TESTING FOR CLIMATE AND ELEVATION CONTROLS ON PENNSYLVANIAN PLANT COMMUNITIES IN VALLEY FILLS OF THE BREATHITT GROUP IN EASTERN KENTUCKY

by

MARJEAN A. CONE

(Under the Direction of Steven M. Holland)

ABSTRACT

There is debate on whether climate or elevation controls the distribution of Pennsylvanian plant communities. Studying logjam deposits in valley fills of the Breathitt Group of eastern Kentucky offers a way to test for these controls. If plant distribution was elevation-controlled, communities would be expected to pass from drier assemblages at the base of a valley fill to wetter assemblages upwards within a valley fill. Similarly, wetter assemblages should occur down-dip, and drier assemblages should occur up-dip. If plants were controlled by climate, communities would be expected to transition from drier assemblages at the base of a valley to wetter assemblages at the top and should be regionally uniform. Studied valley fills were dominated by wetland flora, particularly lycopsids, implying that lowland coastal areas may have been occupied by relatively uniform plant communities, making it difficult to evaluate whether climate or elevation is the dominant control on Pennsylvanian plant communities.

INDEX WORDS: Valley fill, wet, dry, elevation, climate, lycopsid

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DEDICATION

This thesis is dedicated to my Uncle David, who has continued to inspire my interest in geology since I was young. Thank you for encouraging me to pursue this science and for always being someone I can talk to about geology. I cherish being able to speak the language of geology with someone who helped spark my desire to learn more. I know we will continue to share stories, collections, and exchange rocks as Christmas gifts for years to come.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

This research extends the application of stratigraphic architecture to the paleontology of nonmarine systems. Understanding the stratigraphic architecture of marine and nonmarine systems allows us to interpret the fossil record as predictable and structured, enabling us to better understand how communities change through time (Patzkowsky and Holland 2012; Holland and Loughney 2021). An important tenet of stratigraphic paleontology is that the occurrence of fossils in space and time is controlled not only by evolution and ecology but also by stratigraphic processes that control deposition and preservation (Patzkowsky and Holland 2012). To make well-grounded interpretations of evolutionary or ecological changes, it is essential to understand how the stratigraphic architecture of these systems controls the distribution of fossils. Although marine systems are well-studied, nonmarine ones are less so (Holland and Loughney 2021).

There is debate as to whether climate or elevation is the principal control on the distribution of Pennsylvanian plant communities (e.g., Bashforth et al. 2021). Resolving this debate is important for understanding the controls on community changes in nonmarine systems (Holland and Loughney 2021). Studies in support of elevation as the principal control propose that differences in community composition occur according to changes in moisture along the coastal plain, in association with elevation changes that can correlate with distance from the shore or a river (Cridland and Morris 1963; Lyons and Darrah 1989; Dimitrova et al. 2011;

DiMichele et al. 2020; Bashforth et al. 2021; Holland 2022). Studies in support of climate as the principal control propose that changes in community composition are due to fluctuations in regional climate (Falcon-Lang and DiMichele 2010; DiMichele et al. 2020; Bashforth et al. 2021). Investigating such controls on trends through nonmarine systems may provide a better picture of what ancient nonmarine systems looked like. In addition, elevation-correlated gradients are well-known in modern settings but are poorly documented in the fossil record (Holland and Loughney 2021). Understanding how environmental gradients are preserved in the fossil record is important for understanding the relationship between stratigraphy and the distribution patterns of fossils.

In paleobotany comparatively, few studies have focused on the fossils preserved in sandstones relative to coals and floodplain mudstones (Falcon-Lang et al. 2004; Gastaldo and Degges 2007; Bashforth et al. 2014, 2021; DiMichele et al. 2020). This is generally because the delicate foliage of plants tend to be poorly preserved when deposited in coarser sediment, such as fluvial sandstone channel deposits (Behrensmeyer and Hook 1992; Behrensmeyer et al. 2000; DiMichele et al. 2020; Bashforth et al. 2021). For example, Pennsylvanian plants have been studied mostly in coal beds and compression deposits where preservation is good, but far less is known of the poorly preserved material in channels and valley fills (Demko et al. 1998; Dimitrova et al. 2011; DiMichele, 2014; Bashforth et al. 2014, 2021; DiMichele et al. 2020). The scarcity and poor preservation quality may make studies of plant fossils in channel sandstones more difficult; however, this presents a need to study them. Studying fossils from such lithologies presents the opportunity to gain a greater understanding of plant communities from a broader range of depositional environments.

Logjams may preserve Pennsylvanian lowland communities and provide the potential to study plant distribution patterns, but they are understudied. Studies of modern logjam deposits have been useful in understanding the relationship between plant communities and their riparian habitats (Beckman and Wohl 2014). Investigating ancient logjams may provide information on the plant communities that lived there. The Pennsylvanian Breathitt Group of eastern Kentucky is composed of shallow marine to fluvio-deltaic deposits, where channel facies within valley fills preserve fossil logjams (Greb and Chesnut 1992; Aitken and Flint 1994, 1995; Le Cotonnec et al. 2020). Vertical changes in plant communities from valley fills have not yet been studied but are potentially an important source of data on the climate versus elevation question (Dimitrova et al. 2011). While wood has been described from channel bases in the Breathitt Group (Greb and Chesnut 1992; Aitken and Flint 1994, 1995), there has been no extensive search for fossil wood vertically and laterally to test for changes in community composition. As a result, this study advances stratigraphic paleobiology as well as the study of Pennsylvanian plant communities.

CHAPTER 2

TESTING FOR CLIMATE AND ELEVATION CONTROLS ON PENNSYLVANIAN PLANT COMMUNITIES IN VALLEY FILLS OF THE BREATHITT GROUP IN EASTERN KENTUCKY

INTRODUCTION

Recent studies have debated whether climate or elevation controls the composition of Pennsylvanian plant communities. Some have argued that changes in elevation, even minor ones, are the primary control on community composition (Cridland and Morris 1963; Lyons and Darrah 1989; Dimitrova et al. 2011, fig. 1). These studies argue that plants that live in drier conditions only need substrates where their roots are not submerged in water, and that elevation differences of as little as a meter can change soil wetness. For example, studies of modern coastal areas of the U.S. have shown that composition of forests varies with topography and along a moisture gradient (Wyant et al. 1991). Other studies argue that climate is the main control on communities with the species composition of vegetation being controlled by regional precipitation and temperature (DiMichele et al. 2020b; Bashforth et al. 2021, fig. 2). This is supported by studies of modern tropical rainforests where uplands and lowlands separated by hundreds of meters of elevation share a similar species pool (Kenfack et al. 2014).

This study will focus on Early to Mid-Pennsylvanian plant communities of the Breathitt Group in eastern Kentucky. The Breathitt Group contains marine, prodelta to delta plain, and fluvial deposits, which contain large valley fills in which vertical and lateral community trends can be sampled. These valley fills are exposed in large roadcuts in numerous locations across eastern Kentucky. This study will test whether vertical and lateral variations in the taxonomic composition of wood or bark in valley fills varies in a way that is consistent with changes in elevation and climate during the filling of valleys.

BACKGROUND

Paleogeography

The Pennsylvanian world was situated in the central part of Pangea, placing present-day eastern North America in the equatorial tropics. At the start of the Pennsylvanian, Pangea's formation was completed with the final collision of Laurasia and Gondwana (Blakey and Wong 2003; Blakey 2008). Pangea can be split into three broad regions across the equator: western, central, and eastern (DiMichele et al. 2020b). The western region includes northern Mexico and western and midwestern parts of the U.S. The central region includes the eastern U.S., parts of the midwestern U.S., eastern Canada, western Europe, and Ukraine. The eastern region includes southern Russia, the Middle East, and China. Eastern North America was situated relatively close to the equator and was therefore in the central tropical region of Pangea (Fig. 3). The central Pangean mountains and their associated basins spanned Euramerica (Blakey 2008; Davies and Gibling 2013; DiMichele et al. 2020b; Scotese 2021). These include the Ouachita Mountains of the south-central U.S. and the eastern Appalachian Mountains (Golanka and Ford 2000). The Appalachian Foreland Basin preserves the deposits of fluvial, deltaic, and shallow marine depositional systems (Tankard 1986; Bashforth et al. 2021).

Climate

The climate in the Carboniferous Period underwent extreme fluctuations. From the Late Mississippian to the early Permian, the global climate was cool during the Late Paleozoic Ice Age but experienced regional climatic oscillations (DiMichele et al. 2020b; Bashforth et al. 2021). The climate varied from perhumid to subhumid to semiarid across equatorial Pangea, with western equatorial Pangea being drier overall compared with central equatorial Pangea (Cecil et al. 2003). Climate trended over time toward overall aridity across equatorial Pangea, and this was superimposed on these regional oscillations and differences, which began in the Early Pennsylvanian and continued through the Permian (Raymond and Metz 2004; DiMichele et al. 2020b).

Although the North American climate was mostly arid in the Mississippian, it shifted to a humid climate at the start of the Pennsylvanian and continued to fluctuate into the Permian (Davies and Gibling 2013). These fluctuations were not spatially or temporally consistent across the equatorial parts of Pangea (Cecil et al. 2003; DiMichele et al. 2020b). Basins across North America in the Pennsylvanian experienced climates that fluctuated between wetter and less wet intervals (e.g., DiMichele et al. 2020b). The wet periods ranged from moist subhumid to humid to perhumid, with perhumid being the wettest overall and the subhumid periods being relatively drier (e.g., Bashforth et al. 2014). Throughout this paper, these less wet subhumid intervals will for brevity be referred to as “dry”.

These complex climate regimes present in eastern North America were a result of glacial–interglacial oscillations on 100,000 to 400,000-year cycles (e.g., Van Den Belt et al. 2015; DiMichele et al. 2020b). There is some disagreement about how climate changes during these glacial–interglacial oscillations (Falcon-Lang and DiMichele 2010; DiMichele 2014, DiMichele et al. 2020b; Bashforth et al. 2021). Early studies argued that the climate was cold and dry during the glacial periods and that it was warm and humid during the interglacial periods (Falcon-Lang and DiMichele 2010). More recent studies argue that climate oscillated between being seasonally dry to wetter and colder during the glacial periods, to drier and warmer in the interglacial periods (DiMichele 2014, DiMichele et al. 2020b; Bashforth et al. 2021). These studies describe climate as being at its wettest during the glacial maximum and at its driest during the interglacial maximum (DiMichele 2014, fig. 4). Longer-term glacial cycles from the Late Paleozoic Ice Age resulted in a drying period that was superimposed on these shorter cycles in the Pennsylvanian. The differing climatic regimes that occurred in accordance with these complex glacial cycles were not static (Bashforth et al. 2021). For example, while in a perhumid period, seasonal climate trends may have also occurred during that interval that caused shorter-term drier periods.

The glacial–interglacial cycles drove eustatic sea-level fluctuations that are reflected in the stratigraphic record of eastern North America (Raymond and Metz 2004; DiMichele et al. 2020b; LeCottonec et al. 2020; Bashforth et al. 2021). Peak glacial periods reflect a time when the sea level was at its lowest, caused by the storage of large volumes of seawater as ice, and these forced the shoreline to regress westward to the northwest part of eastern North America. Peak interglacial periods reflect a time when the sea level was at its highest, during periods with low volumes of glacial ice, causing the shoreline to transgress eastward to the southeast part of eastern North America. These repeated, high-frequency regressions and transgressions are reflected in the rock record as depositional sequences that span across much of eastern North America.

Plants

Climatic fluctuations and vegetation responses varied spatially on such a geographically diverse Pangean landmass (Bashforth et al. 2021). This directly impacted the distribution of moisture across the landscape. While the Pennsylvanian is widely known for its peat-forming landscapes, such wetland areas were not spatially persistent across central Pangea and were restricted to refugia zones during periods of dry climate (Falcon-Lang et al. 2009; Looy et al. 2014; Bashforth et al. 2014, 2021 DiMichele et al. 2020b, fig. 4). The overall seasonally dry periods brought on by interglacials are thought to have lasted longer than the wet periods (DiMichele et al. 2020b; Bashforth et al. 2021). Wetland taxa could have persisted on those drier landscapes by contracting to areas with consistent moisture, such as channels, channel margins, and other high-moisture patches (DiMichele et al. 2010; DiMichele 2014). The wet periods, brought on by glacials, would have caused dryland plants to inhabit areas of reduced moisture, such as substrates higher above the water table.

The Pennsylvanian climate is reflected in the types of plants and their geographical distribution, which change with variations in moisture (Falcon-Lang and DiMichele 2010; Bashforth et al. 2014; DiMichele et al. 2020b; Table 1). The Pennsylvanian witnessed the evolution of drought-tolerant plant types as a result of increasing seasonal aridity (DiMichele et al. 2020b; Bashforth et al. 2021). Such seasonally dry plants tended to live in mesic and xeric conditions and included mostly gymnosperms (DiMichele et al. 2010; Bashforth et al. 2014). Such plants that were generally well-adapted to a range of moisture conditions also include cordaitaleans and conifers, broadly referred to as coniferopsids. Of these, cordaitaleans were the most moisture-tolerant, and conifers were the most drought-tolerant. The cordaitaleans inhabited wetlands and seasonal drylands. Plants that were generally well-adapted to high-moisture conditions include lycopsids, tree ferns, sphenopsids, pteridosperms, and some cordaitaleans. Of these, lycopsids were the most moisture-tolerant, and drought tolerance varied among the other wetland plant types. Major groups of lycopsids preferred high moisture conditions because their stigmarian root structures enabled them to thrive in standing water, but some, like Sigillaria, were able to live in parts of swamps with less moisture (Pfefferkorn and Wang 2009; Bashforth et al. 2014). Tree ferns preferred moist conditions but were more easily able to live in wet refugia zones in riparian areas of seasonally dry landscapes. Sphenopsids, much like the tree ferns, preferred moist conditions, and their range contracted to zones of continuous moisture on a seasonal landscape. Pteridosperms preferred moist conditions and are not thought to have been able to easily contract to zones of moisture like sphenopsids during seasonal dry periods.

These fossil plants are commonly preserved as coalifications, compressions, and impressions, or as sandstone casts of wood, bark, or foliage (Gillespie et al. 1966; Gastaldo and Degges 2007; DiMichele 2014). Throughout this paper, fossil logs will be referred to as “wood” or “bark”. “Wood” describes coniferopsids, such as cordaitalean trunks, while “bark” describes all other types, such as lycopsids, where the bark surrounding a hollow trunk is what is preserved.

GEOLOGIC SETTING

The Breathitt Group contains Lower to Middle Pennsylvanian strata comprising westward-dipping fluviodeltaic and shallow-marine deposits in the central Appalachian foreland basin of eastern Kentucky (Greb and Chesnut 1992; Aitken and Flint 1994, 1995; Le Cotonnec et al. 2020, fig. 5). Eight to ten major facies associations are present in the Breathitt Group, as described by Aitken and Flint (1994, 1995) and more finely resolved by Le Cotonnec et al. (2020). These include offshore, prodelta, delta-front, mouthbar, tidal flat, bedload-dominated fluvial channels, mixed bedload and suspended load fluvial channels, coastal plain, peat swamps, and subaerial slopes.

The stratigraphy of the Breathitt Group is characterized by repeated associations of shallow marine incursions into deltaic systems that are fluvially dominated (Greb and Chesnut 1992; Aitken and Flint 1995; Jerrett et al. 2016; LeCottonec et al. 2020). Erosional surfaces locally truncate these deposits and are typically infilled with fluvio-estuarine deposits and may be capped by coal, which is commonly regionally extensive. This architecture describes a valley that locally truncates underlying marine deposits and is backfilled with fluvial and estuarine sediments. The upper margins of these valley fills and the interfluves between these valleys preserve paleosols that vary from well-drained to poorly drained (Aitken and Flint 1995).

Valley fills are common in the Breathitt Group, and they are characterized by multistory, multilateral fluvial deposits (Greb and Chesnut 1992; Aitken and Flint 1994, 1995; Le Cotonnec et al. 2020). Channels composing valley fills are distinguished from isolated channels or other fluvial complexes because they overlie erosional surfaces with very high relief. These erosional surfaces indicate the bases of valleys because they are of greater relief than would be expected of a single river channel. Valley fills of the Breathitt Group vary in size and depth of incision, and there are three types (Le Cotonnec et al. 2020). Type A infills are wide (4–5 km) and thick (15–20 m), and they incise into marine deposits. These are characterized by dominantly fluvial deposits, which are interpreted as infills of the landward segments of valleys. Type B infills are narrower (1–2.6 km) and thinner (12–17 m), and they truncate coal beds. These are also characterized by dominantly fluvial deposits, interpreted as infills of landward segments of valleys. They can also contain mixed fluvial and shallow marine deposits, interpreted as proximal deposits of bayhead deltas in the middle segments of valleys. Finally, they also contain shallow marine deposits, interpreted as infills of middle to outer segments of valleys. Type C infills are wide (4–5 km) and thick (15–20 m), and they locally truncate coal beds. These contain only fluvial and mixed fluvial to shallow marine deposits of the landward and middle segments of valleys.

Valley fills of the Breathitt Group are thought to form similarly to those throughout the stratigraphic record (Shanley and McCabe 1994; Catuneanu 2006; Slatt 2006, fig. 6). Fluvial incision occurs during base-level fall, and valley filling occurs during subsequent base-level rise. Formation of Breathitt Group valley fills is reflected in sequence stratigraphic architecture where the incision forms during the falling stage systems tract (FSST), creating the erosional surface at the base of the valley. The lower parts of the valley fill were deposited during the lowstand systems tract (LST; Aitken and Flint 1995; Catuneanu 2006, fig. 7). The upper parts of the valley fill were deposited during the early transgressive systems tract (TST), and in some cases, valley fills accumulated entirely during the TST (Catuneanu 2006).

Fossil wood and bark are found in several settings in the Breathitt Group, and logjams of these may be a means for testing community composition controls (Greb and Chesnut 1992; Aitken and Flint 1994, 1995; Le Cotonnec et al. 2020). Fossil wood and bark occur in overbank deposits, minor and major stacked fluvial bodies, and in valley fills as coal and stumps of fragments of trees. These are commonly preserved as logjams at the bases of sandy fluvial channel deposits (Greb and Chesnut 1992; Aitken and Flint 1994, 1995; Behrensmeyer et al. 2000; Trümper et al. 2020). Such logjams can form when an event such as bank failure or flooding occurs, which causes trees along channel margins to fall into the channel (Gastaldo and Degges 2007). Logjam deposits contain the stronger, woody trunks and branches of Pennsylvanian plants (Bashforth et al. 2021). Long-distance transport of wood or bark in the

Breathitt Group is thought to not be a problem because assemblages in channels usually indicate plant communities that lived on channel margins (Behrensmeyer and Hook 1992; Gastaldo and Huc 1992; Behrensmeyer et al. 2000). For example, studies of Early to Mid-Pennsylvanian channel deposits have shown that most preserved logs are preferentially autochthonous communities of proximal wetland flora (Davies and Gibling 2013; Bashforth et al. 2021). Larger, heavier material such as fossil logs have a relatively high spatial fidelity compared to the much lower spatial fidelity and taphonomic resolution of leaves and pollen, which is subject to much greater transport distances by wind or water (Behrensmeyer et al. 2000).

Climate and elevation hypotheses of plant community change

Climate and elevation are two potential principal controls on plant community distribution in the Pennsylvanian, which can be tested for in valley fill logjams. Valley fills provide predictions regarding the distribution of plant communities stratigraphically and geographically (Demko et al. 1998). The sequence-stratigraphic architecture of valley fills preserves the amalgamated channels of inland coastal systems (Blum et al. 2013). Valley fills are cut during relative sea-level fall and are backfilled by fluvial deposits during subsequent sea-level rise. This may preserve community changes associated with elevation and climatic differences during valley filling. Additionally, valley fills are laterally extensive, which may preserve regional trends of community changes (Falcon-Lang and DiMichele 2010; Blum et al. 2013; Fielding et al. 2020). Investigating the plant types preserved in this setting permits the interpretation of the controls on community changes in ancient coastal systems.

Valley fills may record elevation changes associated with transgression, which provides predictions for changes in coastal plant communities. During valley filling, elevation decreases as the shoreline transgresses (Holland 2022). The rise in sea level leads to aggradation of fluvial strata from near the shoreline, and as sea level continues to rise, estuarine strata are deposited next, with marine strata capping the valley fill (Blum et al. 2013; Slatt 2006; Catuneanu 2006). If elevation controls the distribution of plants, plant communities would therefore be expected to change from higher-elevation (dry-adapted) to lower elevation (wet-adapted) flora from the base to the top of a valley fill (Fig. 8). Geographically, elevation control, via differences in soil moisture, should cause assemblages to vary along depositional dip within a single valley fill with low-elevation assemblages depositionally down-dip and high-elevation assemblages depositionally up-dip.

