2013. Proceedings of the Indiana Academy of Science 122(1):27–34

CONODONT BIOSTRATIGRAPHY OF A SHALE LENS OVERLYING THE BUCKTOWN COAL MEMBER OF THE DUGGER FORMATION (PENNSYLVANIAN, DESMOINESIAN), PIKE COUNTY, INDIANA

Alexander Zimmerman: Department of Geology, Lake Superior State University, Sault Ste. Marie, Michigan 49783 USA

Lewis M. Brown: Department of Geology, Lake Superior State University, Sault Ste. Marie, Michigan 49783 USA

Carl B. Rexroad: Indiana Geological Survey, 611 North Walnut Grove Avenue, Bloomington, Indiana 47405 USA

ABSTRACT. We collected conodonts from black and gray shale lenses containing limestone nodules lying immediately above the Bucktown Coal Member of the Dugger Formation (Pennsylvanian, Desmoinesian) in a Solar Sources Pride Creek pit 2 miles south of Petersburg in Pike County, Indiana. The shale lens varied from approximately 0.6 to 0.92 m in thickness and was approximately 190 m wide. Our objectives included describing the fauna, interpreting the paleoenvironment, and continuing the establishment of regional correlations in the Midcontinent. We processed ten samples, nine productive, from four intervals along the pit face and identified 507 elements to species level. Conodont faunas are dominated by *Idiognathodus* and *Adetognathus*. *Neognathodus*, *Hindeodus*, and *Idioprioniodus* are rare.

Adetognathus is uncommonly abundant, indicating that the depositional environment of the shales was very restricted, low energy, shallow-water, possibly a lagoon or a small embayment. The extremely high juvenile to adult ratio of *Idiognathodus* suggests that the paleoenvironment was harsh and resulted in a high juvenile mortality rate. The rare *Idioprioniodus* elements further suggest low-energy, reducing conditions but the fragmentation of the *Idioprioniodus* and *Hindeodus* elements may indicate introduction into the depositional site by irregular storm events. The rarity of *Neognathodus* shows its lack of tolerance for highly euryhaline conditions.

The restricted environmental conditions resulted in a lack of generic and specific diversity, particularly the rarity of *Neognathodus*, the primary biostratigraphic indicator for the Desmoinesian Series. Thus, there are insufficient data for regional correlations.

We interpret the geographically restricted basal black shales overlying the coal to be of flotant marsh origin, representing a localized flooding event. Distributary channels associated with a deltaic system subsequently delivered fresh water that resulted in deposition of brackish water gray shales. The evidence supports a model of localized control on sedimentation rather than sedimentation controlled by glacially influenced eustatic sea level change.

Keywords: Conodonts, Bucktown Coal Member, Dugger Formation, Pennsylvanian

INTRODUCTION

The objectives of our investigation of the conodonts of the Desmoinesian Bucktown Coal Member of the Dugger Formation in the eastern part of the Illinois Basin in Indiana included describing the conodonts, furthering the development of a stable Pennsylvanian conodont taxonomy, interpreting paleoenvironments, and continuing the establishment of regional correlations in the Midwest.

We collected a total of ten 1-kg samples, nine productive, from four closely spaced locations in the Solar Sources Pride Creek Pit about 3 km south of Petersburg in Pike County, Indiana, in the vicinity of coordinates 38° 27′ 01.59″ N, 87° 16′ 19.98″ W (fig. 1). These ditch samples were collected over intervals of lithologic homogeneity not exceeding 0.5 m in thickness (fig. 2). The locations sampled were approximately 60 m apart along the face of the pit with Location A to the west and Location D to the east (fig. 3). The samples are from marine shales, both gray

Corresponding author: Carl B. Rexroad, IN Geological Survey, 611 N. Walnut Grove Avenue, Bloomington, IN 47405, 812-855-1350, 812-855-2862 (fax), e-mail: crexroad@indiana.edu.

