AN ABSTRACT OF THE THESIS OF

Randol L. Wehrbein for the Master of Science degree in Physical Science, Earth Science Concentration presented on March 28, 2017.

Title: Comparisons of Paleoenvironments, Taxa, and Taphonomy of the Late Carboniferous Garnett and Hamilton Quarry Localities, Eastern Kansas

Thesis Chair: Michael Morales

Approved: Michael Morales

Abstract

The Garnett and Hamilton Quarry fossil localities of Kansas represent one of the most comprehensive windows into nearshore terrestrial paleoecosystems of the Late Carboniferous, approximately 299-306 million years ago. Both localities contain exceptionally preserved flora, invertebrate, and vertebrate fossils. When rare comparisons are made between the two localities, it is typically done by investigating only one aspect. The goal of this project was to make direct comparisons between Garnet and the younger Hamilton locality, based on the paleoenviroments, fossil taxa, and taphonomy to gain a better understanding of how the two localities are similar and different.

The paleoenvironment of Garnett is interpreted as an estuary/lagoon shore constrained to a channel during a transgression, whereas Hamilton is interpreted as a stream channel that grades into an estuary that terminates in a sediment lobe.

Garnett and Hamilton each have a total of 126 taxa each, of which only two species and 17 genera are found at both localities. In general, both Garnett and Hamilton

Quarry are similar taphonomically; however, Hamilton has the uniqueness of soft tissue preservation. Garnett and Hamilton have similar faunal and floral communities but with differences in the specific taxa present and in the dominant taxa. Garnet has a coelacanth and three taxa of sharks, whereas Hamilton's fish fauna is richer, including not only a coelacanth and five shark taxa but also an acathodian, two palaeonisciforms, a rhipidistian, and two lungfish. Both Garnet and Hamilton have diapsid and synapsid tetrapods. Garnet has the oldest known diapsid, *Petrolacosaurus kansensis*, whereas Hamilton has a derived form, *Spinoaequalis schultzei*, as expected given their relative stratigraphic positions. In surprising contrast, Hamilton has the more primitive synapsids and Garnet the more advanced forms. The dominate plant life at Garnett is seed ferns, whereas at Hamilton it is conifers.

Keywords: earth science, geology, paleontology, Hamilton Quarry, Garnett

Comparisons of Paleoenvironments, Taxa, and Taphonomy of the

Late Carboniferous Garnett and Hamilton Quarry Localities, Eastern Kansas

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Committee Member

Committee Member

Committee Member

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Chapter 1: Introduction and History of Study

Introduction

The Garnett and Hamilton Quarry fossil localities of eastern Kansas (Figure 1) represent one of the most comprehensive windows to the terrestrial paleoecosystems of the Late Pennsylvanian. Both localities contain exceptionally preserved flora as well as invertebrate and vertebrate fossils within well bounded rock units. The Garnett locality is the older, representing the end Missourian Age to early Virgilian Age (303-306 mya), while the Hamilton Quarry locality represents the middle to late Virgilian Age (299-303 mya), thus allowing a view into the evolution of these paleoecosystems over a relatively short period of time. While multiple papers have been published on each locality, no research has looked into how the entirety of both paleoecosystems relate.

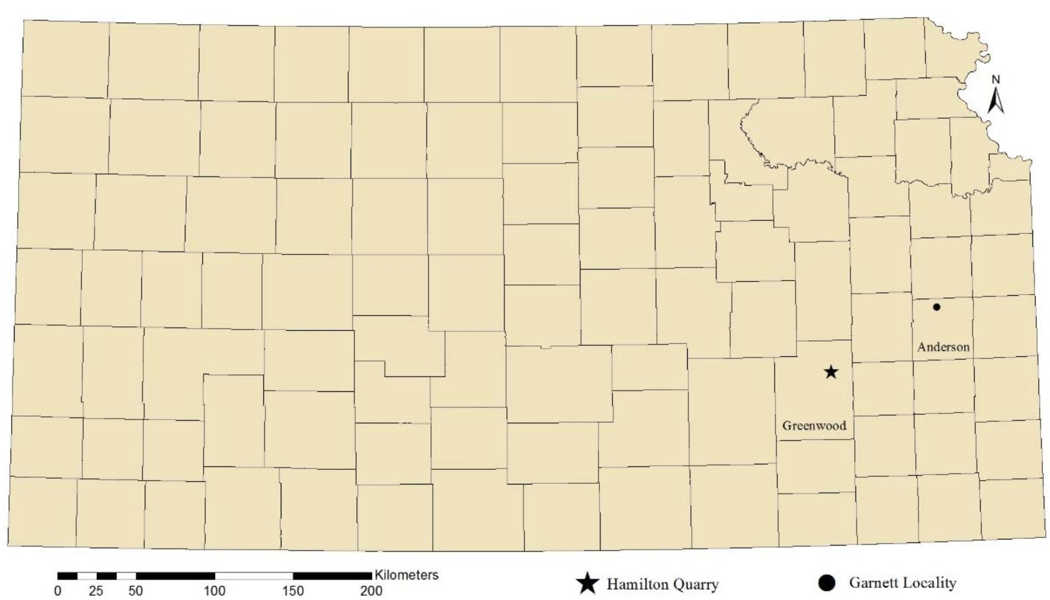

Figure 1: Map of Kansas illustrating the geographic locations of the Garnett and Hamilton Quarry fossil localities. Kansas counties shapefile from Kansas DASC (2016).

While both Garnett and Hamilton Quarry localities contain similar fossil assemblages, these localities are rarely compared to each other. Instead, comparisons are made to other Late Carboniferous/Pennsylvanian age fossil assemblages found globally, such as those described below in the Global Comparison section. When comparisons between the Garnett and Hamilton Quarry assemblages have been made, the focus has tended to be on animal fossil diversity (Maples and Schultze, 1988; Schultze, 1995), one animal group (Schultze and Chron 1988; Kissler and Reisz, 2004), and paleoenvironment interpretations for each locality independently (Schultze, 1995). Whereas, the flora has largely been ignored.

The purpose of this study is to examine all published and unpublished data on Garnett and Hamilton Quarry localities for a taxonomic comparison of the two and for paleoenvironmental interpretations to see if environment affected what biota was present. Primary focus was on the taxa found at these localities to determine if and how the biota changed over time. In addition, stratigraphic and taphonomic comparisons were made to determine the best interpretation of the paleoenvironment in which each biota has been preserved. Combined, these avenues of study can give a preliminary view of how the Late Pennsylvanian terrestrial paleoecosystems of Kansas changed over the approximately 1 to 7 million-year period.

History of Study

"A beginning is a very delicate time." – Frank Herbert's *Dune*

This section provides an overview of the history and major points of study for both the Garnett and Hamilton Quarry fossil localities. The geology and paleontology of both are discussed in greater detail in Chapter 3 for Garnett and Chapter 4 for Hamilton Quarry.

Garnett Locality

The Garnett fossil locality was discovered in 1931 by Norman D. Newell, who described it as a shale layer that contained “Permian” flora in association with both marine and terrestrial invertebrates and vertebrates (Moore et al., 1936). The first publication was an abstract by Maxim K. Elias in 1932, which noted that a fossiliferous shale was overlying the Stanton Limestone and was located directly above an unconformity marking the base of the Virgil series [*sic*]. At the time of publication the geologic setting was not fully understood and would not be published until 1936. Additionally, Elias (1932) suggested that fossils in the fossiliferous shale represented a conifer forest that was near the Pennsylvanian sea. In March 1933, two papers were published describing fauna from the locality. The first was by Claude W. Hibbard describing two new species of coelacanth fish, later revised by Echols (1963), from the Rock Lake Shale Member of the Stanton Limestone Formation. The second was by F.M. Carpenter describing a new megasecopteron; however, the geologic setting of this discovery was ignored. The full description of the Garnett fossil locality was then published in 1936, with coauthors Raymond C. Moore, Elias, and Newell each describing one aspect of the locality.

Moore described the geologic setting, emphasizing that although the flora suggested a Permian age, the Pennsylvanian-Permian boundary in Kansas defined by geologic and paleontologic characteristics and the geology at the locality clearly indicated a Pennsylvanian age within the Missouri series [*sic*]. Additionally, Figure 4 of

Moore et al., (1936) (Figure 2) illustrated the two possible Permian depositional scenarios, with the first showing horizontal deposition and the second showing channel deposition. Moore indicated that local geology did not support either scenario; if the Permian deposition was true, then both the Virgil and Missouri series would be of Permian age.

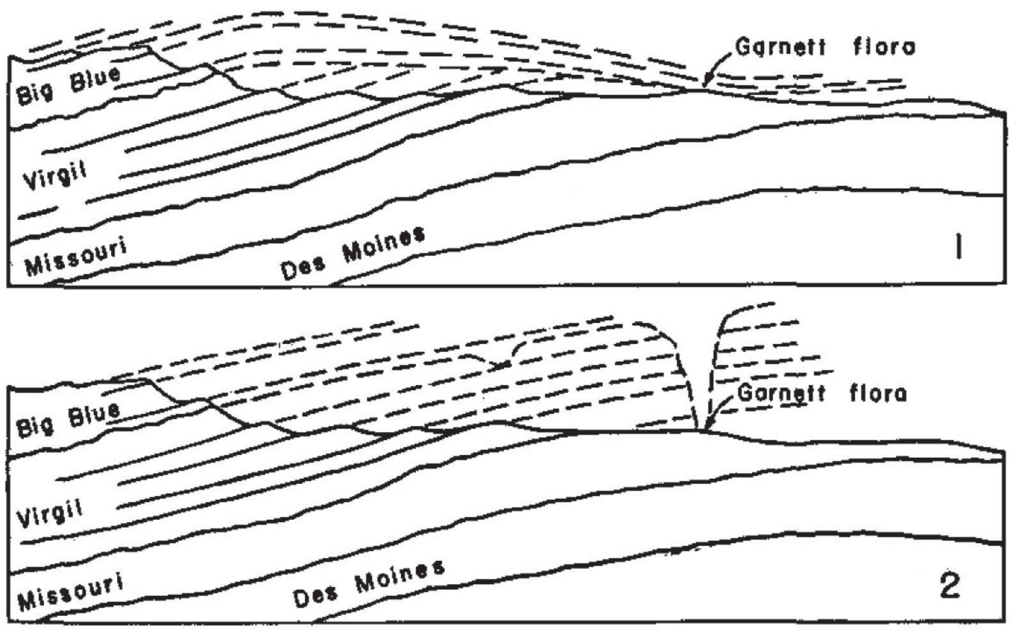

Figure 2: Moore et al. (1936)'s Figure 4 showing hypothetical stratigraphic and structural relationships required for Garnett to be Permian. The top (1) illustration shows massive erosion followed by deposition of Big Blue only to be totally eroded except for the Garnett locality. The bottom (2) illustration shows a possible channel cutting thought the Virgil strata at time of Big Blue deposition, followed by the total erosion of all cut-through strata only leaving the Garnett locality.

Elias focused on the flora, listing a total of 38 species including 20 new species. Elias noted that *Walchia,* which was considered only Permian at the time, was the most abundant; however, both *Neuropteris* and *Sphenopteris,* both known only from the Middle Pennsylvanian, were also present. This, combined with Hibbard (1933) and

Carpenter (1933) taxon descriptions, supported the Pennsylvanian age of the locality. Furthermore, Elias (Moore et al., 1936) identified that the majority of the plants were gymnosperms, suggesting the soil was either dry or well drained. Additionally, Elias identified (Figure 8 no. 11 in Moore et al., 1936) a new genus and species of scorpion, with description published the next year (Elias, 1937) and later revised by Petrunkevith (1953).

Newell described the stratigraphy of the locality, with the initial identification of the fossiliferous shale as the Victory Junction Shale member, of the Stanton Limestone formation, of the Lansing Group, Missourian Stage of the Pennsylvanian System (Moore et al., 1936). Newell also performed a localized correlation of the Stanton Limestone formation based on invertebrate fossils found in the uppermost member, Little Kaw Limestone, which sits directly above the Victory Junction Shale. Newell concluded the correlation supported the Pennsylvanian age and identification as the Victory Junction shale. Additionally, Newell listed the invertebrates found within the *Walchia*-bearing layers. Moore (1936) noted that the members of the Stanton Limestone Formation could be the same as those found in Nebraska, thus equivalating the Victory Junction Shale to the Rock Lake Shale.

In 1940, Carpenter published a description of a second megasecopteron and identification of a third. In 1941, Henry N. Andrews published the first description of one of Elias' new flora species, *Dichophyllum moorie*, later synonymized with *Callipteris flabellifera* as a new variety, *moorei*, by Winston (1983). In 1943, Condra and Reed published a comprehensive stratigraphy of Nebraska in which they noted that the Stanton Limestone Formation had already been described and members named; however, in 1932

Newell ignored convention and renamed the members in Kansas. Additionally, Condra and Reed indicated that the Kansas members closely resembled the original members from Nebraska; therefore, they concluded that the original names were valid. In 1944 Moore et al. produced a correlation of all Pennsylvanian formations of North America, thus synonymizing the Victory Junction Shale with the Rock Lake Shale. In 1945, H.H. Lane described two new genera and species of advanced diapsid reptiles, later revised by Peabody (1952) into one genus and species of *Petrolacosaurus kansensis*, the description of which was later revised by Reisz (1981). Peabody (1952) also published the first comprehensive list of all taxa found at Garnett as part of his interpretation of the environment. He interpreted the depositional environment as either a river-fed lagoon that was cut off from the sea or an embayment based on the presence of both terrestrial and "fluvial" organisms. The bivales identified by Newell (in Moore et al., 1936) were commonly known elsewhere from brackish water, and Elias' scorpion was found in the same surface as bryozoans. Specimens of *Petrolacosaurus* were found in association with *Walchia*, while one specimen of the reptile was found with a crinoid stem segment, bryozoans, and bivalves, which suggested a marine influenced setting. Additionally, specimens of *Walchia* were found with a coelacanth fish pressed into the branches on the same surface as megasecopterons. Furthermore, Peabody noted that *Petrolacosaurus* lacked aquatic adaptations and that most specimens were found articulated. All these factors suggested a low energy environment that was near the shore but protected from the sea.

In 1954, Baxter and Hartman revisited Elias' (in Moore et al., 1936) floral list and noted that most of the identifications were only preliminary and only one description had been published; therefore, Elias' new species identifications in his list were invalid. In 1957, Peabody described the first pelycosaur from Garnett, *Edaphosaurus erordi*, later revised by Reisz et al. (1982) to *Xyrospondylus erordi*. In 1958, Peabody described the first amphibian from the locality, *Hesperherpeton garnettense*, the description was later expanded on by Eaton and Stewart (1960). In 1963, Cridland et al. published a comprehensive list, at the time, of Pennsylvanian plants found in Kansas, during which it was discovered that the majority of Elias' flora specimens were missing. Cridland and Morris (1963) estimated Elias' flora martial was lost before the University of Kansas Botany Department became the collection repository. In 1969, Gupta and Boozer studied the microflora (spores and pollen) from the locality. They identified 47 species, including 18 new ones. Two of the 47 species identified were previously known only from Permian aged strata. In 1973, Eaton described a new genus and species of temnospondyl amphibian, *Actiobatis peabodyi*. In 1977, Currie described the first sphenacodontian pelycosaur from Garnett, *Haptodus garnettensis*, later revised by Laurin (1993) and further revised and split into three genera and species by Splinder (2015), *Euhaptodus garnettensis*, *Kenomagnathus scotti, and Tenuacaptor reiszi.*

In 1982, Reisz et al. reinterred the depositional environment of Garnett. They noted that Peabody had discovered vertebrate trackways in mudflats during his 1953 and 1954 field seasons but died before he could revise the depositional environment. They also noted that during their own 1980 and 1981 field season they discovered several depressions in the Stoner Limestone that are filled in by the Rock Lake Shale, which were interpreted to represent either shallow stream valleys or erosion channels that trend to the north-northeast. Reisz et al. (1982) divided the Rock Lake Shale into three distinct fossil zones.

The first zone sits directly above the Stoner Limestone and is capped by a pelecypod layer. This zone is composed of a well bedded carbonaceous/calcareous mudstone which contains an abundance of terrestrial flora and vertebrate fauna. Except for the capping pelycepod layer, invertebrate fossils are scarce and consist of fragments of marine invertebrates, interpreted to have been reworked from the Stoner Limestone.

The second zone is above the pelecypod layer and is capped by a calcarenite layer. This zone is composed of thinly laminated calcareous claystone that becomes irregularly laminated upwards and desiccation cracks found throughout, mostly near the top of the zone. Fossils of terrestrial plants, invertebrates, and vertebrates are common in the lower part and become rare moving upward. Furthermore, fragments of marine invertebrates are also found in the lower part, with well preserved brachiopods found near the top. Few terrestrial vertebrate trackways are found in the lower part but become more common near the top of the zone.

The third zone sits above the calcarenite layer and is capped by the South Bend Limestone. This zone is composed of a well laminated clayey limestone that shows partial bioturbation. Fossils of marine invertebrates are abundant whereas terrestrial plants are rare and terrestrial vertebrates are absent. Reisz et al. (1982) interpreted this to indicate that the Rock Lake Shale started to be deposited during a seaward regression with the upper part deposited at the start of the South Bend transgression. In 1983, Winston redescribed the flora from Garnett using material collected during the same 1980 and 1981 field season as Reisz et al. (1982). Winston identified 20 species of megaflora, synonymizing many of which Elias (1936) had previously interpreted as new species. Winston also identified 20 known species of microflora, 16 of which had not been previously reported from Garnett. In 1984, Winston redescribed *Lebachia garnettensis* as *Walchia garnettensis* due to the rejection of *Lebachia* as a valid genus. Also in 1984, Woodruff produced an unpublished thesis detailing the stratigraphy, lithology, and depositional environment of Garnett. In 1985, Reisz and Burman described a second edaphosaurid pelycosaur, *Ianthasaurus hardestii*, later revised by Mazierski and Reisz (2010) to *I. hardestiorum*.

In 1988, a Kansas Geological Survey guidebook about the recently discovered Hamilton Quarry fossil locality was published. Several of the guidebook's papers make comparison between Garnett and Hamilton Quarry. Foreman and Martin (1988) produced an updated list of vertebrates found at Garnett and identified two types of terrestrial vertebrate trackways. Rothwell and Mapes (1988) compared conifers found at both sites. Maples and Schultze (1988) compiled the first comprehensive comparison of invertebrate and vertebrate taxa found at both Hamilton Quarry and Garnett and at six other fossil localities: the Robinson Locality, Mazon Creek as two localities based on lithology, Linton, Montceau-les-Mines, and Nŷřnay. In 1989, Wilson produced an unpublished thesis that described an ophiacodontid pelycosaur from Garnett, *Ophiacodon* beckiae. Although the genus is considered to be a correct identification, it is thought that there is not enough material to warrant a new species. Furthermore, his species is invalid because it has never been published.

In 1990, Reisz published an updated taxa list for Garnett. Reisz emphasized the vertebrates, but also briefly discussed the geologic setting, flora, and invertebrates. In

Cunningham's 1993 dissertation on Hamilton Quarry, a one page comparison to Garnett was made, focusing on Reisz et al.'s (1982) second fossil zone. In 1995 Schultze published a study using only abundances of fossil invertebrates and vertebrates to identify depositional setting. This study included an updated comprehensive list of the fauna. Although ignoring the geology and zonation of the fossil assemblage, he identified Garnett as a marine environment. In 2004, Kissler and Reisz described a second sphenacodontia pelycosaur from Garnett, *Ianthodon schultzei*, with the description later revised by Splinder et al. (2015). Additionally, Kissler and Reisz made comparison to other fossil assemblages containing amniotes for a phylogenetic analysis. In 2015, Splinder produced an unpublished dissertation revising the systematics of Sphenacodontia, in which he redescribed the sphenacodontian originally described by Currie (1977) and broke out two new genera and species with descriptions of both, as noted above.

Hamilton Quarry

Hamilton Quarry was discovered in 1964 by amateur fossil collector Walter Lockard while out walking an abandoned quarry in Greenwood County, Kansas (Bridge and Mapes, 1988). At the time Lockard had picked up limestone samples that contained what he thought was a fossilized fish, and he contacted paleobotanist Gil Leisman of Kansas State Teacher College (now Emporia State University, or ESU) Biology Department for identification. Leisman identified the fossil as a fish but took no further interest (Bridge and Mapes, 1988). In 1969 Thomas Bridge, professor of Geology at Emporia State, met Lockard at the Hamilton High School science fair in which Lockard was displaying the fossil he had collected from the quarry. At that time, Bridge tentatively identified the fossilized fish as an acanthodian and he asked Lockard where the fossil had been collected (Bridge and Mapes, 1988). Bridge was put in contact with the landowner and arranged to study the quarry in the fall of 1969 and most of 1970. The field work produced fossils of acanthodians, amphibians, sharks, and plants (Bridge and Mapes, 1988). During this time Leismen identified several plant specimens as *Walchia*, when compared to those found at the Garnett fossil locality (Bridge and Mapes, 1988). In 1970, Bridge presented the initial findings at the 102nd Annual Meeting of the Kansas Academy of Sciences without an abstract. In 1971, the first publication was an abstract by Leisman describing some of the flora. In 1972, Bridge et al. presented an expanded version of Bridge's (1970) presentation, which brought interest from the University of Kansas, Lawrence (KU), thus starting joint KU-ESU field expeditions to the quarry.

In 1973, Hanson produced an unpublished thesis describing terrestrial invertebrates and discussed a eurypterid that had been discovered. The terrestrial invertebrates included specimens of a euphoberid myriapod, later discussed by Hannibal and Feldmann (1988), and a spider, scorpion, and two cockroaches, later revised by Durden (1988) as one genus. None of Hanson's taxa were new. In addition, Hanson (1973) made the first interpretation of the depositional environment as being either a freshwater stream in which all of Hanson's taxa lived or a delta undergoing transgression. Hanson based those proposed depositional environments on the lithology, flora, and fauna. He noted that the fossils were found in a finely laminated clastic limestone that had an "associated channel conglomerate." *Acanthodes* have been commonly found in stream channel deposits and therefore are thought to be a freshwater fish. The exceptional preservation of both terrestrial invertebrates and plants indicated a low energy environment or that minimal transport had occurred. Few marine invertebrates were found near the top of the exposure in association with *Acanthodes*, and eurypterids were thought to live in brackish environments near the coast (Hanson, 1973).

In 1974, Anderson produced an unpublished thesis describing the eurypterids found at the quarry and produced the first stratigraphic description of the locality. Anderson interpreted the fossiliferous outcrops as belonging to the Calhoun Shale Formation, Shawnee Group, Virgilian Stage, which he divided into 11 units based on lithology and paleontology. In 1976, a special session on Hamilton Quarry was held at the 108^{th} Annual Meeting of the Kansas Academy of Science. At this session Anderson, Bridge, Hanson, and Leisman all presented the updated reports on the material they had previously worked, plus two new topics were addressed. The first was by Daly (1976, 1988), who discussed the first labyrinthodont amphibian from the quarry. Later (1993) she described it as a new genus and species, *Eocopus lockardi*. The second was by Zidek (1976a), who described the *Acanthodes* noting that both adult and juvenile specimens had been recovered and the possibility of two species being present. Also at this meeting but not in the special session, Chorn (1976) presented information about a lungfish tooth plate collected from Hamilton Quarry identified as *Sagenodus*. A month after the meeting, Zidek (1976b) would have the first published paper describing the *Acanthodes* bridgei, a new species, with the possibility of a second new but undescribed species based on one specimen.

Between 1977 and 1986 interest in Hamilton Quarry waned, with a total of one paper, one dissertation, and two abstracts published. In 1981, Mapes had an abstract published about the preservation of conifers in Pennsylvanian strata from the midcontinent of North America which included information about the Hamilton Quarry conifers. Also in 1981, Daly completed her unpublished dissertation describing the labyrinthodont amphibian mentioned above. In 1982, Rothwell published a paper discussing the evolution of early conifers in which he used the as of yet undescribed *Lebachia* found at Hamilton Quarry to represent the Upper Pennsylvanian. In 1984, Mapes and Rothwell published the description of the conifer *Labachia lockardii*, later revised and renamed to *Emporia lockardii* by Mapes and Rothwell (1991, 2003).

In 1988, a special session on the Hamilton Quarry was held at the Geological Society of America South Central Sectional meeting in Lawrence, Kansas, in an attempt to revitalize interest in the Hamilton material (Fahrer, 1990). The Kansas Geological Survey (KGS) oversaw the production of a guidebook about Hamilton Quarry for this meeting. The guidebook contains 35 papers, of which 30 deal with aspects of Hamilton Quarry directly. The majority of these papers represent the first publications on material that had previously only been presented at conferences in the 1970s; however, some new material was also published. Bridge (1988) published the first description of Hamilton Quarry as a paleochannel. Both French et al. (1988) and Busch et al. (1988) noted that the northern and southern ends of the Hamilton Paleochanel had different stratigraphy. Gottfried (1988) described, without naming, a palaeoniscoid fish found at the quarry. He later (1993) revised the description and named a new genus and species in his dissertation, but the species has yet to be formally named in a publication. Maisey (1988) discussed the presences of a hybodont shark found at the quarry, and he later (1989) described it as a new genus and species, *Hamiltonichthys mapesi*. Schultze (1988) described an osteolepidid rhipidistian, but was only able to identify it to possible genus, *Megalichthys*. Reisz (1988) discussed two articulated reptile specimens that possibly represented two new taxa, later described by deBraga and Reisz (1995) as a new genus and species of aeroscelid diapsid reptile, *Spinoaequalis schultzei*. McAllister (1988) described the multiple types of coprolites found at the quarry. Leismen et al. (1988) published the first description of the flora as a whole. Mapes and Rothwell (1998) described the conifers in more detail. Taggart and Ghavidel-Syooki (1988) produced the only palynological study of the Hamilton Quarry. Maples and Schultze (1988) compiled the first comprehensive comparison of invertebrate and vertebrate taxa found at Hamilton Quarry with the Garnett locality and the six other fossil localities mentioned above.

Papers in the guidebook make it clear that there are two points of consensus: first, that Hamilton deposits represent a paleochannel; second, that the age of those deposits is Late Pennsylvanian, based on the fossil taxa. However the depositional environment was highly debated, with two groups arguing different interpretations. The first group (Bridge, 1988; Kues, 1988; Kaesler, 1988; Leisman et al., 1988; Maisey, 1988; Mapes and Maples, 1988; Maples and Mapes, 1988; Taggart and Ghavidle-Syooki, 1988; Zidek, 1988) argued that the deposits were freshwater, again based on the taxa. The second group (Busch et al., 1988; French et al., 1988; Maples and Schultz, 1988; Schultze and Chorn, 1988) argued that the deposits were marine, based on the lithology and presence of marine invertebrates.

In 1989, Gottfried described the presences of preserved pigmentation in the palaeoniscoid fish, *Elonichthys*. In 1990, the Society of Vertebrate Paleontology held their 50th annual meeting in Lawrence, Kansas, and produced a guidebook highlighting four vertebrate fossil localities found in eastern Kansas, with two papers about Hamilton Quarry. The first, by Cunningham (1990b), included a non-comprehensive general list of taxa, a west-to-east stratigraphic column of the Main Quarry area, and early work on the taphonomy of the vertebrates, later expanded into the first part of his dissertation (1993a).

The second paper, by Feldman et al. (1990), detailed the geology of Hamilton Quarry, including the first published image of the whole eight kilometer paleochannel with its north-south trend and the first time the Hamilton deposits were called a Lagerstätte (German for deposit). The term Fossil-Lagerstätte is a special kind of fossil locality that includes either a high abundance of fossils or a high degree of preservation (including soft tissues) or both. Also included were three cross sections of the paleochannel measured near the Main Quarry area and an updated stratigraphic column for the Marlin Quarry area. In 1991, Fahrer produced a thesis determining lateral and vertical bounds of the paleochannel (partially published in Feldman et al., 1990), plus the stratigraphy, depositional environment, and stream flow direction.

In fall of 1991, the Denver Museum of Natural History, now Denver Museum of Nature and Science (DMNS), collected from the Main Quarry area for their Prehistoric Journey exhibit (personal study of the DMNS locality worksheets and maps). This exhibit included a reconstruction of Hamilton Quarry at time of deposition (Chapter 4, Figure 26). Also in the fall, Leonard (1991) filed a KGS open file report detailing ten cores taken along the paleochannel.

In 1993, Cunningham produced a two part dissertation, with the first part focusing on the geology and paleontology of Hamilton Quarry, and the second part describing a new genus and species of captorhinomorph reptile, which he called *Coelothyroids chorni*. However, the taxon was formerly described and named *Concordia cunninghami* by

Müller and Reisz (2005). Later Reisz et al. (2016) re-diagnosed the genus and gave it a new name, *Euconcordia*.

The first part of Cunningham's dissertation was published in four papers. The first paper (Cunningham, 1993b) focused on the interpretation of the depositional environment based on the distribution of invertebrate and vertebrate microfossils found in the Main Quarry area. The second (Cunningham et al., 1993) described the paleochannel deposits as being tidally influenced, based on laminations found in the limestones that are similar to known tidal deposits and to the thickening of the basal conglomerate from north to south. The third paper (Feldman et al., 1993) presented a more condensed version of the tidal influenced environment idea, and this paper also included an in-depth description of how tidal deposits are formed. The fourth (Schultz et al., 1993) described the paleochannel as a marine-estuarine environment based on the distribution of terrestrial, freshwater, and marine taxa. Also included was the first published stratigraphic column showing the paleochannel as a separate deposition from the Calhoun Shale, an updated stratigraphic column of the Main Quarry area, and a paleogeographic reconstruction (Chapter 4, Figure 27) showing terrestrial and marine influences on channel.

In 1994, Archer and Feldman proposed a model for how tidal rhythmites formed, based on Hamilton deposits and those from two other locations. In 1995, Schultze published a study ignoring the geology and using only bulk fossil assemblage to identify the depositional setting. By these parameters, he identified Hamilton Quarry as a marine environment. Additionally, this study included an updated comprehensive list of the fauna only. In 1996, Rothwell et al. published a comparison of Paleozoic conifers from four localities, including Hamilton Quarry and Garnett, based on preservation, structural diversity, and environment of growth. Also in 1996, Cunningham and Dickson III published a study suggesting there was wet-dry seasonal variation based on geology and paleontology at Hamilton Quarry and two other vertebrate fossil localities in Kansas. In 1998, Mapes and Rothwell published a study examining the structures of *Walchia* pollen cones collected from Hamilton Quarry. By the late 1990s, ownership of the Main Quarry area was transferred from the ESU Foundation to the university proper, where it is now managed by the Earth Science Department (Morales, personal communication, 2016).

In 2001, Rothwell and Mapes described a new family, genus, and species of conifer (Bartheliaceae: *Barthelia furcate*) from the Main Quarry area of the Hamilton paleochannel. Also in 2001, Hernandez-Castillo et al. published a review of *Walchia* conifers, which included all conifers at the time found at Hamilton Quarry. In 2003, Hernandez-Castillo et al. published a proposed growth model for *Walchia* conifers. Also in 2003, Reisz and Dilkes described a new genus and species of varanopsid reptile, *Archaeovenator hamiltonensis*. In 2005 two papers describing new taxa and a KGS open file report were published. The first by Rothwell et al. (2005) described a new genus and species of conifer from the Main Quarry area of the Hamilton paleochannel. The second, as mentioned above, by Müller and Reisz (2005) described Cunningham's (1993a) captorhinomorph reptile as a different genus and species (*Euconcordia cunninghami*), later revised by Reisz et al. (2016) due to the genus name being previously occupied. The KGS report filed by Salley et al. (2005) detailed the surface geology of the Main Quarry area, later expanded into Salley's (2007) thesis. In 2009 three papers were published regarding the flora. The first by Hernandez-Castillo et al. (2009c) described a new species of the conifer genus *Emporia* from the Main Quarry area. The second by Hernandez-Castillo et al. (2009b) described a new reconstruction of *Emporia lockardii*. The third by Hernandez-Castillo et al. (2009a) described a third species of the conifer genus *Emporia*. In 2014, Reisz and Fröbisch described a new genus and species of caseid reptile, *Eocsea martini*. In 2015, Leblanc and Reisz published a study on tooth development in captorhinid reptiles using Hamilton Quarry specimens as the basal representative. To date little to no work has been performed in the extreme southern end of the paleochannel.

Global Comparisons

The majority of comparisons that have been made in the past between Garnett and another locality or Hamiliton and another locality have been based on a single aspect of the fossil assemblages, e.g. pelycosaurs. Maples and Schultz (1988) comparison is the most comprehensive in terms of fauna and include the six other localities previously mentioned, i.e., the Robinson Locality in Kansas, Mazon Creek in Illinois as two localities based on lithology, Linton in Ohio, Montceau-les-Mines in France, and Nŷřnay in Czech Republic.

This section summarizes fossil localities around the globe that are of approximately the same age as Garnett and Hamilton Quarry localities. Their paleontology, geological setting, and age have been summarized below. Localities are presented in chronological order from oldest to youngest.

Toronto Locality, North America, Kansas, Greenwood County

The Toronto Locality, described by McElroy (2016), is a 261 cm thick mainly paleosol found in the Snyderville Shale Member of the Oread Limestone Formation, Shawnee Group, Virgilian Stage, Upper Pennsylvanian Series, Pennsylvanian System. Fossils collected included the shark *Orthacanthus*, lungfish *Sagenodus*, two families of amphibians, and two families of “Pelycosauria” [*sic*]. Possible indications of root/burrow casts were also found. No invertebrate or plant material was found. The depositional environment was interpreted to represent a depression within a floodplain. The age is approximately 300 to 303 million-years.

Montceau-les-Mines, France

This locality is considered a Lagerstätte and is found in the Great Seams Formation of the Late Stephanian Stage (= Middle Virgilian Stage), Late Carboniferous Series. Montceau-les-Mines was originally discovered in the 1800’s due to the expansion of coal mining and would not be fully examined until the 1970’s, when overlaying strata were removed for open-pit mining (Perrier and Charbonnier, 2014). Maples and Schultze (1988) interpreted this locality as a freshwater basin with no marine connections. Fossils are found within siderite nodules containing a large number of plants, invertebrates, and vertebrates. Charbonnier et al. (2008) identified 50 taxa of plants (Table 1). Invertebrates include multiple forms of annelids, mollusks, onychophorans (velvet worms), merostomes (horseshoe crabs), arachnids (spiders and scorpions), myriapods (millipedes), crustaceans (malacostracans, and ostracods), euthycarcinoids, and hexapods. The hexapods included representatives of: “Monura, Ephemeroptera, Palaeodictyoptera, Megasecoptera, Protorthoptera (Strephocladidae, Blattinopsidae), Caloneurodea, Odonoptera, Miomoptera, Rochdalia” (Perrier and Charbonnier, 2014, p. 11). The majority of vertebrates are fish including hagfish (possibly lampreys), xenacanthiform sharks, lungfish *Sagenodus*, acanthodians, and 12 species of actinopterygians. Tetrapods are primarily temnospondyl amphibians, with few lepospondyli amphibians, and one fragmented specimen of a pelycosaur. Perrier and Charbonnier (2014) noted that the majority of tetrapods are not well preserved and often found in fragments. Fossils have been found as compressions, 3D-preservation, and soft tissue preservation, the majority of which are all articulated. Two types of trace fossils have also been found. The first are coprolites containing fish scales and teeth, whereas the second are trackways which are suggested to be produced by microsaurs, pelycosaurs, and amphibians (Perrier and Charbonnier, 2014). The age is approximately 300 to 302 million-years.

