Conodont Fauna of the Excello Shale (Middle Pennsylvanian), Midcontinent North America

by

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ABSTRACT

The Excello Shale member is the laterally extensive core shale of the Lower Fort Scott major cyclothem of the Desmoinesian Marmaton Group in the Midcontinent Basin of the central United States. It is the first major cyclothem of the group and lies above the Mulky Coal, which marks the transition between the Cherokee and Marmaton groups. The Excello Shale member can generally be divided into a lower black shale facies and an upper gray shale facies. Phosphate laminations as well as phosphate nodules occur through the lower black shale, as well as rare acrotretid brachiopods. Three sections of the Excello Shale member in a south to north transect were sampled in small stratigraphic intervals (5-10 cm) and small samples (200 g) of the shale were completely processed in bleach to obtain an accurate census of conodont genera and species. Rare abundance data was converted to approximate numbers of conodont individuals.

Idiognathodus elements were divided into three species, *I. acutus, I.* species 2 and *I.* sp. 3. *Neognathodus* comprises four species, *N. dilatus, N. roundyi, N*. sp. 3 and *N*. sp. 4. *Gondolella* was separated into two species, *G. wardlawi* and the much rarer *G*. sp. 2.The Excello conodont fauna is significantly different than the more diverse conodont fauna of the highest major Cherokee cyclothem, the Verdigris. The Excello fauna resembles more closely the younger Marmaton conodont faunas, such as the Lost Branch fauna at the top of the Marmaton Group.

The distribution of conodont genera in the Excello Shale member is compatible with the Midcontinent conodont biofacies model. The species provide some additional biofacies information, with differences in proportions of *Idiognathodus* and *Neognathodus* species occurring across the offshore to onshore transect. However, these species-level biofacies changes are not seen in the vertical succession of lithofacies in any one section. This may because the geographic spacing of sections provides greater ecological separation than can be resolved in the condensed vertical lithofacies section of the cyclothem.

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CHAPTER I

INTRODUCTION

The Pennsylvanian Midcontinent Basin is located in the central United States and extends from eastern Oklahoma to central Iowa (Figure 1). It is an area that is home to some of the best examples of Late Paleozoic cyclic deposition termed cyclothems (Figure 2). These are laterally extensive episodes of cyclic marine-nonmarine deposition over a relatively short period of time (50,000 to 400,000 years) resulting from glacio-eustatic rise and fall of sea level (Heckel, 1989). The Excello Shale is a thinly bedded, laterally extensive, black shale that lies at the base of the late Desmoinesian Marmaton Group (Figure 3; Pope, 2012). It is the transgressive core shale of the Lower Fort Scott major cyclothem of the Fort Scott Limestone and has been traced in the subsurface across the Midcontinent Basin. The lithostratigraphy of the Excello Shale is well known, but its conodont faunas are poorly understood.

Desmoinesian conodont faunas have not been extensively studied taxonomically and sampling has been relatively poor in the Midcontinent area, generally at the level of a few samples from the core shale of each cyclothem (e.g., Heckel, 1994). The only detailed systematic study of Desmoinesian conodonts is the work of Stamm and Wardlaw (2003) on the slightly older Verdigris cyclothem at the top of the underlying Cherokee Group. Although a general model of Pennsylvanian conodont biofacies has been proposed for the Midcontinent region (e.g., Heckel and Baesemann, 1975), more data is required to understand how conodonts interacted with the environment as inferred from geochemical studies (e.g., Hermann et al., 2015).

The primary objectives of this study are to sample in detail and fully describe the conodont fauna of the Excello Shale at both the genus and species levels. The information collected from this study will provide a useful framework for comparing conodonts with geochemical data and lithological data from other Pennsylvanian core shales. This research will permit better interpretation of conodont species distributions relative to the mode of deposition as well as to paleoceanographic conditions during deposition of Pennsylvanian cyclothems.

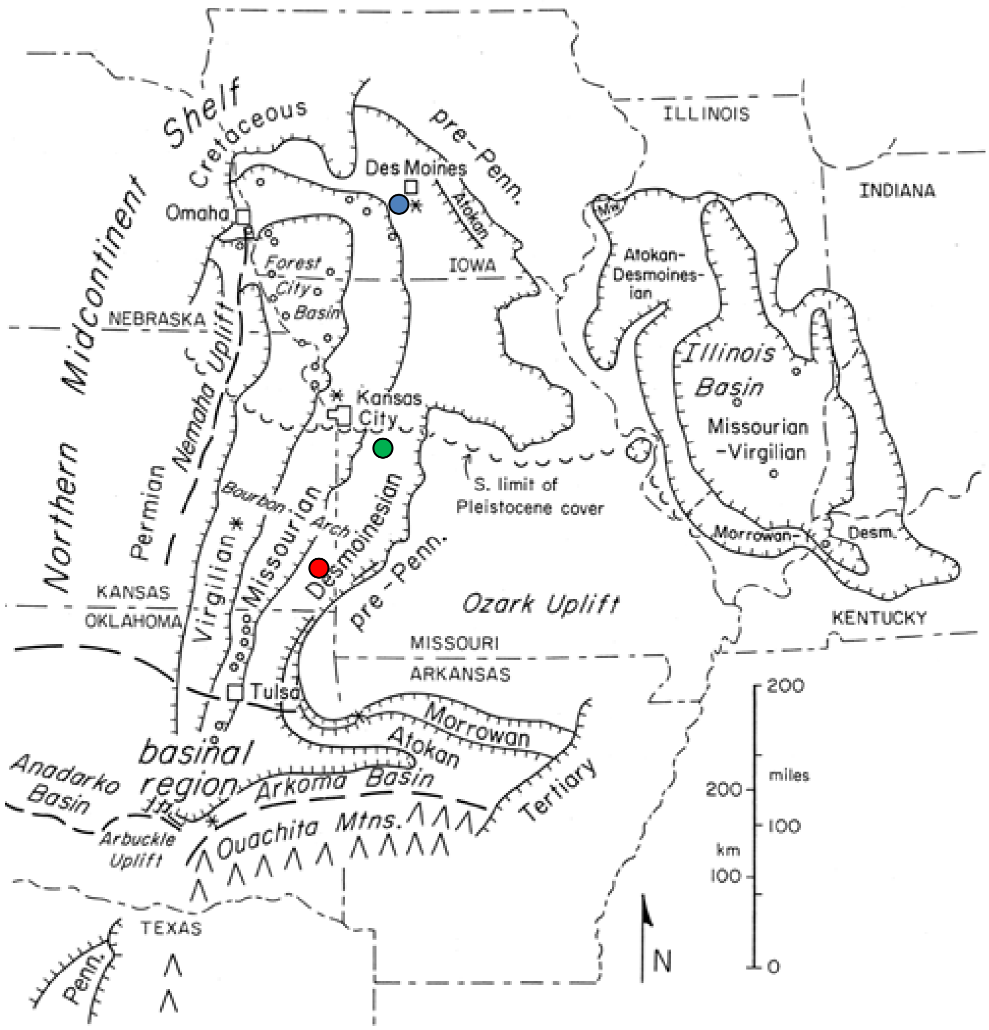

Figure 1: Map of Study Area. The Midcontinent Basin displaying the location of sample sections (Blue= Booneville, Green= Norris Creek, Red= Kansas Highway 69 road cut). (Map modified from Heckel, 2013)

Geologic Setting

The Pennsylvanian Period was a time when North America and most of Europe were suturing with Gondwana during the Alleghenian-Ouachita orogeny and the interior of North America was largely flooded by the Midcontinent Sea. The suturing of these land masses lead to the formation of the northern portion "Protopangea," a supercontinent (Heckel, 2013). It was bounded by Ouachita-

Alleghenian orogens on the south and east, the Laurentian craton to the north, and the Ancestral Rocky Mountains to the west (Herrmann et al., 2015).

At sea-level highstand the North American Midcontinent Sea covered the majority of North America from the Appalachian basin to the Ancestral Rocky Mountains during middle to late Pennsylvanian times (Heckel, 2013).The sea covered an area nearly $2.6x10^6 km^2$ and at glacial highstand was the location of widespread organic-rich black shale deposition (Algeo et al., 2008). At sea-level lowstand, many surfaces display various signs of subaerial exposure such as paleosols, terrestrial clastic material, and coals. This suggests that much of the Midcontinent and other shelf regions were subaerially exposed (Heckel, 2013). At the southwestern region of the Midcontinent, parts of the Arkoma-Anadarko basin and Midland basin along the Ouachita trend remained submerged continually (Wright, 2011; Soreghan et al., 2012).

The basic cyclothem lithofacies model starts with a transgressive limestone at its base, commonly a thin marine skeletal calcilutite. Above lies an offshore (core) shale, usually a thin, non-sandy, grey to black phosphatic shale with occasional phosphatic nodules. The core shale is overlain by a regressive limestone of marine calcilutite that grades upwards to skeletal calcarenite with abraded grains, algae, and crossbedding. Capping the cyclothem is a nearshore (outside) shale composed of thick sparsely fossiliferous prodeltic to nonmarine shales that are sometimes overlain by coal at sequence horizons (Heckel, 1994). Each rock member represents a phase of deposition within the transgressive-regressive cycle, which suggests correspondence with a glacial-eustatic sea level rise and fall (Heckel, 2013).

Three orders of magnitude have been recognized by Heckel (2002, 2013) in the Northern Midcontinent Basin to characterize cyclothems: major, intermediate, and minor. Major cyclothems consist of an extensive black phosphatic shale unit that is conodont rich and extends across the entire shelf and into the basin. These are generally bounded by transgressive and regressive limestone units and are named after the limestone that composes the majority of the unit. Sedimentation cycles range from 235,000 to 400,000 thousand years (Heckel, 1994). These cyclothems are estimated to occur with a sea-level change of 100 m according to Heckel (2008) based on oxygen isotope data from skeletal calcite and apatite (Joachimski et al., 2006), measurement of eustatic range, and oxygen circulation.

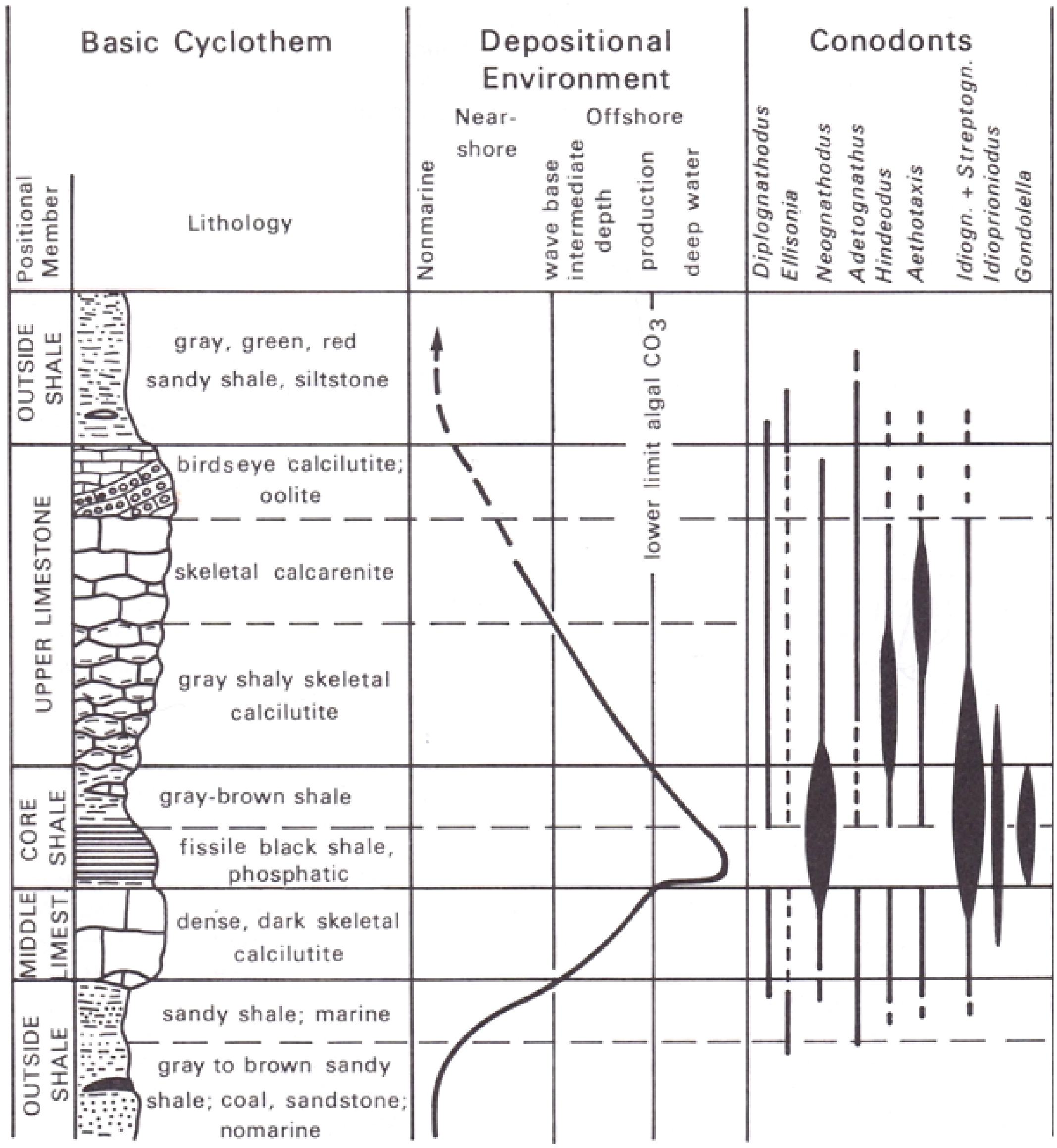

Figure 2: Basic northern Midcontinent cyclothem succession. Cycle displays lithology, conodont distribution, and environment. (Heckel 1977, modified by Sweet, 1988)

Midcontinent Desmoinesian Stratigraphy

The Desmoinesian Stage was named by Keyes (1893) after the Des Moines formation observed from outcrops along the Des Moines River in Iowa and is composed of repetitive shales, coals, limestones, and sandstones. It may be traced through the northern portion of the Midcontinent Basin. It is roughly 180-225 m thick in Kansas and thins northwards into Iowa. Desmoinesian strata thicken southward to 2000 m in the Arkoma Basin, where they are composed almost entirely of shale and sandstone (Heckel, 2013).The Desmoinesian is subdivided informally into three groups, the Cherokee, Marmaton, and lower Bronson. The Cherokee Group comprises the lower Desmoinesian. It is composed of a shale-dominated, coal-bearing multitude of cyclothems with locally prominent sandstone beds. The Cherokee is about 750 m thick in northeastern Oklahoma and thins northward. It is roughly 120 m thick in southeastern Kansas and nearly doubles in thickness northward (Heckel, 2013). The uppermost Cherokee contains the Verdigris, Bevier, and Breezy Hill cyclothems (Heckel, 2002).

The Marmaton Group lies above the Cherokee Group and comprises most of the upper Desmoinesian. The Marmaton consists of limestone-dominated major cyclothems that are divided by locally thick black shales (Heckel, 2013). Within the Marmaton are a total of 11 formations and nine corresponding major and intermediate cyclothems that may be traced throughout the basin. These are the Lower and Upper Fort Scott, Higginsville, Pawnee, Coal City, Farlington, Altamont, Norfleet, and the Lost Branch cyclothems (Heckel, 2002). The Marmaton is about 150 m in thickness in northeastern Oklahoma and extends north to east-central Kansas where it is roughly 75 m thick. It continually thins northward to roughly 42 m thick near Iowa (Heckel, 2013). The Bronson Group contains the Pleasanton Formation at the uppermost Desmoinesian and overlaps into the Missourian Stage.

The Lower Fort Scott major cyclothem is located at the base of the Marmaton group and extends across the Midcontinent Basin and into the Illinois Basin. It extends from the base of the Mulky Coal to the base of the Summit Coal **(**Figure 3**)** and contains the offshore (core) shale, the Excello Shale Member (Heckel, 2013) and corresponds to the Mouse Creek Formation in Iowa nomenclature (Pope, 2012). The Excello is one of the most wide-ranging and best exposed of the cyclothemic black shales (Ece, 1987). It was deposited across the north-central region of the basin and has laterally been traced across the majority of the Midcontinent from southeast Kansas to central Iowa (Heckel, 2013). The study by Ece (1987) noted that there were two lithofacies in the Excello that could be readily recognized, a dark black shale that is bounded both above and below by a yellow brown shale. He also observed that phosphate nodules were common in the black shale.

Global Stage	Stage	Group	Formation	Member
Moscovian	Desmoinesian	Marmaton	Labette Shale	Mystic Coal
				Marshall Coal
			Stephens Forest	Higginsville Limestone
				Black Water Creek Shale
				Unnamed Coal
				Houx Limestone
				Little Osage Shale
				Clanton Creek Limestone
			Morgan School Shale	Summit Coal
			Mouse Creek	Black Jack Creek Limestone
				Excello Shale
				Unnamed Limestone
		Cherokee	Swede Hollow	Mulky Coal

Figure 3: Middle Desmoinesian Stratigraphic column. Units of the upper Cherokee to the lower Marmaton group, modified from Pope (2012).

Conodonts

Conodonts were small marine animals that may have been chordates with a body that resembles an eel (Donoghue et al., 2000). Each conodont was equipped with a set of apatite tooth-like elements that were used for feeding. The exact function and nature of the food source is tentative (Hermann et al., 2015). These elements are abundant, very characteristic, and highly resistant to alteration and because of rapid evolution of some elements, useful for biostratigraphic zonation.

The most widely accepted model of Pennsylvanian cyclothems relates conodont biofacies distribution **(**Figure 4**)** with water column stratification, changes in water depth, and distance from the shoreface (Heckel and Baesemann, 1975; Swade, 1985; Heckel, 1989). *Idiognathodus and Neognathodus* have been interpreted to occupy normal, open-marine, warm surface-water that was ever present in areas that were far away from fresh water sources. *Idioprioniodus* likely occupied the cooler portion of water just above the thermocline and is the reason it is mostly found in offshore shale. *Gondolella* typically lived in the deep, cold, somewhat dysaerobic thermoclinal water and its occurrence in black shale suggests it was likely pelagic (Hermann et al., 2015). *Adetognathus* and *Ellisonia* often inhabited nearshore waters with variable salinity and other conditions. These genera are not typically found in offshore black shale and as such are interpreted to be nektobenthic (Heckel, 2003). *Hindeodus* may have lived in slightly more distal waters associated with carbonate sediment (Heckel, 1989).Some difficulties in the application of this model to all cyclothems (e.g., Herrmann et al., 2015) have yet to be resolved. It is difficult to distinguish depth stratification and lateral distribution of onshore-offshore pelagic and nektobenthic taxa based on distributional patterns alone according to Klapper and Barrick (1978). It has been determined that the conodont distributions also have similarities in distribution with other marine fossils (Boardman et al., 1984).

Recently conodont biostratigraphic zonations have been summarized and new zonations suggested by Barrick et al. (2013) for the Desmoinesian Stage in the Midcontinent. The Atokan-Desmoinesian stage interval is still under study and the zonation is provisional. The conodont zones may be seen in Figure 5. The Desmoinesian Stage contains four zones of *Neognathodus* and five zones of idiognathodids (Barrick et al., 2013). The Excello Shale Member of the Lower Fort

Scott cyclothem lies in the lower part of the *Neognathodus roundyi* Zone and at the base of the *Idiognathodus delicatus* Zone.