Figure 1.—Map of Indiana showing collecting locality for the Bucktown Coal Member of the Dugger Formation. Solar Sources Pit is in the vicinity of 38° 27′ 01.59″ N, 87° 16′ 19.98″ W.

and black, containing limestone nodules, with the black shale lying directly on the Bucktown Coal. The marine shale itself was just about 2 m thick and was not continuous as it extended for only about 180 m. Our focus in this study is on the conodonts that we extracted from this geographically restricted lens of shale overlying the Bucktown Coal.

Recovery in conodont bearing-samples ranged from one element from the black shale in Location D and from the gray shale at the top of Location B to 160 elements from the gray shale at the top of Location A. In total, 507 identifiable specimens representing five genera and four named species were recovered (Table 1). About 86 percent are Pa elements. This reflects the usual overrepresentation of Pa elements reported for most Pennsylvanian studies. With the exception of Location B, conodonts were generally more abundant in the upper gray shales than in the lower black shales and generally increased upward in the section (fig. 3). We interpret the irregular element distribution to show variation in environmental conditions in time and also laterally within a very limited geographic area.

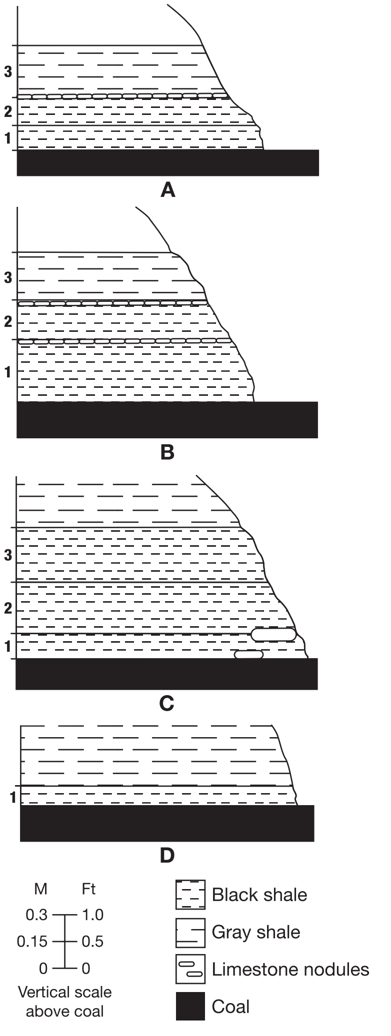

Figure 2.—Columnar sections showing general lithologies and sample numbers for intervals collected for the Bucktown Coal Member of the Dugger Formation.

STRATIGRAPHY AND SEDIMENTATION

In Indiana, the Dugger Formation of the Carbondale Group was first recognized by Wier (1950) for exposures of sandstone, shale, coal, and limestone 3 km northeast of the town of Dugger in Sullivan County, Indiana. He placed the lower boundary of the formation at the unconformity above the Alum Cave Limestone Member (Wier, 1950, 1952) but the boundary was later lowered to include both the Alum Cave and black shale underlying it in the Dugger Formation (Wier and Gray, 1961). The Tri-State Committee on Correlation of the Pennsylvanian System in the Illinois Basin (2001) defined the Dugger to include the strata from the top of the Springfield Coal Member of the Petersburg Formation to the top of the

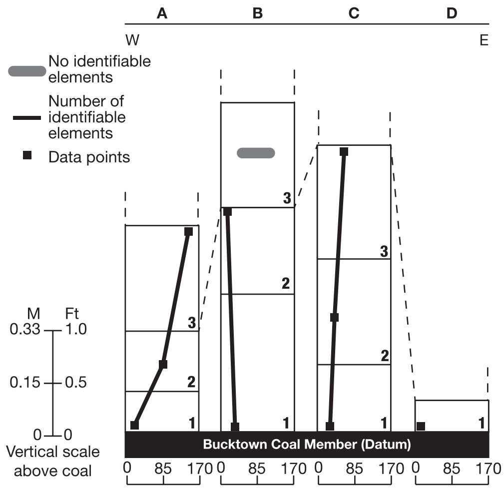

Figure 3.—Lithologic units, sampling locations, and sampling intervals. Scale of identifiable elements is at the base of each column. Approximately 60 m separate each sampling location.

