A STUDY OF THE FLORA IN MISSISSIPPIAN ROCKS OF SOUTHWESTERN MONTANA

Renee Breedlove, McNair Scholar
Dr. Michael Pope, Faculty Mentor
Department of Geology

ABSTRACT

The Late Mississippian (~330 Ma) was a period of global climate change. During this period southwest Montana was near the equator, and records reveal shoreline deposition along the margin of a foreland basin. The Mississippian plant genera Lepidodendron, Calamites, Lepidophylloides, Cordaites, Lepidophloios, and Trigonocarpus occur in a siltstone unit (Kibbey Formation) near Clark Canyon Reservoir, Montana. Calamites spores were deposited in the Big Sheep Creek section, Montana. Gastropods and bivalves fed on suspended or buried flora also occur with the plant remnants. The results of this study show that Mississippian flora was very primitive and grew in a humid, waterlogged, tropical setting.

INTRODUCTION

Late Mississippian (Chesterian) sedimentary rocks were deposited between 315-335 million years ago in southwestern Montana and east-central Idaho (Rhode, 2004). During this period, the South Pole was covered by large continental ice sheets that stretched to 45º south (see Figure 1) indicating Chesterian global climate was generally cooler than today. Early Mississippian global average temperatures were near 19-20° C (60-65° F) with carbon dioxide concentrations near 1500 ppm (see Figure 2). In the Late Mississippian-Early Pennsylvanian, there was a general global cooling with average global temperatures falling to 12° C (54° F) coinciding with a drop in carbon dioxide concentration to approximately 350 ppm (Hieb, 2003).

Many of the Early Carboniferous (Mississippian) plants in the central United States lacked growth rings, suggesting a uniformly tropical to mildly temperate, humid climate along the paleoequator (Hoe et al., 2004). The study area in southwestern Montana was within 15º north or south of this paleoequator, implying that it was one of the warmest areas on the planet at that time and that warm plants should have lived in the study area rather than cool, dry regions. Thus, Chesterian plant fossils and spores in this area were sampled and identified to determine the climate and paleogeography during the deposition of these rocks.

REGIONAL SETTING

A foreland basin formed in the Idaho and Montana region during the Devonian-Mississippian Antler Orogeny along western Laurentia. The eastern shoreline of this basin, currently in southwest Montana, is comprised of shallow-water mixed siliciclastic and carbonate rocks that were deposited on a gently dipping carbonate ramp. Southwestern Montana lies along the edge of the foreland basin paleoshoreline and a deep water Montana trough that transected the basin (Figures 3 and 4). The stratigraphic sequences in this area indicate that the oceans fluctuated throughout the Chesterian period.

1 We would like to thank Dr. Peter Isaacson, Dr. Bill Rember, and Liselle Batt from the University of Idaho for their contributions and assistance during this study.
Figure 1: Continental configurations during the Mississippian to Pennsylvanian Period (Scotese, 2002). Note the change in the size of the continental ice sheets and the resulting increase in the size of the arid zones. The study area is shown with a red star.

LOCATION

Six stratigraphic sections (Figure 5) of the Upper Mississippian strata in southwestern Montana (Bell Canyon, within the Tendoy Mountains, Big Sheep Creek, Conover Ranch, Railroad Canyon, Logan Amsden, and Clark Canyon), were measured and sampled for plant fossils and spores. The sections were measured in detail at a bed-by-bed scale. The units containing the plant fossils, however, are recessive so recovery of fossils was difficult.

In Bell Canyon of the Tendoy Mountains, southwest of the Clark Canyon Reservoir, plant fossils occur in the Upper Mississippian Kibbey Sandstone (Sando et al., 1985). Correlative units are well exposed in the Tendoy Range in Big Sheep Creek and at Clark Canyon, north of Bell Canyon. The samples from Clark Canyon and Bell Canyon did not contain any spores from the Mississippian Period. The Big Sheep Creek section contained Calamites spores.

The Conover Ranch Formation in the Blacktail Mountains southeast of Dillon includes a large outcrop that is age equivalent to the Kibbey Sandstone. Specimens were collected from this unit for spores, however none were recovered. Also, an organic-rich layer of shale near Logan,
Montana is part of the Amsden Group, is an up dip equivalent to the Kibbey Sandstone and Conover Ranch Formation, contains monolete spores, but they were too nondescript to identify accurately.

Figure 2: Atmospheric CO2 concentrations (black line) and average global temperatures (blue line) from the Phanerozoic. The interval of this study area (335-315 million years ago) is outlined and occurs during a steep drop in global temperatures (Hieb, 2003).