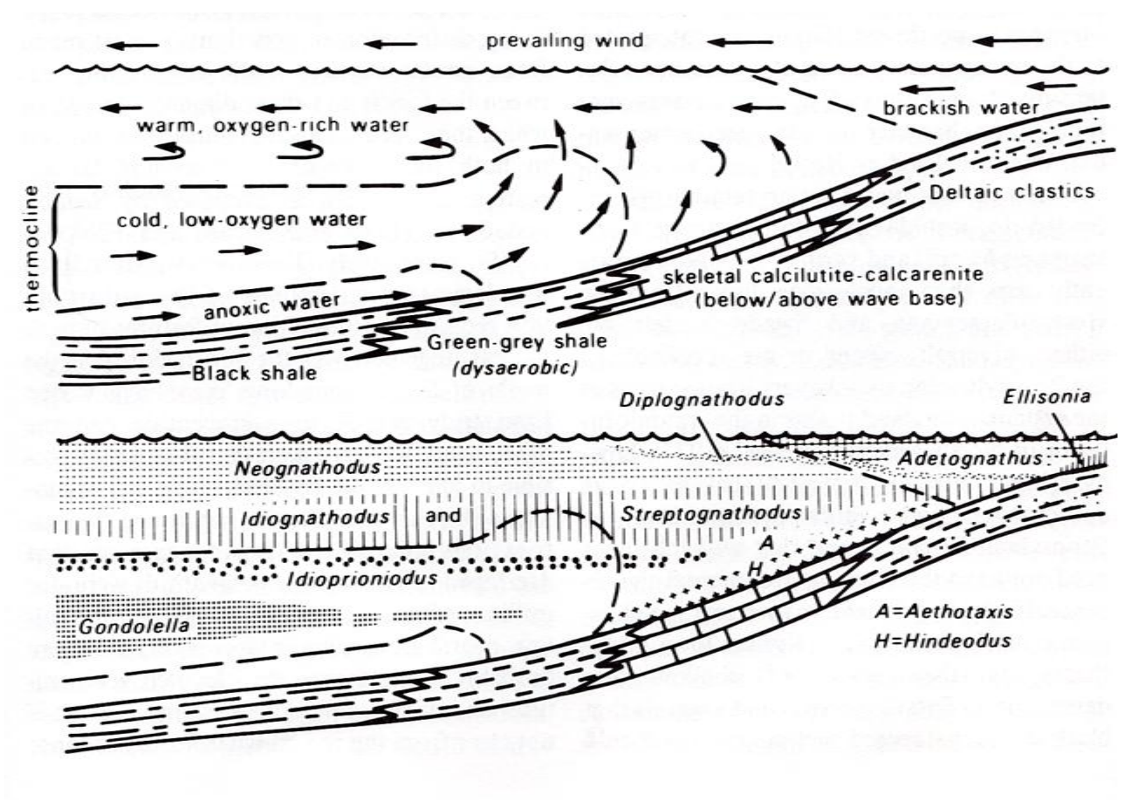

Figure 4: Pennsylvanian conodont biofacies model. (Sweet, 1988; slightly modified from Swade, 1985).

<table>
<tr><th>STAGE</th><th>NEOGNATHODUS</th><th>IDIOGNATHODIDS</th><th colspan="2">CYCLOTHEM</th></tr>
<tr><td rowspan="5">DESMOINESIAN</td><td rowspan="3">N. roundyi
(sensu lato)</td><td>Sw. nodocarinatus</td><td rowspan="3">MARMATON GROUP</td><td>LOST BRANCH
Norfleet</td></tr>
<tr><td>Sw. neoshoensis</td><td>ALTAMONT
Farlington</td></tr>
<tr><td>I. delicatus</td><td>Coal City
PAWNEE
U. FORT SCOTT
L. FORT SCOTT</td></tr>
<tr><td>N. asymmetricus</td><td>I. rectus/
I. iowaensis</td><td rowspan="2">CHEROKEE GROUP</td><td>Bevier
VERDIGRIS
Fleming
Russell Creek
UPPER TIAWAH
Wainwright</td></tr>
<tr><td>N. caudatus</td><td>I. amplificus/
I. obliquus</td><td>INOLA
DONELEY
Sam Creek
McCURTAIN</td></tr>
</table>

Figure 5: Desmoinesian conodont zones. Conodont zones are relative to major and intermediate cyclothems (Barrick et al., 2013).

CHAPTER II

MATERIALS

Stratigraphic Section

Three measured sections of the Excello Shale member were used in the assessment and characterization of the conodont fauna. The sections stretch from southeastern Kansas into central Iowa, from south to north (Figure 1). Detailed descriptions of the sections are in Appendix A. The Excello Shale rests directly on the underlying Mulky Coal member at all three outcrops.

Kansas Highway 69 Section

The Kansas Highway 69 (KS69) exposure is located along US Highway 69 north of Arma, in southeastern Kansas (37º 37.19'N; 94º42.26'W). The Excello Shale interval is 100 cm thick (Figures 6 and 7). This section is composed of black to dark gray shale that is mostly fissile, thin papery to platy at the base and middle (0-90 cm) and transitions to a non-fissile blocky gray shale near the top (90-100 cm). Acrotretids are present at the base of the section and there are uncommon phosphate nodules near the base that grow more abundant in the upper middle of the black shale. A few very large limestone concretions (up to 0.5 m) occur near the base of the shale. The Blackjack Creek Limestone caps the shale section.

Norris Creek Section

The Norris Creek section (NC) is a natural stream exposure and the neostratotype of the Excello Shale Member, east of Blairstown, Missouri, southeast of Kansas City (38º33.85'N; 93º54.86'W; Gentile and Thompson, 2004). The section lies about 105 miles north of KS-69 and is 130 cm thick (Figure 8). This section is composed of very dark black shale near its base that gradually becomes lighter gray in the middle (0-75 cm) and grades into a medium dark to light olive gray shale near the top (75-130 cm). The shale is mostly fissile papery to platy at its base and transitions to a more difficult to split non-fissile platy to blocky shale near the middle. Acrotretids are abundant at the base and found less commonly up to the middle shale. Plant macerals are abundant in the lower to the middle dark shale. Phosphate sand laminations appear near the base and become most abundant in the lower middle part of the section. Phosphate nodules occur near the base to the middle of the lower black shale with just a few near the base of the upper gray shale and are most abundant in the middle of the lower dark shale. Small to medium (<0.2 m) limestone nodules are present from the base to the middle of the lower black shale. Limestone lenses occur in the very top of the shale below the Blackjack Creek Limestone bed.

Booneville Section

The Booneville section (BV) crops out in a natural hillside exposure just southwest of Des Moines, Iowa (41º31.60'N; 93º52.83'W; Nestell, et al., 2012). The section lies roughly 175 miles north of the Norris Creek section and is 1.25 m (125 cm) thick (Figure 9). The Booneville section starts as a brownish black to gray shale near the base and as it approaches the middle shale (0-45 cm) it transitions to a gray shale (45-125 cm) that is medium gray to light olive gray and in the upper middle section it becomes a yellowish gray shale toward the top. It is weakly fissile at the base of the black shale and non-fissile in hand samples in the remaining thickness. It is mostly blocky with some thin platy layers. Thin limestone lenses occur in the lower 10 to 30 cm. Phosphate sand laminations are abundant at the base and middle of the shale with phosphate nodules occurring in the middle shale. The upper shale is fossiliferous.

Comparison of Sections

The three sample sections represent a transect along the Midcontinent Basin from more offshore in the south (KS69) to more onshore in the north (Booneville). The Kansas Highway 69 section is the thinnest and southernmost of the three sections in this study. This section is consistently dark throughout its facies and nearly lacks the lighter grey and yellow shale facies that are present in upper parts of the other sections. There is only a very thin layer of the gray shale in the uppermost 10 cm of the section. Acrotretids were observed only in the lowermost sample. Acrotretids were observed in Norris Creek section in far greater abundance in the lower and middle section but none were seen in the Booneville section. Small phosphate nodules roughly 5 mm in diameter occur in the lower middle Kansas Highway 69 section and increase in size to 2 cm as the upper middle shale, but no nodules were observed above 70 cm. Phosphate nodules occur in a similar manner in the Norris Creek and Booneville sections, but are confined to the middle part of the latter section. The Norris Creek and the Booneville sections have common phosphate sand laminations, but these are sparse in the Kansas Highway 69 section. Large limestone concentrations (up to 0.5 m) occur near the base of the Kansas Highway 69 section, but only smaller ones (<0.2 m) are present at the Norris Creek and Booneville sections.

The Norris Creek Section is the thickest of the three sections. Plant macerals are common in the Norris Creek section near the base and more abundant in the middle shale, whereas neither the Kansas Highway 69 section nor the Booneville section had observable plant macerals. The Booneville is the northernmost section. Unlike the Kansas Highway 69 and Norris Creek sections, which are capped by the Blackjack Creek Limestone, the Booneville section does not have a limestone bed at the top, only thin limestone lenses in brown shale. Nestell et al. (2012) described abundant and well-preserved radiolarian faunas from thin limestone nodule near the base of the Booneville section. In contrast, the larger limestone nodules in the Norris Creek and Kansas Highway 69 sections have not produced radiolarian faunas.

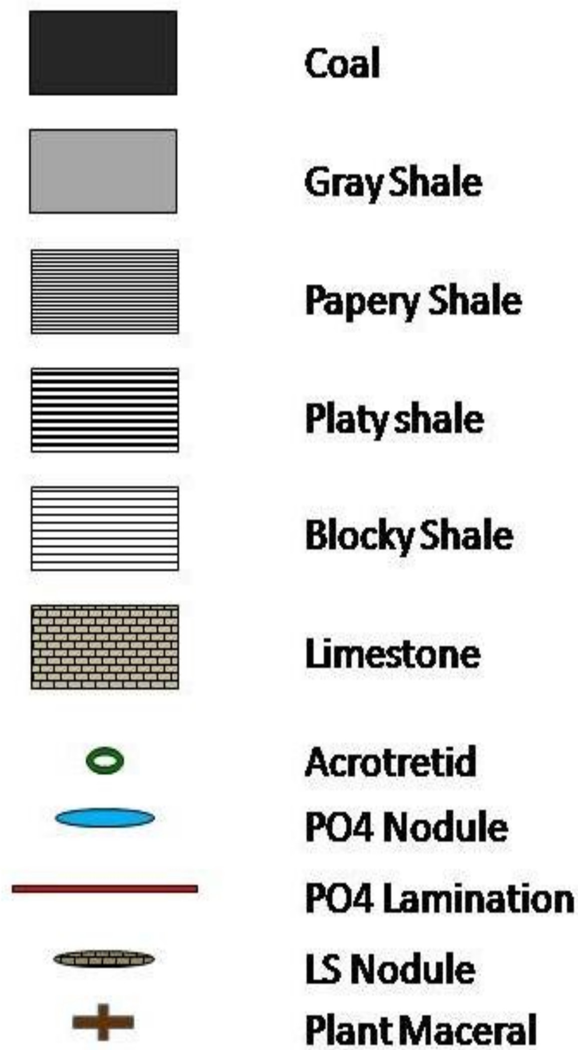

Figure 6: Lithologic symbols for measured stratigraphic sections.

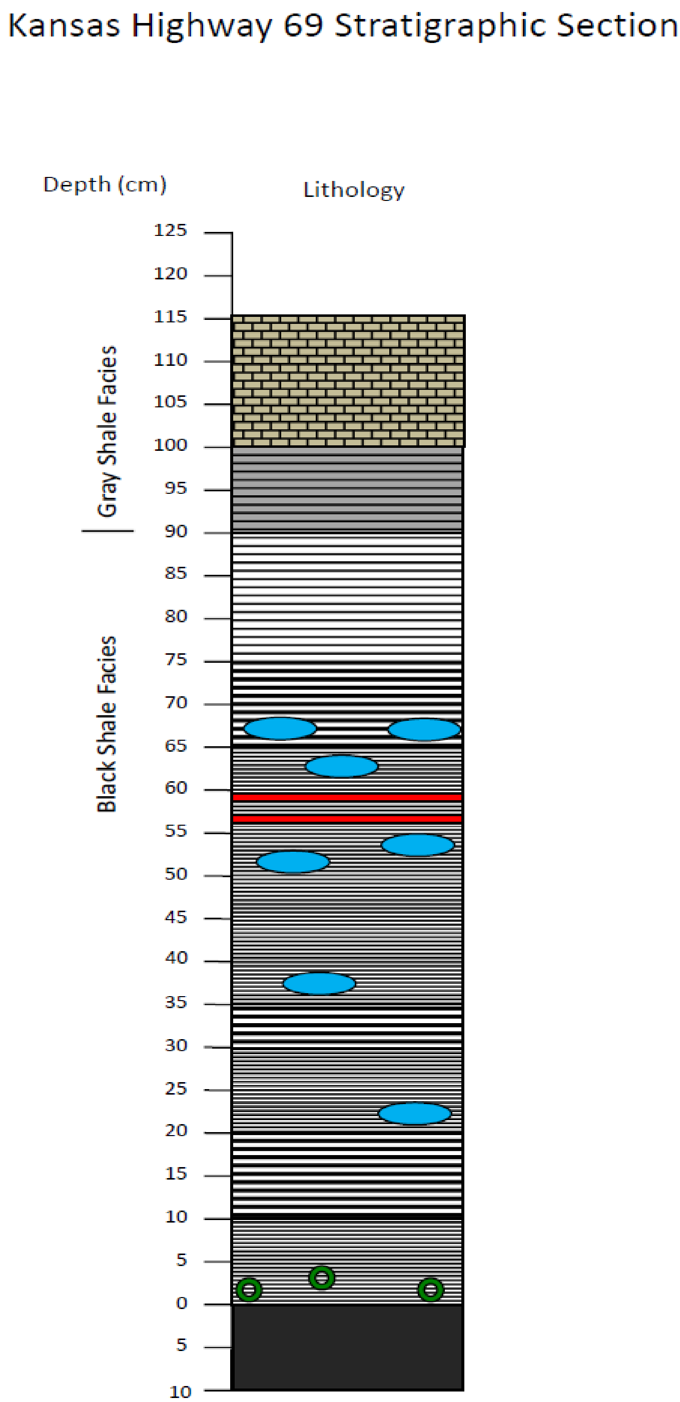

Figure 7: Measured section of the Kansas Highway 69 locality. It is located in southeastern Kansas (37º 37.19'N; 94º42.26'W). Explanation of lithology symbols can be found in Figure 6.

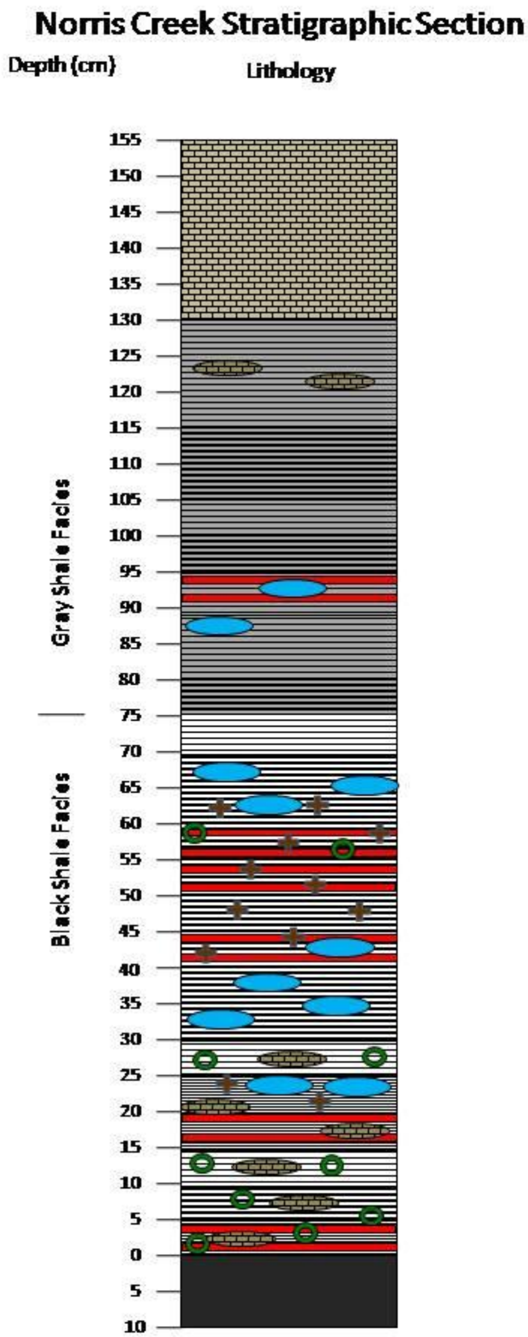

Figure 8: Measured section of the Norris Creek locality. It is located in western Missouri (38º33.85'N; 93º54.86'W; Gentile and Thompson, 2004). Explanation of lithology symbols can be found in Figure 6.

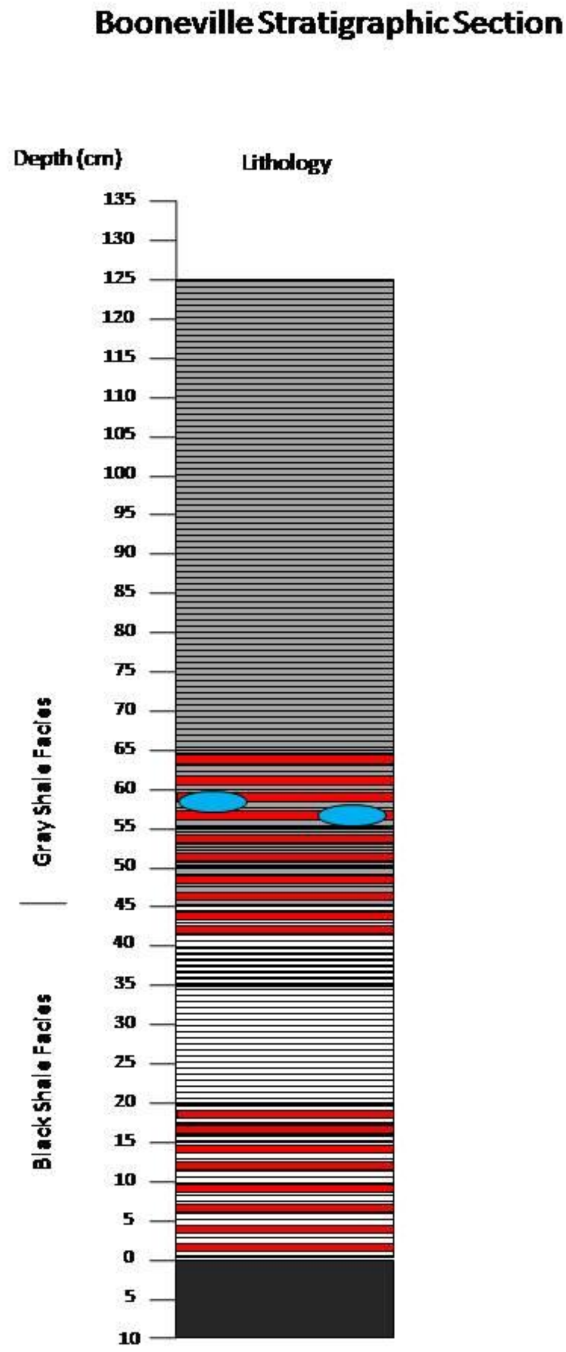

Figure 9: Measured section of the Booneville locality. It is located in central Iowa (41º31.60'N; 93º52.83'W; Nestell et al., 2012). Explanation of lithology symbols can be found in Figure 6.

Methods

The black shale and overlying gray portion of the Excello Shale member were sampled at 5-10 cm intervals and the overlying Blackjack Creek Limestone at 10 cm intervals. The size of the samples processed was limited to amounts that could be completely processed in a reasonable time. This way, actual counts of conodonts per unit weight could be determined, rather than estimating numbers from partially processed samples. When too few conodonts were recovered, usually fewer than 100 elements, additional rock was processed. For black shale samples, 200 g of shale were immersed in a solution of 6% sodium hypochlorite (bleach) to destroy organics. The bleach was replaced and samples washed monthly until organics were completely destroyed. The residue was further disaggregated by drying, immersion in kerosene and then hot water, and washing. For gray and brown shale samples, 500-g samples of shale were processed using only the kerosene process. For limestone samples, 1000-g samples were dissolved in a buffered formic acid solution (Jeppson and Anehus, 1995). Residues were collected on a 120-mesh (125 micron) sieve. Most samples yielded small residues, but larger ones were separated using heavy liquids. The conodont elements analyzed in this study have low conodont color alteration index values (CAI of 1 to 1.5) and are otherwise well preserved.

The distribution of conodont taxa is reported first at the generic level. Many small specimens cannot be identified to the species level, so this provides a better determination of total and relative abundances. Species diversity is low in the Excello Shale and each genus either comprises a single species according to Nestell et al. (2016), or comprises just a small number, two to four, according to this study. Conodont abundances are reported standardized to a 1000-g sample weight. Because the apparatus of each conodont animal contained two P_1 (platform) elements (Purnell and Donoghue, 1997; 1998), the raw abundances of P_1 elements are comparable for most genera. Ramiform elements were too poorly preserved, broken or winnowed out, to be included. The P_1 elements of *Idioprioniodus* are difficult to distinguish from other elements in the ramiform-dominated apparatus, and the total number of elements was counted for this genus. To make the abundances of all taxa comparable and to approximate the number of individual animals represented in a sample, the raw count of P_1 elements was divided by two for genera other than *Idioprioniodus*, and the raw count of all elements of *Idioprioniodus* was divided by 15 (i.e., the total number of elements per conodont apparatus). All results rounded up to the nearest whole number (Appendix B).

The P_1 elements of *Idiognathodus*, *Neognathodus*, and *Gonodolella* were separated into species (See Systematics). The numbers of P_1 elements assigned to each species are without reduction to individuals, for all these species each had 2 P_1 elements per individual (Appendix C). No adjustments were made for sample size. Not all P_1 elements could be assigned to species because they were either too small, or broken in a way that the species could be identified. For this reason the numbers shown in tabulations of the genera do not always sum up to the numbers of individuals of species.