Valley fills may also record climatic changes associated with glacial–interglacial cycles, providing another set of predictions for changes in coastal plant communities. Previous studies of how climate changes during glacial–interglacial periods are in conflict (Falcon-Lang et al. 2009; Falcon-Lang and DiMichele 2010; DiMichele 2014; DiMichele et al. 2020b; Bashforth et al. 2014, 2021). Some studies state that climate was at its wettest during the glacial maximum and at its driest during the interglacial maximum (DiMichele 2014; DiMichele et al. 2020b; Bashforth et al. 2021), but others state the opposite (Falcon-Lang et al. 2009; Falcon-Lang and DiMichele 2010).

Climate change during a valley fill can also be assessed by the sediment directly, where fills typically pass from sandstones at the base of a valley fill to coals at the top (Greb and Chesnut 1992; Aitken and Flint 1994, 1995; LeCottonec et al. 2020, fig. 5). According to Cecil et al. (1985, 2003, 2014) and Cecil and Dulong (2003), the switch from sandstone to coal would indicate a change in climate from drier to wetter during the deposition of a valley fill. In a climate-controlled system, plant communities would therefore be expected to change stratigraphically from a dryland-dominated flora to a wetland-dominated flora from the base to the top of a valley fill (Fig. 8). Geographically, if climate is the dominant control, assemblages would be expected to be regionally uniform within any valley fill along depositional dip.

Testing for variation in wood or bark fossils through and among valley fills provides a way to test climate and elevation controls on coastal plain communities. The elevation model predicts that valley fills will record a vertical shift from higher-elevation (coniferopsid-dominated) to lower-elevation (lycopsid-dominated) flora (Figs. 1, 8). If elevation is an important control, lycopsids should be more common in valley fills that are depositionally down-dip (to the northwest) and coniferopsids should be more common depositionally up-dip (to the southeast). The climate model predicts that valley fills will record a vertical transition from coniferopsid-dominated to lycopsid-dominated flora (Figs. 2, 8). If climate is the principal control on plant communities, assemblages will be regionally uniform within a single valley fill along depositional dip.

METHODS

To test whether climate or elevation controls the distribution of Pennsylvanian plant communities, vertical and lateral trends of wood and bark in valley fills of the Breathitt Group in eastern Kentucky were examined over six weeks (Figs. 5, 9; Appendix A). Outcrops described by Le Cotonnec et al. (2020) in addition to new outcrops of the Breathitt Group were searched for fossil wood or bark so that occurrences could be readily tied to specific valley fills. A UAV (unmanned aerial vehicle, or “drone”) was used to take aerial photos of the outcrops to capture the scope of these large valley fills. Fossil logs were identified from wood or bark impressions, compression fossils, and coalified wood. Close-focus binoculars were used to identify wood that was difficult to reach.

Vertical trends in wood composition were captured by counting specimens of fossil wood or bark within each stacked channel deposit of a valley fill (Fig. 10). At some outcrops, it was easy to access a valley fill from its basal channel to its uppermost channel, but at other outcrops, it was difficult to safely access the upper part of the valley fill. In these cases, the UAV was used to see the extent of the valley in upper areas of the outcrop and binoculars were used to search for fossils that were too high to reach.

Lateral trends in plant composition were captured by visiting the same valley fill at down-dip, mid-dip, and up-dip sections of the study area where possible, that is, valley fills from western, central, and eastern areas within the outcrop belt were identified and correlated by using named coal beds (Rice and Hiett 1994; Jerrett et al. 2016) and published stratigraphic columns (e.g., Le Cotonnec et al. 2020). Plant fossils were identified from monographs, including Gillespie et al. (1966), Taylor et al. (2009), and personal photographs of specimens from the paleobotany collections in the Smithsonian National Museum of Natural History.

RESULTS

Valley fills and Facies

Three main fluvial facies are present within the studied valley fills: amalgamated fluvial channels, heterolithic fluvial channels, and tidally influenced channels (Table 2). All facies are multistory and single-story channels that contain compression fossils and sandstone casts of fossil plants. The amalgamated fluvial channels are characterized by medium-grained sandstone, a well-developed woody lag, and large-scale trough cross-stratification. This facies represents the most inland fluvial channels on the coastal plain. Heterolithic fluvial channels are composed of a basal woody lag, medium-grained sandstone that passes upwards into interbedded mudstone and sandstone, with small-scale current ripple lamination. This facies is interpreted as channels that are positioned intermediately between the most inland channels and channels closest to the shore along the coastal plain. Tidally influenced channels are coarse-grained sandstone with small-scale current ripple lamination and clay partings in the upper parts of the channels; they commonly contain woody lags at the base of the channel. This facies represents channels that are closest to the coast. The facies composition of individual valley fills varies, but in general, valley fills are easily identified by their sharp erosional base, multistory fluvial channels, and their greater thickness (> 20 m), than single-story channels (2–4 m).

Taphonomy

The preservation of wood or bark types varies among the channel deposits. A total of 2,681 specimens were observed among 11 valley fills. The number of specimens per valley fill at each locality varies from 6 to 227, with a median of 89. Lycopsids (indeterminate to genus) are generally preserved as compressed coal (Fig. 11), or as coal that encases a sandstone cast (Fig. 11), with varying morphologies (Fig. 11). *Sigillaria* sp. are sandstone casts of ribbed stems or leaf scars oriented in rows (Figs. 12, 13). *Calamites* sp. are sandstone or mudstone casts of stems with elongated ribs between nodes (Figs. 12, 13). *Diaphorodendron* sp. occur as sandstone casts of a stem with branch scars (Fig. 12). *Lepidophloios* sp. occur as sandstone impressions with wide leaf cushions (Fig. 12). *Stigmaria ficoides* are preserved as sandstone casts of the roots, where circular scars where rootlets attached are infilled with sandstone (DiMichele et al. 2022; fig. 12). Although *Stigmaria ficoides* are present in some fluvial channels, they are more commonly preserved in floodplain facies. *Artisia irregularis* are preserved as narrow sandstone casts with grooves that are impressions of diaphragms (Fig. 13). *Lepidodendron* sp. are sandstone casts of diamond-textured bark created by leaf cushions (Fig. 13). Other unidentifiable plants occur as sandstone casts, impressions, or coalified fragments. These unidentifiable plants were counted because their morphologies suggested that they may be wood or bark, particularly for log-shaped sandstone casts, but they were unidentifiable because they did not have bark impressions that were distinctive of a particular taxon.

Fossils of plant foliage are rarely encountered in fluvial channels of the Breathitt Group. They are relatively common in associated floodplain facies, and photographs are included as a record of the taxonomy of the area (Figs. 14, 15). Some notable foliage includes the leaves of calamitaleans and various seed ferns.

General occurrence patterns

Lycopsids indet. are the dominant plant type within and among valley fills, and the remaining plant types are far less common. This overall uniformity and community dominance by lycopsids can be visualized in figures 17 and 19, where plant community abundance is summarized for individual valley fills and regional valley settings. Lycopsids indet. are the dominant bark type in all valley fills (Fig. 16, Table 3). Unknown (unidentifiable) plants, *Calamites* sp., and *Artisia irregularis* are common but rarer, and they are not present in all valley fills. All other plant types represent a small percentage of the plants per valley (< 5 %). These include *Sigillaria* sp., *Stigmaria ficoides, Diaphorodendron* sp., *Lepidodendron* sp., and *Lepidophloios* sp. Each is present in only a few of the eleven valley fills.

Lycopsids are wetland taxa, and they are widespread and abundant throughout all valley fills (Fig. 16). There are a few consistent trends among the other wetland and dryland taxa through valley fills. For example, rare wetland taxa, such as *Sigillaria* sp. and *Stigmaria ficoides*, are present only in the basal channels of valley fills. However, more common wetland taxa, such as *Calamites* sp., show no trend stratigraphically within the valley fills. They are most common in basal or middle channels, but they also occur in upper channels. Uncommon dryland taxa, possibly *Artisia irregularis* (although some cordaitaleans were wetland taxa), tend to occur in basal channels except in the Frozen and Corbin valleys.

There are no consistent patterns among facies within each valley. Lycopsid indet., the most abundant wetland taxon, occurs in each of the channel facies through each valley (Fig. 16). Other common wetland taxa, such as *Calamites* sp., are more common in inland channel facies, but also occur in heterolithic and tidally influenced channel facies. Inversely, *Artisia irregularis*, a rare and possible dryland species, is most common in tidally influenced channel facies, but it also occurs in inland channel facies. Rare wetland taxa are all common in tidally influenced facies, but *Sigillaria* sp. and *Stigmaria ficoides* also occur in inland channel facies.

When plant abundances are aggregated among down-dip, mid-dip, and up-dip settings, there are few consistent trends in the lateral distribution of plants (Fig. 18). Lycopsid indet., a wetland taxon, dominates in down-dip, mid-dip, and up-dip settings. No other plant type shows this consistency across all the settings. *Diaphorodendron* sp., *Lepidodendron* sp., and *Lepidophloios* sp., rare wetland taxa, are present only in down-dip settings, but they are represented by just a few specimens (Appendix B). *Stigmaria ficoides* and *Sigillaria* sp., other rare wetland taxa, are most common in mid-dip settings, but they are rare in down and up-dip settings. *Calamites* sp., a common wetland taxon, and *Artisia irregularis*, an uncommon possible dryland species, show the opposite pattern.

DISCUSSION

The overall uniformity in the composition of the plant communities shows a lack of variation in fluvial channel plant associations through individual valley fills and among them regionally. Valley fills are consistently and pervasively lycopsid-dominated, indicating wetland plant communities consistently occupied these settings. Vertically, there is little variation in the plant types upwards through valley fills, at all stages of all valley fills throughout the region, suggesting that communities were uniform through time within individual valleys. Laterally, plant types vary little among valley fills in down-dip, mid-dip, and up-dip settings, indicating regional uniformity in plant communities. The lack of variation among successive valleys shows that lycopsid persistence was a long-lived characteristic of lowland ecosystems or that valley fills selectively preserve the intervals of time in which lycopsids dominated the lowlands.

The overwhelming presence of wetland taxa throughout and among valley fills is inconsistent with the vertical and lateral predictions of the elevation model. It is predicted that elevation-controlled communities would pass from drier assemblages at the base of a valley fill to wetter assemblages upwards through the valley fill (Cridland and Morris 1963; figs. 1, 8). While possible dryland taxa are most common in the basal and middle channels, wetland taxa still dominate such basal channels within the valley fills (Fig. 16). However, the abundance of such taxa is much smaller than the dominant wetland taxa found throughout the channels. This supports community uniformity throughout valley fills, which is inconsistent with the vertical predictions of the elevation model. It is also predicted that elevation-controlled communities would transition from wetter assemblages depositionally down-dip to drier assemblages depositionally up-dip (Fig. 8). Possible dryland taxa are present in each of the valley settings, but they are counterintuitively most common in down-dip areas. This is inconsistent with the lateral predictions of the elevation model.

The lack of systematic trends in and among valley fills is inconsistent with the vertical predictions for the climate model, but it supports the lateral predictions of the climate model. It is predicted that climate-controlled communities would pass from drier assemblages at the base of a valley fill to wetter assemblages upwards through the valley fill (Bashforth et al. 2021; figs. 2, 8). Wetland taxa dominate the stacked fluvial channels through each valley fill (Fig. 16), indicating community uniformity through time in individual valley fills, which is inconsistent with the vertical predictions of the climate model. It is also predicted that climate-controlled communities would be regionally uniform, and this is consistent with what is observed in the Breathitt Group, where wetland taxa dominate each of the valley settings. This supports that there was regional uniformity among valley fills, and it is consistent with the lateral predictions of the climate model.

Gradients

The lack of variation through and among valley fills suggests that an elevation-controlled gradient may not have been present or detectable in Pennsylvanian lowland wetlands, and several lines of evidence support this.

Gradients exist in modern temperate, coastal areas. Such gradients are apparent at a range of elevations and distance from a river channel, including the interfluves and adjacent floodplains. For example, in southeastern U.S. coastal wetlands, vegetation varies greatly from environments closest to the shore through upland areas (Wyant et al. 1991; Reinhardt et al. 1998). Geographical range and moisture changes, concurrent with elevation changes, promote sharper differences in plant composition along a coastal plain. Lowlands are in comparison relatively homogeneous in their community composition, consisting of sweetgum, swamp blackgum, red maple, water tupelo, and bald cypress (Wyant et al. 1991; Reinhardt et al. 1998).

Gradients also exist in modern tropical areas. For example, in the tropical Amazon rainforests, strong floral gradients exist with distance from the channel, laterally onto floodplains, and regionally from lowlands to the uplands (Drucker et al. 2008). Such strong gradients are apparent with up to 100 meters in distance from streams and with up to 70 meters of elevation change. However, plant communities directly along the stream margins are consistently compositionally similar. A similar example of this is in tropical Andean forests, where strong gradients exist corresponding to temperature and elevation from the lowlands through the highlands (Idaragga et al. 2016). Lowland communities along strike, however, are similar even across geographic range.

In the Breathitt Group, sampling is limited to channel deposits, so similarly, they may not show a gradient. Sampling purely from channel deposits means that distance from the channel, which is an important metric for capturing gradients, was not accounted for. Additionally, even if elevation changes along the river channel from inland to the shoreline, the communities along those channel margins may still be compositionally similar because the habitat is consistently moist. Some previous studies of plant fossils in valley fills concluded that the occurrence of mesic plant types in channel deposits reflected the marginal river channel environment that favored moisture-tolerant plants, rather than plants transported from nearby areas (Demko et al. 1998; Falcon-Lang et al. 2004). Additionally, this suggests that elevation could still be a principal control on community distribution, but that sampling only from river channels may not reveal whether the elevation model is correct or not.

The lack of a gradient could also be caused by a failure to preserve dryland plants. Some have suggested that dryland plants are poorly preserved because basins experiencing seasonal climate trends on a tropical landscape rarely hosted conditions ideal for plant preservation in drier environments (Falcon-Lang et al. 2009; DiMichele et al. 2010; Davies and Gibling 2013; Bashforth et al. 2021). Moreover, heightened water tables and temperatures during humid conditions promote more wetland flora as well as their preservation (Vormisto et al. 2004; DiMichele et al. 2010, 2020b; Bashforth et al. 2021). During moist climate intervals, lowlands in the Pennsylvanian tropics are widely thought to be waterlogged, thus tending to harbor plants that prefer high moisture settings, and such settings were ideal for preservation, whereas seasonally dry, moisture-reduced settings were not. Furthermore, it has been suggested that the seasonally dry periods may have lasted longer than the well-known peat-forming conditions created by everwet conditions, but that preservation potential was much lower during the drier times (Falcon-Lang et al. 2009; DiMichele et al. 2010; Bashforth et al. 2021). The presence of an overall wetland assemblage could therefore be due partially to a lack of preservation of drier flora. The presence of cordaitaleans thought to also represent drier environments, may be an exception to this pattern of dryland preservation (Falcon-Lang 2003a, b; Falcon-Lang et al. 2004; DiMichele et al. 2010; Bashforth et al. 2014). In general, however, drier taxa thought to have lived in lowland wetlands are poorly preserved.

Although possible dryland taxa are not common in the Breathitt, there may be some suggestion of a weak gradient. The presence of *Artisia irregularis,* a cordaitalean, may suggest a drier environment (Falcon-Lang 2003a, b; Falcon-Lang et al. 2004; DiMichele et al. 2010; Bashforth et al. 2014). Previous studies have shown that dryland communities are indicated by the preservation of cordaitalean leaves and fragments (Bashforth et al. 2014). While cordaitaleans are known to withstand moisture deficits, this is suggestive of some cordaitaleans inhabiting areas along river channel margins in addition to the drier adjacent floodplains (Bashforth et al. 2014). An additional support for the potential presence of a weak gradient is that *Sigillaria* sp., a rare wetland taxon, is the most drought-tolerant of the lycopsid group (DiMichele and Phillips 1994; Falcon-Lang et al. 2004; Pfefferkorn and Wang 2009; Bashforth et al. 2014; Chen et al. 2022). These support that there may have been a subtle gradient reflecting a range in the moisture tolerances of the taxa, even though the assemblages overall reflect a wetland setting.

Lycopsids or Peat mats?

After the summer field study, it was suggested that many of the fossils recorded as lycopsid indet. may be fragments of peat mats, and that this may substantially affect results. Most of the fossils found are compressed coal. Coal found in channel lags is likely evidence of lycopsid remains due to many of the coal morphologies, but some coal fragments may actually be rip-ups of peat mats (Fig. 20, Appendix C). To resolve this issue, a secondary experiment was subsequently conducted to determine the proportion of lycopsid specimens that are possibly fragments of peat mats versus actual lycopsid remains.

Some fossil morphologies, such as interior casts, are clearly lycopsid tree remains. Such morphologies include elliptical coal stringers that taper at either end and surround a sandstone cast (Fig. 11, Appendix C), elliptical coal stringers that partially surround an apparent sandstone cast (Fig. 11, Appendix C), spur-shaped coal stringers that partially surround two adjacent sandstone casts (Fig. 11, Appendix C), and elliptical coal stringers with no cast but that are convex in shape (Fig. 11, Appendix C). All these morphologies are strong evidence of lycopsids. Other coalified remains lacking these features were recorded as possible peat mats. These include coal fragments that are mostly flat and elongated with no obvious tapering or convex shape (Fig. 20, Appendix C).

In fall of 2022, I returned to the Oven Fork exposure and recounted plants, this time distinguishing likely lycopsids versus possible peat mat rip-ups (Appendix C). I found 364 total specimens that would have previously been counted as lycopsid indet. Of those, 16.2% are confirmed lycopsids and 80.8% are possibly peat mat rip-ups. Using these percentages, the lycopsid indet. category of figures 15–18 was split into two categories. Figures 21 and 22 reflect how the peat mat question may bear on the results of this study.

The recalculated trends show that the total abundance of lycopsid indet. has no effect on the relative proportions of other taxa (Fig. 21). Recalculated vertical trends show that lycopsid indet. may have been less abundant in older valleys, reflecting only a change in the relative dominance of lycopsid indet. However, this does not change the patterns within a valley (Fig. 21). There is also no systematic trend among valleys regionally, i.e., lycopsids indet. do not become increasingly or decreasingly abundant among down-dip, mid-dip, or up-dip areas (Fig. 22).

Even if many of the lycopsids identified in the original data set are actually peat rip-ups, it does not impact the conclusions with respect to climate and elevation. While the issue of peat rip-ups may add a layer of uncertainty to the conclusions about the abundance of lycopsids, the observed plant types imply that the representative community assemblages remain relatively homogenous through time and regionally. The reanalysis still suggests that the elevation model is not supported by the observed trends and that the climate model is partially supported, due to the overall dominance of wetland taxa in Breathitt Group channels.

Previous studies

Most studies of Pennsylvanian flora have focused on compression fossils or pollen in swamps and floodplains (e.g., Phillips and Peppers 1984; DiMichele and Phillips 1985, 1994; Demko et al. 1998; Falcon-Lang et al. 2004; Bashforth et al. 2016; DiMichele et al. 2010, 2020b). Comparatively little study has been made with the floras of channel environments (Demko et al. 1998; Falcon-Lang et al. 2009). This study focuses on the fossil flora preserved in fluvial channel deposits to better understand ancient plant communities in the stratigraphic context of nonmarine systems. While taphonomic the resolution, and subsequently taxonomic resolution is poor in these channel deposits, study of flora from such environments is important for understanding coastal communities.

Compression floras of swamp and floodplain deposits are relatively diverse (e.g., Jennings 1986; DiMichele et al. 2020b). Studies of early Pennsylvanian flora throughout the coal basins of Illinois and eastern Kentucky have shown this (e.g., Jennings 1986). For example, such deposits throughout the lower Breathitt Group have diverse wetland assemblages (Spurgeon and Jennings 1985; Jennings 1986). The flora observed in channels in this study, however, differ in that lycopsids are dominant, but few are identifiable to genus, which is in contrast to the finer taxonomic resolution of compression floras in floodplains and swamps.

The low diversity of wetland assemblages in fluvial channel deposits also raises the question of what happens in channel environments in the Middle to Late Pennsylvanian floral transition (Moscovian-Kasimovian) and continuing into the floral transition from the Pennsylvanian to the Permian (Phillips and Peppers 1984; DiMichele et al. 2020a; Bashforth et al. 2021). The transition of flora from the Mid-Pennsylvanian into the Late Pennsylvanian is characterized by extinction of certain lycopsid species and a rise in tree ferns in wetland environments (Phillips and Peppers 1984; DiMichele et al. 2020a; Bashforth et al. 2021). The Pennsylvanian to Permian transition is also interpreted as an overall shift in floral composition to drier assemblages (DiMichele et al. 2000). These two cases are documented mostly from compression floras of swamp and floodplain deposits, and it is less clear what happened in channel settings. For example, across these transitions, do lycopsids remain dominant, or do channel margins show a shift to drier flora? Further study across these boundaries has the potential to provide clarity on riparian communities during ecological and climatic shifts.

CONCLUSIONS

The composition of fossil wood and bark from valley fills of the Breathitt Group varies little among and within valley fills. These valley fills are dominated by lycopsids, consistent with a wetland assemblage. Poor preservation of plants in fluvial sand channels and the common coalification of lycopsids complicate the taphonomic conclusions that can be made about these fossil assemblages. In particular, distinguishing peat rip-ups from lycopsid remains makes it difficult to assess the abundance of specific wetland taxa in fluvial channels of the Breathitt Group.