Danville Coal Member. The strata include, in ascending order, the following named units: the Alum Cave Limestone, Antioch Limestone, Bucktown Coal, Herrin Coal, Providence Limestone, Hymera Coal, Anvil Rock/Bridge Junction Sandstone, Universal Limestone, and Danville Coal, and intervening unnamed beds of shale, sandstone, and coal (fig. 4).

The Bucktown Coal Member was first proposed by Wier in an unpublished manuscript and was first published by Burger and Wier (1970) who designated a type section near Bucktown in Sullivan County, Indiana. It was proposed for a coal that ranges from 0.3 to 1.2 m and averages 0.4 m in thickness but in places contains a shale parting as much as 3.4 m thick. The coal lies stratigraphically 3 to 20 m above the Springfield Coal Member of the Petersburg Formation and is commonly overlain by a black shale. The Bucktown has been correlated with the Briar Hill, formerly 5A, Coal Member of the Carbondale Formation in Illinois (fig. 4) (Hopkins and Simon, 1975). It has also been correlated with the Briar Hill, or Western Kentucky Number 10, Coal of the Carbondale Formation in Kentucky (Burger and Wier, 1970; Greb and others, 1992). Greb and others (2003), however, did not accurately represent the Tri-State Commission (2001) correlations in their study (see their fig. 2). They attribute Briar Hill to the Tri-State nomenclature, but the Tri-State Commission nowhere addresses Briar Hill or Briar Hill correlations.

Table 1.—Distribution of conodonts in the primary 1-kg samples of the Bucktown Coal Member of the Dugger Formation in Indiana by sample and location (see Figures 1 and 2 for locations and sample intervals).

	Location	A			B		C				
	Sample	1	2	3	1	2	1	2	3	D	Totals
Idiognathodus delicatus adult	Pa	1	2	7	-	1	-	1	2	-	**14**
I. delicatus juvenile	Pa	9	48	76	13	43	12	7	35	1	**244**
Neognathodus sp.	Pa	1	-	-	-	-	-	-	-	-	**1**
I/N ramiforms	Pb	-	2	10	2	8	3	2	10	-	**37**
	M	-	-	2	-	-	-	1	-	-	**3**
	Sb	-	-	1	-	-	1	1	-	-	**3**
	Sc	-	-	1	-	1	-	5	1	-	**8**
Hindeodus minutus	Pa	-	-	-	-	-	-	2	-	-	**2**
	M	-	1	-	-	-	-	1	-	-	**2**
	Sb	-	-	-	-	-	-	1	-	-	**1**
Idioprioniodus conjunctus	Pa	-	-	-	-	-	1	-	-	-	**1**
	M	-	-	-	-	-	-	-	1	-	**1**
	Sa	-	-	1	-	-	-	-	-	-	**1**
	Sc	-	-	1	-	-	-	-	-	-	**1**
Adetognathus lautus	Pa	1	29	60	7	47	12	11	10	-	**177**
	Pb	-	-	-	-	-	-	1	-	-	**1**
	M	1	1	-	-	-	1	-	1	-	**4**
	Sc	-	-	1	-	-	-	4	1	-	**6**
Totals		**13**	**83**	**160**	**22**	**100**	**30**	**37**	**61**	**1**	**507**

