tertiary. Exterior tertiary course looped. Quaternary vein fabric irregular reticulate. Quinternary vein fabric irregular reticulate. Areolation moderate development; Freely ending veinlets mostly one branched, with simpletermination. Marginal Ultimate venation not visible. Tooth spacing not applicable, with not applicable orders of teeth; teeth / cm ; sinus shape not applicable. Tooth shapes ; ; ; and . Principal vein not applicable; terminates not applicable; accesory vein not applicable; tooth apex not applicable.

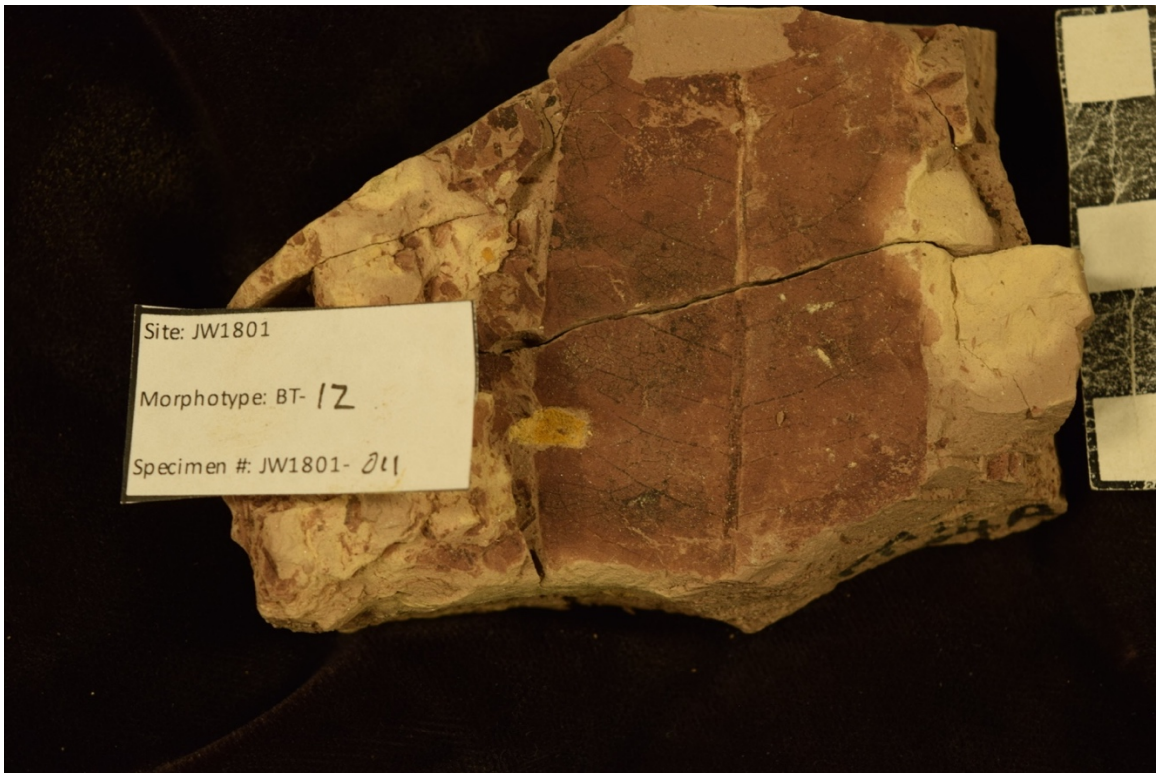


Figure A.12. Morphotype BT-12. Present in locality JW1801. Specimen number JW1801-011, exemplar.

Table A.17. Morphotype BT-13 leaf architecture description. Present in locality JW1801.

| Section I. Leaf Characters | Description |
|---|---|
| Leaf attachment | petiolate |
| leaf arrangement | not visible |
| leaf organization | not visible |
| leaflet organization | not visible |
| Leaflet attachment | not visible |
| Petiole features | petiolar |
| | |
| **Features of the blade:** | |
| Position of lamina attachment | marginal |
| Laminar size | mesophyll |
| laminar L:W ratio | 2:1 |
| laminar shape | elliptic |
| medial symmetry | symmetrical |
| base symmetry | symmetrical |
| base symmetry | symmetrical |
| lobation | unlobed |
| margin type | entire |
| special margin features | not visible |
| Apex angle | not visible |
| apex shape | not visible |
| apex shape | not visible |
| base angle | acute |
| base shape | concave |
| base shape | not visible |
| Terminal apex features | not visible |
| | |
| Surface texture | not visible |
| Surficial glands | not visible |
| | |
| **Section III. Teeth** | |
| Tooth spacing | not applicable |
| number of orders of teeth | not applicable |
| teeth / cm | |
| sinus shape | not applicable |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | not applicable |
| principal vein termination | not applicable |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

| | Section II. Venation | Description |
|---|---|---|
| **1º** | Primary vein framework | pinnate |
| | naked basal veins | not visible |
| | number of basal veins | 1 |
| | agrophic veins | absent |
| **2º** | Major 2º vein framework | eucamptodromous |
| | Interior secondaries | not visible |
| | minor secondary course | not visible |
| | Perimarginal veins | not visible |
| | major secondary spacing | not visible |
| | Variation of secondary angle | not visible |
| **Inter-2º** | Major secondary attachment | not visible |
| | proximal course | not visible |
| | intersecondary length | not applicable |
| | distal course | not applicable |
| | vein frequency | not applicable |
| **3º** | Intercostal tertiary vein fabric | not applicable |
| | Intercostal tertiary vein fabric | not applicable |
| | Angle of percurrent tertiaries | not applicable |
| | vein angle variability | not applicable |
| | Epimedial tertiaries | not visible |
| | proximal course | not visible |
| | distal course | not visible |
| | Exterior tertiary course | not visible |
| **4º** | Quaternary vein fabric | not visible |
| **5º** | Quinternary vein fabric | not visible |
| | Areolation | not visible |
| | FEV branching | not visible |
| | FEV termination | not visible |
| | Marginal Ultimate venation | not visible |

**Text Description:**

Leaf attachment petiolate; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not visible; leaflet organization not visible. Blade attachment marginal. Petiole features petiolar. Laminar size mesophyll; laminar L:W ratio 2:1; laminar shape elliptic with medial symmetrical and base symmetrical to symmetrical. Margin unlobed and entire with not visible edges. Apex angle not visible; apex shape not visible to not visible; base angle acute; base shape concave to not visible. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins not visible; 1basal veins; agrophic veins absent. Major secondaries eucamptodromous, spacing not visible, not visible; attachment not visible. Interior secondaries not visible; minor secondary course not visible; not visiblepresent, proximal course not visible; Intersecondaries not applicable; distal course not applicable; occur at not applicable; Intercostal tertiary veins not applicable, to not applicable; not applicableto midvein; vein angle not applicable. Epimedial tertiaries not visible; proximal course not visible; distal course not visible. Exterior tertiary course not visible. Quaternary vein fabric not visible. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing not applicable, with not applicable orders of teeth; teeth / cm ; sinus shape not applicable. Tooth shapes ; ; ; and . Principal vein not applicable; terminates not applicable; accesory vein not applicable; tooth apex not applicable.

**Diagnostic Features:**

Entire margin, major secondaries eucamptodromous

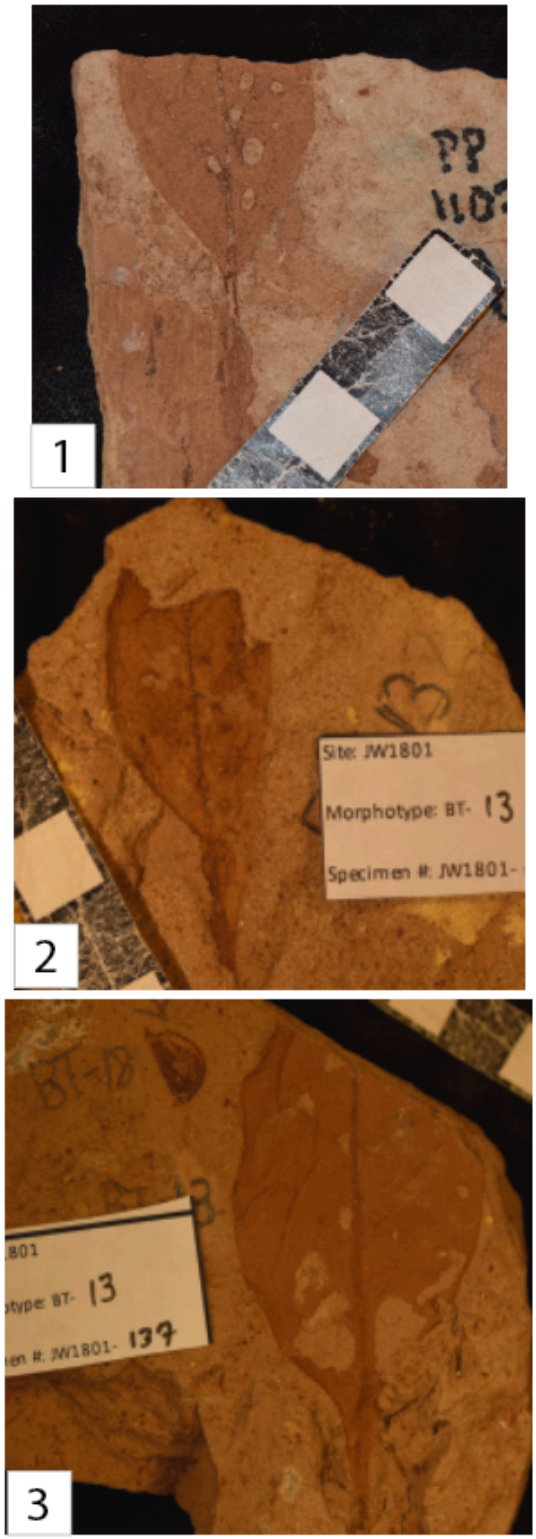


Figure A.13. Morphotype BT-13. Present in locality JW1801. 1. Specimen number JW1801-012, exemplar, 2. Specimen number JW1801-087, 3. Specimen number JW1801-137

Table A.18. Morphotype BT-14 leaf architecture description. Present in locality JW1801.

| Section I. Leaf Characters | Description |
|---|---|
| Leaf attachment | petiolate |
| leaf arrangement | not visible |
| leaf organization | not visible |
| leaflet organization | not applicable |
| Leaflet attachment | not applicable |
| Petiole features | not visible |
| | |
| **Features of the blade:** | |
| Position of lamina attachment | marginal |
| Laminar size | mesophyll |
| laminar L:W ratio | 2:1 |
| laminar shape | obovate |
| medial symmetry | symmetrical |
| base symmetry | symmetrical |
| base symmetry | symmetrical |
| lobation | unlobed |
| margin type | serrate |
| special margin features | not visible |
| Apex angle | not visible |
| apex shape | not visible |
| apex shape | not visible |
| base angle | acute |
| base shape | straight |
| base shape | straight |
| Terminal apex features | not visible |
| Surface texture | not visible |
| Surficial glands | not visible |

| | Section II. Venation | Description |
|---|---|---|
| **1º** | Primary vein framework | pinnate |
| | naked basal veins | not visible |
| | number of basal veins | 1 |
| | agrophic veins | absent |
| **2º** | Major 2º vein framework | semicraspedodromous |
| | Interior secondaries | absent |
| | minor secondary course | not applicable |
| | Perimarginal veins | not applicable |
| | major secondary spacing | regular |
| | Variation of secondary angle | inconsistent |
| **Inter-2º** | Major secondary attachment | decurrent/deflected |
| | proximal course | absent |
| | intersecondary length | not applicable |
| | distal course | not applicable |
| | vein frequency | not applicable |
| **3º** | Intercostal tertiary vein fabric | sinuous opposite percurrent |
| | Intercostal tertiary vein fabric | straight opposite percurrent |
| | Angle of percurrent tertiaries | perpendicular |
| | vein angle variability | consistent |
| | Epimedial tertiaries | opposite percurrent |
| | proximal course | perpendicular to midvein |
| | distal course | parallel to intercostal tertiary |
| | Exterior tertiary course | terminating at the margin |
| **4º** | Quaternary vein fabric | mixed percurrent |
| **5º** | Quinternary vein fabric | regular reticulate |
| | Areolation | moderate development |
| | FEV branching | absent |
| | FEV termination | absent |
| | Marginal Ultimate venation | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | regular |
| number of orders of teeth | one |
| teeth / cm | 2 teeth/1 cm |
| sinus shape | rounded |
| tooth shapes | ST/CC |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | present |
| principal vein termination | on distal flank of tooth |
| course of accessory vein | not applicable |
| features of the tooth apex | mucronate |

**Diagnostic Features:**

Major secondaries semicraspedodromous, serrated margins

**Text Description:**

Leaf attachment petiolate; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not applicable; leaflet organization not applicable. Blade attachment marginal. Petiole features not visible. Laminar size mesophyll; laminar L:W ratio 2:1; laminar shape obovate with medial symmetrical and base symmetrical to symmetrical. Margin unlobed and serrate with not visible edges. Apex angle not visible; apex shape not visible to not visible; base angle acute; base shape straight to straight. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins not visible; 1basal veins; agrophic veins absent. Major secondaries semicraspedodromous, spacing regular, inconsistent; attachment decurrent/deflected . Interior secondaries absent; minor secondary course not applicable; not applicablepresent, proximal course absent; Intersecondaries not applicable; distal course not applicable; occur at not applicable; Intercostal tertiary veins sinuous opposite percurrent, to straight opposite percurrent; perpendicularto midvein; vein angle consistent. Epimedial tertiaries opposite percurrent; proximal course perpendicular to midvein; distal course parallel to intercostal tertiary. Exterior tertiary course terminating at the margin. Quaternary vein fabric mixed percurrent. Quinternary vein fabric regular reticulate. Areolation moderate development; Freely ending veinlets absent, with absenttermination. Marginal Ultimate venation not visible. Tooth spacing regular, with one orders of teeth; teeth / cm 2 teeth/1 cm; sinus shape rounded. Tooth shapes ST/CC; ; ; and . Principal vein present; terminates present; accesory vein not applicable; tooth apex mucronate .

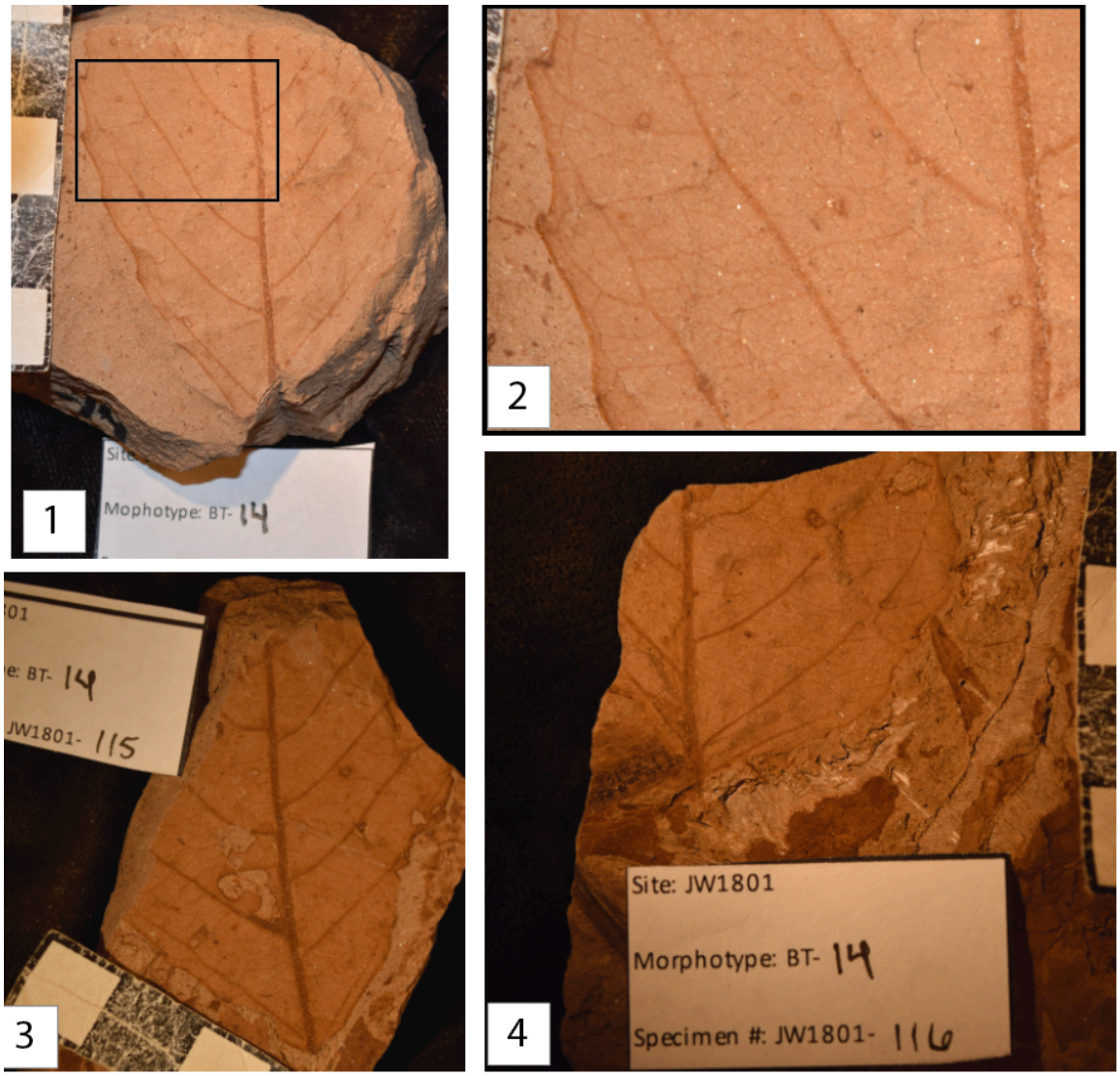


Figure A.14. Morphotype BT-14. Present in locality JW1801. 1. Specimen number JW1801-013, exemplar, 2. Specimen number JW1801-013, enlarged section to show venation, 3. Specimen number JW1801-115, 4. Specimen number JW1801-116.

Table A.19. Morphotype BT-15 leaf architecture description. Present in locality JW1802.

| Section I. Leaf Characters | Description | | Section II. Venation | Description |
|---|---|---|---|---|
| Leaf attachment | petiolate | **1º** | Primary vein framework | pinnate |
| leaf arrangement | not visible | | naked basal veins | absent |
| leaf organization | simple* | | number of basal veins | 1 |
| leaf organization | *possibly compound | | agrophic veins | absent |
| Leaflet attachment | petiolulate | **2º** | Major 2º vein framework | festooned semicraspedodromous |
| Petiole features | absent | | Interior secondaries | present |
| | | | minor secondary course | not applicable |
| **Features of the blade:** | | | Perimarginal veins | not applicable |
| Position of lamina attachment | not visible | | major secondary spacing | irregular |
| Laminar size | noto to meso | | Variation of secondary angle | inconsistent |
| laminar L:W ratio | >3:1 | **Inter-2º** | Major secondary attachment | decurrent |
| laminar shape | oblong | | proximal course | perpendicular to midvein |
| medial symmetry | symmetrical | | intersecondary length | >50% of subjacent secondary |
| base symmetry | symmetrical | | distal course | perpendicular to subjacent major secondary |
| base symmetry | symmetrical | | vein frequency | >1 per intercostal area |
| lobation | unlobed | **3º** | Intercostal tertiary vein fabric | irregular reticulate |
| margin type | entire | | Intercostal tertiary vein fabric | irregular reticulate |
| special margin features | not applicable | | Angle of percurrent tertiaries | not applicable |
| Apex angle | acute | | vein angle variability | inconsistent |
| apex shape | straight to | | Epimedial tertiaries | mixed percurrent |
| apex shape | acuminate | | proximal course | perpendicular to midvein |
| base angle | acute | | distal course | basiflexed |
| base shape | straight | | Exterior tertiary course | terminating at the margin |
| base shape | straight | **4º** | Quaternary vein fabric | irregular reticulate |
| Terminal apex features | absent | **5º** | Quinternary vein fabric | irregular reticulate |
| | | | Areolation | good development |
| Surface texture | not applicable | | FEV branching | mostly two or more branched |
| Surficial glands | not visible | | FEV termination | simple |
| | | | Marginal Ultimate venation | looped |

| Section III. Teeth | |
|---|---|
| Tooth spacing | not applicable |
| number of orders of teeth | not applicable |
| teeth / cm | |
| sinus shape | not applicable |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | not applicable |
| principal vein termination | not applicable |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**Diagnostic Features:**

Entire margin, major secondaries semicraspedodromous, interseconadies

**Text Description:**

Leaf attachment petiolate; leaf arrangement not visible; leaf organization simple*. Leaflet attachment petiolulate; leaf organization *possibly compound. Blade attachment not visible. Petiole features absent. Laminar size noto to meso; laminar L:W ratio >3:1; laminar shape oblong with medial symmetrical and base symmetrical to symmetrical. Margin unlobed and entire with not applicable edges. Apex angle acute; apex shape straight to to acuminate; base angle acute; base shape straight to straight. Termianal apex absent. Surface texture not applicable. Surficial glands not visible. Primary venation pinnate; naked basal veins absent; 1basal veins; agrophic veins absent. Major secondaries festooned semicraspedodromous, spacing irregular, inconsistent; attachment decurrent. Interior secondaries present; minor secondary course not applicable; not applicablepresent, proximal course perpendicular to midvein; Intersecondaries >50% of subjacent secondary; distal course perpendicular to subjacent major secondary; occur at >1 per intercostal area; Intercostal tertiary veins irregular reticulate, to irregular reticulate; not applicableto midvein; vein angle inconsistent. Epimedial tertiaries mixed percurrent; proximal course perpendicular to midvein; distal course basiflexed . Exterior tertiary course terminating at the margin. Quaternary vein fabric irregular reticulate. Quinternary vein fabric irregular reticulate. Areolation good development; Freely ending veinlets mostly two or more branched, with simpletermination. Marginal Ultimate venation looped. Tooth spacing not applicable, with not applicable orders of teeth; teeth / cm ; sinus shape not applicable. Tooth shapes ; ; ; and . Principal vein not applicable; terminates not applicable; accesory vein not applicable; tooth apex not applicable.