CHAPTER III

DISTRIBUTION OF GENERA IN THE EXCELLO SHALE

Several genera of conodonts occur in the Excello Shale. From most abundant to least abundant overall, they are *Idiognathodus, Neognathodus, Gondolella, Idioprioniodus, Hindeodus, and Adetognathus.* Due to their high abundance, widespread distribution, and taxonomic significance *Idiognathodus, Neognathodus, and Gondolella* were examined at both the generic and species levels (Appendix B and C). *Idiognathodus* has a carminiscaphate P_1element with a relatively flat upper surface that is lobate near its ventral platform and bears transverse ridges on the dorsal platform. *Neognathodus* has a carminiscaphate P_1 element with a high central carina extending the length of the upper platform. G*ondolella* P_1elements are segminiplanate with an elongate platform that may or may not have crenulations on its margins with a central ridge extending its length and a ventral cusp. The *Idioprioniodus* apparatus comprises a series of large ramiforms with a large cusp; the P elements are difficult to distinguish from other elements. *Hindeodus* has a simple carminate (blade-like) P_1 element. *Adetognathus* has an asymmetrical P_1 element in which the blade attaches to margin, as opposed to medially.

Kansas Highway 69 Section

Total abundance of calculated conodont individuals (Figures 10 and 11) varies from less than 100/kg near the base of the lower black shale of the Excello Shale member, increases to about 200/kg at 15 cm (sample 13), then spikes at almost 800/kg at 30 cm (sample 16), before rapidly declining to less than 200/kg at 45 cm (sample 19). In the middle part of the black and going into the upper black shale, abundance rises to above 400/kg at 60 cm (sample 22), and near the top to a maximum of 1400/kg at 90cm (sample 28) in the gray shale, before falling to less than 100/kg at 95 cm (samples 29 and 30). *Idiognathodus* is the most abundant genus through most of section and strongly dominates the fauna in the upper part of the shale. *Gondolella* is largely restricted to just a few samples from 30 cm (sample 16) to 40 cm (sample 18), where it becomes more abundant than *Idiognathodus* and dominates the lower peak in abundance. *Idioprioniodus* occurs throughout the section, but in low numbers. It is slightly more abundant in the lower black shale interval than in the upper gray shale. *Neognathodus* is also present throughout the section, but is less common during the *Gondolella* peak. It is more common in the upper black and gray shale. *Hindeodus* and *Adetognathus* are not present in this section.

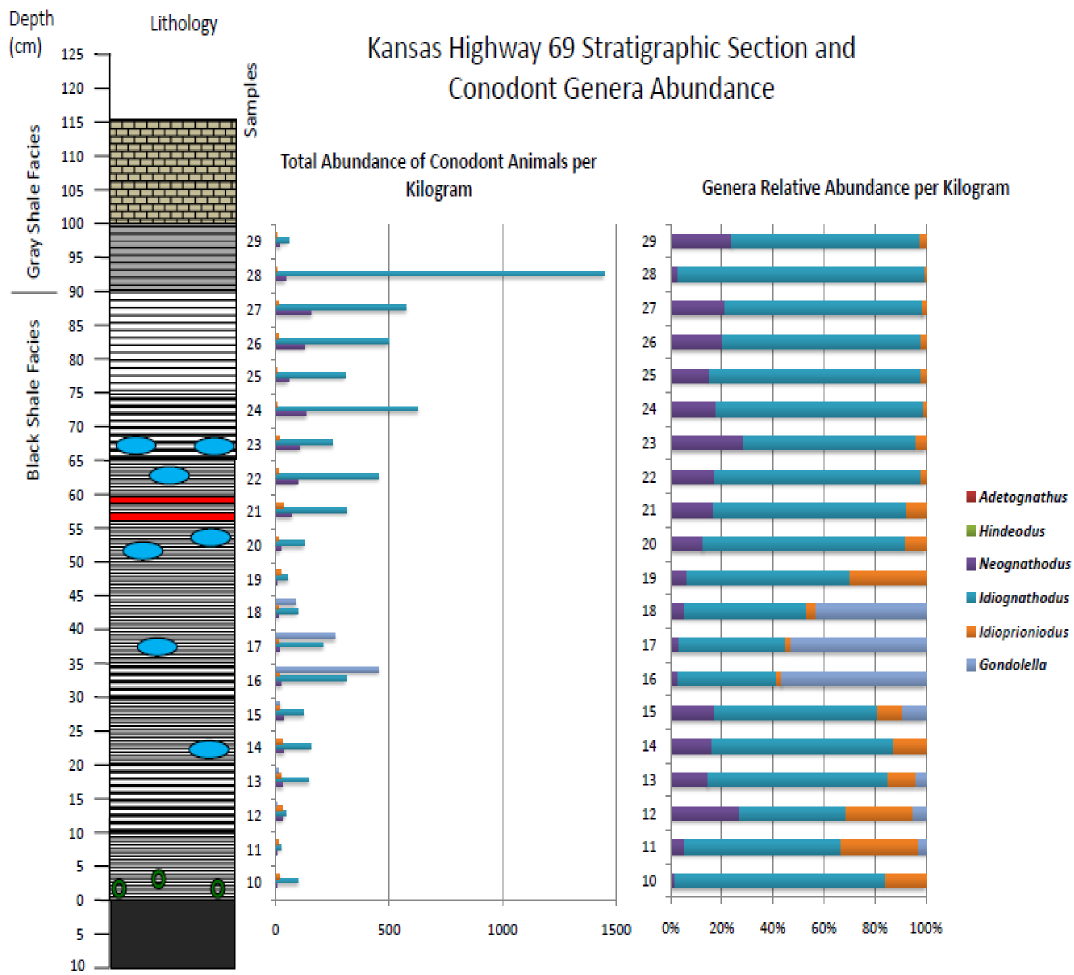

Figure 10: Kansas Highway 69 conodont genera and measured section. Total and relative abundance of conodont genera (calculated individuals) present in the Excello Shale. Samples are scaled to the stratigraphic section.

Norris Creek Section

Calculated totals of abundance of conodont individuals (Figures 12 and 13) varies from just over 200/kg near the base of the lower black shale of the Excello at 10cm (sample 2), then drops to less the 100/kg at 20 cm (sample 4). Total abundance sharply increases to just above 1500/kg at 55 cm (sample 11) in the upper middle black shale and very quickly falls to about 100/kg at 65 cm from the base (sample 13) below the gray shale. In the gray shale, abundance gradually rises to over 200/kg at 100 cm (samples 20 and 24) before falling to less than 50/kg at 140cm (samples 27 and 28). *Idiognathodus* is the most abundant genus through most of the section and is the dominant genus in the lower black shale and upper gray shale. It peaks with *Gondolella* at 55 cm (sample 11). *Gondolella* peaks sharply from 45 to 60 cm (samples 9 to 12) where it is the dominant genus. *Idioprioniodus is* present throughout the section in low to moderate abundance. It is slightly more abundant in the lower black shale than the gray shale above. *Neognathodus* is present throughout the section and is more common in the upper black shale and lower gray shale. It peaks at the first large occurrence of *Gondolella*. *Hindeodus* and *Adetognathus* are not present in this section.

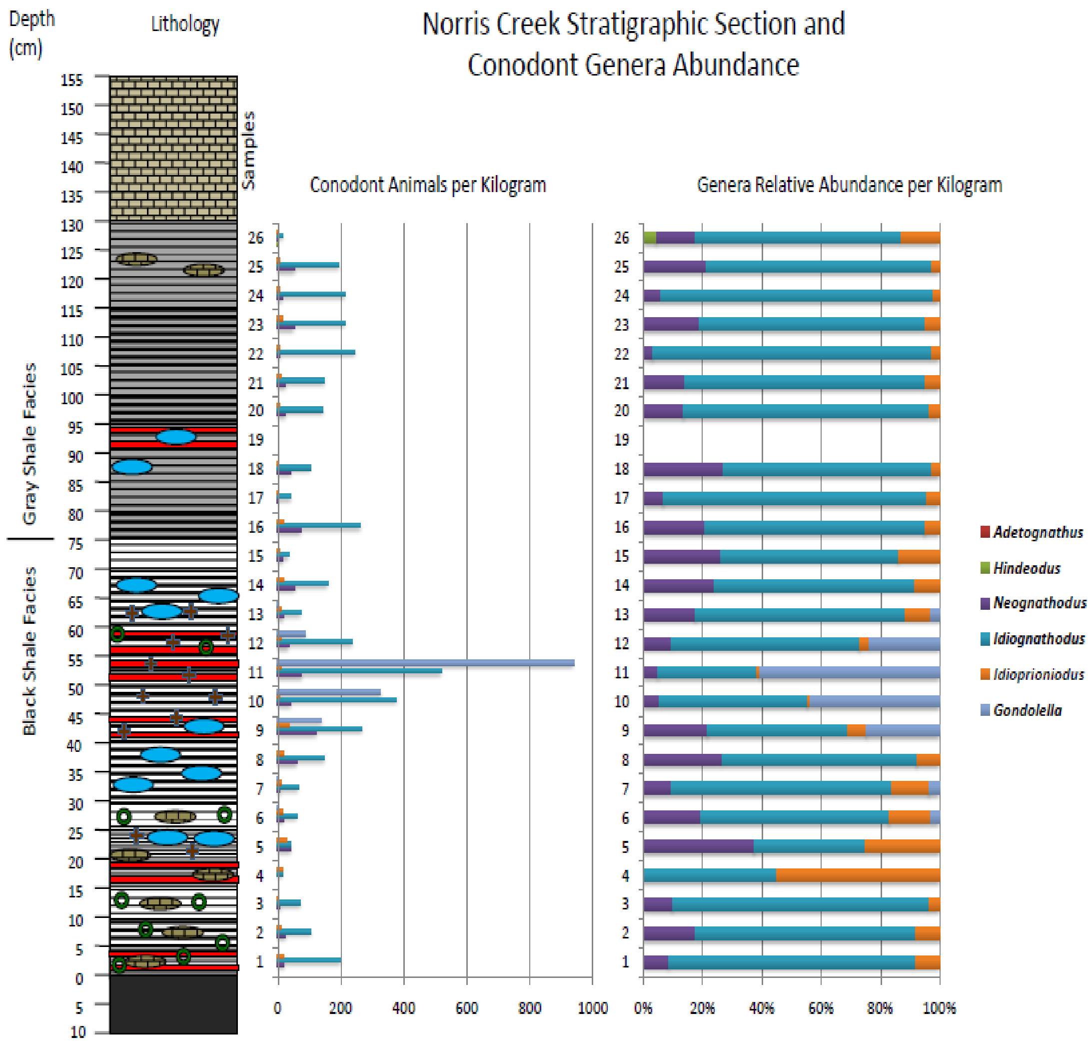

Figure 11: Norris Creek conodont genera and measured section. Total and relative abundance of conodont genera (calculated individuals) present in the Excello Shale. Samples are scaled to the stratigraphic section.

Booneville Section

Total abundance of calculated conodonts individuals (Figures 14 and 15) at the base of the black shale is roughly 100/kg at 5cm (sample 1) and quickly rises to a peak just over 1100/kg at 25 cm (sample 5) and then falls to about 200/kg at 45cm (sample 9) in the upper black shale to lower gray shale. At the base of the gray shale at 50 cm (sample 10), abundance falls to less than 100/kg, then abundance increases slightly at 55 cm (sample 11), where it rises to just over 200/kg and then falls to just over 100/kg in each sample until it peaks at 75 cm (sample 15) to just above 400/kg. The abundance sharply falls to around 100/kg at 85 cm (samples 17) and remains low through the remainder of the section. *Idiognathodus* is the most abundant genus through this section and it is the dominant genus in the upper shale. It has its second highest abundance with *Neognathodus* and *Gondolella* around 20 cm (samples 4 and 5). *Gondolella* is restricted to the black shale (samples 4 through 8) where it is more abundant than *Idiognathodus*. *Idioprioniodus* occurs in low abundance throughout the section with slightly higher abundance in the black shale and lower gray shale. *Neognathodus* occurs in moderate abundance throughout the section and is more abundant in the black shale than the upper gray shale. It begins to peak near the first occurrence of *Gondolella*. *Hindeodus* appears in the upper gray shale starting at 75 cm (sample 16) than *Idioprioniodus. Adetognathus* is barely present in the uppermost sample.

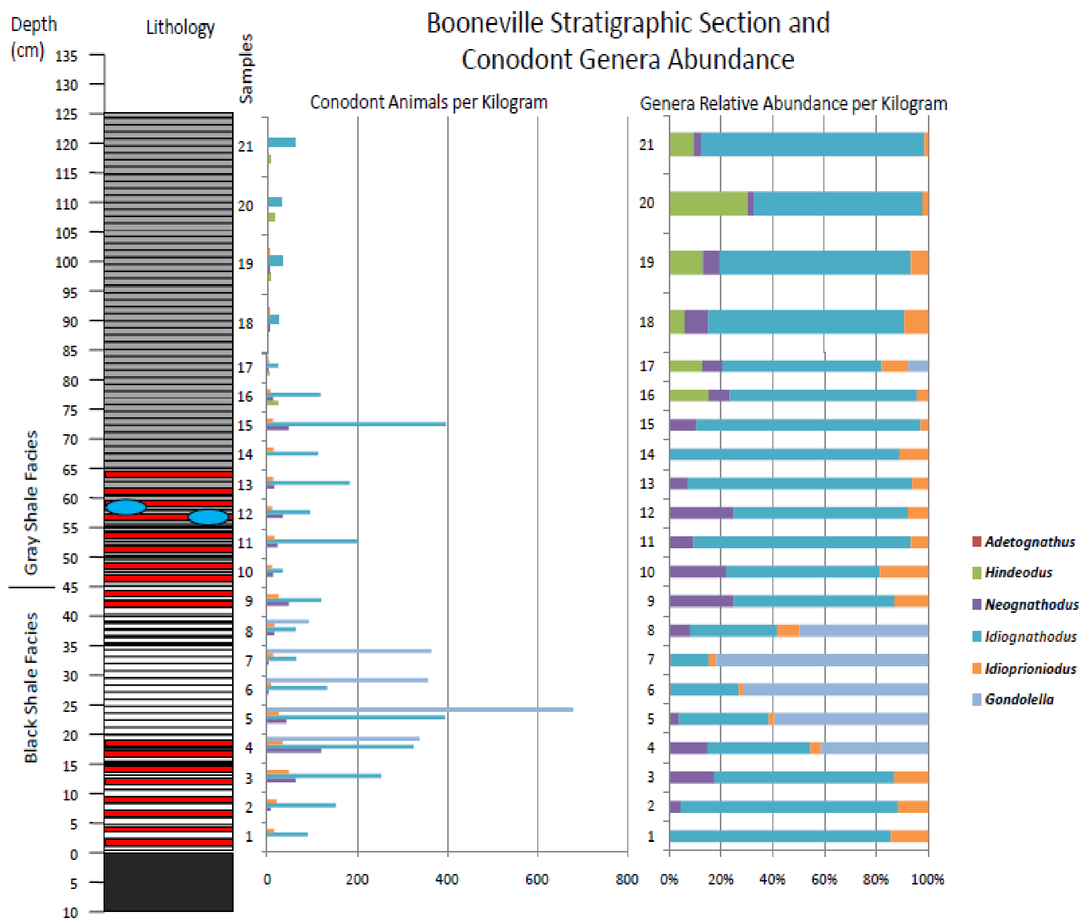

Figure 12: Booneville conodont genera and measured section. Total and relative abundance of conodont genera (calculated individuals) present in the Excello Shale. Samples are scaled to the stratigraphic section.

Discussion

Idiognathodus is the most abundant genus and dominates all but a few samples in each of the three sections. Its highest abundance per kilogram peaks at different stratigraphic levels in each section. In the Kansas Highway 69 section, its greatest abundance occurs in the upper gray shale, in Norris Creek it lies in the upper black shale, and in Booneville it lies in the lower black shale and the gray shale. *Idiognathodus* increases in abundance during the *Gondolella* peak. However, this is only a small increase in the Kansas Highway 69 section.

Neognathodus is present throughout the three sections. It is most abundant in the Kansas Highway 69 section, where it is more common in the upper gray shale with the high abundance of *Idiognathodus.* In the Norris Creek section, it peaks slightly at the beginning of the *Gondolella* and *Idiognathodus* peak and is otherwise more common in the upper black shale and gray shale. The Booneville section has the fewest *Neognathodus* per kilogram. *Neognathodus* is more abundant in the black shale than the gray shale and as at Norris Creek; a *Neognathodus* peak coincides with the first appearance of *Gondolella*.

Gondolella displays large, but stratigraphically restricted peaks at all three section. In the Kansas Highway 69 section, the peak occurs about 30 cm above the base in the upper black shale. In Norris Creek, it peaks at 50 cm above the base in the upper black shale and in Booneville it peaks at 20 cm above the base in the black shale.

Idioprioniodus occurs through the three sections in low abundance. It is typically more common in the lower black shale than in the upper gray shale. Its presence dwindles to less than 5/kg in the upper gray shale. *Hindeodus* is only present in the upper gray shale of the Booneville section in low abundance. Only a few specimens of *Adetognathus* were recovered at the very top of the Booneville section.

The distributions of conodont genera in the Excello Shale are similar to those reported by Heckel (1989, 1994, 2008, 2013) in other core shales of cyclothems. *Gondolella* is typically confined to roughly the middle of the black shale and, according to the Pennsylvanian conodont biofacies model, represents the deepest water, most offshore environment under the thermocline. The distribution of *Gondolella* in the Excello, though, differs in the strong stratigraphic restriction of the genus. Usually *Gondolella* elements display a broader pattern of occurrence in the core shale. *Idioprioniodus* is considered to be the second most offshore conodont genus, one that lived near the level of the thermocline. However, in the Excello Shale, *Idioprioniodus* elements occur up into the gray shale, generally interpreted to represent shallower water facies. Both *Idiognathodus* and *Neognathodus* occur throughout all shale facies in the Excello, as is typical for these forms. *Hindeodus* and *Adetognathus* are typically most abundant in the regressive limestone members and nearer to the shore, but were only recovered from upper gray shale at the Booneville section, and not in the gray shale and limestone at the top of the other two sections.

The three sections form a transect from deeper offshore to shallower offshore going from north to south (Kansas Highway 69- Norris Creek-Booneville). No significant differences in conodont distributions were observed among the sections in the lower black shale unit. The major difference is that the maximum peak of *Gondolella* occurs at a slightly different thickness above the base of the section (Kansas Highway 69 – 30 cm; Norris Creek – 50 cm; Booneville – 20 cm. The *Gondolella* peak is often assumed to represent the maximum flooding surface (Joachimski and Lambert, 2015), and may approximate a time line in the sections. The different thicknesses may be a result of different rates of deposition before maximum flooding.

The greatest differences in faunas among the three sections occur in the upper gray shale interval, the regressive portion of the cyclothem. To the south (more offshore) at the Kansas Highway 69 section, both *Idiognathodus* and *Neognathodus* occur in large numbers, about the highest numbers in any part of any section. In the Norris Creek section, both genera occur in more moderate abundances in the gray shale. In the upper gray shale at the Booneville section, *Hindeodus* occurs in low abundance and here is the only occurrence of *Adetognathus.* These genera indicate shallower water settings, often associated with carbonate deposition, which matches with the Booneville section being the shallower water locality.

CHAPTER IV

CONODONT SPECIES

Most of the genera of conodonts in the Excello Shale appear to be represented by a single species. *Adetognathus* elements can all be assigned to the well-known and long ranging species *A. lautus. Hindeodus* elements are all attributed to *H. minutus*. No examples of *H. calcarus* Stamm and Wardlaw 2003, from the older Verdigris cyclothem were recovered. Nestell et al. (2016) described in detail the apparatus of *Idioprioniodus conjunctus* (Gunnell, 1931) from a limestone nodule in the Excello Shale at the Booneville section. All *Idioprioniodus* elements obtained here belong to that species. Nestell et al. (2016) described just one species of *Idiognathodus, I. acutus*, from the Booneville nodules, but we recognize at least three possible species in our collections: *I. acutus, I.* sp. 2 and *I.* sp. 3 (see Systematics). Nestell et al. (2016) recognized one species of *Neognathodus*, *N*. *roundyi*, but we tentatively identify four species, *N. dilatus*, *N. roundyi*, *N.* sp. 3, and *N*. sp. 4. Also, we found two species of *Gonodolella*, *G*. *wardlawi* (Nestell et al., 2016) and *G*. species 2, whereas Nestell et al. (2016) found just the former species. The recognition of potential multiple species of the more abundant conodont genera permits an examination of whether these "species" display different distributional patterns in the Excello Shale (Appendix C)

In the Kansas Highway 69 section (Figure 16), *Idiognathodus acutus* is present and abundant through the entire thickness of the Excello Shale. It composes roughly 85% of the *Idiognathodus* present in the section. *Idiognathodus* sp. 2 composes about 10% of the species and occurs from near the base of the black shale to the top of the section, but is slightly more abundant in the lower black shale. It was not observed in the lower 15 cm of the section. In contrast, *I.* sp. 3 only occurs at the base of the section in the black shale (lower 30 cm) and composes roughly 5% of the *Idiognathodus* observed in the section. *Neognathodus dilatus* occurs through the entire thickness of the section (Figure 17). It comprises about 55% of the *Neognathodus* in the section and is most abundant in the upper black shale. *Neognathodus roundyi* occurs in a very small numbers in the lower part of the black shale and disappears in the middle of the black shale. It reappears in the upper part of the black shale. It constitutes about 20% of the species in the section. *Neognathodus* sp. 3 is present throughout the thickness of the section and is roughly 20% of the species in the section. It is somewhat rare near the base and middle black shale and is more common in the upper part of the black and lower part of the gray shale. *Neognathodus* sp. 4 is only present in the upper black shale and lower gray shale at the near top and is somewhat discontinuous in distribution, composing 5% of the genus. *Gondolella wardlawi* composes 90% of the *Gondolella* in the section. It is mostly restricted to the middle black shale unit where it is abundant and spans a 15 cm interval in the most abundant part. In the lower portion of the black shale only 2 to 3 specimens were recovered. *Gondolella* sp. 2 occurs only in the middle of the black shale, co-occurring with the abundant G. *wardlawi* specimens. This species only comprises 10% of the specimens in the section.