Table 1: Plants of Montceau-les-Mines

Lycopsids

Asolanus sp. Wood
Cyperites bicarinata Lindley et Hutton
Sigillariostrobus sp. (Schimper) Feistmantel
Syringodendron sp. Sternberg

Sphenopsids

Annularia mucronata Schenk
Annularia sphenophylloides (Zenker) Gutbier
Annularia spicata (Gutbier) Schimper
Annularia stellata Schlotheim ex Wood
Asterophyllites equisetiformis (Sternberg) Brongniart
Calamites sp. Suckow ex Brongniart
Calamites cistii Brongniart
Calamites cruciatus (Sternberg) Brongniart
Calamostachys tuberculata (Sternberg) Jongmans
Sphenophyllostachys sp. Seward
Sphenophyllum angustifolium (Germar) Goeppert
Sphenophyllum longifolium (Germar) Gutbier
Sphenophyllum oblongifolium (Germar et Kaulfuss) Unger

Ferns

Pecopteris sp. Brongniart
Pecopteris aff. *affinis* Sternberg
Pecopteris cyathea Brongniart
Pecopteris aff. *elaverica* Zeiller
Pecopteris feminaeformis Schlotheim ex Sterzel
Pecopteris hemitelioides Brongniart
Pecopteris aff. *launayi* Zeiller
Pecopteris lepidorachis Brongniart
Pecopteris miltoni (Artis) Brongniart
Pecopteris platonii Grand'Eury
Pecopteris polymorpha Brongniart
Pecopteris pseudo-oreopteridia Potonié emend.Vetter
Pecopteris unita Brongniart
Sphenopteris sp. (Brongniart) Sternberg
Sphenopteris aff. *picandeti* Zeiller
Sphenopteris cristata Brongniart
Sphenopteris leptophylla (Bunbury) Alvarez-Ramis

Pteridosperms

Alethopteris sp. Sternberg
Alethopteris zeilleri Jongmans
Callipteridium costei Zeiller
Dicksonites pluckenetii (Schlotheim) Sterzel
Dicksonites sterzelii (Zeiller) Danzé-Corsin
Linopteris sp. Presl
Neuropteris sp. (Brongniart) Sternberg
Neuropteris cordata Brongniart
Neuropteris planchardi Zeiller
Odontopteris minor Brongniart
Odontopteris reichiana Gutbier emend. Potonié
Odontopteris subcrenulata Rost
Pseudomariopteris sp. Danzé-Corsin

Cycadophytes

Taeniopteris jejunata Grand'Eury emend. Doubinger et Vetter

Cordaitaleans

Cordaitanthus sp. Feistmantel
Cordaitanthus aff. *baccifer* Grand'Eury
Cordaites sp. Unger

Table 1: List of plants found at Montceau-les-Mines. Modified form Charbonnier et al. (2008) table 1. No new taxa have been identified since the original publication.

Robinson Locality, North America, Kansas, Brown County

Fossils from the Robinson locality came from a 0 to 40 cm fossiliferous layer of the Solider Creek Shale Member of the Bren Limestone Formation, Nemaha Subgroup, Wabaunsee Group, Virgilian Stage, Upper Pennsylvanian Series, Pennsylvanian System. This locality was originally discovered in 1899 by Beede, who described stromatolites being present. Fossils collected include marine invertebrates, freshwater and marine vertebrates, and terrestrial vertebrates. The majority of the fossils are disarticulated. No plant fossil have been reported. Invertebrates (Table 2) are found within the stromatolite layer and include eight taxa of brachiopods, seven taxa of bivalves (classically known as pelyecypods), seven taxa of gastropods, one coral, one bryozoan, one crinoid, one echinoid, one trilobite, and four taxa of ostracods. Vertebrates (Table 3) are found above, below, and in the stromatolite layer. Aquatic vertebrates include a holocephalan, four taxa of elasmobranch sharks, an acanthodian, an actinopterygian fish, two taxa of lungfish, and a coelacanth. Terrestrial vertebrates include a captorhinomoprh, a pelycosaur, and five taxa of amphibians. The depositional environment has been interpreted as a marginal marine coast due to the presence of both stromatolites and fresh/brackish water fish (Chron and Schultze, 1990; Schultze, 1995). The age is approximately 299 to 300 million-years.

Bushong Locality, Lyon County and Elkridge Locality, Wabaunsee County

Two localities, Bushong and Elkridge, are known from the middle of the Speiser Shale Formation, Council Grove Group, Wolfcampian Stage, Permian System. Only vertebrate fossils have been recovered from both localities, most of which are disarticulated. Fossils include unidentified sphenacodont fragments, six genera of

TABLE 2—Invertebrate fossils, stromatolite horizon, Brown County, Kansas (mostly after Sawin, 1977).

Brachiopods
Crurithyris
Neochonetes
Punctate brachiopod
Pelecypods
Phestia bellistriata
Permophorus?
Aviculopecin
Gastropods
Euphemites
Trepospira?
Euconospira?
Glabrocingulum (*Ananias*)?
Straparollus (*Amphiscapha*)?
Coral
Bryozoa (ramos)
Crinoid
Echinoid
Trilobite
Ostracode

TABLE 3—Vertebrate fauna from Robinson locality, Kansas.

REPTILIA	Pelycosauria:		pelycosaur
	Diapsida:		protorothyridid
AMPHIBIA	Lysorophidae:		lysorophid
	Nectridea:		*Diplocaulus*
	Anthracosauria:		*Cricotus*
	Temnospondyli:	+	trimerorhachid
			dissorophid cf. *Platyhystrix*
RHIPIDISTIA	Osteolepidida:		megalichthyine specimens
ACTINISTIA			coelacanth ?
DIPNOI		++	*Sagenodus copeanus*
		++	*Gnathorhiza*
ACTINOPTERYGII			palaeoniscoids
ACANTHODII		+	*Acanthodes*
ELASMOBRANCHII	Euselachii:		hybodont
	Petalodontida:		*Petalodus*
	Xenacanthida:	+	*Orthacanthus*
	Incertae sedis:		cladodont teeth
HOLOCEPHALI	Chimaerina:		deltodontid teeth

++ very common +common

Tables 2 and 3: Fauna found at the Robinson Locality modified from Chron and Schultze (1990). Table 2 is list the invertebrates, which Shultze (1995) would update the list by adding four brachiopods (*Lingula*, a discinid, *Derbyia*, *Dielasma*, and *Punctospirifer*), three bivalves (*Nuculopsis*, *Septomylina*, and a myalindi), two gastropods (*Euconospira, Strobeus, Worthenia*), and four ostracodes (*Bairdia*, and healdiacean, a hollinellid, and a geisinid). Table 3 is a list of the vertebrates, of which there have been no new discoveries from the site as such no updates have been made to the list.

amphibians, and a lungfish. Furthermore, root casts and lungfish burrows have also been found. The depositional environment has been interpreted as lacustrine due to the presence of root casts and lungfish burrows suggesting subaerial exposure (Cunningham, 1990a). The age is approximately 296 to 299 million-years.

Chapter 2: Methods

Introduction

For this project, information pertaining to taxa, paleoenvironment, and taphonomy of both the Garnett and Hamilton Quarry fossil localities were synthesized to produce a detailed comparison of these two localities. The investigation was primarily a literature search, with both museum and field work to supplement the literature. The gathered data were comprised of all currently published and unpublished information from first description to the present, a total of 246 data sources. Taxa data were recorded in lists and tables for each locality, noting rock units in which specific taxa are found. The information was then divided into the categories of plants, palynomorphs, vertebrates, and aquatic and terrestrial invertebrates. Each category was subdivided to note taxonomic identification to the lowest level, type of preservation, and whether the specimens were whole body or trace fossils.

The analysis was conducted in three phases. The first phase involved the examination of taxa from both localities to search for taxonomic equivalence and what niche was being filled. Taxonomic equivalence is defined here as taxa at any level existing at both localities. The second phase involved examining the geology and taphonomy of the individual localities to interpret paleoenvironment. The third phase combined the results of the first two phases to investigate changes in the paleoecology resulting from changing taxa and environment over time.

Literature Research

Literature research began with finding relevant materials on Garnett and Hamilton Quarry available at Emporia State University (ESU). The reference sections of publications and theses/dissertations were then searched to find any older references. Google Scholar was used to search decade by decade, starting with the beginning of the literature on the two localities in the 1930s, for published abstracts, papers, and unpublished theses. Additionally, Google Scholar was used to find any material that cited the found literature. Material that could not be accessed through Google Scholar was submitted to the ESU library to find via inter library loans (ILL). Physical literature received though ILL was scanned to make PDF copies. Some literature could not be found due to it being in a localized publication, having limited print run, and/or being unpublished talk abstracts. All found literature is listed in the Bibliography appendixes, last updated April 2017. Appendix A for Garnett, Appendix B for Hamilton Quarry, and Appendix C for related texts. Digital copies of the literature were given to the ESU Physical Sciences department for future use.

Museum Research

Fossil specimens were studied from both the Denver Museum of Nature and Science (DMNS) and Emporia State University's (ESU) Johnston Geology Museum. The DMNS houses a small collection of Hamilton material collected from the Main Quarry area during their 1991 field season. ESU also houses a larger collection of Hamilton material collected from the Main and Marlin Quarry areas. These collections include specimens of plants, invertebrates, and vertebrates. Specimens were examined with emphasis on unpublished and/or undescribed material for inclusion in taxa lists (see

Taxa Equivalence section). Notes on fossil preservation type and matrix material were taken, which was used to help determine location in stratigraphic column specimens where collected from. Specimens were also selected for photography based on defined criteria (see Photography section). A research trip to the University of Kansas Natural History Museum (KUNHM) was planned, but fell through due to timing. Instead, the KUNHM collections were viewed through their online catalog, which is separated across the specific disciplines of Invertebrate Paleontology, Paleobotany, and Vertebrate Paleontology.

Field and Lab Work

A research trip was made to the Hamilton Quarry to study rock outcrops and to see where excavations have occurred. Several specimens of the conglomerate and channel fill were collected from debris piles and outcrops. Specimens were cleaned with running water and a toothbrush to remove excess soil. During cleaning charcoalized plant fragments were inadvertently washed away; however, depressions and discolorations indicate the location on the specimens. The specimens were deposited at ESU's Johnston Geology Museum. A research trip to Garnett was planned but fell through due to not getting the landowner's permission.

Photography

Specimens from the DMNS and ESU collections were selected for photographing based on the following criteria:

1. Uniqueness – few fossils have been found

2. Identification – fossil shows majority of features used to identify family or genus, or previously identified in the literature

3. Completeness – fossil shows the majority of the organism

4. Quality – fossil is the best representative of taxon

Photographs were taken using a Nikon D3200 DSLR camera with a Nikon 18-55mm VR image stabilization lens for whole specimen photography and a Tamron SP 60 mm macro lens for detailed photography. The camera was mounted vertically on a specimen photography stand with two attached lamps used for lighting. The lamps were positioned to best illuminate each specimen. A 1:1000 millimeter metric scale was placed next to the specimen for size reference and was propped up to avoid parallax. Specimens were photographed both with and without scale to show features with size reference and an unobstructed view. Photographs were listed by taxon and museum specimen number for organization and processing.

Taxonomic Equivalence

Taxa data was taken from the literature and museum specimens to compose an updated taxa list for both Garnett and Hamilton Quarry. The most up-to-date description of each taxon was used to complete each list, preferably using classic taxonomic ranking; however, some clades (a group of organisms thought to have had a common ancestor) had to be included to best illustrate taxon descriptions. The lists were then used to create tables of plants, pollen and spores, aquatic and terrestrial invertebrates, and vertebrates to compare Garnett and Hamilton Quarry to determine any taxonomic equivalence between the localities. Taxa overviews are included for important taxonomic rank and were limited to a paragraph. Taxa lists and descriptions are located in Chapter 3 for Garnett and Chapter 4 for Hamilton Quarry.

Several biases were found from studying the literature that affected the taxonomic equivalence. The first bias is the insufficient study of the Garnett fossil invertebrate material. The groups fuslinids, crinoids, and ostracods are found at both Garnett and Hamilton Quarry; however, they are only identified to the group level at Garnett whereas at Hamilton they are identified to lower taxonomic levels. Second is a collection bias of plant fossils at Garnett. Winston (1983) noted the majority of fossils collected were conifers, where smaller sized samples of ferns and seed ferns broke upon attempt to collect as such not collected. Third is a study bias on pollen and spores. At Garnett two studies have been performed, whereas at Hamilton Quarry only one study was performed.

Six points of data were rejected: 1. Elias's (in Moore et al., 1936) identification of flora from Garnett due to the lack of descriptions, thus invalidating the binomial and loss or misplacement of the type specimens (Crindland et al., 1963; Winston, 1983), 2. Wilson's (1989) description of *Ophiacodon bekiae* due to lack of evidence to support the species description, 3. Spindler's (2015) description of the clade Haptodontiformes due to it only focusing on Garnett material, 4. Cunningham's (1993a) inclusion of Trilobita in his faunal list for Hamilton Quarry due to no previous studies describing or mentioning a trilobite being found, no mention of a trilobite being found in his dissertation, no reference given, and no published faunal list afterwards includes Trilobita, 5. Schultze's (1995) inclusion of a trilobite in his faunal list for Garnett due to no previous studies describing or mentioning a trilobite being found and no reference given, and 6. Huttenlocker et al.'s (2005) inclusion of the Pelycosaur Subfamily "Haptodontinae" due to cited data sources (Schultze and Chron, 1988; Daly, 1994) not containing this information. It is possible that both Cunningham (1993a) and Schultze (1995) misinterpreted the invertebrate faunal chart in Maples and Schultze (1988) as this chart is hard to read due to a lack of separating lines between fossil assemblages. On the chart, the Robinson locality is listed between Hamilton Quarry and Garnett and is known to contain a trilobite (Maples and Schultze, 1988).

Taxonomic Classification

Taxonomic tables were divided between the fauna, megaflora (herein defined as flora large enough to be see with the naked eye), and microflora (herein defined as pollen and spores requiring use of optical enhancing equipment to view). Tables 4 through 6 are for Garnett (Chapter 3), and Tables 7 through 9 are for Hamilton Quarry (Chapter 4). For this study the Linnaean classification system was used for taxonomic nomenclature of both the megaflora and fauna. The Linnaean ranks used are Kingdom, Phylum/Division (including sub- and infra-), Class (super-, “epi-“, sub-, infra-), Order (super- and sub-), Family (super-), Genus, Species, and Variety. For the megaflora, the botany rank of division is used, which is considered equal to the zoological rank of phylum for fauna.

Palynology uses different taxonomic nomenclature than either botany or zoology. Therefore, instead of the Linnaean classification system, the Potonié turma system (Traverse, 2007) is used for pollen and spores. The ranks in this system are Kingdom, Anteturma, Turma, Subturma, Infraturma, Subinfraturma, Genus, and Species.

For the purpose of this study Class “Amphibia” has been defined as all anamniotic tetrapods. Synapsids are considered a Class, sister to Class Reptila, defined as all non-synapsid amniotes. Amniota has been defined as a clade ranked as “Epiclass,” due to members of both Class Reptila and class Synapsida being amniotes. Furthermore, the "Epiclass" Amniota is under the Superclass Tetrapoda but not making it sister to Class "Amphibia."

Geology, Taphonomy, and Paleoenvironment

The stratigraphy for each locality was reported starting with the earliest description, and emphasis was placed on the most detailed descriptions. Taphonomic pathways are described for taxa, with special types noted for the specific taxon. Taxonomically equivalent taxa were then compared to see if preservation was due to the same taphonomic pathways at both Garnett and Hamilton Quarry. All interpretations of depositional environments were reported for each locality. This was then used to interpret the most likely depositional environment. Stratigraphy and depositional environment are located in Chapter 3 for Garnett and Chapter 4 for Hamilton Quarry.

Comparison to Other Localities

Comparison localities were selected based on approximate age (latest Missourian, through Virgilian, to earliest Permian). For each selected comparison locality the depositional environment, age, and taxa were noted. The comparison localities are listed in Chapter 1 Global Comparisons section.

Chapter 3: Garnett Locality

Introduction

This chapter covers both the geological and paleontological aspects of the Garnett locality. The majority of work on Garnett has focused on the paleontological aspects. Little to no work has been done to establish the geomorphic setting beyond Moore's original efforts (in Moore et al., 1936). The fossil assemblage is confined to the Rock Lake Shale Member of the Stanton Limestone Formation, Lansing Group, Missourian Stage of the Pennsylvanian System. The locality also shows the underlying Stoner Limestone and overlaying South Bend Limestone members of the Stanton. The stratigraphy has been well established by Woodruff (1984). The environment of deposition has been interpreted several times, including a nearshore marine environment (Elias, 1932), a river-fed lagoon that was cut off from the sea (Peabody 1952), a tidal mudflat near an estuary (Reisz et al., 1982; Woodruff, 1984), and a fully marine environment (Schultze, 1995).

Geographic Location

The Garnett fossil site is located in Anderson County, Kansas, approximately 6 miles/9.6 km (Reisz, 1990), north-northwest of Garnett, Kansas (Figure 3). The locality is bisected by county road Northwest 2200 Road, with township and range coordinates of SW ¼, SE ¼, Sec. 32, T. 19 S., R. 19 E. and NW ¼, NE ¼, Sec. 5, T 20 S., R. 19 E. (Carpenter, 1940; Peabody, 1952; Reisz et al., 1982). The Rock Lake Shale is exposed along a roadcut near the north bank of Pottawatomie Creek, with the majority of fossils collected from the westernmost exposures (Reisz et al., 1982).

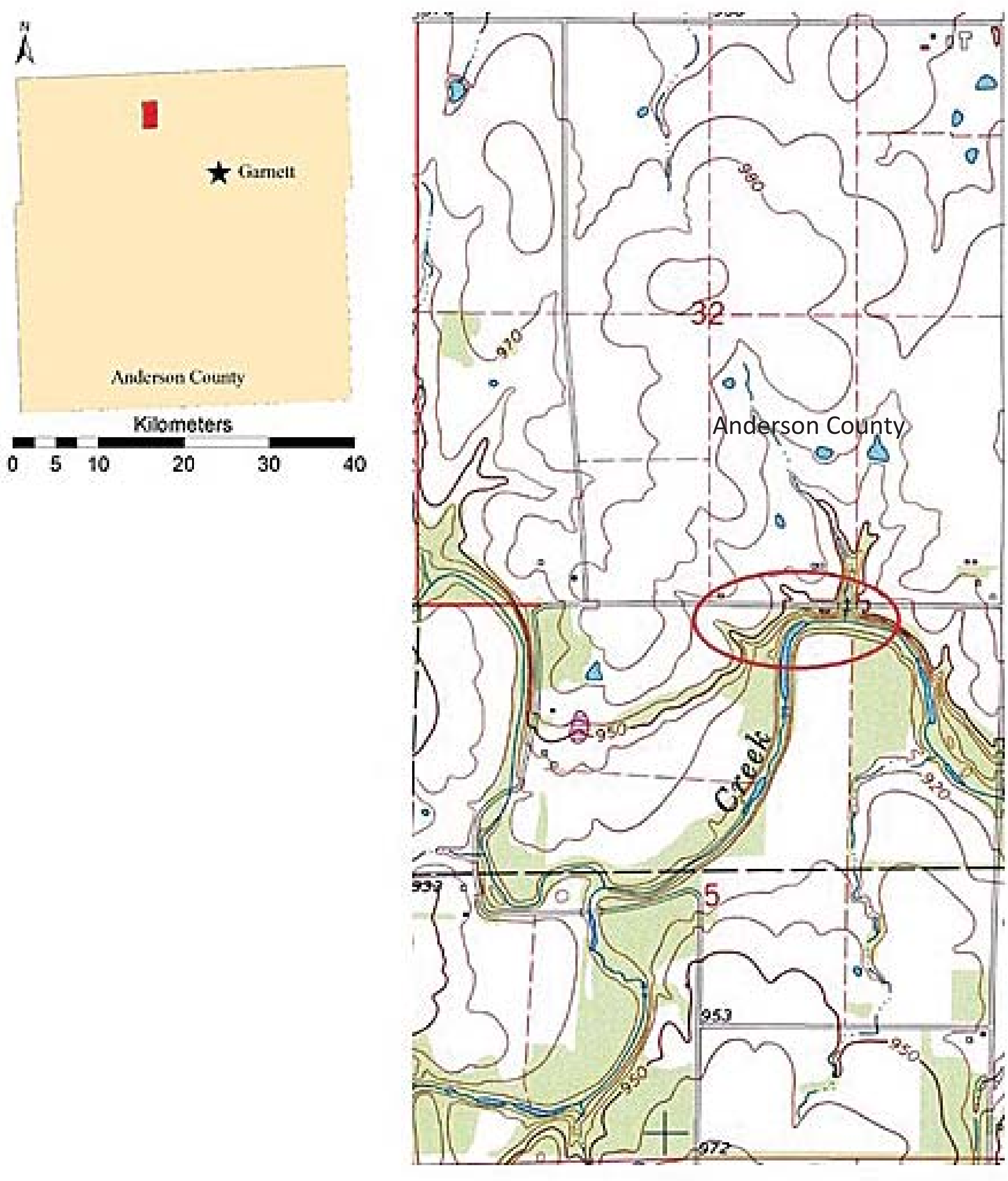

Figure 3: Geographic location and topography of the Garnett study area. The red highlighted area in Anderson County indicates the sections in which the study area is found. Vertebrate fossil section and primary study area is outlined in red. Modified from USGS (1983).

Geomorphic Setting

Moore et al. (1936) noted that the Pennsylvanian rocks in Kansas dip westward away from the Ozark Uplift and have a westward inclination that is generally uniform. Reisz et al. (1982) noted that at the Garnett study area the Rock Lake Shale is confined to two depressions that cut into the Stoner Limestone. The first depression is 200 to 250 meters wide and has a depth of 3 to 5 meters, and is located directly north of the 1953 and 1954 Peabody excavation sites. The second depression is located 750 [*sic*] meters east of the first depression and is less exposed; no measurements were published. The depressions could be followed over a short distance with a north-northeast trend. Reisz et al. (1982) interpreted the depressions to represent channels. Woodruff (1984) noted that these depositions of the Rock Lake Shale are unusual compared to other known exposures due to it being confined to a channel and showing no indication of post-depositional erosion. Woodruff also noted that these channels were similar to channels in the lower Stanton Limestone reported by Heckel (1975), with the primary difference being the absence of algal mounds that flank Heckel’s channels.

Stratigraphy

The stratigraphy (Figure 4 and 5) of the locality was originally established by Newell (in Moore et al., 1936). Newell noted there was approximately 40 feet of exposed strata near the fossil locality; however, no thicknesses were reported. He established that the locality consisted of the Olathe Limestone (Stoner Limestone) which is unconformable overlaid by the Victory Junction Shale (Rock Lake Shale) which is conformable overlain by the Little Kaw Limestone (South Bend Limestone).

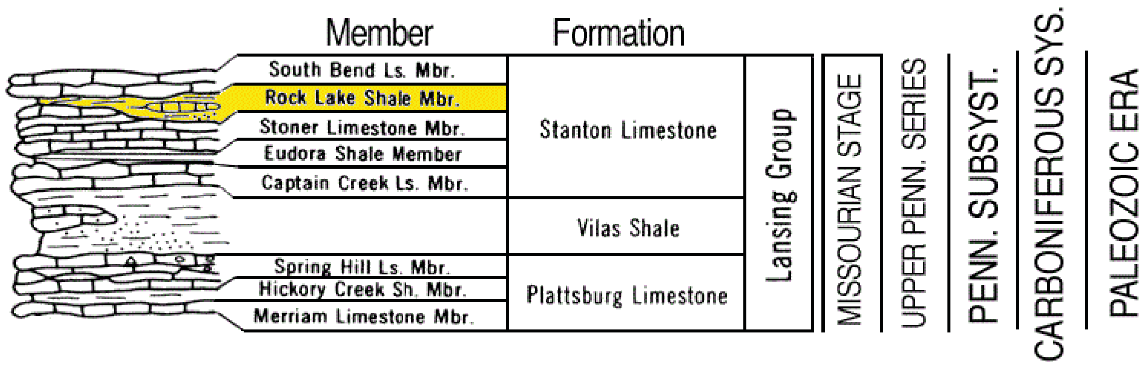

Figure 4: Stratigraphic chart of the Garnett locality. The Lansing Group contains the Stanton Limestone Fm. and Rock Lake Shale Mbr. (yellow highlighted), in which the Garnett fossils are found. (From Zeller, 1968/2013).

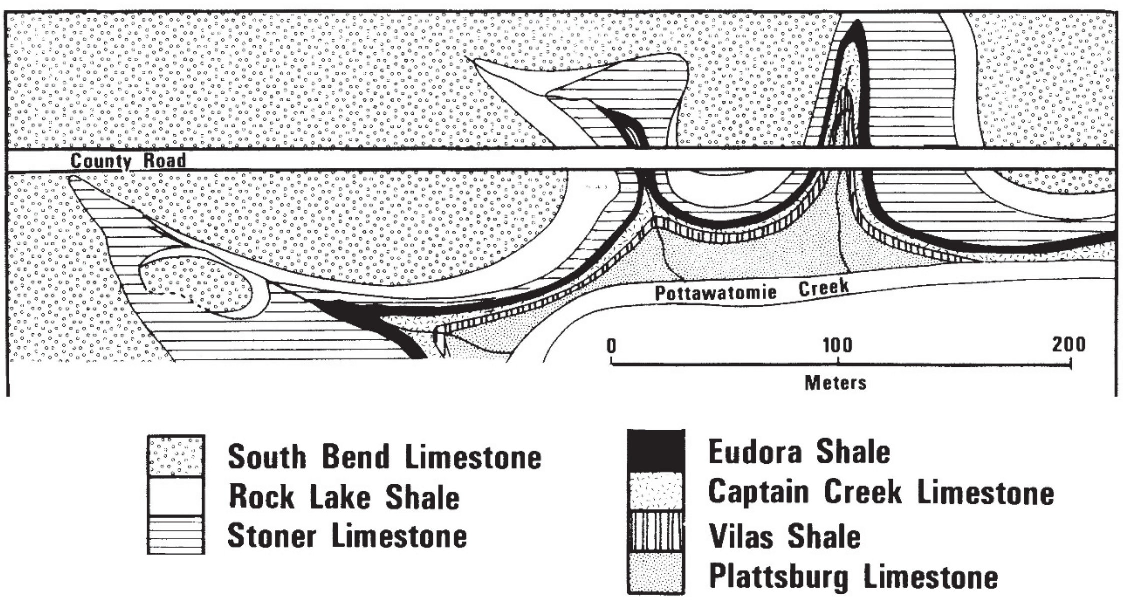

Figure 5: Geologic map of the Garnett study area. County road 2200 runs east-west and bisects the locality. The majority of fossils have been collected from the westernmost exposures of the Rock Lack Shale. Modified from Reisz et al. (1982) figure 2.

Reisz et al. (1982) divided the stratigraphy of the Rock Lake Shale into three fossil zones (Figure 6). The first zone was deposited on an erosion surface on top of the Stoner

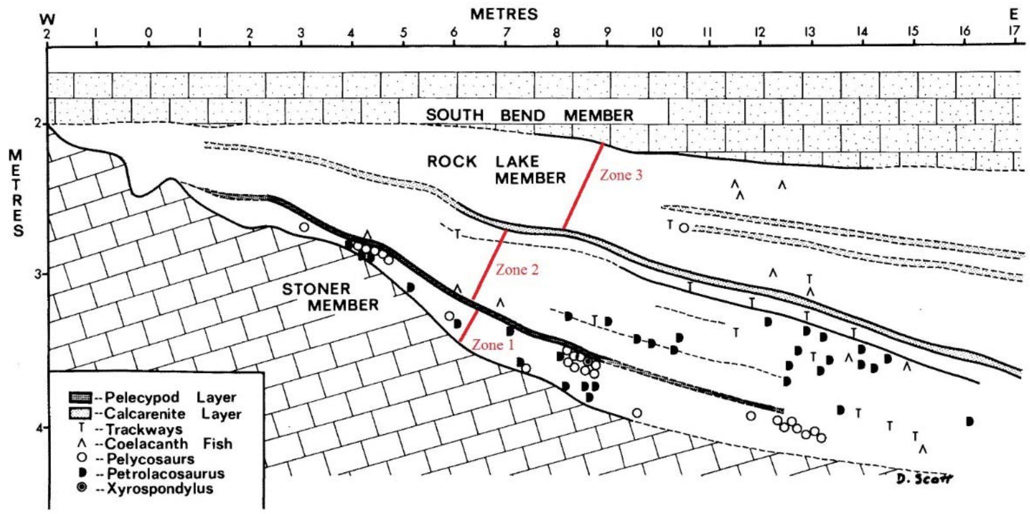

Figure 6: Cross section of the Garnett locality modified from Reisz et al. (1982) figure 5 showing approximate location and abundance of vertebrate fossils and trance fossils. Fossil zones have been marked in red.

Limestone. This zone consists of a well bedded carbonaceous/calcareous mudstone that is dark greyish-brown color. It contains mostly terrestrial fossils, with few fragments of marine invertebrates reworked from the Stoner Limestone. This zone is capped by a pelecypod layer that had a thickness of 2 to 5 centimeters and interpreted to represent a high tide line. The second zone sits above the pelcypod layer and consists of a regularly laminated calcareous claystone that becomes irregularly laminated upwards. The claystone is a light brownish-grey color. This zone contains terrestrial body fossils that become less common upwards and terrestrial vertebrate trackways that become more common upwards. Additionally, few fragments of marine invertebrates are also present.

Desiccation cracks are found throughout the zone and become more common upwards. The zone is capped by a 12 cm thick coarse crystalline calcarenite layer that contains fragments of marine invertebrates. The third zone sits above the calcarenite layer and consists of a well laminated clayey limestone. The limestone transitions from a light brownish-grey color to a yellow-brown color and shows partial bioturbation. This zone contains few terrestrial plant fossils with an abundance of marine invertebrates. Wrinkle marks are present and interpreted to represent either feeding traces of gastropods or weak ripple marks. This layer is capped by the South Bend Limestone, which was deposited directly on top without erosion. Reisz et al. (1982) postulated that the Rock Lake Shale represented a change for a regression to a transgression.

Woodruff (1984) expanded upon Reisz et al. (1982). He measured a total of 18 stratigraphic sections; of these, eight were measured at the Garnett locality. His sections OQ, RG, PO, and JDC follow a west to east trend of the outcrop, whereas section PP, SHP, OQ, SC, and DC follow a north to south trend (Figure 3 in Woodruff, 1984). Section OQ was measured at the main fossil excavation site. Another ten were measured north to south across exposures of the Lancing Group to establish a regional stratigraphic baseline (Figure 2 in Woodruff, 1984). For the Garnett locality, Woodruff separated the Rock Lake Shale into eight district lithofacies and gave each an interpretation of depositional environment. Furthermore, he included descriptions of the Stoner Limestone and South Bend Limestone found at the excavation site. Woodruff’s stratigraphy for the Garnett locality is summarized below. Thicknesses were not reported for Facies VI, VII, or VIII.

Stoner Limestone

The Stoner Limestone is massively bedded with an average thickness of 13 feet. The limestone weathers to a whitish color. Fossils of marine invertebrates are found throughout including: brachiopods, bryozoans, fusilinids, pelecypods, pelmatozoans, and ostracods. Algae is found near the top. The depositional environment is coincided consistent with the rest of the Stoner Limestone, being an offshore marine environment in the photic zone.

Rock Lake Shale

Facies I: This facies was found only in section DC. It is a 1 foot thick well cemented coarse grainstone with a fossiliferous matrix that is light brown to white in color. This facies contains lithoclasts of Stoner Limestone and fossils from the Stoner Limestone. The matrix contains algae, brachiopods, bryozoans, fusilinids, pelmatozoans, and terrestrial plant fragment. The depositional environment was interpreted to represent a basal channel lag in an estuary. Deposition occurred on an erosionary surface cut by the depositing stream, as suggested by the lithoclasts.

Facies II: This facies was found only in section DC. This facies is a 2.1 feet thick layer of interbedding limestone and clay. The clay component increased upward. The limestone is identified as grey colored grainstones and packstones with slightly wavy bedding. The limestone contains lithoclasts fossils as found in Facies I. Additionally, fossils found include arthropods, endothyracea, miliolids, gastropods, and ostracods. Plant fragments were identified as belonging to the genus *Walchia*. The clay is calcareous with a grey-brown color and contains only fossils of *Walchia*. The depositional environment was interpreted as a storm influenced estuary. Clay layers were interpreted to be deposited in calm waters while limestone layers were interpreted to be deposited rapidly during storms.

Facies III: This facies in sections SC, DC, and RG. This facies is a 2.1 feet thick layer of shaly limestone that is similar to the limestone in Facie II both lithologically and paleontologically. Noticeable differences include a blacker coloration and being more fissile. Additionally, freshly exposed surfaces smelts of sulfur. The depositional environment was interpreted as an estuary with constant influx of marine debris. The blacker color was interpreted to be caused either due to anoxic conditions or poor circulation.

Facies IV: This facies is found in sections SC, DC, and RG. This facies has a variable thickness of 0.3 to 2.4 feet composed of laminated clay and mud shales with slightly wavy bedding. The shale layers alternate in color between black and yellow, with yellow dominant near the top. The shale appears to be fining upward. Only fossils of *Walchia* were reported, with high concentration in the black layers. One section included an upward fining limestone which Woodruff interpreted as part of Facies VI. The depositional environment was interpreted as a protected body of water, either being a lagoon or an embayment. The intrusion of Facies VI was interpreted as a storm breach deposition. The shale layering was interpreted to represent either periods of organic rich runoff or annual sedimentation. The upward fining was interpreted to represent a gradual increase in water depth.

Facies V: This facies is found across all sections. It has a maximum thickness of 5.4 feet in the main excavation site and thins towards the eastern edges of the channel.

Woodruff noted that this facies include all three fossil zones defined by Reisz et al. (1982), as such he subdivided this facies into two subfacies.

Subfacies 1: This subfacies is the same as the first zone defined by Reisz et al. (1982). Woodruff (1984) defined this subfacies as a fossiliferous grey clayshale that is deposited directly on the Stoner Limestone in section OQ and Facies IV in southern sections. Reworked fossil bryozoans and brachiopods are found along the base. Section OQ contains abundant fossils of terrestrial vertebrates, flora, and microflora, while section SC only contains plant fragments. This subfacies is capped by a pelecypod layer that pinches out near the edges of the channel. The depositional environment was interpreted as a tidal flat repressing subtidal to intertidal zones, based on the grey coloration. The pelecypod layer was interpreted as a strand line deposit.