Little community change within and among valley fills may suggest that if there was an elevation gradient present, it was subtle. It may also suggest that the channels selectively sampled the wettest portion of a glacial-interglacial cycle. There is little taxonomic variation among inland, tidally influenced, and heterolithic channel facies, suggesting that the taxonomic composition of Pennsylvanian tree communities varied little with distance from the coast. The dominance of wetland taxa vertically through valley fills suggests that elevation was not a principal control on the distribution of Pennsylvanian tree communities in riparian habitats.

Little variation in the overall taxonomic composition within and among valley fills implies that regional climate was relatively uniform through the study interval and across the study region. This regional uniformity is consistent with climate being a principal control on Pennsylvanian tree community distribution in riparian habitats.

CHAPTER 3

CHALLENGES AND FUTURE WORK

This section will focus on challenges that arose during the field work for this research, which was the poor taphonomic resolution and discerning possible peat mat rip-ups from compressed and coalified lycopsid remains. Another challenge that may have impacted the results of this study is the sampling coverage lithologically and stratigraphically. I present recommendations for future work regarding each of these challenges.

While most of the plant fossils counted were lycopsids, the poor taphonomic resolution meant that almost none of them could be identified to genus level. This further presents the need for taphonomic study of woody floras in the Breathitt Group. The plant fossils in this study were identified from cross sections of compressed and coalified lycopsids, sandstone casts, and impressions of bark. If these fossils can be identified to genus or species using the morphology of such in-situ cross sections, and with thin sections to look for diagnostic cell structure, then there could be a study to test for potential gradients among the wetland flora through the Breathitt Group. The taphonomy of Pennsylvanian plants in sand channels has not been widely explored, and because the Breathitt Group preserves a variety of plant types in channels and floodplain deposits collectively, a taphonomic study could help to expand our understanding of paleobiology in such settings.

The first problem that arose from field study is lack of a means to distinguish fragments of lycopsid bark from peat rip-ups. Further study is needed to determine the morphologies and taphonomy that separate the two so that more accurate data can be collected on the types of fossil plants preserved in sandstone channels through valley fills. One recommendation for doing this would be to make thin sections of suspected peat mat rip-ups and potential lycopsid remains to determine if they can be more easily distinguished microscopically. Future research that includes the work to make this distinction is important because it may provide a better understanding of the vegetation being preserved in fluvial systems during the Pennsylvanian.

The second challenge that presents the need for future work is expanding sampling coverage to include associated floodplain facies in addition to fluvial facies. Collecting fossil plant data from the floodplain facies would provide an important test as to whether the composition found in the floodplain facies matches that of the fluvial channels facies. Future studies could include fossil foliage from the floodplain facies in addition to that of channels. This study focused on the wood and bark fossils preserved in fluvial channels, but foliage was found preserved in associated floodplain deposits. Foliage in fluvial channels is rarely identifiable to taxon, but they are likely to be better preserved in floodplain facies. Additionally, few studies have focused on the foliage from the Appalachian region (Gastaldo and Boersma 1983; Jennings 1986; DiMichele et al. 2011; White 1904). Documenting this foliage may provide a better picture of the communities living in riparian areas if new species can be identified from fossils found in the associated floodplains and if they compare to those found in the fluvial channels.

Last, sampling should include a greater number of valleys across a greater stratigraphic range, therefore sampling from stratigraphically higher and lower sections of the Breathitt Group. This may reveal a resolution to the lack of trends within and among valley fills. Also, sampling through stratigraphically higher areas would provide more data through the Late Pennsylvanian and Permian, thus providing the potential to capture changes through a longer time interval. Greater sampling coverage may reveal gradients that were too subtle to be captured within the study interval of this research.

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Table 1 — Climate regimes and their associated plant types, corresponding to moisture (modified from Bashforth et al. 2014).

Climate	Moisture	Plant types	Preferred habitats
Dry subhumid with maximum seasonality	Xeric-to-mesic-to-hydric	Pteridosperms, sphenopsids, cordaitaleans (gymnosperms)	Drylands and clastic wetlands
Moist subhumid with medial seasonality	Mesic-to-hydric	Pteridosperms, sphenopsids, cordaitaleans, lycopsids, ferns	Clastic wetlands and rheotrophic swamp
Humid with minimum seasonality	Hydric	Pteridosperms, sphenopsids, cordaitaleans, lycopsids, ferns	Rheotrophic swamps
Perhumid with no seasonality	Hydric	Lycopsids and ferns	Clastic wetlands and ombrotrophic swamps

Table 2 — Table of facies observed in this study of valley fills of the Breathitt Group. Modified from Le Cotonnec et al. 2020.

Facies	Lithology	Sedimentary structures	Architecture	Fossils
Inland channel	Generally medium-grained sandstone. Some channels are cleaner than others; quartz-rich, micaceous, and very coarse. Rare siderite horizons and heavy wood lag.	Large-scale trough cross-stratification and lateral accretion surfaces.	Channels tend to be multistory in valley fills, with rare single-story channels.	Lycopsids are common in channel lags, usually as compressed coal. *Calamites* sp., *Sigillaria* sp., *Artisia irregularis*, *Diaphorodendron* sp., and plant detritus are also present.
Heterolithic channel	Medium-grained sandstone that fines upward into mudstone with interbedded sandstone lenses.	Small-scale ripples are abundant in the body of the sand channels and in the sandstone lobes.	Multistory and single-story channels.	Lycopsids are common in channel lags, usually as compressed coal. *Calamites* sp. and plant detritus are also present.
Tidally influenced channel	Medium-grained sandstone that tends to be iron-rich. Rare siderite horizons and woody lag.	Large-scale trough cross-stratification, bedding commonly sigmoidal. Small=scale ripples are common towards the tops of channels, organic drapes, and rhythmites that may have clay partings.	Multistory and single-story channels.	Lycopsids are common in channel lags, usually as compressed coal, *Calamites* sp., *Sigillaria* sp., *Artisia irregularis*, *Stigmaria ficoides*, *Lepidodendron* sp., *Lepidophloios* sp., and plant detritus are also present.

Table 3 — Table of overall percent abundance of plant types in this study and their occurrence in valleys and depositional settings.

Taxon	Abundance within overall study	Valleys	Most common stratigraphic setting
Lycopsids indet.	96.6 %	Dave Branch, 4, Corbin, Frozen, Crummies, H, Elkins Fork, Puckett Creek, I, J, K	Mid-dip
Unknown plants	1.64 %	Dave Branch, 4, Corbin, Frozen, Crummies, H, Elkins Fork, Puckett Creek, I, J	Up-dip
Artisia irregularis	0.75 %	4, Corbin, Frozen, Elkins Fork, I	Down-dip
Calamites sp.	0.63 %	Corbin, Frozen, H, Elkins Fork	Up-dip
Sigillaria sp.	0.19 %	Corbin, Elkins Fork, Puckett Creek, I	Mid-dip
Stigmaria ficoides	0.07 %	Elkins Fork, Puckett Creek	Mid-dip
Diaphorodendron sp.	0.04 %	I	Down-dip
Lepidodendron sp.	0.04 %	Elkins Fork	Down-dip
Lepidophloios sp.	0.04 %	Elkins Fork	Down-dip

Fig. 1 — Elevation model in which the composition of Pennsylvanian plant communities is controlled primarily by elevation. A) *Walchia* sp., B) *Dichophyllum* sp., C) *Taenopteris* sp., D) *Cordaites* sp., E) Pteridosperms and ferns, F) *Lepidodendron* sp., G) *Calamites* sp., H) *Sigillaria* sp. (modified from Cridland and Morris (1963), as used by Bashforth et al. (2021)).

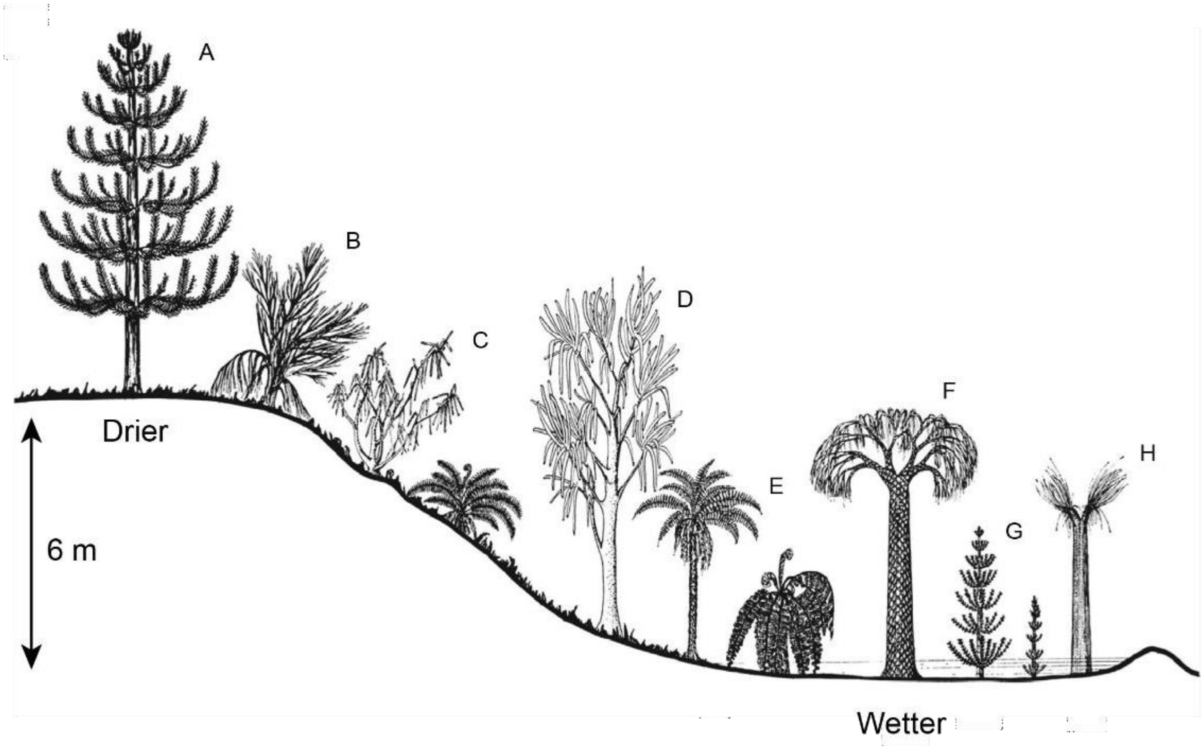
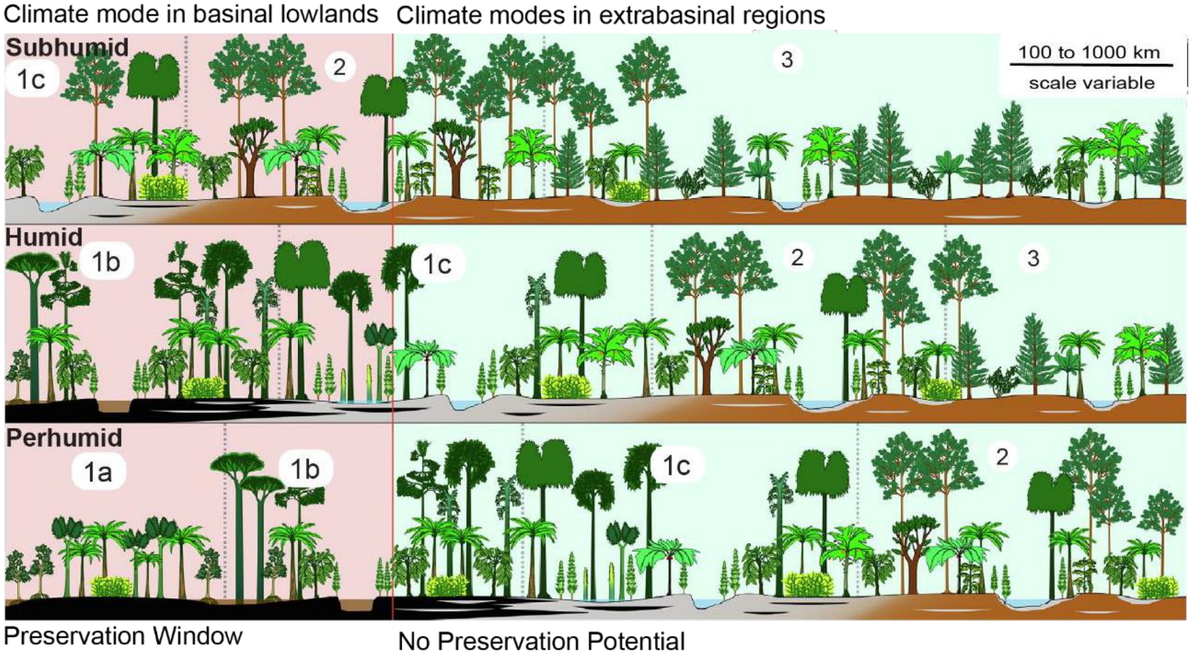

A
B
C
D
F
E
H
G
Drier
6 m
Wetter

Fig. 2 — Climate model, modified from Bashforth et al. (2021) in which the composition of Pennsylvanian plant communities is controlled primarily by climate. Key to plant taxa shown below; plant symbols adapted from Bashforth et al. (2021).



Lycopsids
Arborescent
1 - *Paralycopodites*
2 - *Diaphorodendron*
3 - *Lepidophloios*
4 - *Lepidodendron*
5 - *Sigillaria*
Sub-arborescent
6 - *Polysporia*
7 - *Omphalophloios*

Sphenopsids
8 - *Calamites*
9 - *Sphenophyllum*

Tree Ferns
10 - *Pecopteris s. l.*
11 - *Acitheca*

Pteridosperms
Medullosaleans
12 - *Neuropteris/Macroneuropteris*
13 - *Paripteris/Linopteris*
14 - *Alethopteris*
Peltasperms
15 - *Autunia/Rachiphyllum*
16 - *Supaia/Comia*
Gigantopterids
17 - *Delnortea/Gigantopteridium*

Coniferopsids
18 - Wetland cordaitaleans
19 - Dryland cordaitaleans
20 - Walchian conifers
21 - Voltzian conifers

Other Plants
22 - Progymnosperms
23 - *Lesleya/Megalopteris*
24 - *Taenopteris*
25 - Cycadophytes

Wetland Subbiomes

1a
Ombrotrophic peat swamps

1b
Rheotrophic peat swamps

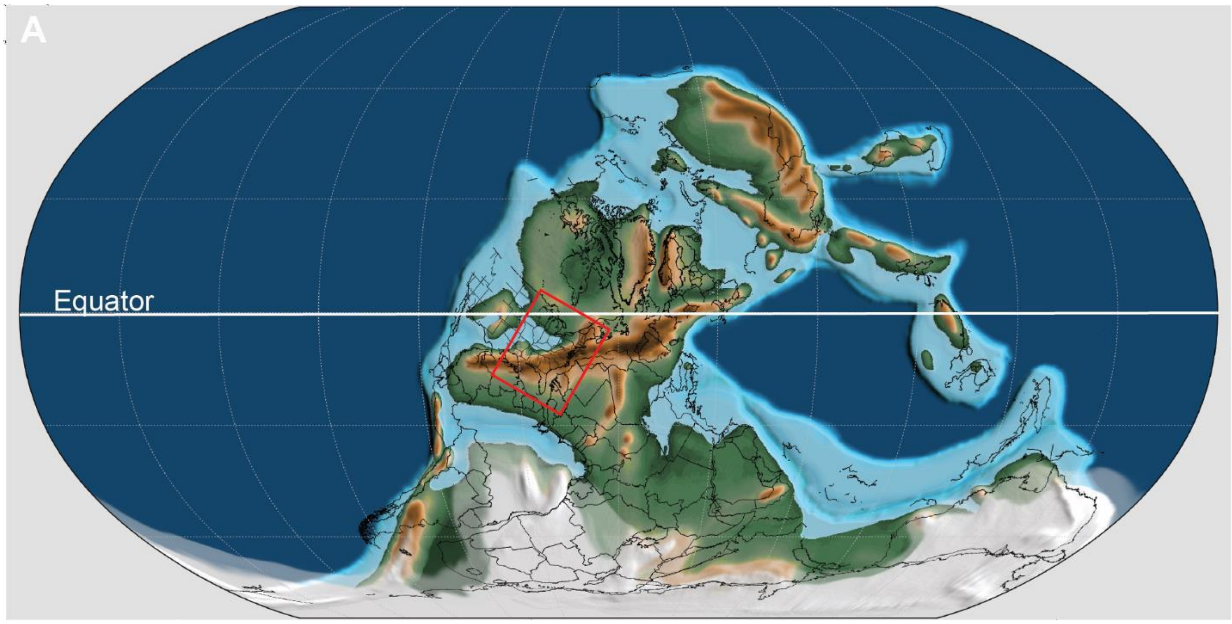
1c
Clastic swamps and associated wetlands

Dryland Biomes

2
Dryland cordaitalean-dominated forests

3
Walchian conifer-dominated forests

Fig. 3 — Maps showing the orientation of present-day eastern U.S. (red rectangle) near the equator during the Early Pennsylvanian (A) and the Middle Pennsylvanian (B) from Scotese (2021).


A
Equator

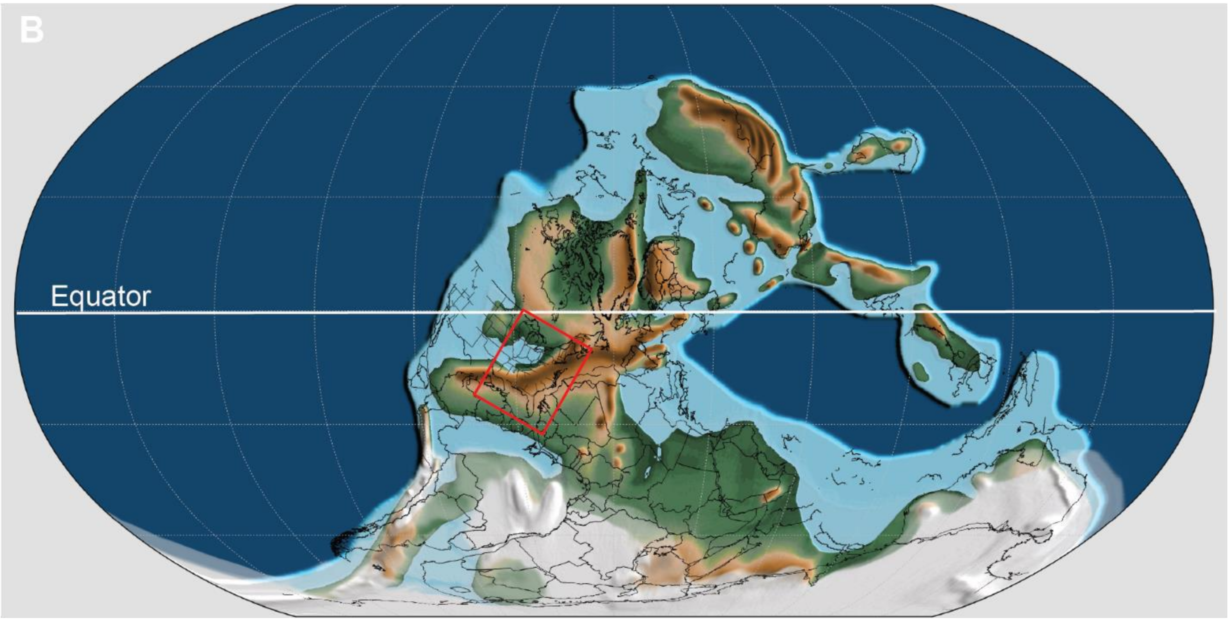

B
Equator

Fig. 4 — Maps showing the orientation of Laurentia during an interglacial period (A) and during a glacial maximum (B). Location of study area indicated by black rectangle. Maps from Ron Blakey, Northern Arizona University, as reprinted by DiMichele (2014).

