AN ABSTRACT OF THE THESIS OF

Aleksander P. McElroy for the Master of Science degree in Physical Science, Earth Science Emphasis presented on April 1, 2016.

Title: Fauna and Depositional Environment of a Late Pennsylvanian Vertebrate Fossil Locality in Southeastern Kansas

Thesis Chair: Michael Morales

Approved: ____

Abstract

A vertebrate fossil locality in Greenwood County, Kansas, near the town of Toronto, in the Snyderville (Shale) member of the Oread (Limestone) Formation (Late Pennsylvanian, Virgilian) contains an abundance of disarticulated fossils weathering out of a paleosol. This new locality is stratigraphically between the previously-described Late Pennsylvanian Hamilton (Virgilian) and Garnett (Missourian) fossil localities, thus helping to fill the temporal gap between these two. The paleosol contains 11 paleohorizons of alternating grey and red clays capped by thin weathered sandstone blocks with micro-crossbedding, which is consistent with channel sand deposits. Over 2000 fossils were collected, all of which were disarticulated, complicating identification. Identified taxa include the xenacanth shark *Orthacanthus*, the lungfish *Sagenodus* c.f. *S. Serratus*, the temnospondyl amphibians, embolomerous and diadectid reptiliomorphs, and synapsid amniotes. So far, no fossil invertebrates or plants have been discovered. The fossil fish and the amphibians indicate the nearby presence of fresh water. This, together with the presence of the weathered sandstone blocks, suggests that the depositional environment was a fluvial floodplain. The remains were probably first disarticulated within the

stream, and then the smaller bones, teeth, and spines were sorted while in the stream and/or during a flood event. They could then have been deposited in a depression in the landscape, such as a swale. The Toronto locality has faunal similarities to both the Hamilton Quarry and Garnett fossil localities. However, unlike both of these other localities, which have articulated specimens, this locality only has disarticulated specimens. Additionally, while the other two localities also each has invertebrates and flora, the Toronto locality has only vertebrates. The Garnett locality was an estuarine setting, whereas the Hamilton Quarry fossils were all deposited within a fluvial channel, and the Toronto locality was a floodplain that shows no direct marine influence.

Keywords: earth science, geology, sedimentology, paleontology, stratigraphy

FAUNA AND DEPOSITIONAL ENVIRONMENT OF A LATE PENNSYLVANINAN VERTEBRATE FOSSIL LOCALITY IN SOUTHEASTERN KANSAS

A Thesis

Presented to

The Department of Physical Sciences

EMPORIA STATE UNIVERSITY

In Partial Fulfillment

of the Requirements for the Degree

Master of Sciences

by

Aleksander Peter McElroy

May 2016

Approved by the Department Chair

Committee Member

Committee Member

Committee Member

Dean of the Graduate School and Distance Education

Table of Contents

Tables and Figures

Chapter 1: Introduction and Previous Work

Introduction

In 2014, vertebrate fossils were discovered weathering out of the late Pennsylvanian (approximately 300 million years) Snyderville (Shale) Member from a former railroad cut near the town of Toronto in southeastern Kansas (Figure 1). Initial examination of the fossils indicated that they were disarticulated bones of temnospondyl amphibians, reptiles, xenacanth sharks, and lungfish. Only two other localities in Kansas are known for terrestrial fossils of approximately the same age: the Hamilton Quarry and Garnett, Kansas localities. The Toronto locality is positioned stratigraphically between these two, which presents a new opportunity to examine the evolution of terrestrial vertebrate faunas of the region during the late Pennsylvanian. The purpose of this study, therefore, was to collect, identify, and describe these fossils in order to develop an understanding of the vertebrate fauna present. A stratigraphic section was measured to determine the outcrop's stratigraphic position within the Snyderville. The section and the fauna were evaluated together to interpret the depositional environment of this locality.

Geographic Location and Setting

This new fossil locality was discovered in Greenwood County, Kansas, approximately 2.5 km (1.6 mi) west of the town of Toronto. Its coordinates are 37˚ 48' 12.3" N latitude and 95˚ 58' 47.3" W longitude. Its township and range coordinates are SW ¼, NW ¼, Sec. 10, T. 26 S., R 13 E. (Figures 2, 3, 4). The locality itself is the northern exposure of a former railroad cut for the Missouri Pacific Railroad, now located by the southern fence of a cattle pasture. Nearby vegetation is abundant and consists primarily of grasses. The outcrop itself is more sparsely vegetated in the fossiliferous sections, with the exception of a few grassy hillocks (Figure 5). The elevation for the locality is approximately 920 feet above sea level at the base of the outcrop.

Geology

The Snyderville (Shale) Member of the Oread Formation was first named by Condra (1927; Condra and Reed, 1943). It was defined as a blue-grey argillaceous shale with lower, red-tinted layers in northern Kansas and southern Nebraska (Bryan, 1999). It is located between the overlying Leavenworth (Limestone) Member and the underlying Toronto (Limestone) Member, of the Oread Formation (Figure 6). However, in locations where the Toronto is absent, the Snyderville instead overlies a shale member of the Lawrence Formation (Sanders, 1959). The contact between the Toronto and the Snyderville is marked by a disconformity, while the Leavenworth has a sharp conformable contact (Joekel, 1994). Strangely, the Snyderville was not given a type section when initially described, but was named for exposures in the Snyderville Quarry near Nehawka, Cass County, Nebraska. Condra and Reed (1937) noted that exposures of the Snyderville northwest of Leavenworth, Kansas are structureless and exhibit characteristics of an underclay, which is simply a characteristic claystone found beneath a coal deposit. The Snyderville also features a persistent zone of fossils of the brachiopod *Chonetes* fossils at the top of the unit. The member's type section is found in the Heebner Creek Valley, east of the Snyderville Quarry (Condra, 1949).

Moore (1949) described the Snyderville in northern Kansas and Nebraska as a mostly grey clay which tends to weather into blocky fragments. This is consistent with underclays, though he notes that the Snyderville in this area is much thicker than typical for underclays of this age. The grey clay Moore described may be overlain by coal beds or carbonaceous layers locally. The upper layers of the Snyderville, approximately 0.3 to 0.5 meters in thickness, are well laminated. To the south, the member becomes sandy and is often underlain with a paleosol. The lower and middle sections of the member are typically interpreted as being non-marine clays, but the presence of marine fossils in the well-laminated upper layers, including brachiopods, gastropods, and bivalves (Moore, 1964; Elias, 1964; Troell, 1965; Joekel, 1994), seems to indicate that they were deposited in a shallow water, low energy saline environment (Moore, 1964; Johnson and Adkinson, 1967). In contrast with the nonmarine interpretation of the lowest Snyderville, von Bitter (1972) noted that small numbers of conodonts have been found in the lowermost few centimeters of the member, which seems to indicate that these layers were deposited in a marine, or at least transitional, environment.

The Snyderville varies greatly in thickness, ranging from an average of approximately 3.7 meters in northeastern Kansas and southern Nebraska, thickening to 22.9 meters in southeastern Kansas (Sanders, 1959). It sometimes is found to contain layers of conglomerate consisting of limestone clasts that had been reworked from the Toronto Member, notably near Baldwin, Kansas (O'Connor, 1960). Some southern exposures may also contain layers of a nodular argillaceous limestone (Jewett et al., 1968).

One of the most prominent features of southern exposures of the Snyderville is an extensive paleosol. Joekel (1994; 1995a) describes this paleosol as vertisol-like and shows noticeable east-west lateral variation. It contains prominent sets of large intersecting slickensides, and lacks strong subsoil horizons. There are relatively few probable illuvial clay (PIC) features within the paleosol. These are criteria used to determine whether the clay minerals within a given paleosol had an illuvial origin, such as sharp boundaries with the adjoining clay matrix, a strongly preferred parallel orientation, and a somewhat layered appearance (Joekel, 1995a).

Depositional Environment of the Snyderville

Cyclothems. The Snyderville (Shale) Member has been interpreted as being deposited during a regressive phase of the Oread Cyclothem, one of a series of cyclothems in the Shawnee Group, termed a megacyclothem (Moore, 1949; 1964; Troell, 1965; Bruemmer, 2003; Turner-Williams, 2003). This is indicated by the presence of paleosols and locally deposited fluvial channel sandstones, which may be found in Oklahoma. This is further supported by a slight to moderate trend of upward-coarsening of the clastic material comprising the lower and middle portions of the member. This has been interpreted as a prodeltaic-deltaic succession (Bruemmer, 2003).

Paleosols. Joekel (1994) performed a mineralogic study of two partially-welded paleosols within the Snyderville in Nebraska. The dominant clay minerals of the studied paleosols were illite, chlorite, and kaolinite. Slickensides found within the paleosols suggested to Joekel that some of the soil material had undergone pedoturbation, which is simply disturbance by physical, chemical, or biological processes. Subvertical, sinuous to zig-zagged veins of noticeably darker polished clays and silt were found prominently in many outcrops. The upper paleosol always contained small crystals of pyrite, but the lower one did not. There were no well-developed soil structures, but silt infillings were common. All of the upper paleosol profiles contained calcitic carbonate nodules.

Regionally, the Snyderville varied more from east to west than it did north to south. This represented a large-scale topohydrosequence, which is when tectonic events cause changes in local shoreline locations, influenced by gentle tectonism, such as that which created the Nemaha Uplift. It may also represent a change from lower or more seasonal rainfall to higher or less seasonal annual rainfall (Joekel, 1994).

Sedimentary Facies. Yang (2006) described three facies found in the upper portion of the Snyderville: a lower nonfossiliferous mudstone facies, a middle conglomerate-sandstone facies, and an upper fossiliferous shale facies. The nonfossiliferous mudstone facies is dark grey, contains sparse burrows, rare to sparse calcitic nodules in the lower portion, and pyrite crystals in the upper portion. Its overall texture, color, lithology, the absence of marine fossils, and its boundary with the other facies indicates that it is a Gleysol, a type of soil formed from waterlogging due to rising groundwater. It seemed to Yang to have formed due to seawater leaching during the Oread Transgression.

The middle conglomerate-sandstone is clast-supported, containing very little matrix. The conglomerate is very well-sorted and dominantly consists of fine pebble to granule-sized clasts, while the sandstone is moderately to well-sorted and dominantly consists of coarse to medium sand grains. The clasts are approximately 95% calcite, with the remaining 5% being quartz and shell fragments. Yang found localized bioturbation within this unit. The unit is well cemented by calcite, and forms a single persistent bed. The clasts were likely reworked from older material and transported by high-energy currents in a marine environment (Yang, 2006).

The upper facies is fossiliferous and is primarily a dark grey shale, with minor mudstone and rare laminae of a silty shale or siltstone. The shale is platy to thickly laminated. The mudstone is massive to platy with relict laminations. It contains possible burrows and small plant fossils may be found locally. The upper portion of the shale contains fossiliferous argillaceous limestone nodules which become larger and less argillaceous further up. Increasing marine fossil abundance upward indicated that this facies was deposited in a shallow, low-energy continental shelf environment which got deeper over time with sea level transgression (Yang, 2006).

Land Fossils

Known terrestrial fossils are rare within the Snyderville but have been described previously. Foreman and Martin (1988) described a single locality in eastern Kansas which contained embolomere vertebrae within a paleosol layer. Morales (2014) noted that the fossils found up to that point at the site that is the focus of this thesis had preliminary had been collected as float, having eroded out of the outcrop, and that they included disarticulated remains of fish, amphibians, and reptiles. Preliminary description by Aber et al. (2014), who interpreted the environment of deposition of the locality, based on the fossil assemblage, as being consistent with being marginal marine or estuarine in nature, but as discussed in chapter 4, the sedimentology of the area does not fit this conclusion. Initial fossil identifications included *Orthacanthus, Sagenodus, Eryops, Archeria, Trimerorhachis, Diasparactus,* and *Ophiacodon* (Aber et al., 2014). However, these conclusions appear dubious at best. *Archeria* and *Trimerorhachis* are Permian genera, so this would represent a significant increase in their geochronological ranges. In addition, many of these identifications were made using elements which may not be truly diagnostic of any particular taxon.

Comparitive Localities

Hamilton Quarry

The Hamilton Quarry, also found in Greenwood County, is known for its abundance of well-preserved fossils. A major feature within this locality is a paleochannel, which is flanked on either side by the Topeka (Limestone) and by the Calhoun (Shale) Formations of the Shawnee Group (Middle Virgilian, Pennsylvanian). In the south, it also cuts into the Ervine Creek (Limestone) Member of the Deer Creek Formation (Bridge, 1988; French et al., 1988; Cunningham et al., 1993). It is unclear when the paleochannel itself formed, but it has been suggested to be between age of the Hartford (Limestone) Member of the Topeka and that of the Severy (Shale) Formation (Middle Virgilian, Pennsylvanian) (Salley et al., 2005). The paleochannel is filled by a basal conglomerate which fines southward, indicating flow direction (Bridge, 1988; French et al., 1988; Cunningham et al., 1993).