Subfacies 2: This subfacies is the combination of the second and third zones defined by Reisz et al. (1982). Woodruff (1984) defined this subfacies as a fossiliferous light brown clayshale with interbedded wackstones. He noted in section OQ the bedding is flat while in section SC bedding dips to the southeast and thickens with dip. Woodruff only noted that burrows, mudcracks, and bird's eye features are found in this subfacies; however, he did not record where, such as Reisz et al. (1982) had. This subfacies is divided into upper (Reisz et al. (1982) second zone) and lower (Reisz et al. (1982) third zone) parts by the intrusion of Facies VI. The lower part in section OQ contains fossils of terrestrial plants, complete body fossils of terrestrial vertebrates, trackways of terrestrial vertebrates, and brachiopods *Lingula*, *Composita*, and *Linoproductus*. The upper part in section OQ contains an abundance of marine invertebrates while containing few coelacanth fish. Additionally plant fragments are rare. The depositional environment was interpreted as a tidal flat representing intertidal to supratidal zones. Periods of subaerial exposure are indicated by the mudcracks and brown color. The presence of trackways and terrestrial vertebrates indicate a close proximity to land.

Facies VI: This facies is a coarse skeletal packstone that was deposited in Facies IV and V subfacies 2. This facies contains fossils of marine invertebrates: brachiopods, bryozoans, and pelmatozoans. Additionally, fragments of *Walchia* and interclasts are found. This was interpreted to represent a storm deposit.

Facies VII: This facies was found only in sections PO and JDC within 100 feet of the Rock Lake Shale pinchout. This facies is composed of packstone and wackstone with interbedded layers of clay, clayshale, and silt. The packstones and wackstones are grey in color and contain lenses of grainstone and mudstone. Fossils of marine invertebrates found within these layers include arthropods, brachiopods, bryozoans, foraminifera, pelecypods, pelmatozoans, and ostracods. The clay, clayshale, and silt layers are a grey-brown to yellow color and include fragments of brachiopods, bryozoans, and pelmatozoans. The depositional environment was interpreted as a restricted lagoon. The clay, clayshale and silt layers were interpreted to represent terrestrial sediments deposited by runoff. The packstone and wackstone layers were interpreted to represent rapid storm deposits.

Facies VIII: This facies was found in sections SHP, SC, DC, and RG. This is a lenses shaped deposit of highly wreathed claystone. Layers of claystone alternate coloration between grey and yellowish-brown. The lower part has a grey coloration with iron staining. Due to the weathering, no interpretation of the depositional interpretation was made. However, Woodruff postulated this facies could be a reworking of Facies V.

South Bend Limestone

The South Bend Limestone has an average thickness of 5 feet across the entire study area, and is easily identifiable by its rounded weathering. It is primarily a coarse-grained packstone with a brown color and contains grainstone and sandstone lenses. In section OQ it is a sandstone that directly overlays Facies V. Woodruff (1984) noted that the sandstone occurs exclusively over the Rock Lake Shale when the latter is a mudstone. The South Bend Limestone is interpreted to represent the return to a marine environment.

Environment of Deposition

The depositional environment of the study area has been interpreted multiple times, each time with more information about the locality. Currently the tidal mudflat interpretation proposed by Reisz et al. (1982) is the most widely accepted and is supported by Woodruff's (1984) work. Described below, in chronological order of their publication, are the proposed depositional environments.

Nearshore Marine

This interpretation was originally proposed by Elias (1932), based on limited evidence, primarily the exceptional preservation of the conifer *Walchia* along with other plant fossils. *Walchia* suggested a terrestrial environment near the Pennsylvanian sea.

River-Fed Lagoon

This environment (Figure 7) was proposed by Peabody (1952) based on his taxon list and the general understanding at the time of lagoon deposition. Peabody noted that the bivalved invertebrates *Lingula*, *Sedwickia*, and *Myalina* are common in brackish water. The presence of *Walchia* suggested that a dryland environment was near; however, fragments of the plant could easily be carried downstream. The abundance of whole body fossils of *Petrolacosaurus kansenis* indicate a low energy environment. Furthermore, *P. kansenis* lacked any aquatic adaptations. Thinly bedded mudstones of the outcrop suggested a lack of a strong current, and in addition no ripple marks were found, suggesting it was protected from direct marine influence. Peabody concluded that the terrestrial organisms floated downstream in a slowly-flowing river that terminated in a protected lagoon.

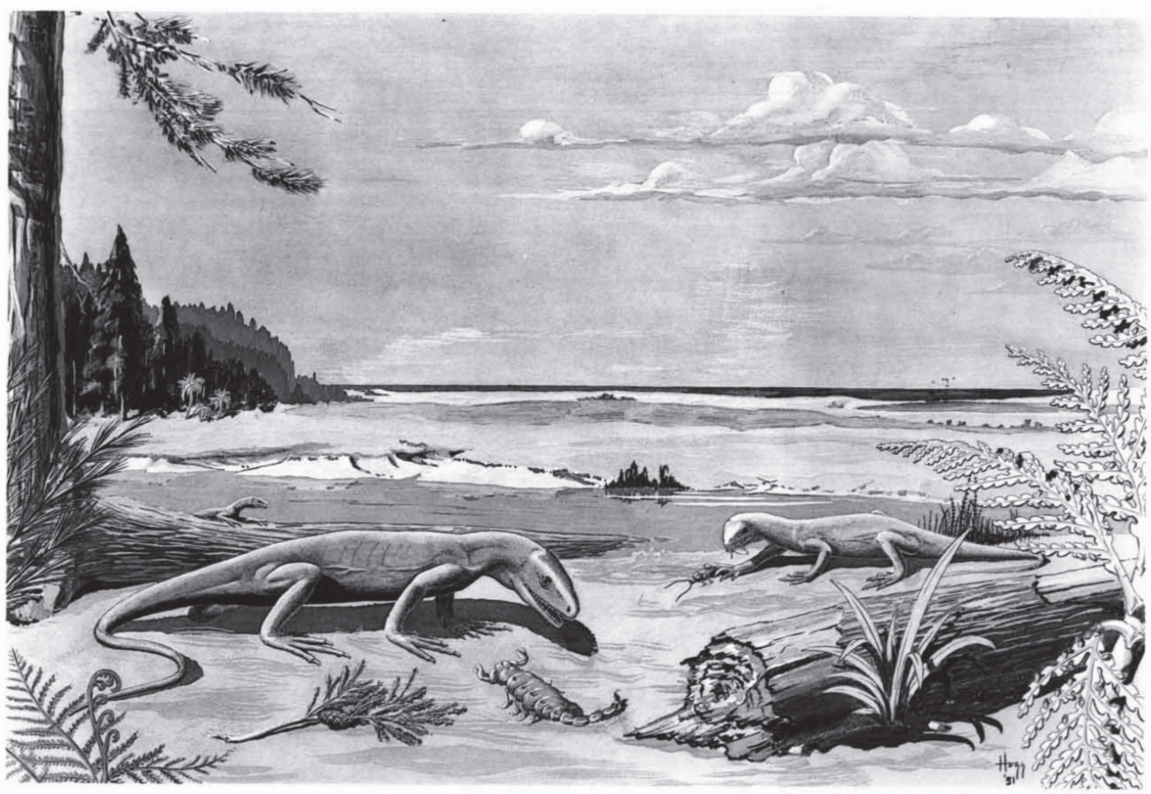

Figure 7: Coastal lagoon in the Late Pennsylvanian of Kansas from Peabody (1952). Reconstruction shows conifers and ferns grown near the coast. The lizard-like reptile *Petrolacosaurus kansenis*, the scorpion *Garnettius hungerfordi*, and a cockroach are inhabiting the area.

Tidal Mudflat

This environment was proposed by Reisz et al. (1982), based on limited sedimentological study and paleontological studies of the main excavation site. Reisz et al. suggested that the channels were cut by streams into the Stoner Limestone during a regression; however, no stream deposits were preserved. Once transgression began the channels became filled with sediment carried in by tides. The pelecypod layer was interpreted to represent the level of high tide. Trackways and desiccation cracks found in the second fossil zone indicated subaerial exposure with a high moisture content. The laminations are interpreted to represent sediment deposition during incoming tides. The calcarenite layer and third fossil zone are interpreted to represent transgression due to the lack of terrestrial fossils and the increase in marine invertebrate fossils.

Transgressive Channel Fill

This environment was proposed by Woodruff (1984) and is an expansion of Reisz et al.'s (1982) tidal mudflat interpretation. This interpretation is based on an extensive sedimentological analysis of the study area and regional comparisons. Woodruff concurred with Reisz et al. (1982) that the channel was formed during a regression, with Facies I showing preserved channel lag. To explain the changing depositional environments between the facies, Woodruff (1984) interpreted the entire deposition of the Rock Lake Shale as occurring during a continual transgression. The confined conditions led at first to a restricted tidal flat and later to the formation of a lagoon or embayment. Facies IV represents the center of the lagoon, whereas Facies V represents the tidal shore of the lagoon and eventual expansion of the tidal flats. Woodruff concluded that the tidal flats filled the channels before the deposition of the South Bend Limestone.

Marine

This environment was suggested only by Schultze (1995). This interpretation is only based on bulk fossil analysis of the fauna, which ignores the fossil zonation established by Reisz et al. (1982), the stratigraphy established by Woodruff (1984), and all paleobotany such as Winston (1983). Schultze argued that marine invertebrates are a better indicator of paleoenvironment because they are less mobile than terrestrial invertebrates; therefore, more commonly preserved *in situ*. As such, the bulk fossil assemblage contains more marine invertebrates than terrestrial fauna; therefore, it is a marine depositional environment.

This Study

The depositional environment is interpreted here as an estuary/lagoon shore constrained to a channel during a transgression. The erosion surface that the Rock Lake Shale sits upon (Reisz et al., 1982; Woodruff, 1984) and Facies I (Woodruff, 1984) are highly suggestive of a stream-cut channel. Woodruff (1984) suggested Facies IV and V were depositing at the same time due to Facies V being found deposited near the western edge of the channel. This is interpreted to represent the shore area of an estuary/lagoon. Reisz et al. (1982) proposed that tidal mud flats are evidenced by the laminations found in the first and second fossil zones, with the pelecypod layer representing a high tide line. However, neither zone contains preserved indicators of current. Furthermore, terrestrial vertebrates are preserved almost entirely articulated, indicating either a low energy environment or rapid burial, but the fine laminations of the zones suggest rapid burial did not occur.

So far there have been no reported fish recovered from the first fossil zone, suggesting the water was not deep enough to support fish or that the water level fluctuated, etc. The fine laminations possibly indicate an influx of water (tides) carrying sediment that buried the terrestrial vertebrates and plants. Fossil plants appear to show little to no decay, suggesting that the sedimentation rate was fast enough to cover them before decay began. The pelecypod layer appears to be composed of *Myalinella*, *Sedgwickia*, and *Yoldia*, which are considered to have lived in brackish environments (Peabody, 1952). Due to the lack of preserved current indicators in the first fossil zone and time required for pelecypods to colonize the area, this layer is interpreted here to represent a short-term deepening of the water level

Afterwards water temporarily regressed, allowing depositional conditions to return to those similar to the first fossil zone. Regression continued, causing the area to become subaerially exposed. This is supported by the increase in desiccation cracks, bird's eye features, and tetrapod trackways. Furthermore, preservation of the terrestrial fauna and flora decreased in number and laminations became irregular from the bottom to the top of the second fossil zone (Reisz et al., 1982; Woodruff, 1984). Desiccation cracks and trackways indicate moisture was present, but there was no standing water. The calcarenite layer is interpreted to represent either a storm event breaking a protective barrier or the sudden rise of water level. Reisz et al. (1982) noted that the fossils in the calcarenite were all marine invertebrates that had been fragmented, suggesting deposition occurred in a high energy environment.

Reisz et al.'s (1982) third fossil zone showed an upward transition into the South Bend Limestone, suggesting transgression returned after the deposition of the calcarenite layer. Woodruff's (1984) data supports this idea due to the presence, across the entire study area, of the upper part of Facies V subfacies 2, which is the equivalent to Reisz et al.'s (1984) third fossil zone. The few plant fragments recovered from this zone suggest there was some terrestrial influence, but were greatly reduced compared to the first and second fossil zones.

Paleontology

The Garnett fossil assemblage contains a total of 126 taxa, two trace fossils, and unidentifiable charcoal. Of the total taxa, 63 are palynomophs representing 62 types of pollen and one fungal spore (Grupta and Boozer, 1969; Winston, 1983), and 18 of the pollen taxa were new species. Twenty-six taxa represent plants (Winston, 1983; University of Kansas Paleobotany Museum database, accessed 2017). Twenty-three taxa represent invertebrates (Maples and Schultze, 1988; Reisz, 1990; Schultze, 1995), 17 are aquatic invertebrates, and six are terrestrial invertebrates of which four were new species. Fourteen taxa represent vertebrates (Maples and Schultze, 1988; Reisz, 1990; Schultze, 1995, Kissler and Reisz, 2004; Spindler, 2015), four are aquatic including one new species, ten are terrestrial of which nine were new species and one is unclear. The trace fossils include two types of trackways. Terrestrial vertebrates appear to be confined to the western edge of the outcrop and are found with reworked marine invertebrates.

Figures of the selected taxa are presented at the end of the chapter. Figures are limited to two terrestrial invertebrate taxa and to vertebrates due to missing plant fossils, older publications lacking images, and aquatic invertebrates being common with a long temporal range.

Taxonomic Classification

Taxonomic nomenclature for botany differs from that used in zoology. The botany rank of division is considered equal to the zoological rank of phylum. Additionally palynology uses different taxonomic nomenclature than either botany or zoology, where there are no equivalent ranks beyond genus and species. Therefore, the biotic lists for the Garnett locality have been divided into three tables: Table 4 lists the fauna (invertebrates and vertebrates), Table 5 lists the megaflora (plants), and Table 6 list the microflora (pollen and spores).

Table 4: Fauna

KINGDOM PROTISTA

Phylum Retaria
Subphylum Foraminifera
Order Fuslinida
Family Endothyracea
Order Miliolida

KINGDOM ANIMALIA

Phylum Porifera
(sponge spicules)

Phylum Cnidaria
Class Anthozoa
Order Rugosa
Family Lophophyllidiidae
Genus *Lophophyllidum* (?)

Phylum Echinodermata
Class Crinoid
Class Echinoidea

Phylum Arthropoda
Subphylum Chelicerate
Class Arachnida
Order Scorpiones
Family Garnettiidae
Genus *Garnettius*
Species *G. hungerfordi*

Subphylum Crustacea
Class Ostracoda
Subphylum Hexapoda
Class Insecta
Order Blattodea
Suborder Cockroashes
Family Archimylacridae
Genus *Phyloblatta*
Genus *Mylacris*
Subclass Pterygota
Superorder Palaeodictypopteroidea
Order Megasecoptera
Family Parabrodiidae
Genus *Parabrodia*
Species *P. carbonaria*
Family Prochoropteridae
Genus *Euchoroptera*
Specie *E. longipennis*
Family 3rd identified

<u>Phylum Annelida</u>
Class Polychaeta
Order Canalipalpata
Family Serpulidae

<u>Phylum Mollusca</u>
Class Bivalvia
Order Myalinida
Family Myalinidae
Genus *Myalina* (or *Myalinella*)
Order Cardiidia
Family Grammysiidae
Genus *Sedgwickia*
Order Nuculoida
Family Yoldiidae
Genus *Yoldia*

<u>Phylum: Brachiopoda</u>
Class: Rhynchonellata
Order: Athyridida
Family: Athyrididae
Genus: *Composita*
Order: Spiriferida
Family: Trigonotretidae
Genus: *Neospirifer*
Class Lingulatta
Order Lingulida
Family Lingulidae
Genus *Lingula*

<u>Phylum Bryozoa</u>
Class: Stenolaemata
Order: Fenestrata
Family: Fenestellidae
Genus: *Fenestella*

Family Polyporidae
Genus *Polypora*
Order: Rhadbomesida
Family: Rhombopirudae
Genus: *Rhombopora*

Phylum Chordata
Subphylum Vertebrata
Infraphylum Gnathostomata
Class Chindrichthyes
Subclass Elasmobranchii
Order Cladoselachiformes
Family Cladoselachidae
Genus "*Cladodus*"
Order Xenacanthida
Order Hybodontiformes

Superclass Osteichthyes
Class Sarcopterygiia
Subclass Actinistia
Order Coelacanthiformes
Family Rhabdodermatidae
Genus *Synaptotylus* (or *Rhabdoderma* (?))
Species *S. newelli* (or *R/ newelli*)

Superclass Tetrapoda
Class "Amphibia"
Subclass Labyrinthodonta
Superorder Batrachomorpha
Order Temnospondyli
Family Dissorophidae
Genus *Actiobates*
Species *A. peadodyi*
Superorder Reptillomorpha
Order Anthracosauria
Suborder Embolomeri
Family Cricotidae
Genus *Hesperoherpeton*
Species *H. garnettense*

"Epiclass" Amniota
Class Reptilia
Subclass Eureptila
Infraclass Diapsida
Order Araeoscelida
Family Petrolacosauridae
Genus *Petrolacosaurus*
Species *P. kansensis*

Class Synapsida
Order "Eupelycosauria"
Family Edaphosauridae
Genus *Ianthasaurus*
Species *I. hardestii*/*hardestiorum*
Genus *Xyrospondylus*
Species *X. ecordia*

Family Ophiacodontidae
Genus cf. *Ophiacodon*
Family Sphenacodontia
Genus *Ianthodon*
Species I. *schultzei*
Genus *Eohaptodus*
Species *E. garnettensis*
Genus *Kenomagnathus*
Species *K. scotti*
Genus *Tenuacaptor*
Species *T. reiszi*

Table 5: Megaflora (Plants)

KINGDOM PLANTAE

(4 unidentified ovules, unidentified wood)

Division Lycopodiophyta (?)
(Lycopod leaves (?))

Division Pteridophyta
Class Fillcopsida
Order Marattiales
Family Marattiaceae
Genus *Pecopteris*
Species unknown
Class Sphenophyta or Equisetopsida
Order Equisetales
Family Calamitaceae
Genus *Annularia*
Species *A. asteris*
Species *A. galloides* (?)

Division Pteridospermatophyta
Class Pteridospermopsida
Order Peltaspermales
Family Peltaspermaceae (?)
Genus *Callipteris*
Species *C. flabellifora*
Variety *flabellifera*
Variety *moorie*
Class Pentoxylopsida
Order Pentoxylales
Family Pentoxylaceae
Genus *Taeniopteris*
Species *T. angelica*
Species *T. coriacea*
T. sp.
Genus *Spermopteris* (?)
S. sp.
Class Peltaspermopsida
Order Trichopityales
Family Trichopityaceae

Genus *Diceratosperma*
Species *D carpenteriana*

Class Pteriodphylleae
Order Medullosales
Family Alethopterides
Genus *Alethopteris*
A. sp.
Family Neurodontopteridaceae
Genus *Neuropteris*
Species *N. attenuatta*
Species *N. fimbriata*

Division Pinophyta or Coniferophyta
Class Pinopsida or Coniferopsida
Order Cordaitales
Family Cordaitaceae
Genus *Cordaicarpon*
C. Sp.
Genus *Cordaites*
C. sp.
Order Voltziales
Family Utrechtiaceae or Walchiaceae
Genus *Walchia*
Species *W. frondous*
Species *W. garnettensis*
Species *W. piniformis*
Species *W. cf. W. schneideri*
Genus *Walchianathus*
Genus *Walchiastrobus*

Table 6: Microflora (Pollen and Spores)

KINGDOM FUNGI

(Fungal Spore (?))

KINGDOM PLANTAE

(Unidentified bissacate miospore)

Anteturma Sporites
Turma Triletes
Subturma Azonotriletes
Infraturma Laevigati
Genus *Leiotriletes*
Species *L. sphaerotriangulus*
Species *L. adnattus*
Species *L. Adnatoides*
Species *L. gulaferus*
Species *L. minutus*
Genus Punctatisporites
Species *P. fenestratus*
Species *P. minutus*

Species *P. orbicularis*
Species *P. stramineus*
Genus Calamospora
Species *C. microrugosa*
Species *C. minuta*
Species *P. cf. P. pusilla*
Infraturma Apiculati
Subinfraturma Granulatia
Genus Granulatisporites
Species *G. microgranifer*
Species *G. parvus*
Species *G. pallidus*
G. sp. A
G. sp. B
Genus Cyclogranisporites
Species *C. aureus*
Genus Microbaculispora
Species *M. novicus*
Subinfraturma Nodati
Genus Lophotriletes
Species *L. commissuralis*
Subinfraturma Nosatia
Genus Pustulatisporites
Species *P. minutus*
Infraturma Murornati
Genus Microreticulatisporites

Subturma Zonotriletes
Infraturma Cingulati
Genus Densosporites
Species *D. anulatus*
Species *D. ruhus*
Subinfraturma Pseudocingulati
Genus Galeatisporites
Species *G. minutus*
Infraturma Zonati
Genus Cirratriradites
Species *C. annuliformis*
Species *C. rarus*
Species *C. tenuis*

Anteturma Pollenites
Turma Saccites
Subturma Monosaccites
Infraturma Triletesacciti
Subinfraturma Intrornati
Genus Wilsonites
Species *W. kosankei*
Genus Guthoerlisporites
Species *G. magnificus*
Genus Endosporites
Species *E. uniformis*
Species *E. cf. E. vesicatus*
Genus Schulzospora
Species *S. elongate*
Species *S. rara*

Infraturma Vesiculomonoraditi
Genus Hoffmeisterites
Species *H. microdens*
Genus Potoniesporites
Species *P. novicus*
Species *P. versus*
Species *P. simplex*
Infraturma Aletisacciti
Genus Florinites
Species *F. florini*
Species *F. volans*
Genus Vesicaspora
Species *V. ovata*
V. sp.
Subturma Disaccites
Infraturma Striatiti
Genus Protohaploxypinus
Species *P. amplus*
Species *P. jacobii*
Species *P. ovatus*
Species *P. parcus*
Species *P. perfectus*
Genus Striatopodocarpites
Species *S. cf. S. octostriatus*
Species *S. novicus*
Genus Taeniasporites
Species *T. decipiens*
Genus Hamiapollenites
Species *H. ambiguous*
Species *H. bullaeformis*
Infraturma Disaccitrileti
Genus Illinites
Genus Piceapollenites
Species P. auroclavatus
Infraturma Disacciatrileti
Genus Pityosporites
Species *P. aetheus*
Species *P. imperspicuus*
Species *P. cf. P. gracilis*
Genus Limitisporites
Species *L. ovalis*
Species *L. radiates*
Species *L. vestustus*
Species *L. vetulus*

Aquatic Invertebrates

Aquatic invertebrates, freshwater to marine, are represented by a total of 17 taxa, none of which have been identified to the species level. Thirteen are considered marine invertebrates, three are considered to be brackish water, and one is tentatively a freshwater form. Both Reisz et al. (1982) and Woodruff (1984) noted that few occur with the terrestrial vertebrates and all show indications of being reworked from the Stoner Limestone. The majority of non-reworked fossils occurred in Woodruff's (1984) Facies I, II, III, VI, VII, and the upper part of V subfacies 2, and in Reisz et al.'s (1982) third fossil zone, which is the same at the latter three facies. The majority of these specimens were collected by Moore, Elias, and Newell and were originally deposited at the University of Kansas (KU) Natural History Museum before the collections were split across the departments of Biology (vertebrates), Botany (plant), and Geology (invertebrates).

Foraminiferans (Retaria)

This group is represented by the foraminiferan orders Fuslinida and Miliolida. They are found in Woodruff's (1984) Facies I, II, III, and VII.

Sponges (Porifera)

Sponge spicules have been recovered from Facies I (Woodruff, 1984). There has been no reported work about the identification of the genus the spicules belonged to.

Rugose Coral (Cnidaria)

Rugose corals are represented by the genus *Lophophyllidium* (?). There is no reported information about where specimens were found stratigraphically.

Echinoderms (Echinodermata)

This group is represented by the classes Crinoidea and Echinoidea. They are primarily found in Woodruff's (1984) Facies I, with reworked crinoids found in Facies V associated with the scorpion *Garnettius hungerfordi* and the reptile *Petrolacosaurus kansensis*. Only segments of the echinoderms were found at this locality.

Crustacean (Arthropoda)

This group is represented by the class Ostracoda. They are found in Woodruff's (1984) Facies II, III, and VII. Woodruff (1984) also noted they appeared to be of a freshwater variety but did not identify which variety.

Polychaetes (Annelida)

This group is represented by the family Serpulidae. They are found in Woodruff's (1984) Facies II, III, and VI.

Bivalves (Mollusca)

This group is represented by the genera *Myalina* (or *Mylinella*), *Sedgwickia*, and *Yoldia*. These compose the majority of the bivalves (Reisz et al., 1984) and are also found in Woodruff's (1984) Facies VII. Peabody (1982) noted that these genera inhabited brackish water. Additionally few reworked specimens have been found in association with *P. kansensis*.

Brachiopods (Brachiopoda)

This phylum is represented by the genera *Composita*, *Neospirifer*, and *Lingula*. Peabody (1952) reported *Lingual* as occurring with the bivalves. They are found in Woodruff's (1984) Facies I, upper part of V subfacies 2, VI, and VII, with reworked specimens found in Facies V subfacies 1.

Bryozoans (Bryozoa)

This phylum is represented by two genera of the order Fenestrata and one genus of the order Rhadbomesida. They are found in Woodruff's Facies I, II, III, VI, and VII, with reworked specimens found in Facies V associated *G. hungerfordi* and *P. kansensis*.

Terrestrial Invertebrates

Terrestrial invertebrates are represented by six taxa, of which all are arthropods. Four were new taxa originally described from Garnett. There is no reported stratigraphic information of where the fossils were collected; however, they most likely were found in Reisz et al.'s (1982) second fossil zone. These specimens were collected in the 1930s and were originally deposited at the University of Kansas (KU) Natural History Museum before the collections were split.

Scorpion (Chelicerate)

This group is represented by species G*arnettius hungerfordi* (Figure 8). To date only one specimen had been reported from Garnett. *Mazonia hungerfordi* was described by Elias (1937) as a new species, later revised by Petrunkecitch (1953) into a new genus *Garnettius*.

Blattodea (Hexapoda)

This group is represented by the cockroach genera *Phyloblatta* and *Mylacris*.

Megasecoptera (Hexapoda)

This group is represented by three taxa, two of which represent new genus/species. Carpenter described both *Parabrodia carbonaria* in 1933 and *Euchoptera longipennis* (Figure 9) in 1940. Carpenter (1940) noted that a third specimen had details weathered away although body size and shape were preserved. As such, Carpenter (1940) could only identify it to the order level.

Vertebrates

Vertebrates, both aquatic and terrestrial, are represented by 15 taxa, of which only four are fish and seven are amniotes. The vertebrates appear to be confined to the western-most outcrop. Specimens were deposited at the KU Museum of Natural History and Royal Ontario Museum.

Cartilaginous Fish (Chondrichthyes)

This group is represented by three taxa from the orders Cladoselachiformes, Xenacanthida, and Hybodontiformes. These specimens are only known as isolated spines and teeth (Reisz, 1990).

Coelacanth (Sarcopterygiia)

This group is represented by *Synaptoylus newelli* (or *Rhabdoderma newelli*). Hibbard (1933) originally described it as two new genera/species; however, Echols (1963) revised this to be one genus/species. Scattered remains are found throughout Reisz et al's (1982) second and third fossil zones.

Amphibians (Amphibia)

This class is represented by three taxa, two of which represent new genera/species, and both are of the labyrinthodont subclass. Eaton (1973) described *Actiobatis peadodyi* as a new genus/species of the Batrachomorpha. Peabody (1958) described *Hesperherpeton garnettense* as a new genus/species of the Reptillomorpha. Reisz (1990) noted that multiple isolated bones have been collected and identified to Amphibia; however, these elements have not been described.

Diapsid (Reptilia)

This group is represented by *Petrolacosaurus kansensis* (Figure 10). Lane (1945) originally described it as two new genera/species; however, Peabody (1952) revised this to be one genus/species. Specimens of *P. kansensis* are found in Reisz et al's (1982) first and second fossil zones. Preservation ranges between near full articulation to partial disarticulation, with the exception of the skulls that appear to be fully articulated. To date, *P. kansensis* is considered the oldest diapsid and is known exclusively from Garnett.

Eupelycosaurs (Synapsida)

This group is represented by seven taxa, of which six represent new genera/species. Two belong to the family Edaphosauridae. The first is *Ianthasaurus hardestiorum* (Figures 11 and 12), described as a new genus/species by Reisz and Berman (1985). The second is *Xyrospondylus ecordia*, originally described by Peabody (1957) as a new species of *Edaphosaurus* and revised by Reisz et al. (1982) as a new genus. One belongs to the family Ophiacodontidae and compares favorably with the genus *Ophiacodon* (Figure 13). Four belong to the family Sphenacodontia, all of which represent new genera/species. The first is *Ianthodon schultzei* (Figures 14 and 15), described by Kissler and Reisz (2004). The second is *Eohaptodus garnettensis*, originally described by Currie (1977) as a new species of *Haptodus* and revised by Spindler (2015) as a new genus (Figures 16 and 17). The third is *Kenomagnathus scotti*, described by Spindler (2015). The fourth is *Tenuacaptor reiszi*, described by Spindler (2015).

Megaflora

The study of the Garnett plants has a strange history in that Elias' (in Moore et al., 1936) original 38 species cannot be confirmed due to the specimens being missing. This possibly resulted as the specimens were originally deposited at the KU Natural History Museum before the collections were split across the departments of Biology (vertebrates), Botany (plant), and Geology (invertebrates). The KU Paleobotany (KUPB) collection database shows that few of Elias's specimens have been retained, with the majority of the Garnett plant collection composed of fossils collected during later field season.

Winston (1983) was able to identify 15 species along with four unidentified ovules and one unidentified wood fragment. Collection occurred in a 1 m^2 area with a thickness of 1.45 m of the same facies Reisz et al. (1982) described. Winston noted that isolated conifer leaves were not collected whereas all "fern-like" fossils were collected. Furthermore, several specimens broke during collection and small specimens were not collected at all, but only identified in the field. It is possible that this has created a collection bias. Winston's specimens were deposited at the Invertebrate Paleontology Collection of the Royal Ontario Museum, Toronto, Canada.

The plants occur throughout Woodruff's (1984) Facies II through VII. Plant fossils have the highest concentration in Facies V and are the only reported fossils found in Facies IV.

Lycopods (Lycopodiophyta)

Few possible leaves have been recovered; however, identification is not certain due to poor fossil condition. These specimens are held in KUPB collections.

Ferns and Horsetails (Pteridophyta)

Ferns are represented by one species, the Marattiales fern *Pecopteris* sp. This type of fern is noted as being more primitive, having more fleshy stocks and larger fronds, than typical ferns. The other two species belong to the horsetail genus *Annularia*.

Seed Ferns (Pteridospermatophyta)

Seed ferns are represented by nine species, of which *Callipteris flabellifora* has two varieties present. Furthermore, the genera *Alethopteris* and *Neuropteris* have an ambiguous placement as both have also been reported as cycads due to similarity of the leaves when found without seeds.

Conifers (Pinophyta or Coniferophyta)

Conifers are represented by eight taxa and appear to be the most abundant (Winston, 1983; KU Paleobotany database, accessed 2017); however, this could be due to collection or preservation bias. Two genera belong to the Order Cordaitales, one being of the genus *Cordaites* and the other being of the genus *Cordaicarpon*. Four species of Walchia have been identified (Table 4). Additionally, both *Walchianthus* (male cone) and *Walchiastrobus* (female cone) have been found. Garnett is noted for being key to pushing the age range of *Walchia* from Permian to the Pennsylvanian.

Microflora

Only two studies have reported on the palynology of Garnett. The first was by Grupta and Boozer (1969), in which they described 47 species of pollen/spores, of which 18 were new species. Additionally a stratigraphic age analysis was performed for the 29 known species. This revealed that two species were previously found only in the Permian, one was found in the Late Pennsylvanian and Permian, five were only found in the Late Pennsylvanian, five were found in the Early to Late Pennsylvanian, four were found from the Late Mississippian to Late Pennsylvanian, eight were found only in the Middle Pennsylvanian, one was only found in the Early Pennsylvanian, one was found only in the Late Mississippian, one was found from the Late Mississippian to Middle

Pennsylvania, and one was found from the Late Mississippian to Early Pennsylvania. They concluded that the age of the Garnett fossil locality is Stephanian (= upper Pennsylvanian). Grupta and Boozer (1969) did not describe their sampling techniques; however, laboratory techniques included a 12 hour treatment in a solution 10% HCl, followed by an 8 hour treatment in a solution 52% HF, and 8 minute ultrasonic vibration at low frequency before mounting slides. Specimens were deposited at the Department of Earth Sciences, East Texas State University, Commerce, Texas.

The second study on Garnett palynomorphs was by Winston (1983), in which he reported 20 species, of which 16 were newly reported for the Garnett locality. Of the 16 new species, one is a probable fungal spore, whereas the rest are all from plants. Only one of the pollen/spore specimens could not be identified. Winston (1983) noted samples were collected by Heaton at 4 cm intervals through a 1.49 m column of the same facies described by Reisz et al. (1982) and prepared by the University of Toronto Palynological Laboratory. Specimens were deposited in the Paleobotany Laboratory at the University of Illinois, Urbana.

Trace Fossils

Only two types of trace fossils have been found at Garnett. They are tetrapod trackways that have been identified as *Megabaropus* and *Notalacerta* (Reisz, 1990). Reisz suggested the *Megabaropus* trackway was made by a large amphibian, and the *Notalacerta* trackways were made by a protorothyridid captorhinomorph. Charcoal has also been found, and its presence was suggested to indicate possible nearby fires (Winston, 1983).

Taphonomy

Taphonomy of the marine invertebrates has been all but ignored. The fossils appear to be preserved by replacement. The pelecypod layer appears to be preserved in place, with specimens being nearly complete. In the calcarenite layer all fossils are broken, possibly representing a storm assemblage. The terrestrial invertebrates are preserved as impressions. The vertebrates are all fossilized with no soft tissues preserved. Furthermore, most are partially disarticulated, with the exceptions of the chondrichthyan fish and *Petrolacosaurus kansensis*. The chondrichthyan fish are only found as isolated spines and teeth. Specimens of *P. kansensis* are found nearly fully articulate and partially disarticulated. The plants are preserved as impressions, compressions, and carbonizations. The palynomorph preservation was not reported by either study.

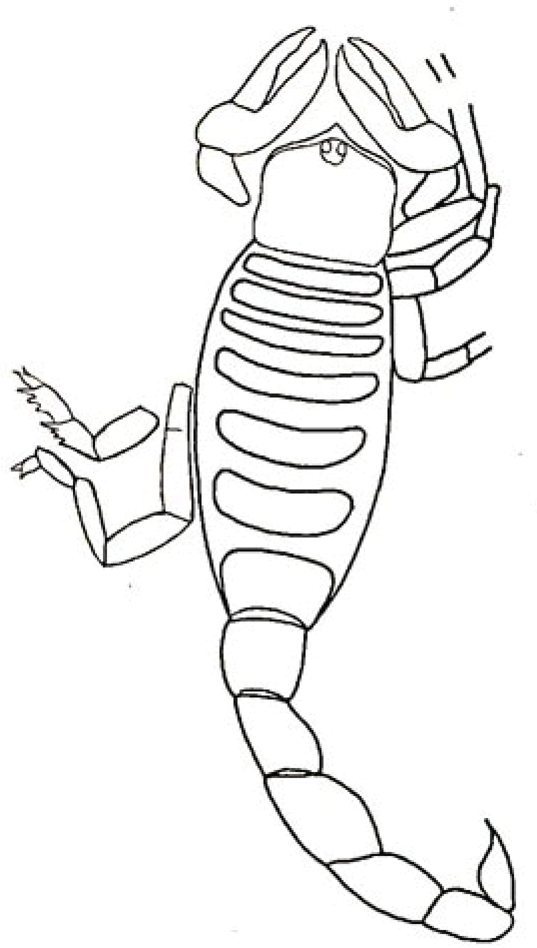

Figure 8: Reconstruction of *Garnettius hungerfordi* modified from Petrunkecitch (1953) figure 37. Elias (in Moore et al., 1936, and 1937) did not use a scale in photography or report measurements of the specimen. Petrunkecitch (1953) reported the carapace has a median line length of 17.2 mm, the pre-abdomen has a median line length of 475 mm, and the tail has total length of 52.8 mm; however the illustration does not clearly show all measured lengths. The specimen has a total length of 117.5 mm.