Figure 3: Study area (blue box) shown with Big Snowy Trough and Antler Foreland Basin. Note the location of southwestern Montana.
Figure 4: Cross-section of study area showing Antler Orogeny, foreland basin, and paleoshoreline. The green star marks where the Kibbey Sandstone formed.

Figure 5: Mountain Ranges of interest in southwest Montana (Wardlaw, 1985). Notice Bell Canyon and Clark Canyon in the Tendoy Mountains, Railroad Canyon in the Beaverhead Range, Big Sheep Creek and Conover Ranch in the Blacktail Mountains.

Palynology samples at the type section for the Railroad Canyon Formation in the Beaverhead Mountain Range also were collected. These samples occurred in dark, organic layers of platy shale. The palynology results showed that the samples here were slightly metamorphosed and no spores were recovered.
Kibbey Sandstone

The Kibbey Sandstone (Figure 6) was the only rock unit containing plant fossils in the study area. It was locally a good unit for plant preservation because it was deposited near the shoreline and had deposition rates high enough to bury the plant debris before they were oxidized. Plant fossils were only located in the Bell Canyon area. The Kibbey Sandstone is Upper Mississippian and is laterally age equivalent to the Amsden Formation and the Snowcrest Range Group. It unconformably overlies the Madison Group and grades upward into the Lombard Limestone. The Kibbey Formation is a recessive layer (Byrne, 1986) that was deposited during a long-term transgression (Figure 7). The Kibbey Sandstone records the near-shore, shallow-water embayment deposition along the margin of the eastward transgressing Big Snowy Sea (Byrne, 1986; Sando, et al., 1975; Sando 1976).

![Figure 6: Outcrop of Kibbey Sandstone where plant fossils were found in the Bell Canyon location, Tendoy Mountains.](image)

![Figure 7: Correlation chart of the Upper Mississippian units in southwestern-south central Montana. The Kibbey Sandstone (inside red box) youngs to the east and marks a long term transgression. Notice the sea level rise and fall during this time.](image)
Symmetrical, straight-crested ripples (Figure 8) oriented at 310° occur with the fossils. These ripples, with wavelengths of 4 cm and heights of 1.5 cm, are indicative of shallow to intertidal waters. Fine-grained sediments with high organic content and low oxidation were sampled for plant remains.

![Kibbey Sandstone paleocurrent sample found with the plant fossils with a wavelength of 4 cm and a height of 1.5 cm.](image)

**Figure 8:** Kibbey Sandstone paleocurrent sample found with the plant fossils with a wavelength of 4 cm and a height of 1.5 cm.

**PLANT FOSSILS AND PALYNOLOGY SPECIMENS**

**Techniques**

Late Mississippian plant fossils were collected from the Kibbey Sandstone and transported back to Washington State University and University of Idaho for further preparation and identification. These rocks were split, cleaned, and the fossils were identified under a binocular microscope.

Samples that potentially contained ancient spores also were collected in an attempt to provide additional information about the plant community that lived in this area and its paleoclimate. Unoxidized samples containing organic material were studied for spores. These samples were crushed into small pieces and weighed in the initial preparation. 18 grams of sample were placed into two tubes, along with 25 ml of HCl and left to react for 48 hours to dissolve any carbonate. Once the carbonate was dissolved, the samples were rinsed thoroughly and centrifuged. To dissolve the clay that remained in the tube, 20 ml of HF was added to the sample and left to react for 48 hours. The test tubes containing HF were placed in a water bath so they remained at room temperature. The samples were then rinsed and centrifuged in a similar manner as the HCl. An additional 30 grams of HCl (mixed at a ratio of 50:50) was applied to the samples which were placed in a boiling water bath, and then rinsed again. The sample remaining after these dissolution processes were spores, macrofossils, and organic material which was examined by plane light petrographically on a thin section.

**Mississippian Plants**

The plants that grew during the Mississippian Period (Figures 9 and 10) were lycopods, calamites, seed ferns (*pteridosperms*), cordaites, and true ferns (Tidwell, 1998). The lycopods were treelike plants that usually grew in fresh or brackish swamps. They were the largest plants at that time growing to heights of more than 20 meters and had trunks up to 2 meters in diameter.
The arborescent lycopods are widely believed to have descended from Late Silurian and Early Devonian Zosterophylls (Jennings, 1990). Many of these plants became extinct in the Pennsylvanian period (Hieb, 2003).

Figure 9: Evolution of the Mississippian Plants. In the yellow box, Sphenopsids (Calamites), True Ferns, Seed Ferns, Cordaites, and Lycopods are shown (Stanley, 1999).