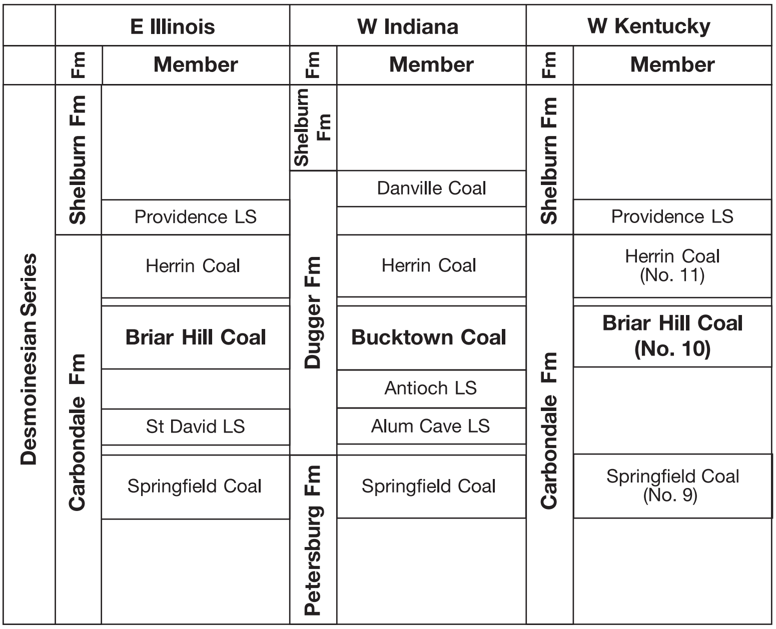

Figure 4.—Chart showing correlations of named stratigraphic units for part of the Desmoinesian Series in Indiana. No thicknesses are implied by the position of the names. Modified from Tri-State Committee on Correlation of the Pennsylvanian System in the Illinois Basin, 2001.

THE CONODONT FAUNA

As is commonly the case with Pennsylvanian conodont studies, Pa elements of *Idiognathodus* dominate the collection. We assign these morphotypes to *Idiognathodus delicatus* Gunnell. *Adetognathus lautus* (Gunnell) is found in 90 percent of the samples and it ranges from 9 percent to 52 percent of the total Pa elements. Elements of *Hindeodus minutus* (Ellison) and *Idioprioniodus conjunctus* (Gunnell) are rare and we recovered only one broken element of *Neognathodus* sp. cf. *medexultimus* Merrill. The collection is reposited in the Indiana Geological Survey/Indiana University repository as numbers 18,225 through 18,267.

Many workers recognize that early ontogenetic specimens of *Idiognathodus* have morphologic features of another genus, *Streptognathodus* (for example, Van den Boogaard and Bless, 1985: Sweet, 1988). *Streptognathodus*-like morphologies develop paedomorphically from *Idiognathodus* in that *Streptognathodus* retains a trough into the adult stage, whereas in *Idiognathodus*, the trough fills (Brown and Rexroad, 2009). In our collection we have an excellent example of the ontogenetic growth stages of *Idiognathodus* (Plate 1). In most juvenile specimens of *Idiognathodus*, the carina extended to the posterior tip of the platform. During ontogeny the oral surface of the platform surrounding the carina gradually filled in progressively from the posterior tip towards the anterior part of the platform. This process resulted in the filling of the trough with the transverse ridges that define adult *Idiognathodus*. Additionally, ancillary nodes began to develop and grow with ontogeny. We believe that infilling of the trough and ancillary lobe development was environmentally driven and carries no taxonomic significance. Thus, we do not agree with those workers who split species on the basis of numbers of transverse ridges, morphology of the transverse ridges, or number or morphology of the ancillary nodes (for example, Lambert and others, 2003). Instead we accept variation in platform morphologic features as attributable to both ontogeny and the effects of environmental conditions on growth.

We think that the complex relationships that exist between *Idiognathodus* and *Streptognathodus* must be investigated from the inception of these morphologies, from Morrowan and Atokan time, and that all troughed and partially troughed forms prior to Missourian