Figure 9: Holotype specimen for *Euchoptera longipennis* modified from Carpenter (1940). 1 is an X 1.7 magnification of the specimen showing the whole body. Carpenter (1940) noted the wings are 20 mm long and 5 mm wide at maximum, the abdomen is 17 mm long and ~4 mm wide, and the persevered cercus (rear appendage) is 50 mm long. 2 is an X 5 magnification for the main body.

Figure 10: Life reconstruction of *Petrolacosaurus kansensis* based on Reisz (1977 and 1981). Art is by Nobu Tamura and available on Wikimedia Commons (2017).

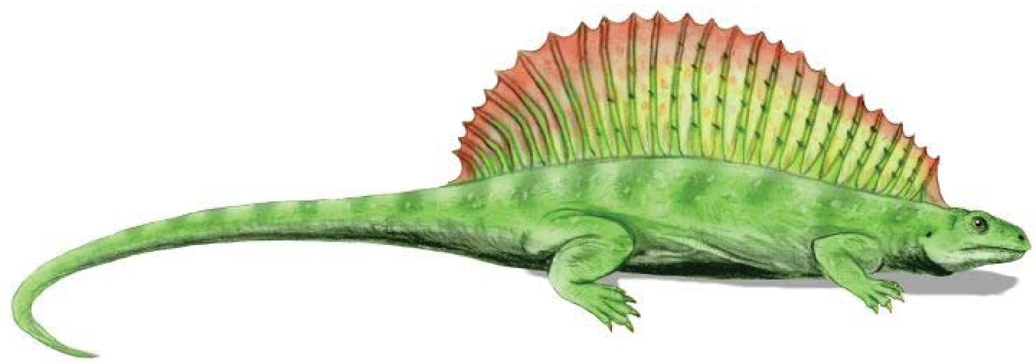

Figure 11: Life reconstruction of *Ianthasaurus hardestiorum* based on Reisz and Berman (1986) and Modesto and Reisz (1990). Art is by Nobu Tamura and available on Wikimedia Commons (2017).

Figure 12: Holotype of *Ianthasaurus hardestiorum* from Reisz et al. (1982) figure 3. The specimen is composed of the majority of the vertebra and neural spines along with the upper part of the skull, located near the scale bar. The specimen number is KUVP 69035.

Figure 13: Life reconstruction of the type species of *Ophiacodon*. Art is by ДиБгд and is available on Wikimedia Commons (2017).

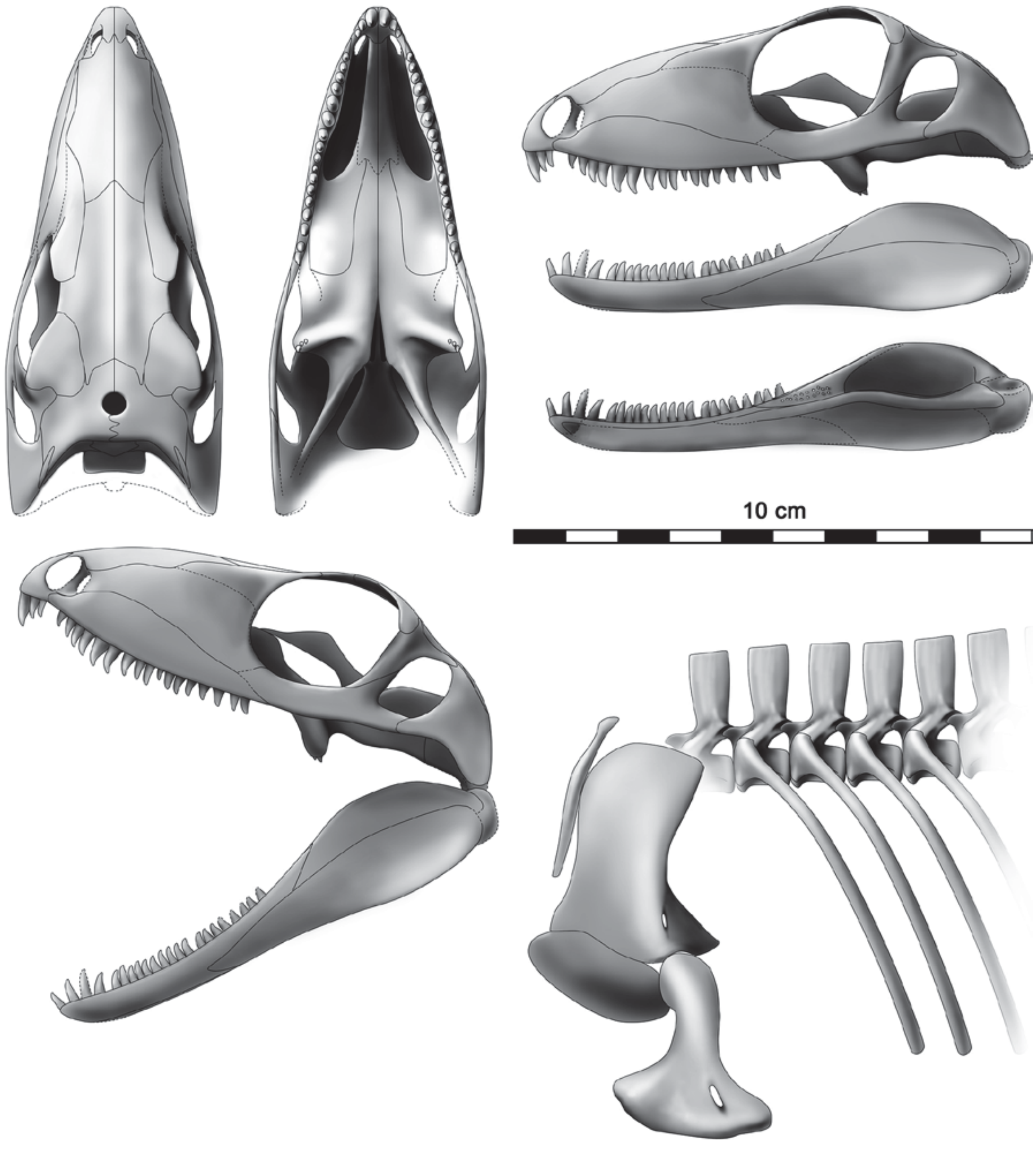

Figure 14: Cranial reconstruction of *Ianthodon schultzei* from Spindler et al. (2015) figure 6. Reconstruction is based on holotype material found after the fossil was fully prepared.

Figure 15: Holotype of *Ianthodon schultzei* from Spindler et al. (2015) figure 2. Photograph was taken before Kissler and Reisz (2004) work was performed. The specimen number is KUVP 133735.

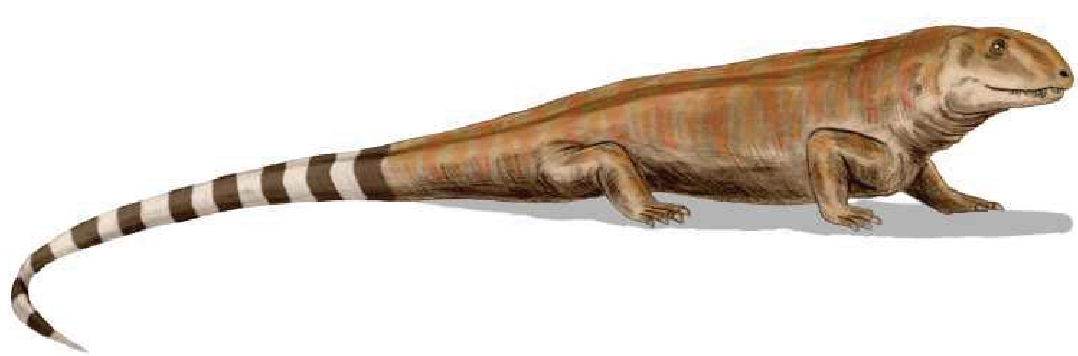

Figure 16: Life reconstruction of *Eohaptodus garnettensis* based on Currie (1977). Art is by Nobu Tamura and available on Wikimedia Commons (2017).

Figure 17: Holotype of *Haptodus garnettensis* (*Eohaptodus garnettensis*) as diagnosed by Currie (1977). Reevaluation of the specimen has shown it to be a juvenile *E. garnettensis* (Spindler, 2015). The specimen number is RM 14,156.

Chapter 4: Hamilton Quarry

Introduction

This chapter covers both the geological and paleontological aspects of Hamilton Quarry. Along the paleochannel, there are two major locations of study, the Main Quarry area and the Marlin Quarry. At both sites numerous geological and paleontological studies have been performed focusing primarily on the Main Quarry area and some on the Marlin Quarry. Stratigraphically, Hamilton Quarry was originally thought to be part of the Calhoun Shale Formation of the Shawnee Group, Virgilian Stage, Pennsylvanian System (Anderson, 1974). This was later revised as it was shown that a paleochannel cut through the Topeka Limestone Formation, Calhoun Shale Formation, and into the Ervine Creek Limestone Member of the Deer Creek Limestone Formation, all of the Shawnee Group (Bridge, 1988). The channel was later filled by deposits which are now referred to by various names, but here will be called the Hamilton channel fill.

The timing of deposition is unclear due to the lack of conformably overlying strata. Bridge (1988) suggested deposition occurred alongside the Topeka Limestone due to interfingering the beds; however, no evidence of this has been documented. Salley (2007) suggested that deposition could have occurred around the time the Severy Shale Formation (Sacfox Subgroup, Wabanunsee Group, Virgilian Stage) was deposited, based on the presence of an erosional surface between the Severy Shale and Topeka Limestone and the reported clast of both Curzon Limestone and Harford Limestone members of the Topeka being found in channel fill conglomerates. The depositional environment is highly debated, with arguments based on the lithology, taxa, or both (detailed below in the Environment of Deposition section). It has been agreed that the paleochannel had a north to south flow based on lithology (French et al., 1988; Busch et al., 1988) and orientation of plants (Feldman et al., 1990; Fahrer, 1993), and that the age of the cut and fill is most likely Late Pennsylvanian, based on the taxa.

Geographic Location

The Hamilton Paleochannel (Figure 18) is located in northern Greenwood County, Kansas, approximately 2.6 miles east of Hamilton, Kansas. The paleochannel is approximately 8 km long and has a variable width between 5 and 20 m (Feldman et al., 1990). Based on Feldman et al.'s (1990) study, the northern end of the paleochannel is located in the western ½ of Sec. 34, T 23 S, R. 12 E. then angles west-southwest through the southern ½ of Sec. 33, T 23 S, R. 12 E. It then cuts through the SE ¼, Sec 32, T 23 S, R. 12 E. trending southwest into Sec. 5, T 24 S., R 12 E. From here the paleochannel angles south with some sinuosity through Sec. 8, Sec, 17 and Sec. 20, T 24 S., R 12 E. The channel outcrops then terminates in the eastern ½ of Sec. 29, T 24 S., R 12 E. Some channel outcrop is reported from the SW ¼, SW ¼, Sec 21, T 24 S., R 12 E and NW ¼, NW ¼, Sec. 28, T 24 S., R 12 E. (Feldman et al., 1990; Cunningham et al., 1993; Salley, 2007). The Main Quarry area is located in the SW ¼, Sec 5, T 24 S., R 12 E. The Marlin Quarry is located in the NE ¼, Sec 17, T 24 S., R 12 E., approximately 1.6 miles south of the Main Quarry area. Emporia State University (ESU) currently owns and manages the Main Quarry area, which includes all of Sec. 5 and the northern ½ of Sec 8.

Geomorphic Setting

The geomorphic setting has been well studied by French et al. (1988), Busch et al. (1988) Feldman et al. (1990), Cunningham et al. (1993), and Salley (2007). Quarrying

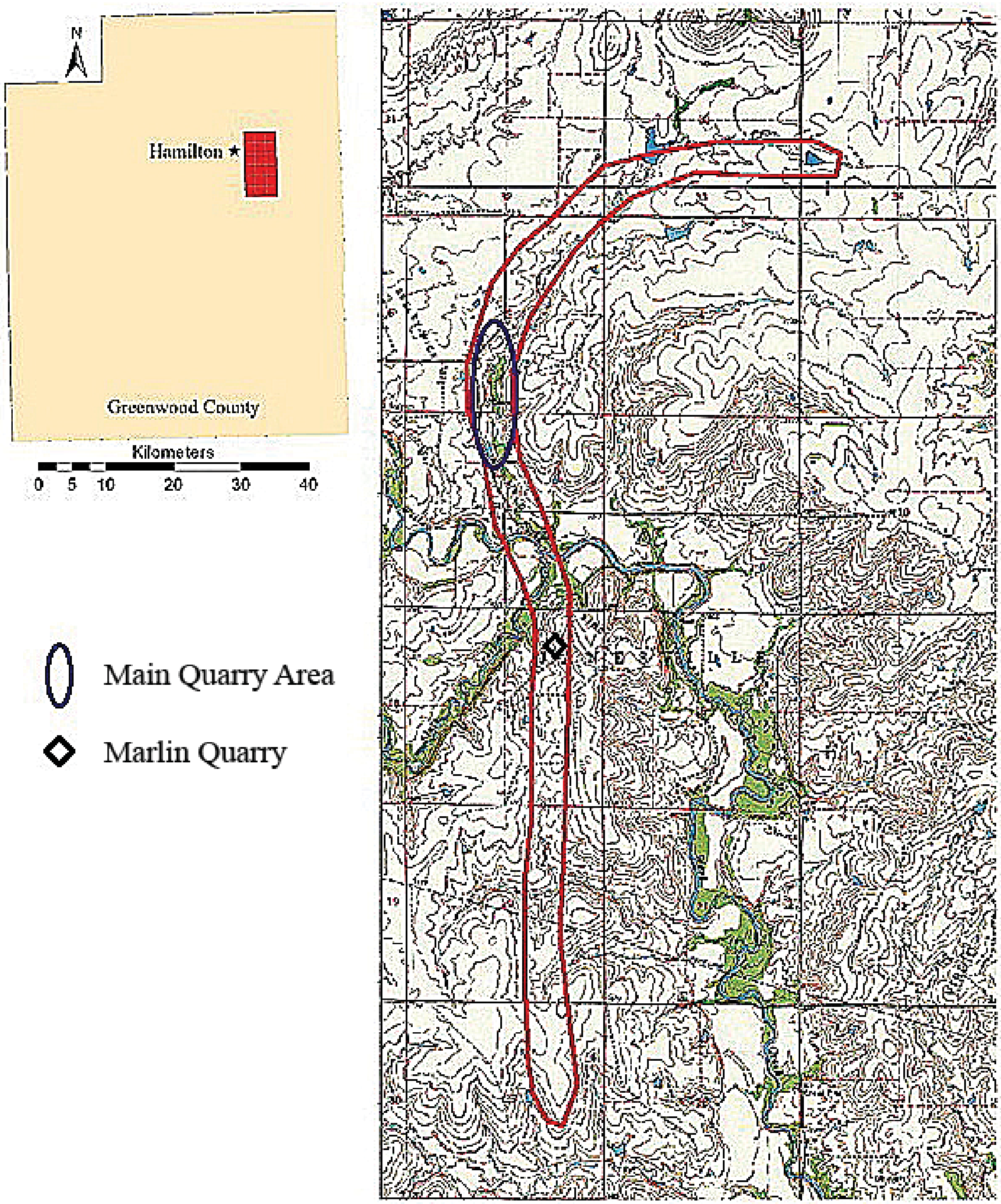

Figure 18: Geographic location and topography of the Hamilton Paleochannel. Highlighted section in Greenwood County indicates the enlarged sections. Red outline indicates the approximate position and known extent established by Feldman et al. (1990). The Main Quarry is outlined in purple. The Marlin Quarry is marked by the black diamond. Modified from USGS (1967 and 1969).

has exposed both paleochannel and surrounding deposits. A modern stream runs through the Main Quarry area parallel to the quarries. Coring (Feldman et al., 1990; Leonard, 1991; Fahrer, 199l Cunningham et al., 1993) has established the currently understood boundaries of the paleochannel

Stratigraphy

Introduction

Stratigraphic studies of the paleochannel have focused on the Main and Marlin quarry areas, whereas the extreme northern and southern ends have been mostly ignored. While both French et al. (1988) and Busch et al. (1988) noted lithological differences between the northern and southern areas of the paleochannel, neither published detailed descriptions. Andersen's (1974) original description of the stratigraphy at the Main Quarry matches later stratigraphic columns presented by Mapes and Maples (1988) and Salley et al. (2005), although Anderson considered what is now referred to as the channel fill to be part of the Calhoun Shale. Differences between the three works can be attributed to scale and lumping of units. Cunningham's (1990b, 1993a, 1993b) description of the stratigraphy at the Main Quarry is the most detailed, but it cannot be easily correlated with those of Andersen (1974) or the stratigraphic columns of Mapes and Maples (1988) and Salley et al. (2005). Cunningham (1993a, et al., 1993) also described the stratigraphy at the Marlin Quarry; however, the stratigraphy here is more lumped than his work on the Main Quarry stratigraphy, leading to issues for correlation between both areas. Unfortunately Mapes and Maples (1988) did not report thickness of channel units in their publication. Furthermore, Salley et al.'s (2005) reported thicknesses of surrounding strata did not match the thicknesses shown in their stratigraphic column

(Figure 19). Fahrer (1991) gave the best generalized stratigraphy of the entire area and divided the paleochannel into the four sections: northern, Main Quarry area, south-central (= Marlin Quarry), and southern. Therefore, the stratigraphy will be discussed in two major parts. First will be the stratigraphy of the units that the paleochannel cuts through and the basal conglomerate. Second will be the rest of the channel fill proper (i.e., above the basal conglomerate) divided between the northern area, Main Quarry, Marlin Quarry, and the southern area to best show lithologic changes and the amount of study. To date no capping strata have been found for the channel fill.

Deer Creek Limestone Formation

The paleochannel is flanked by and cuts into the Ervine Creek Member, which is the uppermost member of the Deer Creek Limestone (Bridge, 1988; French et al., 1988). Regionally the Ervine Creek is 1 to 10 meters thick with a blue-gray color that weathers yellow and has two distinctive lithologies (Fahrer, 1991; Salley, 2007). The lower layer is noted as having wavy beds that contain corals, fusulinids, crinoids, echinoderms, bryozoans, brachiopods, and mollusks (Fahrer, 1991; Salley, 2007). The upper layer is noted as being fine grained with massive bedding and generally lacks fossils (Fahrer, 1991; Salley, 2007). Exposure in the channel is only of the lower layer, with its thickness of 1 to 2 meters (French et al., 1988; Fahrer, 1991; Salley, 2007).

Calhoun Shale Formation

The paleochannel is flanked by cuts through the entirety of the Calhoun Shale; however, members are not noted in the channel. Moore (1949) noted that the Calhoun Shale is composed of clayey to sandy shale with few lenses of sandstone, has a maximum thickness 50 feet, and contains terrestrial plant fossils. In the channel the Calhoun Shale

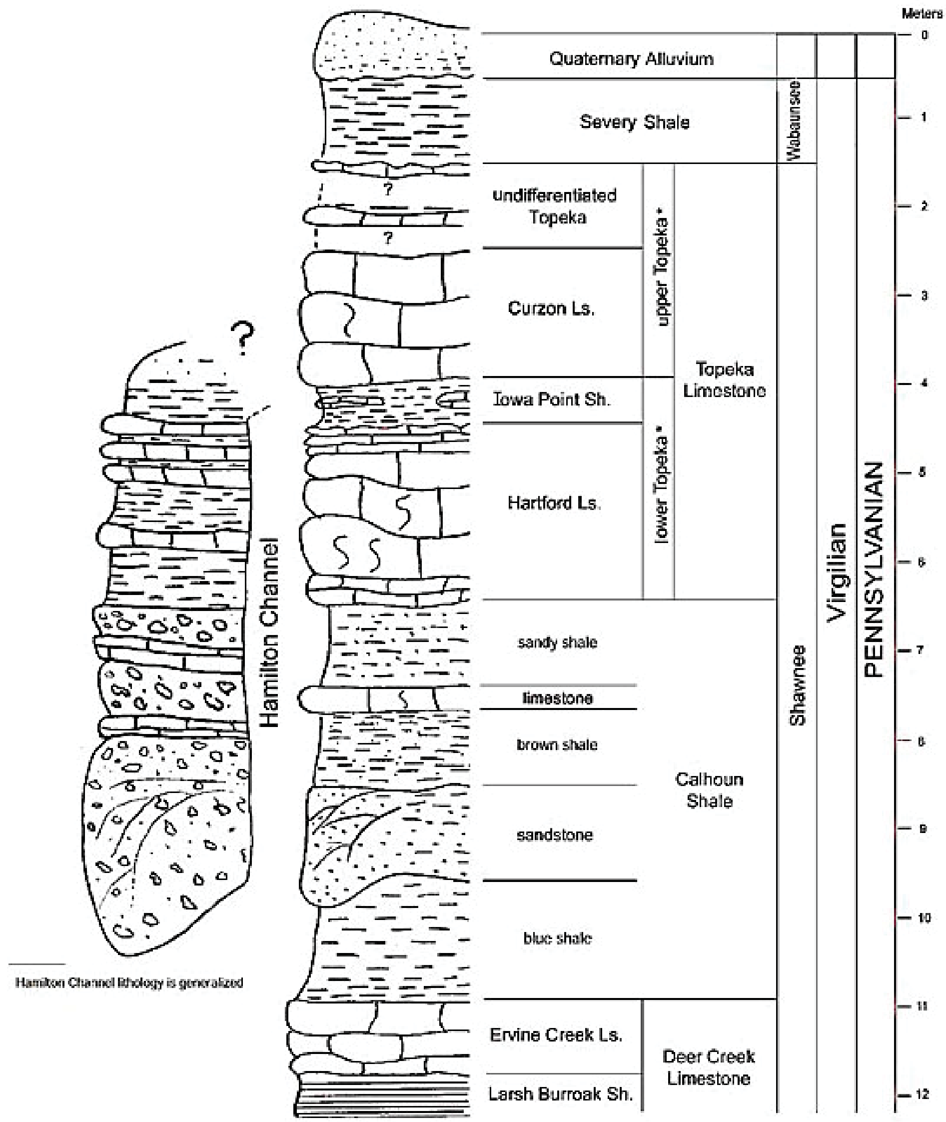

Figure 19: Stratigraphic column of Pennsylvanian deposits in the Hamilton Quarry area, modified from Salley et al. (2005). Illustrated thicknesses do not match those recorded in Salley et al. (2005)'s KGS open-file repot.

has an average thickness of 13 meters; French et al. (1988) reported a maximum of 13 m, Fahrer (1991) reported a maximum of 12 m, and Salley et al. (2005) reported a maximum of 11.5 m; Salley (2007) later reported a maximum of 15.5 m. This variation may be due to measurements being taken in different sections of the channel. Salley et al. (2005) noted four distinct lithologies. First is a lower blue-gray shale that sits on the Deer Creek which contains brachiopods, crinoids, and bryozoans. Second is a sandstone that grades into a brown sandy shale and contains plant fossils. Third is a fossiliferous limestone that contains bivalves, crinoids, sponges, forams, brachiopods, fusulinids, and bryozoans. Fourth is an upper sandy shale that contains plant fossils, burrows, and the brachiopod *Lingula*. Fahrer (1991) noted there was no plant or invertebrate fossils in the section he looked at.

Topeka Limestone Formation

The paleochannel is flanked by and cuts through the lowest three members of the Topeka Limestone; the upper six are not present at the channel. The lowermost is the Hartford Limestone Member, which is a dark gray color that weathers orange and averages 4 meters thickness (Fahrer, 1991; Salley, 2007). Sally et al. (2005) noted the Hartford contains brachiopods, bryozoans, and crinoids. Second is the Iowa Point Shale Member, which is a yellow to blue-gray color and contains plant fossils (Fahrer, 1991). Salley (2007; et al., 2005) reported an average thickness of 1.35 meters, while Fahrer (1991) reported a thickness of 5 cm in the channel. Neither reported fossils being found. The third is the Curzon Limestone Member, which is a blue-gray color that weathers orange and contains fusilinids, brachiopods, bryozoans, echinoids, and crinoids (Fahrer, 1991; Salley et al., 2005; Salley, 2007). Salley (2007) noted that the Curzon was not present at the channel; however, he was able to identify a few clast in the basal conglomerate as belonging to it. Fahrer (1991) noted that some outcrops in the area show the Curzon sitting directly on the Harford.

Hamilton Channel Fill: Basal Conglomerate

The basal conglomerate of the channel fill (Figure 20) has been recognized along the entire paleochannel. Thickness varies along the length with different authors reporting different thicknesses. Cunningham (1993a; et al., 1993) reported approximately 1 m thinness in the Marlin Quarry area, while also reporting approximately 5 cm thickness at the Main Quarry. Fahrer (1991) reported the approximated thickness of 15 to 20 cm at the northern end increasing to approximately 5 m at the southern end. Andersen (1974) reported a 1 ft/30.5 cm thickness at the Main Quarry. Sally (2007) noted that the clasts were larger and more angular in the northern end and decreased in size, becoming more rounded moving south. Furthermore, Salley (2007) was able to identify some of the clasts as belonging to the Curzon and Hartford members of the Topeka Limestone and to the Calhoun Shale. Cunningham (1993a) noted that the conglomerate contained fragments of plants, fusulinids, forams, ostracods, brachiopods, bryozoan, bivalves, gastropods, crinoids, echinoids, tooth plates of *Orthacanthus*, xenocanth sharks, hybodont sharks, a single tooth of *Petalodus*, and the maxilla of an ophiacodont. Fahrer (1991) reported similar taxa with the addition of conodonts. Furthermore, the ostracods and bivalves found in the conglomerate are of genera typically found in brackish to marine waters (detailed in the Aquatic Invertebrates section).

Northern Area

Fahrer (1991) noted the basal conglomerate is capped by nonmarine carbonaceous shales and limey mudstones with a thickness of 60 to 80 cm. The shales are a light brown color and contain flakes of mica. The mudstone is brown to gray in color and contains ostracods and plant remains.

Figure 20: Typical example of the basal conglomerate.

Main Quarry

Anderson (1974) described the outcrop (although attributing it to the Calhoun Shale) as composed of 11 units. He described unit 1 as a one foot thick cobble sized sandstone (= basal conglomerate) that sits unconformably on the Ervine Creek Limestone and contains ostracods and plants. Unit 2 is a two foot thick white limestone that contains eurypterids. Unit 3 is a three foot thick limestone pebble conglomerate that contains abraded bones, brachiopods, bryozoans, fusulinids, mollusks, echinoids and crinoids. Unit 4 is a three foot thick white laminated limestone and contains eurypterids, plants, and ostracods. Unit 5 is a five foot thick conglomerate that has the same description as Unit 3. Unit 6 is a one foot thick dark gray to blue limestone that contains eurypterids, myriapods, arachnids, insects, plants, amphibians and fish (*Acanthodes*). Unit 7 is six inch thick gray shale that contains plants. Unit 8 is a laminated limestone that contains eurypterids and plants; thickness was not reported. Unit 9 is a 20 foot thick gray shale that contains plants. Unit 10 is a three to five foot thick yellow sandstone that contains plants. Unit 11 is a gray shale that contains plants; no thickness was given.

French et al. (1988) briefly described the stratigraphy, but the way it is presented is not clear because no section drawing was given, no measurements were given in the text, and the units were not defined. Mapes and Maples (1988) illustrated a generalized stratigraphic column (Figure 21) showing eight units but without thickness. Unit 1 is a conglomerate (= basal conglomerate). Unit 2 is a laminated limy mudstone that contains eurypterids. Unit 3 is another conglomerate. Unit 4 is a laminated limy mudstone that contains eurypterids. Unit 5 is another conglomerate. Unit 6 is a shale. Unit 7 is a finely laminated limy mudstone that is tan to grey in color. Unit 8 is shale. Units 1 through 5 are probably the same as Anderson's (1974) Unit 1 through 5.

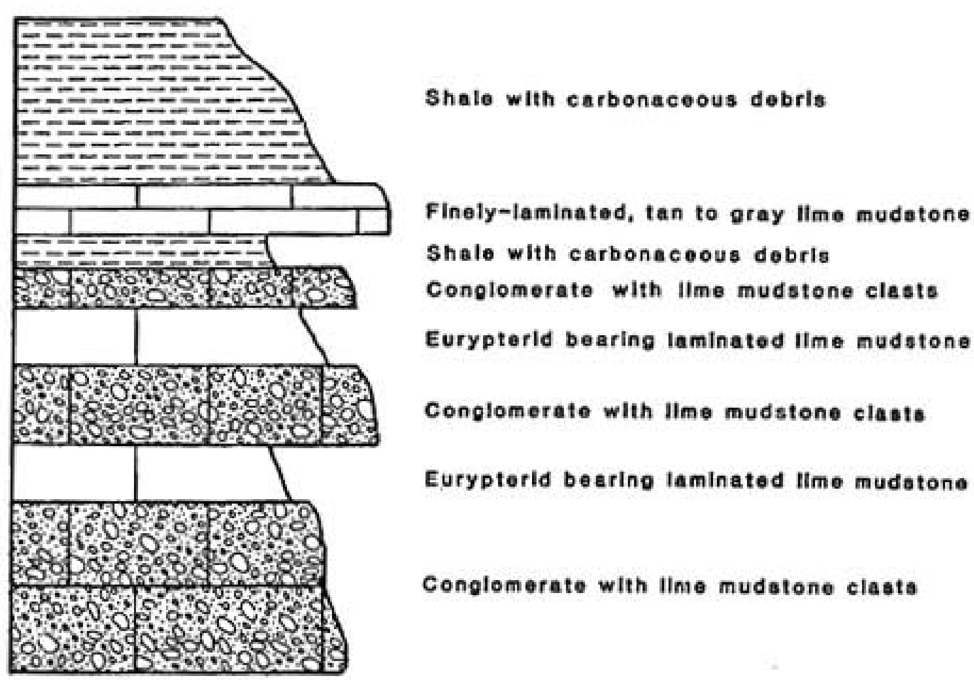

Figure 21: Stratigraphy of the channel fill in the Main Quarry as illustrated by Mapes and Maples (1988), figure 1.

Fahrer (1991) noted the conglomerate is capped by carbonaceous shales, similar to those in the northern area, and carbonate mudstones (Figure 22) that have clear laminations (Figure 23). Fahrer (1991) referred to tan-gray laminated carbonate mudstones as containing the vertebrate fossils in addition to invertebrates and plants.

Cunningham (1993, updated from 1990b) described the channel fill as being composed of 15 units, however he reversed numeric order so 1 is the top and 15 is the

Figure 22: Example of the tan-gray laminated carbonate mudstone of Fahrer, 1991. Note all the black to lite brown patches are preserved plant material. The sample was collected from scree pile near the quarry pond in the south the Main Quarry area.

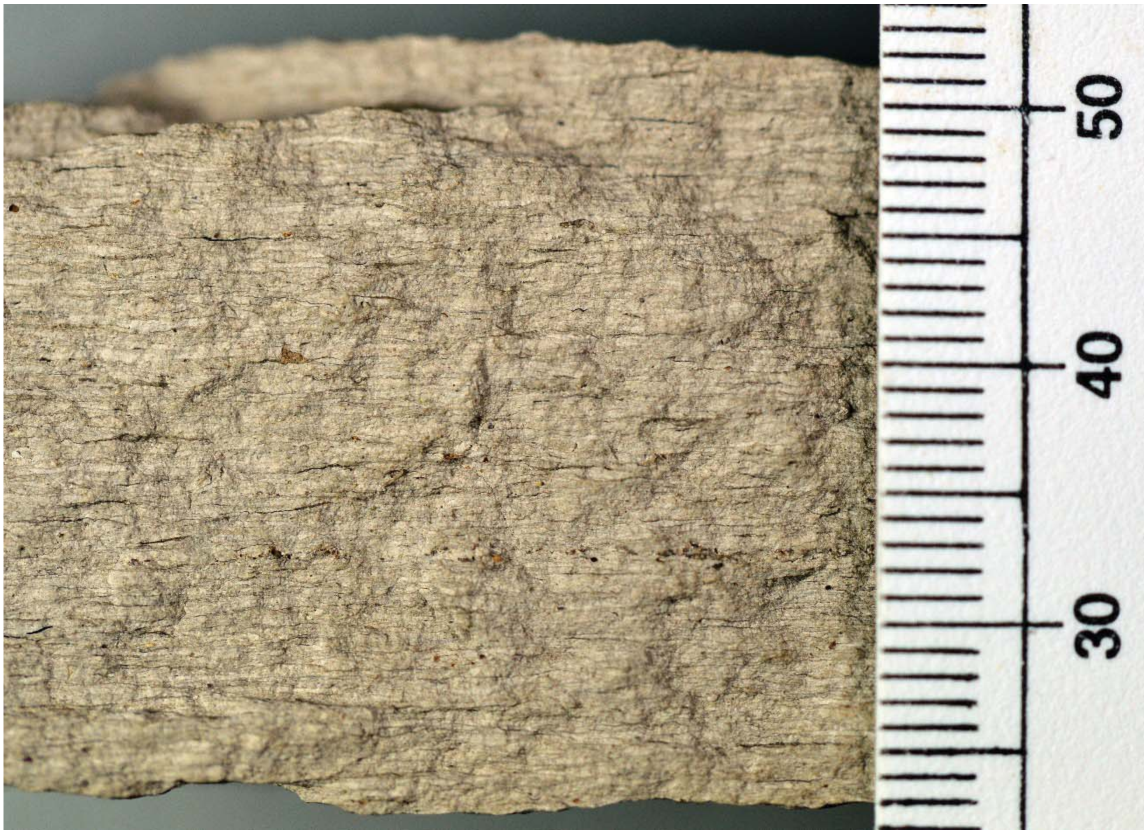

Figure 23: Example of the tan-gray laminated carbonate mudstone showing fine laminations. The sample was collected from scree pile near the quarry pond in the south the Main Quarry area.

bottom. Additionally he illustrated two stratigraphic columns to show a cross-section of the 1989 University of Kansas excavation site. Invertebrates were found as fragments, and *Darwinula* is the most common ostracod. Unit 15 is the basal conglomerate. Unit 14 is a laminated mudstone that contains plants, fusulinids, and spirorbids. Unit 13 is a laminated limestone. Unit 12 is a laminated calcareous mudstone that contains plants, fusulinids, bryozoans, spirorbids, echinoids, gastropods, crinoids, brachiopods, and fish scales and denticles. Unit 11 is a laminated carbonate mudstone that contains plants, brachiopods, and ostracods. Unit 10 is a laminated carbonate mudstone that contains plants, fusulinids, bryozoans, spirorbids, echinoids, gastropods, crinoids, brachiopods, ostracods, bivalves, and fish scales and denticles. Unit 9 is a calcareous laminated mudstone that contains plants, fusulinids, bryozoans, spirorbids, echinoids, crinoids, brachiopods, ostracods, bivalves, and fish scales, denticles and teeth. Unit 8 is a laminated limestone. Unit 7 is a laminated calcareous mudstone that contains plants, fusulinids, spirorbids, brachiopods, ostracods, and fish scales and teeth. Unit 6 is a finely laminated limestone. Unit 5 is a laminated calcareous mudstone that contains fusulinids, spirorbids, brachiopods, ostracods, bivalves, and fish scales and teeth. Unit 4 is a finely laminated limestone that contains plants, ostracods, terrestrial invertebrates, and articulated aquatic and terrestrial vertebrates. Unit 3 is a calcareous mudstone that contains plants, brachiopods, and ostracods. Unit 2 is a laminated calcareous mudstone that contains plants, ostracods, brachiopods, and fish scales. Unit 1 is a limestone (ostracod wackstone) that is laminated in the lower part and massively bedded in the upper, and contains plants, ostracods, forams, sponge spicules, brachiopods, and rare fish scales and teeth.