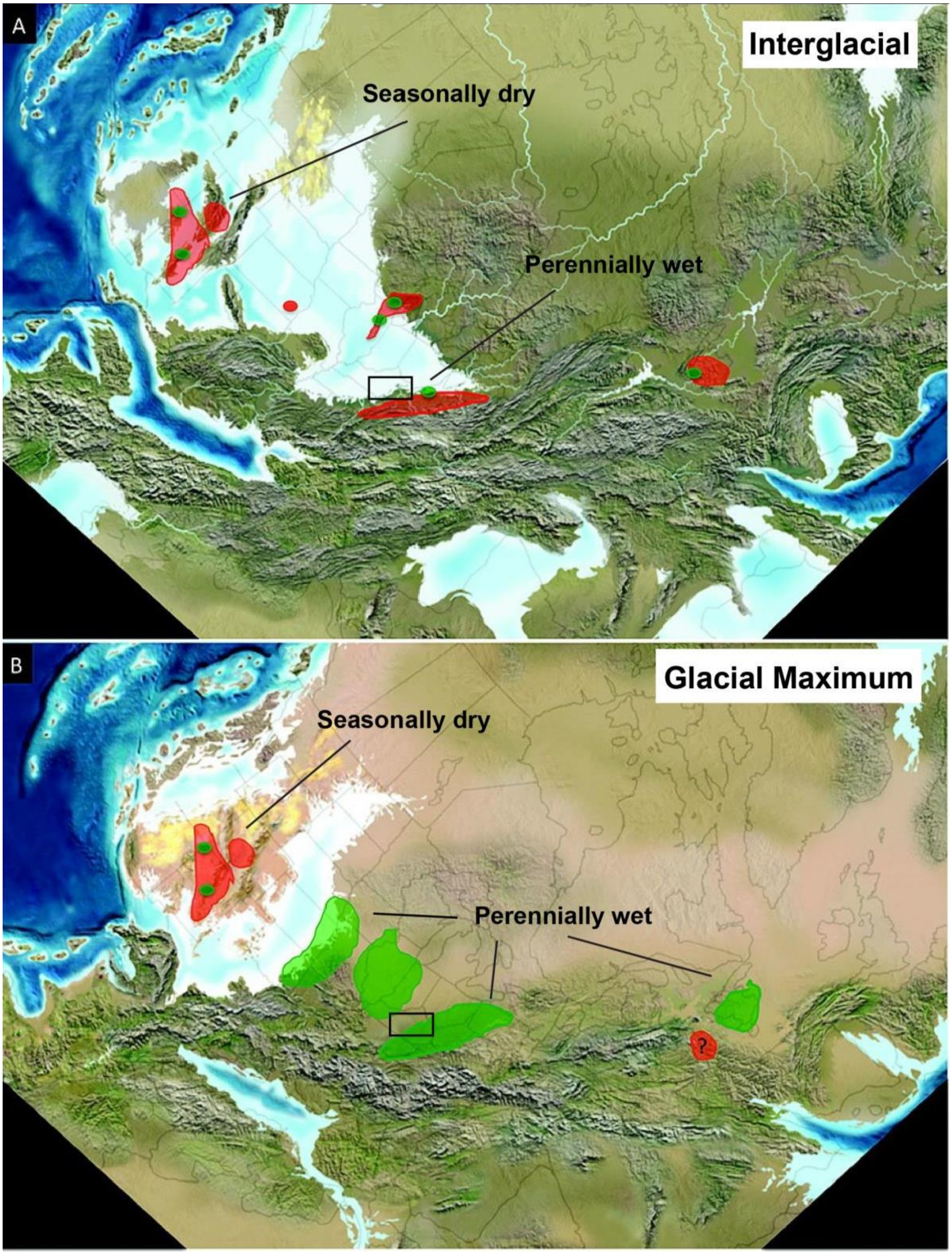

A
Interglacial
Seasonally dry
Perennially wet
B
Glacial Maximum
Seasonally dry
Perennially wet
?

Fig. 5 — Lithostratigraphy of the Breathitt Group showing sampling of incised valleys (modified from Le Cotonnec et al. 2020). Values shown at right are number of channels/number of fossils counted in each valley fill in this study.

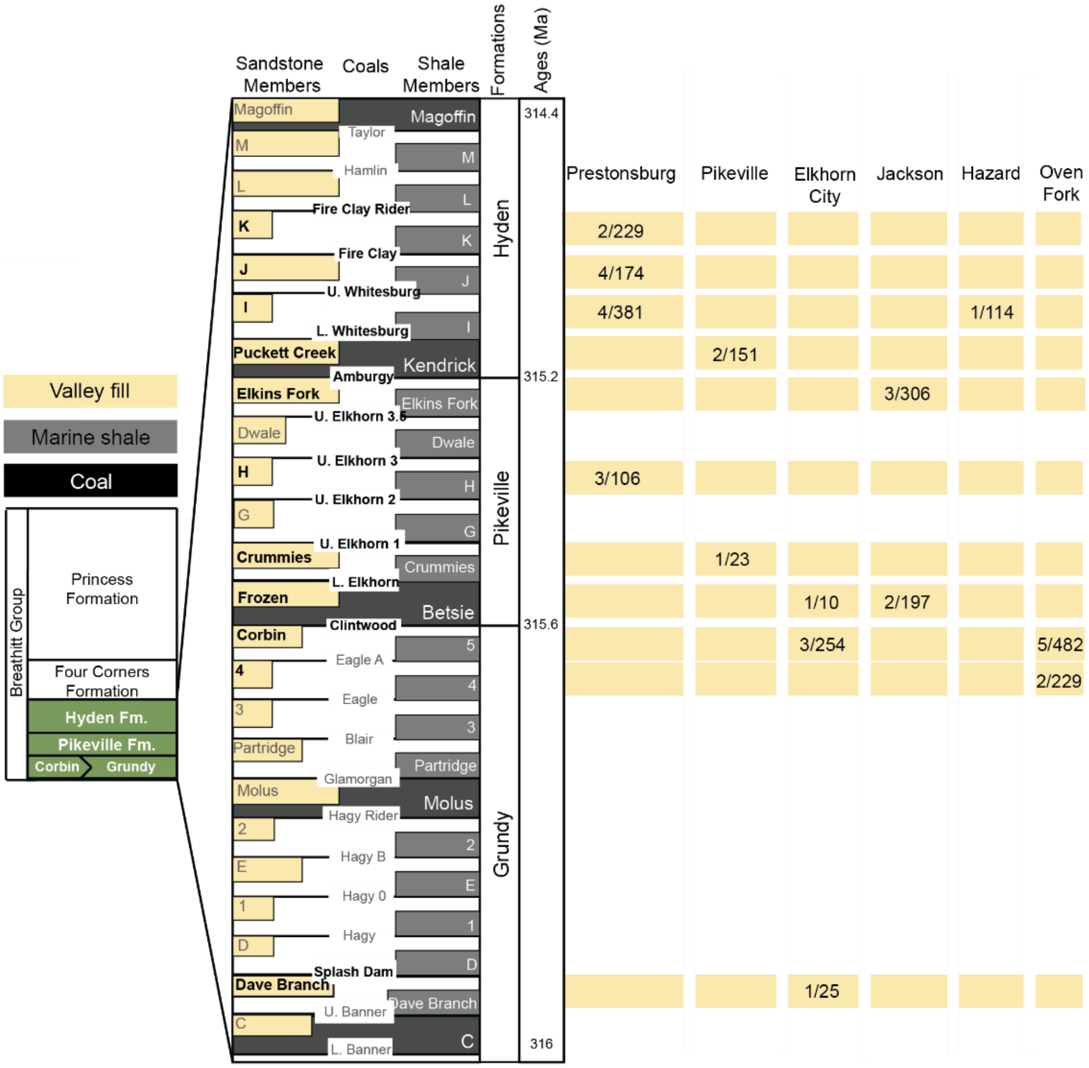

Valley fill
Marine shale
Coal
Breathitt Group
Princess Formation
Four Corners Formation
Hyden Fm.
Pikeville Fm.
Corbin
Grundy
Sandstone Members
Coals
Shale Members
Formations
Ages (Ma)
Magoffin
Taylor
Magoffin
M
Hamlin
M
L
Fire Clay Rider
L
K
Fire Clay
K
J
U. Whitesburg
J
I
L. Whitesburg
I
Puckett Creek
Amburgy
Kendrick
Elkins Fork
U. Elkhorn 3.5
Elkins Fork
Dwale
U. Elkhorn 3
Dwale
H
U. Elkhorn 2
H
G
U. Elkhorn 1
G
Crummies
L. Elkhorn
Crummies
Frozen
Clintwood
Betsie
Corbin
Eagle A
5
4
Eagle
4
3
Blair
3
Partridge
Glamorgan
Partridge
Molus
Hagy Rider
Molus
2
Hagy B
2
E
Hagy 0
E
1
Hagy
1
D
Splash Dam
D
Dave Branch
U. Banner
Dave Branch
C
L. Banner
C
Hyden
Pikeville
Grundy
314.4
315.2
315.6
316
Prestonsburg
Pikeville
Elkhorn City
Jackson
Hazard
Oven Fork
2/229
4/174
4/381
1/114
2/151
3/306
3/106
1/23
1/10
2/197
3/254
5/482
2/229
1/25

Fig. 6 — Stratigraphic architecture of fluvial deposits in a valley fill (modified from Catuneanu 2006 and based on Shanley and McCabe (1993)).

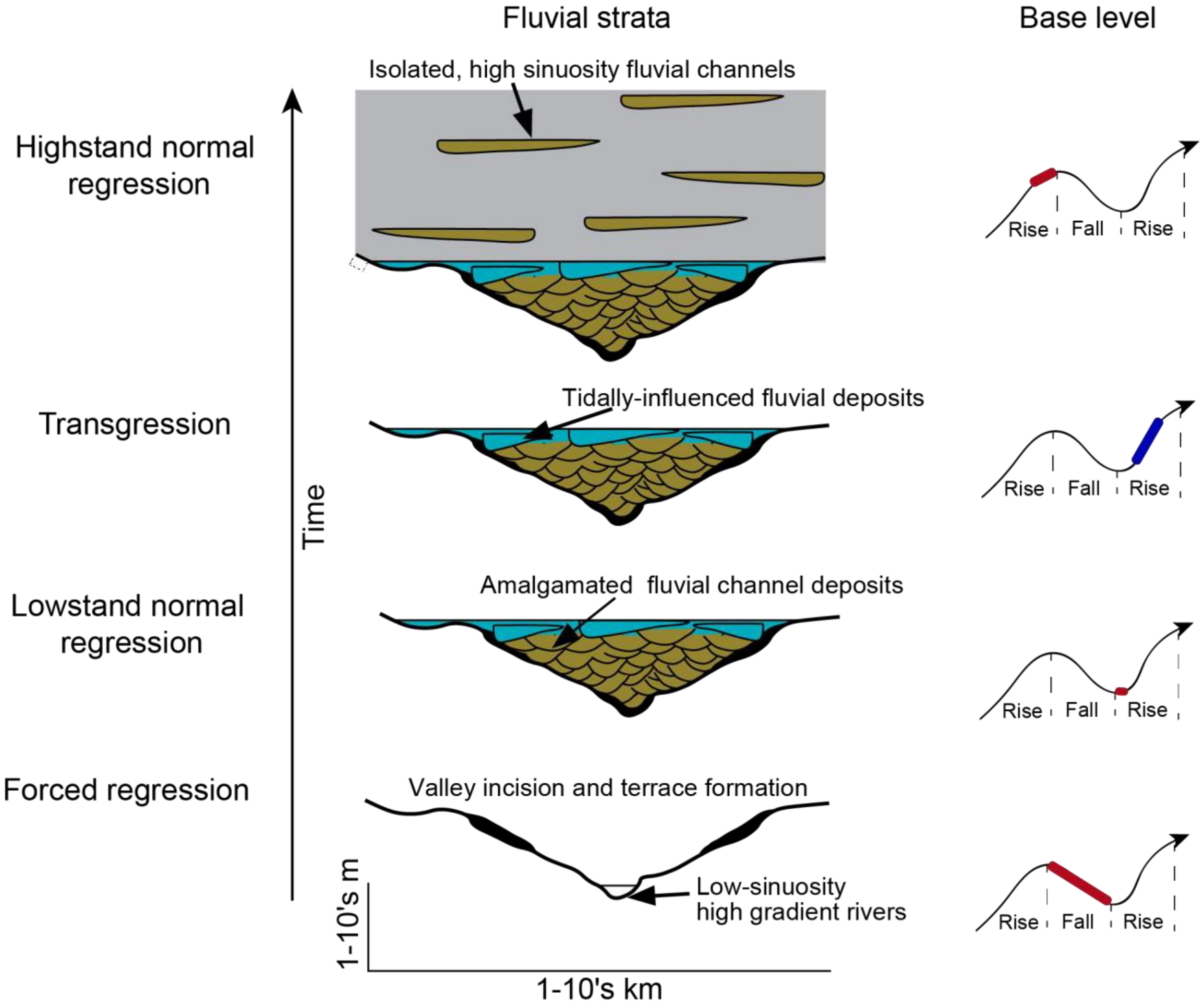

Fluvial strata
Base level
Isolated, high sinuosity fluvial channels
Highstand normal regression
Rise
Fall
Rise
Tidally-influenced fluvial deposits
Transgression
Time
Rise
Fall
Rise
Amalgamated fluvial channel deposits
Lowstand normal regression
Rise
Fall
Rise
Forced regression
Valley incision and terrace formation
Low-sinuosity high gradient rivers
1-10's m
1-10's km
Rise
Fall
Rise

Fig. 7 — Histories for eustatic sea level and accommodation rates with changes in climate and elevation that occur as a valley is incised and subsequently filled. The top curve shows the position of eustatic sea level during a glacial cycle with expected climate changes. The bottom curve shows corresponding rates of accommodation and sedimentation. Marine systems tracts (HST, FSST, LST, and TST) and nonmarine systems tracts (HAST and LAST) are shown. HST: Highstand Systems Tract, FSST: Falling Stage Systems Tract, LST: Lowstand Systems Tract, TST: Transgressive Systems Tract, HAST: High Accommodation Systems Tract, and LAST: Low Accommodation Systems Tract.

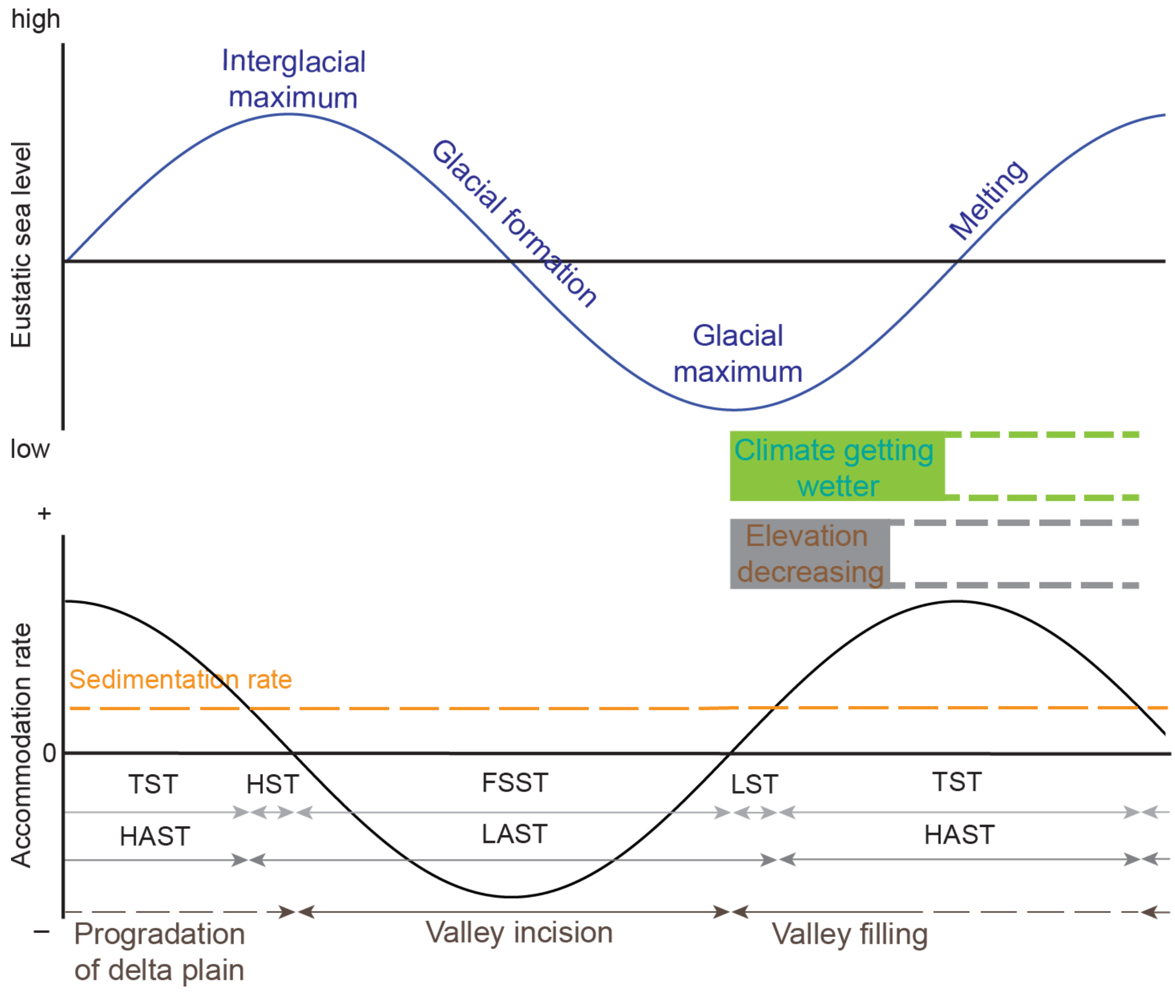

high
Interglacial maximum
Glacial formation
Melting
Glacial maximum
Eustatic sea level
low
Climate getting wetter
Elevation decreasing
+
Accommodation rate
Sedimentation rate
0
TST
HST
FSST
LST
TST
HAST
LAST
HAST
–
Progradation of delta plain
Valley incision
Valley filling

Fig. 8 — Predicted distribution of plant types through a valley fill for the climate and elevation models. Left column: typical upward change in the lithofacies filling a valley (based on Greb and Chesnut 1992; Aitken and Flint 1994, 1995; LeCottonec et al. 2020). Elevation changes are shown at left, with corresponding changes in plants, assuming a simple transgression with a corresponding upward decrease in elevation (Holland 2022). Climate changes are shown at right, with corresponding changes in plants (based on Cecil et al. 1985, 2003, 2014 and Cecil and Dulong 2003).

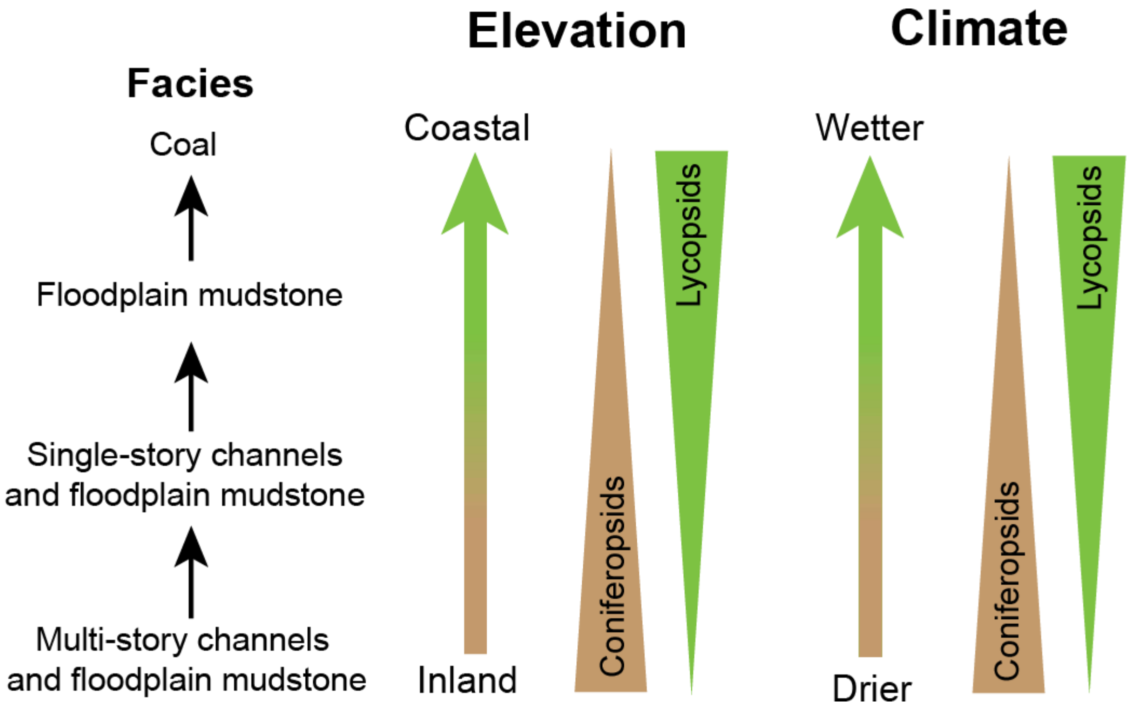

Facies
Coal
Floodplain mudstone
Single-story channels and floodplain mudstone
Multi-story channels and floodplain mudstone
Elevation
Coastal
Inland
Coniferopsids
Lycopsids
Climate
Wetter
Drier
Coniferopsids
Lycopsids

Fig. 9 — Map showing locations of studied outcrops of the Breathitt Group in eastern Kentucky (black points). Outcrops are grouped into named regions (see Fig. 5), which are then grouped into three regions along depositional dip. Base map is from Kentucky Geological Map Service (Kentucky Geological Survey, 2020).