Notable fossils of this location include terrestrial invertebrates such as cockroaches and spiders, aquatic invertebrates, such as euripterids, aquatic vertebrates including *Acanthodes*, xenacanthid sharks,d and lungfish (Zidek, 1976), and tetrapods, including dissorophoid amphibians (Daly, 1988) and diapsid reptiles (Reisz, 1988). Recently, a new species of caseid synapsid called *Eocasea martini* has been described, which appears to be significantly older than other known species of the Caseidae clade (Reisz and Fröbisch, 2014). The diapsid *Spinoaequalis schultzei* was also found in the quarry, and has been described by deBraga and Reisz (1995). Plant fossils are also found at this locality (Leisman et al., 1988).

The depositional environment of this locality is that of a fluvial system that flows into an estuarine or coastal region. The northern portion of the stream was more riparian, as shown by the taxa and lithology (Bridge, 1988; Kaesler, 1988; Kues, 1988; Leisman et al., 1988; Mapes and Maples, 1988a; Maples and Mapes, 1988b; Zidek, 1988). Further south, the lithology and taxa suggest that estuarine or coastal marine influence is more dominant (Busch et al, 1988; French et al., 1988; Schultze and Chorn, 1988; Schultze, 1995).

Garnett Fossil Locality

In addition to these two localities, another near Garnett in Anderson County has also yielded vertebrate fossils. The fossiliferous unit within this locality is the Rock Lake (Shale) Member of the Stanton Formation, Lansing Group (Missourian, Pennsylvanian) (Moore, 1964). This is the oldest of these three localities.

This locality is notable for having the most diverse and advanced terrestrial taxa from the Pennsylvanian Period in North America. Aquatic invertebrate taxa include fusilinids, rugose corals, bryozoans, brachiopods, bivalves, annelid worms, ostracods, and echinoderms, while terrestrial invertebrates include scorpions and insects (Schultze, 1995). Aquatic vertebrates consist of elasmobranch sharks (Schultze, 1995). Terrestrial vertebrate taxa include *Hesperoherpton garnettense*, *Edaphosaurus* species, *Ianthasaurus hardestiorum*, *Haptodus garnettensis*, and a yet to be described ophiacodontid (Peabody, 1958; Reisz et al., 1982; Mazierski and Reisz, 2010), but the most notable and abundant species found here is the diapsid *Petrolacosaurus kansensis* (Reisz et al., 1982). Flora at this locality include Pteridospermidae, Cycadales, Sphenopsida, Lycopsida, Cordaitales, and possibly Ginkgoales (Baxter and Hartman, 1954).

The depositional environment for this locality is somewhat unclear. Peabody (1958) suggested it was a marine lagoon. However, Reisz et al. (1982) interpret it as an estuarine tidal mudflat which developed during a major oceanic transgression.

Chapter 2: Methods

Introduction

Methods include field work, laboratory preparation, photographing of specimens, and identification of taxa.

Field Work

Collecting

In order for any collected fossils to be precisely located within the outcrop, a grid system was first established. The grid was aligned with the outcrop and fixed upon a fence which runs along the railroad cut (Figure 1). The boundaries for each column of the grid were aligned with the fence posts, totaling 50 columns. The cells of the grid were labeled by hanging weather-resistant tags which had been marked with the column numbers along the fence. Using a Brunton compass to sight, iron stakes were installed at the foot of the outcrop directly in front of the posts between sections 33 and 42 parallel to the fence to indicate the columns which were assumed to feature more fossils. The outcrop was then divided vertically into lower, middle, and upper sections to note how high up stratigraphically the fossils would be found.

Working within a single grid column, collection began by looking for any surface fossils which had weathered out of the outcrop. Once that was done, digging with hand tools was started. When a potential fossil was found, it was first photographed *in situ*, using a scale to notate size and orientation. Then, it was carefully extracted using precision tools, taking care to not damage it. Once extracted, the specimen was placed in a sample bag labelled with the column number in which it was found. The bag was left open to prevent condensation from accumulating within the bag and potentially damaging the fossil. If a large number of fossils were found in a specific spot, it would be marked with a wire flag or series of wired flags.

Measured Section

A stratigraphic section was also measured for this outcrop. This was accomplished by hiring a backhoe to dig a 6-foot wide trench in column 36, going down to the bedrock. Using a Jacob's staff, each unique layer within the Snyderville found in the outcrop was measured and described. (Figures 7 and 8).

At a later date, further measurements were taken to determine the stratigraphic placement of the outcrop within the Snyderville member. First, the contact between the underlying Toronto and the Snyderville was found in a nearby road cut. A Jacob's staff and a field level were used to sight to a telephone pole close to the outcrop. This was then sighted to the top of a utility pole which had been cut down within the locality itself. This pole was then measured to the base of the outcrop. The pole height was then subtracted from the total measured height to give the stratigraphic level of the outcrop from the bottom of the Snyderville.

After that, the next goal was to determine how far below the contact with the Leavenworth member the top of the outcrop was. Since the Leavenworth had been eroded away at the locality, this was accomplished by using a topographic map of the region to compare the elevation of the top of the outcrop with that of the approximated contact on a nearby hill. The elevation of the outcrop was then subtracted from that of the hill to determine the vertical distance between them.

To get a full view of the studied section of the outcrop, small format aerial photographs of the locality were taken using a remote-controlled quadcopter with an attached camera approximately 40 meters above the ground.

Lab Work

Once the fossils had been collected, they were allowed to dry out for one to three days, depending on how damp the soil conditions were at the time of collection, then carefully washed off with water and left to dry completely, keeping specimens from each section together. More fragile specimens, rather than risk damaging them by exposing them to water, were instead cleaned off using dental picks to gently scrape away as much matrix as possible.

Some specimens had been diagenetically encrusted with calcium carbonate, which made acid etching necessary. Diluted hydrochloric acid was dripped onto the encrusting material to dissolve its cement. It was then gently scraped away using dental picks.

Cataloging

Once the fossils were cleaned enough for fine detail to be visible, they were then sorted by morphology and stored in specimen boxes. The boxes included labels noting both the location within the site where the specimens were collected and morphology. These boxes were then placed in museum specimen drawers arranged by the section number for the locality.

Photographing

Individual specimens were selected, based on size, distinctiveness, and quality of preservation, to be photographed to later make photo plates. The photos were taken using a Nikon 3300 DSLR camera with a Tamron SP 60 mm macro lens, which was mounted vertically on a specimen photography stand. To provide proper lighting, two desk lamps with natural-light colored bulbs were arranged so the light sources were directly above and in the upper left corner from the camera, respectively. The specimens were placed on the stand with important features facing the camera. If the specimen was unable to stay in position by itself, a small amount of clay was used to hold it in place. A 1:1000 metric scale was placed next to the specimen, propped up to avoid parallax with the features being focused on. The specimens were then photographed and assigned a number for easier sorting and processing.

Identification of Elements and Taxa

Once the specimens were photographed, they needed to be identified by their taxa. Comparisons were made from the photographs taken to photos and illustrations found in literature. The photographs were also shared with experts on stem tetrapods, most notably Dr. Robert Reisz at the University of Toronto Mississauga. Select specimens were also brought to the 2015 meeting of the Society of Vertebrate Paleontology, where they were shown to Dr. Reisz to aid in further identification.

Chapter 3: Data

Stratigraphy

The bottom of the outcrop is 4 ft, 1.2 in (1.25 m) above the contact between the Toronto and the Snyderville Members. The contact is covered at the locality, but is visible at a nearby road cut. The contact is marked by an unconformable transition from limestone to claystone facies.

Paleosol

The outcrop itself is a paleosol made up of 11 paleohorizons of varying thickness (Figures 8 and 9), totaling a thickness of 261 cm (approx. 8 ft, 6.72 in).

Unit 1. The first horizon is made of friable silty clay, 30 cm thick. Its primary color is olive grey, but is also mottled light olive brown. Its constituent peds have a subangular, blocky texture, and feature abundant slickensides. Calcareous material is found throughout the unit. This horizon contains a majority of the *in situ* fossils from the locality, with bones found 6.5 cm from the top of the unit, and other small bones and fragments found throughout the unit. At the top of the unit are one-centimeter-thick lenses of bituminous coal.

Unit 2. The second unit is 40 cm thick, of reddish brown claystone with yellowish brown slickensides. There are no significant sedimentary structures or diagenetic features within this unit.

Unit 3. Unit three has a thickness of 64 cm. The contact with unit two is gradual. This claystone is brown with patches of a reddish yellow coating. The coating reacts with diluted acid, though the clay itself does not. In addition, abundant sub-rounded calcareous concretions are found throughout the unit.

Unit 4. Unit four is 11 cm thick and made up of friable clay. This layer is greenish grey with reddish yellow mottles. This unit does not react with acid. It contains microscopic fossil and lithic fragments.

Unit 5. Unit five is 15 cm thick and is thinly laminated clay. It is primarily reddish brown with a secondary color of dark greyish brown. It does not react to acid and has no significant sedimentary structures or diagenetic features.

Unit 6. Unit six is 11 cm thick. It is olive gray in color. It contains microscopic fossil and lithic fragments. It contains small amounts of dark gray bituminous coal fragments.

Unit 7. Unit seven is 12 cm thick and is friable. It is dark reddish gray in color and does not react with acid.

Unit 8. Unit eight is only three cm thick and friable. It is greenish gray with reddish brown as an accessory color and has a blocky texture. It does not react with acid and has no discernable diagenetic features.

Unit 9. Unit nine is 34 cm thick and is fissile. It is dark reddish gray, and it does not react with acid. Well rounded, pebble sized clasts of hematite are abundant in this unit.

Unit 10. Unit 10 is 25 cm thick. This unit consists of two distinct clays which interfinger. One of these units is reddish brown with a weak red-colored matrix. The other unit is dark greenish gray.

Unit 11. Unit 11 is 16 cm thick to weathered top of the outcrop. It is olive gray in color and firm. It reacts strongly with acid.

Sandstone

Atop the outcrop may be found cobbles of quartz sandstone (Figure 10). The cobbles are sparse in the fossil-bearing sections, but are more common in sections 1-8. The sandstone contains micro-crossbedding and very thin flaser beds (Figure 11).

Leavenworth

The contact between the Snyderville and the overlying Leavenworth (Limestone) Member is eroded away at the locality, but may be found on a nearby hill. Its stratigraphic location is 50 ft (15.24 m) above the top of the outcrop. The total thickness of the Snyderville member in this region is approximately 62 ft, 7.92 in (19.10 m).

Fossil Abundance and Preservation

Not including unidentifiable fragments, approximately 2,080 individual fossils were collected in the course of this study. The primary preservation is mineral replacement. Some of the specimens may also exhibit partial permineralization. The fossil material has all been disarticulated, and a majority of the fossils feature heavy weathering or encrustation of calcareous material.

Taxa Identification

Identification of the taxa was difficult because of the disarticulation. This was further complicated by the heavy weathering and calcareous encrustation, which destroyed features which might have been diagnostic of certain taxa. Together, these factors meant that a vast majority of the specimens were unable to be positively identified to a specific taxon.

Even with these complications, seven taxa were recognized from the locality, two fish and five families of tetrapods (Table 1). Only the two fish were able to be identified past the family level. The following is a list of all taxa identified from the locality with Linnaean classifications, which were modified from the taxon listing by Benton (2015).

Discussion

Orthacanthus

Sharks of the family Xenacanthidae (Figure 12A) are easily recognized by a long spine which protrudes from the anterior of the skull (Figure 13) (Beck et al., 2016). Paired rows of barbs run down the distal half of the spine, many of which are still sharp (Figure 12c). A longitudinal growth canal may be found along the spine's proximal end. 176 fragments of these spines have been found at the Toronto locality. Another unique feature of xenacanths is their teeth. These have a tricuspid morphology, with the outer cusps larger than the center one. Even within the family, the morphology of the tooth cusps is distinct, and therefore identifiable, to each genus. Teeth found at the Toronto locality are often broken, but those which are found intact have flattened cusps with microscopically serrated edges (Figure 14). This morphology is consistent with the genus *Orthacanthus*. The intact cusps range in size from 0.55 cm to 1.65 cm in length from the base. Unfortunately, due to variation among individuals, as well as ontogenetic variation, identification of exact species is not possible (Carpenter et al., 2011). 43 *Orthacanthus* teeth have been found at the Toronto locality.