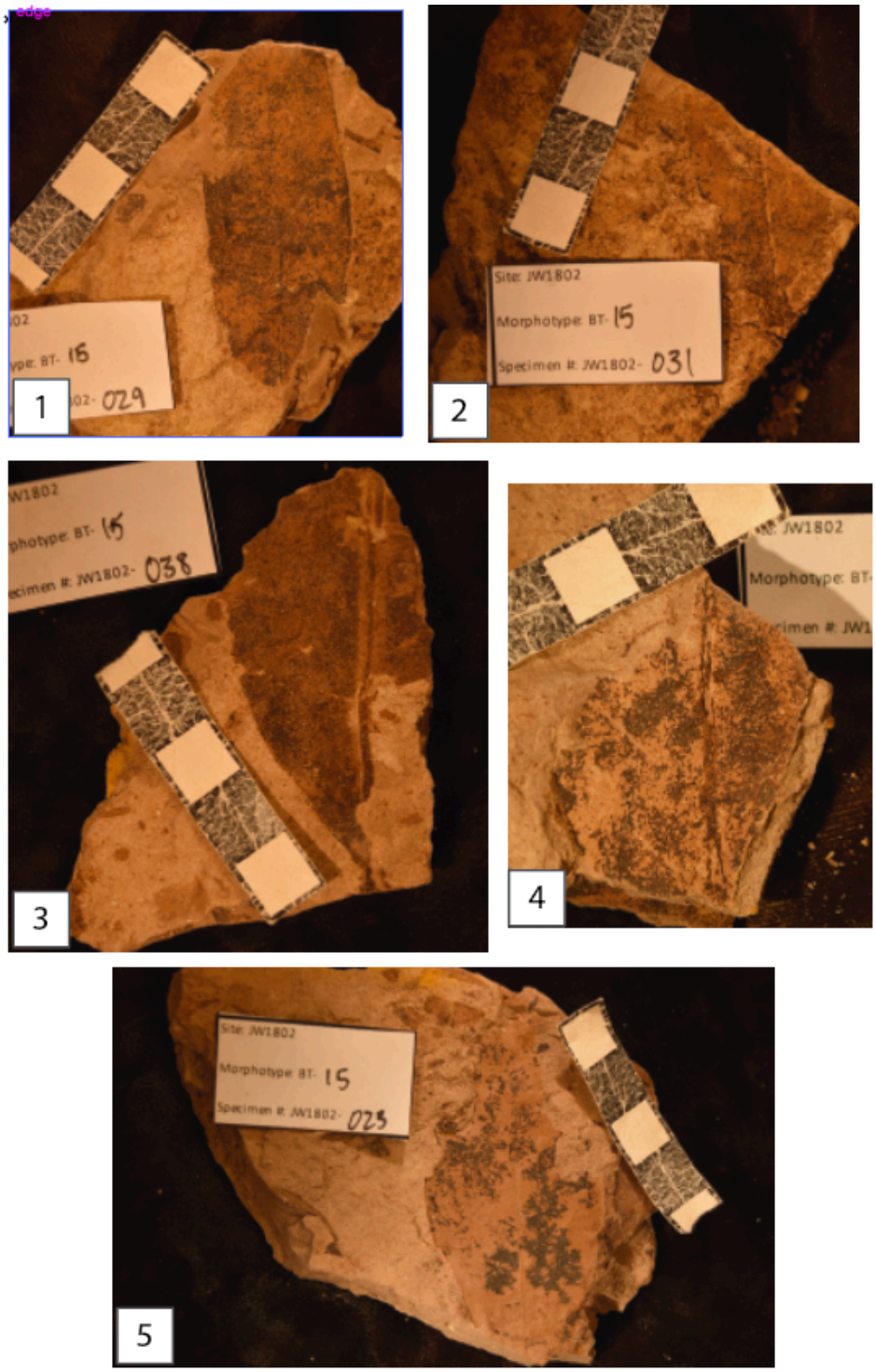


Figure A.15. Morphotype BT-15. Present in locality JW1802. 1. Specimen number JW1802-029, exemplar, 2. JW1802-031, 3. JW1802-038, 4. JW1802-033, 5. JW1802-023.

Table A.20. Morphotype BT-16 leaf architecture description. Present in locality JW1801.

| Section I. Leaf Characters | Description | | Section II. Venation | Description |
|---|---|---|---|---|
| Leaf attachment | petiolate | **1º** | Primary vein framework | pinnate |
| leaf arrangement | not visible | | naked basal veins | absent |
| leaf organization | not visible | | number of basal veins | 1 |
| leaflet organization | not visible | | agrophic veins | absent |
| Leaflet attachment | not visible | **2º** | Major 2º vein framework | simple brochidodromous |
| Petiole features | alate | | Interior secondaries | present |
| | | | minor secondary course | not visible |
| **Features of the blade:** | | | Perimarginal veins | not visible, possible |
| Position of lamina attachment | marginal | | major secondary spacing | regular |
| Laminar size | noto-meso | | Variation of secondary angle | uniform |
| laminar L:W ratio | >4:1 | | Major secondary attachment | excurrent |
| laminar shape | elliptic | **Inter-2º** | proximal course | parallel to major secondaries |
| medial symmetry | symmetrical | | intersecondary length | >50% of subjacent secondary |
| base symmetry | symmetrical | | distal course | parallel to subjacent major secondary |
| base symmetry | symmetrical | | vein frequency | ~ 1 per intercostal area |
| lobation | unlobed | **3º** | Intercostal tertiary vein fabric | straight opposite percurrent |
| margin type | entire | | Intercostal tertiary vein fabric | convex opposite percurrent |
| special margin features | not applicable | | Angle of percurrent tertiaries | acute |
| Apex angle | acute | | vein angle variability | consistent |
| apex shape | straight | | Epimedial tertiaries | not visible |
| apex shape | straight | | proximal course | not visible |
| base angle | acute | | distal course | not visible |
| base shape | straight | | Exterior tertiary course | not visible |
| base shape | straight | **4º** | Quaternary vein fabric | opposite percurrent |
| Terminal apex features | absent | **5º** | Quinternary vein fabric | not visible |
| | | | Areolation | not visible |
| Surface texture | not visible | | FEV branching | not visible |
| Surficial glands | not visible | | FEV termination | not visible |
| | | | Marginal Ultimate venation | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | not applicable |
| number of orders of teeth | not applicable |
| teeth / cm | |
| sinus shape | not applicable |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | not applicable |
| principal vein termination | not applicable |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**Diagnostic Features:**

Entire margin, major secondaries simple brochidodromous, interseconadies

**Text Description:**

Leaf attachment petiolate; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not visible; leaflet organization not visible. Blade attachment marginal. Petiole features alate. Laminar size noto-meso; laminar L:W ratio >4:1; laminar shape elliptic with medial symmetrical and base symmetrical to symmetrical. Margin unlobed and entire with not applicable edges. Apex angle acute; apex shape straight to straight; base angle acute; base shape straight to straight. Termianal apex absent. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins absent; 1basal veins; agrophic veins absent. Major secondaries simple brochidodromous, spacing regular, uniform; attachment excurrent. Interior secondaries present; minor secondary course not visible; not visible, possiblepresent, proximal course parallel to major secondaries; Intersecondaries >50% of subjacent secondary; distal course parallel to subjacent major secondary; occur at ~ 1 per intercostal area; Intercostal tertiary veins straight opposite percurrent, to convex opposite percurrent; acuteto midvein; vein angle consistent. Epimedial tertiaries not visible; proximal course not visible; distal course not visible. Exterior tertiary course not visible. Quaternary vein fabric opposite percurrent. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing not applicable, with not applicable orders of teeth; teeth / cm ; sinus shape not applicable. Tooth shapes ; ; ; and . Principal vein not applicable; terminates not applicable; accesory vein not applicable; tooth apex not applicable

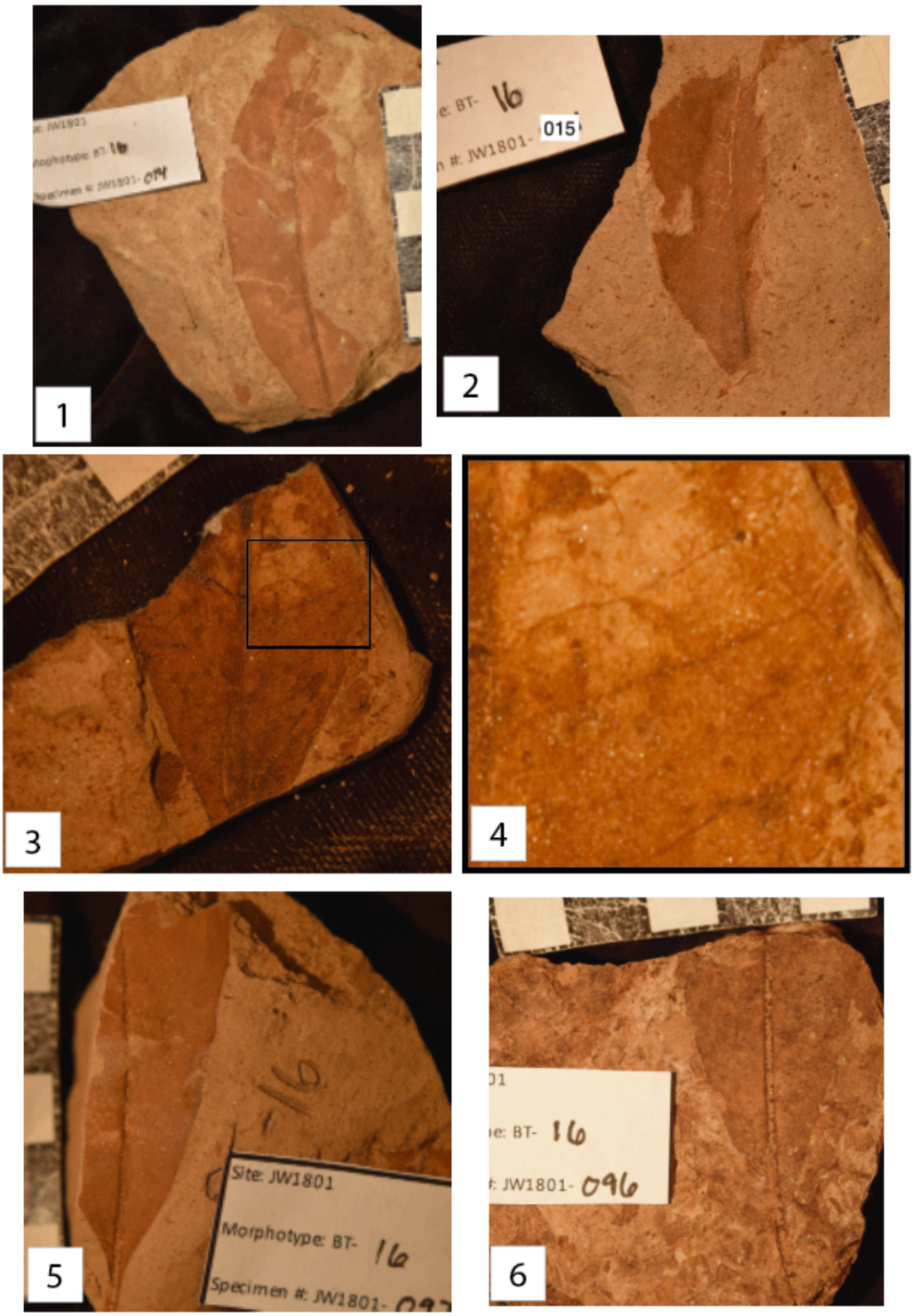


Figure A.16. Morphotype BT-16. Present in locality JW1801. Specimen number: 1. JW1801-014, exemplar, 2. JW1801-015, 3. JW1801- 094, 4.JW1801-094, enlarged to show venation, 5. JW1801-092, 6. JW1801-096.

Table A.21. Morphotype BT-17 leaf architecture description. Present in locality JW1802.

| Section I. Leaf Characters | Description | | Section II. Venation | Description |
|---|---|---|---|---|
| Leaf attachment | petiolate | **1º** | Primary vein framework | pinnate |
| leaf arrangement | not visible | | naked basal veins | not visible |
| leaf organization | not visible | | number of basal veins | 1 |
| leaflet organization | not visible | | agrophic veins | not visible |
| Leaflet attachment | petiolulate | **2º** | Major 2º vein framework | craspedodromous |
| Petiole features | absent | | Interior secondaries | not visible |
| | | | minor secondary course | not visible |
| **Features of the blade:** | | | Perimarginal veins | not applicable |
| Position of lamina attachment | marginal | | major secondary spacing | regular |
| Laminar size | mesophyll | | Variation of secondary angle | uniform |
| laminar L:W ratio | 3:1 | **Inter-2º** | Major secondary attachment | deflected |
| laminar shape | obovate | | proximal course | not visible |
| medial symmetry | symmetrical | | intersecondary length | not applicable |
| base symmetry | symmetrical | | distal course | not applicable |
| base symmetry | Uncertain? | | vein frequency | not applicable |
| lobation | unlobed | **3º** | Intercostal tertiary vein fabric | opposite percurrent |
| margin type | toothed | | Intercostal tertiary vein fabric | opposite percurrent |
| special margin features | not visible | | Angle of percurrent tertiaries | obtuse |
| Apex angle | not visible | | vein angle variability | consistent |
| apex shape | not visible | | Epimedial tertiaries | not visible |
| apex shape | not visible | | proximal course | perpendicular to midvein |
| base angle | acute | | distal course | parallel to intercostal tertiary |
| base shape | straight | | Exterior tertiary course | not visible |
| base shape | straight | **4º** | Quaternary vein fabric | not visible |
| Terminal apex features | not visible | **5º** | Quinternary vein fabric | not visible |
| | | | Areolation | not visible |
| Surface texture | not visible | | FEV branching | not visible |
| Surficial glands | not visible | | FEV termination | not visible |
| | | | Marginal Ultimate venation | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | irregular |
| number of orders of teeth | 1 |
| teeth / cm | 1 per 2 cm |
| sinus shape | rounded |
| tooth shapes | not visible |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | present |
| principal vein termination | on distal flank of tooth |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**Diagnostic Features:**

Toothed margin, possibly lobed, major secondaries craspedodromous,interseconadies

**Text Description:**

Leaf attachment petiolate; leaf arrangement not visible; leaf organization not visible. Leaflet attachment petiolulate; leaflet organization not visible. Blade attachment marginal. Petiole features absent. Laminar size mesophyll; laminar L:W ratio 3:1; laminar shape obovate with medial symmetrical and base symmetrical to ? Guess, uncertain. Margin unlobed and toothed with not visible edges. Apex angle not visible; apex shape not visible to not visible; base angle acute; base shape straight to straight. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins not visible; 1basal veins; agrophic veins not visible. Major secondaries craspedodromous, spacing regular, uniform; attachment deflected. Interior secondaries not visible; minor secondary course not visible; not applicablepresent, proximal course not visible; Intersecondaries not applicable; distal course not applicable; occur at not applicable; Intercostal tertiary veins not visible, to not applicable; not applicableto midvein; vein angle not applicable. Epimedial tertiaries not visible; proximal course not visible; distal course not visible. Exterior tertiary course not visible. Quaternary vein fabric not visible. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing irregular, with 1 orders of teeth; teeth / cm 1 per 2 cm; sinus shape rounded. Tooth shapes not visible; ; ; and . Principal vein present; terminates present; accesory vein not applicable; tooth apex not applicable.

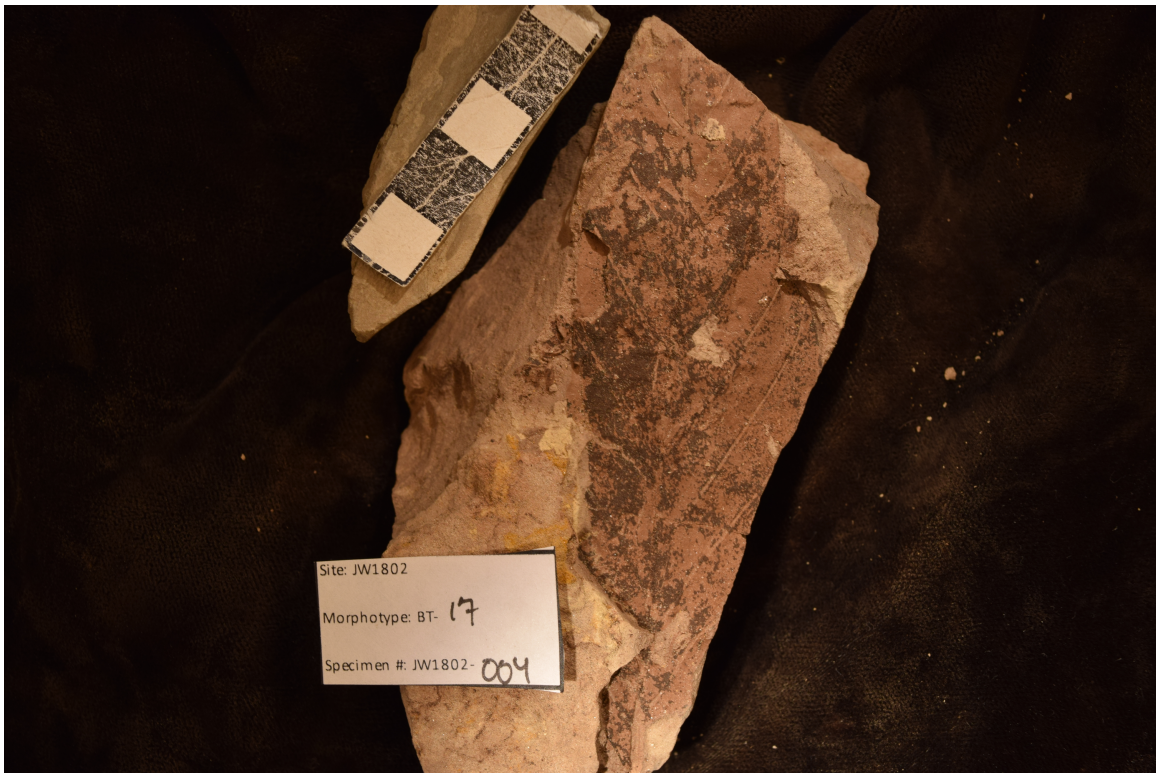


Figure A.17. Morphotype BT-17. Present in locality JW1802. Specimen number JW1802-004, exemplar.

Table A.22. Morphotype BT-19 leaf architecture description. Present in locality JW1801.

| Section I. Leaf Characters | Description | | Section II. Venation | Description |
|---|---|---|---|---|
| Leaf attachment | petiolate | **1º** | Primary vein framework | pinnate |
| leaf arrangement | not visible | | naked basal veins | not visible |
| leaf organization | simple | | number of basal veins | 1 |
| leaflet organization | not visible | | agrophic veins | not visible |
| Leaflet attachment | not visible | **2º** | Major 2º vein framework | eucamptodromous |
| Petiole features | not visible | | Interior secondaries | not visible |
| | | | minor secondary course | not visible |
| **Features of the blade:** | | | Perimarginal veins | not visible |
| Position of lamina attachment | marginal | | major secondary spacing | not visible |
| Laminar size | meso-macro | | Variation of secondary angle | not visible |
| laminar L:W ratio | ~1:1 | **Inter-2º** | Major secondary attachment | not visible |
| laminar shape | ovate | | proximal course | not visible |
| medial symmetry | symmetrical? | | intersecondary length | not applicable |
| base symmetry | symmetrical? | | distal course | not applicable |
| base symmetry | not visible | | vein frequency | not applicable |
| lobation | unlobed | **3º** | Intercostal tertiary vein fabric | not applicable |
| margin type | entire | | Intercostal tertiary vein fabric | not applicable |
| special margin features | not visible | | Angle of percurrent tertiaries | not applicable |
| Apex angle | acute | | vein angle variability | not applicable |
| apex shape | not visible | | Epimedial tertiaries | not visible |
| apex shape | not visible | | proximal course | not visible |
| base angle | obtuse | | distal course | not visible |
| base shape | concavo-convex | | Exterior tertiary course | not visible |
| base shape | not visible | **4º** | Quaternary vein fabric | not visible |
| Terminal apex features | not visible | **5º** | Quinternary vein fabric | not visible |
| | | | Areolation | not visible |
| Surface texture | not visible | | FEV branching | not visible |
| Surficial glands | not visible | | FEV termination | not visible |
| | | | Marginal Ultimate venation | not visible |

| Section III. Teeth | | : |
|---|---|---|
| Tooth spacing | not applicable | |
| number of orders of teeth | not applicable | |
| teeth / cm | | |
| sinus shape | not applicable | |
| tooth shapes | | |
| tooth shapes | | |
| tooth shapes | | |
| tooth shapes | | |
| Principal vein | not applicable | |
| principal vein termination | not applicable | |
| course of accessory vein | not applicable | |
| features of the tooth apex | not applicable | |

**Text Description:**

Leaf attachment petiolate; leaf arrangement not visible; leaf organization simple. Leaflet attachment not visible; leaflet organization not visible. Blade attachment marginal. Petiole features not visible. Laminar size meso-macro; laminar L:W ratio ~1:1; laminar shape ovate with medial symmetrical? and base symmetrical? to not visible. Margin unlobed and entire with not visible edges. Apex angle acute; apex shape not visible to not visible; base angle obtuse; base shape concavo-convex to not visible. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins not visible; 1basal veins; agrophic veins not visible. Major secondaries eucamptodromous, spacing not visible, not visible; attachment not visible. Interior secondaries not visible; minor secondary course not visible; not visiblepresent, proximal course not visible; Intersecondaries not applicable; distal course not applicable; occur at not applicable; Intercostal tertiary veins not applicable, to not applicable; not applicableto midvein; vein angle not applicable. Epimedial tertiaries not visible; proximal course not visible; distal course not visible. Exterior tertiary course not visible. Quaternary vein fabric not visible. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing not applicable, with not applicable orders of teeth; teeth / cm ; sinus shape not applicable. Tooth shapes ; ; ; and . Principal vein not applicable; terminates not applicable; accesory vein not applicable; tooth apex not applicable.