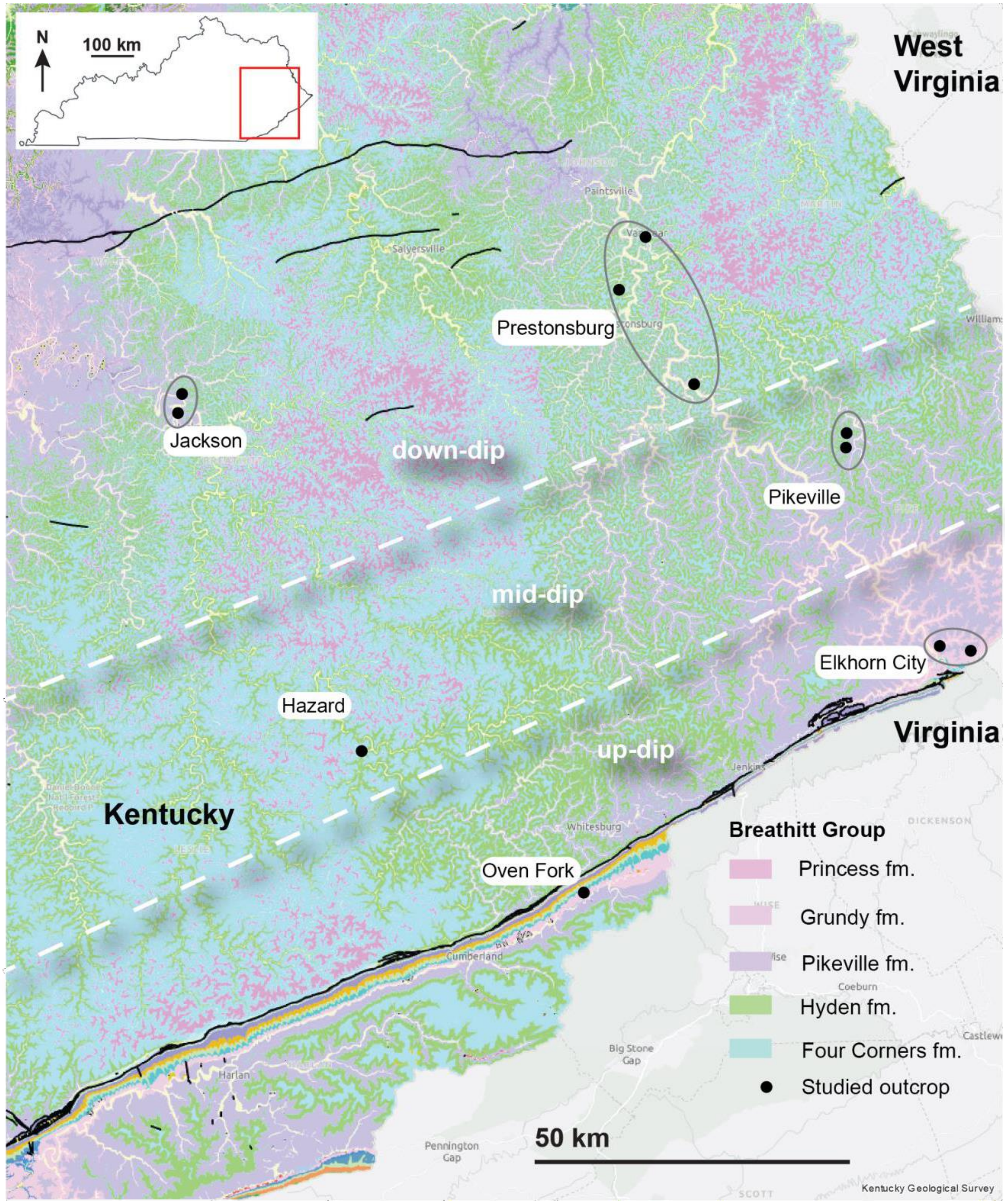

N
100 km
West Virginia
Paintsville
Salyersville
Prestonsburg
Jackson
down-dip
Pikeville
mid-dip
Elkhorn City
Hazard
Virginia
up-dip
Jenkins
Kentucky
Whitesburg
Oven Fork
Cumberland
Harlan
Big Stone Gap
Pennington Gap
Coeburn
DICKENSON
SCOTT
Breathitt Group
Princess fm.
Grundy fm.
Pikeville fm.
Hyden fm.
Four Corners fm.
Studied outcrop
50 km
Kentucky Geological Survey

Fig. 10 — A) Photograph of a typical roadcut exposure of the Breathitt Group, at Oven Fork (Appendix A) showing typical facies associations. Orange outlines one valley fill, which is composed of stacked fluvial channel deposits, shown in B.

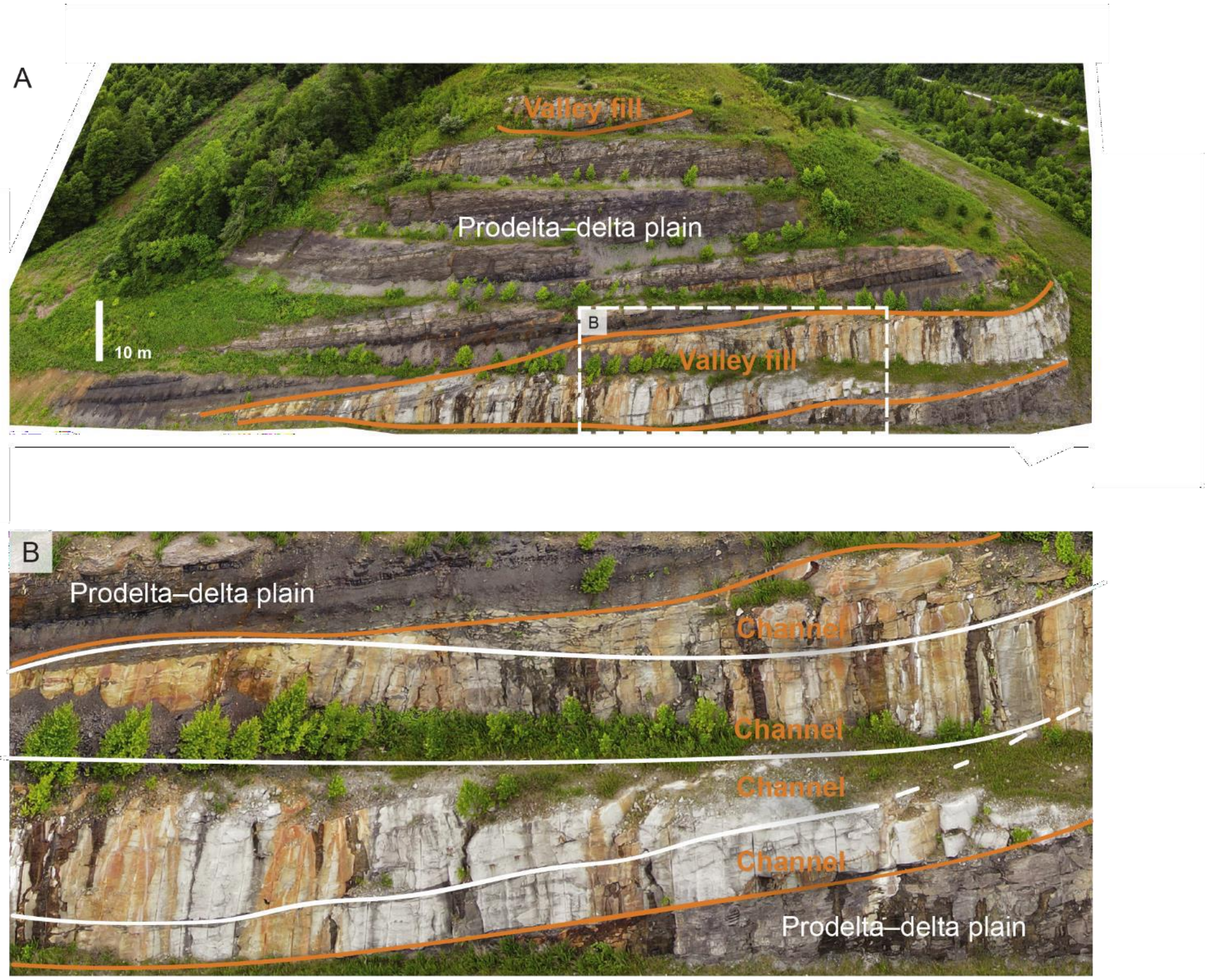

A
Valley fill
Prodelta–delta plain
B
10 m
Valley fill
B
Prodelta–delta plain
Channel
Channel
Channel
Channel
Prodelta–delta plain

Fig. 11 — Examples of lycopsids indet., based on ellipsoid-shaped coal morphology. Note coal that commonly surrounds a circular sandstone cast. A, B) Ellipse with cast, C, G) ellipse without a cast, D) double spur with partial cast, E) spur with partial cast, F) spur with cast. See Appendix C for the abundance of each of these categories. Because of a lack of bark impressions, these cannot be identified to genus. Identifications based on Gillespie et al. (1996), Taylor et al. (2009), and W.A. DiMichele personal communication (2022).

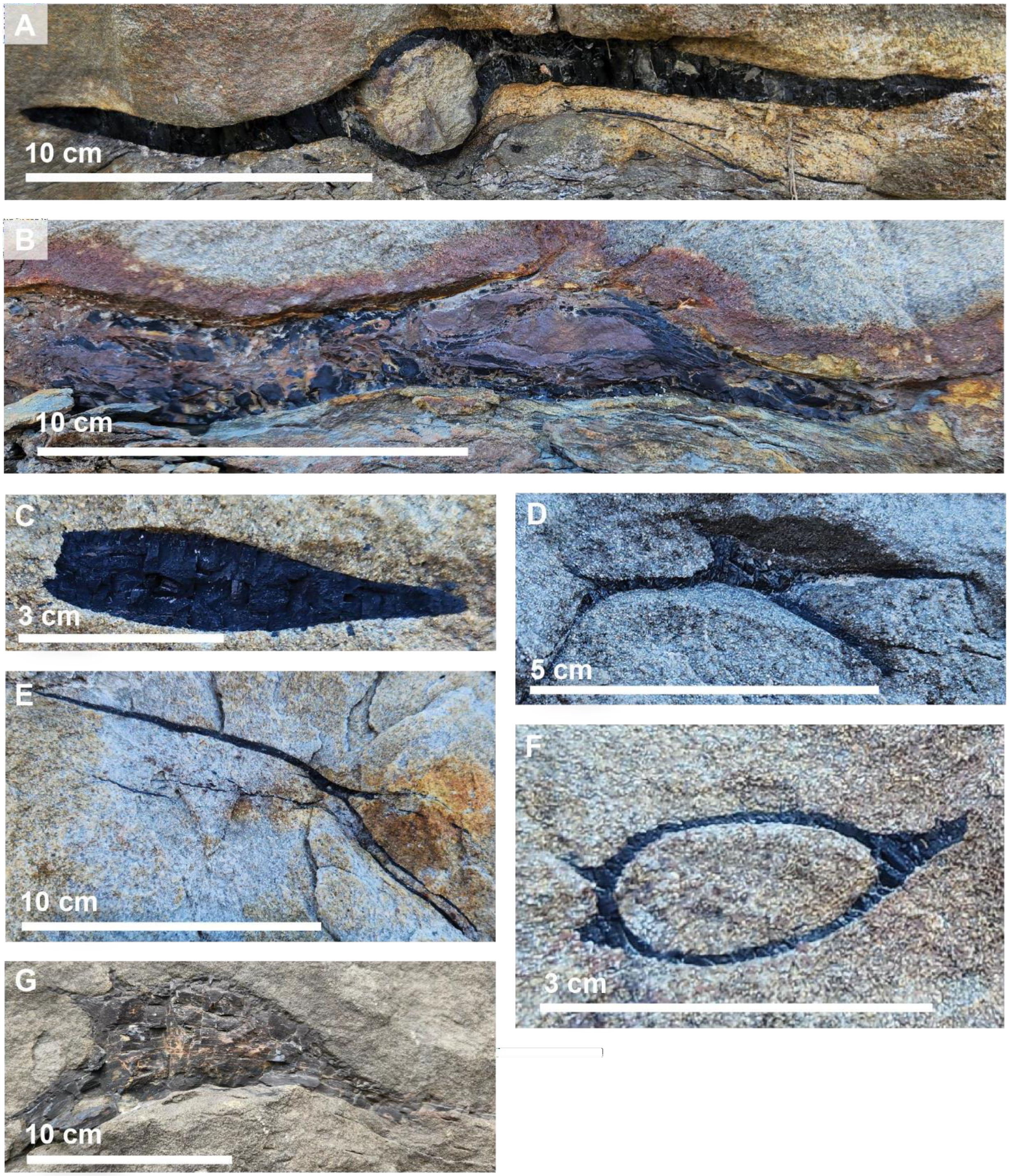

A
10 cm
B
10 cm
C
3 cm
D
5 cm
E
10 cm
F
3 cm
G
10 cm

Fig. 12 — Examples of bark and wood preserved in fluvial channel deposits. A) *Sigillaria* Brongniart, B) *Sigillaria* sp., C) *Calamites cisti* (this specimen is from a floodplain facies), D) unknown, E) *Diaphorodendron*, F) *Lepidophloios,* G) *Stigmaria ficoides,* H) *Calamites carinatus.* Identifications based on Gillespie et al. (1996), Taylor et al. (2009), and W.A. DiMichele personal communication (2022).

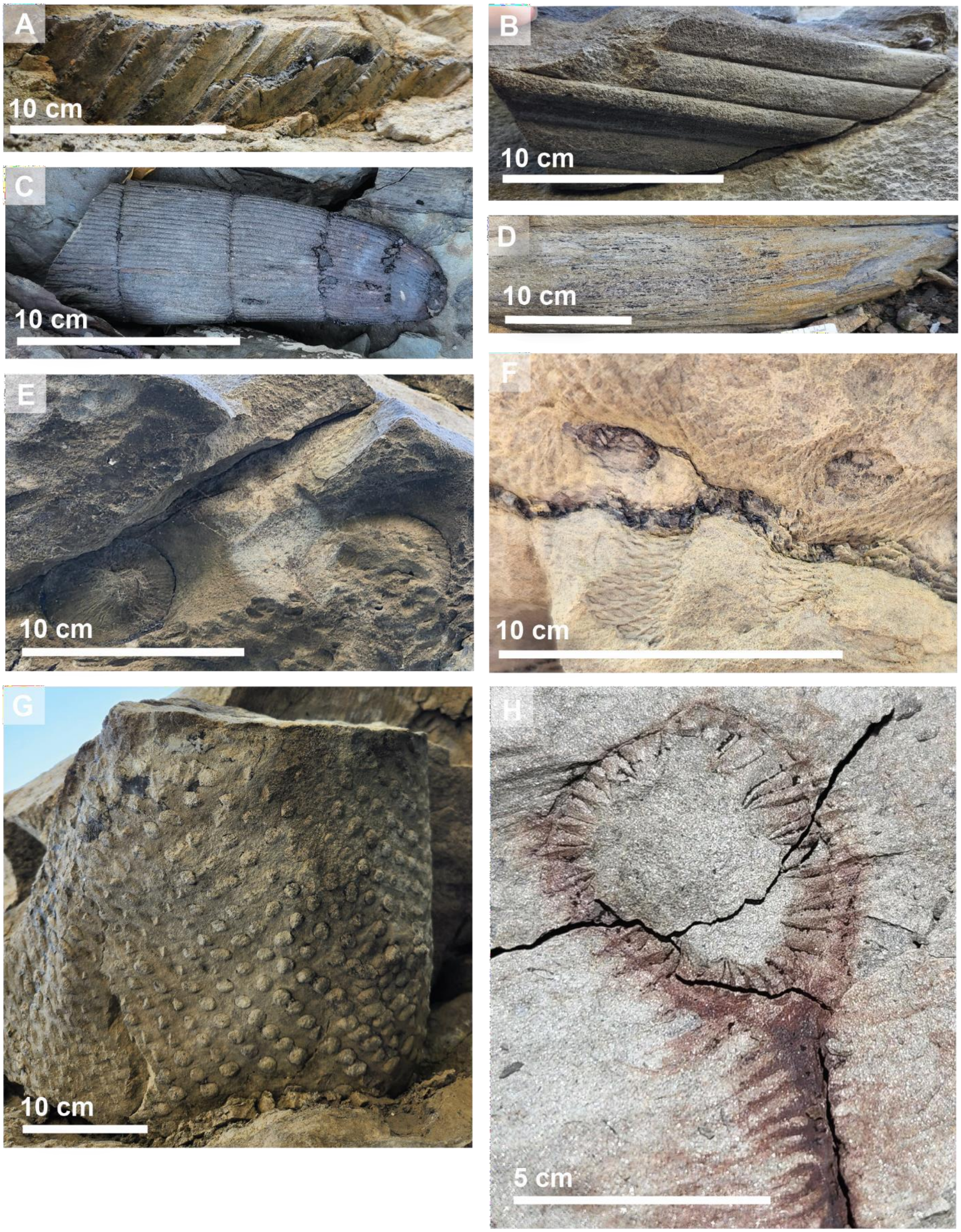

A
10 cm
B
10 cm
C
10 cm
D
10 cm
E
10 cm
F
10 cm
G
10 cm
H
5 cm

Fig. 13 — Examples of bark and wood preserved in fluvial channel deposits. I) *Artisia irregularis*, J) Lycopsid cast surrounded by coalified bark. Note flanges extending from either side, K) *Sigillaria davreuxi*, L) *Calamites suckowii*, M) *Lepidodendron aculeatum*, N) Leaf of *Cordaites* sp. Identifications based on Gillespie et al. (1996), Taylor et al. (2009), and W.A. DiMichele personal communication (2022).

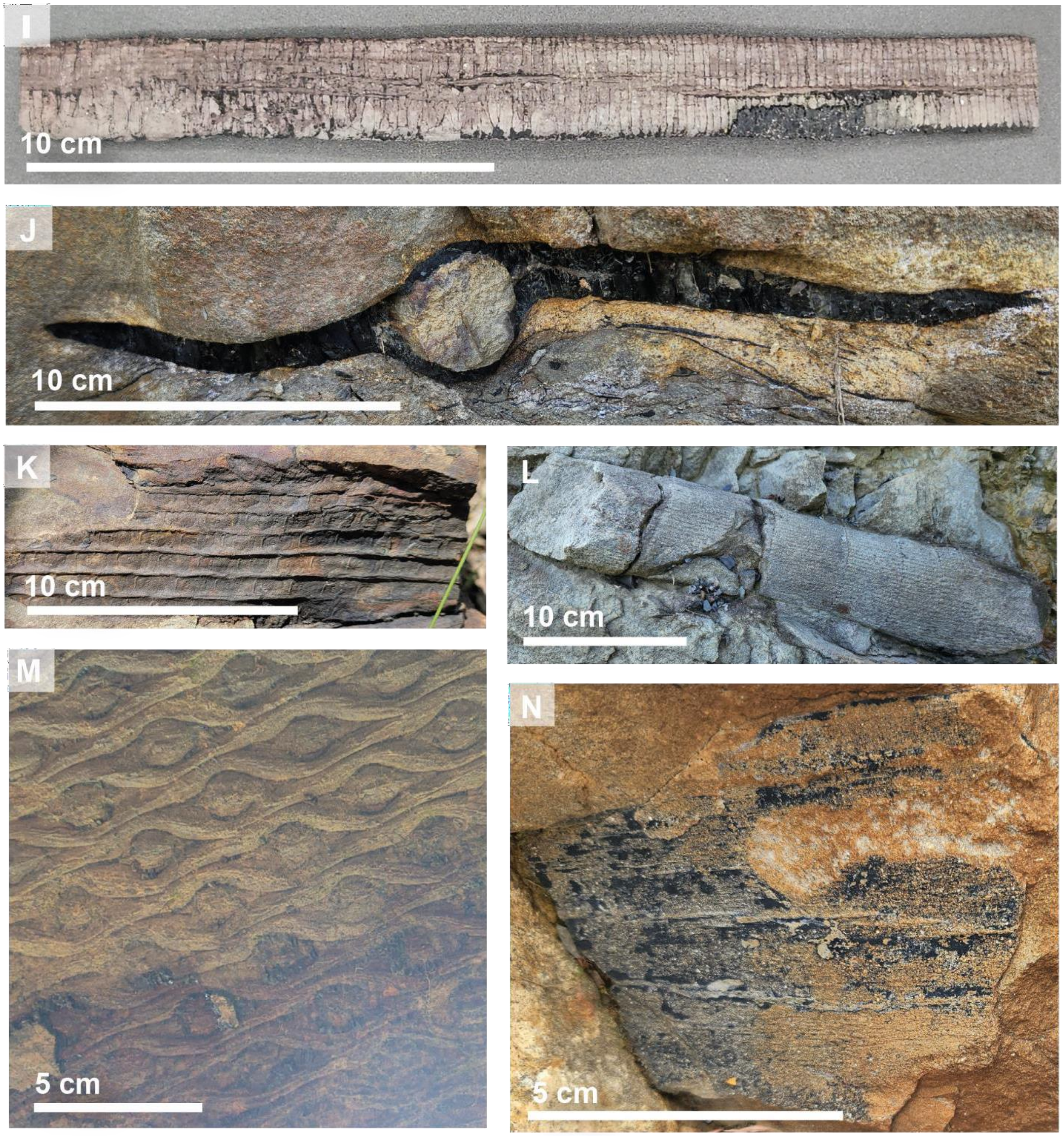

I
10 cm
J
10 cm
K
10 cm
L
10 cm
M
5 cm
N
5 cm

Fig. 14 — Examples of plant foliage, most of which were found in floodplain facies. A) *Neuralethopteris pocahontas*, B, E) *Neuralethopteris schlehani*, C) *Sphenopteris* sp., D) *Neuralethopteris* sp. Identifications based on Gillespie et al. (1996), Taylor et al. (2009), and W.A. DiMichele and M. Blake personal communication (2023).