Sagenodus

Fossils of the Dipnoi, colloquially known as lungfish (Figure 12B), may be immediately recognized by their distinctive tooth plates (Figure 15). If found intact, these plates are enough to identify the genus and species of an individual specimen, based on the morphology, the ratio of its length to its height, and the number of tooth ridges present. One of the plates found at the Greenwood County locality clearly demonstrates a radial pattern with its ridges. Among Paleozoic lungfish, this is consistent with the genus *Sagenodus*. This toothplate has eight ridges and a length/height ratio of 2.42, which is most consistent with the lower left toothplate of a member of the species *S. serratus* (Schultze and Chorn, 1997). These appear to be one of the rarest individual elements at the locality, with only two intact and one broken tooth plates found thus far.

Temnospondyli

A major hallmark of the Temnospondyli (Figure 12C) is the rhachitomous structure of the spinal column. The spine consists of two types of centra, larger crescent or saddle-shaped intercentra, and smaller, paired pleurocentra (Benton, 2015). 33 intercentra have been found at the locality (Figure 16), ranging in size from 0.72 cm to 2.90 cm in length and from 0.45 cm to 2.10 cm in height. Another feature of temnospondyls is one or more pairs of large tusks which are attached to the palate, rather than to the jaw (Laurin and Steyer, 2000). One of these tusks has been found at the locality (Figure 17C). Further elements consistent with temnospondyls include an element which has been identified as belonging to the posterior of the skull and another which may be a section of the jugal (Figure 17A and B). It has been suggested by Dr. Robert Reisz (pers. comm., 2015) that these fossils belong to a member of the family Eryopoidea, and Aber et al. (2014) have even gone as far to state that they belong to the genus *Eryops*. However, sufficient evidence has not been found to corroborate either assertion.

Embolomeri

Unlike the rhachitomous centra of the temnospondyls, embolomere (Figure 12D) centra are comprised of intercentra and pleurocentra which are approximately equal in size (Benton, 2015). These centra are quite common at the Toronto locality, as approximately 345 have been found. These may be either oblong (Figure 18A, F) or near-circular (Figure 18B-E, G), and range from 0.70 cm to 3.85 cm in width and 0.95 cm to 4.15 cm in height. Further identification is not possible with the available material.

Diadectidae

The family Diadectidae (Figure 12E) is notable among tetrapods for being the first to develop herbivory, and the only one in the Carboniferous (Kissel and Reisz, 2011). A single small tooth fragment was found which is tooth is worn and rounded, which indicates that it was used for grinding and chewing, rather than piercing or slicing (Figure 19). This indicates that this is the tooth of an herbivore, not a carnivore.

Therefore, this tooth is consistent with that of a diadectid. However, since only a single tooth fragment has been found so far, it is not possible to identify further.

Amniota

Unlike the other taxa identified from the locality, amniotes lack differentiated pleuro- and intercentra. Instead, the vertebrae consist of a single cylindrical centrum which may fuse to the neural spine to form a single bone. 188 centra consistent with this morphology have been found at the Toronto locality (Figure 20), ranging in size from 0.70 cm to 3.55 cm in diameter and 0.70 cm to 2.85 cm in length. Another common feature, particularly in synapsids, which may be found at the locality is digits that terminate in claws (Figure 21). 22 of these have been collected, ranging in size from 0.65 cm to 2.55 cm in length. Another notable fossil is a section of an amniote longbone that was fractured and partly healed (Figure 22). The segment's vascularity and the morphology of the spongy tissue are consistent with amniotes, as explained by Canoville and Laurin (2010). It has been suggested by Reisz (pers. comm., 2015) that some specimens of the vertebrae belong to a member of the family Ophiacodontidae (Figure 12F), while some of the clawed distal phalanges may belong to a member of the family Sphenacodontidae (Figure 12G). However, the concrete data required to confirm these suggestions are lacking.

A large number of other fossils are identifiable to element, but not to taxon (Figure 22, 23). Approximately 220 phalanges (Figure 22), 410 rib fragments, 100 shoulder or pelvic girdle fragments, and 390 limb bone fragments (Figure 23) were collected. While these are not able to be used for identification, they illustrate the abundance of fossils present.

Chapter 4: Discussion and Conclusions

Discussion

It is well established that the Snyderville (Shale) Member was deposited during the transgressive phase of a cyclothemic sequence (Moore, 1949; 1964; Troell, 1965; Bruemmer, 2003; Turner-Williams, 2003). This is corroborated within this locality by certain diagenetic features found within the outcrop. The calcareous encrustation on many of the fossils may indicate that after burial, they were subject to seawater percolation and a reducing environment, resulting in calcareous material precipitating out of the water. This is also a possible source for the yellow calcareous concretions found abundantly in horizon two. The reducing environment which caused the calcareous material to precipitate out of the water would also have altered the organic material present within the paleosol, causing it to develop into a Gleysol. The presence of coal within the paleosol indicates that the region was vegetated, and may also account for the reducing environment.

The majority of the fossils found have been tetrapods. Three of the tetrapods, the temnospondyls, embolomeres, and diadectids, were non-amniotes, which means that they required freshwater in which to lay their eggs. This likely points to there being a body of fresh water nearby. Ophiacodonts have also sometimes been suggested to be semi-aquatic (Palaios, 2010). It should be noted that none of these taxa has ever been found in a marine or brackish water environment, suggesting that this locality was at least a little inland, away from the coast. The relatively small number of fish fossils found corroborates the idea that water was nearby.

There is evidence that this outcrop was deposited in a fluvially-influenced environment. There is no direct evidence of a channel in the outcrop. However, abundant weathered sandstone blocks were found *ex situ* atop the outcrop, with further blocks found less commonly atop other sections. No sandstone could be found *in situ* either above or below the outcrop in the sections containing fossils, which suggests that it was originally deposited stratigraphically above the outcrop, but was eroded away previously. The sandstone itself is fine-grained and prominently features micro-crossbedding. These are consistent with channel sands, which could indicate the presence of a nearby migrating stream system.

Another feature of the outcrop that would be consistent with a fluvial environment is the presence of a number of structures made of hematite, which have been suggested to be rip-up clasts (Sleezer, pers. comm., 2015). If they are, then they would provide further evidence of a nearby channel. However, some of these structures have been interpreted to instead possibly be root or burrow casts (Newell, pers. comm., 2015).

I suggest that this particular outcrop of the Snyderville was been deposited in a flood plain environment. The fossils described here were all found between study sections 33 and 43, which suggests that they collected in a depression in the landscape, such as a swale. This could suggest that they were deposited by one or more flooding events. The fossils were probably first disarticulated within the stream. The smaller bones, teeth, and shark spines were then sorted within the stream and/or by the flooding. This could explain why all of the described fossils are disarticulated and/or broken, as well as why only small fossils have been found at the locality. Flooding would also account for the presence of the proposed rip-up clasts and the fish fossils, which would settle out of the floodwaters as they slowed down.

Comparison with Other Localities

This locality lies stratigraphically between the Hamilton Quarry and Garnett, Kansas fossil localities. All three are late Pennsylvanian in age, were deposited near the paleocoastline (Figure 25), and feature abundant vertebrate fossils, including both fish and tetrapods. Taxa that the Toronto locality shares with Hamilton are lungfish and xenacanth sharks. Both Garnett and the Toronto locality feature amniotes which may be ophiacodontid, but which haven't been identified further.

However, this is the extent of the similarities between this and the other localities (Table 2). Hamilton Quarry and Garnett both feature numerous articulated specimens, unlike this locality, where all collected specimens have been disarticulated. Hamilton and Garnett each feature abundant flora and invertebrate fossils in addition to vertebrates, while the Toronto locality only has vertebrates. The fossils in the Hamilton Quarry locality are deposited in conglomerate, and the Garnett fossils are deposited in shale, while the Toronto locality fossils are in a paleosol. Hamilton Quarry may have been a terrestrial, coastal marine, or estuarine depositional environment, and Garnett also may have been estuarine or possibly a marine lagoon. The Toronto locality, however, was deposited in a floodplain.

Conclusions

The goals of this thesis were to collect, identify, and describe the fossils at this locality to develop an understanding of the fauna present. Identified taxa include the xenacanth shark *Orthacanthus*, the lungfish *Sagenodus* cf. *serratus*, temnospondyl amphibians, embolomere and diadectid reptiliomorphs, and synapsid amniotes.

This outcrop is a paleosol, as shown by the presence of mottling, the development of soil horizons, and the possible presence of root and/or burrow casts. The presence of the fish and non-amniote fossils suggests that there was a body of water nearby. Weathered blocks of a channel sandstone found atop the locality is evidence for a fluvially-influenced environment. The fossils were heavily concentrated in a small portion of the outcrop, which potentially represents a depression within a floodplain.

Kingdom Animalia							
Phylum Chordata							
Subphylum Vertebrata							
Infraphylum Gnathostomata							
		Class Chondricthyes					
			Subclass Elasmobranchii				
				Order Xenacanthiformes			
					Family Xenacanthidae		
						Genus cf. *Orthacanthus*	
		Class Osteichthyes					
			Subclass Sarcopterygii				
				Order Dipnoi			
					Family Sagenodontidae		
						Genus *Sagenodus*	
							cf. *Sagenodus serratus*
	Superclass Tetrapoda						
		Class "Amphibia"					
			Superorder Batrachomorpha				
				Order Temnospondyli			
					Family cf. Eryopoidea?		
			Superorder Reptiliomorpha				
				Order cf. Embolomeri			
				Order Diadectomorpha			
					Family Diadectidae		
	Series Amniota						
		Class Synapsida?					
			Superorder "Pelycosauria"				
					Family cf. Ophiacodontidae?		
					Family cf. Sphenacodontidae?		

Table 1. Classification of identified taxa.

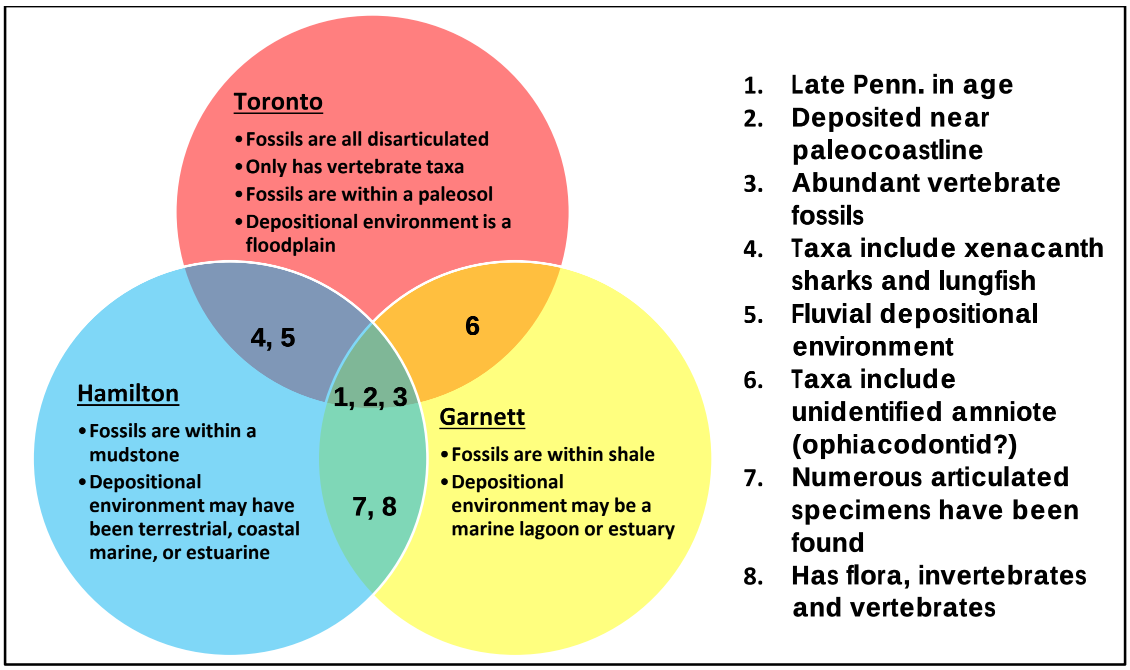

Table 2. Venn diagram illustrating the similarities and differences between the Hamilton Quarry, Garnett, and the Toronto localities.

Figure 1. Low-oblique aerial photograph of the outcrop. Cattle and SUV provide scale. Kite Aerial Photography by Dr. J. S. Aber and Dr. S. W. Aber. Used with permission.