Salley et al. (2005) illustrated an update stratigraphic column showing 14 units. However, reported thickness for surrounding strata do not match those shown on the stratigraphic column, as such thickness of the channel fill cannot be inferred. Unit 1 is a conglomerate (= basal conglomerate), Unit 2 is a limestone, 3 is a conglomerate, 4 is a limestone, 5 is a conglomerate, 6 is a shale, 7 is a limestone, 8 is a shale, 9 is a limestone, 10 is a shale, 11 is a limestone, 12 is a shale, 13 is a limestone, and 14 is a shale. Units 1 through 8 are probably the same as Mapes and Maples (1988) Units 1 through 8. No fossil information was reported.

Marlin Quarry

Fahrer (1991) noted the (basal) conglomerate is capped by ostracod wackstones that contained eurypterids. He postulated that the carbonaceous shales and limy mudstones missing from the Marlin Quarry (Figure 24), but present everywhere else along the paleochannel, were either not deposited or eroded away and then replaced by the wackstones. Fahrer (1991) suggested that erosion and replacement were more probable because of the presence of shales and mudstone in the southern area and absences of wackstones.

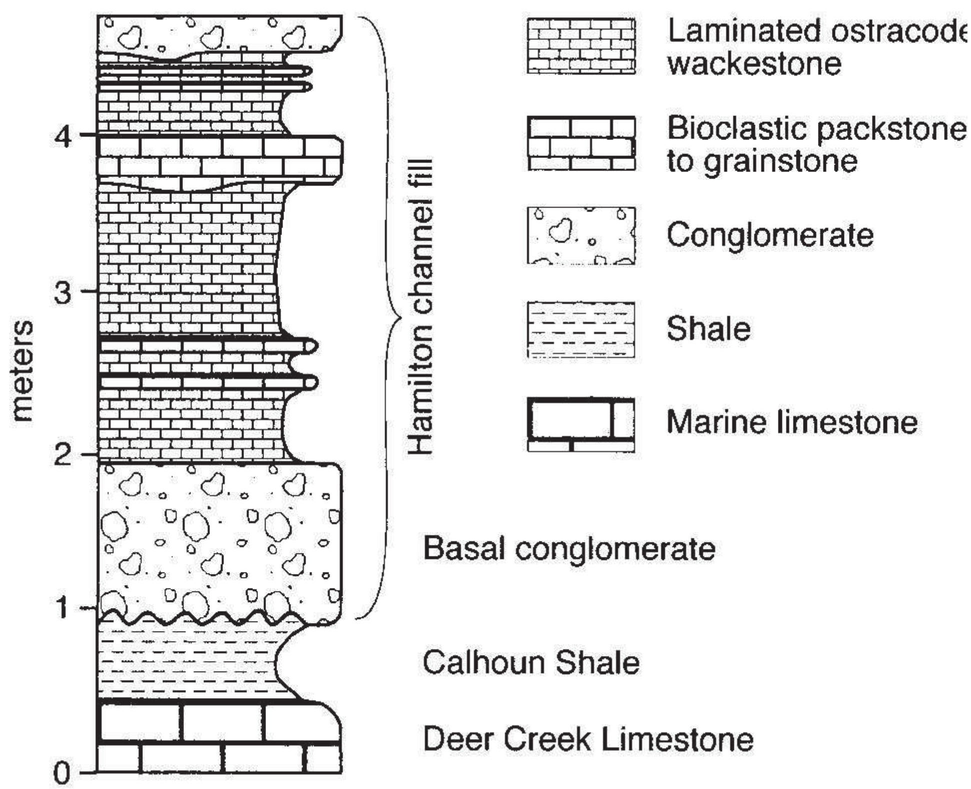

Figure 24: Stratigraphy of the Marlin Quarry channel fill as illustrated by Cunningham et al. (1993) figure 3.

Cunningham et al. (1993) described this area as having a two- meter thick ostracod wackstone capping the (basal) conglomerate (Figure 25). The wackstone is tan to brown in color with irregular laminations and ostracods accounting for approximately 90% of the bioclasts. Unfortunately, the genus of ostracods was not reported. Fossils have the highest abundance in the upper part and decrease downward. Plant fossils include cordaite leaves, seed ferns, ferns, and sphenopsids. Cunningham et al. (1993) noted the conifers were absent, whereas in the Main Quarry they are the most abundant plant. Animal fossils include the bivalve *Anthraconaia*, eurypterids, rare articulated brachiopods, shrimp (malacostracans), fish scales, and one complete lungfish *Gnathorhiza*. They proposed the wackstone represented a low energy shallow water environment, possibly a tidal estuary.

Southern Area

Fahrer (1991) noted there are few outcrops; however, at the extreme southern end the (basal) conglomerate outcrops as a large lobe. Leonard (1991) reported a thickness of 1.4 meters in core, whereas Fahrer (1991) reported a tightness of 5 meters. A road cut just north of the conglomerate lobe shows the conglomerate being capped by shales and thin carbonate mudstones. The mudstones contain plant fragments and annelids. Fahrer (1991) indicated this was the area Schram’s (1988) malacostracans were collected, but unfortunately Schram did not note collection locality in his paper.

Environment of Deposition

The depositional environment has been interpreted multiple times. Currently the only consensus is that deposition occurred in a paleochannel, with arguments focusing on whether it is marine or terrestrially influenced. Both sides use fossil evidence to support their argument; however, they tend to overlook data from the entire paleochannel. Both Fahrer (1991) and Feldman et al. (1993) suggested deposition occurred over a short period of time, which is supported by the large number of exceptionally preserved vertebrates. Described below are the proposed depositional environments in chronological order.

Stream or Delta

This environment (Figure 25) was suggested by Hanson (1973) before it was determined the deposit was a paleochannel. This interpretation was based on the presences of *Acanthodes,* which is thought to be a freshwater fish, the large number of well-preserved arthropods, and a large number of plants found with seeds. Additionally the finely grained and laminated limestone was interpreted as a stream deposit.

Freshwater Stream

This environment has been suggested by Bridge (1988), Kues (1988), Kaesler (1988), Leisman et al. (1988), Maisey (1988), Mapes and Maples (1988), Maples and Mapes (1988), Taggart and Ghavidle-Syooki (1988), and Zidek (1988). This interpretation is based on the presence of freshwater taxa within the channel fill and the abundance of well-preserved plants. These taxa include the freshwater ostracods *Darwinula*, *Geisina*, and *Carbonita* (Kaesler, 1988), freshwater bivalve *Anthraconaia* (Maples and Mapes, 1988), and freshwater fish *Acanthodes* (Zidek, 1988). Additionally Mapes and Maples (1988) reported that marine invertebrates found in the vertebrate-bearing limestone were reworked and/or fragmented by transport.

Figure 25: Reconstruction of the Hamilton paleovalley as a stream environment.

Near Shore Marine

This environment has been suggested by Busch et al. (1988), French et al. (1988), Maples and Schultze (1988), and Schultze and Chorn (1988). This interpretation is based on the lithology of the channel fill being predominantly limestones and shales that contain marine invertebrates.

Tidal Estuary

This environment (Figure 26) was suggested by Cunningham (1993b), Feldman et al. (1993), and Schultze et al. (1993). This interpretation is based on the fine laminations found in the lithology in the Main and Marlin quarries resembling laminations found in known tidal depositions and the mixing of marine and nonmarine invertebrates. Schultze et al. (1993) illustrated possible water influx sources. Schultze et al. (1993) indicated that the northern and Main Quarry areas had freshwater influx from the north due to a stream and surface runoff, whereas the southern area had an influx of marine water from the south due to daily tides, and the Marlin Quarry area acted as a mixing zone.

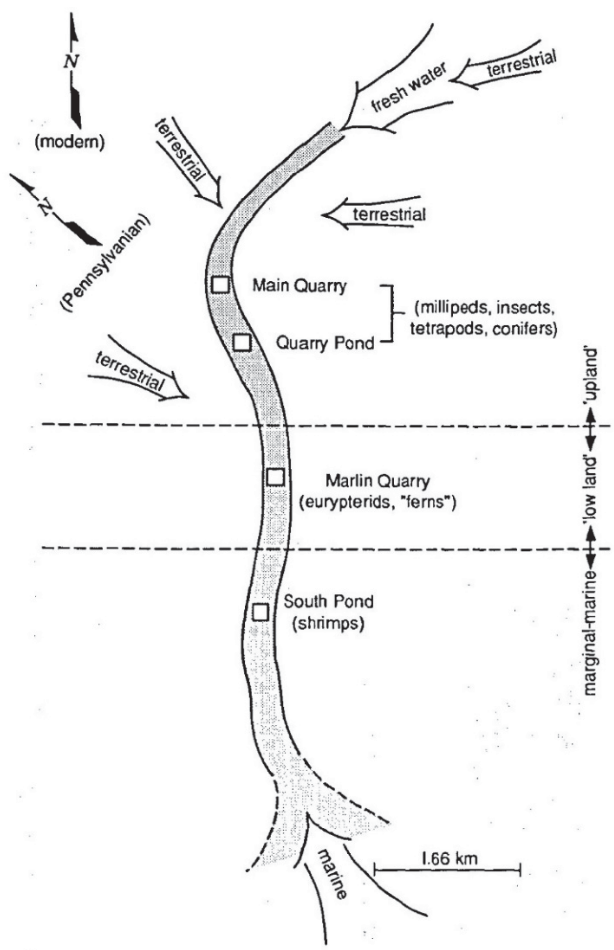

Figure 26: Paleogeographic reconstruction of the Hamilton paleochannel as a tidal estuary showing sources of water. (From Schultze et al., 1993, Figure 4)

Marine

This environment was suggested only by Schultze (1995). This interpretation is based only on bulk fossil analysis of the fauna, which ignores the works of Mapes and Maples (1988), Maples and Mapes (1988), Kaesler, (1988), Zidek, (1988), and all paleobotany of Leisman et al. (1988). He argued that marine invertebrates are a better indicator of environment because they are less mobile than terrestrial invertebrates; therefore, more commonly preserved *in situ*. As such, the bulk fossil assemblage contains more marine invertebrates than terrestrial fauna; therefore, it is a marine depositional environment.

This Study

The depositional environment is interpreted here as a stream channel that grades into an estuary and terminates in a sediment lobe, which may or may not be a delta. The northern and Main Quarry areas are interpreted to have been predominantly freshwater with little to no mixing of marine water. The change in lithology at Marlin Quarry is interpreted to represent a mixing of fresh and marine water, with the upwards increase of terrestrial fossils suggesting freshwater had a greater influence later in deposition. Fahrer (1991) suggested that wackstones represented replacement of eroded shales and mudstones; however, this suggestion lacks evidence as no erosional surface has been seen between the wackstones and the basal conglomerate. The southern area is interpreted to represent the most seaward part of the channel, possibly being an abandoned deltaic lobe. The idea of an abandoned lobe is suggested by the change of lithology between the southern area and Marlin Quarry; however, no research has been done between these areas. The thickness of the basal conglomerate suggests erosion started near the southern end and eroded northward.

Plant fossils are found throughout the entire length of the channel indicating a stream flowing to the south flow (Feldman et al., 1990; Fahrer, 1993). The only marine vertebrates found are conodonts; however, the total number is so few they most likely were transported in. Both hybodontiform and xenacanthid sharks are found in marine and freshwater deposits; therefore, they cannot be used to indicate salinity. *Acanthodes* is commonly found in freshwater deposits; therefore, they can be used as an indication of non-marine environments. Thus, the presence of *Acanthodes* indicates freshwater was in the northern and Main Quarry areas. Additionally, the presence of juvenile *Acanthodes* and a *Palaeoxyris* shark egg (Schultze, 1995) suggest low energy areas of the stream were used for breeding. The multitude of exceptionally preserved terrestrial invertebrates and both fish and small amphibians with soft tissue suggest rapid burial due to either high sedimentation rate or a single high energy event that caused a large influx of sediment. The latter can explain why there are few marine invertebrates and conodonts found in the vertebrate bearing limestone. The abundance of well-preserved plants suggests low energy and the lack of transport. The presence of conifers in the Main Quarry and absence in the Marlin Quarry suggest conifers were living near the stream in its upstream areas and energy was too low to transport remains far downstream. Alternatively, it is possible conifers are present at the Marlin Quarry but have not been collected and/or identified; more research is needed.

Paleontology

The Hamilton Lagerstätte contain a total of 126 taxa and two types of trace fossils and unidentifiable charcoal. Of the total taxa, 26 represent palynomorphs (Liesman et al., 1988; Taggart and Ghaviel-Syooki, 1988), none of which were new species. Twenty-eight taxa represent plants, of which five were new species (Mapes and Rothwell, 1984; Liesman et al., 1988; Rothwell and Mapes, 2001; Mapes and Rothwell, 2003; Rothwell et al., 2005; Hernandez-Castillo et al., 2009a; 2009b; 2009c). Forty-nine taxa represent invertebrates (Hanson, 1973; Andersen, 1974; Douglass, 1988; Durden, 1988; Hannibal and Feldman, 1988; Kaesler, 1988; Maples and Mapes, 1988; Maples and Schultze, 1988; Pabian and Holterhoff, 1988; Schram, 1988), of which 39 are aquatic invertebrates and ten are terrestrial invertebrates, with two being new species. Twenty-three taxa represent vertebrates (Zidek, 1976b; Schultze and Chorn 1988; Schultze, 1988; Daly, 1988; Zidek, 1988b; Chorn and Schultze, 1988; Maisey, 1989; Fahrer, 1991; Gottfried, 1993; Cunningham, 1993a; Daly, 1994; deBragga and Reisz, 1995; Reisz and Dikes, 2003; Muller and Reisz, 2005; Reisz and Frocisch, 2014), of which 13 are aquatic vertebrates with three being new species, and ten are terrestrial vertebrates with five being new species. The trace fossils include coprolites and a fossilized shark egg (*Palaeoxyris*).

Figures of selected taxa are located at the end of the chapter. Due to the majority of aquatic invertebrates being common with a wide temporal range, few figures are presented of this group.

Taxonomic Classification

As mentioned in Chapter 3, taxonomic nomenclature for botany differs from that used in zoology. The botany rank of division is considered equal to the zoological rack of phylum. Additionally palynology uses different taxonomic nomenclature than either botany or zoology, as such taxa classification has been divided into three tables. Table 7 lists the fauna, Table 8 lists the megaflora, and Table 9 lists the microflora.

Table 7: Fauna

KINGDOM PROTISTA

Phylum Retaria
Subphylum Foraminifera
- Order Fuslinida
  - Family Biseriamminidae
    - Genus *Globivalvulina*
  - Family Schwagerinidae
    - Genus *Dunbarinella*
      - Species *D. ervinensis*
    - Genus Triticites
      - Species *T. cullomensis*
      - Species T. plummeri
      - Species *T. ventricosus*

KINGDOM ANIMALIA

Phylum Porifera
(sponge spicules)

Phylum Echinodermata
- Class Crinoid
  - Order Dendrocrinida
    - Family Apographiocrinidae
      - Genus *Apographiocrinus*
        - Species *A. cf. calycinus*
    - Family Cromyocrinidae (?)
    - Family Catacrinidae
      - Genus *Delocrinus*
        - Species *D. cf. vulatus*
    - Family Pirasocrinidae
      - Genus *Plaxocrinus*
        - Species *P. cf. crassidiscus*
    - Family Scytalocrinidae
- Class Echinoidea

Phylum Arthropoda
Subphylum Chelicerata
- Class Arachnida
  - Order Thelyphonida
    - Family Thelyphonidae
      - Genus *Prothelyphonus*
  - Order Scorpiones
    - Family Archaeoctonidae

Genus *Archaeoctonous*
Species *A. cf. A. glaber*
Class Merostomata
Order Eurypterida
Family Adelophthalmidae
Genus *Adelophthalmus*
Species *A. cf. A. mazonensis*
Subphylum Myriapoda
Class Diplopoda
Superorder Archipolypoda
Order Euphoberiidae
Superorder Juliformia
Subphylum Crustacea
Class Malacostrace
Superorder Peracarida
Order Spelaeogriphacea
Superorder Syncarida
Order Palaeocaridacea
Class Ostracoda
Order Palaeocopida
Family Amphissitidae
Genus *Amphissites*
Family Knoxitidae
Genus *Geisina*
Order Platycopida
Family Geisinidae
Genus *Gutschickia*
Order Podocopida
Family Bairdiidae
Genus *Bairdia*
Family Bairdiocyprididae
Genus *Pseudobythocypris*
Family Carbonitidae
Genus *Carbonita*
Family Darwinulidae
Genus *Darwinula*
Subphylum Hexapoda
Class Insecta
Order Blattodea
Suborder Cockroaches
Family Mylacridae
Genus *Paromylacris*

Subclass Pterygota
Order Protorthoptera
Family Geraroidea
Superorder Orthopterida
Order Orthoptera
Family Oedischiidae
Genus *Oedischia*
Superorder Odontaptera
Order Meganisoptera or Protoodonata
Family Meganeuridae
Genus *Meganeura*
Genus *Titanophasma*
Superorder Palaeodictypopteroidea

Order Palaeodictyoptera
Family Calvertiellidae
Genus *Carrizopteryx*

Phylum Annelida
Class Polychaeta
Order Canalipalpata
Family Serpulidae
Genus *Serpula*
Genus *Spirorbis*

Phylum Mollusca
Class Bivalvia
Order Myalinida
Family Myalinidae
Genus *Anthraconaia*
Species unknown
Genus *Myalinella*
Species *M. meeki*
Order Cardiidia
Family Permophoridae
Genus *Permophorus*
Order Nuculanoida
Family Nuculanidae
Genus *Phestia*
Order Trigoniida
Family Schizodidae
Genus *Schizodus*
Class Gastropoda
Order Bellerophontida
Family Bellerophontidae
Genus *Bellerophon*
Family: Euphemitidae
Genus *Euphemites*

Phylum: Brachiopoda
Class: Rhynchonellata
Order: Spiriferida
Family Punctospiriferidae
Genus *Punctospirifer*
Family Trigonotretidae
Genus: *Neospirifer*
Class: Strophomenata
Order Productida
Family Echinoconchidae
Genus: *Juresania*
Family Productidae
Genus *Antiquatonia*
Genus *Kozlowskia*
Family Rugosochonetidae
Genus *Neochonetes*

Phylum Bryozoa
Class Stenolaemata
Order Fenestrata
Order Cystoporate

<u>Phylum Chordata</u>

Subphylum Vertebrata
- Class Conodonta
  - Order Ozarkodinida
    - Suborder Ozarkodinia
      - Superfamily Polygnathacea
        - Family Polygnathidae
          - Genus *Streptognathodus*

Infraphylum Gnathostomata
- Class Chindrichthyes
  - Subclass Elasmobranchii
    - Order Xenacanthida
      - Family Orthacanthidae
        - Genus *Orthacanthus*
      - Family Xenacanthidae
        - Genus *Expleuracanthus*
          - Species *E. cf. E. parallelus*
        - Genus *Xenacanthus*
    - Order Hybodontiformes
      - Genus *Hamiltonichthys*
        - Species *H. mapesi*
  - Subclass Holocephali
    - Order Petalodontiformes
      - Family Petalodontidae
        - Genus *Petalodus*
- Class Acanthodii
  - Order Acanthodiformes
    - Genus *Acanthodes*
      - Species *A. bridgei*

Superclass Osteichthyes
- Class Actinopterygii
  - Order Palaeonisciformes
    - Family Elonichthyidae
      - Genus *Elonichthys*
    - Family Palaeoniscidae
      - Genus *Feroniscus*
        - Species *F. hamiltoni* or *hamiltonensis*
- Class Sarcopterygii
  - Subclass Actinistia
  - Subclass Rhipidistia
    - Family Megalichthyidae
  - Subclass Dipnoi
    - Family Gnathorhizidae
      - Genus *Gnathorhiza*
    - Family Sagenodontidae
      - Genus *Sagenodus*
        - Species *S. cf. copeanus*

Superclass Tetrapoda
- Class "Amphibia"
  - Subclass Labyrinthodonta
    - Superorder Batrachomorpha
      - Order Temnospondyli
        - Superfamily Dissorophoidea

Family Amphibamidae
Genus *Eoscopus*
Species *E. lockardi*
Superfamily Eryopoidea
Family Eryopidae
Suborder Dvinosauria
Family Trimerorhachidae

"Epiclass" Amniota
Class Reptilia
Subclass Eureptilia
Order Captorhinomorpha
Family Captorhinidae
Genus *Euconcordia*
Species *E. cunninghami*
Infraclass Diapsida
Order Araeoscelida
Genus *Spinoaequalis*
Species *S. schultzei*
Class Synapsida
Order Caseasauria
Family Caseidae
Genus *Eocasea*
Species *E. martini*
Order "Eupelycosauria"
Family Varanopidae
Genus *Archaeovenator*
Species *A. hamiltonensis*
Family Edaphosauridae
Genus *Ianthasaurus*
Species *I.* cf. *I. hardestii*/*hardestiorum*
Genus *Lupeosaurus* (?)
Family Ophiacodontidae

Table 8: Megaflora (Plants)

KINGDOM PLANTAE

Division Lycopodiophyta
Class Isoetopsida
Order Lepidodendrales
Family Sigillariaceae
Genus *Sigillaria*
Species *S. brardii*

Division Pteridophyta
Class Polypodiopsida
Family Sphenopteridae
Genus *Sphenopteris*
Species *S. cf. S. germanica*

Class Sphenophyta or Equisetopsida
Order Equisetales

Family Calamitaceae
Genus Asterophyllites
Species *A. equisetiformis*
Species *A. longiformis*
Genus *Annularia*
Species *A. mucronata*
Genus *Paleostachya*
P. sp.

Division Pteridospermophyta

Class Pteridospermopsida
Order Peltaspermales
Family Peltaspermaceae (?)
Genus *Callipteris*
Species *C. conferta*
Species *C. flabellifora*
Variety *moorei*
Species *C. scheibei*
Class Pteriodphylleae
Order Medullosales
Family Neurodontopteridaceae
Genus *Cyclopteris*
Genus *Neuropteris*
N. sp. A
N. sp. B
Genus *Odontopteris*
Class Spermatopsida
Order Trigonocarpales
Family Trigonocarpaceae
Genus *Trigonocarpus*

Division Pinophyta or Coniferophyta

Class Pinopsida or Coniferopsida
Order Cordaitales
Family Cordaitaceae
Genus *Cordaites*
Species *C. principalis*
Genus *Cordaianthus*
Species *C. cf. pitcairniae*
Genus *Samaropsis*
Species *S. fluitans*
Order Voltziales
Family Emporiaceae
Genus *Emporia*
Species *E. cryptica*
Species *E. lockardii*
Species *E. royalii*
Genus *Hanskerpia*
Species *H. hemiltonensis*
Family Bartheliaceae
Genus *Barthelia*
Species *B. furcata*
Family Utrechtiaceae or Walchiaceae
Genus *Gomphostrobus* (stem/leaf)
Genus *Walchia* (leaves)
Species *W. hypnoides*

Species *W. piniformis*
Species *W. schneideri*
Genus *Walchianathus* (male cone)
Genus *Walchiastrobus* (female cone)

Table 9: Microflora (Pollen and Spores)

KINGDOM PLANTAE

Anteturma Sporites
Turma Triletes
Subturma Azonotriletes
Infraturma Laevigati
Genus *Leiotriletes*
L. sp.
Genus *Calamospora*
C. sp.
Genus *Triletes*
T. sp.
Infratruma Apiculati
Subinfraturma Nosatia
Genus *Acanthoriletes*
Species *A. teretriangulatus*

Anteturma Pollenites
Turma Saccites
Subturma Monosaccites
Infraturma Triletesacciti
Genus Nuskoisporites
Species *N. trianguloris*
Infraturma Vesiculomonoraditi
Genus Potoniesporites
Species *P. gtranulatus*
Species *P. neglectus*
Subturma Disaccites
Infraturma Sulcati
Genus *Sulcatisporites*
Species *S. splendens*
S. sp.
Infraturma Striatiti
Genus *Protohaploxypinus*
Species *P. samoilocichii*
Genus *Striatopodocarpites*
S. sp. A
S. sp. B
Genus *Hamiapollenites*
Species *H. perisporites*
Species *H. succatus*
Infraturma Disaccitrileti
Genus *Striatoabitites*
Species *S. multistriatus*
S. sp.

Infraturma Disacciatrileti
Genus *Alisporites*
Species *A. indarraensis*
Species *A. gracilis*
Species *A. nuthalensis*
Genus *Falcisporites*
Species *F. zapfei*
Genus *Limitisporites*
L. sp.
Subturma Striattes
Genus *Lueckisporites*
Species *L. vickkiae*
Genus *Striatites*
Species *S. splendens*
Turma Plicates
Subturma Polyplicates
Genus *Vittatina*
Species *V. cf. V. subsuccata*
Species *V. cf. V. verrucosa*
V. sp.

Aquatic Invertebrates

Aquatic invertebrates are represented by a total of 39 taxa, 33 of which are considered marine invertebrates, one is considered to be a brackish water invertebrate, four are considered freshwater invertebrates, and one is considered to transition between marine and freshwater. With few exceptions, the stratigraphic positions of the aquatic invertebrates have not been reported in the literature. Mapes and Maples (1988) noted few specimens (total of ~41) of brachiopods, marine bivalves, gastropods, bryozoa, crinoids, and annelids have been recovered from the same limestone layer that the majority of vertebrates are found in at the Main Quarry area. Due to their broken nature compared to the vertebrates, the invertebrates were most likely transported into the area, and as such should not be used as indicators of salinity. Specimens were deposited at the University of Kansas Invertebrate Paleontology (KUIP) Museum, Emporia State University geology museum (ESU), Ohio University, San Diego Natural History Museum, and in private collections.

Foraminiferans (Retaria)

This group is represented by five taxa all from the order Fuslinida. One is the genus *Globivalvulina* from the family Biseriamminidae. Four are from the family Schwagerinidae, with one from the genus *Dunbarinella* and three from the genus *Triticites*. Douglass (1988) tentatively identified all of the Schwagerinidae to the species level (Table 1). All specimens have been collected from the basal conglomerate.

Sponges (Porifera)

Sponge spicules have been reported (Maples and Schultze, 1988); however, no further work has been done to identify the specific taxa.

Echinoderms (Echinodermata)

This group is represented by the classes Crinoidea and Echinoidea. Crinoids are represented by 5 taxa all of the family Dendrocrinida, of which three have tentatively been identified to the species level by Pabian and Holterhoff (1988). Additionally, Pabian and Holterhoff (1988) noted that examined specimens fell into two categories: 1) small unweathered specimens from the basal conglomerate and 2) larger weathered and partially dissolved specimens from the vertebrate bearing limestone in the Main and Marlin Quarry areas. They suggested that specimens in category 1 somehow avoided strong current to explain the unweathered nature and those of category 2 represented transported martial. Echinoids are only represented by a few fragment with no further work performed.

Eurypterids (Arthropoda)

Eurypterids are represented by the species *Adelophthalmus cf. A. mazonensis* (Figures 27-30) as described by Anderson (1974) and Kues (1988). This genus is thought to have been able to transition between marine and fresh waters. All specimens were collected from the limestone layers in the Main Quarry area. Specimens are held by ESU and are in private collections.

Crustacean (Arthropoda)

Crustaceans are represented by the classes Malacostraca and Ostracoda. Malacostracans are represented by two taxa, one each of the orders Spelaeogriphacea and Palaeocaridacea (Schram, 1988). Ostracods are represented by seven genera, of which three are freshwater and four are marine. Kaesler (1988) noted that specimens came from limestones in both Main and Marlin quarries. Furthermore, Kaesler (1988) noted that the most abundant in all samples is *Darwinula*, an exclusively freshwater ostracod. Few marine ostracods were found in the Marlin Quarry samples.

Polychaetes (Annelida)

This group of worms is represented by two taxa from the family Serpulidae. The taxa are identified as *Serpula* and *Spirorbis*. Mapes and Maples (1988) noted that the only specimens were found in the northernmost part of the Main Quarry in the vertebrate bearing limestone. Additionally, *Spirorbis* (Figure 31) was found encrusting cordaite leaves (Mapes and Maples, 1988).

Bivalves (Mollusca)

Bivalves are represented by five genera, of which one is freshwater, one is brackish water, and three are marine. The freshwater bivalve is of the genus *Anthraconaia* and are found in the Main Quarry area (Maples and Mapes, 1988). The brackish water bivalve is *Mylinella*. Marine bivalves are from the genera *Schizodus*, *Phestia*, and *Permophorus*. Mapes and Maples (1988) noted that only five bivalve specimens of *Mylinella*, *Schizodus*, and *Phestia* were recovered from the vertebrate bearing limestone in the Main Quarry area.

Gastropods (Mollusca)

Gastropods are represented by the genera *Bellerophon* and *Euphemites*. Only three specimens were recovered from the vertebrate bearing limestone (Mapes and Maples, 1988), with all other specimens found in the basal conglomerate.

Brachiopods (Brachiopoda)

This phylum is represented by the orders Spiriferida and Productida. Spirifers are represented by two genera and productids are represented by four genera. Mapes and Maples (1988) noted that 18 specimens were recovered from the vertebrate bearing limestone, with all other specimens found in the basal conglomerate.

Bryozoans (Bryozoa)

This phylum is represented by the orders Fenestrata and Cystoporate. Mapes and Maples (1988) noted that only five specimens were recovered from the vertebrate bearing limestone, with all other specimens being from the basal conglomerate.

Terrestrial Invertebrates

Terrestrial invertebrates are represented by ten taxa, all of which are arthropods. All were recovered from the limestone layers in the Main Quarry area. Specimens were deposited at KUIP Museum, ESU and the Denver Museum of Nature and Science (DMNS).

Arachnids (Chelicerate)

This group is represented by a single whip scorpion specimen (Figure 32) and a single scorpion specimen (Figure 33). Both were originally described by Hanson (1973), with only slight revision by Hanson et al. (1988). The whip scorpion compares favorably to the genus *Prothelyphonus*; species identification could not be made due to the poor condition of the specimen. The scorpion belongs to the genus *Archaeoctonous* and compares favorably with the species *A. glaber*. Specimens are held by ESU.

Millipedes (Myriapoda)

This group is represented by the class Diplopoda. Specimens were originally described by Hanson (1973) and revised by Hannibal and Feldman (1988). The majority of specimens belong to the order Euphoberiida (Figure 34), with several being found nearly complete. Hannibal and Feldman (1988) noted a few specimens possibly represent the superorder Juliformia; however, the specimens are not clear enough to be identified farther. Additionally, parts of myriapods have been found in coprolites (McAllister, 1988).

Blattodea (Hexapoda)

This order is represented by the cockroach genus *Paromylacris* (Figure 35). Hanson (1973) originally thought there were two genera present; however, this was revised by Durden (1988) to be of one genus. Blattods are by far the most abundant invertebrate found in the Main Quarry.

Pterygota (Hexapoda)

This subclass is represented by five taxa. The order Protorthoptera are walking sticks which are represented by the family Geraroidea. The order Orthoptera are crickets which are represented by the genus *Oedischia*. The order Meganisoptera (or Protoodonata) (Figure 36) are ancient dragonflies which are represented by the genera

Meganeura and *Titanophasma*. The order Palaeodictyoptera are ancient six-winged insects which are represented by the genus *Carrizopteryx* (Figure 37).

Vertebrates

Vertebrates are represented by 23 taxa, of which 13 are aquatic and ten are terrestrial. Three of the aquatic vertebrates and five of the terrestrial vertebrates were described as eight new species and seven new genera. With few exceptions, the majority of the vertebrates were collected from the limestone layers in the Main Quarry area. Specimens were deposited at University of Kansas Vertebrate Paleontology (KUVP) Museum, ESU and DMNS.

Conodonts (Conodonta)

Nine specimens of the conodont genus *Streptognathodus* were recovered. Two specimens came from the basal conglomerate; however, it is not clear if they were part of the matrix or the conglomeratic clasts. Seven specimens came from the vertebrate bearing limestone; Farhrer (1991) suggested they were transported in by the same event that transported the marine invertebrates described by Mapes and Maples (1988). *Streptognathodus* is known from the Virgilian stage, as such suggests the earliest time that the Hamilton paleochannel could form (Fahrer, 1991).

Cartilaginous Fish (Chindrichthyes)

This class is represented by five taxa from the subclasses Elasmobranchii and Holocephali. The Elasmobranchii are represented by the orders Xenacanthida and Hybodontiformes. Zidek (1988b) identified the xenacanthids as belonging to the genera *Orthacanthus*, *Expleuracanthus* (Figure 38 and 39), and *Xenacanthus*. The majority of specimens are exceptionally well preserved and of the whole body. Few broken tooth plates were recovered from the basal conglomerate. Maisey (1989) described the hybodontiform as a new genus/species *Hamiltonichthys mapesi* (Figure 40). Furthermore, the majority of specimens of this species are exceptionally preserved and of the whole body. Cunningham (1993a) collected the only specimen of a holocephalian from the basal conglomerate. He identified it to the genus *Petalodus*.

Acanthodes (Acanthodii)

This class of fish is represented only by the species *Acanthodes bridgei* (Figures 41-43). Zidek (1976b) described *A. bridgei* as a new species. He noted that the Hamilton Quarry contained multiple whole body specimens of both juveniles (Figure 42) and adults (Figure 43), suggesting the paleochannel was used for breeding.

Actinopterygii (Osteichthyes)

This group of fish is represented by two taxa from the order Palaeonisciformes. Gottfried (1993) described the first as a new genus/species *Feroniscus hamiltoni* (or *hamiltonensis*) (Figures 44 and 45). Cunningham (1993a) identified the second genus *Elonichthys*. Most specimens are partly disarticulated.

Sarcopterygii (Osteichthyes)

This group of fish is represented by four taxa from the subclasses Actinistia, Rhipidistia, and Dipnoi. Actinista is possibly represented by isolated scales of a single morphology. Either the specimens' conditions prevent further identification or no further work was performed. Rhipidistia is represented by a single specimen of a lower jaw identified to the family Megalichthyidae (Schultze, 1988). Dipnoi is represented by the lungfish genera *Gnathorhiza* and *Sagenodus* (Figures 46 and 47) (Chorn and Schultze, 1988).