Idiognathodus acutus occurs throughout the thickness of the Norris Creek section and composes roughly 80% of the genus in the section (Figure 18). It is most common in the upper part of the black shale and through the gray shale. It is somewhat rare in the base and lower middle of the black shale. *Idiognathodus* sp. 2 ranges through the section, but is somewhat discontinuous in occurrence. It is most abundant in the upper part of the black shale and much less common in the gray shale. Roughly 15% of *Idiognathodus* is composed of *I.* sp. 2. *Idiognathodus* sp. 3 comprises only about 5% and is only found in basal 25 cm of the shale. *Neognathodus dilatus* occurs sporadically through the thickness of the Norris Creek section (Figure 19). It is more common in the upper part of the black shale and lower part of the gray shale and somewhat rare in the lower part of the black shale. It composes roughly 25% of the *Neognathodus* in the section. *Neognathodus roundyi* is present through the thickness of the section and composes about 15% of the species. It is most common in the upper part of the black shale and somewhat rare in the lower part of the black shale and upper part of the gray shale. *Neognathodus* sp. 3 occurs through the section, except near the base of the black shale. It is most common in the middle part of the black shale and comprises about 50% of the *Neognathodus. Neognathodus* sp. 4 is most common in the upper part of the black shale and somewhat less common in the overlying gray shale. It is absent in the basal 35 cm of the black shale and the uppermost 15 cm of the gray shale. It only composes about 10% of the *Neognathodus*. *Gondolella wardlawi* is present in great abundance in the upper black shale where it and spans a 20 cm interval. It comprises about 95% of the *Gondolella*. *Gondolella* species 2 is present in the upper black shale in relatively low abundance (about 5% of *Gondolella*) and co-occurs with *G. wardlawi.*

Idiognathodus acutus is abundant through the thickness of the Booneville section in both the black and gray shale and is about 75% of the *Idiognathodus* in the section (Figure 20). *Idiognathodus* sp. 2 comprises roughly 20% of the *Idiognathodus* and ranges through entire thickness of the section. It is most common in the middle part of the black shale and much less abundant in the gray shale. *Idiognathodu*s sp. 3 only occurs in the basal 25 cm of the shale and composes about 5% of the *Idiognathodus*. *Neognathodus dilatus* occurs in low abundance and is almost exclusive to the gray shale with very few examples in the black shale (Figure 21). It comprises about 20% of the *Neognathodus*. *Neognathodus roundyi* occurs sporadically through the section. It is most abundant in the lower part of the black shale and the lower part of the upper gray shale and composes about 15% of the species. *Neognathodus* sp. 3 is most abundant in the middle of the black shale and occurs in low abundance through the gray shale. It comprises about 55% of the *Neognathodus*. *Neognathodu*s sp. 4 is present mostly in the upper part of the black and lower part of the gray shale. It makes up only 10% of the species present. *Gondolella wardlawi* is very abundant in the middle and upper black shale and comprises 90% of the *Gondolella*. *Gondolella* sp. 2 co-occurs in the same samples as *G. wardlawi* and comprises about 10% of the genus.

Discussion

Idiognathodus acutus is the most abundant conodont in this study. It was observed in abundance through the entire thickness of the Excello at each locality. Moving from south to north, *I. acutus* gradually decreases both in total abundance and relative proportion (5% decrease), in contrast to *Idiognathodus* sp. 2, which increases (5% increase) northward through the sections. *Idiognathodus* sp. 2 is less abundant than *I*. *acutus* and is almost always more abundant where *Gondolella wardlawi* is abundant in the upper part of the black shale. *Idiognathodus* sp. 3 occurs in the basal 25 to 30 cm of shale at each section and is slightly more abundant in Kansas Highway 69 and Booneville localities and the rarest *Idiognathodus* species in the Excello Shale.

The *Neognathodus* fauna is the most diverse group of species in the Excello Shale. *Neognathodus dilatus* occurs through the full thickness of the Excello Shale with the exception of the Booneville locality where it first appears 10 cm above the base. It is increasingly less common compared with the other *Neognathodus* species going from south to north (55% at KS69, 25% at NC, at 20% at BV). Also, it is always relatively more abundant in the upper part of the gray shale than in the black shale below. *Neognathodus roundyi* is less common in the three sections, but is always more abundant in the black shale than the gray shale. Its relative proportion to the other *Neognathodus* species remains similar in all three localities. In contrast to N. *dilatus*, *N*. sp. 3 is relatively more abundant northward (20% at KS69, 50% at NC, 55% at BV). *Neognathodus* sp. 4 is mostly restricted to the black shale with just a few specimens present in the gray shale in the Norris Creek and Booneville localities. It is the rarest of the *Neognathodus* species observed in the Excello shale.

Gondolella wardlawi is very abundant in the lower middle upper parts of the black shale in all three sections. It comprises about 90% to 95% of all *Gondolella* observed and is typically restricted to a 15 cm to 25 cm interval where it is abundant. *Gondolella* sp. 2 is the uncommon and always occurs with *G*. *wardlawi*.

It is difficult to clearly resolve stratigraphic patterns within sections among species of the different genera, for the changes are relatively slight and somewhat erratic. The lowest part of the shale of the sections has the rare occurrences of *Idiognathodus* sp. 3, but otherwise little difference can be seen between the other two *Idiognathodus* species going up each shale section. The species of *Neognathodus* display some differences in stratigraphic distribution, but the pattern, if any, is not clear. Both *Gondolella* species always occur together. The greatest difference in species distributions is observed, geographically, going from south to north, from an offshore position to a more onshore position. *Idiognathodus acutus* displays a slight decrease in relative abundance and *I.* sp. 2 a corresponding slight increase. A stronger contrast is seen between two of the *Neognathodus* species. *Neognathodus dilatus* decreases greatly in relative abundance from south to north, and *N*. sp. 3 proportionally increases in abundance. Based on the general cyclothem model in which conodont genera is suggested occurring at various intervals, we tentatively outline the possible areas occupied by the conodont species on the conodont biofacies model (Figure 19).

According to general cyclothem model, the lithofacies in the middle to upper part of each cyclothem represent a shallowing upward series of environments, ending with a carbonate unit and nonmarine shale at the top. One would expect the distribution of conodont genera and species to reflect the same upward shallowing water conodont biofacies within a section and across an offshore to onshore, deeper water to shallower water transect. In the Excello Shale, however, the offshore-onshore transect displays far greater differences in the conodont faunas than does the shallowing upward facies succession in any of the sections. Conodont faunas in the sections display very minor to no change through the shallowing upwards facies. Each section is likely condensed and subtle differences in biofacies obscured, which prevents the separation of the shallowing upward conodont biofacies from being observed in individual sections. Only when the unit is spread along a great distance can the offshore-onshore ecological differences be seen and detailed biofacies patterns discerned.

The Excello Shale Member and Other Desmoinesian Conodont Faunas

Few studies have been published on conodont species from Desmoinesian cyclothems in Midcontinent North America. The only comprehensive work on species is that of Stamm and Wardlaw (2003) on the Lower Kittanning cycle, which includes the highest Cherokee major cyclothem, the Verdigris cyclothem. This is the major cyclothem just below the Lower Fort Scott cyclothem. Four species of *Idiognathodus* described in the Stamm and Wardlaw (2003) study: *I. ignisitus, I. crassadens, I. robustus, and I. podolskensis*, none of which range up into the Excello Shale. Three species of *Neognathodus* were identified in their study: *N.intrala*, *N. asymmetricus*, and *N. roundyi*, only last of which ranges up into the Excello. Two species of H*indeodus* were described; *H. calcarus* and *H. minutus,* and only latter occurs in the Excello. Overall, the Excello fauna, the lowest Marmaton fauna, differs greatly from the uppermost Cherokee Verdigris fauna in the absence of most of the characteristic upper Cherokee species.

Conodont faunas have not been described at the species level from most of the Marmaton cyclothems and the species composition and ranges are poorly understood (see Barrick et al., 2013). The Lost Branch cyclothem represents the final major cyclothem of the Desmoinesian in the Midcontinent Basin, the core shale of which is the Nuyaka Creek Shale. Rosscoe (2005) described the conodont fauna of the Lost Branch to the species level. The Lost Branch cyclothem contains only one species of *Idiognathodus, I. expansus,* and at least two species of the closely related genus *Swadelina.* Two species of *Gondolella* were recovered, a large crenulated form *G. magna,* and a "naked" species, unlike the Excello fauna. Five species of *Neognathodus* were identified, including *N. roundyi*, and *N*. dilatus, and some similar to *N.* sp. 4 (see Systematics). One species each of *Idiognathodus, Hindeodus, Adetognathus* were found. Overall, with the major exception of the *Swadelina* species, the Lost Branch cyclothem, which lies five cyclothems higher, is more like the Excello fauna, than the Excello is like the only slightly older Verdigris fauna.

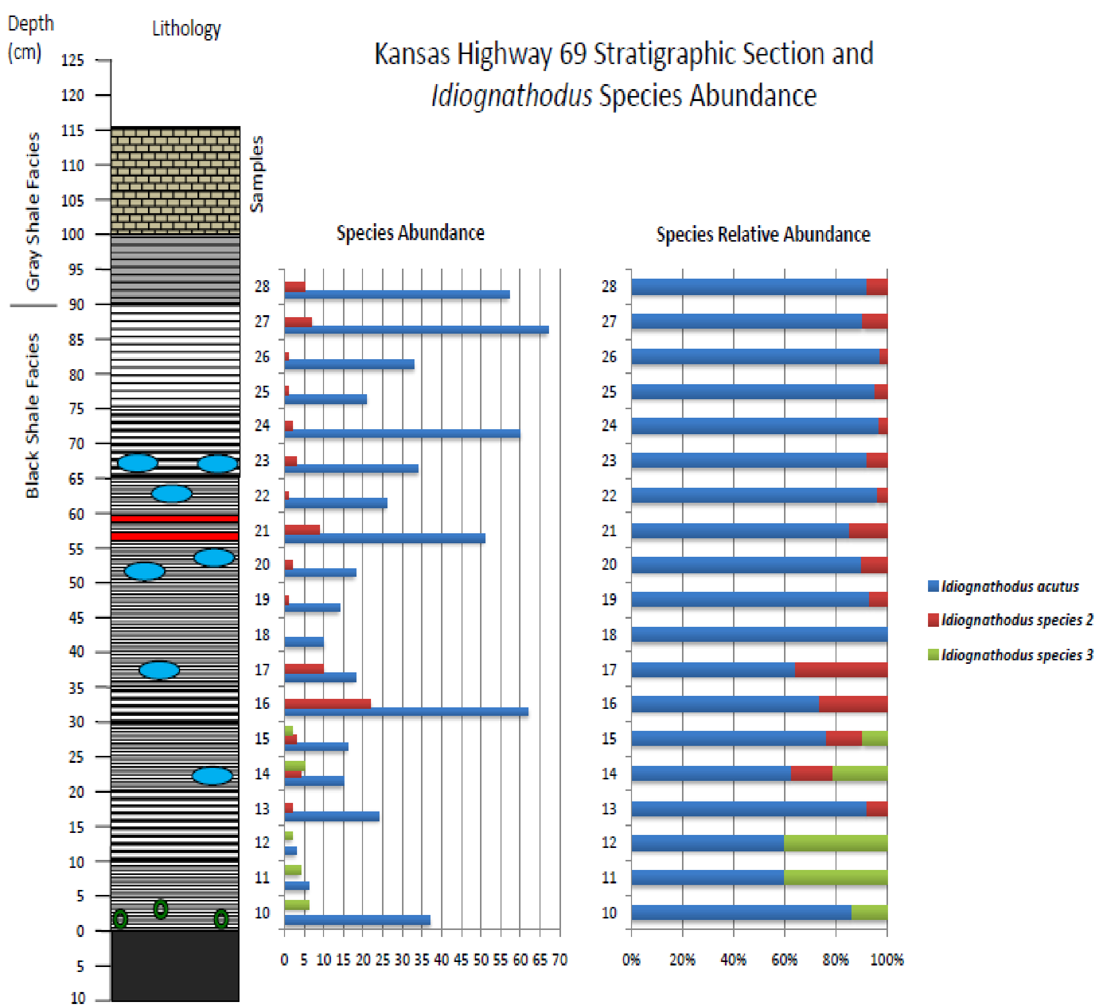

Figure 13: Kansas Highway 69 *Idiognathodus* species and measured section. Total and relative abundance of *Idiognathodus* conodont species present in the Excello Shale. Spacing of samples is scaled to the stratigraphic section.

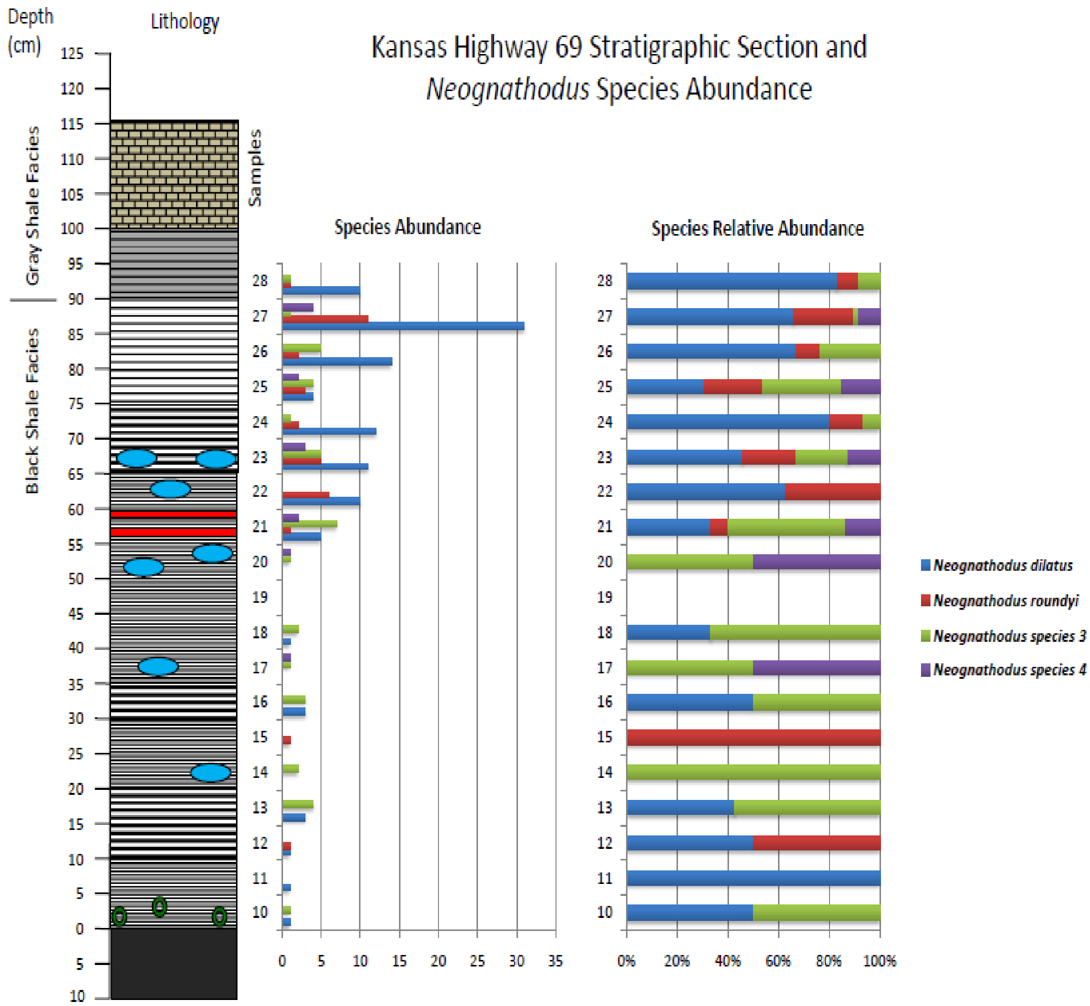

Figure 14: Kansas Highway 69 *Neognathodus* species and measured section. Total and relative abundance of *Neognathodus* conodont species present in the Excello Shale. Spacing of samples is scaled to the stratigraphic section.

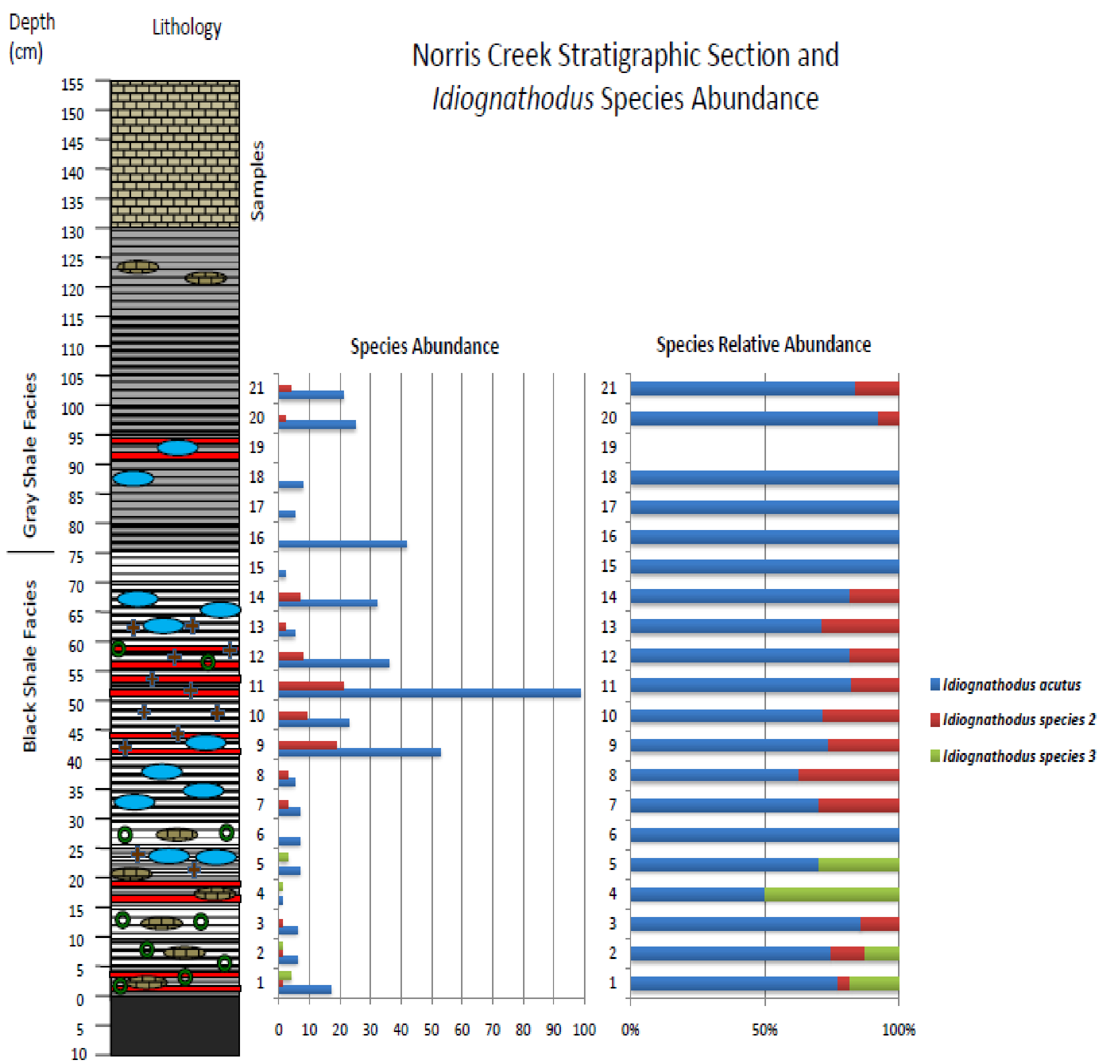

Figure 15: Norris Creek *Idiognathodus* species and measured section. Total and relative abundance of *Idiognathodus* conodont species present in the Excello Shale. Spacing of samples is scaled to the stratigraphic section.