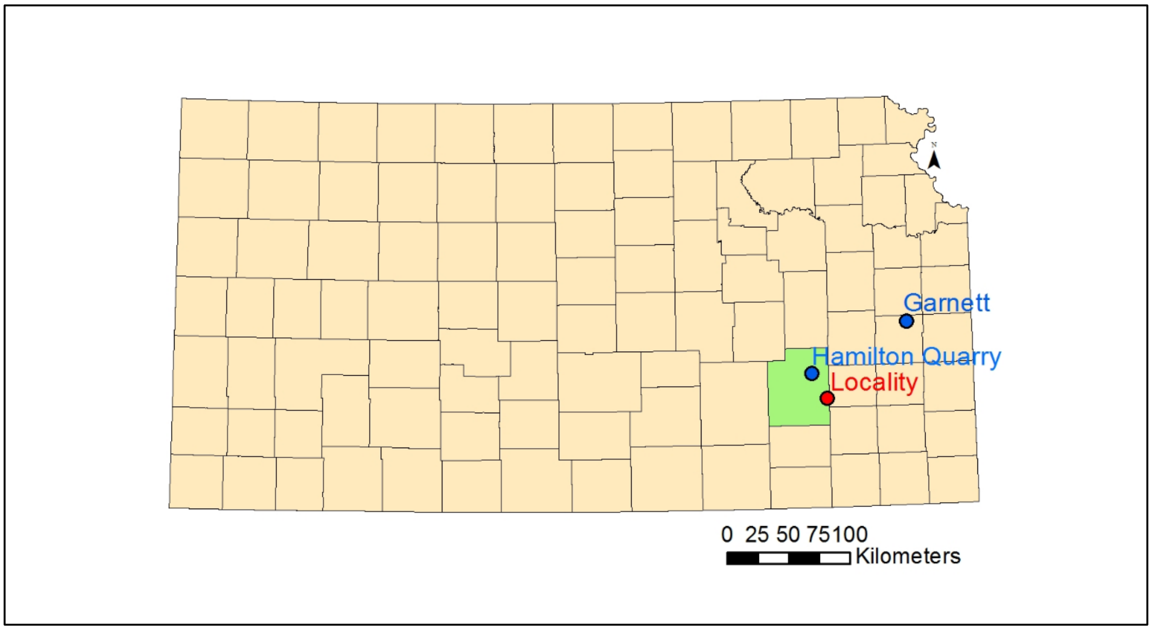

Figure 2. Map of Kansas illustrating the geographic locations of the Hamilton Quarry, Garnett, and the locality being described. Greenwood County is highlighted in green. Kansas counties shapefile from Kansas DASC (2016).

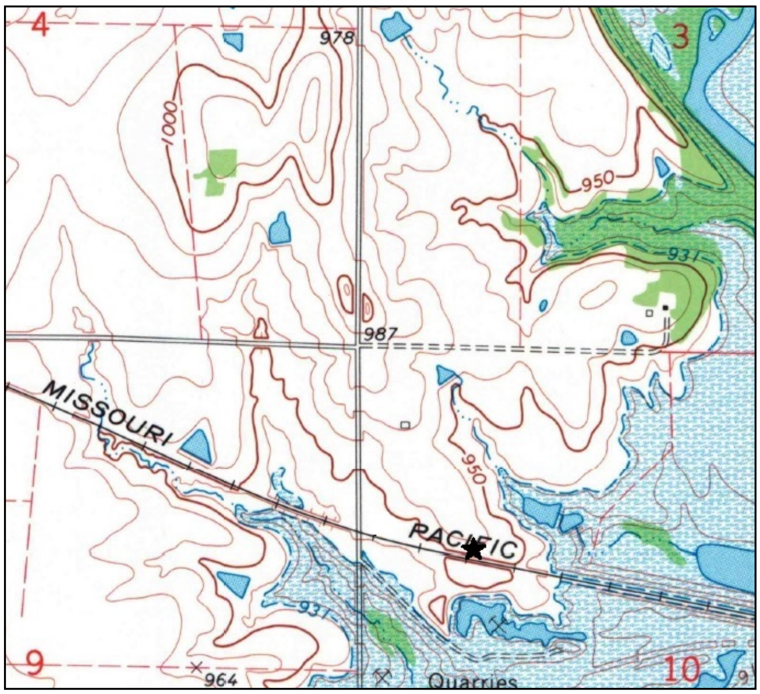

Figure 3. Topographic map of the region. Field site is marked with a black star. Modified from USGS (1969).

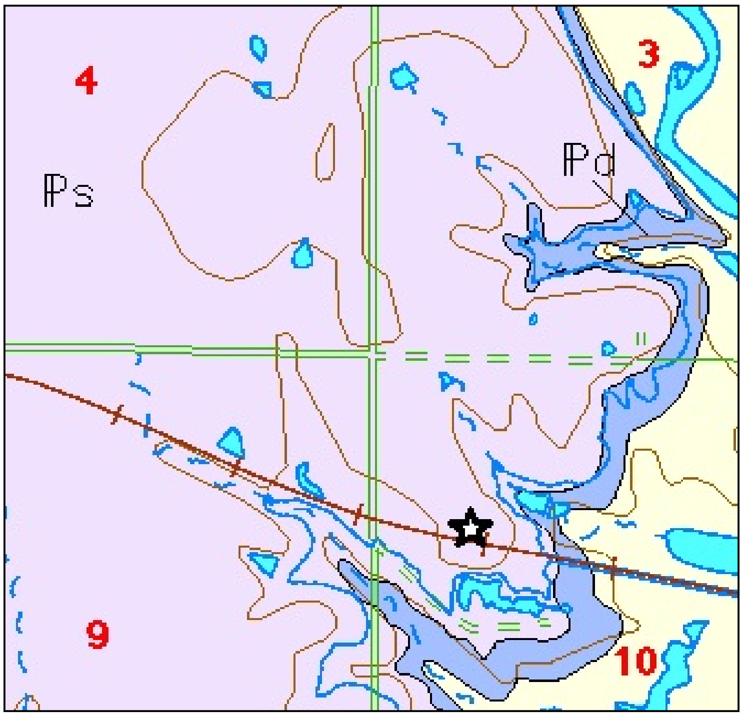

Figure 4. Geologic map of the region. The locality is marked with a black star. Modified from Merriam (1999).

Figure 5. Drone aerial photograph of the main section of outcrop studied. Pink and white squares are each 1 m^2.

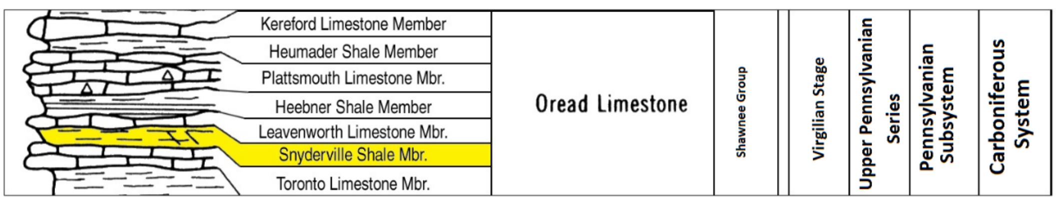

Figure 6. Stratigraphy of the Oread Limestone. Modified from Zeller (2013).

Figure 7. Author measuring the stratigraphic section.

Figure 8. Mosaicked photograph of the units measured in the trench. Jacob's staff sections are each 10 cm.

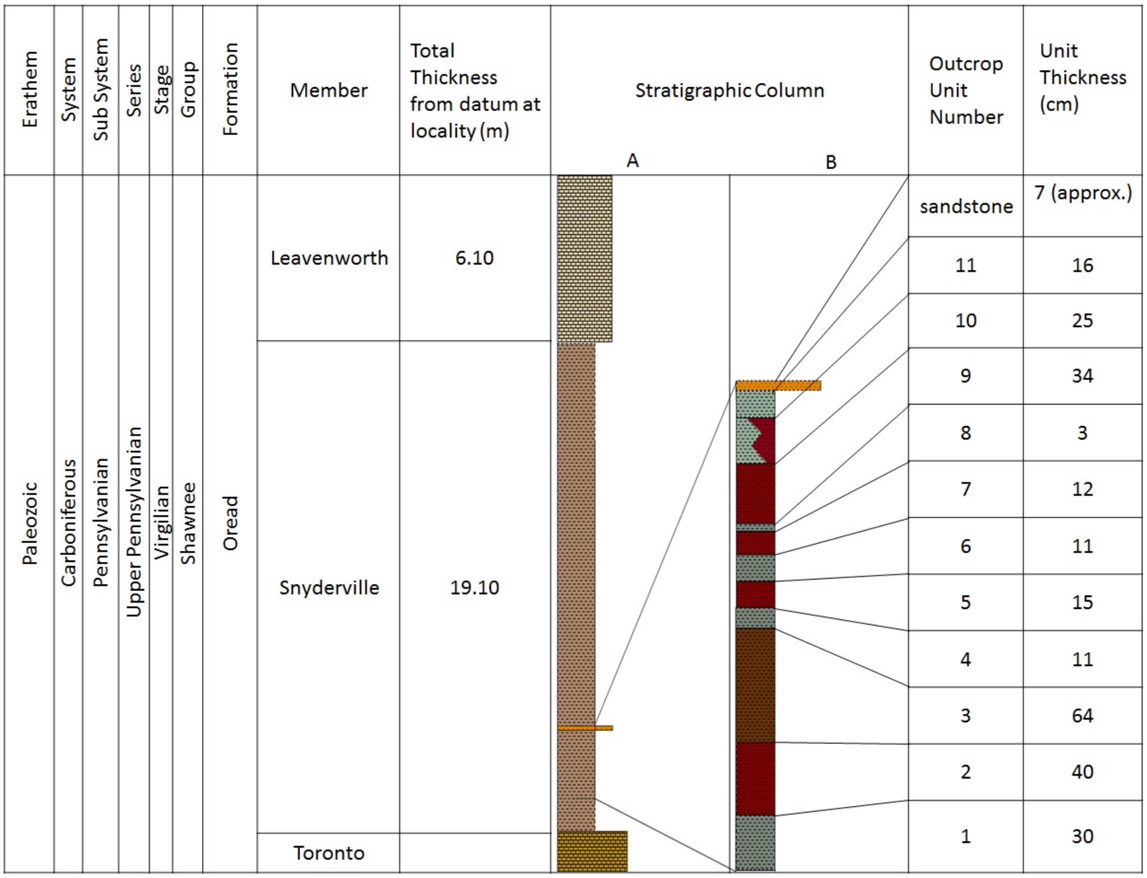

Figure 9. Stratigraphy of the region, with emphasis on the outcrop being studied. A) Regional stratigraphy showing the total thickness of the Snyderville Member B) Stratigraphy of the outcrop in the fossil-bearing sections.

Figure 10. Eroded blocks of sandstone resting atop the outcrop in section 6. Geologic hammer is 28.1 cm long.

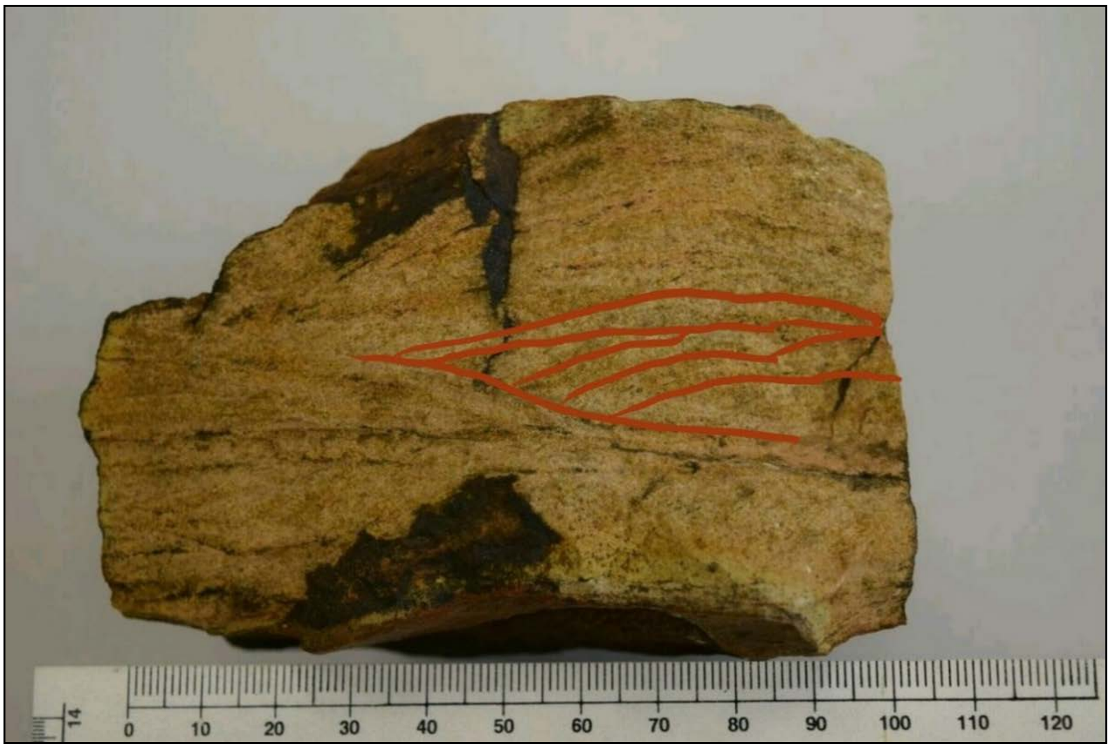

Figure 11. Detail of a block of sandstone from atop the locality. Note the micro-crossbeds present, denoted by red lines. Scale is in mm.