The Calamites were conifers with many varieties in the Carboniferous; however, only two genera are known in the western US, the Calamostachys and the Paleostachya (Tidwell, 1998). Like the lycopods, Calamites also were spore-bearing plants that grew as tall as modern-day trees. They are relatives to living horsetails or scouring rushes and lived in moist areas commonly with standing-water (Gore, 1999). The cordaites were gymnosperms that grew as large trees and shrub-like plants and have very characteristic long, strap-like leaves. The two types of ferns, seed and true, are difficult to distinguish from each other based on foliage. The main difference between the two is in the way they reproduced. The cordaite and fern plants were abundant on higher ground.

Trees the same size as the Lepidodendron were supported by a thick periderm similar to modern day bark. A soft, pith-like tissue was enclosed in this bark, as the trunks contained very little secondary wood (Taggart, 2004). The tissue inside the trunk had internal cells that had to be fully expanded with abundant water or the trees would buckle under their own weight. Thus, these plants were unable to grow far away from nearby water sources.

These five groups of Mississippian plants occur in select parts of the western US. Not much is known about the western United States Mississippian floras because an extensive study of these formations has yet to occur and because thick sequences of marine sediments were deposited in the seas; thus, plants were only locally deposited along their shores. Globally, Paleozoic plants were more uniform than floras at any other time due to the well-defined climatic zones at this time (Tidwell, 1998). Their annual growth rings indicate little fluctuation in humidity and droughts in each zone.
Figure 10: All pictures taken of fossils from Bell Canyon have a centimeter scale. A: Representation of plant showing Lepidophylloides, a name assigned to the leaves of the Lepidodendron Tree (Hoe, 2004). B and C: Lepidophylloides, showing the end of a branch with leaves attached. D: Picture of a similar fossil found in a West Virginia shale unit (Hieb, 2003). E: Leaves of Lepido¬dendron plant for comparison (Hoe, 2004). F, G and H: Branches of the Lepidodendron tree. I: Cross-sectional view of a branch of Lepidodendron from the Kibbey Sandstone. J and K: Pictures for comparison from the Kanawha Formation (Hieb, 2003). L: Picture of reconstructed Lepidodendron tree (Hieb, 2003).
Figure 10 (continued): M: Lepidostrobus, a cone of the Lepidodendron Tree N: Cone from the Kanawha Formation for comparison (Hieb, 2003). O and P: Lepidodendron leaf cushions from Bell Canyon Location. Q: Picture of leaf cushions also found in the Kanawha Formation (Hieb, 2003). R: Bark of a Lepidophloios tree. This tree differs from the Lepidodendron by the shape of the leaf cushions. S: Cross-section of a modified leaf that made the diamond-shaped impressions on the bark. T: Picture for comparison of Lepidophloios (Kidston). U: Leaves of Lepidodendron from study site. V and W: Pictures for reference of Lepidophylloides (Hieb, 2003).
Figure 10 (continued): X: Cordaites stem that occurs in southwestern Montana. Y: Stem for comparison (Hieb, 2003). Z: Representation of a cordaite tree (Hoe, 2004). AA: Representation of the calamites tree (Hoe, 2004). BB and CC: Calamites Leaves. DD: Calamites Stem with joint exposed. EE: A similar plant found also showing stem structure of Calamites (Hoe, 2004). FF: Trigonocarpus, a seed from unknown foliage from southwestern Montana. GG: To compare, this is the same seed from another location. HH: Neuropteris, a seed fern that trigonocarpus has been associated with. II: Alethopteris, another seed fern that trigonocarpus may have belonged to (Glasgow).
RESULTS

Pieces of bark of a lycopod, *Lepidodendron*, occur in the Kibbey Sandstone at Bell Canyon (Figure 10). The diamond-shaped bark impressions from the leaf scars are characteristic of this plant. The individual leaves that made these scars also occurred in the sandstone unit. *Lepidophylloides*, the leaves of *Lepidodendron*, occur with *Lepidophloios*, a lycopod similar to *Lepidodendron*. The *Lepidophylloides* were found attached to branches and detached to the plant, lying haphazardly in the sandstone. The long, grass-like *Lepidophylloides* are thought to have covered the entire plant, not just the terminal part of the branches (Taggart, 2004). Also, a cross-section of a piece of bark with leaves still attached occurs in the Kibbey Formation.