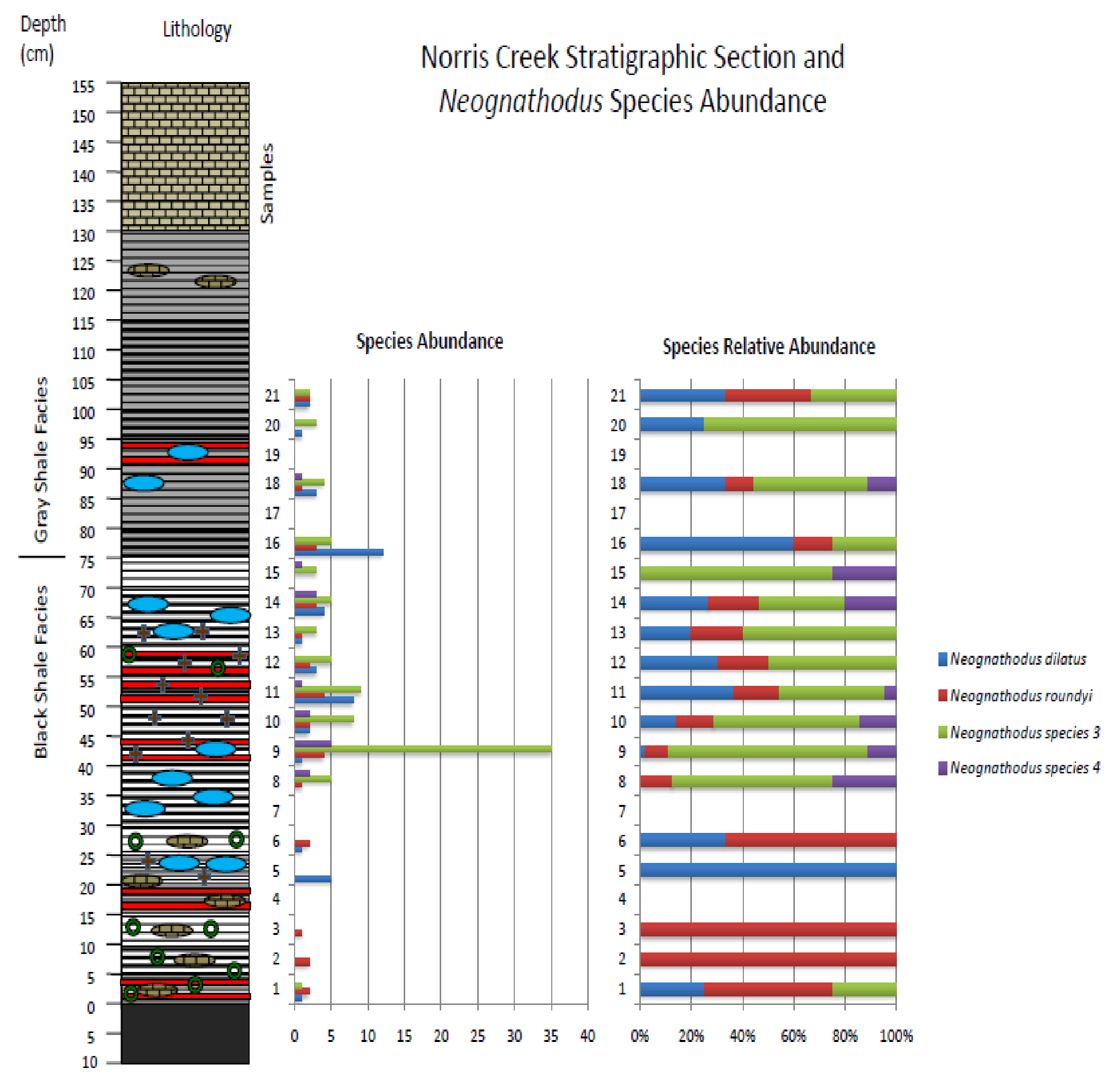

Figure 16: Norris Creek *Neognathodus* species and measured section. Total and relative abundance of *Neognathodus* conodont species present in the Excello Shale. Spacing of samples is scaled to the stratigraphic section.

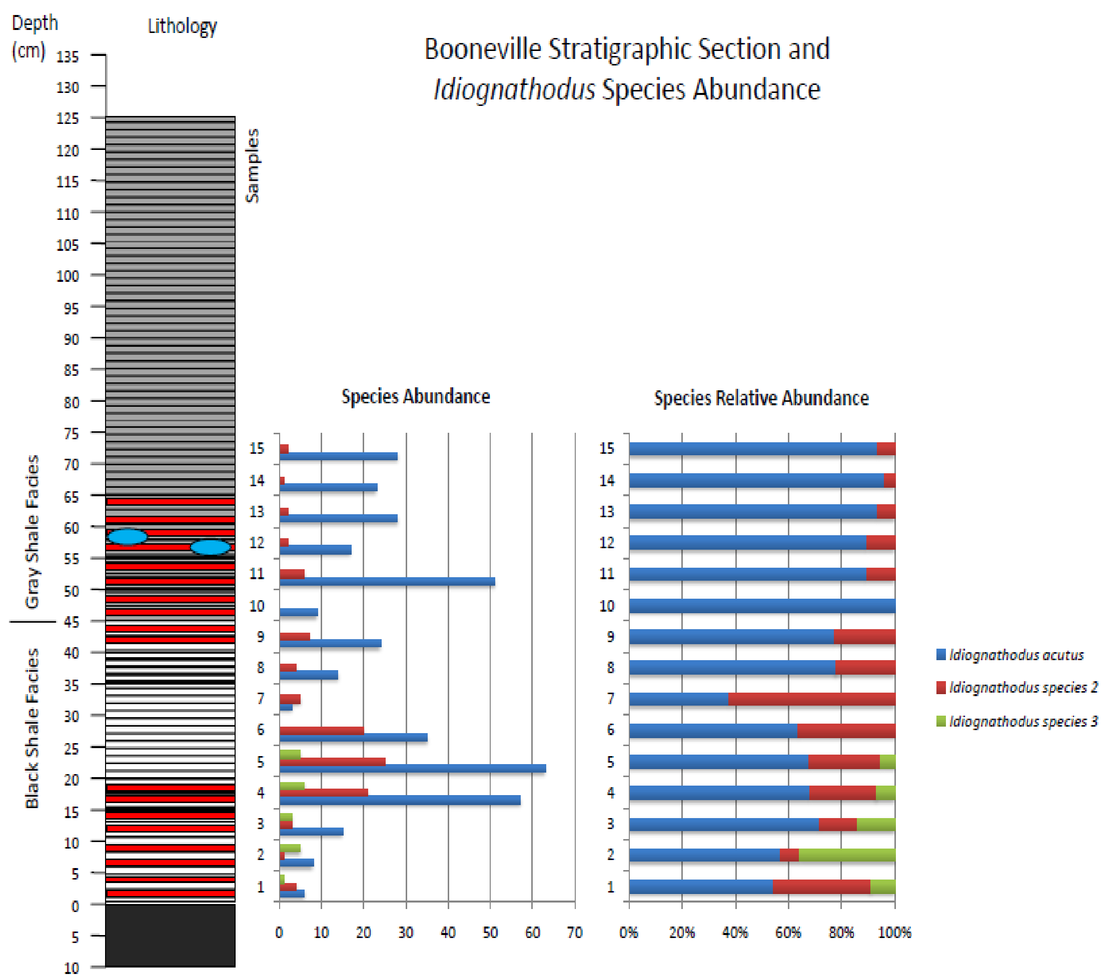

Figure 17: Booneville *Idiognathodus* species and measured section. Total and relative abundance of *Idiognathodus* conodont species present in the Excello Shale. Spacing of samples is scaled to the stratigraphic section.

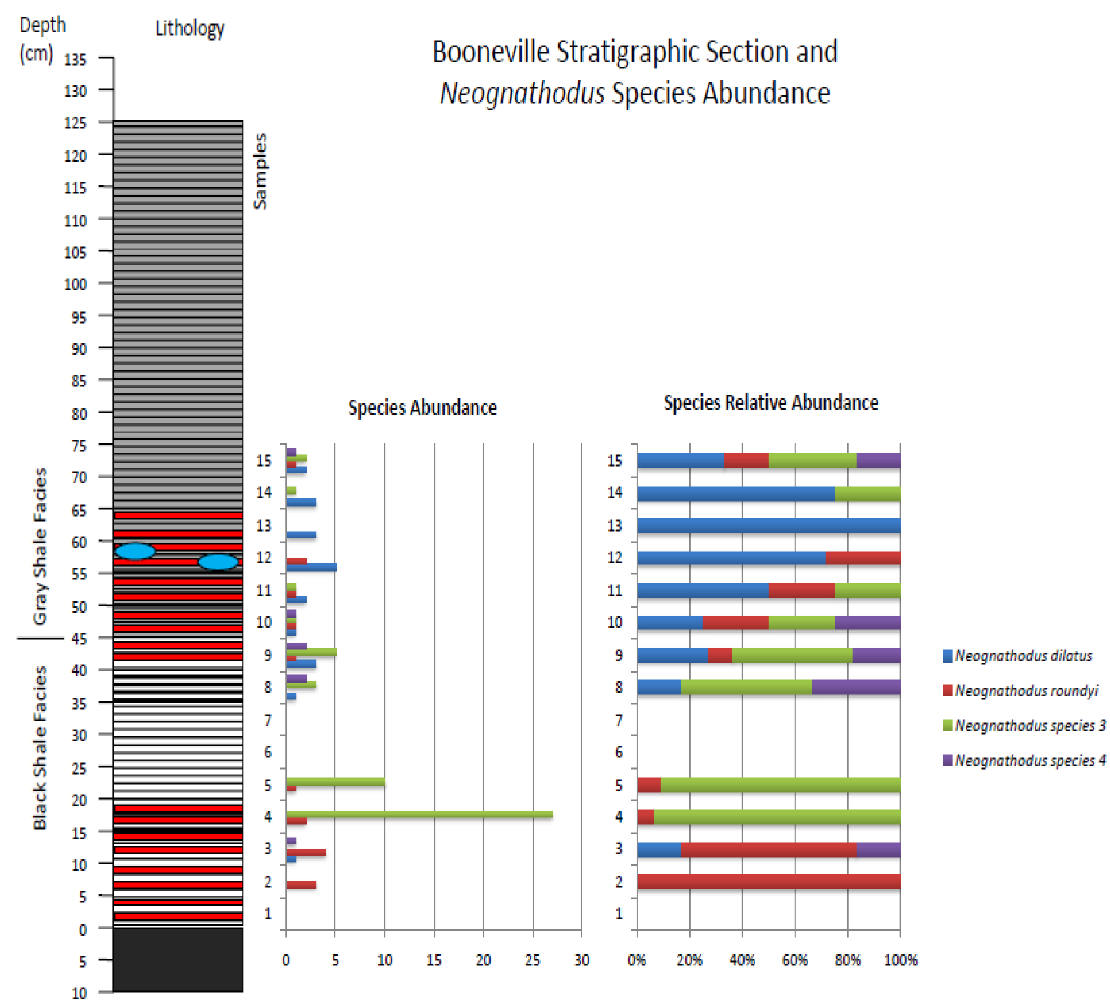

Figure 18: Booneville *Neognathodus* species and measured section. Total and relative abundance of *Neognathodus* conodont species present in the Excello Shale. Spacing of samples is scaled to the stratigraphic section.

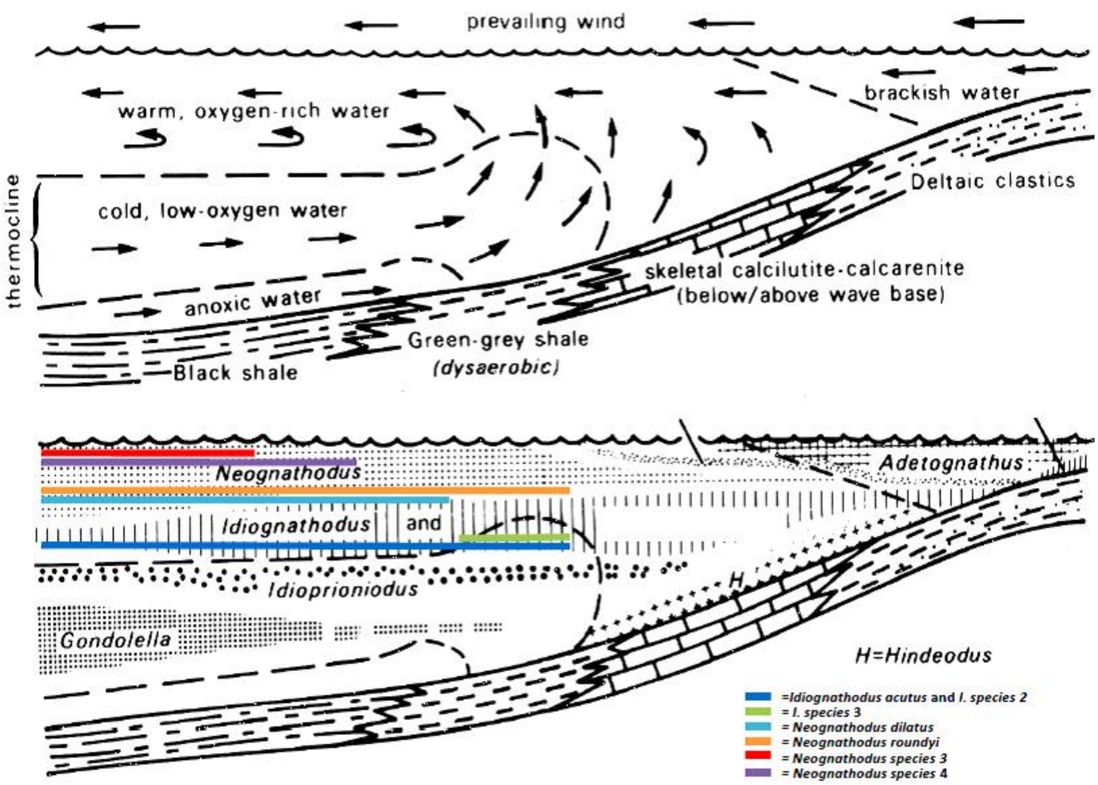

Figure 19: Cyclothem biofacies model with possible living area of *Idiognathodus* and *Neognathodus* species shown based on conodont total abundance. (Modified from Sweet, 1988)

CHAPTER V

SYSTEMATIC PALEONTOLOGY

Conodont elements were described using the terminology of Purnell et al. (2000) and Rosscoe (2008). Photomicrographs are oriented dorsal end down for comparisons both within the study and other publications. Specimens are reposited in the collections in the Department of Geosciences, Texas Tech University.

Phylum **CONODONTA** Pander, 1856

Class **CONODONTI** Branson, 1938

Family **IDIOGNATHODONTIDAE** Harris and Hollingsworth, 1933

Genus **IDIOGNATHODUS** Gunnell, 1931

Diagnosis: Carminiscaphate P_1 element with ventral end of platform typically composed of asymmetrical lobes adorned with varying amounts of nodes. Dorsal platform composed of transverse ridges.

*Remarks: Idiognathodu*s Gunnell, 1931, *Streptognathodus* Staffer and Plummer, 1932, and *Swadelina* Lambert, Heckel and Barrick, 2003, are some of the most characteristic Pennsylvanian conodonts and share many features. *Idiognathodus,* which ranges from the Morrowan into the Virgilian, possesses an upper platform surface that bears continuous transverse ridges. In contrast, *Streptognathodus,* which ranges from the Missourian into the early Permian, has a characteristic medial trough that cut the transverse ridges on the upper platform surface. In similar fashion, the late Desmoinesian genus *Swadelina* also has a medial trough that cuts the transverse ridges on the dorsal platform.

IDIOGNATHODUS ACUTUS Ellison, 1941

Plate 1, Specimens 1-18.

Diagnosis: The P_1 element has a platform that is moderately narrow with a long dorsal section bearing several fine to medium transverse ridges. The ventral platform has two distinct lobes, of which the caudal lobe is usually slightly larger.

Description: The P_1 element has a slight to moderately arched upper platform surface. The carina of the free blade extends into the middle ventral section of the platform between the lobes and terminates there. Adcarinal grooves run parallel from the base of the ventral platform to the upper platform where the free blade attaches and terminate with the carina. The caudal and rostral lobes may be similar in size or the caudal lobe margin may be slightly larger than the rostral lobe. The lobes are adorned with several nodes that often form concave outward ridges near the adcarinal grooves on both sides of the platform and become more randomly arranged near the outer edge of the lobe. The dorsal platform of larger elements has 6 to 10 medium to fine transverse ridges. Smaller, likely juvenile, specimens have fewer ridges. The transverse ridges will occasionally break up into nodes and ridges near the dorsal tip or may barely cut by a small trough lengthwise, especially in large specimens.

Discussion: This is by far the most abundant conodont species in the Excello Shale. *Idiognathodus acutus* has less well-developed lobes, a narrower, and more arched platform than *Idiognathodus* sp. 2. The dorsal platform of *I. acutus* is also more elongate and often contains finer, more numerous transverse ridges than in *I.*sp. 2. Also, the lobes are not offset in *I. acutus* as much as in *I.* sp. 2. Nestell et al (2016) presented a reconstruction of the apparatus of *I. acutus*. *Idiognathodus acutus* differs from the *Idiognathodus* species described by Stamm and Wardlaw (2003) from the slightly older Verdigris cyclothem. *Idiognathodus crassadens* Stamm and Wardlaw, 2003 lacks well-developed lobes and the transverse ridges are more discontinuous compared to *I. acutus. Idiognathodus acutus* is straighter and possesses coarser transverse ridges than *I. podolskensis* Goreva, 1984. *Idiognathodus robustus* Kossenko 1978 has a more triangular shape and just a few coarser transverse ridges than *I. acutus.*

Distribution: It occurs through the entire thickness of the Excello Shale at the Kansas Highway 69 section, the Norris Creek section, and the Booneville section.

<u>*IDIOGNATHODUS* sp. 2</u>

Plate 2, Specimens1-9

Diagnosis: P_1 element has a relatively short, broad platform with two large well-developed, offset lobes. Transverse ridges are moderate to coarse and range from fairly straight to a slightly sinuous.

Description: The P_1 element is fairly flat with very little arching. The carina extends from the free blade onto the ventral one-quarter of the platform. The dorsal platform tends to be short and pointed with 4 to 8 moderate to coarse transverse ridges that may break up into nodes as they reach the middle of the platform. Ridges break up more commonly in larger specimens. Transverse ridges are widely spaced and may be bisected by a shallow medial trough. The transverse ridges range from relatively straight to slightly sinuous. Lobes are very large and well developed on both sides and are slightly offset from one another. The caudal lobe is nearer to the ventral end of the platform and the rostral lobe is longer and more medial to the platform. Lobes are composed of many nodes and in some specimens the nodes form concave out ridges near the carina that are less ordered near the outer margin. The basal cavity is low and slightly larger than the platform and tends to flare outward.

Discussion: Idiognathodus sp. 2 can be distinguished from *I. acutus* by the shorter dorsal platform, the coarser transverse ridges, the offset large lobes, and the less arched platform. *Idiognathodus acutus* tends to have a longer dorsal platform, more transverse ridges that are finer, and its platform is more arched than *I.* sp. 2. Nestell et al. (2016) named a new species, *I. turberis*, which has a shelf on the rostral margin. We did not find good examples of this form, although some elements included herein *I.* sp. 2 possess a wider rostral lobe that may correspond to the *I. tuberis* shelf.

Distribution: It occurs through the entire thickness of the Excello Shale at the Kansas Highway 69 and Booneville sections. It is present through the Norris Creek section, but there are some gaps in occurrence. (NC 1-3, NC 7-14, NC 20-21). The species is more abundant in the middle part of the shale.

<u>*IDIOGNATHODUS* sp. 3</u>

Plate 2, Specimens10-13

Diagnosis: The P_1 element has a platform with a tear-drop shape and has nodal protrusions along the perimeter of the platform. Lobes and transverse ridges are poorly developed and nodes are randomly scattered in the central portion of the platform.