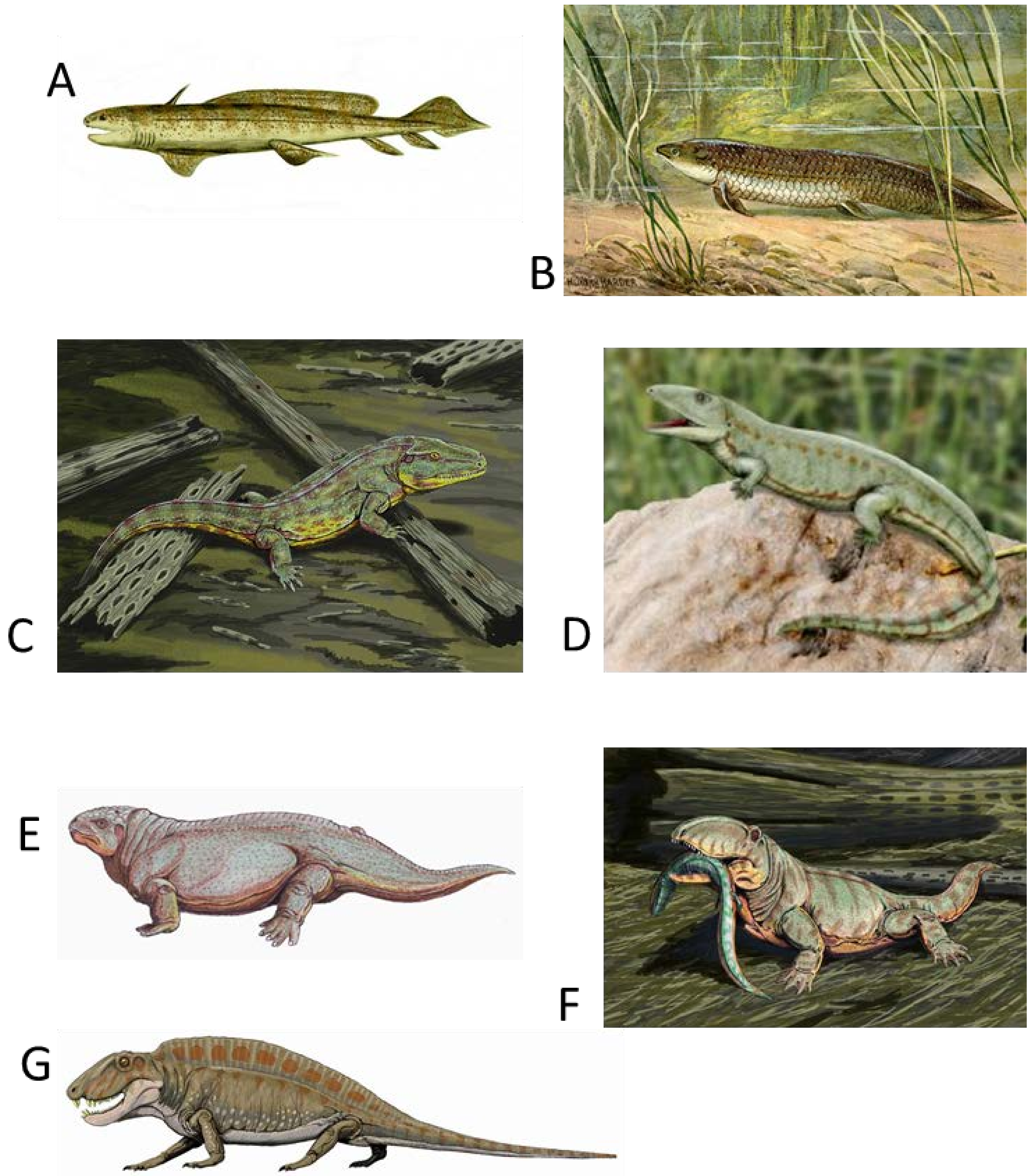

Figure 12. Reconstructions of stereotypical examples of the various identified taxa from the Toronto locality. A) *Orthacanthus*, a xenacanth shark B) lungfish C) temnospondyl D) embolomere E) diadectid F) ophiacodont G) sphenacodont. All images from Wikimedia Commons (2016).

Figure 13. Xenacanth shark dorsal spine fragments. Scale is in mm. A) Distal end of spine, which tapers to a point B) Detail of barbs found on anterior of spine C) Section of spine featuring the longitudinal growth canal down the center of the spine. D) Proximal end of dorsal spine, featuring the growth canal and hollow attachment point.

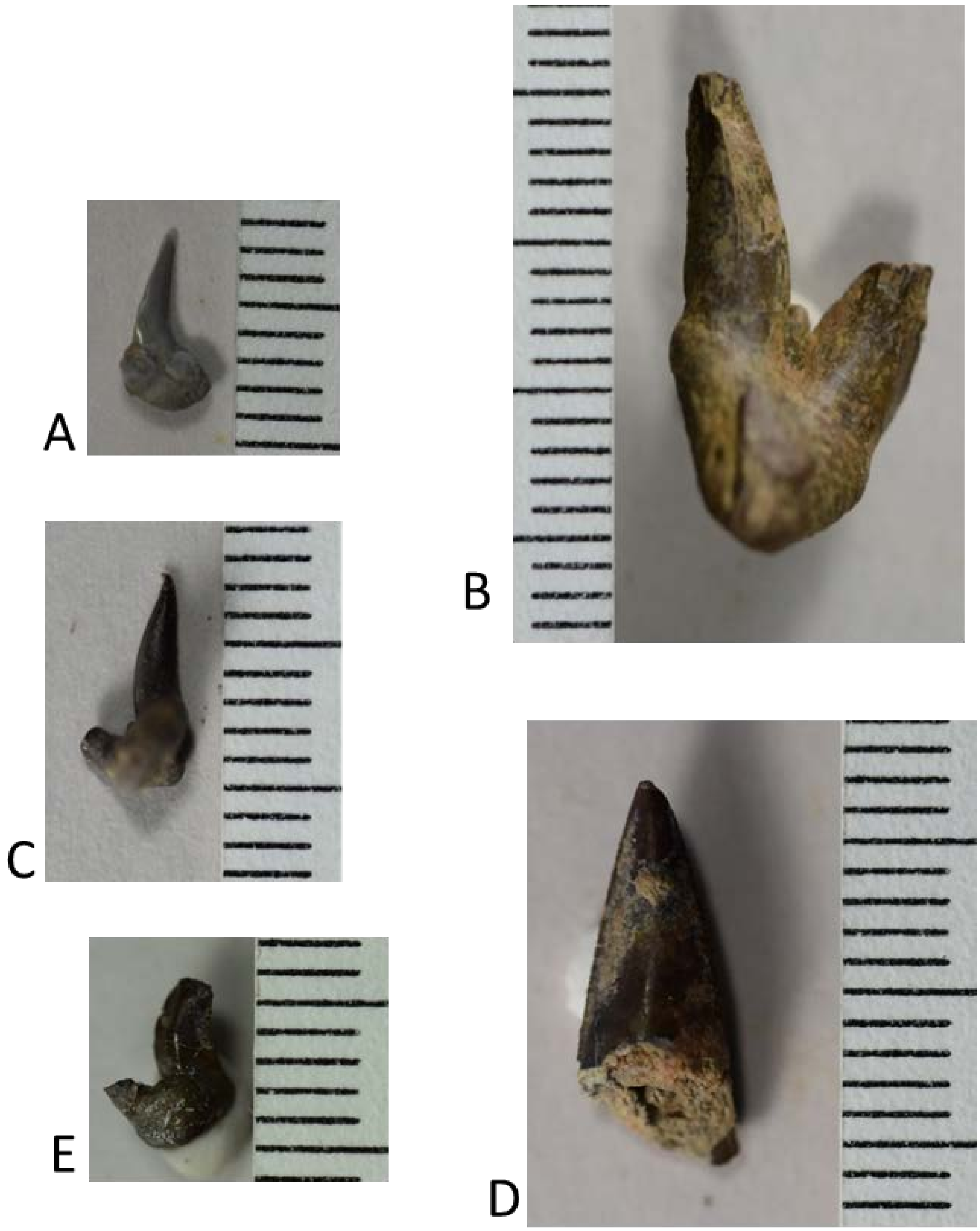

Figure 14. *Orthacanthus* teeth of varying size. Scale is in mm.

Figure 15. *Sagenodus* tooth plates. Scale is in mm. A) *S. serratus* lower tooth plate B) Upper tooth plate C) Tooth plate fragment.

Figure 16. Various temnospondyl intercentra. Scale is in mm.

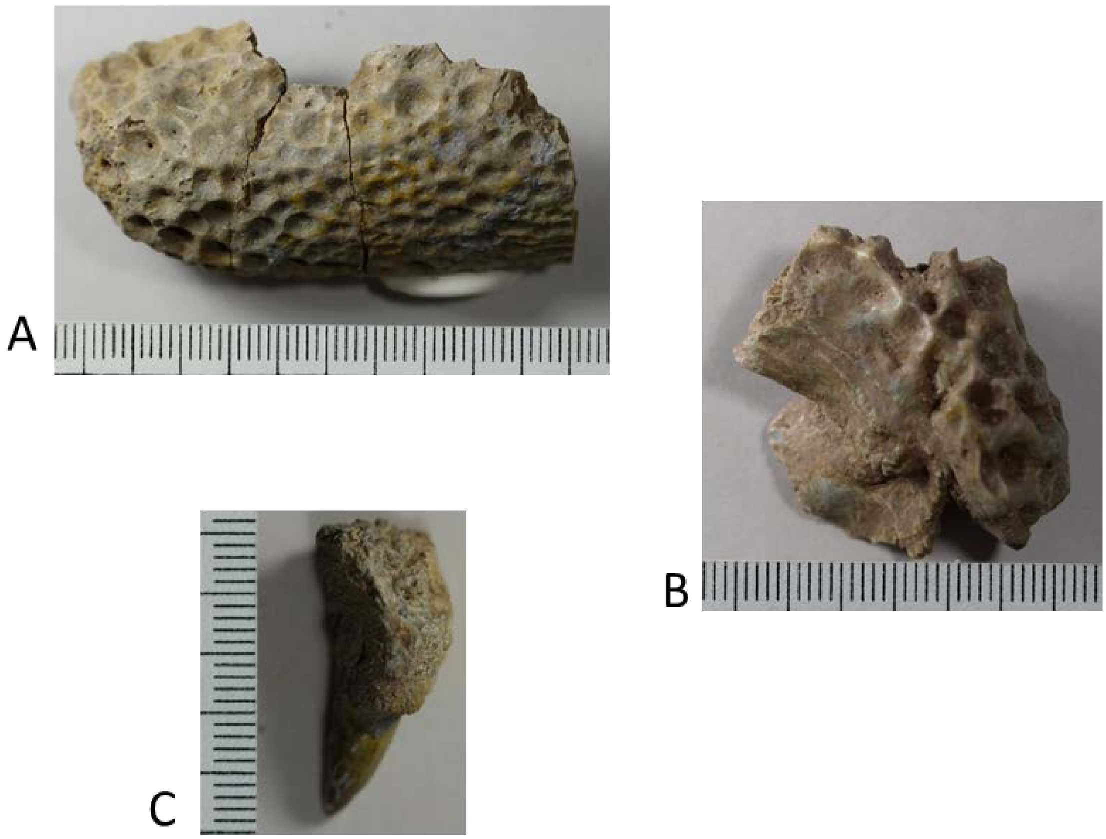

Figure 17. Various temnospondyl elements. Scale is in mm. A) Fragment of squamosal. B) Posterior skull fragment C) Palatal tusk.

Figure 18. Various embolomere centra. Scale is in mm.