**Diagnostic Features:**

Entire margin, major secondaries eucamptodromous, base shape concavo-convex

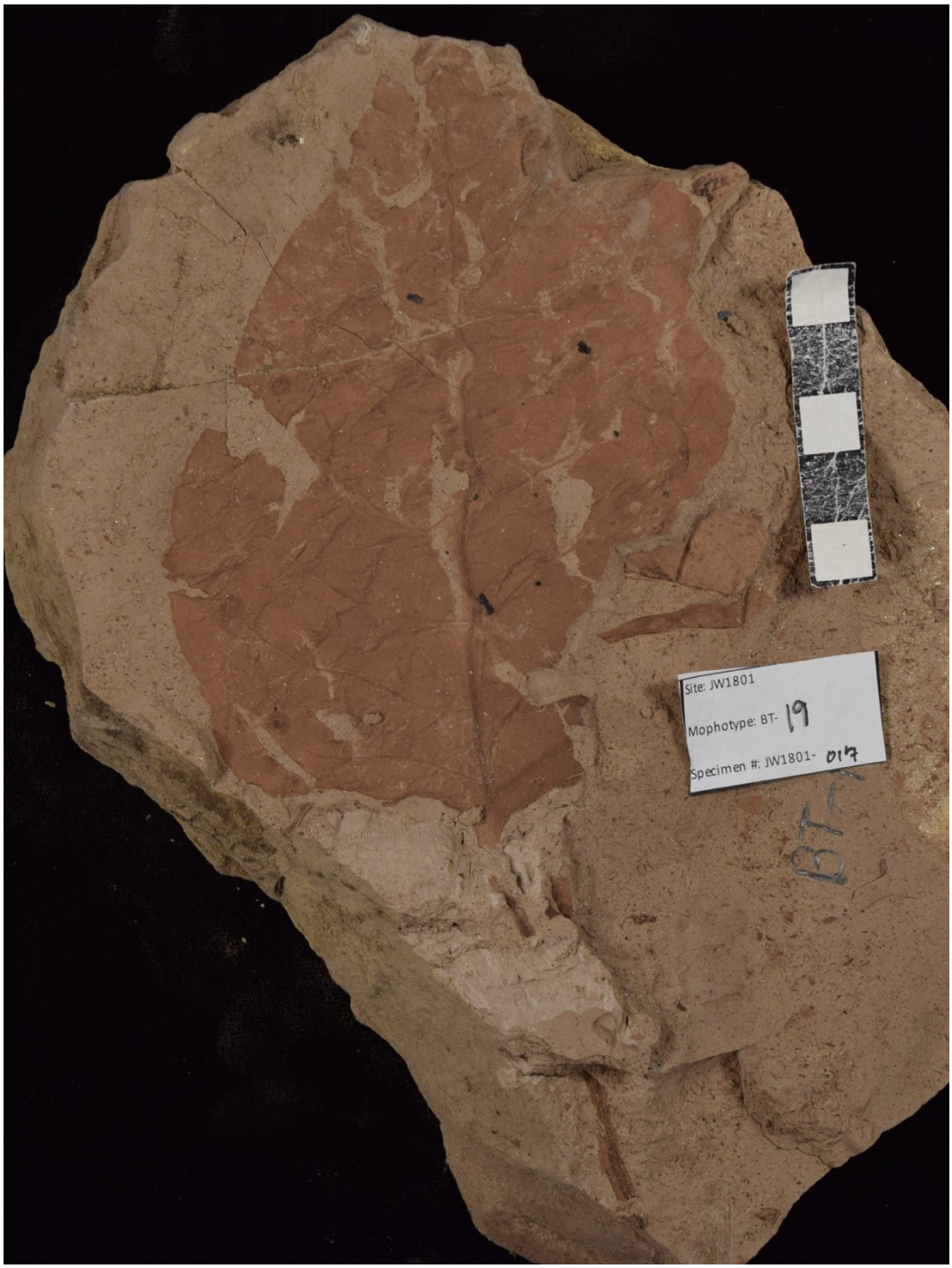


Figure A.18. Morphotype BT-19. Present in locality JW1801. Specimen number JW1801-017, exemplar.

Table A.23. Morphotype BT-22 leaf architecture description. Present in locality JW1803.

| Section I. Leaf Characters | Description | | Section II. Venation | Description |
|---|---|---|---|---|
| Leaf attachment | not visible | **1º** | Primary vein framework | pinnate |
| leaf arrangement | not visible | | naked basal veins | not visible |
| leaf organization | not visible | | number of basal veins | 1 |
| leaflet organization | not visible | | agrophic veins | absent |
| Leaflet attachment | not visible | **2º** | Major 2º vein framework | semicraspedodromous |
| Petiole features | not visible | | Interior secondaries | present |
| | | | minor secondary course | not applicable |
| **Features of the blade:** | | | Perimarginal veins | intramarginal secondary |
| Position of lamina attachment | not visible | | major secondary spacing | regular |
| Laminar size | notophyll | | Variation of secondary angle | uniform |
| laminar L:W ratio | >3:1 | | Major secondary attachment | decurrent |
| laminar shape | linear | **Inter-2º** | proximal course | parallel to major secondaries |
| medial symmetry | asymmetrical | | intersecondary length | <50% of subjacent secondary |
| base symmetry | asymmetrical | | distal course | basiflexed, not joining subjacent secondary at right angles |
| base symmetry | asymmetrical | | vein frequency | < 1 per intercostal area |
| lobation | unlobed | **3º** | Intercostal tertiary vein fabric | irregular reticulate |
| margin type | toothed | | Intercostal tertiary vein fabric | irregular reticulate |
| special margin features | not visible | | Angle of percurrent tertiaries | not applicable |
| Apex angle | acute | | vein angle variability | inconsistent |
| apex shape | straight | | Epimedial tertiaries | reticulate |
| apex shape | straight | | proximal course | not visible |
| base angle | not visible | | distal course | not visible |
| base shape | not visible | | Exterior tertiary course | not visible |
| base shape | not visible | **4º** | Quaternary vein fabric | not visible |
| Terminal apex features | absent | **5º** | Quinternary vein fabric | not visible |
| | | | Areolation | not visible |
| Surface texture | not visible | | FEV branching | not visible |
| Surficial glands | not visible | | FEV termination | not visible |
| | | | Marginal Ultimate venation | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | irregular |
| number of orders of teeth | not applicable |
| teeth / cm | 3/cm |
| sinus shape | rounded |
| tooth shapes | CV/ST |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | absent |
| principal vein termination | not applicable |
| course of accessory vein | not applicable |
| features of the tooth apex | none |

**Text Description:**

Leaf attachment not visible; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not visible; leaflet organization not visible. Blade attachment not visible. Petiole features not visible. Laminar size notophyll; laminar L:W ratio >3:1; laminar shape linear with medial asymmetrical and base asymmetrical to asymmetrical. Margin unlobed and toothed with not visible edges. Apex angle acute; apex shape straight to straight; base angle not visible; base shape not visible to not visible. Termianal apex absent. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins not visible; 1basal veins; agrophic veins absent. Major secondaries semicraspedodromous, spacing regular, uniform; attachment decurrent. Interior secondaries present; minor secondary course not applicable; intramarginal secondarypresent, proximal course parallel to major secondaries; Intersecondaries <50% of subjacent secondary; distal course basiflexed, not joining subjacent secondary at right angles; occur at < 1 per intercostal area; Intercostal tertiary veins irregular reticulate, to irregular reticulate; not applicableto midvein; vein angle inconsistent. Epimedial tertiaries reticulate; proximal course not visible; distal course not visible. Exterior tertiary course not visible. Quaternary vein fabric not visible. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing irregular, with not applicable orders of teeth; teeth / cm 3/cm; sinus shape rounded. Tooth shapes CV/ST; ; ; and . Principal vein absent; terminates absent; accesory vein not applicable; tooth apex none.

**Diagnostic Features:**

Toothed margin, major secondaries semicraspedodromous, interseconadies intercostal tertiaries irregular reticulate

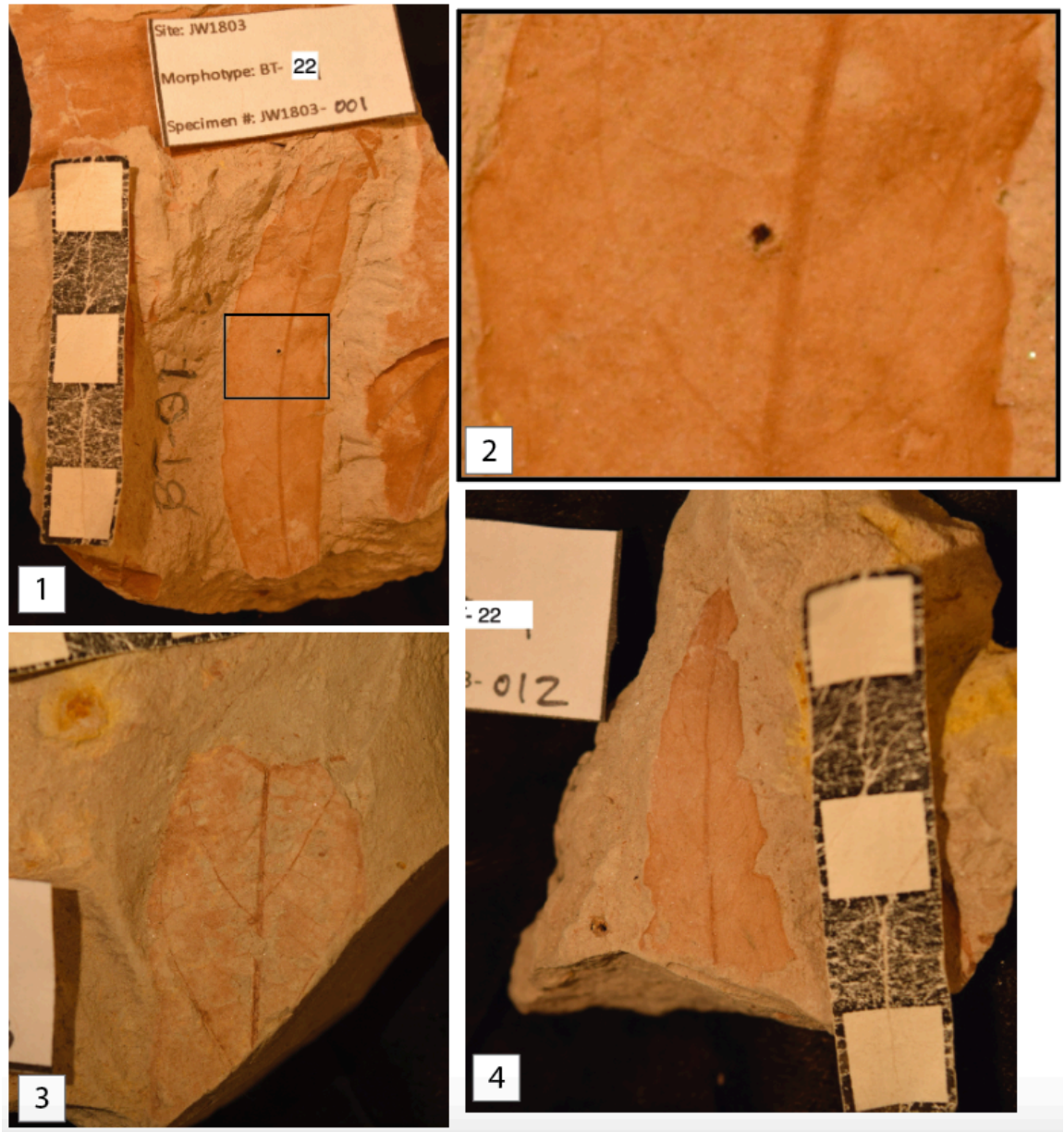


Figure A.19. Morphotype BT-22. Present in locality JW1803. Specimen numbers: 1. JW1803-001, exemplar, 2. JW1803-001, enlarged to show venation, 3. JW1803-013, 4. JW1803-012.

Table A.24. Morphotype BT-24 leaf architecture description. Present in locality JW1803.

| Section I. Leaf Characters | Description |
|---|---|
| Leaf attachment | petiolate |
| leaf arrangement | not applicable |
| leaf organization | not visible |
| leaflet organization | not visible |
| Leaflet attachment | not visible |
| Petiole features | not visible |
| **Features of the blade:** | |
| Position of lamina attachment | marginal |
| Laminar size | notophyll |
| laminar L:W ratio | 4-5:1 |
| laminar shape | ovate |
| medial symmetry | symmetrical |
| base symmetry | not visible |
| base symmetry | not visible |
| lobation | unlobed |
| margin type | serrate |
| special margin features | not applicable |
| Apex angle | acute |
| apex shape | acuminate |
| apex shape | not visible |
| base angle | not visible |
| base shape | not visible |
| base shape | not visible |
| Terminal apex features | not visible |
| Surface texture | not visible |
| Surficial glands | not visible |

| | Section II. Venation | Description |
|---|---|---|
| **1º** | Primary vein framework | pinnate |
| | naked basal veins | absent |
| | number of basal veins | 1 |
| | agrophic veins | absent |
| **2º** | Major 2º vein framework | festooned brochidodromous |
| | Interior secondaries | absent |
| | minor secondary course | not applicable |
| | Perimarginal veins | not applicable |
| | major secondary spacing | irregular |
| | Variation of secondary angle | uniform |
| **Inter-2º** | Major secondary attachment | excurrent |
| | proximal course | absent |
| | intersecondary length | not applicable |
| | distal course | not applicable |
| | vein frequency | not applicable |
| **3º** | Intercostal tertiary vein fabric | irregular reticulate |
| | Intercostal tertiary vein fabric | irregular reticulate |
| | Angle of percurrent tertiaries | acute |
| | vein angle variability | consistent |
| | Epimedial tertiaries | reticulate |
| | proximal course | not visible |
| | distal course | not visible |
| | Exterior tertiary course | not visible |
| **4º** | Quaternary vein fabric | irregular reticulate |
| **5º** | Quinternary vein fabric | not visible |
| | Areolation | not visible |
| | FEV branching | not visible |
| | FEV termination | not visible |
| | Marginal Ultimate venation | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | regular |
| number of orders of teeth | one |
| teeth / cm | 3/1 cm |
| sinus shape | rounded |
| tooth shapes | RT/FL |
| tooth shapes | ST/FL |
| tooth shapes | |
| tooth shapes | |
| Principal vein | absent |
| principal vein termination | not applicable |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**Diagnostic Features:**

Toothed margin, major secondaries festooned brochidodromous,

**Text Description:**

Leaf attachment petiolate; leaf arrangement not applicable; leaf organization not visible. Leaflet attachment not visible; leaflet organization not visible. Blade attachment marginal. Petiole features not visible. Laminar size notophyll; laminar L:W ratio 4-5:1; laminar shape ovate with medial symmetrical and base not visible to not visible. Margin unlobed and serrate with not applicable edges. Apex angle acute; apex shape acuminate to not visible; base angle not visible; base shape not visible to not visible. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins absent; 1basal veins; agrophic veins absent. Major secondaries festooned brochidodromous, spacing irregular, uniform; attachment excurrent. Interior secondaries absent; minor secondary course not applicable; not applicablepresent, proximal course absent; Intersecondaries not applicable; distal course not applicable; occur at not applicable; Intercostal tertiary veins irregular reticulate, to irregular reticulate; acuteto midvein; vein angle consistent. Epimedial tertiaries reticulate; proximal course not visible; distal course not visible. Exterior tertiary course not visible. Quaternary vein fabric irregular reticulate. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing regular, with one orders of teeth; teeth / cm 3/1 cm; sinus shape rounded. Tooth shapes RT/FL; ST/FL; ; and . Principal vein absent; terminates absent; accesory vein not applicable; tooth apex not applicable.

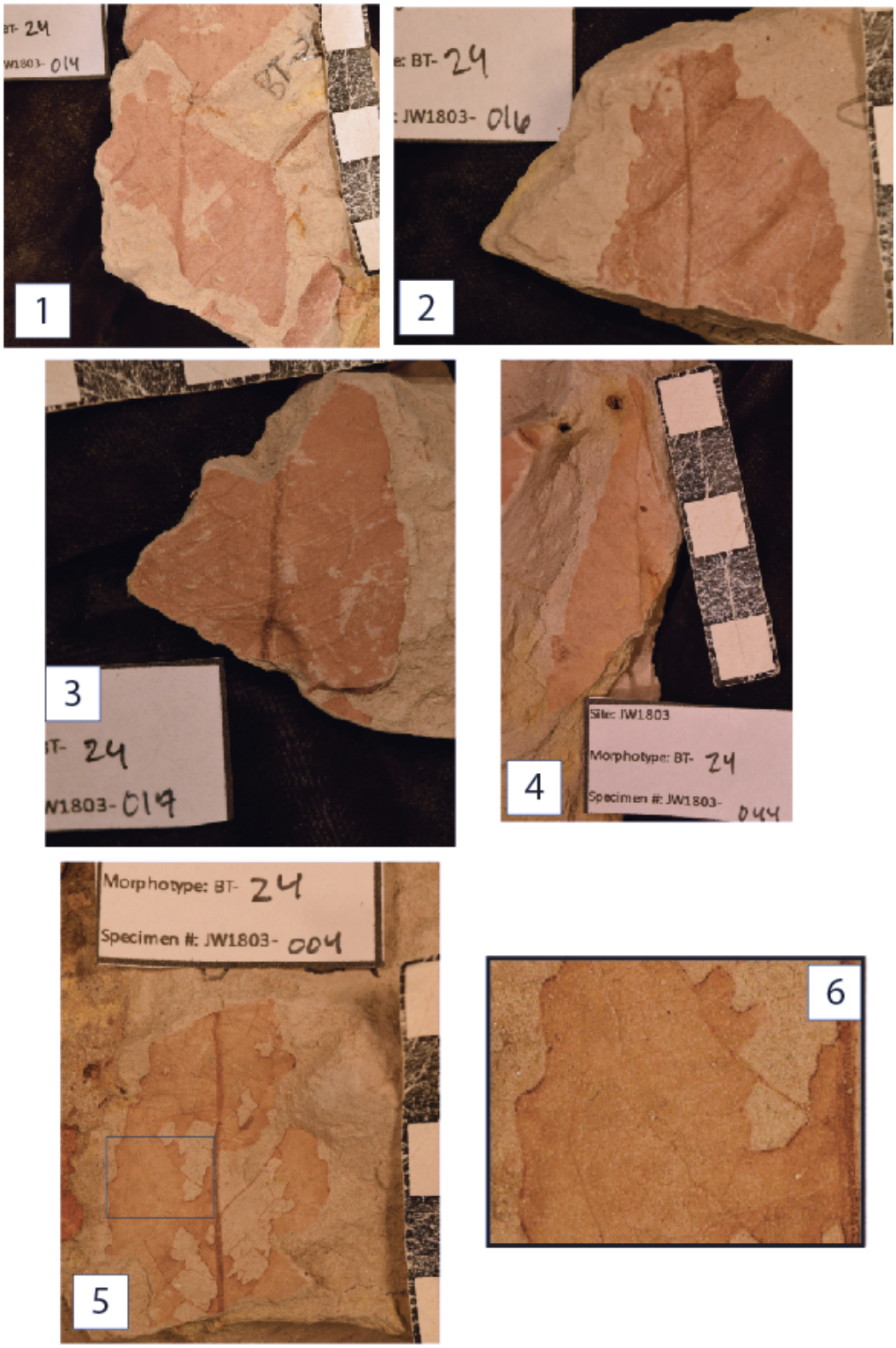


Figure A.20. Morphotype BT-24. Present in locality JW1803. Specimen number: 1. JW1803-014, 2. JW1803-016, 3. JW1803-017, 4. JW1803-044, 5. JW1803-004, exemplar, 6. JW1803-004, enlarged to show venation and serration.

Table A.25. Morphotype BT-25 leaf architecture description. Present in locality JW1803.

| Section I. Leaf Characters | Description | | Section II. Venation | Description |
|---|---|---|---|---|
| Leaf attachment | not visible | 1º | Primary vein framework | pinnate |
| leaf arrangement | not visible | | naked basal veins | not visible |
| leaf organization | not visible | | number of basal veins | 1 |
| leaflet organization | not visible | | agrophic veins | not visible |
| Leaflet attachment | not visible | 2º | Major 2º vein framework | simple brochidodromous |
| Petiole features | not visible | | Interior secondaries | present |
| | | | minor secondary course | not visible |
| **Features of the blade:** | | | Perimarginal veins | fimbrial vein |
| Position of lamina attachment | marginal | | major secondary spacing | irregular |
| Laminar size | macrophyll | | Variation of secondary angle | uniform |
| laminar L:W ratio | 2:1 | Inter-2º | Major secondary attachment | decurrent |
| laminar shape | ovate | | proximal course | parallel to major secondaries |
| medial symmetry | symmetrical | | intersecondary length | >50% of subjacent secondary |
| base symmetry | not visible | | distal course | parallel to subjacent major secondary |
| base symmetry | not visible | | vein frequency | >1 per intercostal area |
| lobation | unlobed | 3º | Intercostal tertiary vein fabric | mixed percurrent |
| margin type | entire | | Intercostal tertiary vein fabric | alternate percurrent |
| special margin features | not applicable | | Angle of percurrent tertiaries | obtuse |
| Apex angle | not visible | | vein angle variability | increasing exmedially |
| apex shape | not visible | | Epimedial tertiaries | mixed percurrent |
| apex shape | not visible | | proximal course | parallel to subjacent secondary |
| base angle | not visible | | distal course | parallel to intercostal tertiary |
| base shape | not visible | | Exterior tertiary course | looped |
| base shape | not visible | 4º | Quaternary vein fabric | alternate percurrent |
| Terminal apex features | not visible | 5º | Quinternary vein fabric | reticulate |
| | | | Areolation | not visible |
| Surface texture | not visible | | FEV branching | not visible |
| Surficial glands | not visible | | FEV termination | not visible |
| | | | Marginal Ultimate venation | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | not applicable |
| number of orders of teeth | not applicable |
| teeth / cm | |
| sinus shape | not applicable |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | not applicable |
| principal vein termination | not applicable |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**Diagnostic Features:**

Ovate laminar shape, entire margin, major secondaries simple brochidodromous, intersecondaries

**Text Description:**

Leaf attachment not visible; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not visible; leaflet organization not visible. Blade attachment marginal. Petiole features not visible. Laminar size macrophyll; laminar L:W ratio 2:1; laminar shape ovate with medial symmetrical and base not visible to not visible. Margin unlobed and entire with not applicable edges. Apex angle not visible; apex shape not visible to not visible; base angle not visible; base shape not visible to not visible. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins not visible; 1basal veins; agrophic veins not visible. Major secondaries simple brochidodromous, spacing irregular, uniform; attachment decurrent. Interior secondaries present; minor secondary course not visible; fimbrial veinpresent, proximal course parallel to major secondaries; Intersecondaries >50% of subjacent secondary; distal course parallel to subjacent major secondary; occur at >1 per intercostal area; Intercostal tertiary veins mixed percurrent, to alternate percurrent; obtuseto midvein; vein angle increasing exmedially. Epimedial tertiaries mixed percurrent; proximal course parallel to subjacent secondary; distal course parallel to intercostal tertiary. Exterior tertiary course looped. Quaternary vein fabric alternate percurrent. Quinternary vein fabric reticulate. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing not applicable, with not applicable orders of teeth; teeth / cm ; sinus shape not applicable. Tooth shapes ; ; ; and . Principal vein not applicable; terminates not applicable; accesory vein not applicable; tooth apex not applicable.