Amphibians (Amphibia)

This class is represented by three taxa, one of which was a new genus/species. All belong to the order Temnospondyli. Daly (1976, 1988, 1994) described *Eoscopus lockardi* (Figure 48), a new genus/species belonging to the superfamily Dissorophoidea. Small specimens are noted to be nearly complete and articulated; whereas, larger ones are incomplete and disarticulated. Schultze and Chorn (1988) identified isolated elements as belonging to the families Eryopidae and Trimerorhachidae.

Captorhinomorphs (Reptilia)

This group is represented by a single taxon that was described twice as a new genus/species. The first description was unpublished in Cunningham's (1993a) dissertation as *Coelothyroides chorni.* The second description was published by Müller and Reisz (2005) as *Concordia cunninghami* (Figure 49), later revised to *Euconcordia cunninghami* (Reisz et al., 2016). Müller and Reisz (2005) take name priority due to the International Code of Zoological Nomenclature not considering theses and dissertations to be valid publications for the purpose of description of new taxa. As such Cunningham's (1993a) *Coelothyroides chorni* is a *nomen nudum*.

Diapsid (Reptilia)

This group of reptiles is represented by *Spinoaequalis schultzei* (Figures 50 and 51), known from two partially disarticulated specimens. Reisz (1988) originally thought specimens represented two new taxa, but later deBraga and Reisz (1995) would describe them as a new genus/species.

Caseasaurid (Synapsida)

This group is represented by *Eocasea martini* (Figures 52 and 53), known from a single specimen. Reisz and Frönisch (2014) described the specimen as a new genus/species, which represents the oldest and most basal caseid synapsid.

Eupelycosaurs (Synapsida)

This group is represented by four taxa, of which one was a new genus/species. The first belongs to the family Edaphosauridae and is identified from a single complete vertebra specimen that compares favorably with *Ianthasaurus hardestiorum* (Chapter 3, Figure 11) (Schultze and Chorn, 1988). The second is also a possible edaphosaurid that possibly belongs to the genus *Lupeosaurus* identified from a partial ilium in the DMNS collections (Figure 54). However, this genus is known only from a few incomplete specimens (Reisz, 1986). The third taxon tentatively belongs to the family Ophiacodontidae (Figures 55 and 56) and was identified from a single broken maxilla collected from the basal conglomerate (Schultz and Chron, 1988). Cunningham (1993a) also reported ophiacodontid fossil(s) in the vertebrae bearing limestone. The fourth belongs to the family Varanopidae and was described by Reisz and Dikes (2003) as a new genus/species, *Archaeovenator hamiltonensis* (Figures 57 and 58). *A. hamiltonensis* represents basal eupelycosaurs and basal varanopids (Reisz and Dikes, 2003).

Megaflora

Plants are represented by 28 taxa and are found throughout the entire paleochannel. The vertebrate bearing limestone in the Main Quarry area contains the majority and most diversity of plant fossils. Specimens were deposited at the University of Kansas Paleobotany division, ESU, DMNS, and Ohio University Paleobotanical Herbarium.

Lycopods (Lycopodiophyta)

Lycopods are represented by the presence of the bark of *Sigillaria* (Figure 59). Leisman et al. (1988) identified the bark to the species *S. brardii*.

Ferns and Horsetails (Pteridophyta)

Ferns are represented by five species of the classes Polypodiopsida and Sphenophyta (or Equisetopsida). Polypodiopsida is represented by the species *Sphenopteris cf. S. germanica*. Sphenophyta (or Equisetopsida) is represented by four genera, all of the family Calamitaceae. Two species belong to the genus *Asterophyllites* (Figure 60), one belongs to the genus *Annularia* (Figure 61), and one belongs to the genus *Paleostachya* (Figure 62) (Leisman et al., 1988).

Seed Ferns (Pteridospermatophyta)

Seed ferns are represented by seven taxa of the classes Pteridospermopsida, Pteriodphylleae, and Spermatopsida. Pteridospermopsida is represented by three species of the genus *Callipteris* (Figure 63). Pteriodphylleae is represented by three genera of the order Medullosales, one species belongs to the genus *Cyclopteris* (Figure 64), one to *Odontopteris*, and two to the genus *Neuropteris* (Figure 65). Spermatopsida is represented by the genus *Trigonocarpus* (Figure 66) (Leisman et al., 1988). Both Pteriodphylleae and Spermatopsida have an ambiguous classification as both have also been reported as cycads due to similarity of the leaves when found without seeds.

Conifers (Pinophyta or Coniferophyta)

Conifers are represented by 14 taxa and appear to be the most diverse and abundant plants. Three taxa belong to the order Cordaitales: one species is of the genus *Cordaites* (Figure 67 and 68), one of *Cordaianthus*, and the other is *Samaropsis*. Eleven taxa belong to the order Voltziales, represented by the families Emporiaceae, Bartheliaceae, and Utrechtiaceae (or Walchiaceae). Both Emporiaceae (Mapes and Rothwell, 1991; 2003) and Bartheliaceae (Rothwell and Mapes, 2001) were new families described from the Hamilton Quarry. Emporiaceae is represented by the three species of the genus *Emporia*. The first is *Emporia locardii* (Mapes and Rothwell, 1984; revised 1991) which was originally described as *Labachia lockardii*. While most *Labachia* have been reattributed to *Walchia*, *E. lockardii* shows enough difference to be considered a new family/genus (Mapes and Rothwell, 2003). The second was a new species *E. royalii* (Hernandez-Castillo et al., 2009a), and the third is *E. cryptica* (Hernandez-Castillo et al., 2009c). Bartheliaceae is represented by the species *Barthelia furcate* (Rothwell and Mapes, 2001). Utrechtiaceae (or Walchiaceae) is represented by three species of the genus *Walchia* (Figure 69 and 70), the genus *Gomphostrobus* (stem/leaf), the genus *Walchianthus* (male cone), and the genus *Walchiastrobus* (female cone) (Figure 71) (Leisman et al., 1988; Mapes and Rothwell, 1988).

Microflora

Palynomorphs are represented by 26 taxa. Taggart and Ghavidel-Syooki (1988) noted that all specimens were recovered from the vertebrate bearing limestone of the Main Quarry area; however, laboratory methods were not listed. They noted that all are similar to pollen/spores commonly found in Early Permian sediments. In addition, they noted that their study was too limited to make any determination of sources of the palynomorphs and of their abundance. Leisman et al. (1988) noted the presence of the calamite megaspore *Calamospora* and the lycopod megaspore *Triletes*. Hernandez-

Castillo et al. (2009a) attributed the pollen genus *Potonieisporites* to the conifer *Emporia royalii*.

Trace Fossils

To date two types of trace fossils have been reported, with the majority collected from the Main Quarry area. The first and most abundant are coprolites (Figure 72), which have a varied composition. The coprolite contents include: acanthodian scales and spines, palaeoniscoid scales, elasmobranch teeth, myriapod fragments, brachiopod fragments, and various unidentifiable bone and invertebrate fragments. Second is the *Palaeoxyris* shark egg (Figure 73) reported by Schultze (1995), which suggests the paleochannel was used for breeding. The charcoal (Figure 74) has been suggested to indicate the possibility of nearby forest fires (personal observation, DMNH display on Hamilton Quarry).

Taphonomy

Taphonomy of the marine invertebrates has been all but ignored. The fossils appear to be preserved by replacement. Mapes and Maples (1998) noted that the specimens recovered from the vertebrate bearing limestone were fragmented, suggesting transport or reworking. The terrestrial invertebrates are preserved as impressions, with an abundance of whole body specimens. Vertebrates have three distinct modes of preservation. First are fish and small amphibians that are found as whole body specimens, often showing soft tissue preservation included as carbonaceous films (Figures 40, 43, and 49). This is suggestive of high sediment influx causing burial before decay began. Second are the disarticulated *Acanthodes* and *Palaeonisciformes* preserved as strings of scales.

Cunningham (1993a) suggested this is due to the dead fish floating with pieces slowly breaking off and dropping to the bottom. Third are partly to fully disarticulated larger terrestrial vertebrates such as amphibians and reptiles. The skulls are found with elements slightly separated and often near or attached to articulated vertebral columns. The limbs are found near the body but not attached. This partial disarticulation suggests water flow caused some transport. Isolated elements have also been found, suggesting full disarticulation and transport. Additionally Gottfried (1989) found preserved pigments in bony fish *Elonichthys*, noting that it was rare to find preserved pigments in fish specimens of this age, being more common in younger deposits. Also, Tanaka et al. (2014) found evidence of preserved rods and cones in the eyes of a specimen of the fish *Acanthodes bridgei*. The plants are preserved as impressions, compressions, and carbonizations, with larger specimens found in the Main Quarry area. The palynomorph preservation was not reported. Preserved coprolites show the outline of the fecal matter with some contents preserved in the center. The reported *Palaeoxyris* shark egg is preserved as an impression.

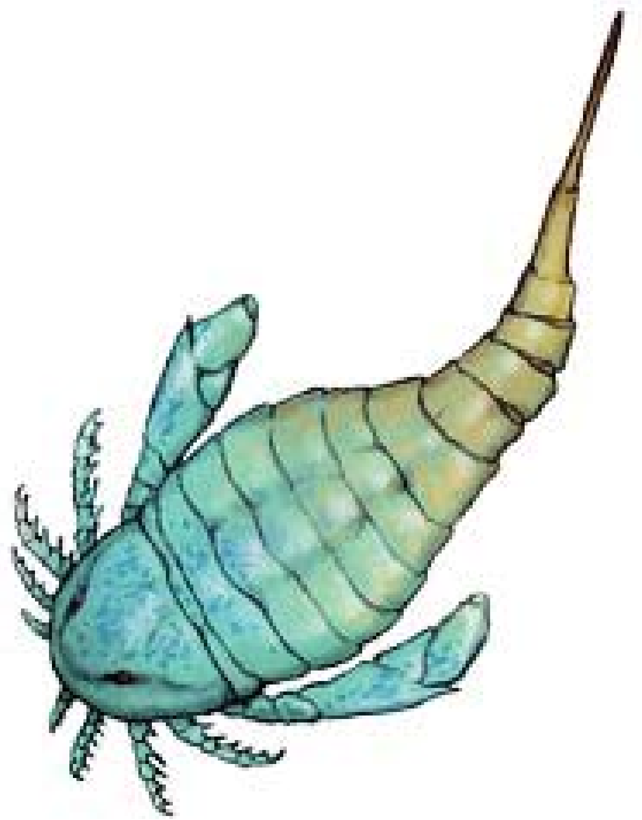

Figure 27: Life reconstruction of *Adelophthalmus. cf. A. mazonensis*. Artist unknown, available on redlegagenda.com (2017).

Figure 28: Cephalon of *Adelophthalmus cf. A. mazonensis*. ESU specimen number HQ 133b.

Figure 29: Body of *Adelophthalmus cf. A. mazonensis*. Note the preserved body segmentation and appendages. ESU specimen number HQ 603a.

Figure 30: Telson of *Adelophthalmus cf. A. mazonensis*. ESU specimen number HQ 280.

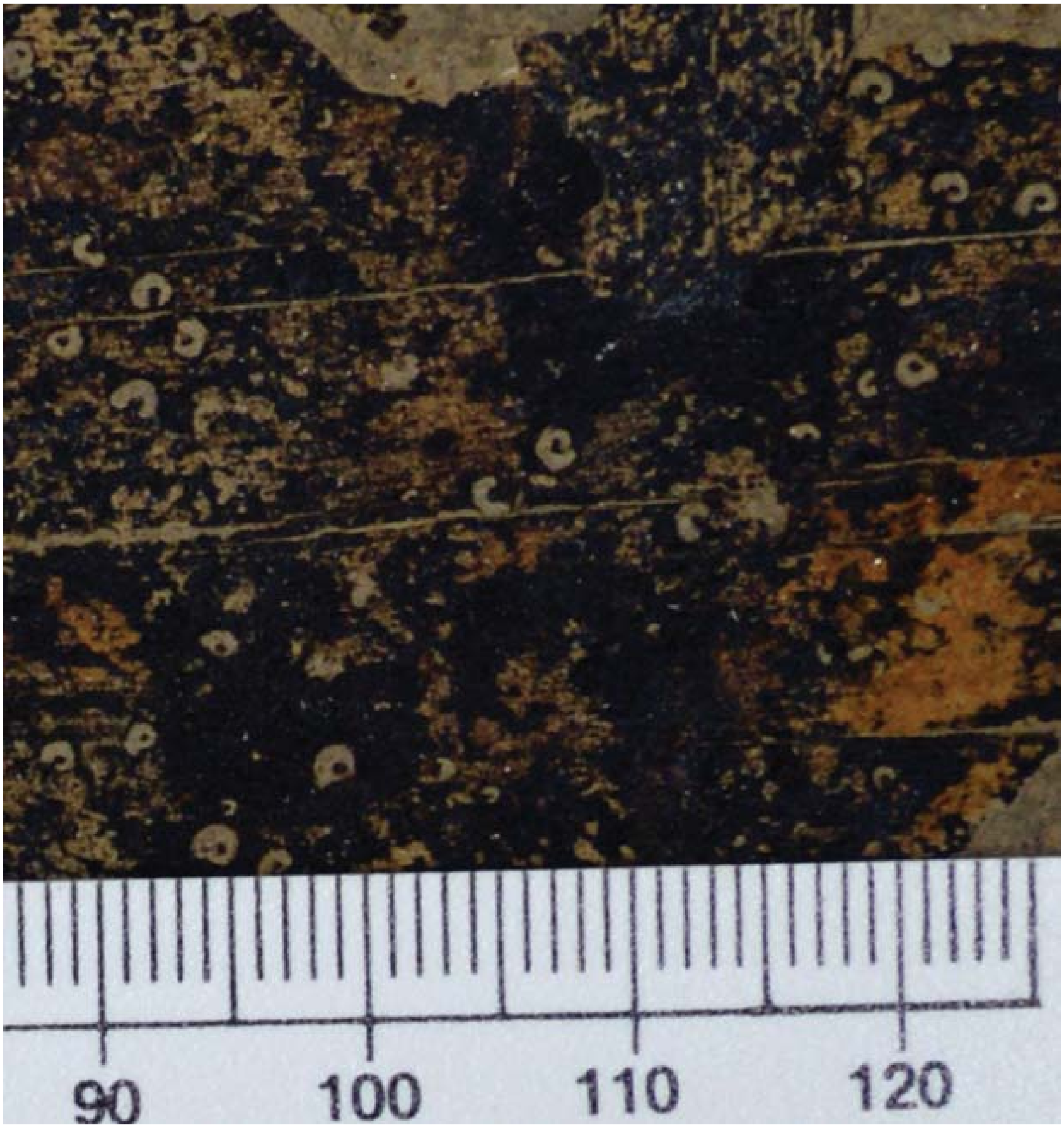

Figure 31: Possible *Spirorbis* encrusting on a *Cordaites* leaf. ESU specimen number unknown.

Figure 32: Near complete whip scorpion c.f. *Prothelyphonus*. This is the only reported specimen collected. ESU specimen number is unknown.

Figure 33: Nearly complete scorpion *Archaeoctonous cf. A. glaber*. This is the only reported specimen collected. ESU specimen number is HQ 20α.

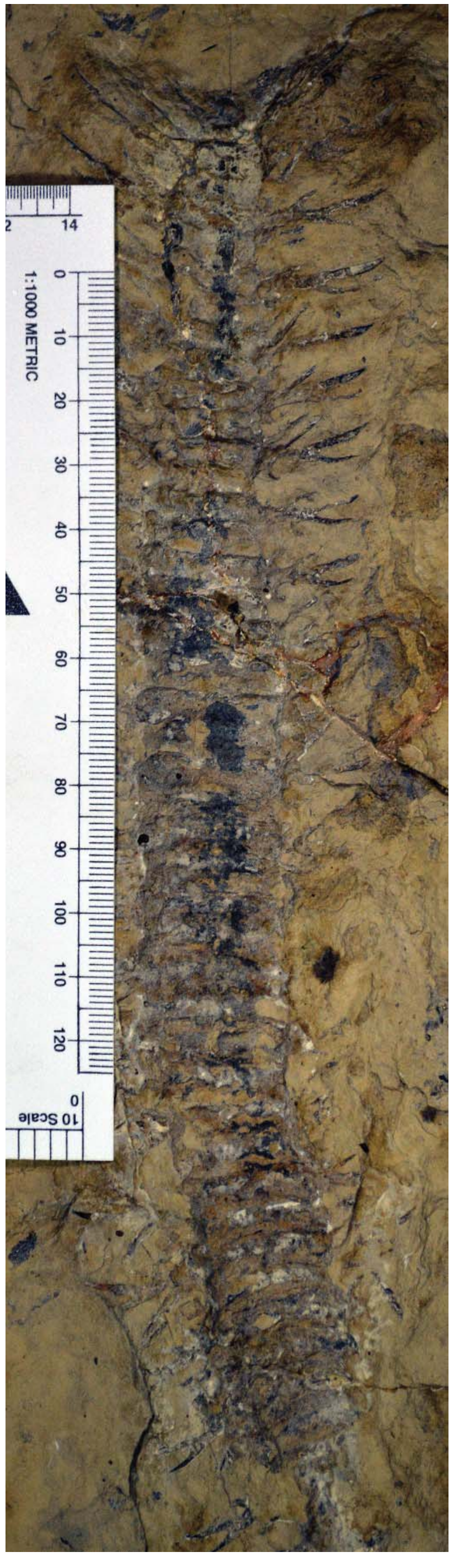

Figure 34: Near complete euphoberiid millipede. ESU specimen number unknown.

Figure 35: Near complete *Paromylacris*. ESU specimen number unknown.

Figure 36: Partial wing of a meganisoptera dragonfly. The wing possibly belongs to *Meganeura*. ESU specimen number unknown.

Figure 37: Near complete body of *Carrizopteryx*. ESU specimen number unknown.

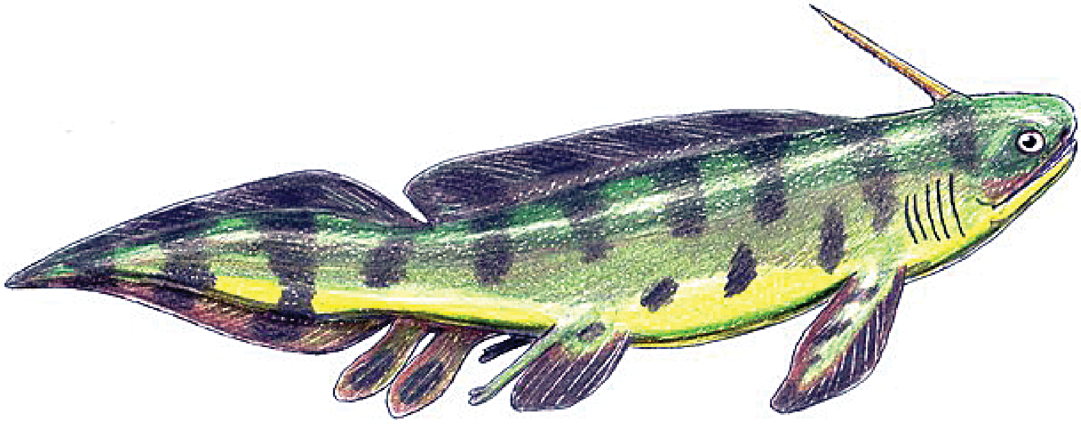

Figure 38: Life reconstruction of *Expleuracanthus.* Art by Dmitry Bogdanov, available on Wikimedia Commons (2017)

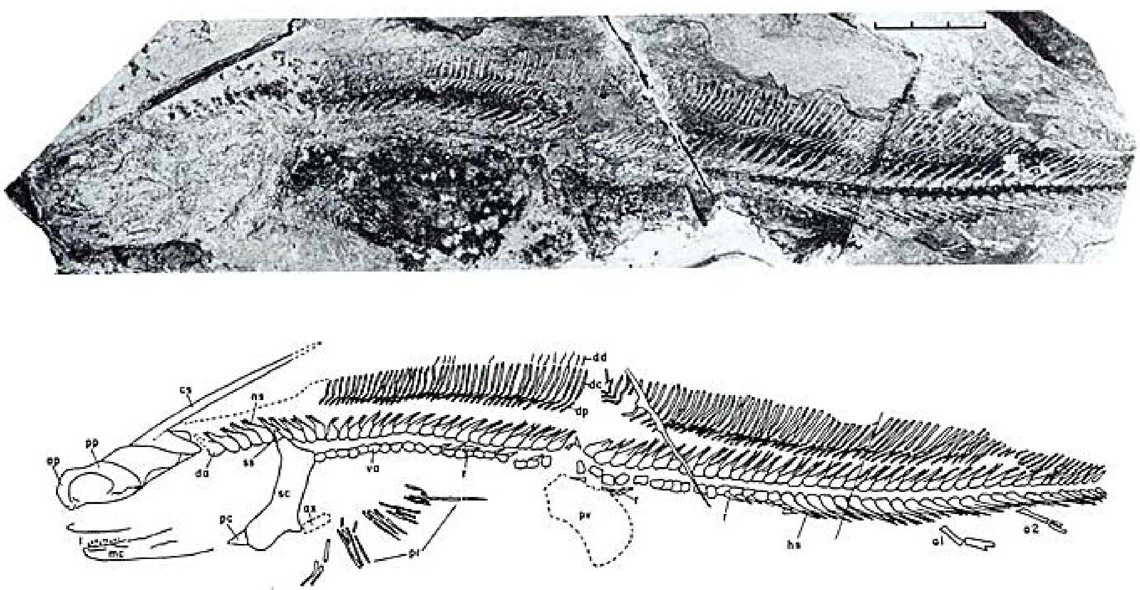

Figure 39: Whole body specimen of *Expleuracanthus* and reconstruction. Modified from Zidek (1988b) figure 2. The black areas show soft tissue preservation. The specimen number is ESU 697A and was located in the Johnston Geology Museum until it was stolen.

Figure 40: UV fluorescent image of *Hamiltonichthys mapesi*. Modified from Maisey (1989) figure 2. KU Specimen number KUVP 65016.

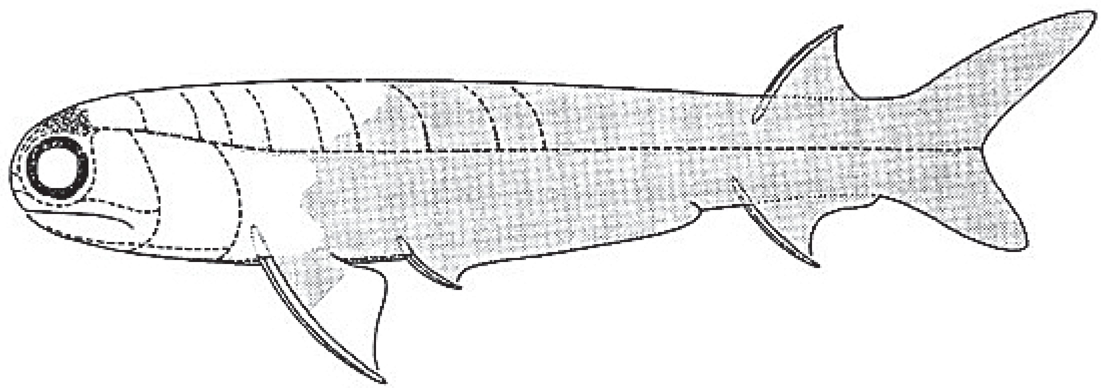

Figure 41: Reconstruction of *Acanthodes bridgei*. Modified from Zidek (1988a) figure 1.

Figure 42: Juvenile Acanthodes *bridgei*. Black areas indicate preserved soft tissue. DMNS specimen number DMNH 51657.

Figure 43: Adult *Acanthodes bridgei*. ESU specimen number unknown.

Figure 44: Cast of the holotype of *Feroniscus hamiltoni* (or *hamiltonensis*). ESU specimen number HQ 167.

Figure 45: Disarticulated scales of *Feroniscus hamiltoni* (or *hamiltonensis*). ESU specimen number HQ 178A

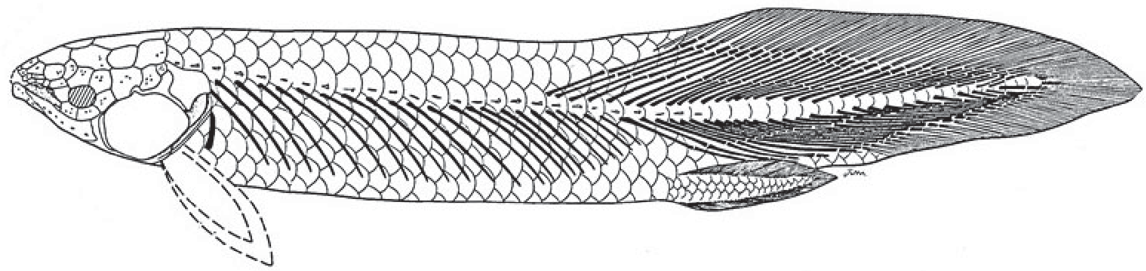

Figure 46: Reconstruction of *Sagenodus*, from Schultze and Chron (1997) figure 39. The reconstruction is based on the Hamilton Quarry specimen (Figure 48).

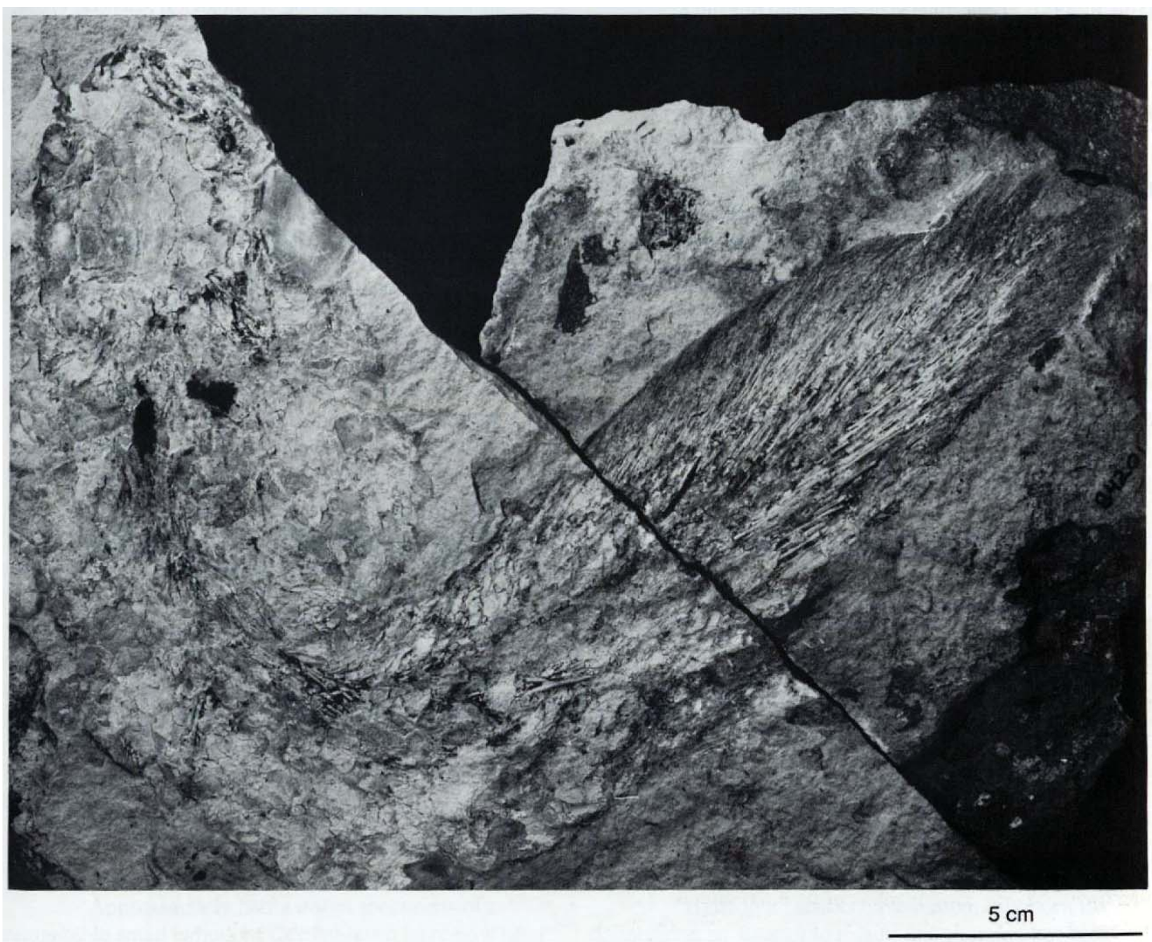

Figure 47: Complete specimen of Sagenodus. From Chron and Schultze (1988) figure 2. The specimen number is KUVP 84201.

Figure 48: Near complete *Eoscopus lockardi*. Note the soft tissues preservation around the tail. ESU specimen number unknown.

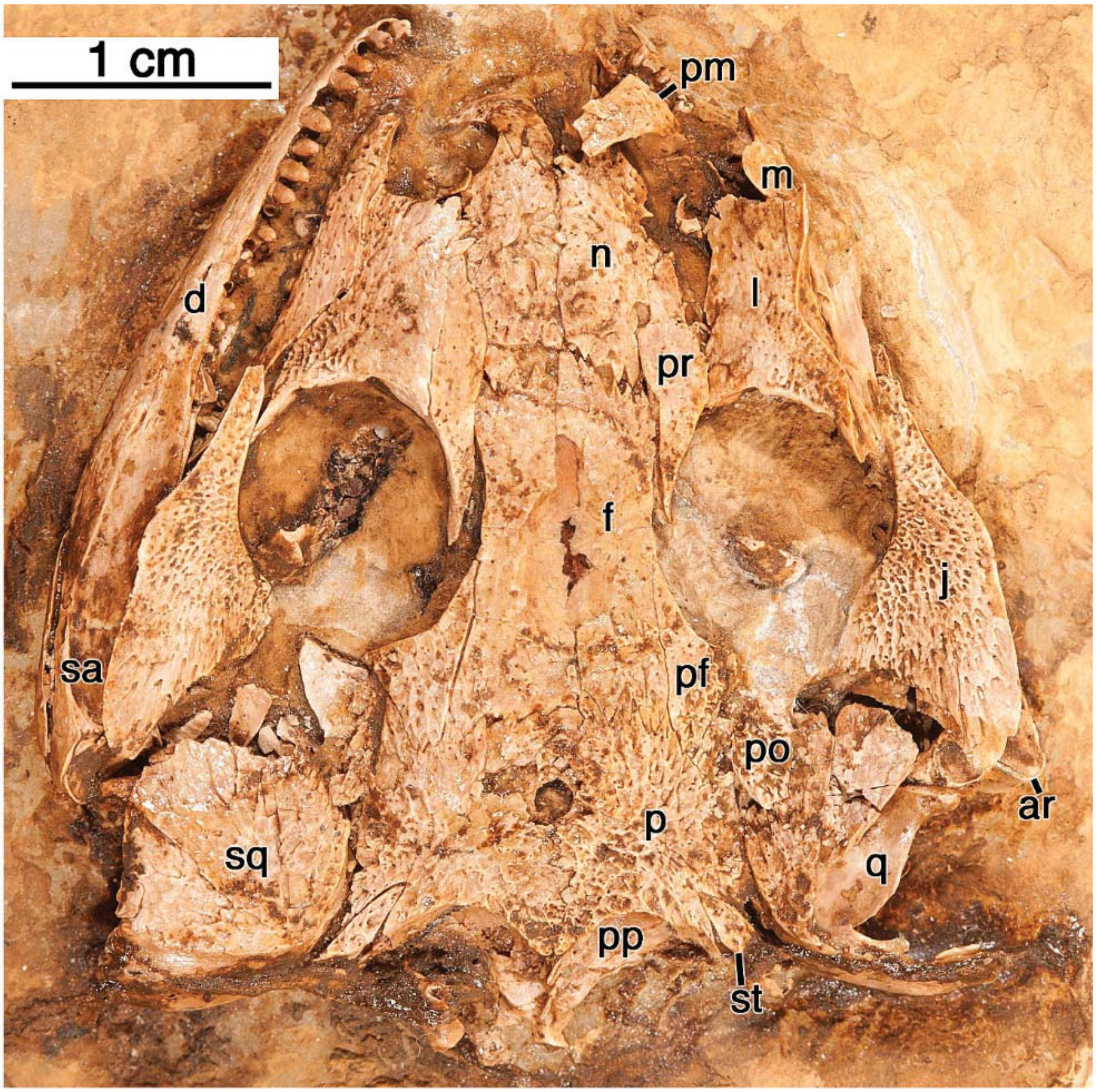

Figure 49: Holotype of *Euconcordia cunninghami*. Modified from Reisz et al. (2016) figure 1. The specimen number is KUVP 96164a.

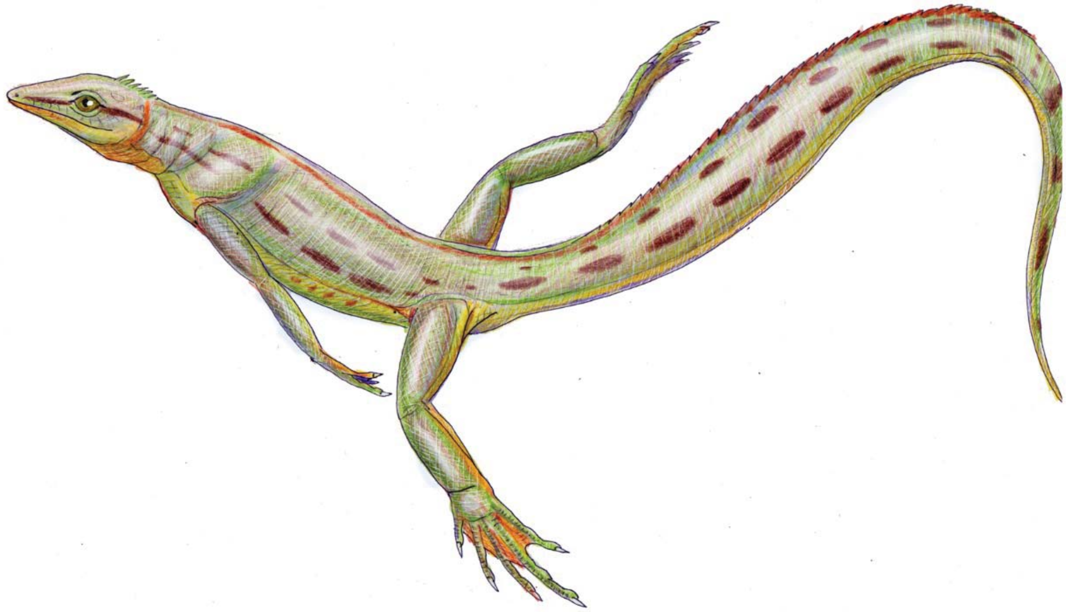

Figure 50: Life reconstruction of *Spinoaequalis schultzei*. Art is by ДиБгд, available on Wikimedia Commons (2017).