Stems and leaves of a calamites plant occur with the *Lepidodendron*. The branches have vertical ribs that run perpendicular to the joints with slender leaves radiating off of the joints (Figure 10). The leaves look similar to the *Lepidodendron* leaves and are difficult to distinguish unless attached to the plants’ stem. Also, a seed with a length of 6 cm and a width of 2 cm from an unknown group of plants, called *Trigonocarpus*, occur with the plant fossils. This seed likely came from *Medullosa*, either *Neuropteris* or *Alethopteris*, a seed fern (Tidwell, 1998; Hoe, 2004). Also, cordaites stems occur in the Kibbey Sandstone. A distinguishing characteristic of these stems are ribs oriented perpendicular to the width of the stem.

Spores

Pollen did not evolve until the Pennsylvanian Period so none occurs in the rocks of the study area. However, there were many spores in these Mississippian rocks. The *Lepidodendron* spore occurred as a type of trilete spore which developed in tetrahedral-shaped bundles (Rember, 2004). The calamites, cordaites, and true fern spores occurred in two forms, monolete and trilete. Spores are very tough and can withstand a number of diagenetic processes which is why they survive deposition hundreds of millions years ago.

Spores occur in the Conover Ranch, Logan Amsden, Big Sheep Creek, and Railroad Canyon samples. The spores were nondescript so the plants cannot be determined precisely, however, the tentative identifications are: *Camptotriletes paprothii*, *Convolutispora ampla*, *Pulvinispora scolephora*, and *Pustulatisporites sp* (Rember, 2004). Some of these samples were contaminated by modern day pollen, but only fossilized Mississippian spores were identified. Some monolete inapertuate spores from calamites occur in the Big Sheep Creek section.

Fauna

Two organisms, *Aviculopecten* and *Straparollus sp*., occur with the plant fossils (Figure 11). *Aviculopecten* is a free lying bivalve that lived as a suspension feeder. *Straparollus sp* was a gastropod that lived as a deposit feeder in the intertidal zone. *Straparollus* lived in very muddy environments so it must have been transported to its depositional site (Isaacson, 2004). Both of these species fed off of the organic plant matter that was transported into this depositional setting.

Paleoclimate and Paleogeography

The ancient flora and fauna of the Kibbey Sandstone suggest a number of things about the paleoenvironment during deposition. The plant fragments are allochthonous and were likely transported by rivers to this near-shore setting. The plants that relied on moist environments probably lived near rivers and the shoreline. Taller plants (e.g. Cordaites) may have lived in both drier and moister environments (Gensel, 2001).

Evidence of the inner pith-like material of large trees suggests the plants were only adapted to live around water filled environments and thus only grew along the Mississippian Antler Orogeny shoreline (Taggart, 2004). The structure of the trees could not support themselves away from this
water resource and they would collapse under their own weight. The plants that lived the farthest away from the water are in descending order: cordaites, ferns (true and seed), lycopods, and calamites. The cordaites and some fern varieties likely grew in areas with low hills near water sources, the lycopods lived in moist areas such as deltas and estuaries, and the calamites and other fern varieties lived in standing water environments (e.g. swamps).

The limited area in which the plants were deposited could indicate an area of greater local subsidence. The study area likely contained variable paleotopography (Figure 12) which existed prior to and during early Kibbey deposition (Byrne, 1986). The plant communities in conjunction with physical characteristics of these rocks indicate that the paleoclimate of southwestern Montana during the Chesterian was humid and subtropical with abundant standing water.

Figure 11: A. Aviculopecten, a bivalve that was found next to the plant fossils. B. Straparollus sp., also found in the Kibbey Sandstone

Figure 12: Representation of the near-shore paleogeography the study area in the Mississippian Period. Notice U: Shoreline margin vegetation including calamites, true ferns and seed ferns, P: Lycopod and true fern dominated vegetation in the hilly to low land environments, K: Cordaites dominated vegetation in the higher to low environments, and Si: Calamites in standing water (Meier, 2002).
CONCLUSION

The Late Mississippian was a period of global climate transition from a greenhouse in the Early Mississippian toward the Pennsylvanian icehouse. Upper Mississippian shoreline terrestrial sedimentary rocks in southwestern Montana formed during the Antler Orogeny. The area of southwest Montana was a shoreline of an active basin that records large eustatic fluctuations due to the development of continental glaciers. The primitive flora and fauna in the Kibbey Sandstone (*Lepidodendron, Calamites, Lepidophyloides, Cordaites, Lepidophloios, and Trigonocarpus*) indicate a warm humid environment during deposition. The plants were deposited along an ocean shoreline where *Aviculopecten* and *Straparollus* lived off their remnants.

REFERENCES