A
3 cm
B
3 cm
C
3 cm
D
3 cm
E
3 cm

Fig. 15 — Examples of plant foliage, found in floodplain facies. F) *Annularia radiata*, G) *Sphenopteris schatzlarensis*. Identifications based on Gillespie et al. (1996), Taylor et al. (2009), and W.A. DiMichele and M. Blake personal communication (2023).


F
1 cm
G
1 cm

Fig. 16 — Bar graphs showing percent abundance of each plant type within each channel of each valley. Note variation in the vertical scales, needed to show abundance of rare taxa. Stratigraphic position increases from right to left.

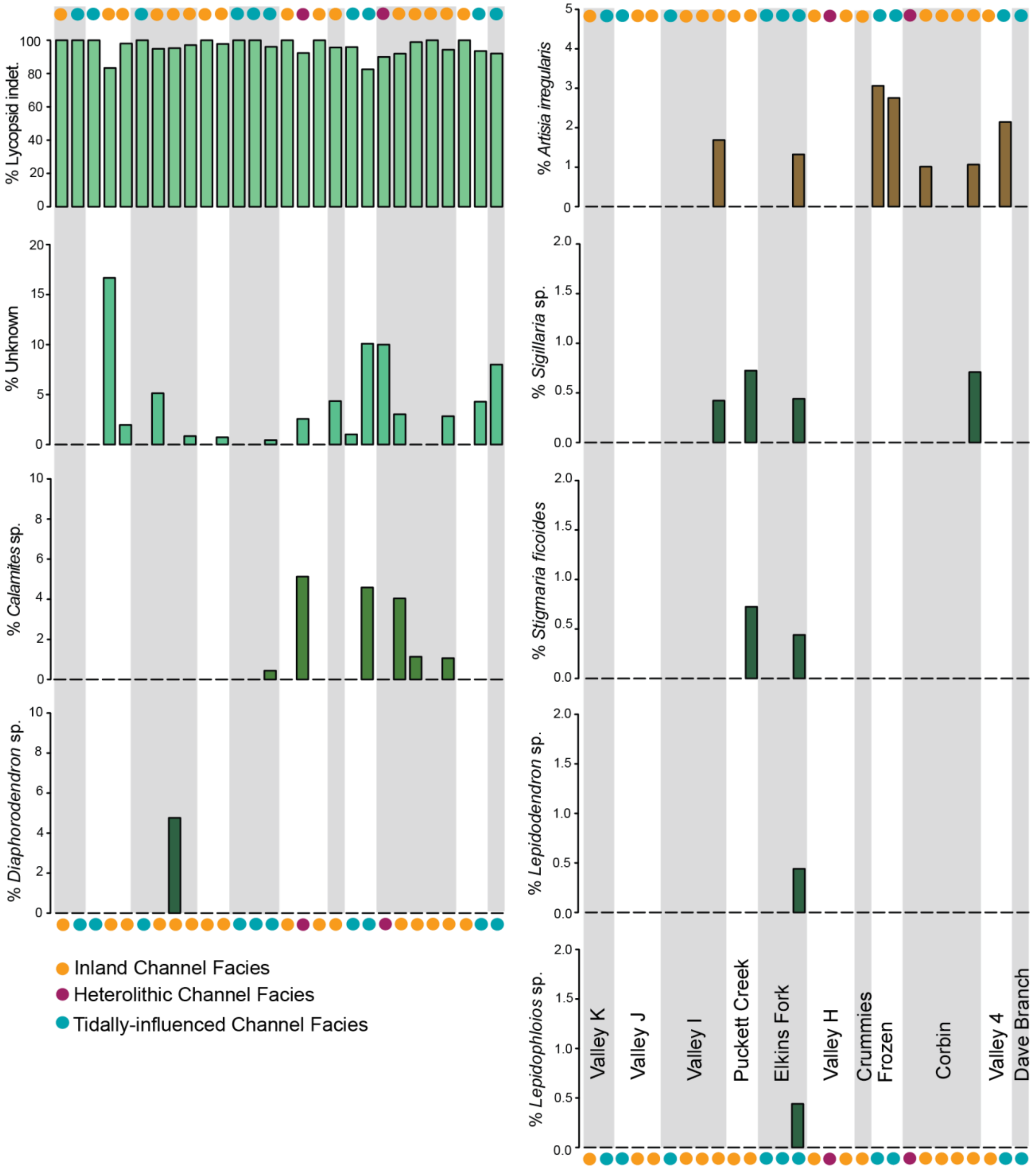

% Lycopsid indet.
0
20
40
60
80
100
% Unknown
0
5
10
15
20
% Calamites sp.
0
2
4
6
8
10
% Diaphorodendron sp.
0
2
4
6
8
10
% Artisia irregularis
0
1
2
3
4
5
% Sigillaria sp.
0.0
0.5
1.0
1.5
2.0
% Stigmaria ficoides
0.0
0.5
1.0
1.5
2.0
% Lepidodendron sp.
0.0
0.5
1.0
1.5
2.0
% Lepidophloios sp.
0.0
0.5
1.0
1.5
2.0
Valley K
Valley J
Valley I
Puckett Creek
Elkins Fork
Valley H
Crummies
Frozen
Corbin
Valley 4
Dave Branch
Inland Channel Facies
Heterolithic Channel Facies
Tidally-influenced Channel Facies

Fig. 17 — Bar graphs showing percent abundance for each of the plant types in each valley. Note the dominance of lycopsid indet. in all valley fills.

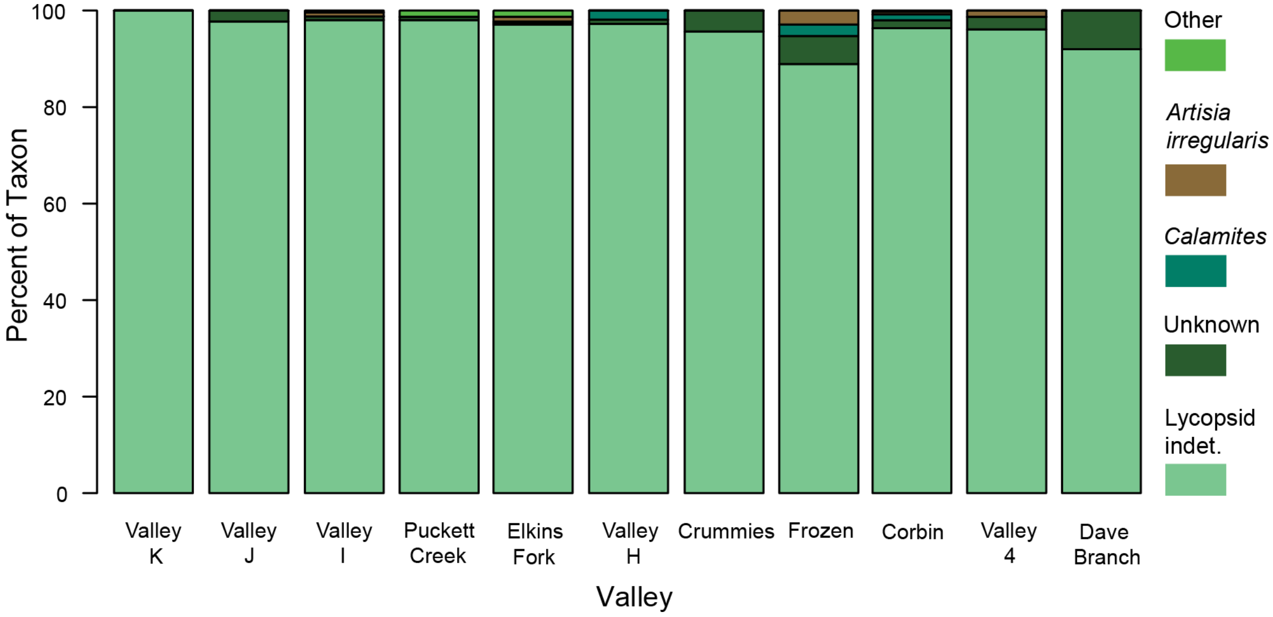

Percent of Taxon
0
20
40
60
80
100
Valley K
Valley J
Valley I
Puckett Creek
Elkins Fork
Valley H
Crummies
Frozen
Corbin
Valley 4
Dave Branch
Valley
Other
Artisia irregularis
Calamites
Unknown
Lycopsid indet.

Fig. 18 — Bar graphs showing variation in plant abundance among valleys in stratigraphically up-dip, mid-dip, or down-dip positions. Note the different vertical scales, needed to show the abundance of rare taxa. Lycopsid indet. Dominates in all valley settings with little consistent variation in species abundance with valley setting.

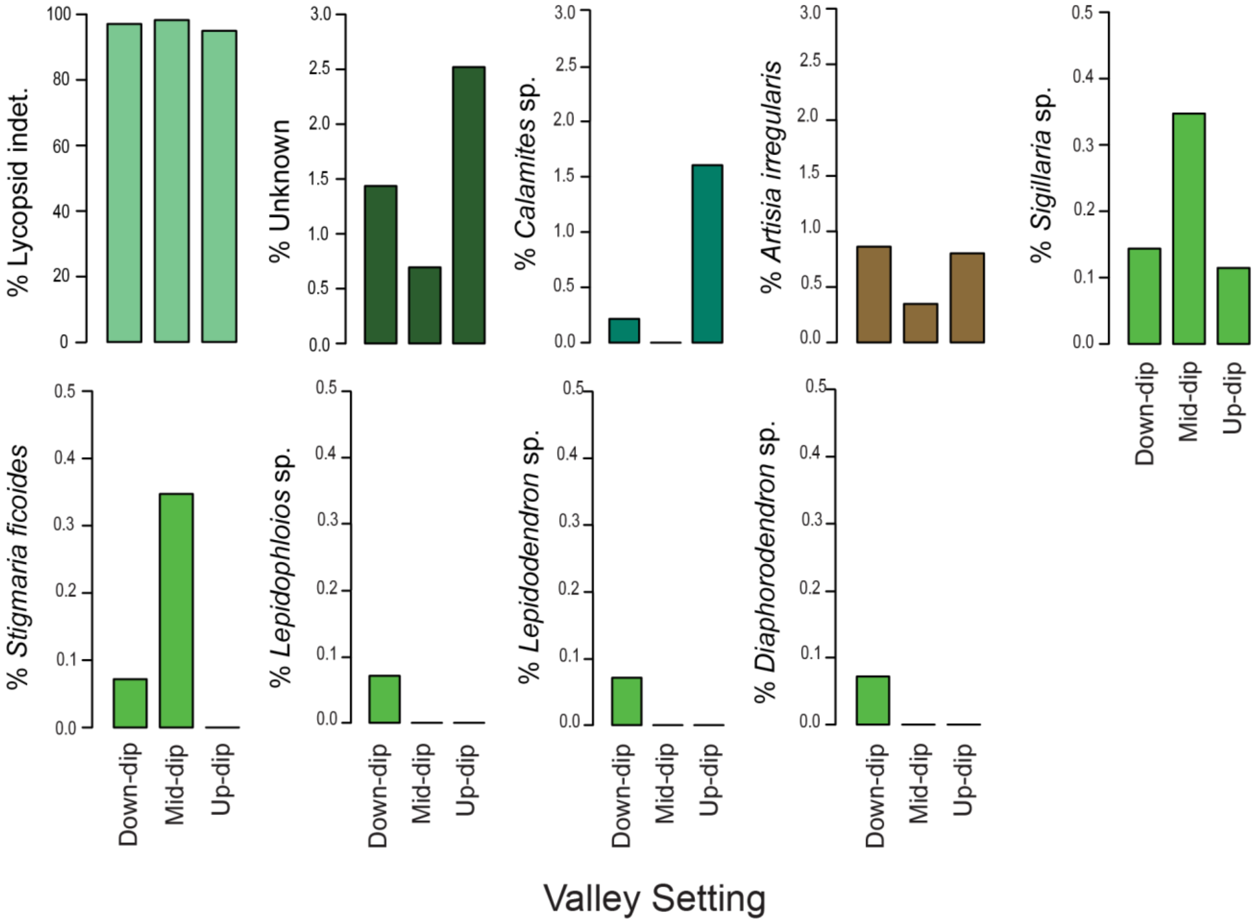

% Lycopsid indet.
% Unknown
% *Calamites* sp.
% *Artisia irregularis*
% *Sigillaria* sp.
% *Stigmaria ficoides*
% *Lepidophloios* sp.
% *Lepidodendron* sp.
% *Diaphorodendron* sp.
0
20
40
60
80
100
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0.1
0.2
0.3
0.4
0.5
Down-dip
Mid-dip
Up-dip
Valley Setting

Fig. 19 — Bar graphs comparing percent abundance of plant types among valleys from down-dip, mid-dip, and up-dip settings. Note the dominance of lycopsid indet. in all valley fills.

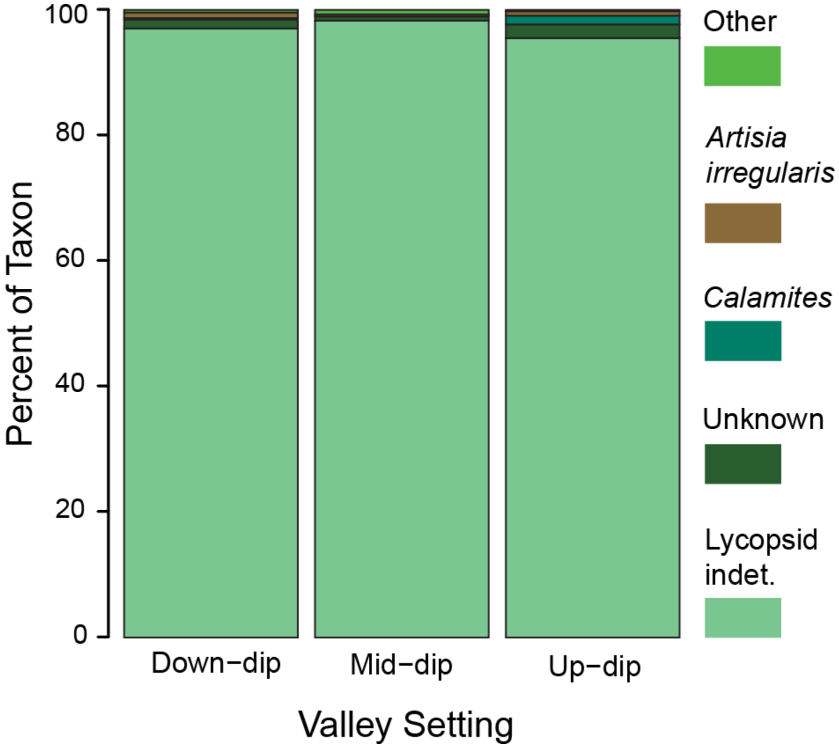
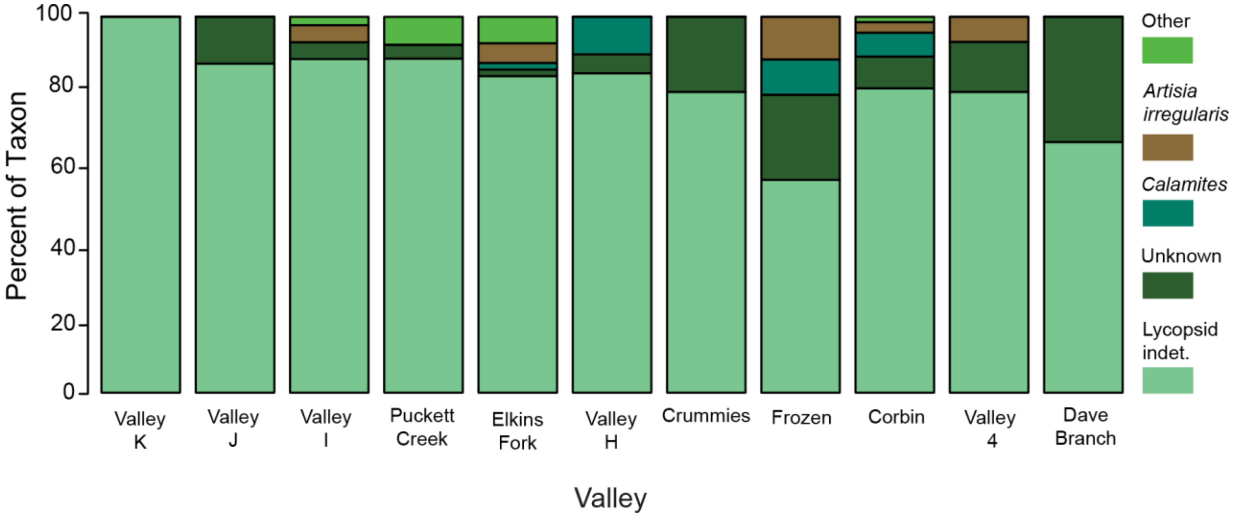

100
80
60
40
20
0
Percent of Taxon
Down−dip
Mid−dip
Up−dip
Valley Setting
Other
Artisia irregularis
Calamites
Unknown
Lycopsid indet.

Fig. 20 — Examples of coal that may be peat mat rip-ups rather than lycopsid indet., based on their shapes: A) spur and pronged, B) flat, and C) branching (Appendix C).

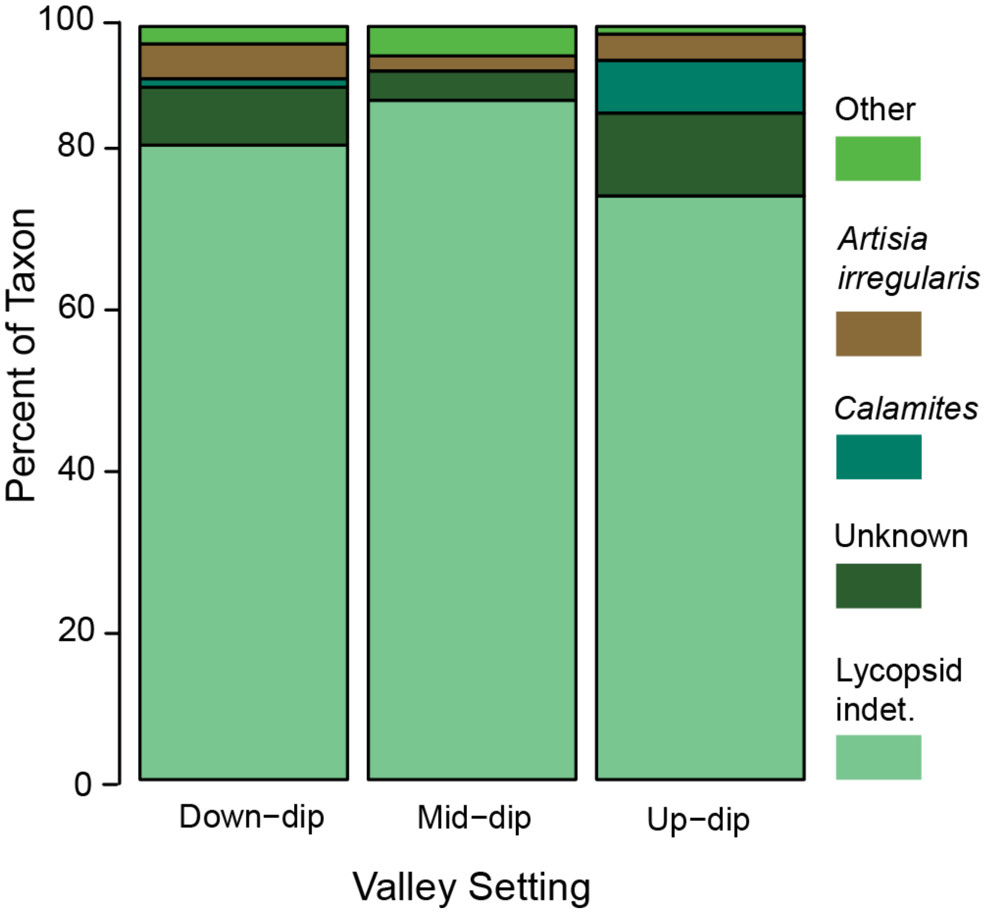

A
3 cm
B
3 cm
C
3 cm

Fig. 21 — Bar graphs of abundance of plant taxa in incised valley fills, excluding possible peat mat rip-ups.