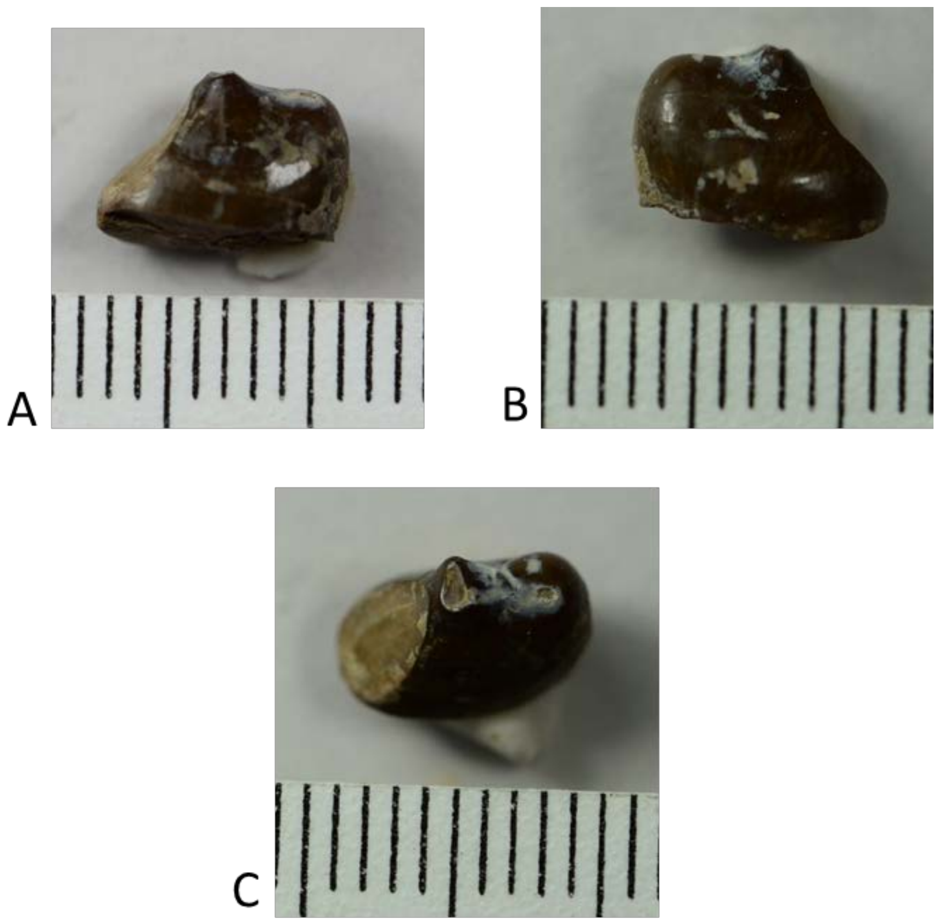

Figure 19. A diadectid(?) tooth. Scale is in mm. A) Side view B) Opposite side view C) Crown view. Note the roundness of the crown.

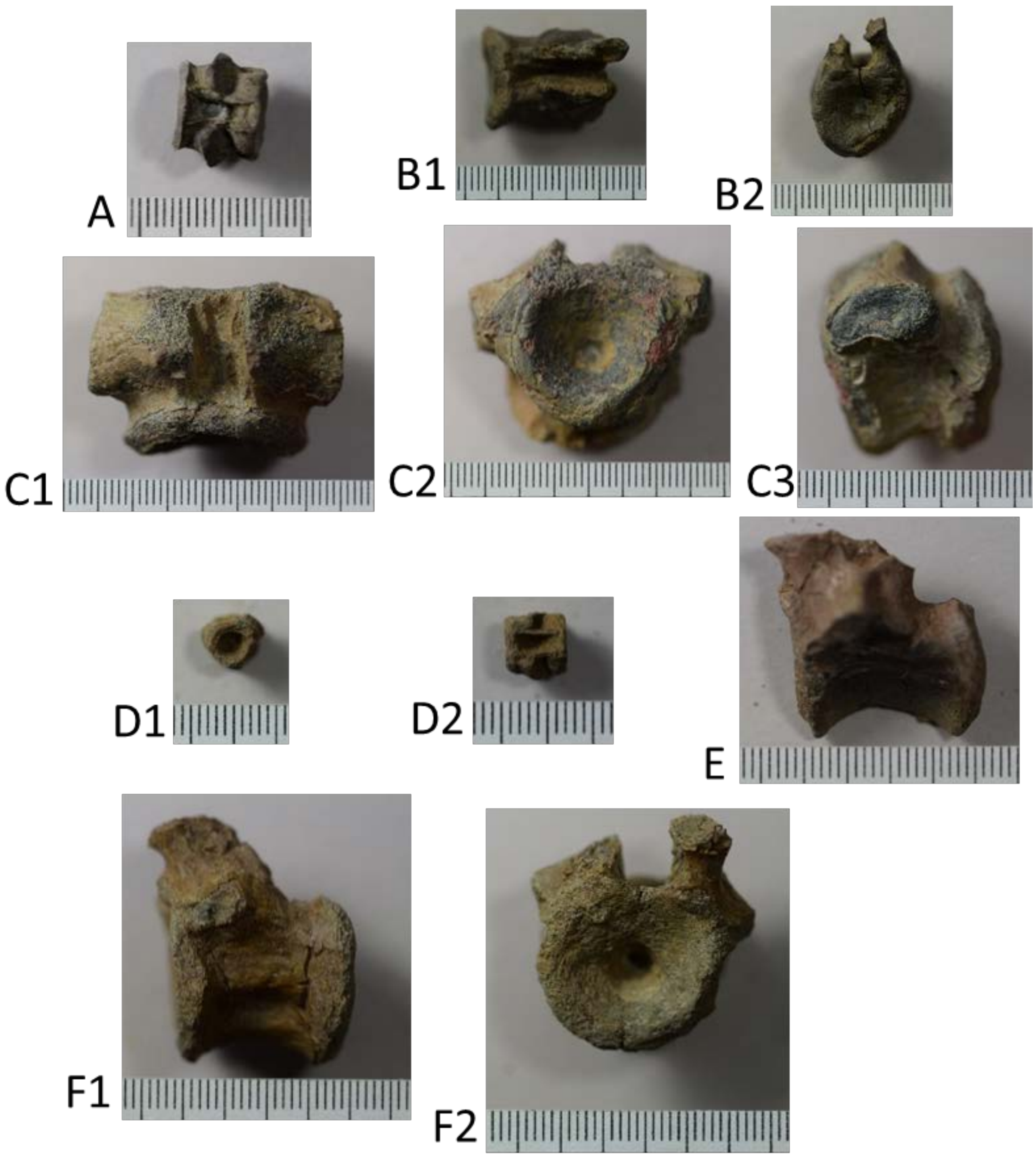

Figure 20. Various amniote centra. Scale is in mm.

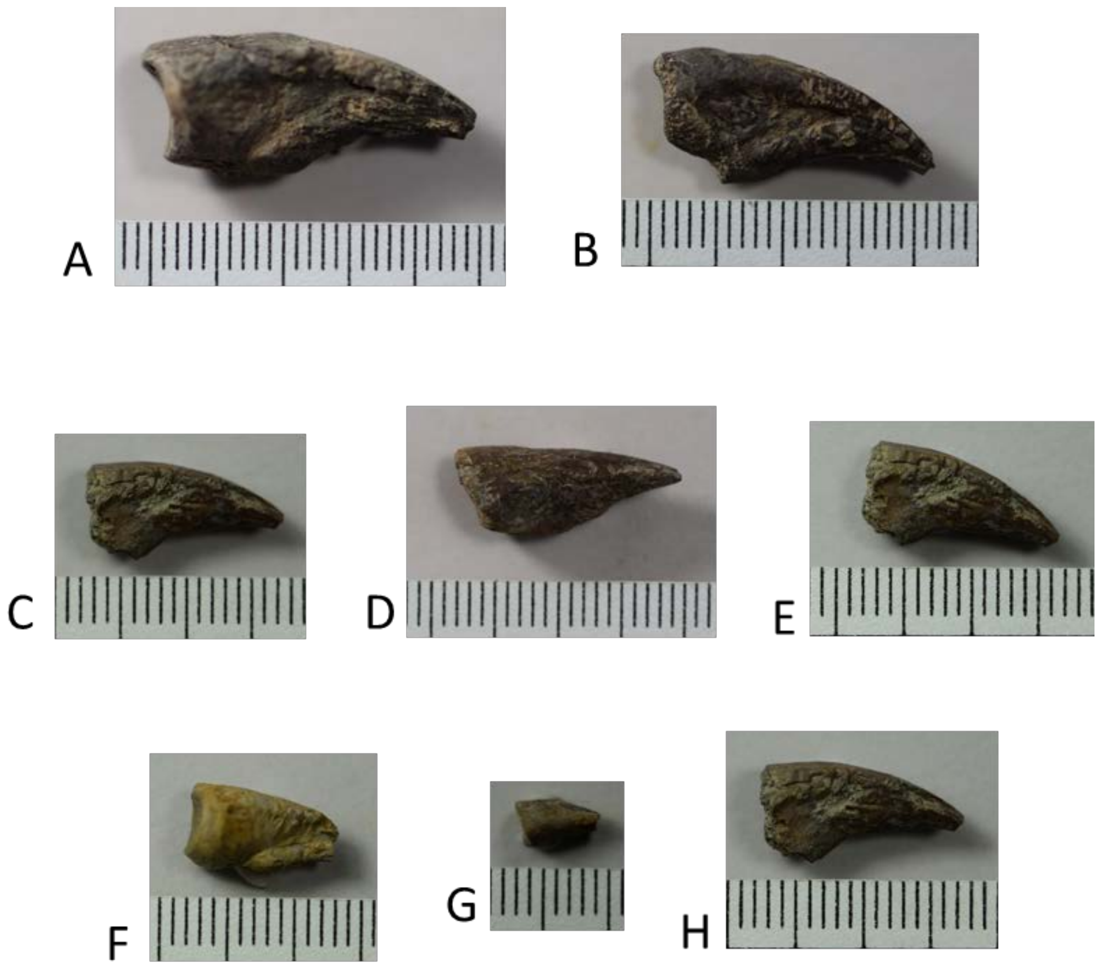

Figure 21. Synapsid (claw-bearing) terminal phalanges. Scale is in mm.

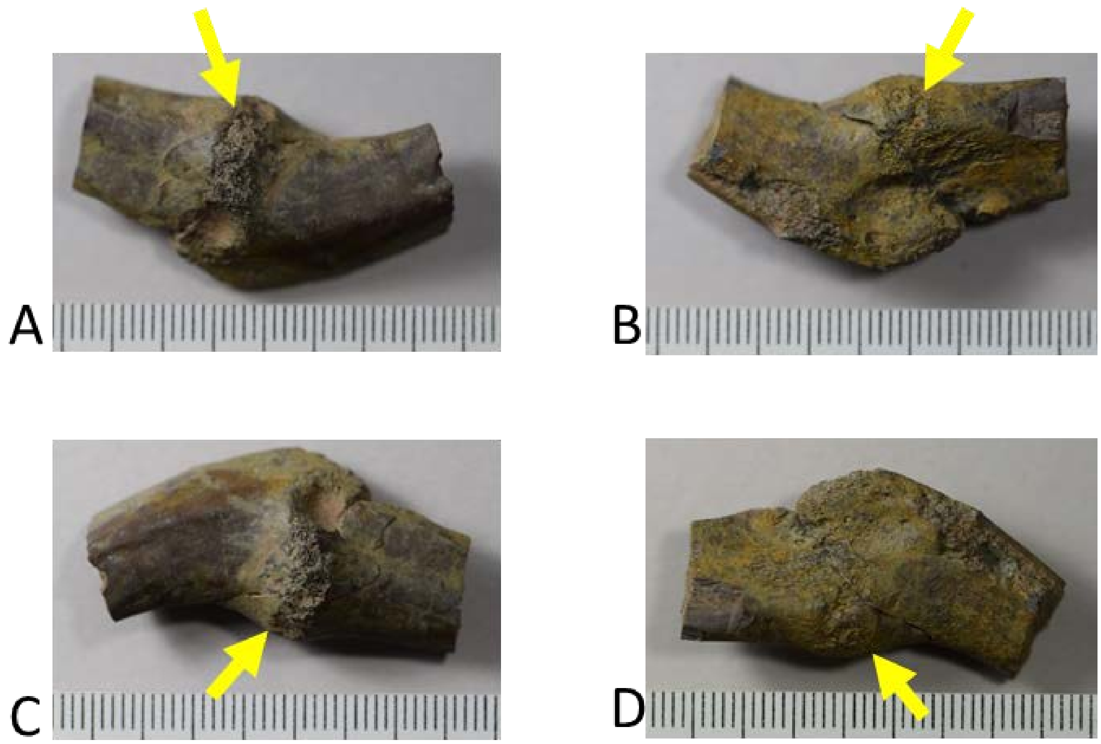

Figure 22. An amniote limb bone which fractured and healed. Callous is marked with a yellow arrow. Scale is in mm.

Figure 23. Various unidentified phalanges. Scale is in mm.