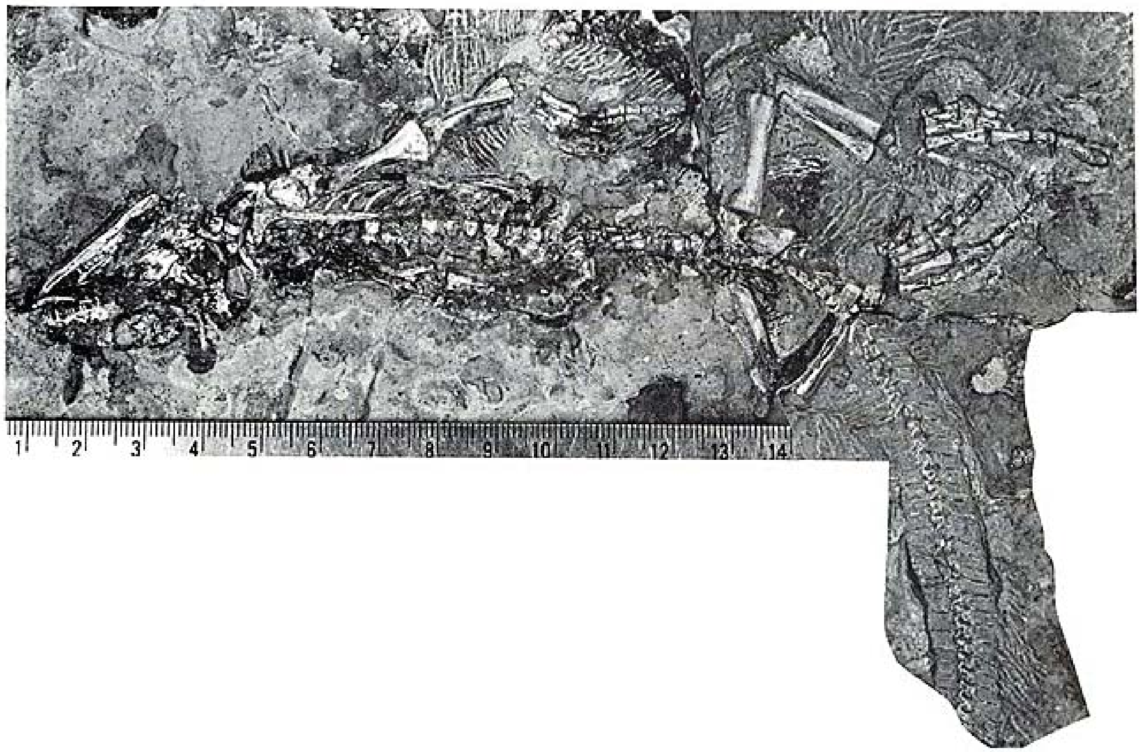

Figure 51: Holotype of *Spinoaequalis schultzei*. The specimen is nearly complete. Modified from Reisz (1988) figure 3. Specimen number is KUVP 12484.

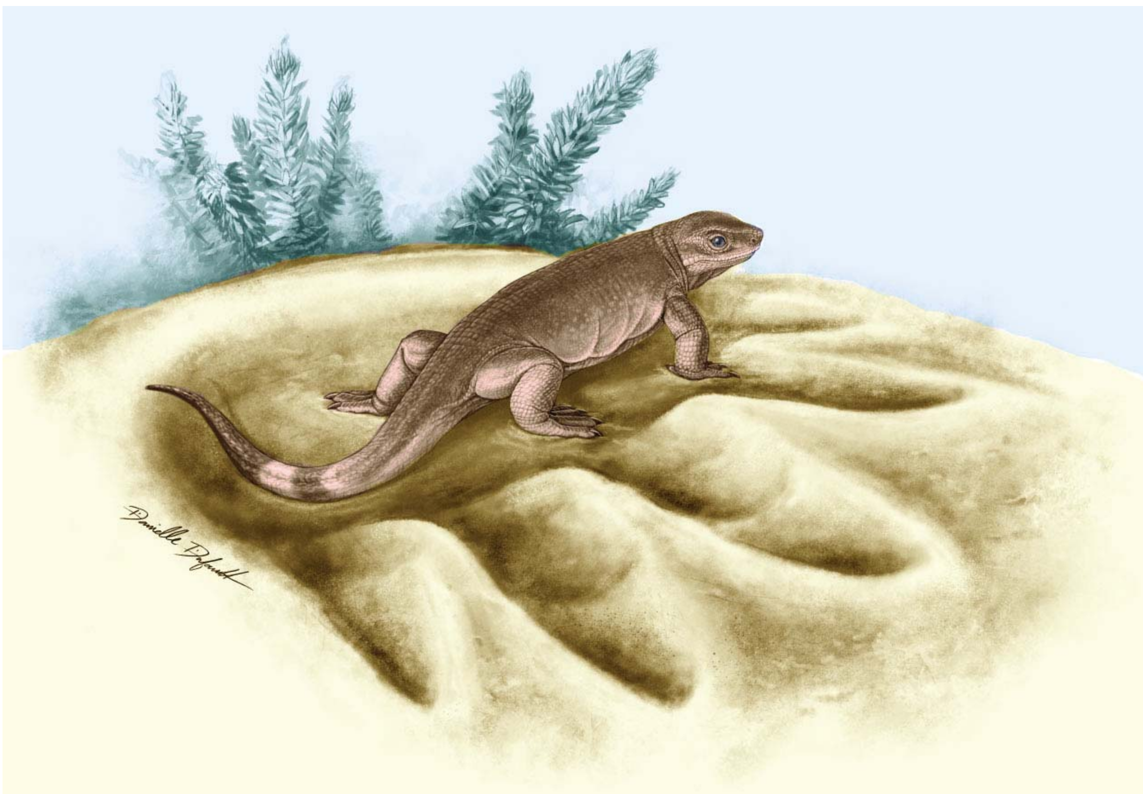

Figure 52: Life reconstruction of *Eocasea martini*. Art from sci-news.com.

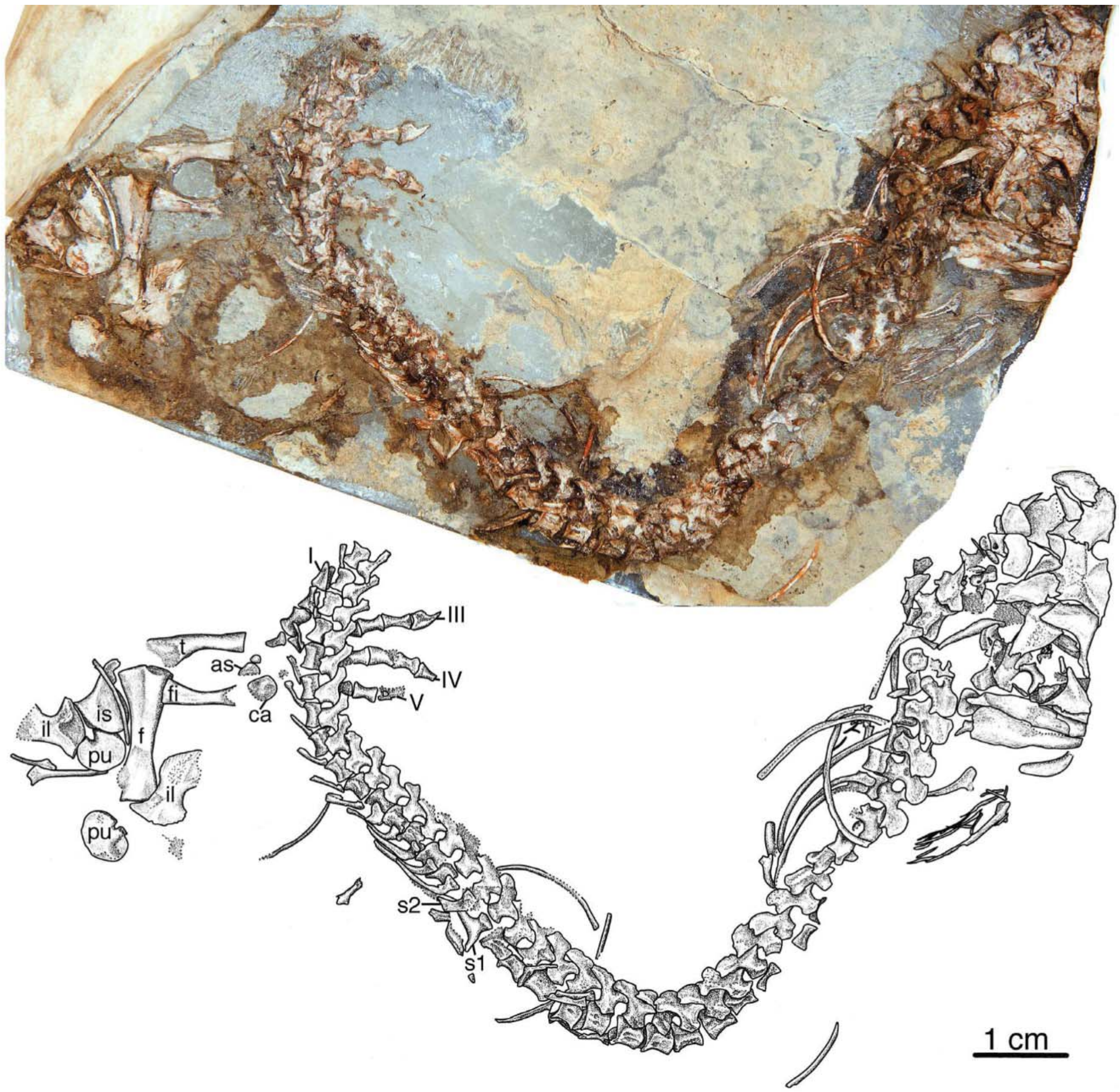

Figure 53: Holotype of *Eocasea martini*. Modified from Reisz and Frönisch (2014) figure 1. The specimen number is KUVP 9616b.

Figure 54: Ilium of *Lupeosaurus* (?). DMNS specimen number DMNH 51647.

Figure 55: Upper jaw of an ophiacodontid. Specimen in display and could not be removed, as such no scale could be used. DMNS specimen number DMNH 12844.

Figure 56: Fibulae of ophiacodontid (?). Specimen was collected during field work and compares favorably with fibulae of *Ophiacodon* illustrated in Reisz (1986).

Figure 57: Life reconstruction of *Archaeovenator hamiltonensis*. Art by DiBgd, available on Wikimedia Commons (2017).

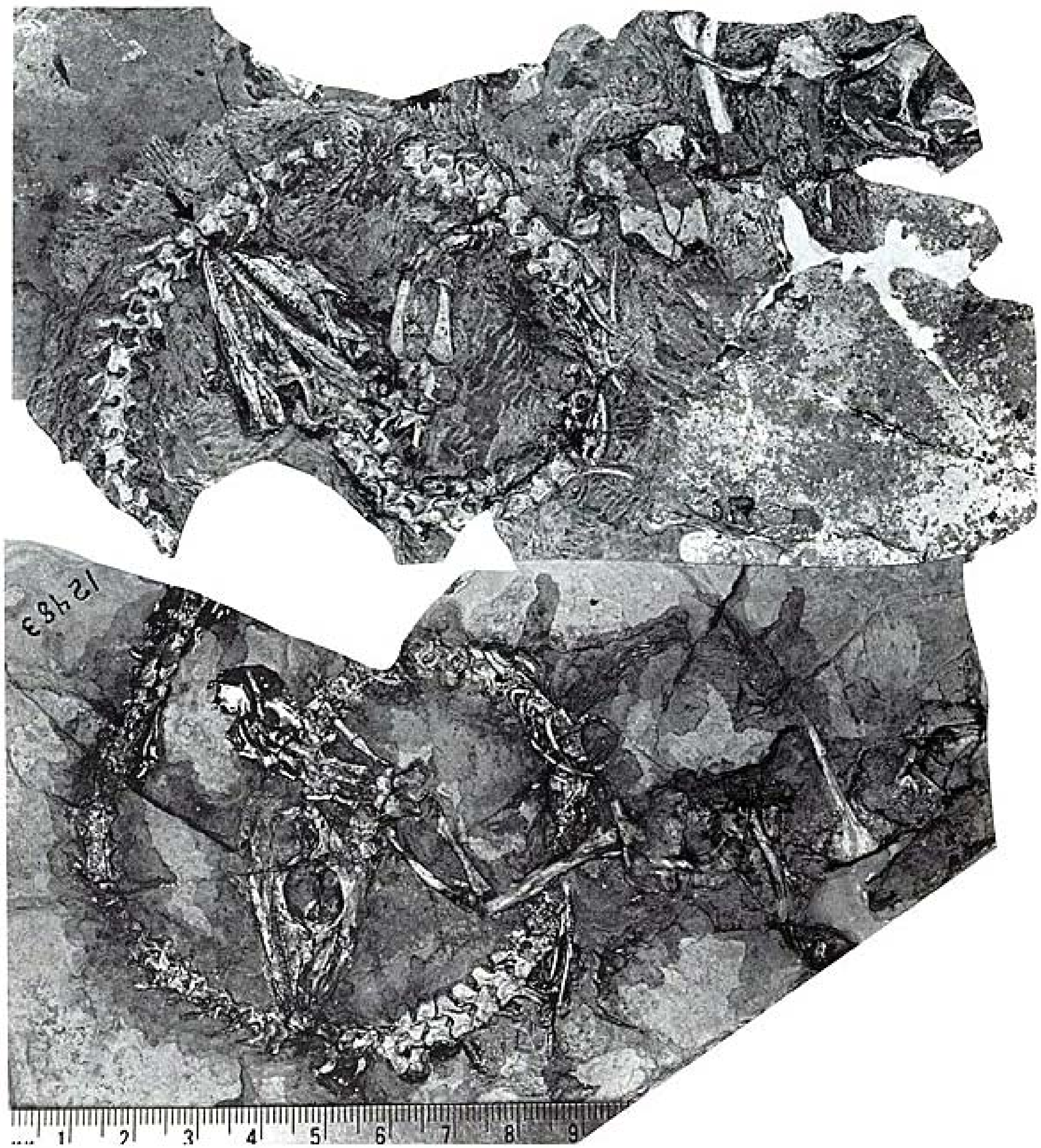

Figure 58: Holotype of *Archaeovenator hamiltonensis*. Modifired from Reisz (1988) figure 2. The specimen number is KUVP 12483.

Figure 59: *Sigillaria brardii*. *S. brardii* is the preserved bark of a lycopod. ESU specimen number HAM 466.

Figure 60: *Asterophyllites*. ESU specimen number HAM 238.

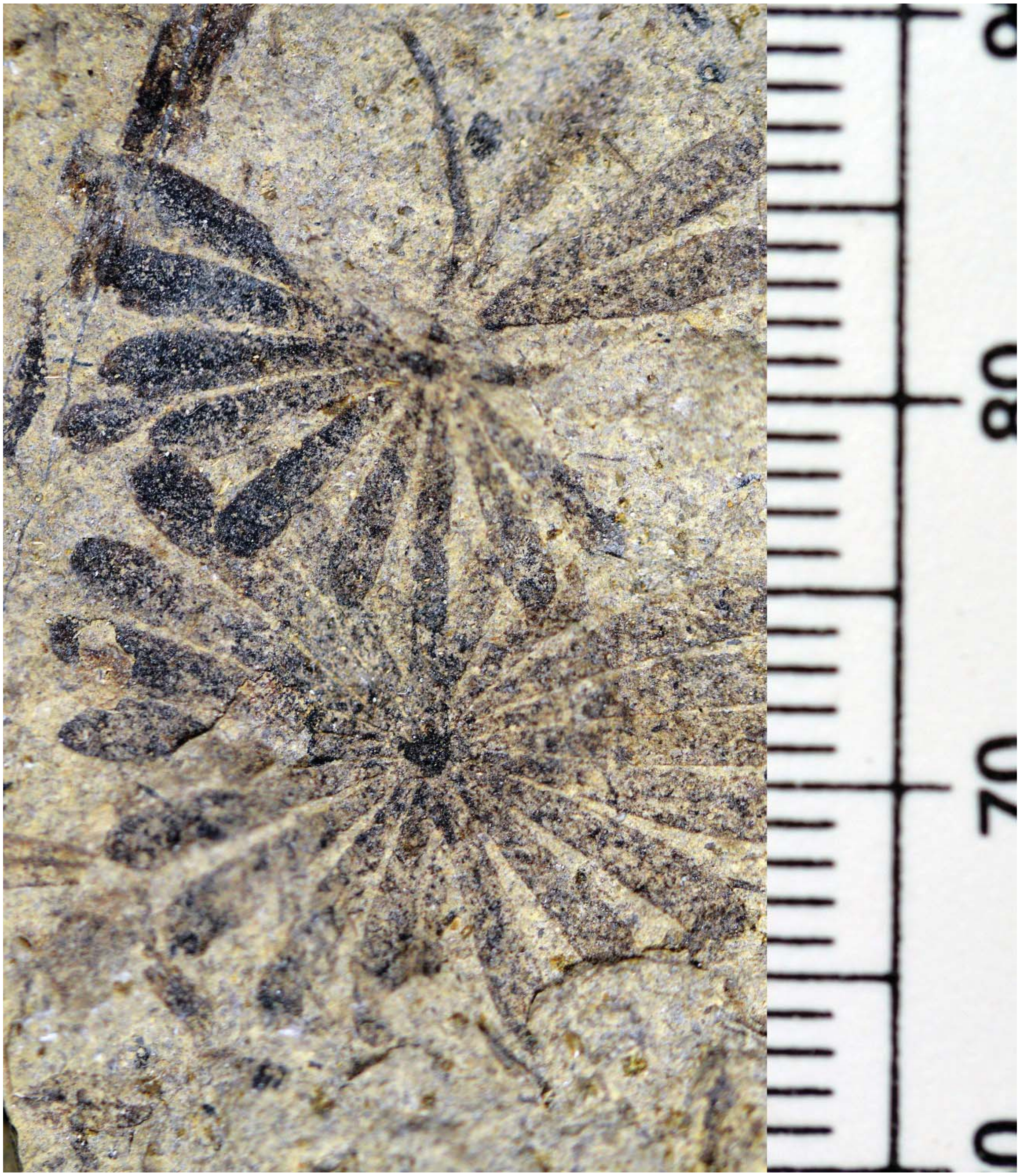

Figure 61: *Annularia*. ESU specimen number HAM 407

Figure 62: *Paleostachya*. ESU specimen number HAM 415A

Figure 63: *Callipteris*. ESU specimen number HAM 443.

Figure 64: *Cyclopteris*. ESU specimen number HAM 100.

Figure 65: *Neuropteris*. ESU specimen number unknown.

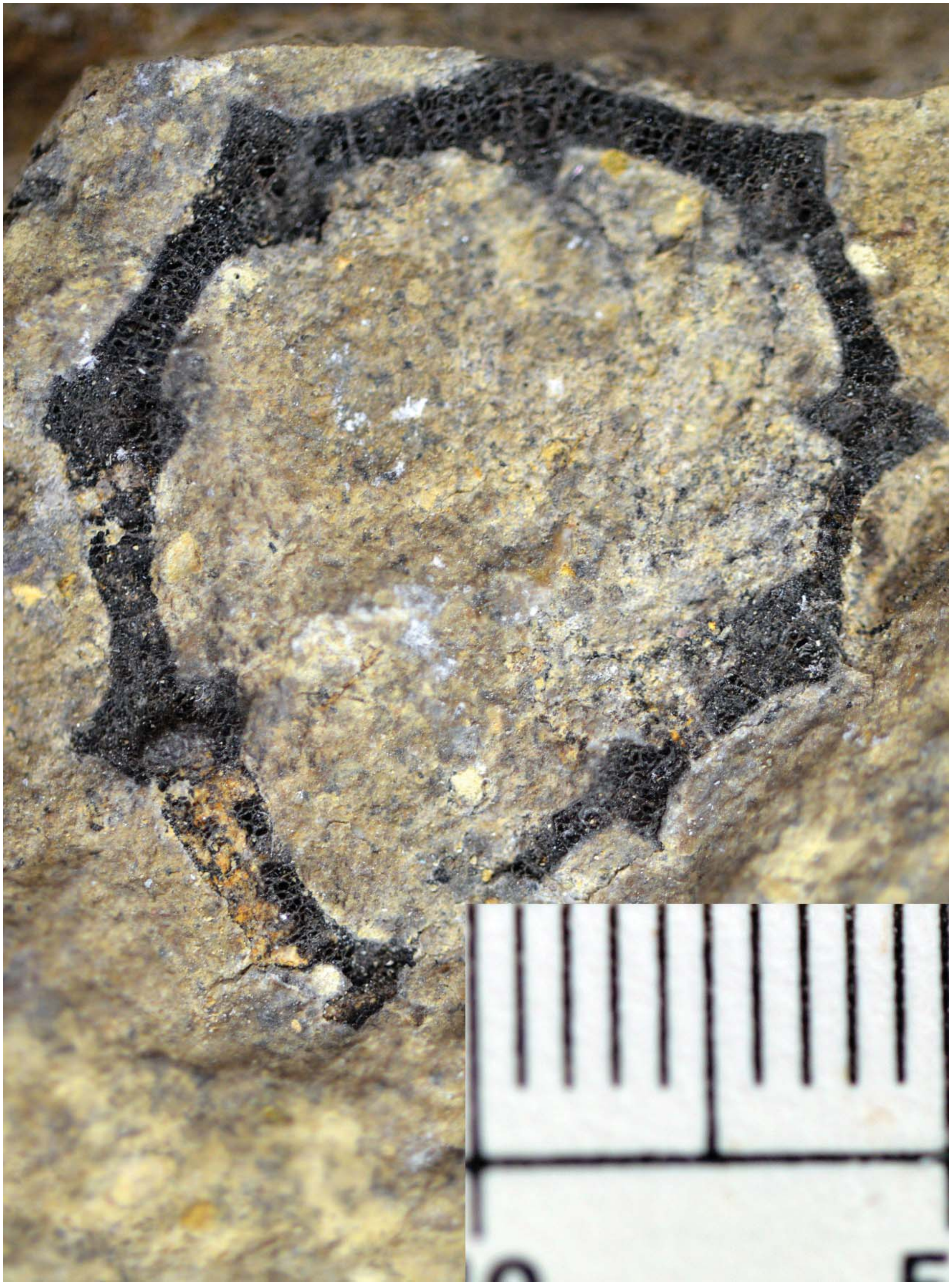

Figure 66: *Trigonocarpus*. ESU specimen number HAM 164B.

Figure 67: Whole *Cordaites* leaf. Specimen was in display and could not be removed, as such no scale was used. DMNS specimen number DMNH 5110.

Figure 28: *Cordaites* branch (?). ESU specimen number HQ 465.

Figure 69: Preserved log. This log represents some of the largest plant material collected. ESU specimen number KU 5994.

Figure 70: *Walchia* branch. Specimen has multiple attached stems with leaves and a seed (bottom left). ESU specimen number unknown.

Figure 71: Cone of *Walchia*. ESU specimen number unknown.

Figure 72: Coprolite part and counterpart. Coprolite contains broken bones of unidentified taxa. DMNS specimen number DMNH 51636.

Figure 73: *Palaeoxyris* shark egg. DMNS specimen number DMNH 5999.

Figure 74: Charcoal.

Chapter 5: Comparisons and Conclusions

Introduction

This chapter compares Garnett and Hamilton Quarry (detailed in Chapter 3 and Chapter 4) in terms of interpreted environment of deposition, taxonomic equivalence, diversity, and taphonomy. In addition, a comparison between these two localities and the four other localities mentioned in Chapter 1 is given at the end of this chapter.

Environment of Deposition

As indicated in Chapters 3 and 4, both Garnett and Hamilton Quarry have similarities in that both are tidal influenced near shore/coastal environments, while differences include energy level, presence and quality of water, and presence of a fluvial system. Garnett represents a low energy, transgressively filled, restricted lagoon/estuary near the coast. Hamilton Quarry represents a low energy, flowing freshwater stream in the north that changes to an estuary as it nears the coast in the south.

The presence of an active stream at Hamilton Quarry was interpreted by Feldman et al. (1990), Fahrer (1991), and Cunningham (1993a and b), all of whom show that the plants have a distinctive north-to-south orientation indicating flow direction. Furthermore, the basal conglomerate also suggests north-to-south flow based on clast size. In the north, clasts are larger and decrease in size moving south; this indicates the loss of energy as the stream neared the coast. There have been no such studies performed at Garnett.

Garnett has both preserved trackways and desiccation cracks that suggest water was not present at all times allowing for subaerial exposure. Furthermore, the pelecypod layer suggests either tidal influence or a transgressive period, the latter being more likely due to lack of tidal laminations within the layer. Hamilton Quarry lacks any indication of subaerial exposure, which implies water was always present. Additionally, laminations found in the rock layers indicate tidal influence.

Taxa at both localities indicate a mixture of terrestrial and marine influences. Terrestrial influence was more dominate based on the larger number of well-preserved terrestrial vertebrates, freshwater vertebrates, plants, and freshwater invertebrates. In the vertebrate-bearing layers at Garnett, all marine invertebrates are reworked and/or broken, suggesting that they were transported prior to burial. Marine invertebrates become the most abundant fossils in the upper layer, e.g., Reisz et al.'s (1982) third fossil zone. This indicates that Garnett slowly transitioned from a coastal lagoon/estuary to a fully marine environment as transgression occurred. At Hamilton Quarry, marine invertebrates in the north are few and broken in the vertebrate-bearing limestone, which suggests they were transported into the area. In the south, freshwater vertebrates and terrestrial vertebrates and invertebrates all become fewer, possibly due to an increase in salinity. However, this could also be due to a collection bias, as the majority of research has focused on the Main Quarry area.

Garnett appears to have had lower energy evidenced by the lack of a stream and more articulated vertebrates, whereas Hamilton Quarry had an actively flowing stream with some calm water areas. The whole body soft tissue preservation found at Hamilton Quarry typically occurs due to anoxic conditions in a marine environment and quick burial in a freshwater environment. Due to the large number of *Acanthodes* found with soft tissue preserved, quick burial most likely occurred. Calm water areas are indicated by the presence of juvenile *Acanthodes* and a shark egg. Both fossils suggest breeding was occurring in the area, which requires calm water for the protection of eggs and young.

During the time of vertebrate burial, both Garnett and Hamilton Quarry appear to have had some tidal influence and both had terrestrial and marine influences, but neither were marine dominate. Garnett had periods of subaerial exposure whereas water was always present at Hamilton Quarry. Garnett had a lower overall energy, whereas Hamilton Quarry shows a decrease in energy moving southward.

Taxonomic Equivalence and Diversity

The following definitions are those used in this report. Taxonomic diversity is defined as the number of taxa (named species, genera, families, etc.) collected from either Garnett or Hamilton Quarry localities. Taxonomic abundance is the number of individual fossils of the same taxon from either locality. Taxonomic equivalence is the presence of taxa at the pertinent level at both localities.

Garnett and Hamilton Quarry have a similar number of taxa (126); however, this cannot be used directly as a valid measure of diversity due to the different levels of study completeness for each locality. The lack of completeness is primarily an issue for aquatic invertebrates and palynomorphs. For aquatic invertebrates, studies at Hamilton Quarry placed more emphasis on the identification to the lowest possible taxonomic level, whereas at Garnett most aquatic invertebrates are largely ignored. For the palynomorphs, detailed studies have been performed for Garnett, whereas only one study with a small sample size had been performed for Hamilton Quarry. As a result, neither aquatic invertebrates nor palynomorphs can truly represent the taxonomic equivalence nor diversity; however, they are still useful for interpreting depositional environment and age. Furthermore, recently described taxa from either locality could be present at the other; however, this will require a full scale reexamination of all material which is beyond the scope of this study.

Taxonomic equivalence levels are based on the 126 identified taxa from Garnett and 126 identified taxa from Hamilton Quarry. All pertinent taxonomic levels are included on the tables (10 through 14), with only the lowest possible levels indicating taxonomic equivalence. Equivalences at lower levels are included in higher-level equivalences: e.g., a species level equivalence is also included at the genus level, etc. As such, there is a grand total of 413 possible taxonomic equivalences based on the tables (10 through 14). Tables 10 through 14 show taxonomic equivalence, with green indicating the presence of the taxon. A question mark in a green means that the taxon identification is uncertain, but that the group that the taxon is a member of is present at the locality. Selected taxonomic ranks are abbreviated as:

Order = O (superO and subO)
Family = F (superF),
Genus = G
Species = Sp
Variety = V

For Tables 11 through 13, kingdom level was left out due to all taxa on each table belonging to the same kingdom. Phylum level was left out for Tables 12 and 13, due to all taxa on Table 12 belong to the phylum Arthopoda and Table 13 due to all taxa belonging to the phylum Chordata.

Aquatic Invertebrates

Of the total 73 possible taxonomic equivalences, there were 21 actual equivalences (Table 10). Of the nine species in the table, no equivalences were found; however, this could be due to identification biases. Of the 37 genera in the table, three equivalences were found. Of the two families, no equivalences were found. Of the six orders, three equivalences were found. Of the six classes, four equivalences were found. Of the two subphyla, one equivalence was found. Of the nine phyla, eight equivalences were found. Of the two kingdoms, two equivalences were found.

Table 10: Taxonomic Equivalence of Aquatic Invertebrates

	Garnett	Hamilton
Kingdom Protista		
Phylum Retaria		
O Fuslinida		
G *Globivalvulina*		
Sp *Dunbarinella ervinensis*		
Sp *Triticites. cullomensis*		
Sp *Triticites plummeri*		
Sp *Triticites* ventricosus		
O Miliolida		
Kingdom Animalia		
Phylum Porifera		
Phylum Cnidaria		
G Lophophyllidum	?	
Phylum Echinodermata		
Class Crinoid		
Sp *Apographiocrinus cf. A. calycinus*		
F Cromyocrinidae		?
Sp *Delocrinus cf. D. vulatus*		
Sp *Plaxocrinus cf. P. crassidiscus*		
F Scytalocrinidae		
Class Echinoidea		
Phylum Arthropoda		

Subphylum Chelicerata		
Sp *Adelophthalmus cf. A. mazonensis*		
Subphylum Crustacea		
<u>Class Malacostraca</u>		
O Spelaeogriphacea		
O Palaeocaridacea		
<u>Class Ostracoda</u>		
G *Amphissites*		
G *Geisina*		
G *Gutschickia*		
G *Bairdia*		
G *Pseudobythocypris*		
G *Carbonita*		
G *Darwinula*		
Phylum Annelida		
G *Serpula*		
G *Spirorbis*		
Phylum Mollusca		
<u>Class Bivalvia</u>		
G *Anthraconaia*		
G *Myalinella*		
Sp *Myalinella meeki*		?
G *Sedgwickia*		
G *Permophorus*		
G *Yoldia*		
G *Phestia*		
G *Schizodus*		
<u>Class Gastropoda</u>		
G *Bellerophon*		
G *Euphemites*		
Phylum Brachiopoda		
G *Composita*		
G *Punctospirifer*		
G *Neospirifer*		
G *Lingula*		
G *Juresania*		
G *Antiquatonia*		
G *Kozlowskia*		
G *Neochonetes*		
**Phylum Bryozoa*		
O Fenestrata		

G *Fenestella*		
O Cystoporate		
G *Polypora*		
G *Rhombopora*		

Kingdom Protista (foraminifera) is present at Garnett and Hamilton Quarry; however, there is an identification bias favoring the Hamilton Quarry specimens. Fuslinid forams are present at both, with those found at Garnett only identified to the order Fuslinida whereas those at Hamilton Quarry have been to both genus and species level (see Table 10). Furthermore, the order Miliolida was only identified at Garnett. The phylum Porifera (sponges) is found at both localities; however, no work has been reported about any lower level identification. Phylum Cnidaria (e.g., corals) is only found at Garnett.

Phylum Echinodermata is present as crinoids and echinoids at both Garnett and Hamilton Quarry. Again there is an identification bias; at Garnett crinoids are only identified to the class level, whereas specimens from Hamilton Quarry have been identified to family and species levels (see Table 10). Echinoids have not been identified beyond the class level at either locality.

Phylum Arthropoda is present as ostracods at both Garnett and Hamilton Quarry. For ostracods there is an identification bias; Garnett specimens have only been identified to the class level, whereas Hamilton Quarry specimens have been identified to seven genera (see Table 10). Additionally, chelicerates (e.g., eurypterids) and malacostracans (e.g., shrimp) are found only at Hamilton Quarry. Phylum Annelida (worms) is present as the genus *Spirorbis* at both localities and additionally as the genus *Serpula* at Hamilton Quarry.

Phylum Mollusca is represented by the class Bivalvia at both Garnett and Hamilton Quarry. Both localities have the bivalve *Myalinella*, possibly identified to species at Hamilton Quarry. Garnett has two additional genera of bivalves not found at Hamilton Quarry, whereas Hamilton Quarry has four genera of bivalves not found at Garnett (see Table 10). The class Gastropoda is found only at Hamilton Quarry, where two genera are known, *Bellerophon* and *Euphemites*.

Phylum Brachiopoda is present at both localities; however, only the genus *Neospirifer* was found at both. Garnett has an additional two genera not found at Hamilton Quarry, whereas Hamilton Quarry has five genera not found at Garnett (see Table 10). Phylum Bryozoa is present at both Garnett and Hamilton Quarry, as the orders Fenestrata and Cystoporate; however, there is an identification bias favoring Garnett. At Garnett bryozoans have been identified to a genera of Fenestrata and two of Cystoporate, whereas at Hamilton Quarry two taxa have been identified only to the order level.

Hamilton Quarry appears to have the higher overall diversity of aquatic invertebrate, with a total of 39 taxa, whereas Garnett has 17. Comparative diversity of protists, echinoderms, and ostracods cannot be interpreted due to an identification bias favoring Hamilton Quarry, and bryozoans cannot be interpreted due to an identification bias favoring Garnett. Diversity of sponges also cannot be interpreted due to the lack of subphylum identification at both localities. Just one genus of Cnidaria is present at Garnett only. The occurrence of eurypterids, malacostracans and ostracods indicates Hamilton Quarry has higher diversity of Arthropoda. Hamilton Quarry also has a very slightly higher diversity of annelids due to the presence of a second genus. Hamilton

Quarry has a higher diversity of mollusks indicated by the presence of gastropods which are absent from Garnett and slightly more genera of bivalves. Hamilton Quarry has more than double the genera of brachiopods. Overall, Hamilton Quarry has about twice the reported diversity of Garnett (39 vs. 17 taxa); however, this may be due to the lack of lower level identifications at Garnett.

Terrestrial Invertebrates

All the terrestrial invertebrates belong to the Phylum Arthropoda. Of the total 29 possible taxonomic equivalences, there were 10 actual equivalences (Table 11). Of the four species in the table, no equivalences were found. Of the eight genera, no equivalences were found. Of the two families no equivalences were found. Of the three orders, three equivalence were found. Of the two superorders, one equivalence was found. Of the one subclass, one equivalence was found. Of the two classes, two equivalences were found. Of the three subphyla, three equivalences were found.