Percent of Taxon
0
20
40
60
80
100
Valley K
Valley J
Valley I
Puckett Creek
Elkins Fork
Valley H
Crummies
Frozen
Corbin
Valley 4
Dave Branch
Valley
Other
Artisia irregularis
Calamites
Unknown
Lycopsid indet.

Fig. 22 — Bar graphs of abundance of plant taxa from down-dip, mid-dip, and up-dip valley settings, excluding peat mat rip-ups.


100
80
60
40
20
0
Percent of Taxon
Down−dip
Mid−dip
Up−dip
Valley Setting
Other
Artisia irregularis
Calamites
Unknown
Lycopsid indet.

APPENDIX A

LOCATION OF STUDIED VALLEYS

Appendix A. Location of studied valleys

Region	Locality	Stratigraphic region	Latitude	Longitude	Valley fills
Elkhorn City	Onramp 1373	Up-dip	37.314°	-82.357°	Dave Branch
Oven Fork	Oven Fork	Up-dip	37.056°	-82.811°	4, Corbin
Elkhorn City	Dead End Breaks	Up-dip	37.314°	-82.300°	Corbin, Frozen
Jackson	Jackson 1	Down-dip, Up-dip	37.596°	-83.400°	Frozen
Pikeville	Phelps Offramp	Mid-dip	37.558°	-82.430°	Crummies
Prestonsburg	Banner	Down-dip	37.612°	-82.709°	H
Jackson	Jackson 2	Down-dip	37.569°	-83.392°	Elkins Fork
Pikeville	Phelps South	Mid-dip	37.549°	-82.435°	Puckett Creek
Hazard	Jeff	Down-dip, Up-dip	37.205°	-83.142°	I
Prestonsburg	Prestonsburg	Down-dip, Mid-dip	37.696°	-82.791°	I, J
Prestonsburg	Jenny Wiley	Down-dip	37.728°	-82.741°	J, K

APPENDIX B

TAXON COUNT

Appendix B. Taxon Counts

Valley	Position	Facies	Lycopsid indet.	*Calamites* sp.	*Calamites suckowi*	*Calamites cisti*	*Calamites undulatus*	*Artisia irregularis*	Unknown
DaveBranch	basal	tidal	23	0	0	0	0	0	2
V4	basal	inland	131	0	0	0	0	3	6
V4	middle	tidal	89	0	0	0	0	0	0
Corbin	basal	inland	126	0	0	0	0	0	0
Corbin	middle	inland	135	0	0	0	0	0	0
Corbin	upper	inland	109	0	0	1	1	0	0
Corbin	upper1	inland	91	3	1	0	0	1	3
Corbin	upper2	heterolithic	9	0	0	0	0	0	1
Frozen	basal	tidal	3	3	1	0	1	0	2
Frozen	basal	tidal	87	0	0	0	0	3	9
Frozen	middle	tidal	94	0	0	0	0	3	1
Crummies	basal	inland	22	0	0	0	0	0	1
H	basal	inland	61	0	0	0	0	0	0
H	middle	heterolithic	36	0	0	2	0	0	1
H	upper	inland	6	0	0	0	0	0	0
Elkins Fork	basal	tidal	218	0	1	0	0	3	1
Elkins Fork	middle	tidal	61	0	0	0	0	0	0
Elkins Fork	upper	tidal	18	0	0	0	0	0	0
Puckett Creek	basal	inland	135	0	0	0	0	0	1
Puckett Creek	middle	inland	13	0	0	0	0	0	0
I	basal	tidal	113	0	0	0	0	1	0
I	basal	inland	117	0	0	0	0	3	2
I	middle	inland	20	0	0	0	0	0	0
I	upper1	inland	37	0	0	0	0	0	2
I	upper2	tidal	198	0	0	0	0	0	0
J	basal	inland	61	0	0	0	0	0	3
J	basal	inland	89	0	0	0	0	0	0

J	middle	inland	5	0	0	0	0	0	1
J	upper	tidal	15	0	0	0	0	0	0
K	basal	tidal	138	0	0	0	0	0	0
K	middle	inland	91	0	0	0	0	0	0

Appendix B. Taxon Counts

Valley	Position	Facies	*Stigmaria ficoides*	*Sigillaria* sp.	*Sigillaria brardi*	*Diaphorodendron* sp.	*Lepidodendron* sp.	*Lepidophloios* sp.
DaveBranch	basal	tidal	0	0	0	0	0	0
V4	basal	inland	0	0	0	0	0	0
V4	middle	tidal	0	0	0	0	0	0
Corbin	basal	inland	0	1	0	0	0	0
Corbin	middle	inland	0	0	0	0	0	0
Corbin	upper	inland	0	0	0	0	0	0
Corbin	upper1	inland	0	0	0	0	0	0
Corbin	upper2	heterolithic	0	0	0	0	0	0
Frozen	basal	tidal	0	0	0	0	0	0
Frozen	basal	tidal	0	0	0	0	0	0
Frozen	middle	tidal	0	0	0	0	0	0
Crummies	basal	inland	0	0	0	0	0	0
H	basal	inland	0	0	0	0	0	0
H	middle	heterolithic	0	0	0	0	0	0
H	upper	inland	0	0	0	0	0	0
Elkins Fork	basal	tidal	1	0	1	0	1	1
Elkins Fork	middle	tidal	0	0	0	0	0	0
Elkins Fork	upper	tidal	0	0	0	0	0	0
Puckett Creek	basal	inland	1	1	0	0	0	0
Puckett Creek	middle	inland	0	0	0	0	0	0
I	basal	tidal	0	0	0	0	0	0
I	basal	inland	0	1	0	0	0	0
I	middle	inland	0	0	0	1	0	0
I	upper1	inland	0	0	0	0	0	0
I	upper2	tidal	0	0	0	0	0	0
J	basal	inland	0	0	0	0	0	0
J	basal	inland	0	0	0	0	0	0

J	middle	inland	0	0	0	0	0	0
J	upper	tidal	0	0	0	0	0	0
K	basal	tidal	0	0	0	0	0	0
K	middle	inland	0	0	0	0	0	0

APPENDIX C

FIELD TEST OF LYCOPSIDS VERSUS POSSIBLE PEAT MAT RIP-UPS

Appendix C — A secondary field study was conducted to determine the abundance of lycopsids indet. compared to the abundance of possible peat mat rip-ups. This table shows the counts of the coal shapes that are likely lycopsids indet. and the counts of coal shapes that are possible peat mat rip-ups (pages 28–29 in main text).

Appendix C. Field test of lycopsids versus possible peat mat rip-ups

Valley	Position	Facies	Ellipse with cast (Fig. 11 A, B)	Ellipse without cast (Fig. 11 C, G)	Spur with cast (Fig. 11 F)	Spur with partial cast (Fig. 11 E)	Double spur with partial cast (Fig. 11 D)	Flat (Fig. 20 B)	Branching (Fig. 20 C)	Spur and pronged (Fig. 20 A)
Corbin	basal	inland	1	0	2	3	0	85	0	0
Corbin	middle	inland	1	1	1	5	4	52	0	0
Corbin	upper	inland	2	0	0	4	0	35	0	0
Corbin	upper1	inland	4	0	2	3	1	25	0	0
Corbin	upper2	heterolithic	1	0	0	1	0	11	0	0
V4	basal	inland	7	0	2	12	1	77	5	0
V4	middle	inland	0	0	0	0	0	13	0	0
V4	upper	tidal	1	0	0	0	0	1	0	1