Description: The platform is tear-drop shaped with medial bulges. Nodal projections are present along the perimeter of the platform. The margins are otherwise relatively smooth and rounded. There are no clearly defined lobes or transverse ridges. The central portion of the platform is composed of randomly oriented nodes with some bearing a transversely elongate shape typically in the dorsal half of the specimen. The dorsal tip often comes to a sharp point.

Discussion: Idiognathodus sp. 3 may be distinguished from *I. acutus*, and *I*. species 2 by the unusual perimeter node placement, nodose upper platform surface, the lack of transverse ridges, and the lack of distinct lobes.

Distribution: It occurs in the lower part of the Kansas Highway 69 section (KS69 10-15), the Norris Creek Section (NC 1-5), and the Booneville section (BV 1-5).

Genus **NEOGNATHODUS** Dunn, 1970

Diagnosis: Carminiscaphate P_1 element has a high central carina extending the length of the element. The platform margins range from complete margins with transverse ridges to reduction of one margin with one or multiple nodes, to complete loss of one margin of the platform.

Remarks: The size of specimens (younger versus older) appears to have a limited effect on the features present. It has been observed that some of the small, likely juvenile, specimens share similar characteristic in larger adult specimens. As specimens increase in size features may become somewhat distorted and difficult to assess. Nestell et al. (2016) grouped similar specimens regardless of the distribution of nodes on the margins into one species, *Neognathodus roundyi* (Gunnell, 1931) because they interpreted these variations to represent growth phases and not separate species. Here, four possible *Neognathodus* species from the Excello Shale are described.

Stamm and Wardlaw (2003) reported three species of Neognathodus from the slightly older Verdigris cyclothems: *N. intrala* Stamm and Wardlaw, 2003, *N. roundyi* (Gunnell, 1931), and *N. asymmetricus* Stibane, 1967. Rosscoe (2005) also recognized at least three species of *Neognathodus* in the highest Desmoinesian cyclothem, the Last Branch cyclothem, that differ in the nature of the platform margins.

In an attempt to use the *Neognathodus* species as a biostratigraphic indicator Brown et al. (2013) employed the *Neognathodus* Index (NI), which was proposed to be a measure of gradual evolutionary advancement during the Desmoinesian. The process takes certain *Neognathodus* species and assigns them a number between one and nine that is then averaged. The results should theoretically provide a stratigraphic age. Stamm and Wardlaw (2003) presented a harsh review of this procedure. The *Neognathodus* morphotypes from this study could not be used because the Excello species do not match the morphotypes used to calculate NI.

NEOGNATHODUS DILATUS Stauffer and Plummer, 1932

Plate 3, Specimens 2, 3, 8, 9, 13, 15

Diagnosis: The carina of the P_1 element extends the length of the platform and terminates at or near the dorsal end of the platform. The rostral platform margin is a continuous ridge and the caudal margin is a smooth surface without nodes.

Description: The P_1 element has a central carina that extends the length of the platform. The carina is composed of fused nodes ventrally that break up into nodes dorsally. Denticles on the blade increase in size and height as they extend ventrally. On the rostral side, the platform margin is composed of a steep, transversely reclined ridge that bulges medially and joins the carina dorsally. A deep adcarinal groove separates the margin from the carina. It is ornamented with weak, widely spaced transverse ridges along the entire length. The opposing margin of the platform is smooth, widens medially and thins dorsally, in some cases terminating before the dorsal tip. No ridge or nodes are present. The basal cavity flares outward and varies from similar size as the platform to larger than the platform.

Discussion: The smooth caudal margin on both sinistral and dextral elements distinguishes *Neognathodus dilatus* from other *Neognathodus* species in this study. Most species of *Neognathodus* have nodes on the caudal margin and a ridge on the rostral margin. *N.* sp. 4 has ridges on both margins. Nestell et al. (2016) interpreted these forms to be the earliest growth stages of *N. roundyi.*

Distribution: It occurs through the entire thickness the Excello Shale at the Kansas Highway 69 sections and Norris creek sections. It is uncommon low in the Booneville sections and relatively more abundant in the upper part of the Booneville section (BV 3, BV 8-15).

NEOGNATHODUS ROUNDYI (GUNNELL, 1931)

Plate 3, Specimens 10,14,17,21

Diagnosis: On the P_1 element the carina terminates at or near the dorsal end of the platform. The rostral margin is a ridge typically extending the length of the margin. A single node lies on the caudal margin. The node may be elongate and parallel to the carina and is typically in a ventral to medial position.

Description: The P_1 element is slightly biconvex and relatively thin compared to its length. The carina extends the length of the platform and is composed of fused nodes ventrally that break up dorsally into nodes. Denticles on the blade increase in size and height as they extend out from the ventral platform. The rostral side of the margin is composed of a transversely reclined ridge that bulges medially and joins the carina dorsally. A deep adcarinal groove separates the margin from the carina. The margin is ornamented with widely spaced, weak transverse ridges along its length. The last one or two ridges of the rostral ridge may fuse with the carina. The caudal margin bulges medially and thins to the dorsally tip and may terminate before the dorsal tip. This margin is smooth with the exception of a single node located medially where the margin bulges. The node may form a small elongate parapet in some specimens. The basal cavity is outwardly flared and varies from similar size to larger than the platform size.

Discussion: Neognathodus roundyi is distinguished from *N. dilatus* by its single caudal node that may be elongate, located on the ventral margin opposite the rostral ridge in both the sinistral and dextral elements. *Neognathodus dilatus* has a smooth featureless surface on the caudal side. *N.* sp. 3 has both rostral and caudal margin ridges and *N.* sp. 4 has an extra node near the dorsal tip that is not present in *N. roundyi*.

Distribution: It occurs through the entire thickness of the Norris Creek, and the Booneville sections. It is more abundant in upper samples of the Kansas Highway 69 (KS 69 21-28).

NEOGNATHODUS sp. 3

Plate 3, Specimens 1, 4-7, 11, 12, 18

Diagnosis: On the P_1 element the carina extends from the blade to the dorsal tip of the platform. Both the rostral and caudal margins have high ridges that bulge medially and extend the entire length of the platform margins.

Description: The carina extends the length of the platform, but in some specimens may terminate near the dorsal end by fusing with the caudal margin. The denticles of the free blade increase in size and height and become more blade like as they extend from the ventral platform. The platform has asymmetrical biconvex margins. The caudal margin is typically smaller than the rostral margin. Both of the margins are steep, transversely reclined ridges that bulge medially. The bases of the marginal ridges terminate at the base of the carina. Both margins bear weak transverse ridges that are more pronounced on the larger rostral margin. The basal cavity is smaller than to roughly the same size as the platform.

Discussion: Neognathodus sp. 3 may be distinguished from other *Neognathodus* species in this study by its biconvex, complete ridged margins. This form is similar to *N. intrala* as they both have ridged margins, but they differ in several ways. In many of the *N.* sp. 3 specimens, the carina extends the entire length of the platform and terminates at the dorsal tip whereas as in *N. intrala* the carina terminates before reaching the dorsal tip. The margin ridges are transversely reclined at a low angle in *N. intrala*, whereas in *N.* sp. 3 they tend to be fairly steep. The platform of *N. intrala* tends to have a more pronounced curvature and the margin ridges are rounded, whereas in *N.* sp. 3 they bulge medially and approach the dorsal tip at a straighter angle.

Distribution: It occurs through the entire thickness of the Kansas Highway 69 section but more abundant in the middle to upper parts of the Norris Creek Section (NC 8-21). It occurs near the base and in the upper Booneville section (BV 4, 15).

<u>*NEOGNATHODUS* sp. 4</u>
Plate 3, Specimens 16, 19, 20, 22-24

Diagnosis: On the P_1 element the carina extends the length of the platform. The rostral margin is a ridge and two or more nodes occur on the caudal side separated by a gap. A single node lies at the dorsal end followed by a large gap and typically two or more nodes near the ventral end of the platform.

Description: The P_1 element has a carina that extends the length of the platform. The carina tends to be fused medially and composed of tightly spaced nodes dorsally. Denticles on the free blade are thin and increase in size and height as they extend from the ventral platform. The platform margins are somewhat biconvex and bulge medially. On the rostral side of the platform margin is a steep, transversely reclined ridge that bulges medially and joins the base of the carina. The rostral margin bears transverse ridges from the medial bulge to the dorsal tip. The caudal margin is composed of one or two nodes at the dorsal end, a large gap, and then the presence of one or two nodes, sometimes elongated, at the medial bulge. The rostral margin and carina fuse to the dorsal tip. The basal cavity is outwardly flared and tends to extend further out on the caudal side of the element.

Discussion: Neognathodus sp. 4 resembles *N. roundyi* by the possession of nodes on the caudal margin. *Neognathodus* sp. 4 is distinguished by the dorsal node and gap with ventral nodes that is not present in other *Neognathodus* species in this study. Rosscoe (2005) described elements similar to these that also possess a gap in the caudal nodes as *N. expansus* (Jones, 1941), but the pattern of caudal nodes appear to be somewhat different.

Distribution: It occurs in the middle to upper parts of the Kansas Highway 69 section (KS69 17-27), and the middle to upper parts of the Norris Creek section (NC 8-18). It is more abundant in the middle part of Booneville section (BV 8-10, 15).

Family **GONDOLELLIDAE** Lindstrom 1970

Genus **GONDOLELLA** Stauffer and Plummer, 1932

Diagnosis: Segminiplanate P_1 element with row of denticles forming a medial ridge extending the length of the element. Platform of P_1 element is elongate with margins that are transversely crenulated along its full length.

Remarks: Gondolella is not a very common conodont but when it occurs it is often in great abundance (Merrill and von Bitter, 1976). The appearance of the oldest *Gondolella* with well-developed crenulated margins in the Midcontinent region is generally considered be in the Excello Shale (e.g., Barrick, et al., 2013). However, Stamm and Wardlaw (2003) suggested that a crenulated *Gondolella* species element discovered in the Chimney Rock Shale of the Paradox Formation in Utah is the oldest crenulated species of *Gondolella*. The formation is considered to be comparable in age as the uppermost Cherokee Lower Kittanning Cyclothem in the Appalachian Basin and the Verdigris Shale of the Midcontinent region.

GONDOLELLA WARDLAWI Nestell and Pope, 2016 (in Nestell et al., 2016)
Plate 4, Specimens 3, 4, 18-33

Diagnosis: A single large cusp is present at the ventral end of the platform that transitions to a row of medial nodal projections that extend the length of the platform. Large specimens are often heavily crenulated (rugose). Small and medium specimens typically have light to moderate crenulations. Crenulations run transversely from margin edge to a medial furrow running parallel along the medial ridge and terminate at the dorsal tip.

Description: The P_1 element is relatively thin and elongate with a single reclined ventral cusp. The platform has low nodal projections that form a low medial ridge that extends its length. Typically these ridges will range from 4 widely spaced to 10 closely spaced nodes. As the medial ridge approaches the dorsal end, the nodes become higher and more blade-like. Platform margins are heavily crenulated in specimens with a high node count and appear less so in examples with a low number of nodes. This is typically a function of element size; however some species do have slightly wider node spacing and in those samples it has been observed to correspond to a reduction in crenulations in those specimens. Conversely, smaller specimens with tighter node spacing tend to have more crenulations. A small thin smooth furrow of variable width borders the base of the medial ridge along the length of the platform. The basal cavity extends the length of the P_1element. At the ventral end it is a deep flared ring that transitions to deep V-shaped groove dorsally where it terminates at a point. In some larger specimens the platform margins terminate before the dorsal end, leaving only the small medial ridge at the dorsal tip.

Discussion: Gondolella wardlawi is similar to *Gondolella* sp. 2, but it may be distinguished by its reclined single ventral cusp whereas *G*. species 2 has two cusps. Nestell et al. (2016) provided comparisons of *G. wardlawi* to other *Gondolella* species. The *G. wardlawi* specimens in their study share all features in common with our material.

Distribution: It is restricted to thin intervals in the lower middle part of the Kansas Highway 69 section (KS69 12-18), the middle part of the Norris Creek Section (NC 9-12), and the lower middle part of the Booneville section (BV 4-8).

<u>GONDOLELLA</u> <u>sp.2</u>

Plate 4, Specimens 1, 2, 5-17

Diagnosis: Like *Gondolella wardlawi,* but with two or more cusps are present at the ventral end of the platform. The second cusp is often small and attached near to the base of the first cusp, but some examples have two large cusps.

Description: The P_1 element is elongate and often slightly curved with two reclined ventral cusps. Secondary cusps are typically large in adult specimens and smaller in juvenile specimens. The secondary cusp projects from the base of the primary cusp just above the basal cavity, often at an angle slanting in the same direction as the curve of the platform. The platform has small, low nodal projections that form a small ridge centrally that extend its entire length. Typically these will range from 4 widely spaced to 10 closely spaced nodes. As the medial ridge approaches the dorsal end the nodes become higher and more blade-like. Platform margins are transversely crenulated along their entire length. The size of the crenulations cover more of the margin in older, larger specimens with a high node count and slightly less so in examples with a low number of nodes. Crenulations are perpendicular and range from straight to slightly slanted down from the medial ridge outward toward the margin edge. A small thin smooth furrow of variable width lies between the base of the medial nodes and the transverse crenulations running the length of the platform. The basal cavity extends the length of the P_1 element. At the ventral end is a deep flared pit that transitions to a deep V-shaped groove as it moves dorsally where it terminates to a point.

Discussion: *Gondolella* sp. 2 is similar to *Gondolella wardlawi* in many ways, but is distinguished by the additional cusp protruding near the base of the primary cusp. *Gondolella* sp. 2 appears to be more crenulated in smaller specimens compared to *G. wardlawi,* in which smaller specimens with widely spaced nodes are not heavily crenulated, if at all. It is difficult to determine if *G.* species 2 is a separate species, or just a variant of *G*. *wardlawi*. *Gondolella* sp. 2 is far less abundant than *G. wardlawi* and only occurs in samples where *G. wardlawi* is present.

Distribution: It is restricted to a thin interval in the middle part of Kansas Highway 69 section (KS 69 16-18), the middle part of Norris Creek Section (NC 10-11), and the lower middle part of the Booneville section (BV 4-8)

Plate 1.
Conodont illustrations, *Idiognathodus* species. All are upper views of P_1 elements, X 50. Specimens are reposited in the collections in the Department of Geosciences, Texas Tech University.

1-18 *Idiognathodus acutus* Ellison, 1941.

1, 2, 12 – Kansas Highway 69, sample 21.

3, 4, 6, 13 – Booneville, sample 11.

5 – Norris Creek, sample 11.

7, 14, 16, 17 – Kansas Highway 69, sample 23.

8, 9, 10 – Norris Creek, sample 20

11 – Norris Creek, Sample 22

15 – Booneville, sample 9.

18 – Kansas Highway 69, sample 22.

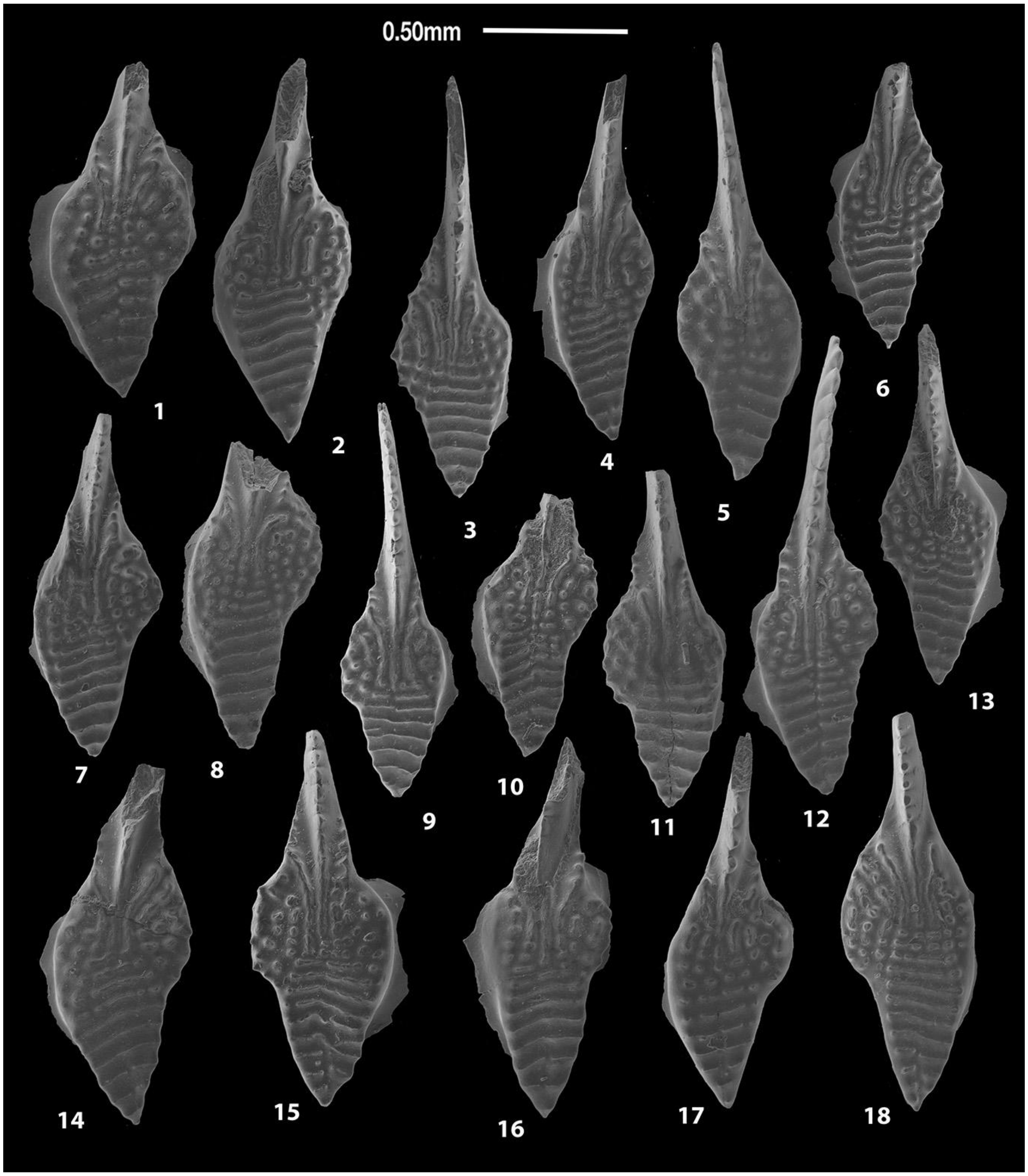
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Plate 2.

Conodont illustrations, *Idiognathodus* species. All are upper views of P_1 elements, X 50. Specimens are reposited in the collections in the Department of Geosciences, Texas Tech University

1-9 *Idiognathodus* sp. 2

1, 2, 3 - Norris Creek, sample 11.

4 - Boonevile, sample 11.

5, 7, 9 - Kansas Highway 69, sample 17.

6, 8 - Kansas Highway 69, sample 21.

10-13 *Idiognathodus* sp. 3.

10, 12, 13 – Kansas Highway 69, sample 10.

11 – Booneville, sample 3.