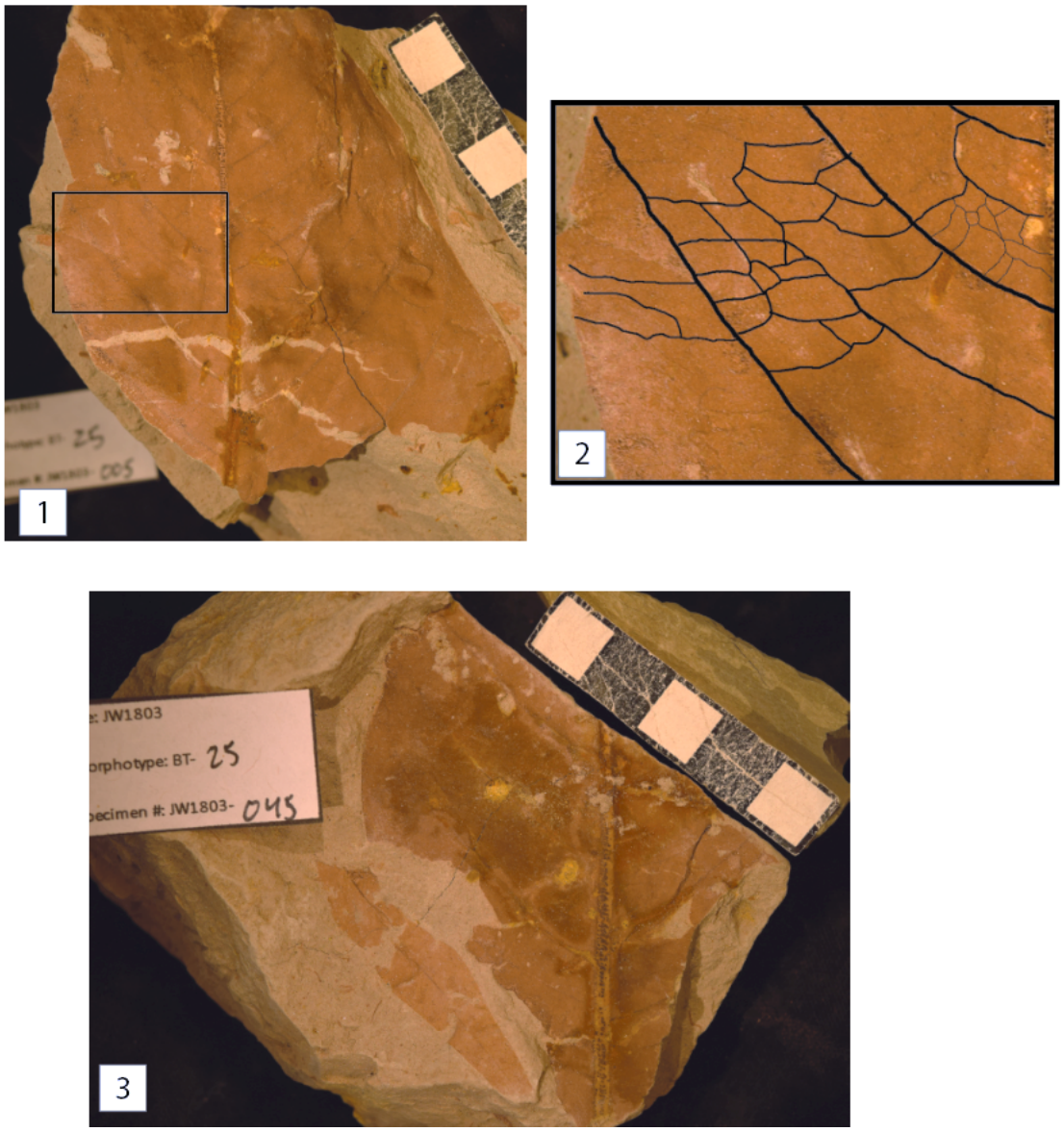


Figure A.21. Morphotype BT-25. Present in locality JW1803. Speciemn number: 1. JW1803-005, exemplar, 2. JW1803-005, enlarged section to show venation, 3. JW1803-045.

Table A.26. Morphotype BT-26 leaf architecture description. Present in locality JW1801.

| Section I. Leaf Characters | Description | | Section II. Venation | Description |
|---|---|---|---|---|
| Leaf attachment | not visible | **1º** | Primary vein framework | pinnate |
| leaf arrangement | not visible | | naked basal veins | not visible |
| leaf organization | not visible | | number of basal veins | |
| leaflet organization | not visible | | agrophic veins | not visible |
| Leaflet attachment | not visible | **2º** | Major 2º vein framework | eucamptodromous |
| Petiole features | not visible | | Interior secondaries | not visible |
| | | | minor secondary course | not visible |
| **Features of the blade:** | | | Perimarginal veins | not visible |
| Position of lamina attachment | not visible | | major secondary spacing | not visible |
| Laminar size | unknown | | Variation of secondary angle | not visible |
| laminar L:W ratio | | | Major secondary attachment | not visible |
| laminar shape | | **Inter-2º** | proximal course | not visible |
| medial symmetry | not visible | | intersecondary length | not applicable |
| base symmetry | not visible | | distal course | not applicable |
| base symmetry | not visible | | vein frequency | not applicable |
| lobation | not visible | **3º** | Intercostal tertiary vein fabric | not applicable |
| margin type | not visible | | Intercostal tertiary vein fabric | not applicable |
| special margin features | not visible | | Angle of percurrent tertiaries | not applicable |
| Apex angle | not visible | | vein angle variability | not applicable |
| apex shape | not visible | | Epimedial tertiaries | not visible |
| apex shape | not visible | | proximal course | not visible |
| base angle | obtuse | | distal course | not visible |
| base shape | not visible | | Exterior tertiary course | not visible |
| base shape | not visible | **4º** | Quaternary vein fabric | not visible |
| Terminal apex features | not visible | **5º** | Quinternary vein fabric | not visible |
| | | | Areolation | not visible |
| Surface texture | not visible | | FEV branching | not visible |
| Surficial glands | not visible | | FEV termination | not visible |
| | | | Marginal Ultimate venation | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | not applicable |
| number of orders of teeth | not applicable |
| teeth / cm | |
| sinus shape | not applicable |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | not applicable |
| principal vein termination | not applicable |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**Diagnostic Features:**

Possibly serrate margin, major secondaries eucamptodromous

**Text Description:**

Leaf attachment not visible; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not visible; leaflet organization not visible. Blade attachment not visible. Petiole features not visible. Laminar size unknown; laminar L:W ratio ; laminar shape unknown with medial not visible and base not visible to not visible. Margin not visible and not visible with not visible edges. Apex angle not visible; apex shape not visible to not visible; base angle obtuse; base shape not visible to not visible. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins not visible; basal veins; agrophic veins not visible. Major secondaries eucamptodromous, spacing not visible, not visible; attachment not visible. Interior secondaries not visible; minor secondary course not visible; not visiblepresent, proximal course not visible; Intersecondaries not applicable; distal course not applicable; occur at not applicable; Intercostal tertiary veins not applicable, to not applicable; not applicableto midvein; vein angle not applicable. Epimedial tertiaries not visible; proximal course not visible; distal course not visible. Exterior tertiary course not visible. Quaternary vein fabric not visible. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing not applicable, with not applicable orders of teeth; teeth / cm ; sinus shape not applicable. Tooth shapes ; ; ; and . Principal vein not applicable; terminates not applicable; accesory vein not applicable; tooth apex not applicable.

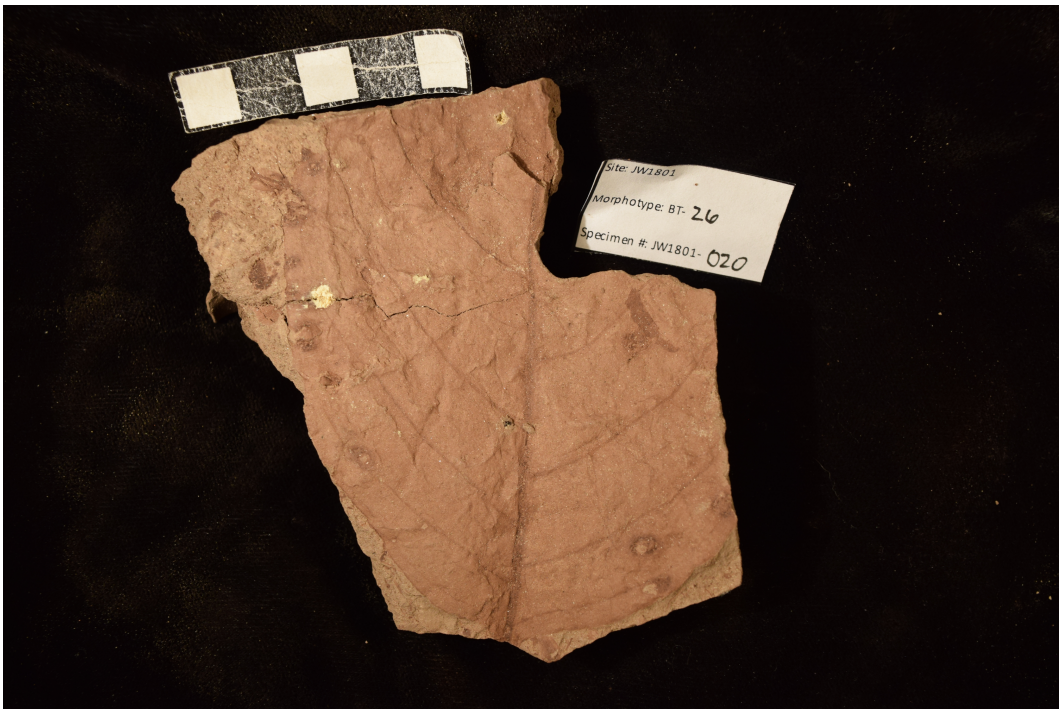


Figure A.22. Morphotype BT-26. Present in locality JW1801. Specimen number JW1801-020, exemplar.

Table A.27. Morphotype BT-28 leaf architecture description. Present in locality JW1802 and JW1803.

| Section I. Leaf Characters | Description | | Section II. Venation | Description |
|---|---|---|---|---|
| Leaf attachment | petiolate | **1º** | Primary vein framework | pinnate |
| leaf arrangement | not visible | | naked basal veins | absent |
| leaf organization | not visible | | number of basal veins | 1 |
| leaflet organization | not visible | | agrophic veins | simple |
| Leaflet attachment | not visible | **2º** | Major 2º vein framework | craspedodromous |
| Petiole features | not visible | | Interior secondaries | absent |
| | | | minor secondary course | craspedodromous |
| **Features of the blade:** | | | Perimarginal veins | not applicable |
| Position of lamina attachment | marginal | | major secondary spacing | regular |
| Laminar size | mesophyll/macro? | | Variation of secondary angle | uniform |
| laminar L:W ratio | 1.5:1?? | | Major secondary attachment | decurrent |
| laminar shape | unknown | **Inter-2º** | proximal course | absent |
| medial symmetry | not visible | | intersecondary length | not applicable |
| base symmetry | not visible | | distal course | not applicable |
| base symmetry | not visible | | vein frequency | not applicable |
| lobation | Possibly, or deep waves | **3º** | Intercostal tertiary vein fabric | sinuous opposite percurrent |
| margin type | serrate | | Intercostal tertiary vein fabric | sinuous opposite percurrent |
| special margin features | not visible | | Angle of percurrent tertiaries | acute |
| Apex angle | acute | | vein angle variability | consistent |
| apex shape | acuminate | | Epimedial tertiaries | mixed percurrent |
| apex shape | not visible | | proximal course | acute to midvein |
| base angle | not visible | | distal course | parallel to intercostal tertiary |
| base shape | not visible | | Exterior tertiary course | terminating at the margin |
| base shape | not visible | **4º** | Quaternary vein fabric | opposite percurrent |
| Terminal apex features | not visible | **5º** | Quinternary vein fabric | regular reticulate |
| | | | Areolation | not visible |
| Surface texture | not visible | | FEV branching | not visible |
| Surficial glands | not visible | | FEV termination | not visible |
| | | | Marginal Ultimate venation | not visible |

**Section III. Teeth**

| | |
|---|---|
| Tooth spacing | regular |
| number of orders of teeth | one |
| teeth / cm | 2-Jan |
| sinus shape | rounded |
| tooth shapes | ST/FL |
| tooth shapes | CV/FL |
| tooth shapes | |
| tooth shapes | |
| Principal vein | present |
| principal vein termination | on distal flank of tooth |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**Diagnostic Features:**

Macrophyll, possibly toothed margin, major secondaries craspedodromous, intersecondaries craspedodromous

**Text Description:**

Leaf attachment petiolate; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not visible; leaflet organization not visible. Blade attachment marginal. Petiole features not visible. Laminar size mesophyll/macro?; laminar L:W ratio 1.5:1??; laminar shape unknown with medial not visible and base not visible to not visible. Margin Possibly, or deep waves and serrate with not visible edges. Apex angle acute; apex shape acuminate to not visible; base angle not visible; base shape not visible to not visible. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins absent; 1basal veins; agrophic veins simple. Major secondaries craspedodromous, spacing regular, uniform; attachment decurrent. Interior secondaries absent; minor secondary course craspedodromous; not applicablepresent, proximal course absent; Intersecondaries not applicable; distal course not applicable; occur at not applicable; Intercostal tertiary veins sinuous opposite percurrent, to sinuous opposite percurrent; acuteto midvein; vein angle consistent. Epimedial tertiaries mixed percurrent; proximal course acute to midvein; distal course parallel to intercostal tertiary. Exterior tertiary course terminating at the margin. Quaternary vein fabric opposite percurrent. Quinternary vein fabric regular reticulate. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing regular, with one orders of teeth; teeth / cm 43102; sinus shape rounded. Tooth shapes ST/FL; CV/FL; ; and . Principal vein present; terminates present; accesory vein not applicable

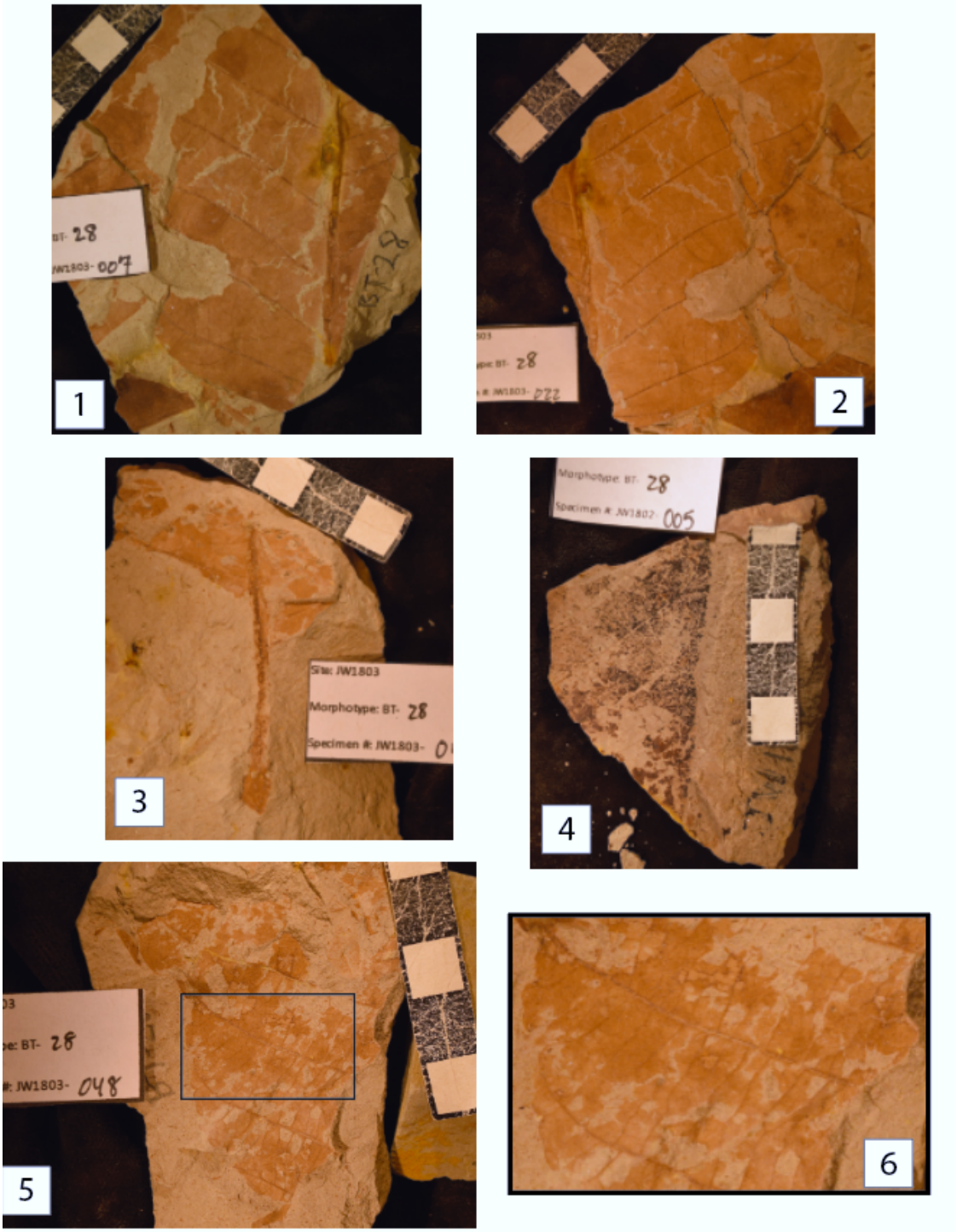


Figure A.23. Morphotype BT-28. Present in localities JW1802 and JW1803. Specimen number: 1. JW1803-007, exemplar, 2. JW1803-022, 3. JW1803-049, 4. JW1802-005, exemplar, 5. JW1803-048, 6. JW1803-048, enlarged to show serration and margin.

Table A.28. Morphotype BT-29 leaf architecture description. Present in locality JW1801 and JW1803.

| Section I. Leaf Characters | Description |
|---|---|
| Leaf attachment | petiolate |
| leaf arrangement | not visible |
| leaf organization | not visible |
| leaflet organization | not visible |
| Leaflet attachment | not visible |
| Petiole features | not visible |
| | |
| **Features of the blade:** | |
| Position of lamina attachment | marginal |
| Laminar size | mesophyll |
| laminar L:W ratio | ? |
| laminar shape | Elliptic-ovate |
| medial symmetry | symmetrical |
| base symmetry | symmetrical |
| base symmetry | symmetrical |
| lobation | unlobed |
| margin type | entire |
| special margin features | not visible |
| Apex angle | not visible |
| apex shape | not visible |
| apex shape | not visible |
| base angle | not visible |
| base shape | not visible |
| base shape | not visible |
| Terminal apex features | not visible |
| | |
| Surface texture | not visible |
| Surficial glands | not visible |

| | Section II. Venation | Description |
|---|---|---|
| **1º** | Primary vein framework | pinnate |
| | naked basal veins | absent |
| | number of basal veins | 1 |
| | agrophic veins | absent??? |
| **2º** | Major 2º vein framework | not visible |
| | Interior secondaries | not visible |
| | minor secondary course | not visible |
| | Perimarginal veins | not visible |
| | major secondary spacing | not visible |
| | Variation of secondary angle | not visible |
| **Inter-2º** | Major secondary attachment | decurrent |
| | proximal course | not visible |
| | intersecondary length | not applicable |
| | distal course | not applicable |
| | vein frequency | not applicable |
| **3º** | Intercostal tertiary vein fabric | not applicable |
| | Intercostal tertiary vein fabric | not applicable |
| | Angle of percurrent tertiaries | not applicable |
| | vein angle variability | not applicable |
| | Epimedial tertiaries | not visible |
| | proximal course | not visible |
| | distal course | not visible |
| | Exterior tertiary course | not visible |
| **4º** | Quaternary vein fabric | not visible |
| **5º** | Quinternary vein fabric | not visible |
| | Areolation | not visible |
| | FEV branching | not visible |
| | FEV termination | not visible |
| | Marginal Ultimate venation | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | not applicable |
| number of orders of teeth | not applicable |
| teeth / cm | |
| sinus shape | not applicable |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | not applicable |
| principal vein termination | not applicable |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**Diagnostic Features:**

Mesophyll, entire margin, thick midvein

**Text Description:**

Leaf attachment petiolate; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not visible; leaflet organization not visible. Blade attachment marginal. Petiole features not visible. Laminar size mesophyll; laminar L:W ratio ?; laminar shape Elliptic-ovate with medial symmetrical and base symmetrical to symmetrical. Margin unlobed and entire with not visible edges. Apex angle not visible; apex shape not visible to not visible; base angle not visible; base shape not visible to not visible. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins absent; 1basal veins; agrophic veins absent???. Major secondaries not visible, spacing not visible, not visible; attachment decurrent. Interior secondaries not visible; minor secondary course not visible; not visiblepresent, proximal course not visible; Intersecondaries not applicable; distal course not applicable; occur at not applicable; Intercostal tertiary veins not applicable, to not applicable; not applicableto midvein; vein angle not applicable. Epimedial tertiaries not visible; proximal course not visible; distal course not visible. Exterior tertiary course not visible. Quaternary vein fabric not visible. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing not applicable, with not applicable orders of teeth; teeth / cm ; sinus shape not applicable. Tooth shapes ; ; ; and . Principal vein not applicable; terminates not applicable; accesory vein not applicable; tooth apex not applicable.

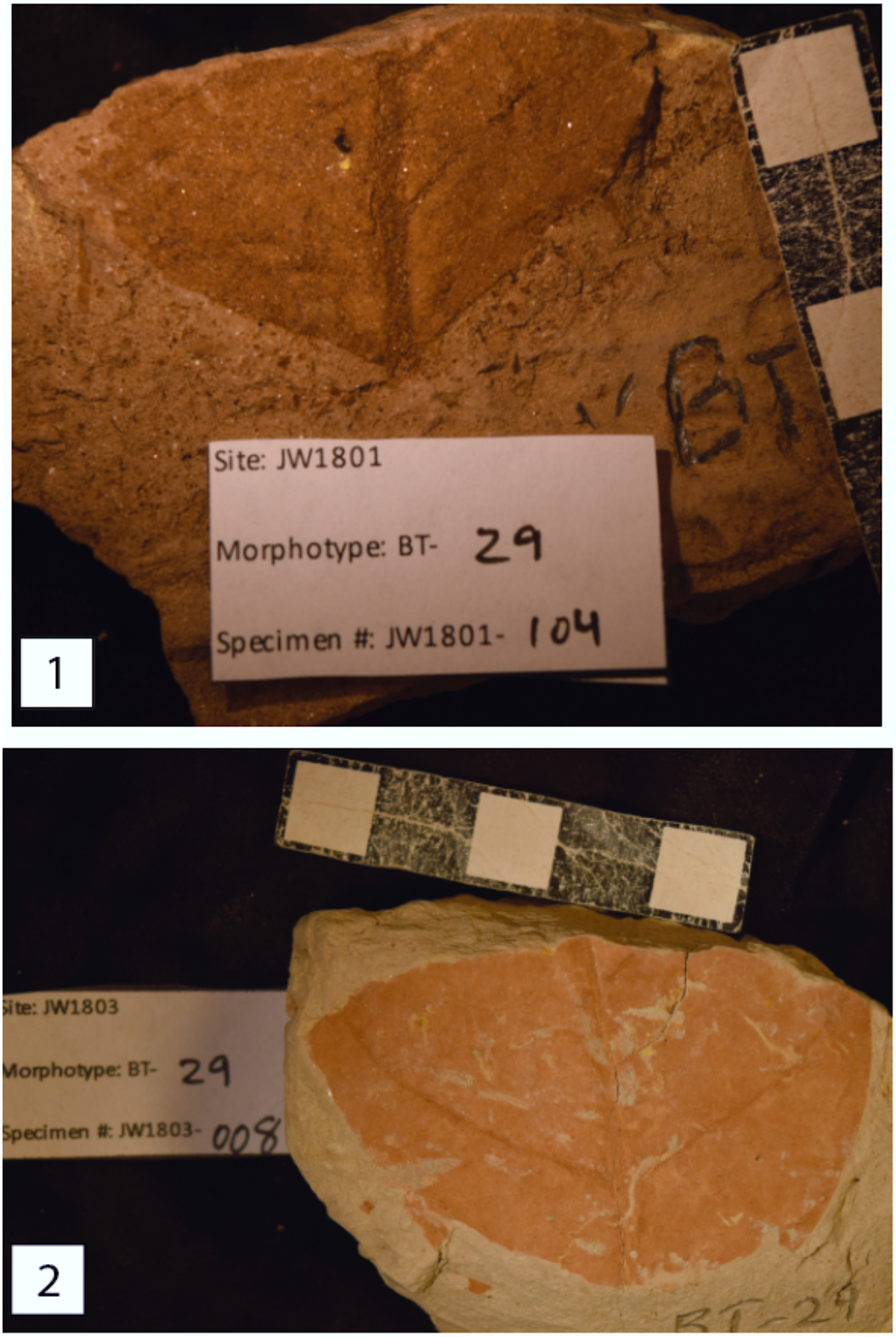


Figure A.24. Morphotype BT-29. Present in localities JW1801 and JW1803. Specimen number: 1. JW1801-104, 2. JW1803-008.