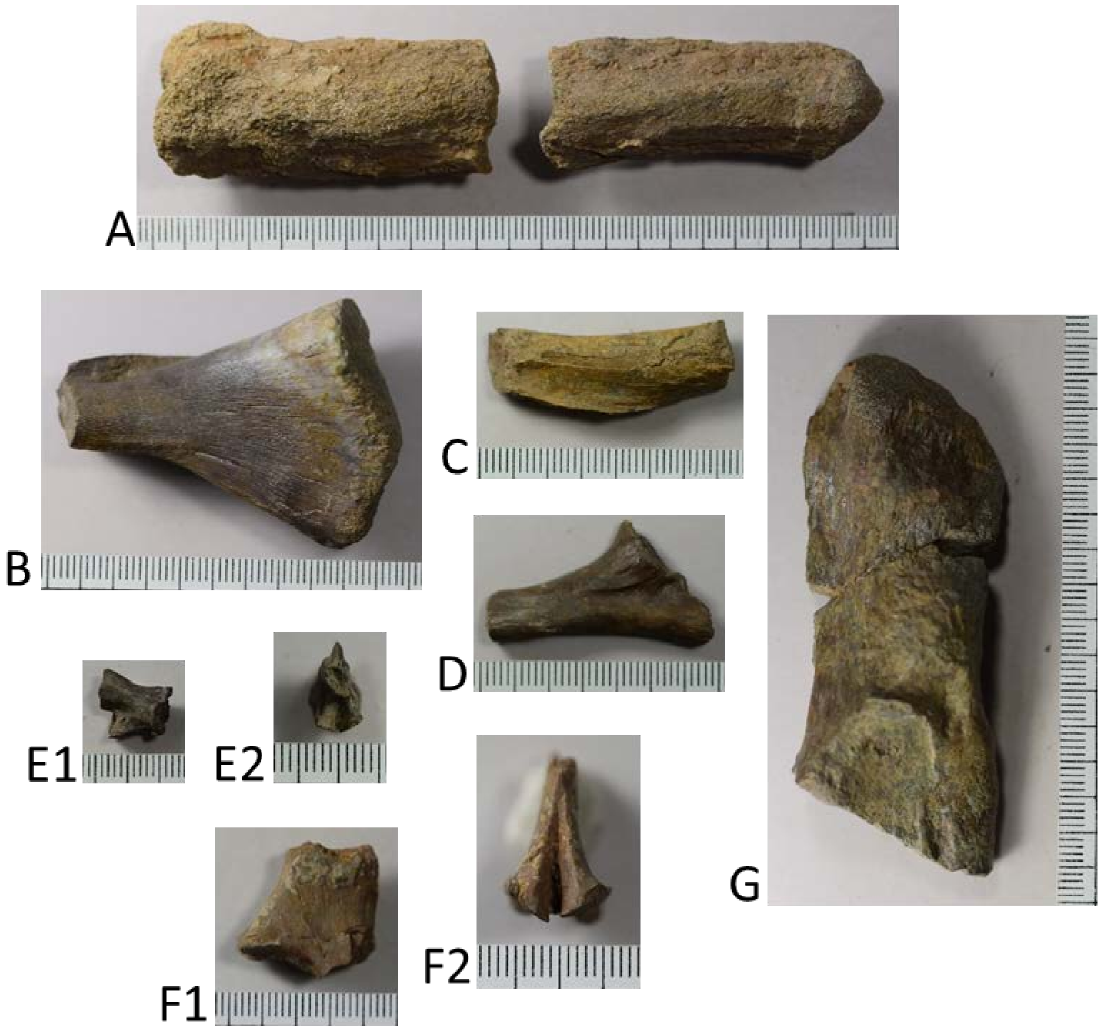

Figure 24. Various fossil fragments which have been identified to element, but not taxon. Scale is in mm. A) limb bone B) humerus C & D) rib fragments E & F) neural spines in side (1) and posterior (2) views G) shoulder girdle

Figure 25. Paleogeographic map of the contiguous United States during the late Carboniferous. The approximate location of the three localities is marked with a red dot. Modified from Blakey (2011).

References

Aber, J.S., and S.W. Aber, 2016. Personal communication. <jaber@emporia.edu>

Aber, S.W., A. Peterson, N. Peterson, & P. Johnston, 2014. Upper Pennsylvanian Vertebrate Fossil Display from the Snyderville Shale, Greenwood County, Kansas. *Transactions of the Kansas Academy of Science* 117:1-2, p.1.

Aber, S.W., N. Peterson, W.J. May, P. Johnston, & J.S. Aber, 2014. First Report of Vertebrate Fossils in the Snyderville Shale (Oread Formation; Upper Pennsylvanian), Greenwood County. *Transactions of the Kansas Academy of Science* 117:3-4, pp. 193-202.

Algeo, T.J., L. Schwark, & J.C. Hower, 2004. High-Resolution Geochemistry and Sequence Stratigraphy of the Hushpuckney Shale (Swope Formation; Eastern Kansas): Implications for Climato-Environmental Dynamics of the Late Pennsylvanian Midcontinent Seaway. *Chemical Geology* 204(3-4), pp. 259-288.

Baxter, & Hartman, 1954. The Coal-age Flora of Kansas—V. A Fossil Coniferophyte Wood. *Phytomorphology*, p. 316-325.

Beck, K.G., R. Soler-Gijón, J.R. Carlucci, & R.E. Willis, 2016. Morphology and histology of dorsal spines of the xenacanthid shark *Orthacanthus platypternus* from the Lower Permian of Texas, USA: palaeobiological and palaeoenvironmental implications. *Acta Palaeontologica Polonica* 61:1, p. 97–117.

Benton, M.J., 2015. *Vertebrate Paleontology, 4th ed*. Wiley Blackwell, Sussex, UK.

Blakey, R., 2011. Paleogeography and Geologic Evolution of North America. <http://jan.ucc.nau. edu/~rcb7/nam.html> Accessed 12 April 2016.

Brainard, R.H. 1978. Scolecodonts from the Leavenworth limestone and Snyderville shale of eastern Kansas. *Transactions of the Kansas Academy of Science*, 8:2, p. 134.

Bridge, T.E., 1988. Geology and Stratigraphy of the Hamilton Quarry Area. In: *Guidebook Series 6: Regional Geology and Paleontology of Upper Paleozoic Hamilton Quarry Area in Southeastern Kansas*, G. Mapes and R. Mapes, editors, Kansas Geological Survey, p. 27-35.

Bruemmer, M.R., 2003. *Three-Dimensional Cyclo-Stratigraphic Architecture of Nonmarine and Marine Mixed Siliciclastic and Carbonate Oread Cyclothem (Upper Pennsylvanian), SE Kansas and NE Oklahoma.* Wichita State University, 338 pp.

Bryan, M.R., 1999. *Sequence Stratigraphy of the Shawnee Group (Virgilian, Pennsylvanian) in Southeastern Kansas*. Oklahoma State University, 183 pp.

Burchett, R.R., 1983. Surface to Subsurface Correlation of Pennsylvanian and Lower Permian Rocks Across Southern Nebraska. *Nebraska Geological Survey Report of Investigations* 8, 24 pp.

Busch, R.M., M.A. Bogina, & M.H. Clark, 1988. Preliminary Report on the Genetic Stratigraphy of the Hamilton, Kansas, Fossil Localities—Deer Creek Fifth-order T-R Unit. In: *Guidebook Series 6: Regional Geology and Paleontology of Upper Paleozoic Hamilton Quarry Area in Southeastern Kansas*, G. Mapes and R. Mapes, editors, Kansas Geological Survey, p. 59-66.

Canoville, A. & M. Laurin, 2010. Evolution of Humeral Microanatomy and Lifestyle in Amniotes, and Some Comments on Palaeobiological Inferences. *Biological Journal of the Linnean Society* 100, p. 384-406.

Carpenter, D., H.J. Falcon-Lang, M.J. Benton, & W.J. Nelson, 2011. Fishes and Tetrapods in the Upper Pennsylvanian (Kasimovian) Cohn Coal Member of the Mattoon Formation of Illinois, United States: Systematics, Paleoecology, and Paleoenvironments. *Palaios* 26:10, p. 639-657.

Condra, G.E. and Reed, E.C., 1937. Correlation of the Members of the Shawnee Group in Southeastern Nebraska and Adjacent Areas of Iowa, Missouri and Kansas. *Nebraska Geological Survey Bulletin* 11, 64 pp.

Condra, G.E. and Reed, E.C., 1943. The Geological Section of Nebraska. *Nebraska Geological Survey Bulletin* 14, 83 pp.

Condra, G.E., 1927. The Stratigraphy of the Pennsylvanian System in Nebraska. *Nebraska Geological Survey Bulletin* I, Second Series, 291 pp.

Condra, G.E., 1935. Geologic Cross-Section, Forest City, Missouri to Du Bois, Nebraska. *Nebraska Geological Survey Bulletin* 8, 23 pp.

Condra, G.E., 1949. The nomenclature, type localities and correlation of the Pennsylvanian subdivisions in eastern Nebraska and adjacent States. *Nebraska Geological Survey Bulletin* 16, 65 pp.

Cunningham, C.R., H.R. Feldman, E.K. Franseen, R.A. Gastaldo, G. Mapes, C.G. Maples, & H.-P. Schultze, 1993. The Upper Carboniferous Hamilton Fossil-Lagerstätte in Kansas: a Valley-fill, Tidally Influenced Deposit. *Lethaia* 26:3, p. 225-236.

Daly, E., 1988. A Note on the Dissorophoid Amphibian of Hamilton Quarry. In: *Guidebook Series 6: Regional Geology and Paleontology of Upper Paleozoic Hamilton Quarry Area in Southeastern Kansas*, G. Mapes and R. Mapes, editors, Kansas Geological Survey, p. 185-187.

deBraga, M. and R. Reisz, 1995. A New Diapsid Reptile from the Uppermost Carboniferous (Stephanian) of Kansas. *Paleontology* 38:1, pp. 199-212.

DiMichele, W.A., C.B. Cecil, I.P. Montañez, & H.J. Falcon-Lang, 2010. Cyclic Changes in Pennsylvanian Paleoclimate and Effects on Floristic Dynamics in Tropical Pangaea. *International Journal of Coal Geology* 83:2-3, pp. 329-344.

Elias, M.K., 1964. Depth of the Late Paleozoic Sea in Kansas and its Megacyclic Sedimentation. *Kansas Geologic Survey Bulletin* 169, pp. 87-106.

Feldman, H.R., A.W. Archer, & R.M. Joeckel, 1995. Virgilian (Upper Pennsylvanian) Paleosols in the Upper Lawrence Formation (Douglas Group) and its Snyderville Shale Member (Oread Formation, Shawnee Group) of the Northern Midcontinent, USA; Pedologic Contrasts in a Cyclothem Sequence; Discussion and Reply. *Journal of Sedimentary Research* 65:4a, pp. 712-718.

Foreman, B.C., and L.D. Martin, 1988. Paleozoic Tetrapod Localities. In: *Guidebook Series 6: Regional Geology and Paleontology of Upper Paleozoic Hamilton Quarry Area in Southeastern Kansas*, G. Mapes and R. Mapes, editors, Kansas Geological Survey, p. 133-145.

French. J.A., W.L. Watney, & J.E. Anderson, 1988. Stratigraphic and Sedimentologic Considerations Relating to the Fossiliferous Limestones (Upper Pennsylvanian?) at Hamilton Quarry, Greenwood County, Kansas. In: *Guidebook Series 6:*

Regional Geology and Paleontology of Upper Paleozoic Hamilton Quarry Area in Southeastern Kansas, G. Mapes and R. Mapes, editors, Kansas Geological Survey, p. 37-58.

Hanley, K.D., 2001. High Resolution Correlation of the Shawnee Group (Virgilian, Pennsylvanian) Cyclothems from Northwestern Missouri to Exposures in Southern Kansas and Northern Oklahoma. *State University of New York at Albany Master's Thesis*, 219 pp.

Henning, M.L. and J.P. Pope, 2007. Paleontology of the Upper Snyderville Shale Member of the Oread Formation, Shawnee Group, Virgilian Stage I-229, Andrew County, Missouri. *Abstracts with Programs – Geological Society of America* 39:3, p. 56.

Jewett, J.M., H.G. O'Connor, & D.E. Zeller, 1968. The Stratigraphic Succession in Kansas. *Kansas Geological Survey Bulletin* 189. <http://www.kgs.ku.edu/ Publications/ Bulletins/189/ index.html> Accessed 13 July 2015.

Joeckel, R.M., 1994. Virgilian (Upper Pennsylvanian) Paleosols in the Upper Lawrence Formation (Douglas Group) and its Snyderville Shale Member (Oread Formation, Shawnee Group) of the Northern Midcontinent, USA; Pedologic Contrasts in a Cyclothem Sequence. *Journal of Sedimentary Research* 64:4, pp. 853-866.

Joeckel, R.M., 1995a. Tectonic and Paleoclimatic Significanceof a Prominent Upper Pennsylvanian (Virgilian/Stephanian) Weathering Profile, Iowa and Nebraska, USA. *Palaeogeography, Palaeoclimatology, Palaeoecology* 118, pp. 159-179.