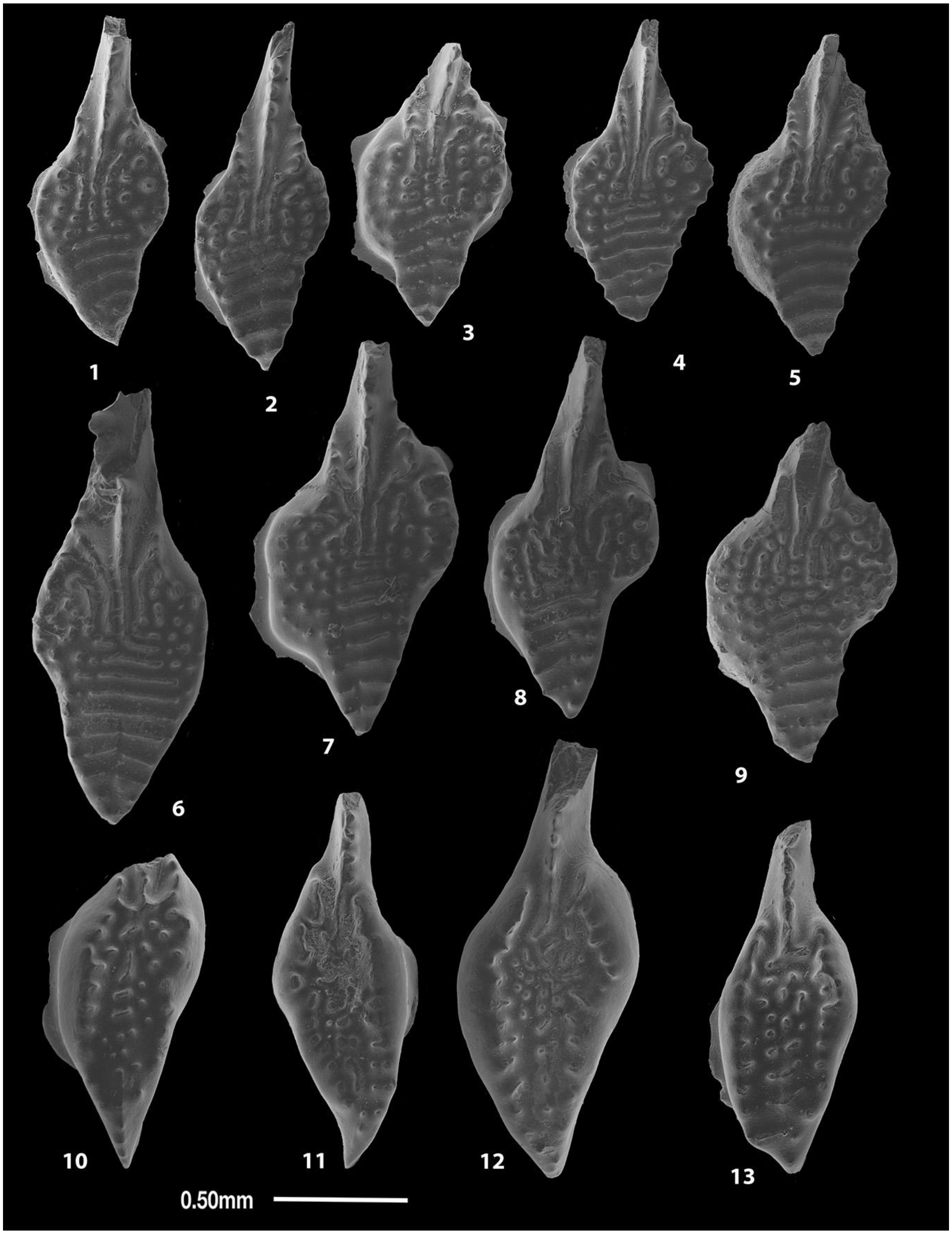
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Plate 3.

Conodont illustrations, *Neognathodus* species. All are upper views of P_1 elements, X 75. Specimens are reposited in the collections in the Department of Geosciences, Texas Tech University.

2, 3, 8, 9, 13, 15 *Neognathodus dilatus* (Stauffer and Plummer, 1932).

2, 3 – Booneville, sample 14.

8, 9 – Norris Creek, sample 9.

13 – Booneville, sample 5.

15 – Booneville, sample 15.

10, 14, 17, 21 *Neognathodus roundyi* (Gunnell, 1931).

10 – Booneville, sample 5.

14 – Booneville, sample 4.

17 – Kansas Highway 69, sample 21.

21 – Booneville, sample 12.

1, 4-7, 11, 12, 18 *Neognathodus* sp. 3.

1, 7, 12 – Booneville, sample 4.

4, 6, 11 – Norris Creek, sample 9.

5 - Norris Creek, sample 11.

18 – Kansas Highway 69, sample 24.

16, 19, 20, 22-24 *Neognathodus* sp. 4.

16 – Norris Creek, sample 8.

19 – Kansas Highway 69, sample 27.

20 – Kansas Highway 69, sample 26.

22 – Booneville, sample 14.

23 – Kansas Highway 69, sample 21.

24 – Booneville, sample 12.

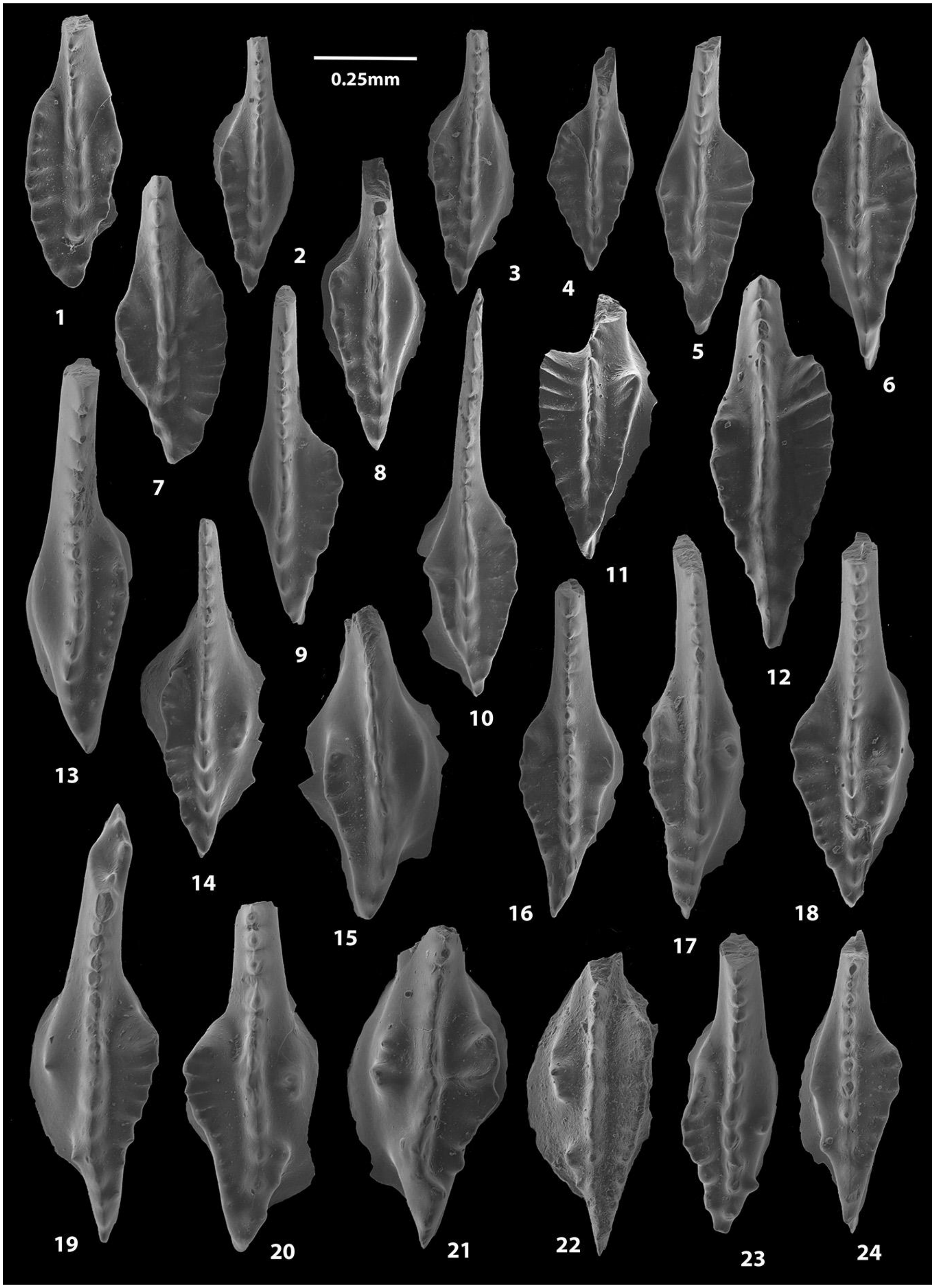
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Plate 4.

Conodont illustrations, *Gondolella* species. All are upper views of P_1 elements, except as noted, X 50. Specimens are reposited in the collections in the Department of Geosciences, Texas Tech University.

1, 2, 5-17 *Gondolella* sp. 2.

1, 5-8 Booneville, sample 5.

5, 6 – lateral and lower views of same element.

7, 8 – upper and lateral views of same element.

2, 9, 10, 11, 13, 17 Norris Creek sample 11.

9, 10 - lateral views.

13 – lateral view.

12, 14-17 Kansas Highway 69 sample 16.

15, 16 – upper and lateral view of same element.

3, 4, 18-33 *Gondolella wardlawi* Nestell and Pope, 2016.

3, 4, 27, 28, 30 Booneville, sample 7.

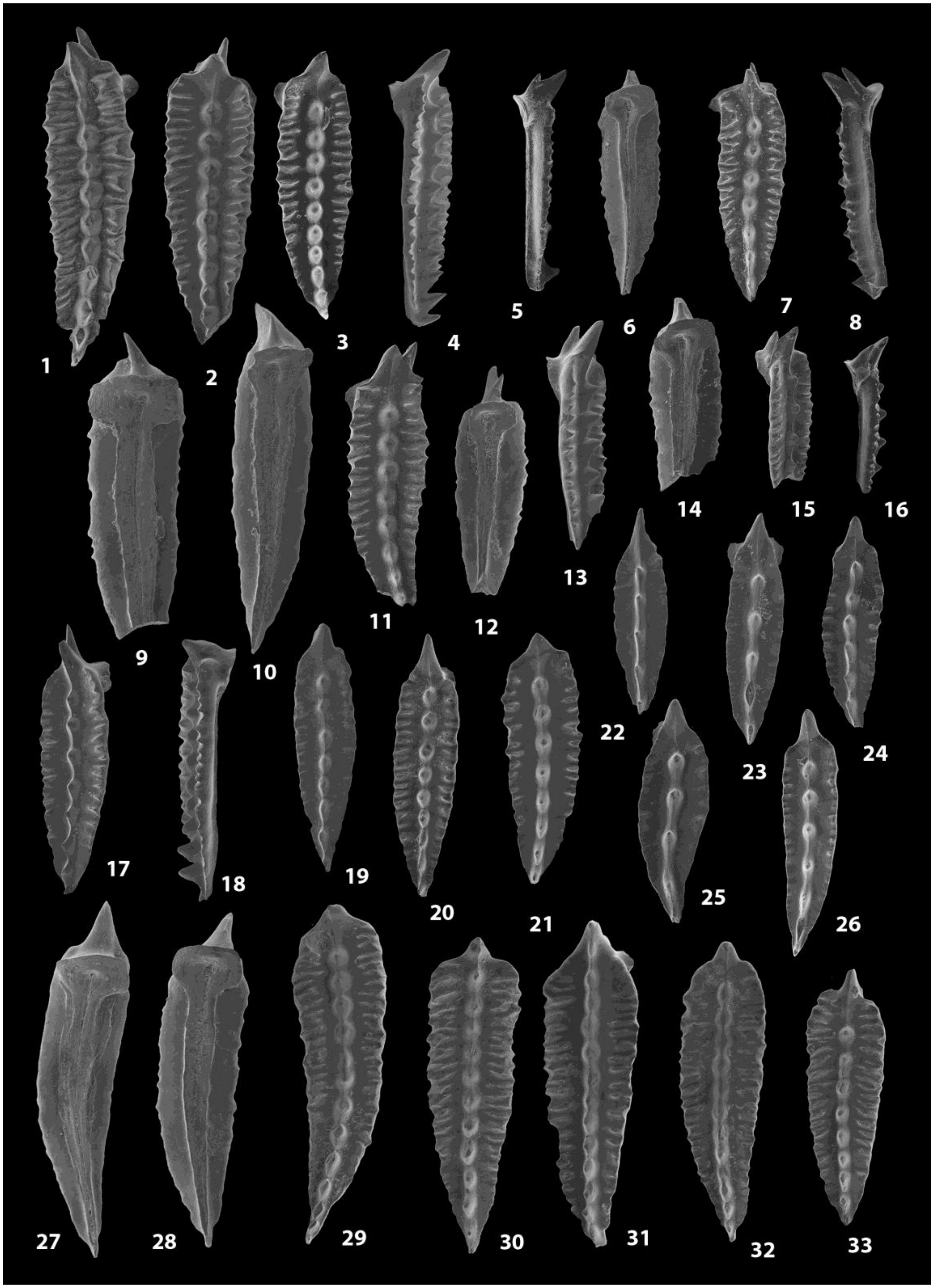
3, 4, - upper and lateral views of same element.

27, 28 – lower views.

18, 19, 21-26 Norris Creek, sample 11.

18 – lateral view

20, 29, 31-33 Kansas Highway 69, sample 16.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CHAPTER VI

SUMMARY AND CONCLUSIONS

The Excello Shale is the laterally extensive core shale of the Lower Fort Scott major cyclothem of the Desmoinesian Marmaton Group. It is the first major cyclothem of the group and lies above the Mulky Coal member, which marks the transition between the Cherokee and Marmaton groups. The Excello can generally be divided into a lower black shale facies and an upper gray shale facies. Phosphate laminations as well as phosphate nodules occur through the lower black shale, as well as rare acrotretid brachiopods. Three sections of the Excello in a south to north transect (Kansas Highway 69, Norris Creek, and Booneville) were sampled in small stratigraphic intervals (5-10 cm) and small samples (200 to 500 g) of the shale were completely processed in bleach to obtain an accurate census of conodont genera and species. Raw abundance data were converted to approximate numbers of conodont individuals.

The conodont fauna of the Excello Shale is abundant and characterized by elements of *Idiognathodus, Neognathodus, Gondolella, Idioprioniodus* and rare *Adetognathus* and *Hindeodus*. *Idiognathodus* dominates the faunas at nearly every level in both the black and gray facies. *Gondolella* is confined to a short interval (20-30 cm) roughly in the middle of the black shale, where it can rise to be more abundant than *Idiognathodus. Neognathodus* and *Idioprioniodus* occur in small numbers through the black and gray shale. Rare *Hindeodus* and *Adetognathus* were confined to the upper gray shale of the northern section at Booneville.

Idiognathodus elements were divided into three species, *I. acutus, I.* sp. 2 and *I.* sp. 3. *Idiognathodus acutus* dominates all samples, but in the more northern sections, *I.* sp. 2 becomes slightly more common. *Idiognathodus* sp. 3 is rare and generally occurs only near the base of the shale. Neognathodus comprises four species, *N. dilatus, N. roundyi, N*. sp. 3 and *N.* sp. 4. *Neognathodus dilatus* is relatively more common in the southern section, Kansas Highway 69, and *N. roundyi* and *N*. sp. 3 are relatively more common in the middle, Norris Creek, and northern, Booneville, sections. The two *Gondolella* species, *G. wardlawi* and the much rarer *G*. sp. 2 always occur together. The Excello conodont fauna is significantly different than the more diverse conodont fauna of the highest Cherokee cyclothem, the Verdigris. The Excello fauna resembles more closely the younger Marmaton conodont faunas, such as the Lost Branch fauna at the top of the Marmaton Group.

The current Midcontinent cyclothem model suggests a basal deepening followed by a series of shallowing upward environments capped by carbonate and nonmarine shale. The overall distribution of conodont genera is compatible with the general model of Pennsylvanian conodont biofacies in Midcontinent cyclothems. The *Gondolella* acme, which represents the deepest water, most offshore biofacies, occurs near the base in all three sections. In the Excello Shale, at the two offshore sections, Kansas Highway 69 and Norris Creek, the conodont faunas at the generic and species levels do not indicate a large change in the shallowing upward conodont biofaces above the *Gondolella* acme. Only at the more northern, more onshore section, Booneville, does the upper gray shale contain a nearshore conodont fauna with *Hindeodus* and *Adetognathus*. A more obvious difference in conodont biofacies is seen in the species distributions of *Idiognathodus* and *Neognathodus* above the *Gondolella* acme across the onshore-offshore transect of the three sections moving south to north. However, these onshore-offshore faunal changes were not found in the shallowing-upward succession in any of the three sections. We propose that the Midcontinent core shale sections may be too condensed to resolve more subtle differences in conodont distribution patterns, especially those at the species level, even with detailed sampling. Instead, a better representation of conodont species distribution can only be obtained in offshore-onshore transects that represent greater separation of shallower water shelf facies.

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APPENDIX A

SAMPLE DESCRIPTIONS

Kansas Highway 69 Section

The Kansas Highway 69 exposure is located at a road cut along US Highway 69 in southeastern Kansas and is 100 cm thick (Figure 7; Table A1). At the base, 10 cm (samples KS69, 10-11) is composed of very thin (papery) fissile grayish black (N2) to very dark gray (N3) shale with the presence of acrotretids. The next 10 cm (samples KS69, 12-13) is thick grayish black (N2) shale with a massive texture and is broken in to chunks rather than sheets. Above, 5 cm (sample KS69, 14) is papery fissile grayish black (N2) shale with the presence of very small phosphate nodules. Above, that is 10 cm (samples KS69,15-16) range from papery to platy fissile grayish black shale (N2).The next 5 cm (sample KS69,17) is composed of fissile papery dark grayish black shale (N2) with the presence of small phosphate nodules. Above that, 10 cm (samples KS69, 18-19) is composed of fissile papery dark grayish black shale (N2). The next 5 cm (sample KS69, 20) is fissile papery grayish black (N2) to dark gray (N3) with phosphate nodules. On top of that is 5 cm (sample KS69, 21) of a fissile papery dark grayish black (N2) to dark gray (N3) shale with layers of phosphate sand. The next 5 cm (sample KS69, 22) is papery fissile black shale (N2-N1) and above that 5 cm (sample KS69, 23) is somewhat fissile platy black shale (N2-N1) with moderate sized phosphate nodules. The following 5 cm (sample KS69, 24) is large chunks with platy laminations that are somewhat fissile and are gray black (N2) to dark gray (N3). The final 25 cm (sample KS69, 25-29) is grayish black (N2) to dark gray (N3) and very clayey and broken into non-fissile chunks.

Norris Creek Section

The Norris Creek section (NC) is a natural stream exposure in northwestern Missouri, southeast of Kansas City and lies about 105 miles north of KS69 and is 130 cm (Figure 8;Table A2) thick. The first 5 cm (sample NC, 1) of the section is papery fissile grayish black shale (N2) with layers of phosphate sand and acrotretids. The next 10 cm (samples NC, 2-3) is platy fissile grayish black shale (N2) with acrotretids. Following is 5 cm (sample NC, 4) of papery fissile grayish black shale (N2) with layers of phosphate sand. Above that, 5 cm (sample NC, 5) is papery fissile grayish black shale (N2) with small phosphate nodules and plant maceral and just above that, 5 cm (sample NC, 6) is composed of grayish black shale (N2) and has a thin layer of phosphate sand and acrotretids. The next 10 cm (samples NC, 7-8) is very dark fissile platy black shale (N2-N1) with large phosphate nodules, the shale layers deform around the nodules. The following 5 cm (sample NC, 9) is fissile platy dark black shale (N2-N1) with small phosphate nodules, layers of phosphate sand, and plant maceral. Above is 10 cm (samples NC, 10-11) of dark platy grayish black shale (N2) with layers of phosphate sand and plant maceral. On top of that is 5 cm (sample NC, 12) of grayish black shale (N2) broken in to large slabs with layer of phosphate sand, plant maceral, and acrotretids. Then 5 cm (sample NC, 13) is grayish black shale (N2) broken into slabs with phosphate or clay lenses and plant maceral. Then 10 cm (samples NC, 14-15) is platy dark gray shale (N2-N3) with small clay or phosphate lenses and somewhat fissile. The following 5 cm (sample NC, 16) is dark brownish gray platy shale (5YR4/1–N2). The next 15 cm (sample NC, 17-19) is medium dark gray (N4) well lithified with a clayey surface with phosphate lenses. The following 20 cm (sample NC, 20-23) is dark gray (N3) to medium gray (N5) platy chunks with a clayey surface and uneven laminations. Above that, 10 cm (samples NC, 24-25) is a medium olive to dark gray (N4-5Y5/2) very clayey and well lithified chunks of clay. The final 5 cm (sample NC, 26) is yellowish gray (5Y7/2-5Y6/4) very soft and porous clay.

Booneville Section

The Booneville section (BV) is a natural hillside exposure that lies just southwest of the Des Moines, Iowa, where the Excello Shale is 125 cm thick (Figure

9;Table A3). At the base of the section 5 cm (sample BV, 1) is a somewhat fissile gray black to brownish gray shale (N2-5YR4/1) with phosphate sand. The next 5 cm (sample BV, 2) is somewhat fissile medium dark gray shale (N4) with phosphate sand laminations. The following 5 cm (sample BV, 3) is brownish gray (5YR4/1), somewhat fissile and brittle with layer of phosphate sand. Then, 5 cm (sample BV, 4) is brownish black (5YR2/1) muddy, somewhat fissile, and platy. Above that 15 cm (sample BV, 5-7) is dark brownish gray to black (5YR4/1-5YR2/1) muddy chunks that are very brittle and soft. Then just above 5 cm (sample BV, 8) is platy laminated clayey medium gray (N5-5Y6/1). The next 5 cm (sample BV, 9) is clayey medium gray (N5-5Y6/1) with layers of phosphate sand and is brittle. The following 5 cm (sample BV, 10) is light olive gray (5Y6/1) with papery laminations and phosphate sand layers. Then 10 cm (sample BV, 11-12) is light olive gray (5Y6/1) with phosphate nodules and layers of interbedded phosphate sand and is brittle. Then following, 15 cm (sample BV, 13-15) is even lighter olive gray (5Y7/1) with thin layers of clay and phosphate sand. The next 5 cm (sample 16) is moderate yellow (5Y7/6) fossiliferous, porous clay and is very brittle. After that 20 cm (samples BV, 17-19) is yellowish gray clay (5Y7/2- 5Y6/4) that is fossiliferous, porous, and very brittle. The final 25 cm (sample BV, 19-21) is light yellowish gray clay (5Y7/2-5Y8/1) that is very brittle, porous, and fossiliferous.