Table A.29. Morphotype BT-31 leaf architecture description. Present in locality JW1801.

| Section I. Leaf Characters | Description | | Section II. Venation | Description |
|---|---|---|---|---|
| Leaf attachment | not visible | **1º** | Primary vein framework | pinnate |
| leaf arrangement | not visible | | naked basal veins | absent |
| leaf organization | not visible | | number of basal veins | 1 |
| leaflet organization | not visible | | agrophic veins | absent |
| Leaflet attachment | not visible | **2º** | Major 2º vein framework | craspedodromous |
| Petiole features | not visible | | Interior secondaries | absent |
| | | | minor secondary course | not visible |
| **Features of the blade:** | | | Perimarginal veins | not visible |
| Position of lamina attachment | marginal | | major secondary spacing | regular |
| Laminar size | mesophyll | | Variation of secondary angle | smoothly increasing proximally |
| laminar L:W ratio | not visible | | Major secondary attachment | excurrent |
| laminar shape | | **Inter-2º** | proximal course | absent |
| medial symmetry | symmetrical | | intersecondary length | not applicable |
| base symmetry | not visible | | distal course | not applicable |
| base symmetry | not visible | | vein frequency | not applicable |
| lobation | unlobed | **3º** | Intercostal tertiary vein fabric | mixed percurrent |
| margin type | not visible | | Intercostal tertiary vein fabric | mixed percurrent |
| special margin features | not visible | | Angle of percurrent tertiaries | obtuse |
| Apex angle | not visible | | vein angle variability | consistent |
| apex shape | not visible | | Epimedial tertiaries | opposite percurrent |
| apex shape | not visible | | proximal course | acute to midvein |
| base angle | not visible | | distal course | parallel to intercostal tertiary |
| base shape | not visible | | Exterior tertiary course | not visible |
| base shape | not visible | **4º** | Quaternary vein fabric | mixed percurrent |
| Terminal apex features | not visible | **5º** | Quinternary vein fabric | not visible |
| | | | Areolation | not visible |
| Surface texture | not visible | | FEV branching | not visible |
| Surficial glands | not visible | | FEV termination | not visible |
| | | | Marginal Ultimate venation | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | not applicable |
| number of orders of teeth | not applicable |
| teeth / cm | |
| sinus shape | not applicable |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | not applicable |
| principal vein termination | not applicable |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**Text Description:**

Leaf attachment not visible; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not visible; leaflet organization not visible. Blade attachment marginal. Petiole features not visible. Laminar size mesophyll; laminar L:W ratio not visible; laminar shape unknown with medial symmetrical and base not visible to not visible. Margin unlobed and not visible with not visible edges. Apex angle not visible; apex shape not visible to not visible; base angle not visible; base shape not visible to not visible. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins absent; 1basal veins; agrophic veins absent. Major secondaries craspedodromous, spacing regular, smoothly increasing proximally; attachment excurrent. Interior secondaries absent; minor secondary course not visible; not visiblepresent, proximal course absent; Intersecondaries not applicable; distal course not applicable; occur at not applicable; Intercostal tertiary veins mixed percurrent, to mixed percurrent; obtuseto midvein; vein angle consistent. Epimedial tertiaries opposite percurrent; proximal course acute to midvein; distal course parallel to intercostal tertiary. Exterior tertiary course not visible. Quaternary vein fabric mixed percurrent. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing not applicable, with not applicable orders of teeth; teeth / cm ; sinus shape not applicable. Tooth shapes ; ; ; and . Principal vein not applicable; terminates not applicable; accesory vein not applicable;

**Diagnostic Features:**

Major secondaries craspedodromous, Intercostal tertiary veins mixed percurrent

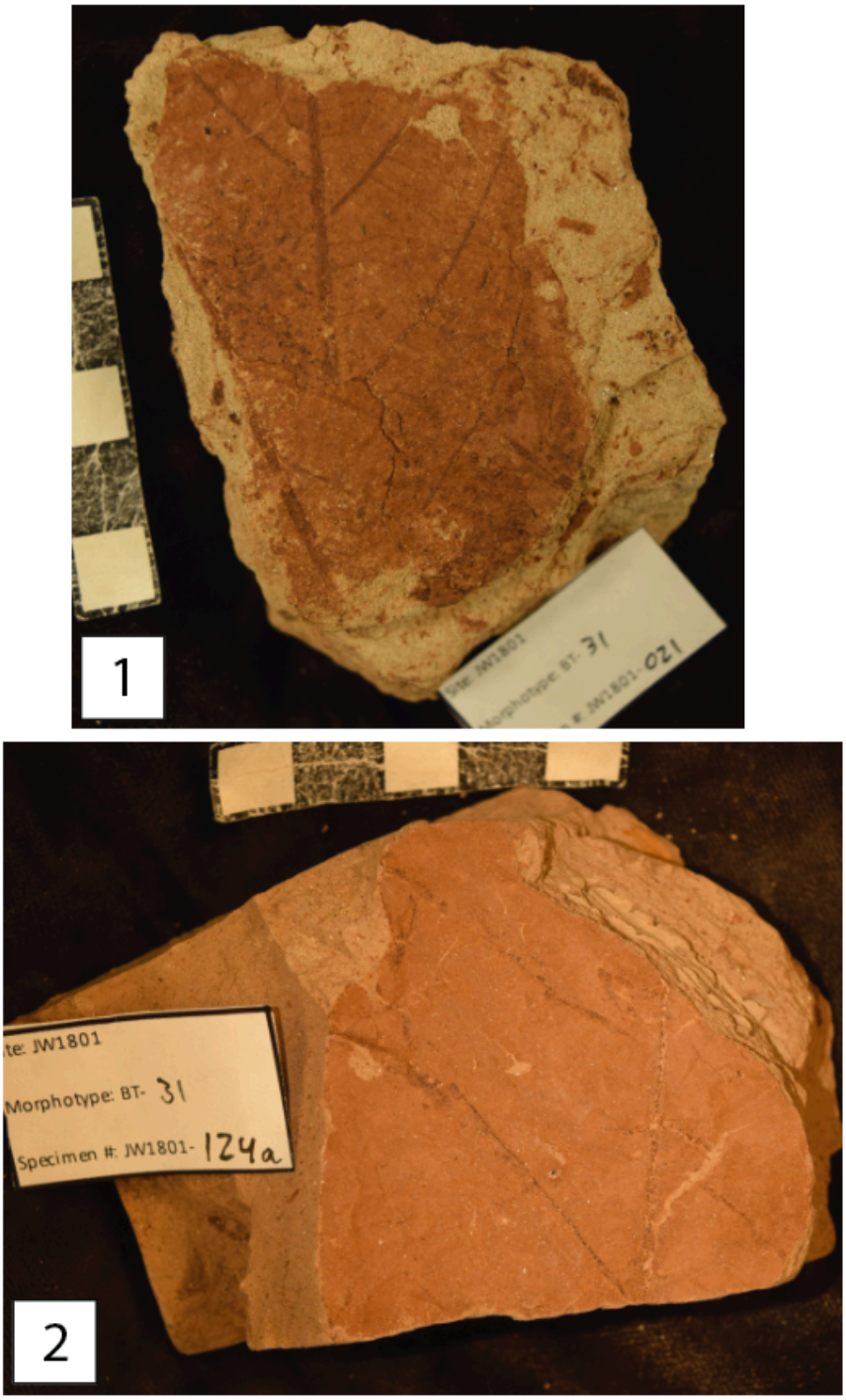


Figure A.25. Morphotype BT-31. Present in locality JW1801. Specimen number: JW1801-021, exemplar, 2. JW1801-124a.

Table A.30. Morphotype BT-33 leaf architecture description. Present in locality JW1801.

| Section I. Leaf Characters | Description | | Section II. Venation | Description |
|---|---|---|---|---|
| Leaf attachment | petiolate | 1º | Primary vein framework | pinnate |
| leaf arrangement | not visible | | naked basal veins | absent |
| leaf organization | simple | | number of basal veins | 1 |
| leaflet organization | not applicable | | agrophic veins | absent |
| Leaflet attachment | not visible | 2º | Major 2º vein framework | craspedodromous |
| Petiole features | absent | | Interior secondaries | not applicable |
| | | | minor secondary course | not applicable |
| **Features of the blade:** | | | Perimarginal veins | not applicable |
| Position of lamina attachment | marginal | | major secondary spacing | decreasing proximally |
| Laminar size | mesophyll | | Variation of secondary angle | inconsistent |
| laminar L:W ratio | 3:1* | | Major secondary attachment | decurrent |
| laminar shape | unknown | Inter-2º | proximal course | absent |
| medial symmetry | not visible | | intersecondary length | not applicable |
| base symmetry | symmetrical | | distal course | not applicable |
| base symmetry | symmetrical | | vein frequency | not applicable |
| lobation | Likely* | 3º | Intercostal tertiary vein fabric | straight opposite percurrent |
| margin type | toothed* | | Intercostal tertiary vein fabric | straight opposite percurrent |
| special margin features | not visible | | Angle of percurrent tertiaries | obtuse |
| Apex angle | not visible | | vein angle variability | increasing exmedially |
| apex shape | not visible | | Epimedial tertiaries | opposite percurrent |
| apex shape | not visible | | proximal course | not visible |
| base angle | acute | | distal course | not visible |
| base shape | straight | | Exterior tertiary course | not visible |
| base shape | straight | 4º | Quaternary vein fabric | not visible |
| Terminal apex features | not visible | 5º | Quinternary vein fabric | not visible |
| | | | Areolation | not visible |
| Surface texture | not visible | | FEV branching | not visible |
| Surficial glands | not visible | | FEV termination | not visible |
| | | | Marginal Ultimate venation | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | irregular |
| number of orders of teeth | one |
| teeth / cm | not visible |
| sinus shape | |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | present |
| principal vein termination | on distal flank of tooth |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**Diagnostic Features:**

Obovate, margin possibly serrate, major secondaries craspedodromous, spacing decreasing proximally

**Text Description:**

Leaf attachment petiolate; leaf arrangement not visible; leaf organization simple. Leaflet attachment not visible; leaflet organization not applicable. Blade attachment marginal. Petiole features absent. Laminar size mesophyll; laminar L:W ratio 3:1*; laminar shape unknown with medial not visible and base symmetrical to symmetrical. Margin Likely* and toothed* with not visible edges. Apex angle not visible; apex shape not visible to not visible; base angle acute; base shape straight to straight. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins absent; 1basal veins; agrophic veins absent. Major secondaries craspedodromous, spacing decreasing proximally, inconsistent; attachment decurrent. Interior secondaries not applicable; minor secondary course not applicable; not applicablepresent, proximal course absent; Intersecondaries not applicable; distal course not applicable; occur at not applicable; Intercostal tertiary veins straight opposite percurrent, to straight opposite percurrent; obtuseto midvein; vein angle increasing exmedially. Epimedial tertiaries opposite percurrent; proximal course not visible; distal course not visible. Exterior tertiary course not visible. Quaternary vein fabric not visible. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing irregular, with one orders of teeth; teeth / cm not visible; sinus shape . Tooth shapes ; ; ; and . Principal vein present; terminates present; accesory vein not applicable; tooth apex not applicable.

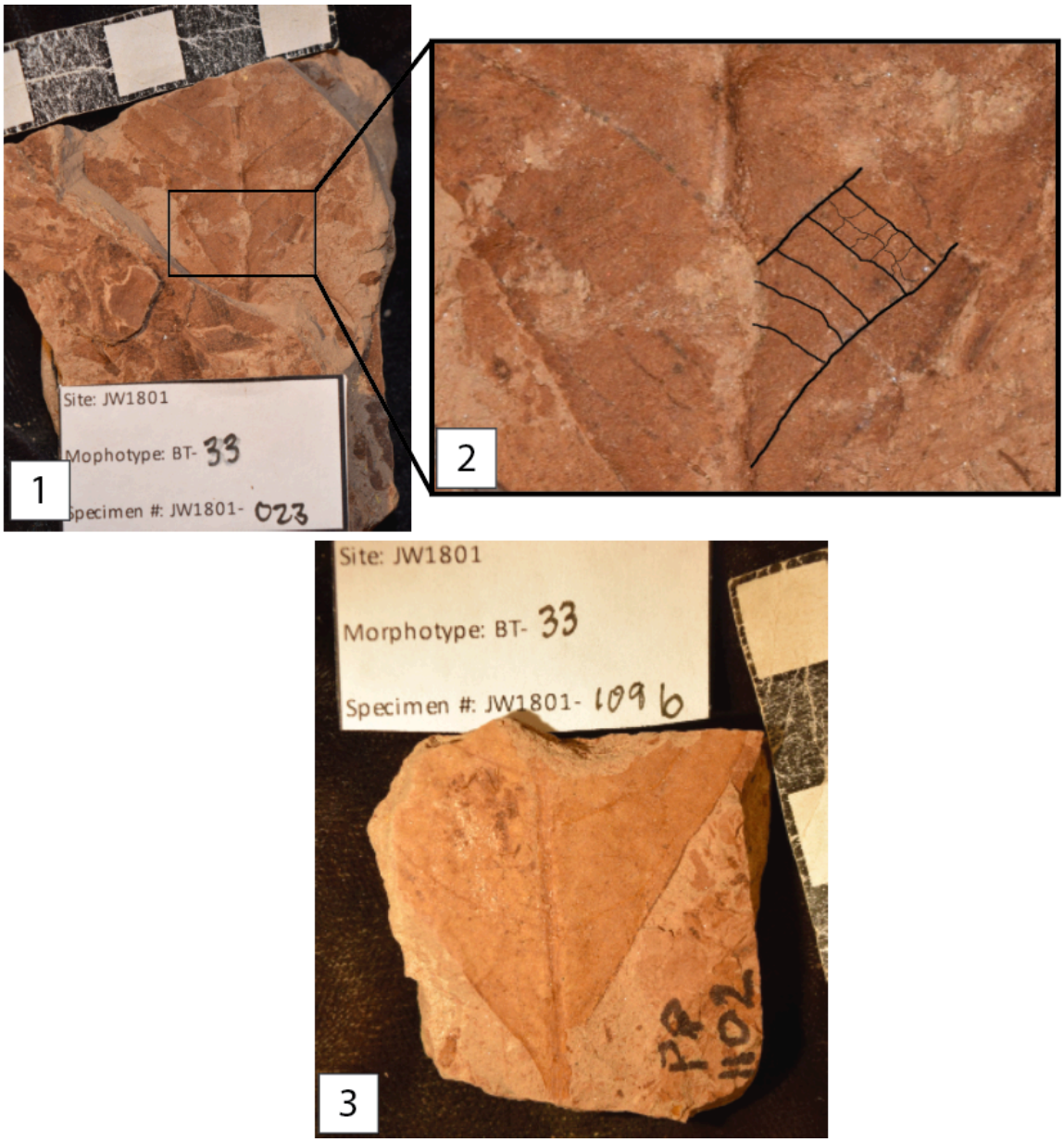


Figure A.26. Morphotype BT-33. Present in locality JW1801. Specimen number: JW1801-023, exemplar, 2. JW1801-023, enlarged to show venation, 3. JW1801-109b.

Table A.31. Morphotype BT-34 leaf architecture description. Present in locality JW1802 and JW1803.

| Section I. Leaf Characters | Description | | Section II. Venation | Description |
|---|---|---|---|---|
| Leaf attachment | petiolate | **1º** | Primary vein framework | suprabasal acrodromous |
| leaf arrangement | not visible | | naked basal veins | absent |
| leaf organization | not visible | | number of basal veins | 3 |
| leaflet organization | not visible | | agrophic veins | present |
| Leaflet attachment | not applicable | **2º** | Major 2º vein framework | simple brochidodromous |
| Petiole features | absent | | Interior secondaries | present |
| | | | minor secondary course | simple brochidodromous |
| **Features of the blade:** | | | Perimarginal veins | intramarginal secondary |
| Position of lamina attachment | marginal | | major secondary spacing | irregular |
| Laminar size | Noto/mesophyll | | Variation of secondary angle | uniform |
| laminar L:W ratio | ~ 2:1 | **Inter-2º** | Major secondary attachment | decurrent |
| laminar shape | ovate | | proximal course | parallel to major secondaries |
| medial symmetry | symmetrical | | intersecondary length | <50% of subjacent secondary |
| base symmetry | symmetrical | | distal course | parallel to subjacent major secondary |
| base symmetry | symmetrical | | vein frequency | ~ 1 per intercostal area |
| lobation | unlobed | **3º** | Intercostal tertiary vein fabric | convex opposite percurrent |
| margin type | entire | | Intercostal tertiary vein fabric | mixed percurrent |
| special margin features | not visible | | Angle of percurrent tertiaries | acute |
| Apex angle | acute | | vein angle variability | consistent |
| apex shape | straight | | Epimedial tertiaries | mixed percurrent |
| apex shape | straight | | proximal course | acute to midvein |
| base angle | obtuse | | distal course | acroflexed |
| base shape | concave | | Exterior tertiary course | looped |
| base shape | concave | **4º** | Quaternary vein fabric | irregular reticulate |
| Terminal apex features | not visible | **5º** | Quinternary vein fabric | reticulate |
| | | | Areolation | not visible |
| Surface texture | not visible | | FEV branching | not visible |
| Surficial glands | not visible | | FEV termination | not visible |
| | | | Marginal Ultimate venation | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | not applicable |
| number of orders of teeth | not applicable |
| teeth / cm | |
| sinus shape | not applicable |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | not applicable |
| principal vein termination | not applicable |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**Diagnostic Features:**

Ovate, entire margin, 3 basal veins, agrophic veins, intersecondaries

**Text Description:**

Leaf attachment petiolate; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not applicable; leaflet organization not visible. Blade attachment marginal. Petiole features absent. Laminar size Noto/mesophyll; laminar L:W ratio ~ 2:1; laminar shape ovate with medial symmetrical and base symmetrical to symmetrical. Margin unlobed and entire with not visible edges. Apex angle acute; apex shape straight to straight; base angle obtuse; base shape concave to concave. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation suprabasal acrodromous; naked basal veins absent; 3basal veins; agrophic veins present. Major secondaries simple brochidodromous, spacing irregular, uniform; attachment decurrent. Interior secondaries present; minor secondary course simple brochidodromous; intramarginal secondarypresent, proximal course parallel to major secondaries; Intersecondaries <50% of subjacent secondary; distal course parallel to subjacent major secondary; occur at ~ 1 per intercostal area; Intercostal tertiary veins convex opposite percurrent, to mixed percurrent; acuteto midvein; vein angle consistent. Epimedial tertiaries mixed percurrent; proximal course acute to midvein; distal course acroflexed. Exterior tertiary course looped. Quaternary vein fabric irregular reticulate. Quinternary vein fabric reticulate. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing not applicable, with not applicable orders of teeth; teeth / cm ; sinus shape not applicable. Tooth shapes ; ; ; and . Principal vein not applicable; terminates not applicable; accesory vein not applicable; tooth apex not applicable.

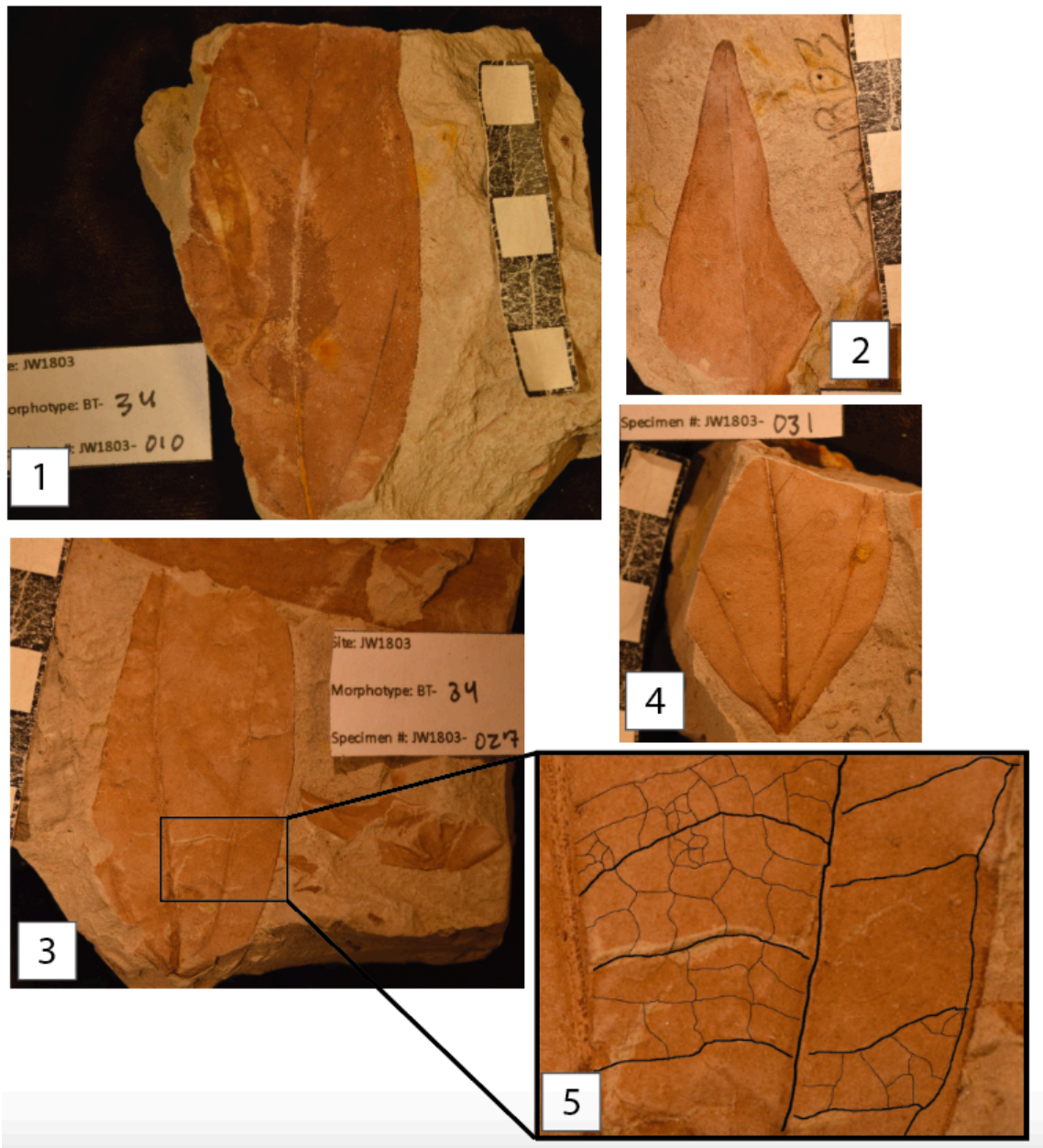


Figure A.27. Morphotype BT-34. Present in localities JW1802 and JW1803. Specimen numbers: 1. JW1803-010, exemplar, 2. JW1803-030, 3. JW1803-027, 4. JW1803-031, 5. JW1803-027, enlarged to show venation.