APPENDIX D

R CODE FOR FIGURES

```
#This file contains the code for all plots in thesis
#NOTE: axes, colors, labels, size, widths were all adjusted and finalized in adobe
#Figure 16
logs <- read.table(file='countData.csv', header=TRUE, sep=',')
speciesPercents <- function(x) {
    Calamites <-sum(logs[x,c('CalamitesSp', 'CalamitesSuckowi', 'CalamitesCisti', 'CalamitesUndulatus')])
    Lycopsid <-sum(logs[x,c('unidentifiableLycopsid')])
    Artisia <-sum(logs[x,c('ArtisiaIrregularis')])
    Diaphorodendron <-sum(logs[x,c('DiaphorodendronSp')])
    Stigmaria <-sum(logs[x,c('StigmariaFicoides')])
    Unknown <-sum(logs[x,c('Unknown')])
    Lepidophloios <-sum(logs[x,c('LepidophloiosSp')])
    Lepidodendron <-sum(logs[x,c('LepidodendronAculeatum', 'LepidodendronSp')])
    Sigillaria <-sum(logs[x,c('SigillariaBrardi', 'SigillariaBrogniart','SigillariaSp')])
    total <- Calamites + Lycopsid + Artisia + Diaphorodendron + Stigmaria + Unknown + Lepidophloios + Lepidodendron + Sigillaria
    percents <- c(Lycopsid/total*100, Artisia/total*100, Diaphorodendron/total*100, Calamites/total*100, Stigmaria/total*100, Unknown/total*100, Lepidophloios/total*100, Lepidodendron/total*100, Sigillaria/total*100)
    return(percents)
}
#Data frame of species by position
Ibasal <-speciesPercents(logs$Valley=='I' & logs$Position =='basal')
Imiddle <-speciesPercents(logs$Valley=='I' & logs$Position =='middle')
Iupper1 <-speciesPercents(logs$Valley=='I' & logs$Position =='upper1')
Iupper2 <-speciesPercents(logs$Valley=='I' & logs$Position =='upper2')
```

```
Jbasal <-speciesPercents(logs$Valley=='J' & logs$Position =='basal')

Jmiddle <-speciesPercents(logs$Valley=='J' & logs$Position =='middle')

Jupper <-speciesPercents(logs$Valley=='J' & logs$Position =='upper')

Hbasal <-speciesPercents(logs$Valley=='H' & logs$Position =='basal')

Hmiddle <-speciesPercents(logs$Valley=='H' & logs$Position =='middle')

Hupper <-speciesPercents(logs$Valley=='H' & logs$Position =='upper')

Kbasal <-speciesPercents(logs$Valley=='K' & logs$Position =='basal')

Kmiddle <-speciesPercents(logs$Valley=='K' & logs$Position =='middle')

PuckettCreekbasal <-speciesPercents(logs$Valley=='PuckettCreek' & logs$Position =='basal')

PuckettCreekmiddle <-speciesPercents(logs$Valley=='PuckettCreek' & logs$Position =='middle')

Crummiesbasal <-speciesPercents(logs$Valley=='Crummies' & logs$Position =='basal')

Frozenbasal <-speciesPercents(logs$Valley=='Frozen' & logs$Position =='basal')

Frozenmiddle <-speciesPercents(logs$Valley=='Frozen' & logs$Position =='middle')

ElkinsForkbasal <-speciesPercents(logs$Valley=='ElkinsFork' & logs$Position =='basal')

ElkinsForkmiddle <-speciesPercents(logs$Valley=='ElkinsFork' & logs$Position =='middle')

ElkinsForkupper <-speciesPercents(logs$Valley=='ElkinsFork' & logs$Position =='upper')

Corbinbasal <-speciesPercents(logs$Valley=='Corbin' & logs$Position =='basal')

Corbinmiddle <-speciesPercents(logs$Valley=='Corbin' & logs$Position =='middle')

Corbinupper <-speciesPercents(logs$Valley=='Corbin' & logs$Position =='upper')

Corbinupper1 <-speciesPercents(logs$Valley=='Corbin' & logs$Position =='upper1')

Corbinupper2 <-speciesPercents(logs$Valley=='Corbin' & logs$Position =='upper2')

Valley4basal <-speciesPercents(logs$Valley=='V4' & logs$Position =='basal')

Valley4middle <-speciesPercents(logs$Valley=='V4' & logs$Position =='middle')

DaveBranchbasal <-speciesPercents(logs$Valley=='DaveBranch' & logs$Position =='basal')


positionTable <- data.frame(Kmiddle, Kbasal, Jupper, Jmiddle, Jbasal, Iupper2, Iupper1, Imiddle, Ibasal,

PuckettCreekmiddle, PuckettCreekbasal, ElkinsForkupper, ElkinsForkmiddle, ElkinsForkbasal, Hupper, Hmiddle,
```

```
Hbasal, Crummiesbasal, Frozenmiddle, Frozenbasal, Corbinupper2, Corbinupper1, Corbinupper, Corbinmiddle,
Corbinbasal, Valley4middle, Valley4basal, DaveBranchbasal)
positionTable
positionTable_transpose = t(positionTable)

'Kfactor$Kmiddle', 'Kfactor$Kbasal', 'Jfactor$Jupper', 'Jfactor$Jmiddle', 'Jfactor$Jbasal', 'Ifactor$Iupper2',
'Ifactor$Iupper1', 'Ifactor$Imiddle', 'Ifactor$Ibasal', 'PucketteCreekfactor$PuckettCreekmiddle',
'PuckettCreekfactor$PuckettCreekbasal', 'ElkinsForkfactor$ElkinsForkupper', 'ElkinsForkfactor$ElkinsForkmiddle',
'ElkinsForkfactor$ElkinsForkbasal', 'Hfactor$Hupper', 'Hfactor$Hmiddle', 'Hfactor$Hbasal',
'Crummiesfactor$Crummiesbasal', 'Frozenfactor$Frozenmiddle', 'Frozenfactor$Frozenbasal',
'Corbinfactor$Corbinupper2', 'Corbinfactor$Corbinupper1', 'Corbinfactor$Corbinupper',
'Corbinfactor$Corbinmiddle', 'Corbinfactor$Corbinbasal', 'Valley4factor$Valley4middle',
'Valley4factor$Valley4basal', 'DaveBranchfactor$DaveBranchbasal'

dev.new()
xRange <- c(min(0), max(28))
yRange <- c(min(0), max(120))
barplot(as.matrix(positionTable_transpose[,1]), width=0.7, xlim=xRange, ylim=yRange, las=1, space=c(0.4),
col=c('#6ADE97'),  names.arg=c('Kfactor$Kmiddle', 'Kfactor$Kbasal', 'Jfactor$Jupper', 'Jfactor$Jmiddle',
'Jfactor$Jbasal', 'Ifactor$Iupper2', 'Ifactor$Iupper1', 'Ifactor$Imiddle', 'Ifactor$Ibasal',
'PucketteCreekfactor$PuckettCreekmiddle', 'PuckettCreekfactor$PuckettCreekbasal',
'ElkinsForkfactor$ElkinsForkupper', 'ElkinsForkfactor$ElkinsForkmiddle', 'ElkinsForkfactor$ElkinsForkbasal',
'Hfactor$Hupper', 'Hfactor$Hmiddle', 'Hfactor$Hbasal',  'Crummiesfactor$Crummiesbasal',
'Frozenfactor$Frozenmiddle', 'Frozenfactor$Frozenbasal',  'Corbinfactor$Corbinupper2',
'Corbinfactor$Corbinupper1', 'Corbinfactor$Corbinupper', 'Corbinfactor$Corbinmiddle', 'Corbinfactor$Corbinbasal',
'Valley4factor$Valley4middle', 'Valley4factor$Valley4basal', 'DaveBranchfactor$DaveBranchbasal'), xlab='Valley',
ylab='Percent Unidentifiable Lycopsid', beside=TRUE)
```

```
dev.new()
xRange <- c(min(0), max(28))
yRange <- c(min(0), max(5))
barplot(as.matrix(positionTable_transpose[,2]), width=0.7, xlim=xRange, ylim=yRange, las=1, space=c(0.4),
col=c('#896A39'),  names.arg=c('Kfactor$Kmiddle', 'Kfactor$Kbasal', 'Jfactor$Jupper', 'Jfactor$Jmiddle',
'Jfactor$Jbasal', 'Ifactor$Iupper2', 'Ifactor$Iupper1', 'Ifactor$Imiddle', 'Ifactor$Ibasal',
'PucketteCreekfactor$PuckettCreekmiddle', 'PuckettCreekfactor$PuckettCreekbasal',
'ElkinsForkfactor$ElkinsForkupper', 'ElkinsForkfactor$ElkinsForkmiddle', 'ElkinsForkfactor$ElkinsForkbasal',
'Hfactor$Hupper', 'Hfactor$Hmiddle', 'Hfactor$Hbasal',  'Crummiesfactor$Crummiesbasal',
'Frozenfactor$Frozenmiddle', 'Frozenfactor$Frozenbasal',  'Corbinfactor$Corbinupper2',
'Corbinfactor$Corbinupper1', 'Corbinfactor$Corbinupper', 'Corbinfactor$Corbinmiddle', 'Corbinfactor$Corbinbasal',
'Valley4factor$Valley4middle', 'Valley4factor$Valley4basal', 'DaveBranchfactor$DaveBranchbasal'), xlab='Valley',
ylab='Percent Artisia Irregularis', beside=TRUE)

dev.new()
xRange <- c(min(0), max(28))
yRange <- c(min(0), max(10))
barplot(as.matrix(positionTable_transpose[,3]), width=0.7, xlim=xRange, ylim=yRange, las=1, space=c(0.4),
col=c('#2F6142'),  names.arg=c('Kfactor$Kmiddle', 'Kfactor$Kbasal', 'Jfactor$Jupper', 'Jfactor$Jmiddle',
'Jfactor$Jbasal', 'Ifactor$Iupper2', 'Ifactor$Iupper1', 'Ifactor$Imiddle', 'Ifactor$Ibasal',
'PucketteCreekfactor$PuckettCreekmiddle', 'PuckettCreekfactor$PuckettCreekbasal',
'ElkinsForkfactor$ElkinsForkupper', 'ElkinsForkfactor$ElkinsForkmiddle', 'ElkinsForkfactor$ElkinsForkbasal',
'Hfactor$Hupper', 'Hfactor$Hmiddle', 'Hfactor$Hbasal',  'Crummiesfactor$Crummiesbasal',
'Frozenfactor$Frozenmiddle', 'Frozenfactor$Frozenbasal',  'Corbinfactor$Corbinupper2',
'Corbinfactor$Corbinupper1', 'Corbinfactor$Corbinupper', 'Corbinfactor$Corbinmiddle', 'Corbinfactor$Corbinbasal',
```

```
'Valley4factor$Valley4middle', 'Valley4factor$Valley4basal', 'DaveBranchfactor$DaveBranchbasal'), xlab='Valley',
ylab='Percent Diaphorodendron', beside=TRUE)
dev.new()
xRange <- c(min(0), max(28))
yRange <- c(min(0), max(10))
barplot(as.matrix(positionTable_transpose[,4]), width=0.7, xlim=xRange, ylim=yRange, las=1, space=c(0.4),
col=c('#48820C'),  names.arg=c('Kfactor$Kmiddle', 'Kfactor$Kbasal', 'Jfactor$Jupper', 'Jfactor$Jmiddle',
'Jfactor$Jbasal', 'Ifactor$Iupper2', 'Ifactor$Iupper1', 'Ifactor$Imiddle', 'Ifactor$Ibasal',
'PucketteCreekfactor$PuckettCreekmiddle', 'PuckettCreekfactor$PuckettCreekbasal',
'ElkinsForkfactor$ElkinsForkupper', 'ElkinsForkfactor$ElkinsForkmiddle', 'ElkinsForkfactor$ElkinsForkbasal',
'Hfactor$Hupper', 'Hfactor$Hmiddle', 'Hfactor$Hbasal',  'Crummiesfactor$Crummiesbasal',
'Frozenfactor$Frozenmiddle', 'Frozenfactor$Frozenbasal',  'Corbinfactor$Corbinupper2',
'Corbinfactor$Corbinupper1', 'Corbinfactor$Corbinupper', 'Corbinfactor$Corbinmiddle', 'Corbinfactor$Corbinbasal',
'Valley4factor$Valley4middle', 'Valley4factor$Valley4basal', 'DaveBranchfactor$DaveBranchbasal'), xlab='Valley',
ylab='Percent Calamites', beside=TRUE)

dev.new()
xRange <- c(min(0), max(28))
yRange <- c(min(0), max(2))
barplot(as.matrix(positionTable_transpose[,5]), width=0.7, xlim=xRange, ylim=yRange, las=1, space=c(0.4),
col=c('#2F6142'),  names.arg=c('Kfactor$Kmiddle', 'Kfactor$Kbasal', 'Jfactor$Jupper', 'Jfactor$Jmiddle',
'Jfactor$Jbasal', 'Ifactor$Iupper2', 'Ifactor$Iupper1', 'Ifactor$Imiddle', 'Ifactor$Ibasal',
'PucketteCreekfactor$PuckettCreekmiddle', 'PuckettCreekfactor$PuckettCreekbasal',
'ElkinsForkfactor$ElkinsForkupper', 'ElkinsForkfactor$ElkinsForkmiddle', 'ElkinsForkfactor$ElkinsForkbasal',
'Hfactor$Hupper', 'Hfactor$Hmiddle', 'Hfactor$Hbasal',  'Crummiesfactor$Crummiesbasal',
'Frozenfactor$Frozenmiddle', 'Frozenfactor$Frozenbasal',  'Corbinfactor$Corbinupper2',
'Corbinfactor$Corbinupper1', 'Corbinfactor$Corbinupper', 'Corbinfactor$Corbinmiddle', 'Corbinfactor$Corbinbasal',
```

```
'Valley4factor$Valley4middle', 'Valley4factor$Valley4basal', 'DaveBranchfactor$DaveBranchbasal'), xlab='Valley',
ylab='Percent Stigmaria Ficoides', beside=TRUE)
dev.new()
xRange <- c(min(0), max(28))
yRange <- c(min(0), max(20))
barplot(as.matrix(positionTable_transpose[,6]), width=0.7, xlim=xRange, ylim=yRange, las=1, space=c(0.4),
col=c('#4BC990'),  names.arg=c('Kfactor$Kmiddle', 'Kfactor$Kbasal', 'Jfactor$Jupper', 'Jfactor$Jmiddle',
'Jfactor$Jbasal', 'Ifactor$Iupper2', 'Ifactor$Iupper1', 'Ifactor$Imiddle', 'Ifactor$Ibasal',
'PucketteCreekfactor$PuckettCreekmiddle', 'PuckettCreekfactor$PuckettCreekbasal',
'ElkinsForkfactor$ElkinsForkupper', 'ElkinsForkfactor$ElkinsForkmiddle', 'ElkinsForkfactor$ElkinsForkbasal',
'Hfactor$Hupper', 'Hfactor$Hmiddle', 'Hfactor$Hbasal',  'Crummiesfactor$Crummiesbasal',
'Frozenfactor$Frozenmiddle', 'Frozenfactor$Frozenbasal',  'Corbinfactor$Corbinupper2',
'Corbinfactor$Corbinupper1', 'Corbinfactor$Corbinupper', 'Corbinfactor$Corbinmiddle', 'Corbinfactor$Corbinbasal',
'Valley4factor$Valley4middle', 'Valley4factor$Valley4basal', 'DaveBranchfactor$DaveBranchbasal'), xlab='Valley',
ylab='Percent Unknown', beside=TRUE)

dev.new()
xRange <- c(min(0), max(28))
yRange <- c(min(0), max(2))
barplot(as.matrix(positionTable_transpose[,7]), width=0.7, xlim=xRange, ylim=yRange, las=1, space=c(0.4),
col=c('#2F6142'),  names.arg=c('Kfactor$Kmiddle', 'Kfactor$Kbasal', 'Jfactor$Jupper', 'Jfactor$Jmiddle',
'Jfactor$Jbasal', 'Ifactor$Iupper2', 'Ifactor$Iupper1', 'Ifactor$Imiddle', 'Ifactor$Ibasal',
'PucketteCreekfactor$PuckettCreekmiddle', 'PuckettCreekfactor$PuckettCreekbasal',
'ElkinsForkfactor$ElkinsForkupper', 'ElkinsForkfactor$ElkinsForkmiddle', 'ElkinsForkfactor$ElkinsForkbasal',
'Hfactor$Hupper', 'Hfactor$Hmiddle', 'Hfactor$Hbasal',  'Crummiesfactor$Crummiesbasal',
'Frozenfactor$Frozenmiddle', 'Frozenfactor$Frozenbasal',  'Corbinfactor$Corbinupper2',
'Corbinfactor$Corbinupper1', 'Corbinfactor$Corbinupper', 'Corbinfactor$Corbinmiddle', 'Corbinfactor$Corbinbasal',
```

```
'Valley4factor$Valley4middle', 'Valley4factor$Valley4basal', 'DaveBranchfactor$DaveBranchbasal'), xlab='Valley',
ylab='Percent Lepidophloios', beside=TRUE)
dev.new()
xRange <- c(min(0), max(28))
yRange <- c(min(0), max(2))
barplot(as.matrix(positionTable_transpose[,8]), width=0.7, xlim=xRange, ylim=yRange, las=1, space=c(0.4),
col=c('#2F6142'),  names.arg=c('Kfactor$Kmiddle', 'Kfactor$Kbasal', 'Jfactor$Jupper', 'Jfactor$Jmiddle',
'Jfactor$Jbasal', 'Ifactor$Iupper2', 'Ifactor$Iupper1', 'Ifactor$Imiddle', 'Ifactor$Ibasal',
'PucketteCreekfactor$PuckettCreekmiddle', 'PuckettCreekfactor$PuckettCreekbasal',
'ElkinsForkfactor$ElkinsForkupper', 'ElkinsForkfactor$ElkinsForkmiddle', 'ElkinsForkfactor$ElkinsForkbasal',
'Hfactor$Hupper', 'Hfactor$Hmiddle', 'Hfactor$Hbasal',  'Crummiesfactor$Crummiesbasal',
'Frozenfactor$Frozenmiddle', 'Frozenfactor$Frozenbasal',  'Corbinfactor$Corbinupper2',
'Corbinfactor$Corbinupper1', 'Corbinfactor$Corbinupper', 'Corbinfactor$Corbinmiddle', 'Corbinfactor$Corbinbasal',
'Valley4factor$Valley4middle', 'Valley4factor$Valley4basal', 'DaveBranchfactor$DaveBranchbasal'), xlab='Valley',
ylab='Percent Lepidodendron', beside=TRUE)

dev.new()
xRange <- c(min(0), max(28))
yRange <- c(min(0), max(2))
barplot(as.matrix(positionTable_transpose[,9]), width=0.7, xlim=xRange, ylim=yRange, las=1, space=c(0.4),
col=c('#2F6142'),  names.arg=c('Kfactor$Kmiddle', 'Kfactor$Kbasal', 'Jfactor$Jupper', 'Jfactor$Jmiddle',
'Jfactor$Jbasal', 'Ifactor$Iupper2', 'Ifactor$Iupper1', 'Ifactor$Imiddle', 'Ifactor$Ibasal',
'PucketteCreekfactor$PuckettCreekmiddle', 'PuckettCreekfactor$PuckettCreekbasal',
'ElkinsForkfactor$ElkinsForkupper', 'ElkinsForkfactor$ElkinsForkmiddle', 'ElkinsForkfactor$ElkinsForkbasal',
'Hfactor$Hupper', 'Hfactor$Hmiddle', 'Hfactor$Hbasal',  'Crummiesfactor$Crummiesbasal',
'Frozenfactor$Frozenmiddle', 'Frozenfactor$Frozenbasal',  'Corbinfactor$Corbinupper2',
'Corbinfactor$Corbinupper1', 'Corbinfactor$Corbinupper', 'Corbinfactor$Corbinmiddle', 'Corbinfactor$Corbinbasal',
```

```
'Valley4factor$Valley4middle', 'Valley4factor$Valley4basal', 'DaveBranchfactor$DaveBranchbasal'), xlab='Valley',
ylab='Percent Sigillaria', beside=TRUE)



#Figure 17
#New function for combined plots
speciesPercents2 <- function(x) {
	Calamites <-sum(logs[x,c('CalamitesSp', 'CalamitesSuckowi', 'CalamitesCisti', 'CalamitesUndulatus')])
	Lycopsid <-sum(logs[x,c('unidentifiableLycopsid')])
	Artisia <-sum(logs[x,c('ArtisiaIrregularis')])
	Unknown <-sum(logs[x,c('Unknown')])
	Other <- sum(logs[x,c('DiaphorodendronSp', 'StigmariaFicoides', 'LepidophloiosSp', 'LepidodendronSp',
'LepidodendronAculeatum', 'SigillariaBrardi', 'SigillariaBrogniart','SigillariaSp')])
	total <- Calamites + Lycopsid + Artisia + Unknown + Other
	percents <- c(Lycopsid/total*100, Unknown/total*100, Calamites/total*100, Artisia/total*100,
Other/total*100)
	return(percents)
}

speciesPercents2(logs$Valley=='Frozen')

I <-speciesPercents2(logs$Valley=='I')
J <-speciesPercents2(logs$Valley=='J')
K <-speciesPercents2(logs$Valley=='K')
H <-speciesPercents2(logs$Valley=='H')
PuckettCreek <-speciesPercents2(logs$Valley=='PuckettCreek')
```

```
Crummies <-speciesPercents2(logs$Valley=='Crummies')
Frozen <-speciesPercents2(logs$Valley=='Frozen')
ElkinsFork <-speciesPercents2(logs$Valley=='ElkinsFork')
Corbin <-speciesPercents2(logs$Valley=='Corbin')
Valley4 <-speciesPercents2(logs$Valley=='V4')
DaveBranch <-speciesPercents2(logs$Valley=='DaveBranch')

percentsTable2 <- data.frame(I, J, K, H, PuckettCreek, Crummies, Frozen, ElkinsFork, Corbin, Valley4,
DaveBranch)
percentsTable2
dev.new()
opar = par(oma = c(0,0,0,9))#Large right margin for plot
barplot(as.matrix(percentsTable2), las=1, bty='n', col=c('#6ADE97', '#4BC990', '#48820C', '#896A39', '#2F6142'),
names.arg=c('I', 'J', 'K', 'H', 'Puckett Creek', 'Crummies', 'Frozen', 'Elkins Fork', 'Corbin', 'Valley 4', 'Dave Branch'),
xlab='Valley', ylab='Percent of Taxon', beside=FALSE)
par(opar) # Reset par
opar = par(oma = c(0,0,0,0), mar = c(0,0,0,2), new = TRUE)
par(opar) # Reset par

#Figure 18
downDip <-speciesPercents(logs$stratPosition=='down')
midDip <-speciesPercents(logs$stratPosition=='mid')
upDip <-speciesPercents(logs$stratPosition=='up')
columnNames <- c('downDip', 'midDip', 'upDip')
percentsTable1 <- data.frame(downDip, midDip, upDip)
percentsTable1
percentsTable1_transpose = t(percentsTable1)
```

```
colnames(percentsTable1_transpose) <- c('Unidentifiable Lycopsid', 'Artisia Irregularis', 'Diaphorodendron',
'Calamites', 'Stigmaria Ficoides', 'Unknown', 'Lepidophloios', 'Lepidodendron', 'Sigillaria')
percentsTable1_transpose

dev.new()
xRange <- c(min(0), max(28))
yRange <- c(min(0), max(100))
barplot(as.matrix(percentsTable1_transpose[,1]), width=0.7, xlim=xRange, ylim=yRange, las=1, space=c(0.4),
col=c('#6ADE97'),  names.arg=c('Down-dip', 'Mid-dip', 'Up-dip'), xlab='Stratigraphic position', ylab='Percent
Indeterminate Lycopsid', beside=TRUE)

dev.new()
xRange <- c(min(0), max(28))
yRange <- c(min(0), max(1))
barplot(as.matrix(percentsTable1_transpose[,2]), width=0.7, xlim=xRange, ylim=yRange, las=1, space=c(0.4),
col=c('#896A39'),  names.arg=c('Down-dip', 'Mid-dip', 'Up-dip'), xlab='Stratigraphic position', ylab='Percent Artisia
irregularis', beside=TRUE)

dev.new()
xRange <- c(min(0), max(28))
yRange <- c(min(0), max(0.5))
barplot(as.matrix(percentsTable1_transpose[,3]), width=0.7, xlim=xRange, ylim=yRange, las=1, space=c(0.4),
col=c('#2F6142'),  names.arg=c('Down-dip', 'Mid-dip', 'Up-dip'), xlab='Stratigraphic position', ylab='Percent
Diaphorodendron', beside=TRUE)

dev.new()
xRange <- c(min(0), max(28))
```

```
yRange <- c(min(0), max(2))
barplot(as.matrix(percentsTable1_transpose[,4]), width=0.7, xlim=xRange, ylim=yRange, las=1, space=c(0.4), col=c('#48820C'),  names.arg=c('Down-dip', 'Mid-dip', 'Up-dip'), xlab='Stratigraphic position', ylab='Percent Calamites', beside=TRUE)

dev.new()
xRange <- c(min(0), max(28))
yRange <- c(min(0), max(0.5))
barplot(as.matrix(percentsTable1_transpose[,5]), width=0.7, xlim=xRange, ylim=yRange, las=1, space=c(0.4), col=c('#2F6142'),  names.arg=c('Down-dip', 'Mid-dip', 'Up-dip'), xlab='Stratigraphic position', ylab='Percent Stigmaria Ficoides', beside=TRUE)

dev.new()
xRange <- c(min(0), max(28))
yRange <- c(min(0), max(3))
barplot(as.matrix(percentsTable1_transpose[,6]), width=0.7, xlim=xRange, ylim=yRange, las=1, space=c(0.4), col=c('#4BC990'),  names.arg=c('Down-dip', 'Mid-dip', 'Up-dip'), xlab='Stratigraphic position', ylab='Percent Unknown', beside=TRUE)

dev.new()
xRange <- c(min(0), max(28))
yRange <- c(min(0), max(0.5))
barplot(as.matrix(percentsTable1_transpose[,7]), width=0.7, xlim=xRange, ylim=yRange, las=1, space=c(0.4), col=c('#2F6142'),  names.arg=c('Down-dip', 'Mid-dip', 'Up-dip'), xlab='Stratigraphic position', ylab='Percent Lepidophloios', beside=TRUE)

dev.new()
```

```
xRange <- c(min(0), max(28))
yRange <- c(min(0), max(0.5))
barplot(as.matrix(percentsTable1_transpose[,8]), width=0.7, xlim=xRange, ylim=yRange, las=1, space=c(0.4), col=c('#2F6142'),  names.arg=c('Down-dip', 'Mid-dip', 'Up-dip'), xlab='Stratigraphic position', ylab='Percent Lepidodendron', beside=TRUE)

dev.new()
xRange <- c(min(0), max(28))
yRange <- c(min(0), max(0.5))
barplot(as.matrix(percentsTable1_transpose[,9]), width=0.7, xlim=xRange, ylim=yRange, las=1, space=c(0.4), col=c('#2F6142'),  names.arg=c('Down-dip', 'Mid-dip', 'Up-dip'), xlab='Stratigraphic position', ylab='Percent Sigillaria', beside=TRUE)

#Figure 19
downDip <-speciesPercents2(logs$stratPosition=='down')
midDip <-speciesPercents2(logs$stratPosition=='mid')
upDip <-speciesPercents2(logs$stratPosition=='up')
percentsTable3 <- data.frame(downDip, midDip, upDip)
percentsTable3

dev.new()
opar = par(oma = c(0,0,0,9))#Large right margin for plot
barplot(as.matrix(percentsTable3), width=c(0.1, 0.1, 0.1), space=c(0.1, 0.1, 0.1), las=1, bty='n', col=c('#6ADE97', '#4BC990', '#48820C', '#896A39', '#2F6142'), names.arg=c('Down-dip', 'Mid-dip', 'Up-dip'), xlab='Stratigraphic Position', ylab='Percent of Taxon', beside=FALSE)
par(opar) # Reset par
opar = par(oma = c(0,0,0,0), mar = c(0,0,0,2), new = TRUE)
```

```
par(opar) # Reset par



#Figure 21
#New function to exclude possible peat mats
speciesPercentslycopsidIndet <- function(x, percentTrueLycopsid) {
	Calamites <- sum(logs[x,c('CalamitesSp', 'CalamitesSuckowi', 'CalamitesCisti', 'CalamitesUndulatus')])
	lycopsidIndet <- round(sum(logs[x,c('unidentifiableLycopsid')] * percentTrueLycopsid))
	Artisia <- sum(logs[x,c('ArtisiaIrregularis')])
	Unknown <- sum(logs[x,c('Unknown')])
	Other <- sum(logs[x,c('DiaphorodendronSp', 'StigmariaFicoides', 'LepidophloiosSp', 'LepidodendronSp', 'LepidodendronAculeatum', 'SigillariaBrardi', 'SigillariaBrogniart','SigillariaSp')])
	total <- Calamites + lycopsidIndet + Artisia + Unknown + Other
	percents <- c(lycopsidIndet/total*100, Unknown/total*100, Calamites/total*100, Artisia/total*100, Other/total*100)
	return(percents)
}

percentTrueLycopsid = 0.162
speciesPercentslycopsidIndet(logs$Valley=='I',  percentTrueLycopsid=percentTrueLycopsid)

I  <-speciesPercentslycopsidIndet(logs$Valley=='I',  percentTrueLycopsid=percentTrueLycopsid)
J  <-speciesPercentslycopsidIndet(logs$Valley=='J',  percentTrueLycopsid=percentTrueLycopsid)
K <-speciesPercentslycopsidIndet(logs$Valley=='K', percentTrueLycopsid=percentTrueLycopsid)
H <-speciesPercentslycopsidIndet(logs$Valley=='H', percentTrueLycopsid=percentTrueLycopsid)
PuckettCreek <-speciesPercentslycopsidIndet(logs$Valley=='PuckettCreek', percentTrueLycopsid=percentTrueLycopsid)
```

```
Crummies <-speciesPercentslycopsidIndet(logs$Valley=='Crummies', percentTrueLycopsid=percentTrueLycopsid)
Frozen <-speciesPercentslycopsidIndet(logs$Valley=='Frozen', percentTrueLycopsid=percentTrueLycopsid)
ElkinsFork <-speciesPercentslycopsidIndet(logs$Valley=='ElkinsFork',
percentTrueLycopsid=percentTrueLycopsid)
Corbin <-speciesPercentslycopsidIndet(logs$Valley=='Corbin', percentTrueLycopsid=percentTrueLycopsid)
Valley4 <-speciesPercentslycopsidIndet(logs$Valley=='V4', percentTrueLycopsid=percentTrueLycopsid)
DaveBranch <-speciesPercentslycopsidIndet(logs$Valley=='DaveBranch',
percentTrueLycopsid=percentTrueLycopsid)

percentsTable6 <- data.frame(K, J, I, PuckettCreek, ElkinsFork, H, Crummies, Frozen, Corbin, Valley4,
DaveBranch)
percentsTable6

dev.new()
opar = par(oma = c(0,0,0,9))#Large right margin for plot
barplot(as.matrix(percentsTable6), las=1, bty='n', col=c('gray', '#4BC990', '#48820C', '#896A39', '#2F6142'),
names.arg=c('K', 'J', 'I', 'PuckettCreek', 'ElkinsFork', 'H', 'Crummies', 'Frozen', 'Corbin', 'Valley4', 'DaveBranch'),
xlab='Valley', ylab='Percent of specimens', beside=FALSE)
par(opar) # Reset par
opar = par(oma = c(0,0,0,0), mar = c(0,0,0,2), new = TRUE)
par(opar) # Reset par

#Figure 22
downDip <-speciesPercentslycopsidIndet(logs$stratPosition=='down', percentTrueLycopsid=percentTrueLycopsid)
midDip <-speciesPercentslycopsidIndet(logs$stratPosition=='mid', percentTrueLycopsid=percentTrueLycopsid)
upDip <-speciesPercentslycopsidIndet(logs$stratPosition=='up', percentTrueLycopsid=percentTrueLycopsid)
percentsTable7 <- data.frame(downDip, midDip, upDip)
```

```
percentsTable7


dev.new()
opar = par(oma = c(0,0,0,9))#Large right margin for plot
barplot(as.matrix(percentsTable7), width=c(0.1, 0.1, 0.1), space=c(0.1, 0.1, 0.1), las=1, bty='n', col=c('gray',
'#4BC990', '#48820C', '#896A39', '#2F6142'), names.arg=c('Down-dip', 'Mid-dip', 'Up-dip'), xlab='Valley position',
ylab='Percent of specimens', beside=FALSE)
par(opar) # Reset par
opar = par(oma = c(0,0,0,0), mar = c(0,0,0,2), new = TRUE)
par(opar)


#Table 3: percent abundance for results table
logs <- read.table(file='countData.csv', header=TRUE, sep=',')
logs <- logs[-grep("\\?", logs$Valley), ]
Calamites <-sum(logs[ ,c('CalamitesSp', 'CalamitesSuckowi', 'CalamitesCisti', 'CalamitesUndulatus')])
        Lycopsid <- sum(logs[ ,c('unidentifiableLycopsid')])
        Artisia <-sum(logs[ ,c('ArtisiaIrregularis')])
        Unknown <-sum(logs[ ,c('Unknown')])
        Calamites <- sum(logs[ ,c('CalamitesSp', 'CalamitesSuckowi', 'CalamitesCisti', 'CalamitesUndulatus')])
        Diaphorodendron <- sum(logs[ ,c('DiaphorodendronSp')])
        Stigmaria <- sum(logs[ ,c('StigmariaFicoides')])
        Lepidophloios <- sum(logs[ ,c('LepidophloiosSp')])
        Lepidodendron <- sum(logs[ ,c('LepidodendronSp', 'LepidodendronAculeatum')])
        Sigillaria <- sum(logs[ ,c('SigillariaBrardi', 'SigillariaBrogniart','SigillariaSp')])
        Other <- sum(logs[ ,c('DiaphorodendronSp', 'StigmariaFicoides', 'LepidophloiosSp', 'LepidodendronSp',
'LepidodendronAculeatum', 'SigillariaBrardi', 'SigillariaBrogniart','SigillariaSp')])
        total <- Calamites + Lycopsid + Artisia + Unknown + Other
```

```
percents <- c(Lycopsid/total*100, Artisia/total*100, Unknown/total*100, Calamites/total*100, Diaphorodendron/total*100, Stigmaria/total*100, Lepidophloios/total*100, Lepidodendron/total*100, Sigillaria/total*100)
percent
```