Joeckel, R.M., 1995b. Virgilian (Upper Pennsylvanian) Paleosols in the Upper Lawrence Formation (Douglas Group) and its Snyderville Shale Member (Oread Formation, Shawnee Group) of the Northern Midcontinent, USA; Pedologic Contrasts in a Cyclothem Sequence – Reply. *Journal of Sedimentary Research* 65:4, p. 714.

Johnson, W. and W.L. Adkinson, 1967. Deposition of Upper Pennsylvanian Strata. <http://www. kgs.ku.edu/General/Geology/Shawnee/E/05_dep.html> Accessed 21 September 2014.

Johnson, W.D. and W.L. Adkinson, W.L., 1967. Geology of Shawnee County, Kansas. *Geological Survey Bulletin* 1215, 96 pp.

Kaesler, R.L., 1988. Ostracoda from the Hamilton Quarry. In: *Guidebook Series 6: Regional Geology and Paleontology of Upper Paleozoic Hamilton Quarry Area in Southeastern Kansas*, G. Mapes and R. Mapes, editors, Kansas Geological Survey, p. 109-111.

Kansas Data Access and Support Center, 2016. Census TIGER/Line Data, Kansas Counties Shapefile. <http://www.kansasgis.org/catalog/index.cfm?data_id=1444&show_cat=1?data_id=1444&show_cat=1?data_id=1444&show_cat=1?data_id=1444&show_cat=1?data_id=1444&show_cat=1?data_id=1444&show_cat=1?data_id=1444&show_cat=1?data_id=1444&show_cat=1> Accessed 30 March 2016.

Kansas Geological Survey, 1960. Stratigraphy of Outcropping Rocks. <http://www.kgs.ku.edu/General/Geology/Douglas/strat05.html> Accessed 30 November 2014.

Keroher, G.C., 1966. Lexicon of Geologic Names of the United States for 1936-1960. *Geological Survey Bulletin* 1200:2, 2886 pp.

Kissel, R.A., & R.R. Reisz, 2011. From Meat to Beet: Phylogeny and Evolution of Diadectomorpha (Tetrapoda: Cotylosauria). < https://gsa.confex.com/gsa/ 2011NE/finalprogram/abstract_184727.htm> Accessed 13 April 2016.

Kues, B.S., 1988. Observations on the Late Pennsylvanian Eurypterids of the Hamilton Quarries, Kansas. In: *Guidebook Series 6: Regional Geology and Paleontology of Upper Paleozoic Hamilton Quarry Area in Southeastern Kansas*, G. Mapes and R. Mapes, editors, Kansas Geological Survey, p. 95-104.

Laurin, M. & J.-S. Steyer, 2000. Phylogenies and Apomorphies of Temnospondyls. Accessed from < http://tolweb.org/accessory/Phylogeny_and_Apomorphies _of_Temnospondyls ?acc_id=582> 18 March 2016.

Leisman, G.A., W.H. Gillespie, & G. Mapes, 1988. Plant Megafossils from the Hartford Limestone (Virgilian-Upper Pennsylvanian) near Hamilton, Kansas. In: *Guidebook Series 6: Regional Geology and Paleontology of Upper Paleozoic Hamilton Quarry Area in Southeastern Kansas*, G. Mapes and R. Mapes, editors, Kansas Geological Survey, p. 203-212.

Mapes, R.H., & C.G. Maples, 1988a. “Marine” Macroinvertebrates, Hamilton Quarry, Kansas. In: *Guidebook Series 6: Regional Geology and Paleontology of Upper Paleozoic Hamilton Quarry Area in Southeastern Kansas*, G. Mapes and R. Mapes, editors, Kansas Geological Survey, p. 67-75.

Maples, C.G., & R.H. Mapes, 1988b. A Preliminary Note on *Anthraconaia* sp. from the Hamilton Quarries (Pennsylvanian: Virgilian), Kansas. In: *Guidebook Series 6: Regional Geology and Paleontology of Upper Paleozoic Hamilton Quarry Area* *in Southeastern Kansas*, G. Mapes and R. Mapes, editors, Kansas Geological Survey, p. 89-93.

Mazierski, D.M. & R.R. Reisz, 2010. Description of a new specimen of *Ianthasaurus hardestiorum* (Eupelycosauria: Edaphosauridae) and a Re-evaluation of Edaphosaurid Phylogeny. *Canadian Journal of Earth Science* 47, p. 901-912.

Merriam, D.F., 1999, Geologic Map, Greenwood County, Kansas: Kansas Geological Survey, Map M-50. <http://www.kgs.ku.edu/General/Geology/County/ghj/greenwood.html> Accessed 13 November 2015.

Moore, R.C., 1949. Divisions of the Pennsylvanian System in Kansas. *Kansas Geological Survey Bulletin* 83. <http://www.kgs.ku.edu/Publications/Bulletins/83/index.html> Accessed July 13 2015.

Moore, R.C., 1964. Paleoecological Aspects of Kansas Pennsylvanian and Permian Cyclothems. *Kanasas Geological Survey Bulletin* 169, pp. 287-380.

Morales, M, 2014. First Report on the Discovery of Vertebrate Fossis in the Snyderville (Shale) Member of the Oread (Limestone) Formation (Upper Pennsylvanian, Virgilian) Near Toronto, Kansas. *Transactions of the Kansas Academy of Science* 117:1-2, p. 131.

Newell, D., 2015. Personal Communication. <dnewell@kgs.ku.edu>

O'Connor, H.G., 1960. Geology and Ground-Water Resources of Douglas County, Kansas. *Kansas Geological Survey Bulletin* 148. <http://www.kgs.ku.edu/General/ Geology/Douglas/ index.html> Accessed 13 July 2015.

Palaeos, 2010. Taxon Index A-Z. <http://palaeos.com/vertebrates/ taxa/taxlist.html> Accessed 18 March 2016.

Peabody, F.E., 1958. An Embolomerous Amphibian in the Garnett Fauna (Pennsylvanian) of Kansas. *Journal of Paleontology* 32:3, p. 571-573.

Pope, J.P., 2006. *Three Groups of Unusual Microfossils in the Pennsylvanian and Permian.* Proquest Information and Learning Company, 97 pp.

Pope, J.P., 2012. Description of Pennsylvanian Units, Revision of Stratigraphic Nomenclature, and Reclassification of the Morrowan, Atokan, Desmoinesian, Missourian, and Virgilian Stages in Iowa. *Iowa Geological and Water Survey Special Report Series* 5, 140 pp.

Reisz, R., 2015. Personal Communication. <robert.reisz@utoronto.ca>

Reisz, R., and J. Fröbisch, 2014. The Oldest Caseid Synapsid from the Late Pennsylvanian of Kansas, and the Evolution of Herbivory in Terrestrial Vertebrates. *PLoS ONE* 9:4, e94518. doi:10.1371/journal.pone.0094518

Reisz, R., M. Heaton, & B. Pynn, 1982. Vertebrate Fauna of Late Pennsylvanian Rock Lake Shale near Garnett, Kansas: Pelycosauria. *Journal of Paleontology*, 56:3, pp. 741-750.

Reisz, R.R., 1988. Two Small Reptiles from a Late Pennsylvanian Quarry near Hamilton, Kansas. In: *Guidebook Series 6: Regional Geology and Paleontology of Upper Paleozoic Hamilton Quarry Area in Southeastern Kansas*, G. Mapes and R. Mapes, editors, Kansas Geological Survey, p. 189-194.

Reisz, R.R., M.J. Heaton, & B.R. Pynn, 1982. Vertebrate Fauna of Late Pennsylvanian Rock Lake Shale near Garnett, Kansas: Pelycosauria. *Journal of Paleontology* 56:3, p. 741-750.

Salley, S., M. Morales, & R. Sleezer, 2005. Surficial Geology of the Hamilton Quarry Area, Greenwood County, Kansas. *KGS Open File Report* 2005-13, 16 pp.

Sanders, D.T., 1959. Sandstones of the Douglas and Pedee Groups in Northeastern Kansas. *Kansas Geological Survey Bulletin* 134:3, 27 pp.

Schultze, H.-P. & J. Chorn, 1997. The Permo-Carboniferous Genus *Sagenodus* and the Beginning of Modern Lungfish. *Contributions to Zoology* 67:1, p. 9-70.

Schultze, H.-P., & J. Chorn, 1988. The Upper Pennsylvanian Vertebrate Fauna of Hamilton, Kansas. In: *Guidebook Series 6: Regional Geology and Paleontology of Upper Paleozoic Hamilton Quarry Area in Southeastern Kansas*, G. Mapes and R. Mapes, editors, Kansas Geological Survey, p. 147-154.

Schultze, H.-P., 1995. Terrestrial Biota in Coastal Marine Deposits: Fossil-Lagerstätten in the Pennsylvanian of Kansas, USA. *Palaeogeography, Palaeoclimatology, Palaeoecology* 119, p. 255-273.

Sleezer, R., 2015. Personal Communication. <rsleezer@emporia.edu>

Thompson, T.L., 2001. Lexicon of Stratigraphic Nomenclature in Missouri. *Missouri Department of Natural Resources, Division of Geology and Land Survey, Report of Investigation* 73, 371 pp.

Toomey, D.F., 1964. Lateral Continuity in a “Middle Limestone Member” (Leavenworth) of a Kansas Pennsylvanian Cyclothem. *Rice University dissertation*, 239 pp.

Troell, A.R., 1965. *Sedimentary Facies of the Toronto Limeston, Lower Limestone Member of the Oread Megacyclothem (Virgilian) of Kansas*, 213 pp.

Turner, M., W. Yang, & C. Burke, 2003. Paleosols in the Regressive Snyderville Shale Interval of the Toronto Limestone - Snyderville Shale Minor Cyclothem, Greenwood County, Eastern Kansas. *Sedimentology and Stratigraphic Architecture of Upper Pennsylvanian Oread Cyclothem in Shelf-to-Delta Transition Zone, SE Kansas and NE Oklahoma*, pp. 12-13.

Turner, M., W. Yang, & M. Bruemmer, 2002. Micro-Variability of Floodplain Paleosols in the Snyderville Shale Member, Oread Limestone Formation (Upper Pennsylvanian), Southeast Kansas. *Poster Presentation from the Geologic Society of America Annual Meeting*.

Turner-Williams, M., 2003. Characteristics, Type, Distribution, and Controlling Factors of Paleosols and their Implications on Paleoclimatic Conditions, Cyclic Sedimentation, and Stratigraphic Correlation, Oread Cyclothem (Upper Pennsylvanian), SE Kansas and NE Oklahoma. *AAPG Search and Discovery* 90018.

United States Geological Survey, 1969. *7.5-Minute Topographic Map of the Toronto Quadrangle*.

United States Geological Survey, 2014. Geolex – Unit Summary; Geologic Unit: Snyderville. <http://ngmdb.usgs.gov/Geolex/Units/Snyderville_10323.html> Accessed 16 December 2014.

Von Bitter, P.H., 1972. Environmental Control of Conodont Distribution in the Shawnee Group (Upper Pennsylvanian) of Eastern Kansas. *The University of Kansas Paleontological Contributions* 59, 105 pp.

Wikimedia Commons, 2016. Pictures of extinct taxa. <https://commons.wikimedia.org/ wiki/ Main_Page> Accessed 8 April 2016.

Wilmarth, M.G., 1938. Lexicon of Geologic Names of the United States (including Alaska): M-Z. *Geological Survey Bulletin* 896, 2396 pp.

Wilson, D., 1959. Geologic Names of North America. *Geological Survey Bulletin* 1056. 622 pp.

Yang, W., 2006. Transgressive Wave Ravinement on an Epicontinental Shelf as Recorded by an Upper Pennsylvanian Soil-Nodule Conglomerate-Sandstone Unit, Kansas and Oklahoma. *Sedimentary Geology* 197:3-4, p. 189- 205.

Zeller, D.E., ed. [1968] 2013. Classification of Rocks in Kansas, revised by Kansas Geological Survey Stratigraphic Nomenclature Committee. *Kansas Geological Survey Bulletin* 189.

Zidek, J, 1976. Kansas Hamilton Quarry (Upper Pennsylvanian) *Acanthodes*, With Remarks on the Previously Reported North American Occurrences of the Genus. *University of Kansas Paleontological Contributions*, paper 83, 48 pp.

Zidek, J., 1988. Hamilton Quarry (Kansas, Late Pennsylvanian) Chondrichthyes. In: *Guidebook Series 6: Regional Geology and Paleontology of Upper Paleozoic Hamilton Quarry Area in Southeastern Kansas*, G. Mapes and R. Mapes, editors, Kansas Geological Survey, p. 167-172.