Table A.32. Morphotype BT-35 leaf architecture description. Present in locality JW1803.

| Section I. Leaf Characters | Description | | Section II. Venation | Description |
|---|---|---|---|---|
| Leaf attachment | petiolate | **1º** | Primary vein framework | pinnate |
| leaf arrangement | not visible | | naked basal veins | absent |
| leaf organization | not visible | | number of basal veins | 1 |
| leaflet organization | not visible | | agrophic veins | absent |
| Leaflet attachment | not visible | **2º** | Major 2º vein framework | semicraspedodromous |
| Petiole features | not visible | | Interior secondaries | present |
| | | | minor secondary course | not applicable |
| **Features of the blade:** | | | Perimarginal veins | not applicable |
| Position of lamina attachment | not visible | | major secondary spacing | regular |
| Laminar size | unknown | | Variation of secondary angle | uniform |
| laminar L:W ratio | > 2:1 | **Inter-2º** | Major secondary attachment | decurrent |
| laminar shape | ovate | | proximal course | parallel to major secondaries |
| medial symmetry | not visible | | intersecondary length | <50% of subjacent secondary |
| base symmetry | not visible | | distal course | parallel to subjacent major secondary |
| base symmetry | not visible | | vein frequency | ~ 1 per intercostal area |
| lobation | unlobed | **3º** | Intercostal tertiary vein fabric | mixed percurrent |
| margin type | serrate | | Intercostal tertiary vein fabric | hard to see |
| special margin features | not visible | | Angle of percurrent tertiaries | obtuse |
| Apex angle | not visible | | vein angle variability | not visible |
| apex shape | not visible | | Epimedial tertiaries | not visible |
| apex shape | not visible | | proximal course | not visible |
| base angle | not visible | | distal course | not visible |
| base shape | not visible | | Exterior tertiary course | not visible |
| base shape | not visible | **4º** | Quaternary vein fabric | not visible |
| Terminal apex features | not visible | **5º** | Quinternary vein fabric | not visible |
| | | | Areolation | not visible |
| Surface texture | not visible | | FEV branching | not visible |
| Surficial glands | not visible | | FEV termination | not visible |
| | | | Marginal Ultimate venation | not visible |

| **Section III. Teeth** | |
|---|---|
| Tooth spacing | regular |
| number of orders of teeth | one |
| teeth / cm | 5 |
| sinus shape | rounded |
| tooth shapes | FL:CC |
| tooth shapes | CC:CV |
| tooth shapes | |
| tooth shapes | |
| Principal vein | not visible |
| principal vein termination | on distal flank of tooth |
| course of accessory vein | not applicable |
| features of the tooth apex | cassidate |

**Diagnostic Features:**

Elliptical, Serrate margin, major secondaries semicraspedodromous, intersecondaries,

**Text Description:**

Leaf attachment petiolate; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not visible; leaflet organization not visible. Blade attachment not visible. Petiole features not visible. Laminar size unknown; laminar L:W ratio > 2:1; laminar shape ovate with medial not visible and base not visible to not visible. Margin unlobed and serrate with not visible edges. Apex angle not visible; apex shape not visible to not visible; base angle not visible; base shape not visible to not visible. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins absent; 1basal veins; agrophic veins absent. Major secondaries semicraspedodromous, spacing regular, uniform; attachment decurrent. Interior secondaries present; minor secondary course not applicable; not applicable present, proximal course parallel to major secondaries; Intersecondaries <50% of subjacent secondary; distal course parallel to subjacent major secondary; occur at ~ 1 per intercostal area; Intercostal tertiary veins mixed percurrent, to hard to see ; obtuse to midvein; vein angle not visible. Epimedial tertiaries not visible; proximal course not visible; distal course not visible. Exterior tertiary course not visible. Quaternary vein fabric not visible. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visible termination. Marginal Ultimate venation not visible. Tooth spacing regular, with one orders of teeth; teeth / cm 5; sinus shape rounded. Tooth shapes FL:CC; CC:CV; ; and . Principal vein not visible; terminates not visible; accesory vein not applicable; tooth apex cassidate.

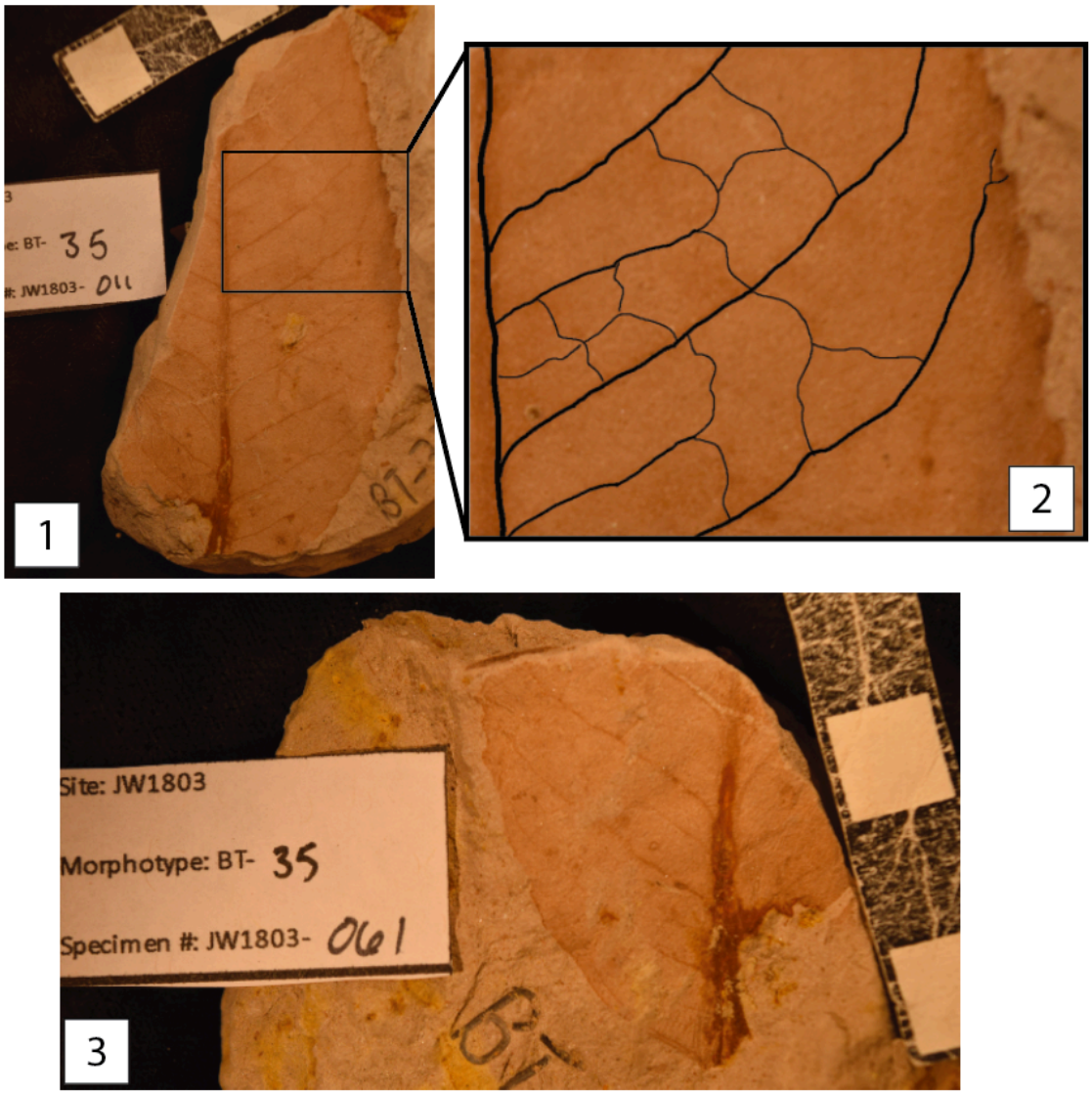


Figure A.28. Morphotype BT-35. Present in locality JW1803. Specimen number: 1. JW1803-011, exemplar, 2. JW1803-011, enlarged box to show leaf venation and serration, 3. JW1803-061.

Table A.33. Morphotype BT-36 leaf architecture description. Present in locality JW1802.

| Section I. Leaf Characters | Description |
|---|---|
| Leaf attachment | not visible |
| leaf arrangement | not visible |
| leaf organization | not visible |
| leaflet organization | not visible |
| Leaflet attachment | not visible |
| Petiole features | not visible |
| | |
| **Features of the blade:** | |
| Position of lamina attachment | not visible |
| Laminar size | mesophyll |
| laminar L:W ratio | not visible |
| laminar shape | |
| medial symmetry | not visible |
| base symmetry | not visible |
| base symmetry | not visible |
| lobation | not visible |
| margin type | toothed |
| special margin features | not visible |
| Apex angle | not visible |
| apex shape | not visible |
| apex shape | not visible |
| base angle | not visible |
| base shape | not visible |
| base shape | not visible |
| Terminal apex features | not visible |
| | |
| Surface texture | not visible |
| Surficial glands | not visible |

| | Section II. Venation | Description |
|---|---|---|
| **1º** | Primary vein framework | pinnate |
| | naked basal veins | not visible |
| | number of basal veins | 1 |
| | agrophic veins | not visible |
| **2º** | Major 2º vein framework | craspedodromous |
| | Interior secondaries | not visible |
| | minor secondary course | not visible |
| | Perimarginal veins | not visible |
| | major secondary spacing | not visible |
| | Variation of secondary angle | not visible |
| | Major secondary attachment | not visible |
| **Inter-2º** | proximal course | absent |
| | intersecondary length | not applicable |
| | distal course | not applicable |
| | vein frequency | not applicable |
| **3º** | Intercostal tertiary vein fabric | convex opposite percurrent |
| | Intercostal tertiary vein fabric | convex opposite percurrent |
| | Angle of percurrent tertiaries | obtuse |
| | vein angle variability | decreasing exmedially |
| | Epimedial tertiaries | not visible |
| | proximal course | parallel to subjacent secondary |
| | distal course | parallel to intercostal tertiary |
| | Exterior tertiary course | not visible |
| **4º** | Quaternary vein fabric | not visible |
| **5º** | Quinternary vein fabric | not visible |
| | Areolation | not visible |
| | FEV branching | not visible |
| | FEV termination | not visible |
| | Marginal Ultimate venation | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | not visible |
| number of orders of teeth | not visible |
| teeth / cm | not visible |
| sinus shape | angular |
| tooth shapes | *may be insect dam |
| tooth shapes | CC/RT |
| tooth shapes | |
| tooth shapes | |
| Principal vein | present |
| principal vein termination | on proximal flank of tooth |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**Diagnostic Features:**

Major secondaries craspedodromous, intercostal tertiary veins convex opposite percurrent

**Text Description:**

Leaf attachment not visible; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not visible; leaflet organization not visible. Blade attachment not visible. Petiole features not visible. Laminar size mesophyll; laminar L:W ratio not visible; laminar shape not visible with medial not visible and base not visible to not visible. Margin not visible and toothed with not visible edges. Apex angle not visible; apex shape not visible to not visible; base angle not visible; base shape not visible to not visible. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins not visible; 1basal veins; agrophic veins not visible. Major secondaries craspedodromous, spacing not visible, not visible; attachment not visible. Interior secondaries not visible; minor secondary course not visible; not visiblepresent, proximal course absent; Intersecondaries not applicable; distal course not applicable; occur at not applicable; Intercostal tertiary veins convex opposite percurrent, to convex opposite percurrent; obtuseto midvein; vein angle decreasing exmedially. Epimedial tertiaries not visible; proximal course parallel to subjacent secondary; distal course parallel to intercostal tertiary. Exterior tertiary course not visible. Quaternary vein fabric not visible. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing not visible, with not visible orders of teeth; teeth / cm not visible; sinus shape angular. Tooth shapes *may be insect dam; CC/RT; ; and . Principal vein present; terminates present; accesory vein not applicable; tooth apex not applicable.

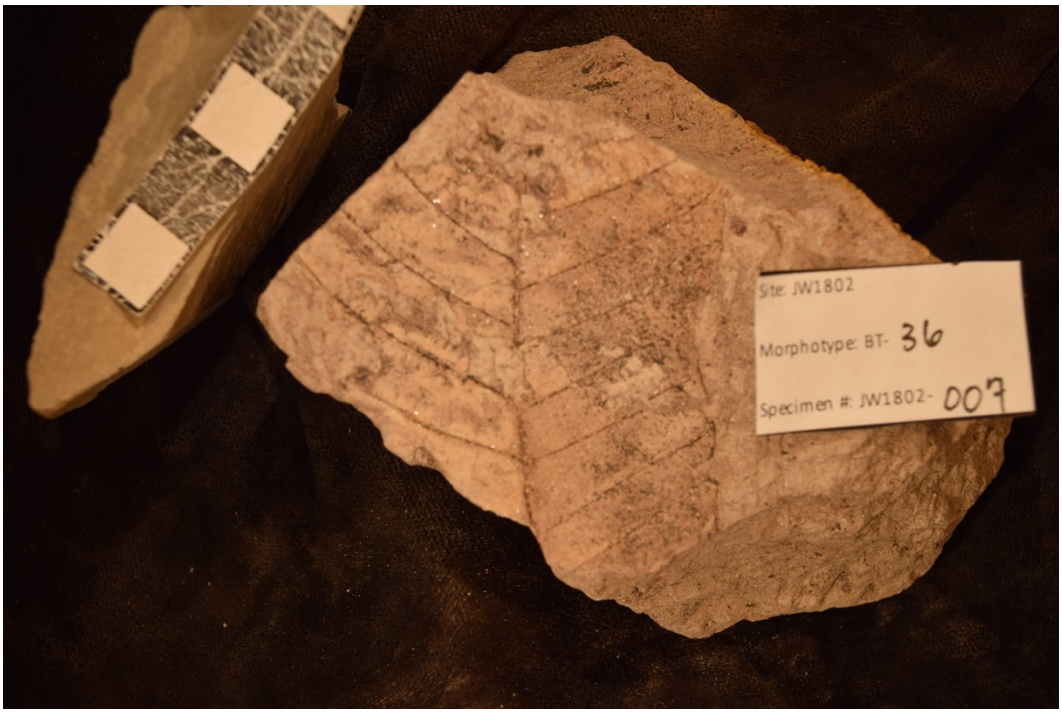


Figure A.29. Morphotype BT-36. Present in locality JW1802. Specimen number JW1802-007, exemplar.

Table A.34. Morphotype BT-37 leaf architecture description. Present in locality JW1802.

| Section I. Leaf Characters | Description | | Section II. Venation | Description |
|---|---|---|---|---|
| Leaf attachment | petiolate | **1º** | Primary vein framework | pinnate |
| leaf arrangement | not visible | | naked basal veins | not visible |
| leaf organization | not visible | | number of basal veins | 1 |
| leaflet organization | not visible | | agrophic veins | not visible |
| Leaflet attachment | not visible | **2º** | Major 2º vein framework | semicraspedodromous |
| Petiole features | not visible | | Interior secondaries | absent |
| | | | minor secondary course | not applicable |
| **Features of the blade:** | | | Perimarginal veins | not visible |
| Position of lamina attachment | marginal | | major secondary spacing | regular |
| Laminar size | mesophyll | | Variation of secondary angle | uniform |
| laminar L:W ratio | >3:1 | | Major secondary attachment | excurrent |
| laminar shape | unknown | **Inter-2º** | proximal course | not visible |
| medial symmetry | not visible | | intersecondary length | not applicable |
| base symmetry | not visible | | distal course | not applicable |
| base symmetry | not visible | | vein frequency | not applicable |
| lobation | not visible | **3º** | Intercostal tertiary vein fabric | not applicable |
| margin type | not visible | | Intercostal tertiary vein fabric | not applicable |
| special margin features | not visible | | Angle of percurrent tertiaries | not applicable |
| Apex angle | not visible | | vein angle variability | not applicable |
| apex shape | not visible | | Epimedial tertiaries | not visible |
| apex shape | not visible | | proximal course | not visible |
| base angle | acute | | distal course | not visible |
| base shape | straight | | Exterior tertiary course | not visible |
| base shape | not visible | **4º** | Quaternary vein fabric | not visible |
| Terminal apex features | not visible | **5º** | Quinternary vein fabric | not visible |
| | | | Areolation | not visible |
| Surface texture | not visible | | FEV branching | not visible |
| Surficial glands | not visible | | FEV termination | not visible |
| | | | Marginal Ultimate venation | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | not applicable |
| number of orders of teeth | not applicable |
| teeth / cm | |
| sinus shape | not applicable |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | not applicable |
| principal vein termination | not applicable |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**Text Description:**

Leaf attachment petiolate; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not visible; leaflet organization not visible. Blade attachment marginal. Petiole features not visible. Laminar size mesophyll; laminar L:W ratio >3:1; laminar shape unknown with medial not visible and base not visible to not visible. Margin not visible and not visible with not visible edges. Apex angle not visible; apex shape not visible to not visible; base angle acute; base shape straight to not visible. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins not visible; 1basal veins; agrophic veins not visible. Major secondaries semicraspedodromous, spacing regular, uniform; attachment excurrent. Interior secondaries absent; minor secondary course not applicable; not visiblepresent, proximal course not visible; Intersecondaries not applicable; distal course not applicable; occur at not applicable; Intercostal tertiary veins not applicable, to not applicable; not applicableto midvein; vein angle not applicable. Epimedial tertiaries not visible; proximal course not visible; distal course not visible. Exterior tertiary course not visible. Quaternary vein fabric not visible. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing not applicable, with not applicable orders of teeth; teeth / cm ; sinus shape not applicable. Tooth shapes ; ; ; and . Principal vein not applicable; terminates not applicable; accesory vein not applicable; tooth apex not applicable.

**Diagnostic Features:**

Very thick midvein, acute/straight base, major secondaries semicraspedodromous

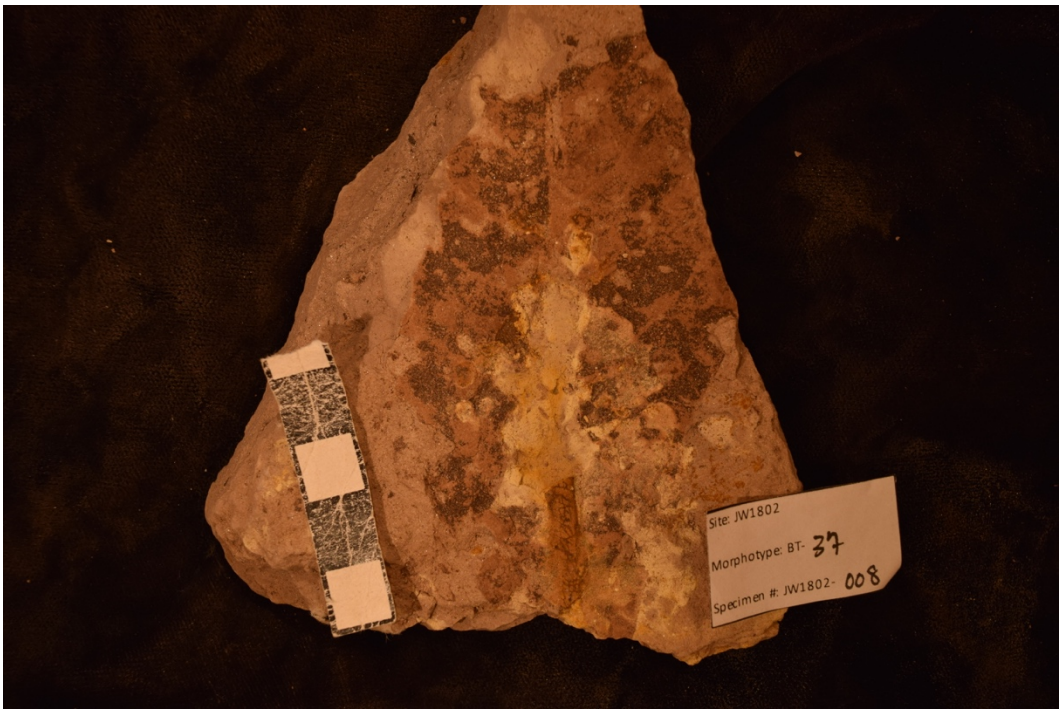


Figure A.30. Morphotype BT-37. Present in locality JW1802. Specimen number JW1802-008, exemplar.