Table 11: Taxonomic Equivalence of Terrestrial Invertebrates

	Garnett	**Hamilton**
Subphylum Chelicerata		
Class Arachnida		
Order Thelyphonida		
G *Prothelyphonus*		
Order Scorpiones		
Sp *Archaeoctonous cf. A. glaber*		
Sp *Garnettius hungerfordi*		
Subphylum Myriapoda		
O Euphoberiidae		
SuperO Juliformia		
Subphylum Hexapoda		
Class Insecta		

Order Blattodea		
G *Phyloblatta*		
G *Mylacris*		
G *Paromylacris*		
Subclass Pterygota		
F Geraroidea		
G *Oedischia*		
G *Meganeura*		
G *Titanophasma*		
Superorder Palaeodictypopteroidea		
Sp *Parabrodia carbonaria*		
Sp *Euchoroptera Longipennis*		
F 3rd identified		
G *Carrizopteryx*		

The subphylum Chelicerata is present at both Garnett and Hamilton Quarry as the class Arachnida. Both localities have a representative of the order Scorpiones (true scorpions); however, the genus/species are different (see Table 11). Additionally, only Hamilton Quarry has a genus, *Prothelyphonus*, of the order Thelyphonida (whip scorpions). The subphylum Myriapoda (millipedes and centipedes) is found only at Hamilton Quarry. Myriapod specimens have been identified only to the order Euphoberriidae and superorder Juliformia.

The subphylum Hexapoda is present at both Garnett and Hamilton Quarry as the order Blattodea (cockroaches) and subclass Pterygota (winged insects). Two genera of cockroaches are found at Garnett, whereas only a different genus is found at Hamilton Quarry (see Table 11). The subclass Pterygota will be discussed as two groups, the advanced forms and the superorder Palaeodictypopteroidea. Advanced forms are found only at Hamilton Quarry, representing four taxa (see Table 11). Three have been identified to genera and the fourth only to the family level. The Palaeodictypopteroidea is found at both localities; however, no taxa are the same. Three taxa have been identified at Garnett, two to the species level and one to the family level (see Table 11). At Hamilton Quarry, only the genus *Carrizopteryx* has been found.

Hamilton Quarry appears to have the higher overall diversity of terrestrial invertebrate, with a total of ten taxa, whereas Garnett has six. Hamilton Quarry has the very slightly higher diversity of chelicerates, which includes one scorpion and one whip-scorpion. Garnett only has one scorpion, which belongs to a different family than the Hamilton Quarry specimen. Hamilton Quarry also has the higher diversity of hexapods. At Garnett, the abundance of hexapod specimens appear to be equal across the various taxa, whereas at Hamilton Quarry cockroaches are the most abundant. Myriapods were only found at Hamilton Quarry. Pterygots at Garnett appear to be at a more primitive stage of evolution compared to those found at Hamilton Quarry, which is expected given their ages. Hamilton Quarry appears to have a more diverse community of terrestrial invertebrates; however, this could be due to collection and/or preservation bias at Garnett.

Vertebrates

All vertebrates belong to the subphylum Vertebrata, phylum Chordata. Of the total 84 possible taxonomic equivalences, there were 24 actual equivalences (Table 12). Of the 20 species in the table, one equivalence was found. Of the 29 genera, one equivalence was found. Of the seven families, two equivalences were found. Of the five orders, four equivalences were found. Of the two superorders, one equivalence was found. Of the one infraclass, one equivalence was found. Of the seven subclasses, four equivalences were found. Of the eight classes, five equivalences were found. Of the one “epiclass”, one equivalence was found. Of the two superclasses, two equivalences were found. Of the one infraphylum, one equivalence was found. Of the one subphylum, one equivalence was found.

Table 12: Taxonomic Equivalence of Vertebrates

	Garnett	**Hamilton**
Subphylum Vertebrata		
Class Conodonta		
G *Streptognathodus*		
Infraphylum Gnathostomata		
Class Chindrichthyes		
Subclass Elasmobranchii		
G “*Cladodus*”		
O Xenacanthida		
G *Orthacanthus*		
Sp *Expleuracanthus cf. E. parallelus*		
G *Xenacanthus*		
O Hybodontiformes		
Sp *Hamiltonichthys mapesi*		
Subclass Holocephali		
G *Petalodus*		
Class Acanthodii		
Sp *Acanthodes bridgei*		
Superclass Osteichthyes		
Class Actinopterygii		
G *Elonichthys*		
Sp *Feroniscus. hamiltoni* or *hamiltonensis*		
Class Sarcopterygii		
Subclass Actinistia		
Sp *Synaptotylus newelli* (or *Rhabdoderma newelli*)		
Subclass Rhipidistia		
F Megalichthyidae		
Subclass Dipnoi		
G *Gnathorhiza*		
Sp *Sagenodus* cf. *S. copeanus*		
Superclass Tetrapoda		
Class “Amphibia”		
Subclass Labyrinthodonta		
Superorder Batrachomorpha		

Sp *Actiobates peadodyi*		
Sp *Eoscopus lockardi*		
F Eryopidae		
F Trimerorhachidae		
Superorder Reptillomorpha		
Sp *Hesperoherpeton garnettense*		
“Epiclass” Amniota		
Class Reptilia		
Subclass Eureptilia		
Sp *Euconcordia cunninghami*		
Infraclass Diapsida		
Order Araeoscelida		
Sp *Spinoaequalis schultzei*		
Sp *Petrolacosaurus kansensis*		
Class Synapsida		
Order Caseasauria		
Sp *Eurasia martini*		
Order Eupelycosauria		
Family Varanopidae		
Sp *Archaeovenator hamiltonensis*		
Family Edaphosauridae		
Sp *Ianthasaurus hardestiorum*		?
G *Lupeosaurus*		?
Sp *Xyrospondylus ecordia*		
Family Ophiacodontidae		
G cf. *Ophiacodon*		
Family Sphenacodontidae		
Sp *Ianthodon schultzei*		
Sp *Eohaptodus garnettensis*		
Sp *Kenomagnathus scotti*		
Sp *Tenuacaptor reiszi*		

The class Conodonta represents the most primitive group of the vertebrates and is found only at Hamilton Quarry, belonging to a single genus. All other vertebrates discussed here belong to the infraphylum Gnathostomata (jawed vertebrates). The class Chondrichthyes (cartilaginous fish) is found at both Garnett and Hamilton Quarry, represented by the subclass Elasmobranchii (e.g., sharks). At both localities elasmobranchs are represented by xenacanthid and hybodontiform sharks. At Garnett these sharks could only be identified to order level. However, at Hamilton Quarry three xenacanthid sharks were identified, two to the genus level and one to the species level, and the hybodontiform shark was identified to the species level. The subclass Holocephali (e.g., ratfish/chimaeras) was found only at Hamilton Quarry. The class Acanthodii (spiny "sharks") was only found at Hamilton Quarry and was identified to the species level.

Representatives of the superclass Osteichthyes (bony fish) are found a both Garnett and Hamilton Quarry. The class Actinopterygii (ray-finned fish) is found only at Hamilton Quarry with two identified taxa. The class Sarcopterygii (lobed-finned fish) is represented by the subclasses Actinistia (coelacanths), Rhipidistia, and Dipnoi (lungfish). Only coelacanths are found at both Garnett and Hamilton Quarry. At Garnett this subclass is present as a taxon identified to the species level, *Synaptotylus newelli*, whereas at Hamilton Quarry identification could only be done to the subclass level. Subclass Rhipidistia was found only at Hamilton Quarry and could be identified to just the family level. Lungfish were found only at Hamilton Quarry, represented by two taxa.

The superclass Tetrapoda was found at both Garnett and Hamilton Quarry and is separated into the classes "Amphibia", Reptilia, and Synapsida (mammal ancestors). At both Garnett and Hamilton Quarry, only labyrinthodont amphibians are present, divided into two groups. Batrachomorphs (those leading to modern amphibians) were found at both localities. At Garnett only one species has been found, whereas at Hamilton Quarry three taxa have been found, one identified to the species level and two to the family level. Reptillomorphs (those leading to reptiles) are known only from Garnett, at the species level. The class Reptilia is found at both localities. A primitive taxon of the subclass Eureptilia (true reptiles) is found only at Hamilton Quarry. The diapsid order Araeoscelida is found at both localities, with a single genus/species identified at each.

The class Synapsida is found at both Garnett and Hamilton Quarry. A species of the order Caseasauria is found only at Hamilton Quarry. Several taxa of the order Eupelycosauria are found at both localities. A species of the evolutionarily basal family Varanopidae is found only at Hamilton Quarry. The family Edaphasauridae has the same single species found at both Garnett and Hamilton Quarry. Additionally, Garnett has a second identified genus/species, whereas Hamilton Quarry has second taxa identified to a different genus. The family Ophiacodontidae is found at both localities; however, Hamilton Quarry's specimens cannot be identified lower than the family level, whereas the Garnett specimens are identified to the genus *Ophiacodon*. The family Sphenacodontidae is found only at Garnett, where it has four identified species.

Hamilton Quarry appears to have the overall higher diversity of vertebrates with a total of 23 taxa, whereas Garnett only has 14. Hamilton Quarry has a higher diversity of fish, of which the majority represent freshwater forms. Furthermore, *Acanthodes* is the most abundant fish as well as vertebrate overall. Garnett has few fish, known only from disarticulated remains, which generally prevents lower level identification. Both localities have about the same diversity of "Amphibia." Hamilton Quarry has a higher diversity of Reptilia, with representatives of the Captorhinomorpha and Araeoscelida. Both Garnett and Hamilton Quarry have representative taxa of Araeoscelida; Garnett's is *Petrolacosaurus kansensis* and Hamilton Quarry's is *Spinoaequalis schultzei*. The more primitive of these two is *P. kansensis*, which is expected because it is also the older.

Garnett has the higher diversity of synapsids, however all belong to the Eupelycosauria, whereas Hamilton Quarry has both eupelycosaurs and the more primitive caseasaurs, represented by *Eurasia martini*, which is the most basal caseasaur. Hamilton Quarry has another primitive synapsid, *Archaeovenator hamiltonensis*, which is the most basal varanopid, the most basal eupelycosaur family. Therefore, the synapsids at Hamilton Quarry overall appear to be more primitive than those at Garnett, which is unexpected given their respective ages. In conclusion, Hamilton Quarry appears to have a more diverse community of fish, whereas Garnett appears to have a more diverse terrestrial vertebrate community.

Megaflora

The megaflora is divided across four divisions representing lycopods, ferns, seed ferns, and conifers. Of the 78 total possible taxonomic equivalences, there were 20 actual equivalences (Table 13). Of the two varieties in the table, one equivalence was found. Of the 31 species, one equivalence was found. Of the 26 genera, seven equivalences were found. Of the five families, two equivalences were found. Of the orders, two equivalences were found. Of the eight classes, three equivalences were found. Of the four divisions, four equivalences were found.

Table 13: Taxonomic Equivalence of Megaflora

	Garnett	**Hamilton**
Division Lycopodiophyta	?	
Sp *Sigillaria brardii*		
Division Pteridophyta		
Class Fillcopsida		
G *Pecopteris*		

Class Polypodiopsida		
Sp *Sphenopteris cf. S. germanica*		
Class Sphenophyta or Equisetopsida		
Sp *Asterophyllites equisetiformis*		
Sp *Asterophyllites longiformis*		
Sp *Annularia mucronata*		
Sp *Annularia asteris*		
Sp *Annularia galloides*	?	
G *Paleostachya*		
Division Pteridospermophyta		
Class Pteridospermopsida		
Sp *Callipteris conferta*		
V *Callipteris flabellifera flabellifera*		
V *Callipteris flabellifera moorei*		
Sp *Callipteris scheibei*		
Class Pentoxylopsida		
Sp *Taeniopteris angelica*		
Sp *Taeniopteris coriacea*		
Sp *Taeniopteris* sp		
G *Spermopteris*	?	
Class Peltaspermopsida		
Sp *Diceratosperma carpenteriana*		
Class Pteriodphylleae		
Family Alethopterides		
G *Alethopteris*		
Family Neurodontopteridaceae		
G *Cyclopteris*		
Sp *Neuropteris attenuatta*		
Sp *Neuropteris fimbriata*		
Sp *Neuropteris* sp. A		
Sp *Neuropteris* sp. B		
G *Odontopteris*		
Class Spermatopsida		
G *Trigonocarpus*		
Division Pinophyta or Coniferophyta		
Order Cordaitales		
G *Cordaicarpon*		
G *Cordaites*		
Sp *Cordaites principalis*		
Sp *Cordaianthus* cf. *C. pitcairniae*		

Sp *Samaropsis fluitans*		
Order Voltziales		
Family Emporiaceae		
Sp *Emporia cryptica*		
Sp *Emporia lockardii*		
Sp *Emporia royalii*		
Sp *Hanskerpia hemiltonensis*		
Family Bartheliaceae		
Sp *Barthelia furcata*		
Family Utrechtiaceae or Walchiaceae		
Sp *Walchia frondous*		
Sp *Walchia garnettensis*		
Sp *Walchia hypnoides*		
Sp *Walchia piniformis*		
Sp *Walchia schneideri*		
G *Walchianathus* (male cone)		
G *Walchiastrobus* (female cone)		
G Gomphostrobus (stem/leaf)		

The division Lycopodiophyta (lycopods) is found at Hamilton Quarry and possibly at Garnett. At Hamilton it is identified as the species *Sigillaria brardii*, whereas at Garnett few leaves have been identified as possibly belonging to lycopods.

The division Pteridophyta (ferns and horsetails) is found at both Garnett and Hamilton Quarry, represented by three classes. A genus of the class Fillcopsida is found only at Garnett. A species of the class Polypodiopsida is found only at Hamilton Quarry. Class Sphenophyta (or Equisetopsida) is found at both localities; at Garnett, only two species of *Annularia* have been identified, whereas at Hamilton Quarry one species of *Annularia*, two species of *Asterophyllites* and the genus *Paleostachya* have been identified.

The division Pteridospermophyta (seed ferns) is found at both Garnett and Hamilton Quarry, represented by five classes. The class Pteridospermopsida is found at both localities, with only the variety *Callipteris flabellifora var. moorei* found at both. At Garnett a second variety has been identified, *C. flabellifora* var. *flabellifora*, whereas at Hamilton Quarry two other species have been identified. Four taxa of the class Pentoxylopsida have been found only at Garnett, with three identified to the species level and one to the genus level. A taxon of the class Petalspermopsida has been found only at Garnett. The class Pteriodphylleae is found at both Garnett and Hamilton Quarry and is divided into two families. A genus of the family Alethopterides had been found only at Garnett. The family Neurodontopteridaceae is found at both localities, with the genus *Neuropteris* found at both. At Garnett two species of *Neuropteris* have been identified, whereas at Hamilton Quarry two species are noted to be present but could not be clearly identified. Additionally, the genera *Cyclopteris* and *Odontopteris* are found only at Hamilton Quarry. The genus *Trigonocarpus* of the class Spermatopsida was found only at Hamilton Quarry.

The division Pinophyta (or Coniferophyta) (conifers) is found at both Garnett and Hamilton Quarry and divided into two orders. Order Cordairales is found at both localities, with the genus *Cordaites* found at both. At Garnett *Cordaites* is only identified to the genus level, whereas at Hamilton Quarry *Cordaites* is identified as the species *C. principalis*. An additional three taxa are found at Hamilton Quarry, with two identified to the species level and one to the genus level. The order Voltziales is found at both localities and is divided into three families. Four species of the family Emporiaceae are found only at Hamilton Quarry. One species of the family Bartheliaceae is found only at Hamilton Quarry. The family Utrechtiaceae (or Walchiaceae) is found at both Garnett and Hamilton Quarry. The genus *Walchia* is found at both localities; however, none are the same species. At Garnett two species have been identified, whereas at Hamilton Quarry three different species have been identified. Both form-genera *Walchianathus* (male cone) and *Walchiastrobus* (female cone) have been found at both localities. The form-genus *Gomphostrobus* (stem/leaf) is found only at Hamilton Quarry.

Garnett has a total of 26 taxa whereas Hamilton Quarry has a total of 28; therefore, both have an equal overall diversity. Across the four divisions, Garnett has a higher diversity of seed ferns, Hamilton Quarry has the higher diversity of ferns and conifers, while both have the same number of lycopods. Furthermore, conifers have the higher abundance of identified/collected specimens from Garnett; however, this could be due to a collection bias. At the Main Quarry area of Hamilton Quarry the divisions of the megaflora appear to have an approximately equal abundance. The abundances of the megaflora at the Marlin Quarry area were not reported, but it is noted that it lacks conifers. Overall, Garnett and Hamilton Quarry appear to be at different floral evolutionary stages. Both localities appear to have complete floral communities, only differing in dominant plant life and genera/species present. At Garnett seed ferns are the most diverse, with ferns being second most; however, neither group is very abundant. Conifers are much less diverse, but have the highest abundance, possibly due to a collection bias. At Hamilton Quarry conifers are the most diverse, with ferns being second most and seed ferns much less. The abundances of all these plant groups are about the same.

Microflora

Of the 150 total possible taxonomic equivalences, there were 20 actual equivalences (Table 14). Of the 82 species no equivalences were found. Of the 38 genera, six equivalences were found. Of the five subinfraturmas, one equivalence was found. Of the 12 infraturmas, six equivalences were found. Of the six subturmas, three equivalences were found. Of the three turmas, two equivalences were found. Of the two anteturmas, two equivalences were found. Of the two kingdoms, one equivalence was found.

Table 14: Taxonomic Equivalence of Microflora

	Garnett	**Hamilton**
KINGDOM FUNGI	?	
KINGDOM PLANTAE		
Anteturma Sporites		
Turma Triletes		
Subturma Azonotriletes		
Infraturma Laevigati		
Sp *Leiotriletes sphaerotriangulus*		
Sp *Leiotriletes* adnattus		
Sp *Leiotriletes* Adnatoides		
Sp *Leiotriletes* gulaferus		
Sp *Leiotriletes* minutus		
Sp *Punctatisporites fenestratus*		
Sp *Punctatisporites minutus*		
Sp *Punctatisporites orbicularis*		
Sp *Punctatisporites stramineus*		
G *Calamospora*		
Sp *Calamospora microrugosa*		
Sp *Calamospora minuta*		
Sp *Calamospora* cf. *C. pusilla*		
G *Triletes*		
Infraturma Apiculati		
Subinfraturma Granulatia		
Sp *Granulatisporites* micrograniferr		
Sp *Granulatisporites* parvus		
Sp *Granulatisporites* pallidus		
Sp *Granulatisporites* sp. A		
Sp *Granulatisporites* sp. B		
Sp *Cyclogranisporites aureus*		
Sp *Microbaculispora novicus*		

Subinfraturma Nodati		
Sp Lophotriletes commissuralis		
Subinfraturma Nosatia		
Sp *Acanthoriletes teretriangulatus*		
Sp Pustulatisporites minutus		
Infraturma Murornati		
G *Microreticulatisporites*		
Subturma Zonotriletes		
Infraturma Cingulati		
Sp *Densosporites anulatus*		
Sp *Densosporites ruhus*		
Subinfraturma Pseudocingulati		
Sp *Galeatisporites minutus*		
Infraturma Zonati		
Sp *Cirratriradites annuliformis*		
Sp *Cirratriradites rarus*		
Sp *Cirratriradites tenuis*		
Anteturma Pollenites		
Turma Saccites		
Subturma Monosaccites		
Infraturma Triletesacciti		
Sp *Nuskoisporites trianguloris*		
Subinfraturma Intrornati		
Sp *Wilsonites kosankei*		
Sp *Guthoerlisporites magnificus*		
Sp *Endosporites uniformis*		
Sp *Endosporites cf. E. vesicatus*		
Sp *Schulzospora elongate*		
Sp *Schulzospora rara*		
Infraturma Vesiculomonoraditi		
Sp *Hoffmeisterites microdens*		
Sp *Potoniesporites novicus*		
Sp *Potoniesporites versus*		
Sp *Potoniesporites simplex*		
Sp *Potoniesporites gtranulatus*		
Sp *Potoniesporites neglectus*		
Infraturma Aletisacciti		
Sp *Florinites florini*		
Sp *Florinites volans*		
Sp *Vesicaspora ovata*		
Sp *Vesicaspora* sp.		

Subturma Disaccites		
Infraturma Sulcati		
Sp *Sulcatisporites splendens*		
Sp *Sulcatisporites* sp.		
Infraturma Striatiti		
Sp *Protohaploxypinus amplus*		
Sp *Protohaploxypinus jacobii*		
Sp *Protohaploxypinus ovatus*		
Sp *Protohaploxypinus parcus*		
Sp *Protohaploxypinus perfectus*		
Sp *Protohaploxypinus samoilocichii*		
Sp Striatopodocarpites cf. S. octostriatus		
Sp *Striatopodocarpites novicus*		
Sp *Striatopodocarpites* sp. A		
Sp *Striatopodocarpites* sp. B		
Sp *Taeniasporites decipiens*		
Sp *Hamiapollenites ambiguous*		
Sp *Hamiapollenites bullaeformis*		
Sp *Hamiapollenites perisporites*		
Sp *Hamiapollenites succatus*		
Infraturma Disaccitrileti		
G *Illinites*		
Sp *Piceapollenites auroclavatus*		
Sp *Striatoabitites multistriatus*		
Sp *Striatoabitites* sp.		
Infraturma Disacciatrileti		
Sp *Alisporites indarraensis*		
Sp *Alisporites gracilis*		
Sp *Alisporites nuthalensis*		
Sp *Falcisporites zapfei*		
Sp *Pityosporites aetheus*		
Sp *Pityosporites P. imperspicuus*		
Sp *Pityosporites cf. P. gracilis*		
Sp *Limitisporites ovalis*		
Sp *Limitisporites radiates*		
Sp *Limitisporites vestustus*		
Sp *Limitisporites vetulus*		
Sp *Limitisporites* sp.		
Subturma Striattes		
Sp *Lueckisporites vickkiae*		
Sp *Striatites splendens*		

Turma Plicates		
Subturma Polyplicates		
Sp *Vittatina cf. V. subsuccata*		
Sp *Vittatina cf. V. verrucosa*		
Sp *Vittatina* sp.		

A possible spore from the kingdom Fungi has been found only at Garnett. All other palynomorphs are from the kingdom Plantae and are divvied into the anteturmas Sporites and Pollenites. All of the Sporites belong to the turma Triletes, which is divided into the subturmas Azontriletes and Zonotriletes. Azontriletes is divided into three infraturmas. First is the infraturma Laevigati, which is found as *Calamospora* at both Garnett and Hamilton Quarry. There are very many species from the two localities; for the complete list, see Table 14. At Garnett a total of 12 species have been identified, belonging to the genera *Calamospora*, Leiotriletes, Punctatisporites, whereas at Hamilton Quarry only the genera *Calamospora* and Triletes have been identified. Second is infraturma Apiculati, which is divided into three subinfraturams. Subinfraturam Granulatai is found only at Garnett with seven identified species (see Table 14). Subinfraturma Nodati is found only at Garnett with one species identified, *Lophotriletes commissuralis*. Subinfraturma Nosatia is found at both Garnett and Hamilton Quarry, each with a single different genus/species; *Acanthoriletes teretriangulatus* from Hamilton and *Pustulatisporites minutus* from Garnett. The third infraturma is Muromati, and it has a single genus, *Microreticulatisporites*, found only at Garnett. Subturma Zonotriletes is found only at Garnett, with six identified species in the genera *Densosporites*, *Galeatisporites*, and *Cirratriradites*.

Anteturma Pollenites is divided into turmas Saccites and Plicates. Saccites is divided into three subturmas. The first subturma is Monosaccites, which is divided into three infraturmas. Infraturma Triletesacciti has a single species found only at Hamilton Quarry and a subinfraturam with six species found only at Garnett (see Table 14). Second is Infraturma Vesiculomonoraditi, which is found at both Garnett and Hamilton Quarry. The genus *Potoniesporites* is found at both Garnett and Hamilton as different species. At Garnett, *Potoniesporites* is known from three species, whereas at Hamilton Quarry only two species are known. Additionally, a species of *Hoffmeisterites* is found only at Garnett.

Subturma Disaccites is divided into four infraturms. Infraturma Sulcati is found only at Hamilton Quarry with two species identified. Infraturma Striatiti is found at both Garnett and Hamilton Quarry, with three of the same genera. Genus *Protohaploxypinus* is found at both localities, with five species found only at Garnett and one species found only at Hamilton Quarry. Genus *Striatopodocarpites* is found at both localities, with two species found at Garnett and two species noted at Hamilton Quarry. A species of *Taeniasporites* was found only at Garnett. Genus *Hamiapollenites* is found at both localities, with two species found only at Garnett and two species found only at Hamilton Quarry.

Infraturma Disaccitrileti is found at both localities. Only at Garnett are the genus *Illinites* and a species of *Piceapollenites* found, whereas at Hamilton Quarry two species of *Striatoabitites* have been found. Infraturma Disacciatrileti is found at both localities, with genus *Limitisporites* found at both. At Garnett, *Limitisporites* has three identified species, whereas at Hamilton Quarry a species of *Limitisporites* is noted. Additionally, found only at Garnett are three species of the genus *Pityosporites*. Furthermore, three species of the genus *Alisporites* and a species of *Falcisporites* are found only at Hamilton Quarry. Two species of the subturma Striattes are found only at Hamilton Quarry. Turma Plicates is found only at Hamilton Quarry, with three species identified.

Garnett has a higher diversity of palynomorphs with a total of 67 taxa, whereas Hamilton Quarry only has 26. The differences in the taxonomic equivalence and diversity of the pollen/spores is most likely due to the limited study of the Hamilton Quarry material (Taggart and Ghavidel-Syooki, 1988) as opposed to a preservation bias. Overall, Garnett pollen/spores indicate that they are from an earlier age, late Carboniferous (Grupta and Boozer, 1969), than those found at Hamilton Quarry, Permian (Taggart and Ghavidel-Syooki, 1988).

Summary

A total of 95 taxonomic equivalences out of a possible 413 were found between Garnett and Hamilton Quarry. For terrestrial invertebrates, vertebrates, and plants, the few taxonomic equivalences suggest communities had changed through time. However, it is possible this could be due to a collection and/or identification bias. Diversity for each group is described in more detail above.

Trace Fossils

Garnett is noted as having two types of trackways, indicating subaerial exposure of the vertebrate beds, whereas Hamilton Quarry is noted for having coprolites and a *Palaeoxyris* shark egg. Charcoal is found at both Garnett and Hamilton Quarry, which suggests fires possibly occurred at or near both localities.

Taphonomy

In general both Garnett and Hamilton Quarry have similar preservation pathways. At both sites aquatic invertebrates appear to be preserved via replacement, with indications of being reworked and/or transported in the vertebrate bearing layers. Only at Garnett in the pelecypod layer and in Reisz et al.'s (1982) third fossil zone are aquatic invertebrates found complete to near complete. Additionally, the terrestrial invertebrates are preserved as impressions and plants are preserved as impressions, compressions, and carbonizations. The palynomorphs are composed of sporopollenin, which is extremely resistant to alteration; however, it can occur. Unfortunately, none of the palynologic studies reported how the pollen/spores were preserved and if any alteration had occurred.

Vertebrates appear to have similar preservation; however, conditions of fossilization seem to have been different. At Garnett, terrestrial vertebrates are found disarticulated with the exceptions of fish, which are only found as isolated elements, and *Petrolacosaurus kansenis*, which is found either fully or partially articulated. At Hamilton Quarry, fish and small amphibians are found as articulated whole or nearly whole bodies with soft tissue preserved. Disarticulated fish are found as strings of scales, and large terrestrial vertebrates are found partly to fully disarticulated. Hamilton Quarry appears to have had either a high overall sedimentation rate or a single high sedimentation event to facilitate the soft tissue preservation quickly burying fish and small amphibians before decay could begin. Isolated bony elements are found at both localities, which is more suggestive of death occurring upstream, followed by transport of the element to the final resting place.

Conclusions

A preliminary view of the paleoecosystems indicate that Garnett and Hamilton Quarry are similar; however, there are major differences. The paleoenvironment of Garnett was likely a restricted coastal lagoon/estuary with primarily seed ferns and ferns as the dominate plant life, while the primary fauna consisted of terrestrial invertebrates and vertebrates, with only little marine influence. The majority of aquatic invertebrates are reworked, with intact aquatic invertebrates being rare and those found suggest brackish waters. Terrestrial invertebrates are also rare but do not show signs of reworking or transport. Terrestrial vertebrates are found mostly disarticulated, suggesting either transport occurred prior to burial or bodies were disarticulated during decay. The exception is the reptile *Petrolacosaurus kansenis,* which was found articulated in the same mudstone layers as the tetrapod trackways. Aquatic vertebrates are rare and found mostly disarticulated as isolated elements in the same layers as the tetrapod trackways, suggesting they were transported in and/or brought onto shore by a predator. The presence of trackways suggests water was not always present, possibly indicating a wet-dry seasonality when combined with the charcoal that suggests nearby fires.

The paleoenvironment of Hamilton Quarry was probably a flowing stream that graded into an estuary from inland (north) to the seacoast (south), with primarily conifers and ferns as the dominate plant life, while the primary fauna consisted of freshwater invertebrates and vertebrates. In regards to the Main Quarry area, specifically marine invertebrates are rare and found broken, suggesting all had been transported in. The presence of eurypterids is suggestive of fresh to marine water. The majority of aquatic vertebrates are found as articulated whole or partial body specimens, often with soft tissue preservation. Additionally both adult and juvenile *Acanthodes* were found, suggesting breeding was occurring in protected calm water areas of the stream. This is supported by the presence of a reported shark egg. A total seven marine conodont elements were found in the Main Quarry area, suggesting transport had occurred. The majority of terrestrial invertebrates are found as nearly complete bodies, suggesting transport did not occur with these specimens. Small terrestrial vertebrates are found articulated, with some amphibian specimens showing soft tissue preservation. Large terrestrial vertebrates are found in various stages of disarticulation, suggesting some transport had occurred. Farther downstream at Marlin Quarry, the terrestrial fauna is reduced and conifers are not present; this suggests that stream current was not strong enough to transport the remains from the north.

Comparatively, Garnett and Hamilton Quarry have similar faunal and floral communities but with differences in the specific taxa present and in the dominant taxa. For aquatic invertebrates, both localities have a similar community composition, but with Hamilton Quarry having a larger number of identified freshwater taxa. For terrestrial invertebrates, again both have similar communities; however, Garnett's is composed of more primitive forms whereas Hamilton Quarry's is composed of more advanced forms. Vertebrates can be separated into two categories: fish and tetrapods. Hamilton Quarry has a large fish community, whereas at Garnett fish are all but absent. As for tetrapods, again both have similar communities; Garnett has the most basal diapsid reptile, whereas the younger Hamilton Quarry has more advanced form, as would be expected. However, Hamilton Quarry has the basal eupelycosaurs, whereas at Garnett the eupelycosaurs are more advanced, which is the opposite of what one would expect. The floral community is similar for both localities, with the difference being Garnett having a seed fern dominated flora and Hamilton Quarry having a conifer dominated flora. Overall, Garnett appears to be more terrestrially influenced, whereas Hamilton Quarry has a larger freshwater aquatic influence due to the presence of a flowing stream.

Global Comparisons

When compared to the localities of similar age that are noted in the Global Comparisons section of Chapter 1, neither Garnett nor Hamilton Quarry is a close match in terms of flora, fauna, or depositional environment. The Toronto locality, while being geographically close and stratigraphically between the two localities, currently lacks a lot of information needed for a full comparison. The presences of fish would suggest it is more like Hamilton Quarry, and the depositional environment and complete disarticulation of the fossils suggests water was a transporting agent, whereas at Hamilton Quarry water was always present in the stream.

At Montceau-les-Mines, which is younger than Hamilton Quarry, the fossils appear to be the closest match of all the global comparisons similar to both Garnett and Hamilton Quarry, although the environments of deposition are quite different. At Montceau-les-Mines, the invertebrates are much more diverse than at either Garnett or Hamilton Quarry. The number of taxa are at least double the number at the two localities. In terms of vertebrates, Montceau-les-Mines is more similar to Hamilton Quarry due to the presence of several fish taxa, but the French locality lacks diapsid reptiles and has only one specimen of a [eu]pelycosaur. The flora of Montceau-les-Mines is more similar to Garnett in that it has many ferns and seed ferns and few, more primitive conifers.

The Robinson locality is overall more similar to Hamilton Quarry, but it lacks plants and had a greater marine influence. Both localities have similar marine invertebrates, with the exception of a trilobite and coral being found at Robinson. Both localities have xenacanthid sharks, *Acanthodes*, paleoniscoid fish, lungfish *Sagenodus* and *Gnathoriza*, actinistan fish, and rhipidistian fish. Furthermore, they both have a trimerorhachid amphibian. A pelycosaur is reported from Robinson but has not been identified further.

Neither the Bushong nor Elkridge localities match Garnett and Hamilton Quarry well. All four localities have amphibians; however, Bushong and Elkridge have a lungfish, which Hamilton Quarry does, whereas Garnett does not. The (eu)pelycosaur from Bushong and Elkridge is of an advanced family that is present at Garnett but not at Hamilton Quarry. The depositional environment of Bushong and Elkridge was interpreted to be lacustrine, which would explain the lungfish, but no plant fossils, except root casts, are reported from either locality, indicating that the area surrounding the aquatic environment was dryer.

Overall Montceau-les-Mines offers a good community comparison to Garnett and Hamilton Quarry. Montceau-les-Mines is the only comparison locality to have plants in addition to invertebrates and vertebrates, whereas the other localities lack plants. Although Montceau-les-Mines has few tetrapods, its plant community matches Garnett's well, while its fish community matches Hamilton Quarry's well, and its invertebrate community matches that of both Garnett and Hamilton Quarry, although it exceeds them in both abundance and diversity due to better preservation.

Importance of Full Examinations

The combination of depositional environment, taxa, and taphonomy are extremely important for interpreting paleoecosystems; however, study biases can and do influence the results. By ignoring preservation conditions of fossils (e.g. articulated, reworked, *in situ*, etc.) and taphonomy, depositional environment cannot be fully understood. Specific types of preservation only occur under specific environmental conditions. By ignoring one aspect of the community, this can and does lead to misinterpretations of the depositional environment. For example, terrestrial plants are rarely found in marine dominated environments, and when they are, it is typically as isolated elements. In order to better understand how paleoecosystems change over time, all aspects must be fully examined at any locality before fruitful comparisons can be made.

Future Work

Both Garnet and Hamilton Quarry require re-examination of previously collected material and further field work. New genera/species have been identified from both localities since the previous direct comparison was made (Maples and Schultze, 1988), as such the new genera/species might be present at the other locality. For example, the conifer genus *Emporia* was identified from Hamilton Quarry material; therefore, a reexamination of Garnett fossils could lead to the identification of *Emporia* being present there as well.

Future work at Garnett should focus on finding the edge of the lagoon/estuary to see if terrestrial vertebrates were just deposited in the one area or more spread out along the shore. Coring needs to be used to establish the boundaries of the lagoon/estuary and a better lithology of the area. New plant material needs to be collected using modern collection techniques to prevent the breakage of specimens. Additionally, already collected aquatic invertebrate specimens need to be reexamined for identification to the lowest taxonomic level.

Future work at Hamilton Quarry should focus on establishing a more detailed lithology along the entire paleochannel to better establish depositional environment. The area between the Marlin Quarry and southern end needs to be examined for potential outcrops to establish what is occurring between these locations. More coring needs to be done along the paleochannel as a whole to better establish its greater extent and potentially find a capping sequence in the northern end where the deposits disappear underground. Discovery of a capping sequence would definitively place the Hamilton deposits in the stratigraphic column and determine the approximate timing of deposition. More samples of the channel fill need to be collected for use in palynology research, preferably with samples collected along the entire paleochannel. Overall, more research needs to be performed in the northernmost and southernmost ends to better establish the lithology and paleontology of these areas.

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Appendix A:

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