Table A1: Kansas Highway 69 lithologic sample descriptions.

Sample #	Color code	Color	Details			
29	(N2)-(N3)	Grayish Black - Dark Gray	Non-fissile	Blocky	Very Clayey/Brittle	
28	(N2)-(N3)	Grayish Black - Dark Gray	Non-fissile	Blocky	Very Clayey/Hard	
27	(N2)-(N3)	Grayish Black - Dark Gray	Non-fissile	Blocky	Very Clayey/Hard	
26	(N2)-(N3)	Grayish Black - Dark Gray	Non-fissile	Blocky	Very Clayey/Hard	
25	(N2)-(N3)	Grayish Black - Dark Gray	Non-fissile	Blocky	Clayey/Hard	
24	(N2)-(N3)	Grayish Black - Dark Gray	Non-fissile	Platy	Hard	
23	(N2)-(N1)	Grayish Black - Black	Fissile	Platy	Hard	Phosphate nodules
22	(N2)-(N1)	Grayish Black - Black	Fissile	Papery	Hard	Phosphate nodules
21	(N2)-(N3)	Grayish Black - Dark Gray	Fissile	Papery	Hard	Phosphate laminations
20	(N2)-(N3)	Grayish Black - Dark Gray	Fissile	Papery	Soft	Phosphate nodules
19	(N2)	Grayish Black	Fissile	Papery	Hard	
18	(N2)	Grayish Black	Fissile	Papery	Soft	
17	(N2)	Grayish Black	Fissile	Papery	Soft	Small phosphate nodules

Table A1: Continued.

16	(N2)	Grayish Black	Non-fissile	Platy	Soft	
15	(N2)	Grayish Black	Fissile	Papery	Hard	
14	(N2)	Grayish Black	Fissile	Papery	Hard	Small phosphate nodules
13	(N2)	Grayish Black	Non-fissile	Blocky	Soft	
12	(N2)-(N1)	Grayish Black - Black	Non-fissile	Blocky	Hard	
11	(N2)-(N3)	Grayish Black - Dark Gray	Fissile	Papery	Soft	
10	(N2)	Grayish Black	Fissile	Papery/platy	Hard	Acrotretids

Table A2: Norris Creek lithologic sample descriptions.

Sample #	Color Code	Color	Details			
26	(5Y 7/2)-(5Y 6/4)	Yellowish Gray - Dusky Yellow	Non-fissile	Blocky	Clayey/soft	Porous
25	(N4)-(5Y 5/2)	Medium Dark Gray - Light Olive Gray	Non-fissile	Blocky	Clayey/soft	Clay laminations
24	(N4)-(5Y 5/2)	Medium Dark Gray - Light Olive Gray	Non-fissile	Blocky	Clayey/hard	
23	(N4)-(N5)	Medium Dark Gray - Medium Gray	Non-fissile	Platy	Clayey/hard	Clay lenses
22	(N4)	Medium Dark Gray	Non-fissile	Platy	Clayey/hard	
21	(N3)-(N4)	Dark Gray - Medium Dark Gray	Non-fissile	Blocky	Clayey/hard	
20	(N3)	Dark Gray	Non-fissile	Platy	Clayey/hard	
19	(N4)	Medium Dark Gray	Non-fissile	Blocky	Clayey/hard	Phosphate lenses
18	(N4)	Medium Dark Gray	Non-fissile	Blocky	Hard	Phosphate lenses
17	(N4)	Medium Dark Gray	Non-fissile	Blocky	Hard	
16	(5YR 4/1)-(N2)	Brownish Gray - Grayish Black	Non-fissile	Platy	Hard	
15	(N2)-(N3)	Grayish Black - Dark Gray	Non-fissile	Blocky	Hard	
14	(N2)-(N3)	Grayish Black - Dark Gray	Non-fissile	Platy	Hard	Small phosphate/clay lenses

Table A2: Continued.

13	(N2)	Grayish Black	Non-fissile	Platy	Hard	Plant maceral/small phosphate lenses
12	(N2)	Grayish Black	Non-fissile	Platy	Hard	Acrotretids/plant maceral/phosphate Sand
11	(N2)	Grayish Black	Non-fissile	Platy	Hard	Plant maceral/phosphate sand
10	(N2)-(N3)	Grayish Black - Dark Gray	Non-fissile	Platy	Hard	Plant maceral
9	(N2)-(N1)	Grayish Black - Black	Fissile	Platy	Soft	Plant maceral/small phosphate Nodules/phosphate sand
8	(N2)-(N1)	Grayish Black - Black	Fissile	Platy	Clayey/soft	Phosphate nodules, deformation around
7	(N2)-(N1)	Grayish Black - Black	Fissile	Platy	Hard	Large phosphate nodules, deformation around
6	(N2)	Grayish Black	Non-fissile	Blocky	Hard	Acrotretids
5	(N2)	Grayish Black	Fissile	Papery	Hard	Plant maceral/small phosphate Nodules
4	(N2)	Grayish Black	Fissile	Papery	Hard	Phosphate laminations
3	(N2)	Grayish Black	Non-fissile	Blocky	Hard	Acrotretids
2	(N2)	Grayish Black	Fissile	Platy	Soft	Acrotretids
1	(N2)	Grayish Black	Fissile	Papery	Soft	Acrotretids/phosphate sand

Table A3: Booneville lithologic sample descriptions.

Sample #	Color Code	color	Details			
21	(5Y 8/1)	Yellowish Gray	Non-fissile	Blocky	Soft/clayey/crumbles/porous	Fossiliferous
20	(5Y 7/2)	Yellowish Gray	Non-fissile	Blocky	Soft/clayey/crumbles/porous	Fossiliferous
19	(5Y 7/2)-(5Y 6/4)	Yellowish Gray - Dusky Yellow	Non-fissile	Blocky	Soft/clayey/crumbles/porous	Fossiliferous
18	(5Y 7/2)-(5Y 6/4)	Yellowish Gray - Dusky Yellow	Non-fissile	Blocky	Soft/clayey/crumbles/porous	Fossiliferous
17	(5Y 7/6)	Moderate Yellow	Non-fissile	Blocky	Soft/crumbles/porous	Fossiliferous
16	(5Y 7/2)	Yellowish Gray	Non-fissile	Blocky	Soft/clayey	Clay laminations
15	(5Y 7/2)	Yellowish Gray	Non-fissile	Blocky	Soft/clayey	
14	(5Y 7/2)	Yellowish Gray	Non-fissile	Blocky	Soft/clayey	Brown nodules
13	(5Y 6/1)	Light Olive Gray	Non-fissile	Blocky	Soft/crumbles	Phosphate laminations
12	(5Y 6/1)	Light Olive Gray	Non-fissile	Blocky	Soft/crumbles	Phosphate lenses and sand
11	(5Y 6/1)	Light Olive Gray	Non-fissile	Papery	Soft/clayey/crumbles	Phosphate laminations
10	(5Y 6/1)	Light Olive Gray	Non-fissile	Blocky	Soft	Phosphate laminations
9	(N5)-(5Y 6/1)	Medium Gray - Light Olive Gray	Non-fissile	Blocky	Soft/clayey/crumbles	Phosphate laminations

Table A3: Continued.

8	(N5)-(5Y 6/1)	Medium Gray - Light Olive Gray	Non-fissile	Platy	Soft/clayey	
7	(5YR 4/1)	Brownish Gray	Non-fissile	Blocky	Soft/crumbles	
6	(5YR 2/1)	Brownish Black	Non-fissile	Blocky	Soft/muddy/crumbles	
5	(5YR 4/1)	Brownish Gray	Non-fissile	Blocky	Soft/crumbles	
4	(5YR 2/1)	Brownish Black	Mildly fissile	Platy	Soft/muddy	Phosphate laminations
3	(5YR 4/1)	Brownish Gray	Mildly fissile	Blocky	Soft/crumbles	Phosphate laminations
2	(N4)	Medium Dark Gray	Mildly fissile	Blocky	Hard	Phosphate laminations
1	(N2)-(5YR 4/1)	Grayish Black - Brownish Gray	Mildly fissile	Blocky	Soft/muddy	Phosphate laminations

APPENDIX B

TABLES OF CONODONT GENERA BY SAMPLE

Two tables are given for each stratigraphic section.

The first table for each section shows the raw counts of conodont elements by sample number and stratigraphic level. The weight processed in kilograms for each sample is provided. All elements of *Idioprioniodus* were counted, but only the P_1 elements for the other genera.

The second table shows the calculated numbers of conodont individuals per kilogram, as explained in the text.

AD = *Adetognathus*
HD = *Hindeodus*
NEOG = *Neognathodus*
IDGN = *Idiognathodus*
IDPR = *Idioprioniodus*
GOND = *Gondolella*

Table B1. Raw counts of elements in the Kansas Highway 69 section.

KS69	level	weight	AD	HD	NEOG	IDGN	IDPR	GOND	SUM
10	0.025	0.5	0	0	2	99	74	0	175
11	0.075	0.5	0	0	2	22	78	1	103
12	0.125	0.2	0	0	11	17	79	2	109
13	0.175	0.2	0	0	12	58	67	3	140
14	0.225	0.2	0	0	14	61	80	0	155
15	0.275	0.2	0	0	13	49	55	7	124
16	0.325	0.2	0	0	9	124	43	181	357
17	0.375	0.2	0	0	6	83	28	104	221
18	0.425	0.2	0	0	4	38	24	34	100
19	0.475	0.5	0	0	5	52	71	0	128
20	0.525	0.2	0	0	8	50	37	0	95
21	0.575	0.2	0	0	27	125	95	0	247
22	0.625	0.2	0	0	38	181	34	0	253
23	0.675	0.2	0	0	42	100	44	0	186
24	0.725	0.2	0	0	54	250	34	0	338
25	0.775	0.2	0	0	22	122	48	0	192
26	0.825	0.2	0	0	51	198	77	0	326
27	0.875	0.2	0	0	63	229	68	0	360
28	0.925	0.2	0	0	17	578	9	0	604
29	0.975	0.2	0	0	7	22	14	0	43
30	1.1	1	0	0	0	6	6	0	12

Table B2. Calculated number of conodont individuals per kilogram in the Kansas Highway 69 section.

KS69	AD	HD	NEOG	IDGN	IDPR	GOND	SUM
10	0	0	2	99	74	0	175
11	0	0	2	22	78	1	103
12	0	0	11	17	79	2	109
13	0	0	12	58	67	3	140
14	0	0	14	61	80	0	155
15	0	0	13	49	55	7	124
16	0	0	9	124	43	181	357
17	0	0	6	83	28	104	221
18	0	0	4	38	24	34	100
19	0	0	5	52	71	0	128
20	0	0	8	50	37	0	95
21	0	0	27	125	95	0	247
22	0	0	38	181	34	0	253
23	0	0	42	100	44	0	186
24	0	0	54	250	34	0	338
25	0	0	22	122	48	0	192
26	0	0	51	198	77	0	326
27	0	0	63	229	68	0	360
28	0	0	17	578	9	0	604
29	0	0	7	22	14	0	43
30	0	0	0	6	6	0	12

Table B3. Raw counts of elements in the Norris Creek section.

Norris Creek	level	weight	AD	HD	NEOG	IDGN	IDPR	GOND	SUM
1	0.025	0.2	0	0	8	79	55	0	142
2	0.075	0.2	0	0	10	42	32	0	84
3	0.125	0.2	0	0	3	28	8	0	39
4	0.175	0.2	0	0	0	5	46	0	51
5	0.225	0.2	0	0	16	16	81	0	113
6	0.275	0.2	0	0	7	24	37	1	69
7	0.325	0.2	0	0	3	26	33	1	63
8	0.375	0.2	0	0	24	59	49	0	132
9	0.425	0.5	0	0	48	106	101	55	310
10	0.475	0.2	0	0	16	150	22	130	318
11	0.525	0.2	0	0	30	207	30	375	642
12	0.575	0.2	0	0	14	94	36	35	179
13	0.625	0.2	0	0	7	29	27	1	64
14	0.675	0.2	0	0	22	63	58	0	143
15	0.725	0.2	0	0	6	14	22	0	42
16	0.775	0.2	0	0	29	104	51	0	184
17	0.825	0.2	0	0	1	16	6	0	23
18	0.875	0.2	0	0	16	41	11	0	68
19	0.925	0.2	0	0	0	0	0	0	0
20	0.975	0.2	0	0	9	57	18	0	84
21	1.025	0.2	0	0	10	59	26	0	95
22	1.075	0.2	0	0	3	97	21	0	121
23	1.125	0.5	0	0	52	212	96	0	360
24	1.175	0.5	0	0	13	139	31	0	183
25	1.225	0.5	0	0	53	193	49	0	295
26	1.275	0.5	0	1	3	16	19	0	39
27	1.35	1.4	0	0	2	10	6	0	18

Table B4. Calculated number of conodont individuals per kilogram in the Norris Creek section.

Norris Creek	AD	HD	NEOG	IDGN	IDPR	GOND	SUM
1	0	0	20	198	19	0	237
2	0	0	25	105	11	0	141
3	0	0	8	70	3	0	81
4	0	0	0	13	16	0	29
5	0	0	40	40	27	0	107
6	0	0	18	60	13	3	94
7	0	0	8	65	11	3	87
8	0	0	60	148	17	0	225
9	0	0	120	265	34	138	557
10	0	0	40	375	8	325	748
11	0	0	75	518	10	938	1541
12	0	0	35	235	12	88	370
13	0	0	18	73	9	3	103
14	0	0	55	158	20	0	233
15	0	0	15	35	8	0	58
16	0	0	73	260	17	0	350
17	0	0	3	40	2	0	45
18	0	0	40	103	4	0	147
19	0	0	0	0	0	0	0
20	0	0	23	143	6	0	172
21	0	0	25	148	9	0	182
22	0	0	8	243	7	0	258
23	0	0	52	212	13	0	277
24	0	0	13	212	5	0	230
25	0	0	53	193	7	0	253
26	0	1	3	16	3	0	23
27	0	0	1	4	1	0	6

Table B5. Raw counts of elements in the Booneville section.

Booneville	level	weight	AD	HD	NEOG	IDGN	IDPR	GOND	SUM
1	0.025	0.2	0	0	0	36	45	0	81
2	0.075	0.2	0	0	3	61	61	0	125
3	0.125	0.2	0	0	25	101	144	0	270
4	0.175	0.2	0	0	48	130	105	135	418
5	0.225	0.2	0	0	17	158	77	272	524
6	0.275	0.2	0	0	1	53	25	143	222
7	0.325	0.2	0	0	1	26	39	146	212
8	0.375	0.2	0	0	6	25	46	37	114
9	0.425	0.2	0	0	19	48	73	0	140
10	0.475	0.2	0	0	5	14	31	0	50
11	0.525	0.2	0	0	9	81	48	0	138
12	0.575	0.2	0	0	14	38	31	0	83
13	0.625	0.2	0	0	6	73	39	0	118
14	0.675	0.2	0	0	10	45	41	0	96
15	0.725	0.5	0	0	11	56	39	0	106
16	0.775	0.5	0	0	19	159	93	0	271
17	0.85	1	0	10	5	47	46	3	111
18	0.95	1	0	4	5	50	32	0	91
19	1.05	1	0	11	5	68	40	0	124
20	1.15	1	0	29	1	63	8	0	101
21	1.32	1	0	13	4	123	5	0	145
22	1.45	2	19	36	2	297	5	0	359

Table B6. Calculated number of conodont individuals per kilogram in the Booneville section.

Booneville	AD	HD	NEOG	IDIGN	IDPR	GOND	SUM
1	0	0	0	90	15	0	105
2	0	0	8	153	21	0	182
3	0	0	63	253	48	0	364
4	0	0	120	325	35	338	818
5	0	0	43	395	26	680	1144
6	0	0	3	133	9	358	503
7	0	0	3	65	13	365	446
8	0	0	15	63	16	93	187
9	0	0	48	120	25	0	193
10	0	0	13	35	11	0	59
11	0	0	23	203	16	0	242
12	0	0	35	95	11	0	141
13	0	0	15	183	13	0	211
14	0	0	0	113	14	0	127
15	0	0	48	397	13	0	458
16	0	25	13	118	7	0	163
17	0	5	3	24	4	3	39
18	0	2	3	25	3	0	33
19	0	6	3	34	3	0	46
20	0	15	1	32	1	0	49
21	0	7	2	62	1	0	72
22	1	9	1	75	1	0	87

APPENDIX C

TABLES OF SPECIES

Table C1: Raw conodont abundance data of P_1 elements of species in the Excello Shale from the Kansas Highway 69 section, samples 10-19.Data has not been adjusted for sample size.

Kansas Highway 69 section - sample	10	11	12	13	14	15	16	17	18	19
Idiognathodus acutus	37	6	3	24	15	16	62	18	10	14
Idiognathodus species 2				2	4	3	22	10		1
Idiognathodus species 3	6	4	2		5	2				
Neognathodus dilatus	1	1	1	3			3		1	
Neognathodus roundyi			1			1				
Neognathodus species 3	1			4	2		3	1	2	
Neognathodus species 4								1		
Gondolella wardlawi				2	3		1	98	80	26
Gondolella species 2								13	5	2

Table C2: Raw conodont abundance data of P_1 elements of species in the Excello Shale from the Kansas Highway 69 section, samples 20-28. Data has not been adjusted for sample size.

Kansas Highway 69 section - sample	20	21	22	23	24	25	26	27	28
Idiognathodus acutus	18	51	26	34	60	21	33	67	57
Idiognathodus species 2	2	9	1	3	2	1	1	7	5
Idiognathodus species 3									
Neognathodus dilatus		5	10	11	12	4	14	31	10
Neognathodus roundyi		1	6	5	2	3	2	11	1
Neognathodus species 3	1	7		5	1	4	5	1	1
Neognathodus species 4	1	2		3		2		4	
Gondolella wardlawi									
Gondolella species 2									

Table C3: Raw conodont abundance data of P_1 elements of species in the Excello Shale from the Norris Creek section, samples 1-10. Data has not been adjusted for sample size.

Norris Creek section - sample	1	2	3	4	5	6	7	8	9	10
Idiognathodus acutus	17	6	6	1	7	7	7	5	53	23
Idiognathodus species 2	1	1	1				3	3	19	9
Idiognathodus species 3	4	1		1	3					
Neognathodus dilatus	1				5	1			1	2
Neognathodus roundyi	2	2	1			2		1	4	2
Neognathodus species 3	1							5	35	8
Neognathodus species 4								2	5	2
Gondolella wardlawi									20	88
Gondolella species 2										11

Table C4: Raw conodont abundance data of P_1 elements of species in the Excello Shale from the Norris Creek section, samples 11-21. Data has not been adjusted for sample size.

Norris Creek section - sample	11	12	13	14	15	16	17	18	19	20	21
Idiognathodus acutus	99	36	5	32	2	42	5	8		25	21
Idiognathodus species 2	21	8	2	7						2	4
Idiognathodus species 3											
Neognathodus dilatus	8	3	1	4		12		3		1	2
Neognathodus roundyi	4	2	1	3		3		1			2
Neognathodus species 3	9	5	3	5	3	5		4		3	2
Neognathodus species 4	1			3	1			1			
Gondolella wardlawi	283	28									
Gondolella species 2	18										

Table C5: Raw conodont abundance data of P_1 elements of species in the Excello Shale from the Booneville section, samples 1-7. Data has not been adjusted for sample size.

Booneville Section - sample	1	2	3	4	5	6	7
Idiognathodus acutus	6	8	15	57	63	35	3
Idiognathodus species 2	4	1	3	21	25	20	5
Idiognathodus species 3	1	5	3	6	5		
Neognathodus dilatus			1				
Neognathodus roundyi		3	4	2	1		
Neognathodus species 3				27	10		
Neognathodus species 4			1				
Gondolella wardlawi				95	182	90	111
Gondolella species 2				7	7	19	11

Table C6: Raw conodont abundance data of P_1 elements of species in the Excello Shale from the Booneville section, samples 8-15. Data has not been adjusted for sample size.

Booneville Section - sample	8	9	10	11	12	13	14	15
Idiognathodus acutus	14	24	9	51	17	28	23	28
Idiognathodus species 2	4	7		6	2	2	1	2
Idiognathodus species 3								
Neognathodus dilatus	1	3	1	2	5	3	3	2
Neognathodus roundyi		1	1	1	2			1
Neognathodus species 3	3	5	1	1			1	2
Neognathodus species 4	2	2	1					1
Gondolella wardlawi	26							
Gondolella species 2	2							