Table A.35. Morphotype BT-38 leaf architecture description. Present in locality JW181.

| Section I. Leaf Characters | Description |
|---|---|
| Leaf attachment | petiolate |
| leaf arrangement | not visible |
| leaf organization | simple |
| leaflet organization | not visible |
| Leaflet attachment | not visible |
| Petiole features | not visible |
| | |
| **Features of the blade:** | |
| Position of lamina attachment | marginal |
| Laminar size | nanophyll |
| laminar L:W ratio | 2:1 |
| laminar shape | elliptic |
| medial symmetry | asymmetrical |
| base symmetry | asymmetrical |
| base symmetry | basal insertion asymmetrical |
| lobation | unlobed |
| margin type | toothed |
| special margin features | |
| Apex angle | acute |
| apex shape | convex |
| apex shape | convex |
| base angle | acute |
| base shape | straight |
| base shape | not visible |
| Terminal apex features | |
| | |
| Surface texture | not visible |
| Surficial glands | not visible |

| | Section II. Venation | Description |
|---|---|---|
| **1º** | Primary vein framework | pinnate |
| | naked basal veins | not visible |
| | number of basal veins | 1 |
| | agrophic veins | absent |
| **2º** | Major 2º vein framework | craspedodromous |
| | Interior secondaries | not visible |
| | minor secondary course | not visible |
| | Perimarginal veins | not applicable |
| | major secondary spacing | regular |
| | Variation of secondary angle | uniform |
| | Major secondary attachment | decurrent |
| **Inter-2º** | proximal course | absent |
| | intersecondary length | not applicable |
| | distal course | not applicable |
| | vein frequency | not applicable |
| **3º** | Intercostal tertiary vein fabric | not applicable |
| | Intercostal tertiary vein fabric | not applicable |
| | Angle of percurrent tertiaries | not applicable |
| | vein angle variability | not applicable |
| | Epimedial tertiaries | not visible |
| | proximal course | not visible |
| | distal course | not visible |
| | Exterior tertiary course | not visible |
| **4º** | Quaternary vein fabric | not visible |
| **5º** | Quinternary vein fabric | not visible |
| | Areolation | not visible |
| | FEV branching | not visible |
| | FEV termination | not visible |
| | Marginal Ultimate venation | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | irregular |
| number of orders of teeth | one |
| teeth / cm | 6/cm |
| sinus shape | angular |
| tooth shapes | FL/CV |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | present |
| principal vein termination | on proximal flank of tooth |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**Diagnostic Features:**

Nanophyll, toothed margin with edges, basal insertion asymmetrical

**Text Description:**

Leaf attachment petiolate; leaf arrangement not visible; leaf organization simple. Leaflet attachment not visible; leaflet organization not visible. Blade attachment marginal. Petiole features not visible. Laminar size nanophyll; laminar L:W ratio 2:1; laminar shape elliptic with medial asymmetrical and base asymmetrical to basal insertion asymmetrical. Margin unlobed and toothed with edges. Apex angle acute; apex shape convex to convex; base angle acute; base shape straight to not visible. Termianal apex . Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins not visible; 1basal veins; agrophic veins absent. Major secondaries craspedodromous, spacing regular, uniform; attachment decurrent. Interior secondaries not visible; minor secondary course not visible; not applicablepresent, proximal course absent; Intersecondaries not applicable; distal course not applicable; occur at not applicable; Intercostal tertiary veins not applicable, to not applicable; not applicableto midvein; vein angle not applicable. Epimedial tertiaries not visible; proximal course not visible; distal course not visible. Exterior tertiary course not visible. Quaternary vein fabric not visible. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing irregular, with one orders of teeth; teeth / cm 6/cm; sinus shape angular. Tooth shapes FL/CV; ; ; and . Principal vein present; terminates present; accesory vein not applicable; tooth apex not applicable.

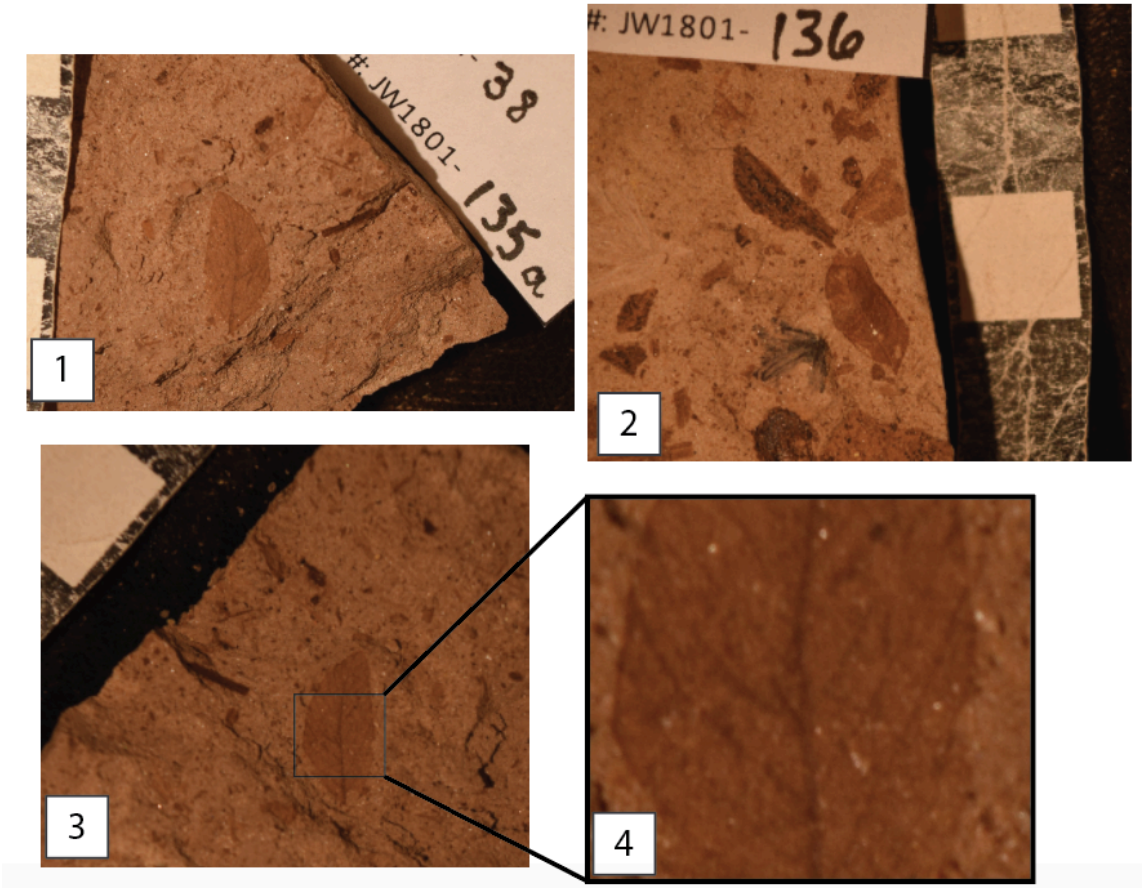


Figure A.31. Morphotype BT-38. Present in locality JW1801. Specimen numbers: 1. JW1801-135a, exemplar, 2. JW1801-136, 3. JW1801-135b, 4. JW1801-135b, enlarged box to show venation and serration.

Table A.36. Morphotype BT-40 leaf architecture description. Present in locality JW1802.

| Section I. Leaf Characters | Description | | Section II. Venation | Description |
|---|---|---|---|---|
| Leaf attachment | not visible | **1º** | Primary vein framework | pinnate |
| leaf arrangement | not visible | | naked basal veins | not visible |
| leaf organization | not visible | | number of basal veins | 1 |
| leaflet organization | not visible | | agrophic veins | present |
| Leaflet attachment | not visible | **2º** | Major 2º vein framework | eucamptodromous |
| Petiole features | not visible | | Interior secondaries | not visible |
| | | | minor secondary course | simple brochidodromous |
| **Features of the blade:** | | | Perimarginal veins | not applicable |
| Position of lamina attachment | not visible | | major secondary spacing | regular |
| Laminar size | notophyll | | Variation of secondary angle | uniform |
| laminar L:W ratio | | | Major secondary attachment | deflected |
| laminar shape | unknown | **Inter-2º** | proximal course | not visible |
| medial symmetry | not visible | | intersecondary length | not applicable |
| base symmetry | not visible | | distal course | not applicable |
| base symmetry | not visible | | vein frequency | not applicable |
| lobation | unlobed | **3º** | Intercostal tertiary vein fabric | not visible |
| margin type | entire | | Intercostal tertiary vein fabric | not applicable |
| special margin features | not visible | | Angle of percurrent tertiaries | not applicable |
| Apex angle | not visible | | vein angle variability | not applicable |
| apex shape | not visible | | Epimedial tertiaries | not visible |
| apex shape | not visible | | proximal course | not visible |
| base angle | not visible | | distal course | not visible |
| base shape | not visible | | Exterior tertiary course | not visible |
| base shape | not visible | **4º** | Quaternary vein fabric | not visible |
| Terminal apex features | not visible | **5º** | Quinternary vein fabric | not visible |
| | | | Areolation | not visible |
| Surface texture | not visible | | FEV branching | not visible |
| Surficial glands | not visible | | FEV termination | not visible |
| | | | Marginal Ultimate venation | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | not applicable |
| number of orders of teeth | not applicable |
| teeth / cm | |
| sinus shape | not applicable |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| tooth shapes | |
| Principal vein | not applicable |
| principal vein termination | not applicable |
| course of accessory vein | not applicable |
| features of the tooth apex | not applicable |

**Diagnostic Features:**

Entire margin, major secondaries eucamptodromous, agrophic veins

**Text Description**

Leaf attachment not visible; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not visible; leaflet organization not visible. Blade attachment not visible. Petiole features not visible. Laminar size notophyll; laminar L:W ratio ; laminar shape unknown with medial not visible and base not visible to not visible. Margin unlobed and entire with not visible edges. Apex angle not visible; apex shape not visible to not visible; base angle not visible; base shape not visible to not visible. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins not visible; 1basal veins; agrophic veins present. Major secondaries eucamptodromous, spacing regular, uniform; attachment deflected. Interior secondaries not visible; minor secondary course simple brochidodromous; not applicablepresent, proximal course not visible; Intersecondaries not applicable; distal course not applicable; occur at not applicable; Intercostal tertiary veins not visible, to not applicable; not applicableto midvein; vein angle not applicable. Epimedial tertiaries not visible; proximal course not visible; distal course not visible. Exterior tertiary course not visible. Quaternary vein fabric not visible. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing not applicable, with not applicable orders of teeth; teeth / cm ; sinus shape not applicable. Tooth shapes ; ; ; and . Principal vein not applicable; terminates not applicable; accesory vein not applicable; tooth apex not applicable.


Figure A.32. Morphotype BT-40. Present in locality JW1802. Specimen number JW1802-009, exemplar.

Table A.37. Morphotype BT-44 leaf architecture description. Present in locality JW1801 and JW1803.

| Section I. Leaf Characters | Description |
|---|---|
| Leaf attachment | not visible |
| leaf arrangement | not visible |
| leaf organization | not visible |
| leaflet organization | not visible |
| Leaflet attachment | not visible |
| Petiole features | not visible |
| **Features of the blade:** | |
| Position of lamina attachment | not visible |
| Laminar size | notophyll |
| laminar L:W ratio | 2:1 |
| laminar shape | ovate |
| medial symmetry | symmetrical |
| base symmetry | not visible |
| base symmetry | not visible |
| lobation | unlobed |
| margin type | toothed |
| special margin features | not visible |
| Apex angle | acute |
| apex shape | acuminate |
| apex shape | acuminate |
| base angle | not visible |
| base shape | not visible |
| base shape | not visible |
| Terminal apex features | not visible |
| Surface texture | not visible |
| Surficial glands | not visible |

| | Section II. Venation | Description |
|---|---|---|
| **1º** | Primary vein framework | pinnate |
| | naked basal veins | absent |
| | number of basal veins | 1 |
| | agrophic veins | absent |
| **2º** | Major 2º vein framework | craspedodromous |
| | Interior secondaries | absent |
| | minor secondary course | not applicable |
| | Perimarginal veins | not applicable |
| | major secondary spacing | regular |
| | Variation of secondary angle | uniform |
| | Major secondary attachment | excurrent |
| **Inter-2º** | proximal course | absent |
| | intersecondary length | not applicable |
| | distal course | not applicable |
| | vein frequency | not applicable |
| **3º** | Intercostal tertiary vein fabric | sinuous opposite percurrent |
| | Intercostal tertiary vein fabric | mixed percurrent |
| | Angle of percurrent tertiaries | obtuse |
| | vein angle variability | consistent |
| | Epimedial tertiaries | opposite percurrent |
| | proximal course | perpendicular to midvein |
| | distal course | parallel to intercostal tertiary |
| | Exterior tertiary course | terminating at the margin |
| **4º** | Quaternary vein fabric | mixed percurrent |
| **5º** | Quinternary vein fabric | not visible |
| | Areolation | not visible |
| | FEV branching | not visible |
| | FEV termination | not visible |
| | Marginal Ultimate venation | not visible |

| Section III. Teeth | |
|---|---|
| Tooth spacing | regular |
| number of orders of teeth | one |
| teeth / cm | 1/cm |
| sinus shape | rounded |
| tooth shapes | FL/ST |
| tooth shapes | FL/FL |
| tooth shapes | |
| tooth shapes | |
| Principal vein | present |
| principal vein termination | on proximal flank of tooth |
| course of accessory vein | not applicable |
| features of the tooth apex | cassidate |

**Diagnostic Features:**
Toothed margin, unlobed, ovate shape, symmetrical, acuminate apex, major secondaries craspedodromous

**Text Description:**

Leaf attachment not visible; leaf arrangement not visible; leaf organization not visible. Leaflet attachment not visible; leaflet organization not visible. Blade attachment not visible. Petiole features not visible. Laminar size notophyll; laminar L:W ratio 2:1; laminar shape ovate with medial symmetrical and base not visible to not visible. Margin unlobed and toothed with not visible edges. Apex angle acute; apex shape acuminate to acuminate; base angle not visible; base shape not visible to not visible. Termianal apex not visible. Surface texture not visible. Surficial glands not visible. Primary venation pinnate; naked basal veins absent; 1basal veins; agrophic veins absent. Major secondaries craspedodromous, spacing regular, uniform; attachment excurrent. Interior secondaries absent; minor secondary course not applicable; not applicablepresent, proximal course absent; Intersecondaries not applicable; distal course not applicable; occur at not applicable; Intercostal tertiary veins sinuous opposite percurrent, to mixed percurrent; obtuseto midvein; vein angle consistent. Epimedial tertiaries opposite percurrent; proximal course perpendicular to midvein; distal course parallel to intercostal tertiary. Exterior tertiary course terminating at the margin. Quaternary vein fabric mixed percurrent. Quinternary vein fabric not visible. Areolation not visible; Freely ending veinlets not visible, with not visibletermination. Marginal Ultimate venation not visible. Tooth spacing regular, with one orders of teeth; teeth / cm 1/cm; sinus shape rounded. Tooth shapes FL/ST; FL/FL; ; and . Principal vein present; terminates present; accesory vein not applicable; tooth apex cassidate.

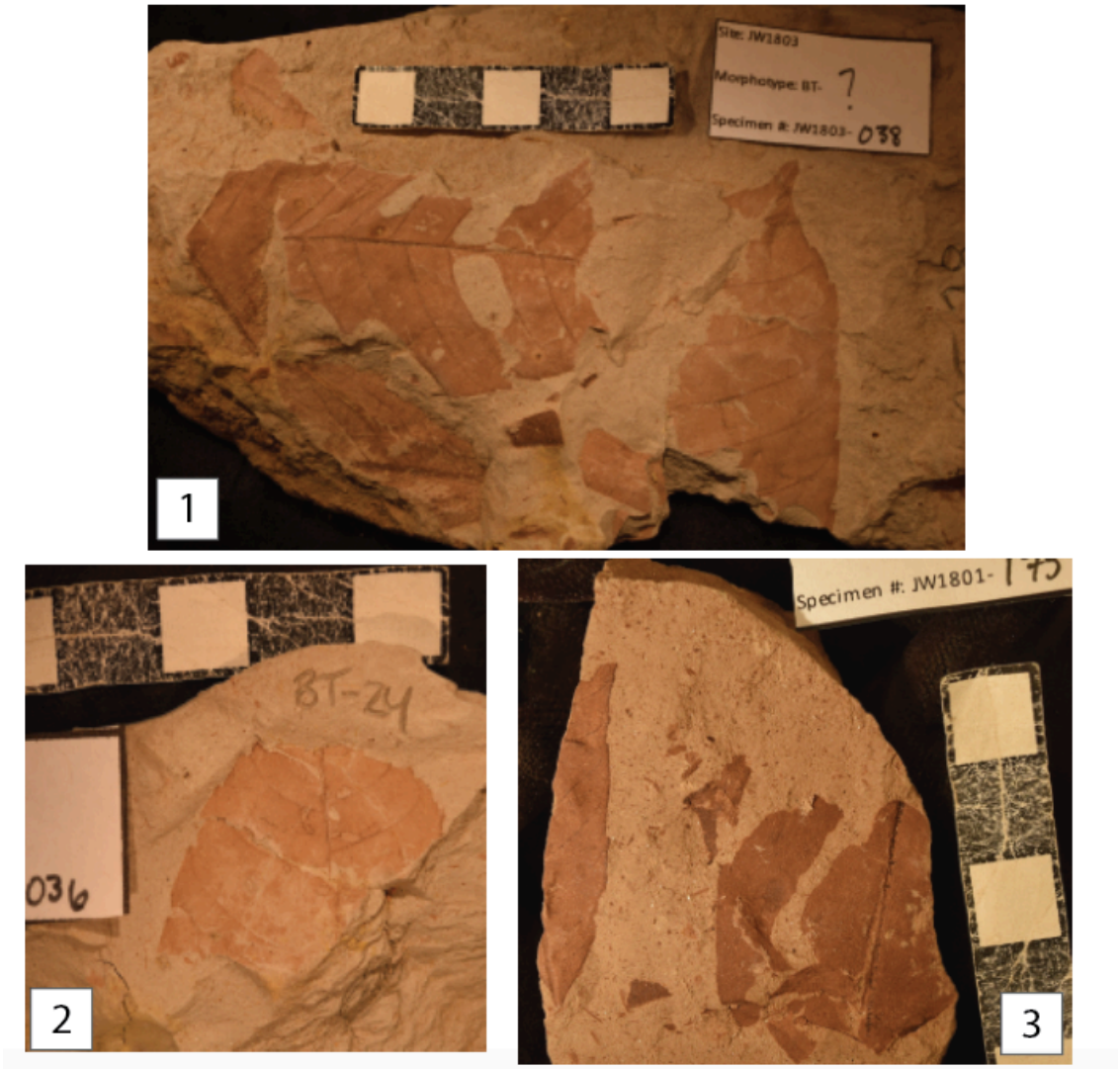


Figure A.33. Morphotype BT-44. Present in localities JW1801 and JW1803. Specimen numbers : 1. JW1803-038, 2. JW1803-036, exemplar, 3. JW1801-175.

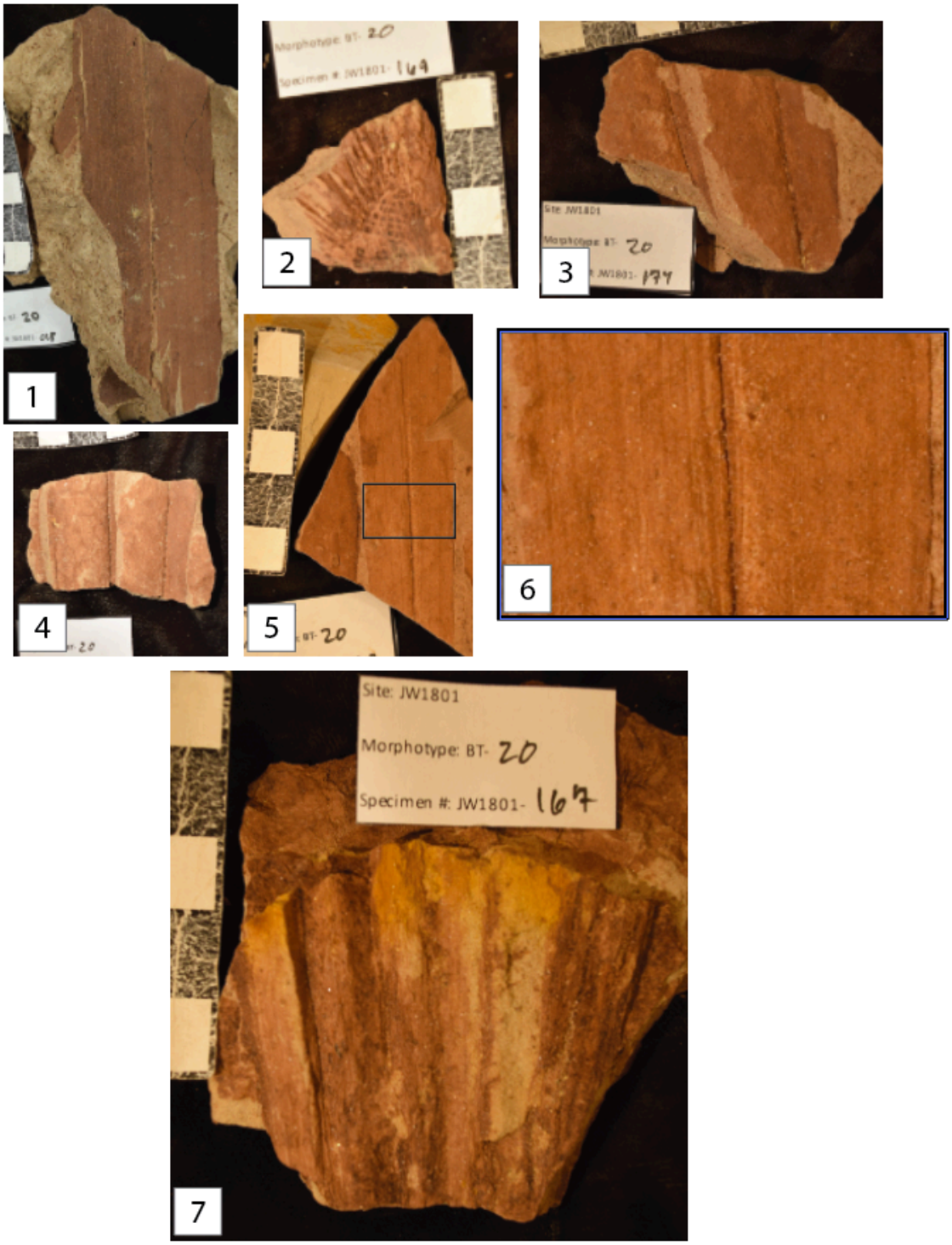


Figure A.34. Morphotype BT-20. Present in locality JW1801. Specimen numbers: 1. JW1801-018, exemplar, 2. JW1801-169, 3. JW1801-174, 4. JW1801-024, 5. JW1801-162, 6. JW1801-162 enlarged box to show venation, 7. JW1801-167.

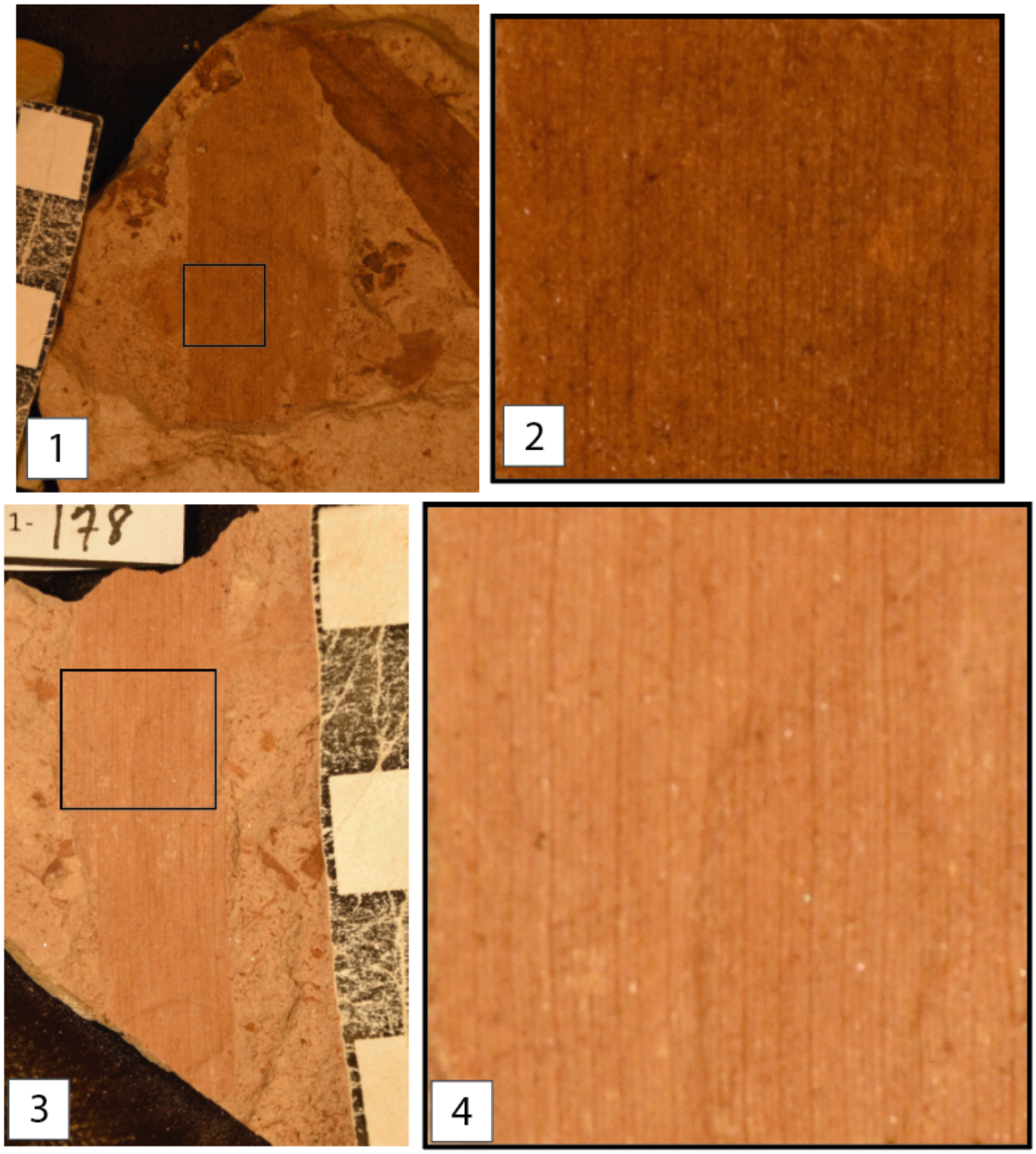


Figure A.35. Morphotype BT-21. Present in locality JW1801 and JW1802. Specimen numbers: 1. JW801-163, 2. JW1801-163 enlarged box to show venation. 3. JW1801-178, 4. JW1801-178 enlarged box to show venation.

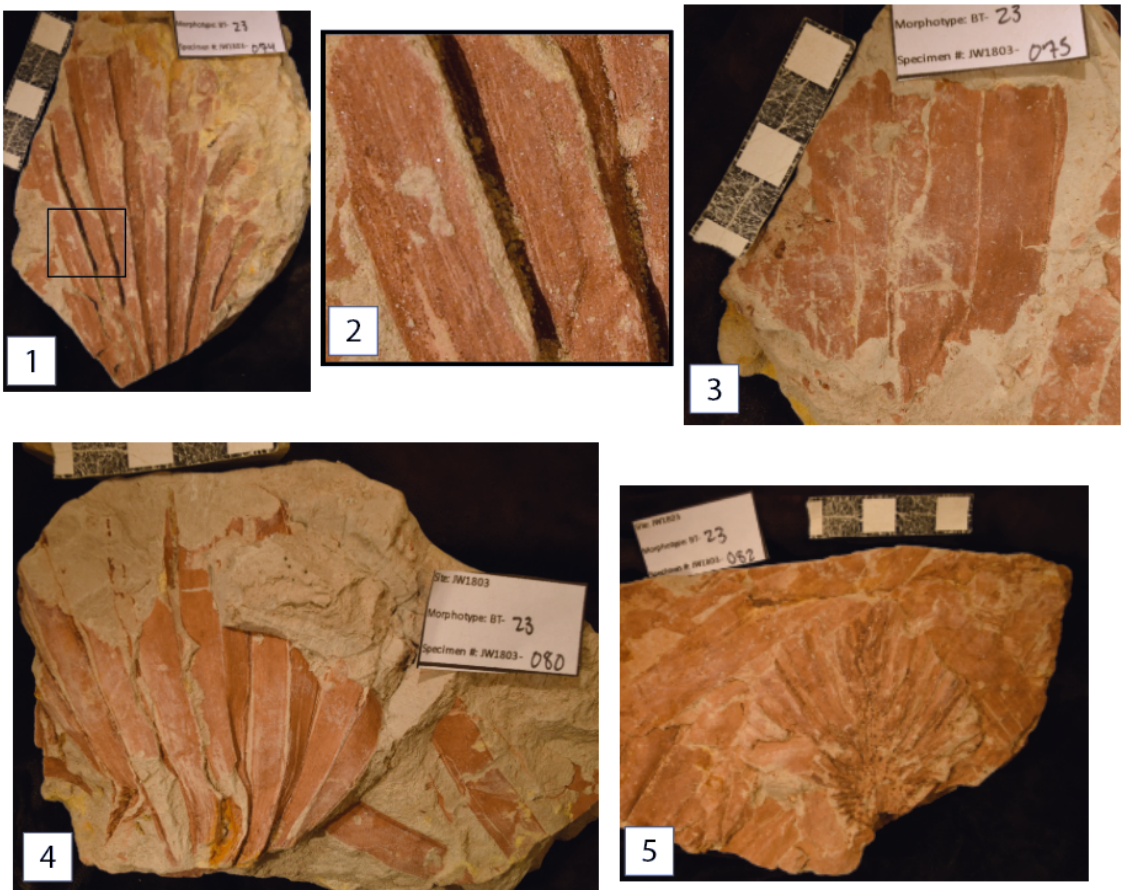


Figure A.36. Morphotype BT-23. Present in locality JW1803. Specimen numbers: 1. JW803-074, 2. JW1803-074 enlarged box to show venation. 3. JW1803-075, 4. JW1803-080, 5. JW1803-082.

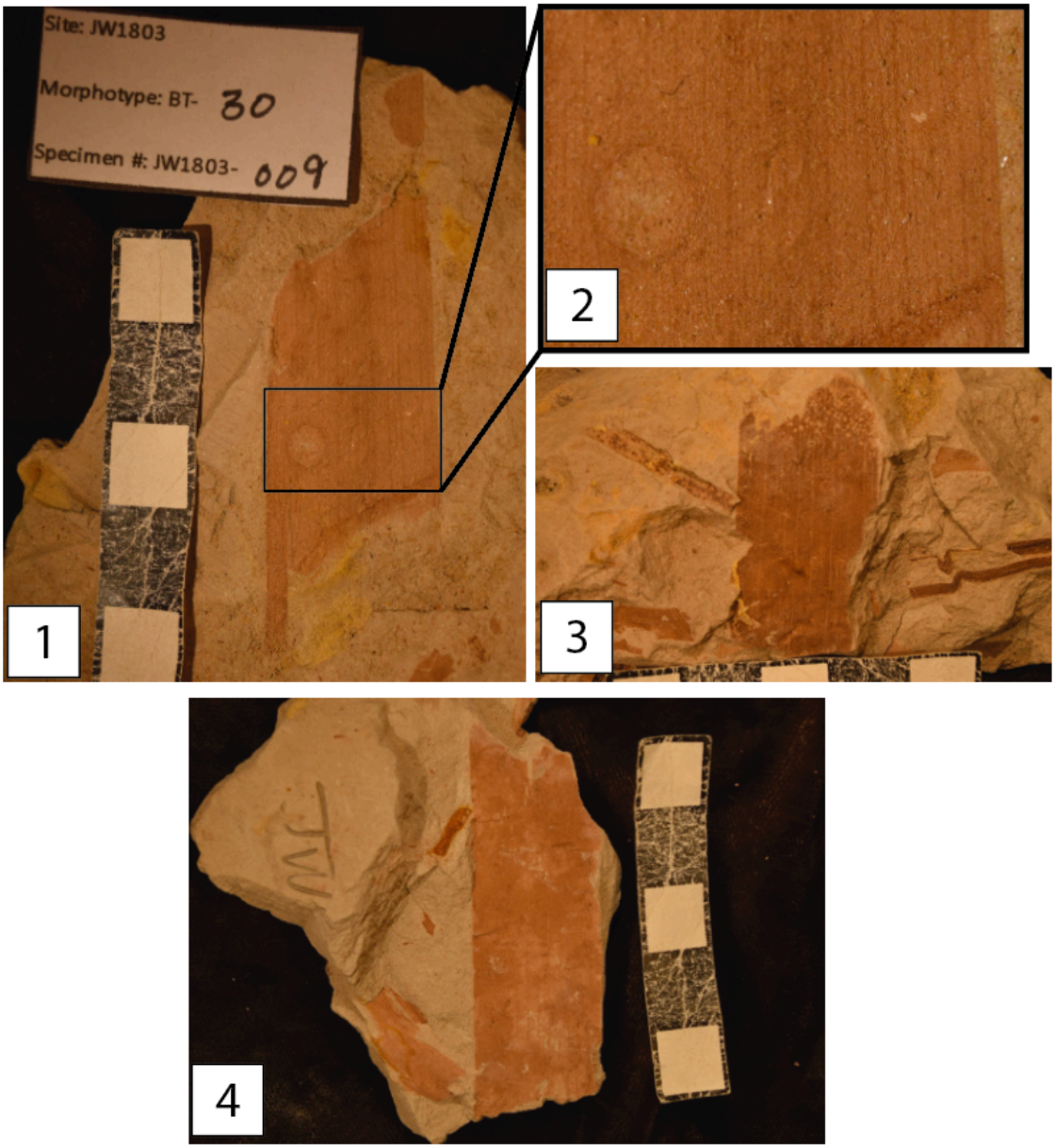


Figure A.37. Morphotype BT-30. Present in locality JW1803. Specimen numbers: 1. JW803-009, exemplar, 2. JW803-009, enlarged box to show venation. 3. JW1803-069, 4. JW1803-067.

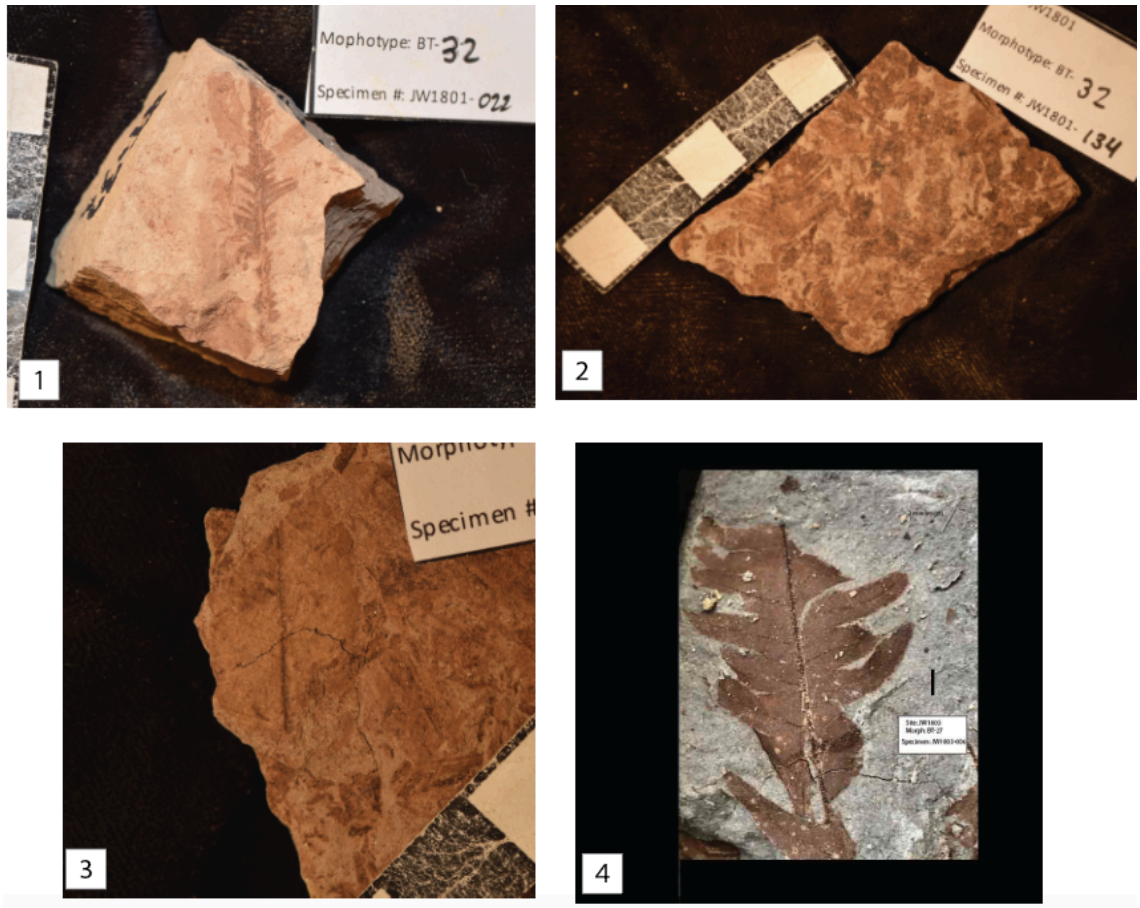


Figure A.38. Fern morphotypes from all localities. 1. Morphotype BT-32, specimen number JW1801-022, exemplar, 2. Morphotype BT-32, JW1801-134, 3. Morphotype BT-39, JW1801-141, 4. Morphotype BT-27, JW1803-006, exemplar, scale bar 1 cm.

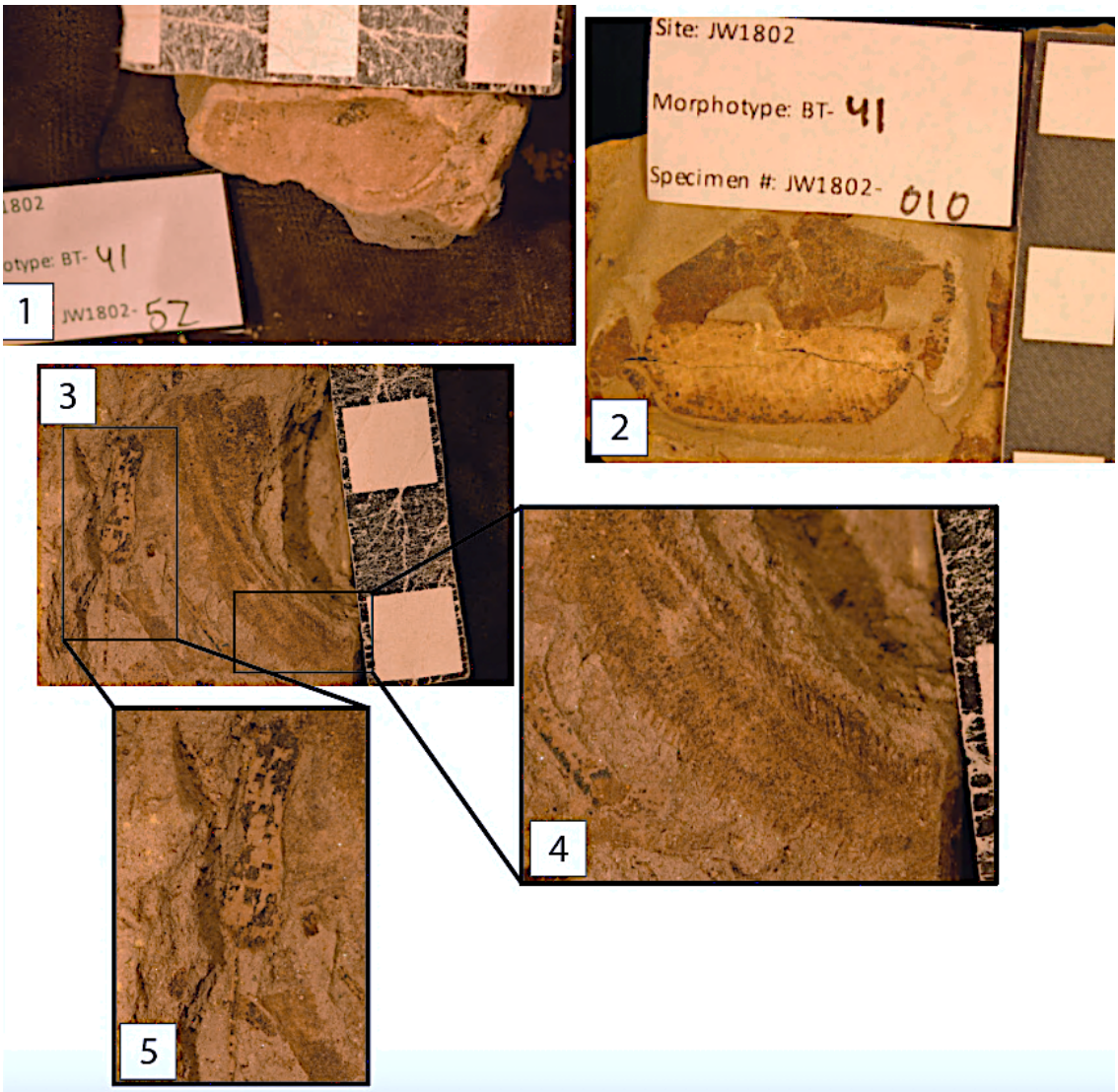


Figure A.39. Reproductive material from locality JW1802. 1. BT-41, JW1802-052, 2. BT-41, JW1802-010, exemplar, 3. BT-42, JW1802-012, exemplar, 4. JW1802-012 enlarged box to show striations on (possible) catkin, 5. BT-41, JW1802-012.

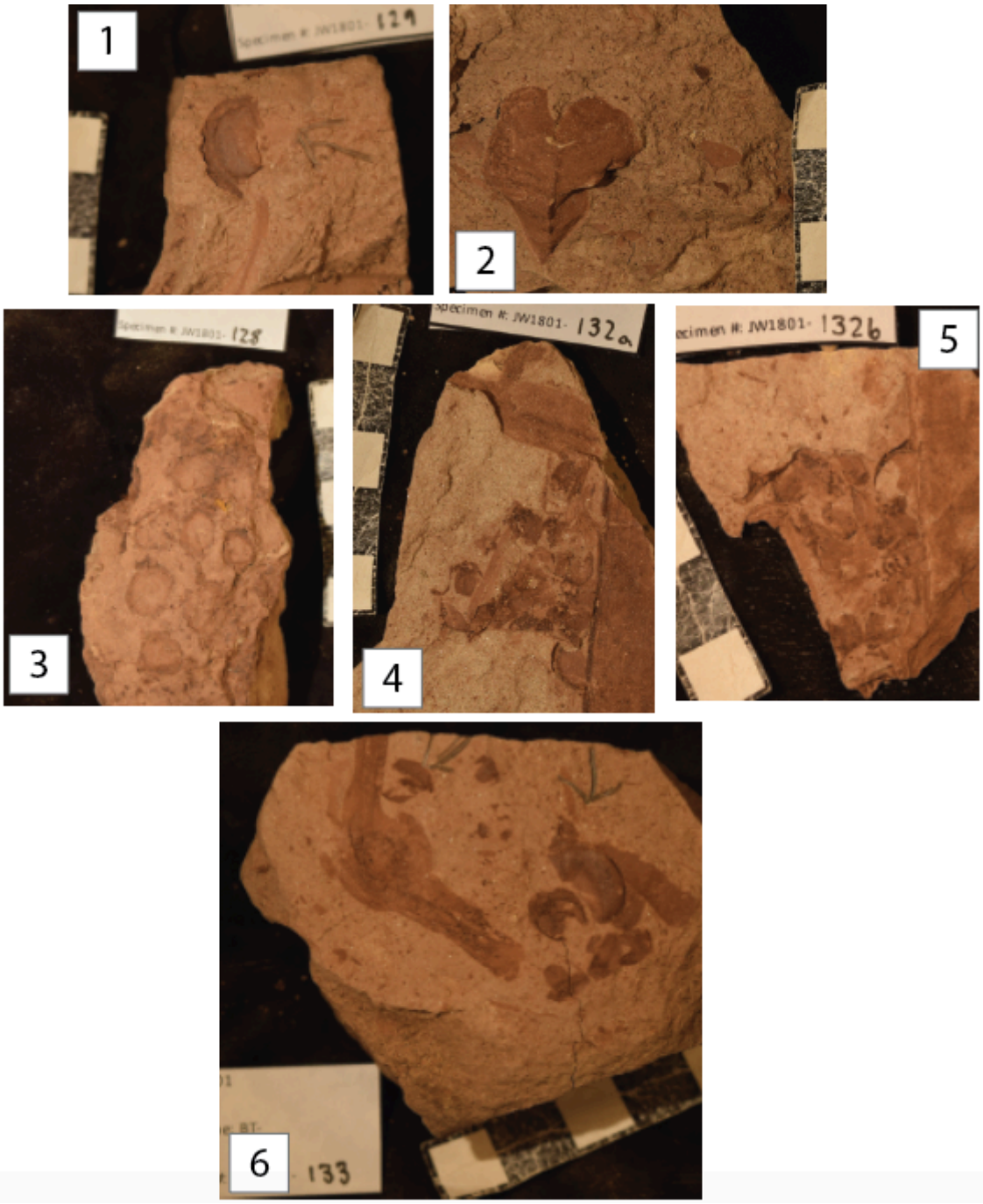


Figure A.40. Reproductive material from locality JW1801. Specimen numbers:. 1. JW1801-129, possible palm fruit, 2. JW1801-130, possible palm-type *Nypa* fruit or buckeye seed, 3. JW1801-128, aggregate fruit, possible palm fuit, 4. JW1801-132a, aggregate fruit with indentation in center, 5. JW1801-132b, aggregate fruit with indentation in center, 6. JW1801-133, winged fruit and palm fruit.

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