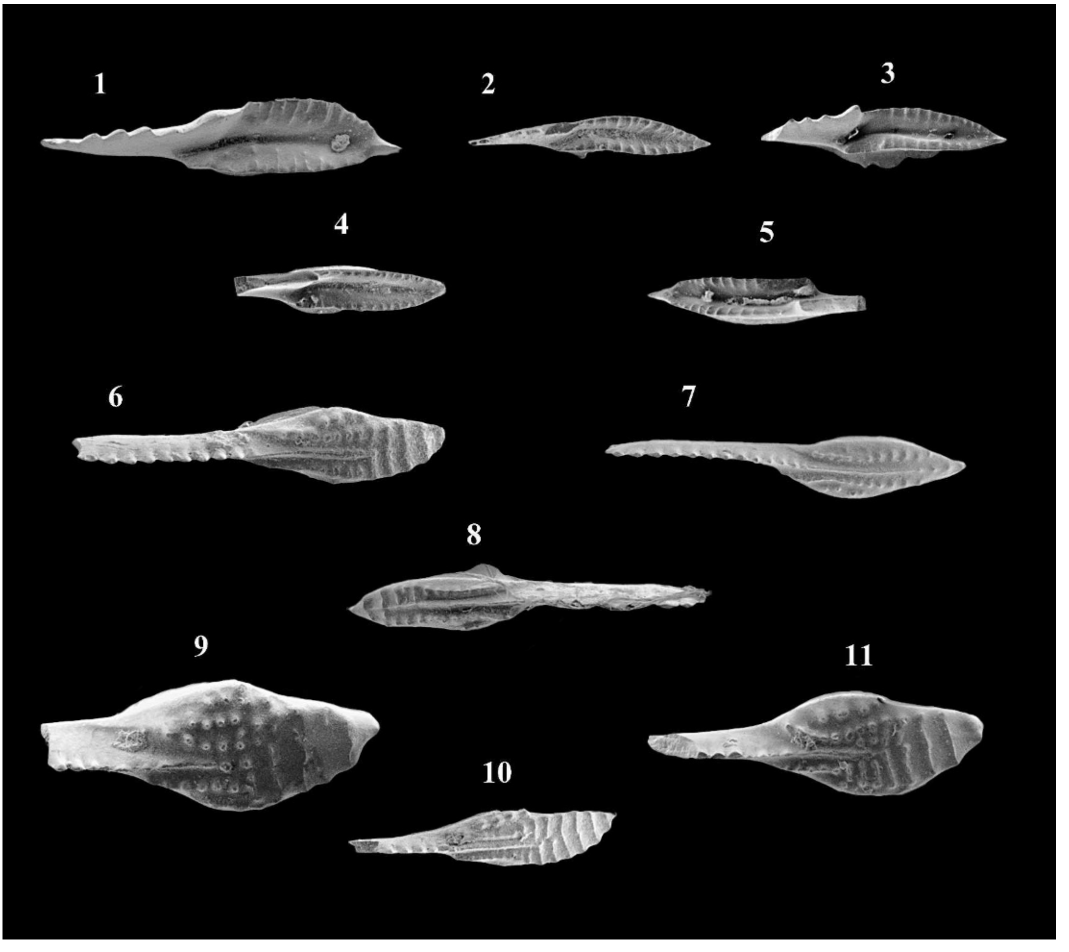

Plate 1.—Scanning electron microscope photographs. Magnifications are X40; locality and sample numbers are in parentheses following the repository number.

should be excluded from *Streptognathodus*. Therefore, in the Desmoinesian, we recognize only one genus, *Idiognathodus*.

We base Desmoinesian zonations on populations of *Neognathodus* species (Merrill 1972, 1975, 1999; Brown and others, 1991; Rexroad and others, 2001; Brown and Rexroad, 2009). Unfortunately, in this study we recovered only one broken Pa element on *Neognathodus*. The carina appears to exhibit a greater amount of fusion of the nodes than is common in this species and we attribute this to the influence of harsh environmental conditions. Based on only one specimen, we cannot meet our goal of contributing to regional correlation other than to say that the specimen exhibits characteristics of Desmoinesian neognathodids.

PALEOECOLOGY

Even though we recognize that the number of elements in our collection is relatively small, we propose an interpretation of the environmental setting that resulted from the deposition of the black and gray shales that overlie the Bucktown Coal Member. The section represents generally shallow-water, low-energy, moderately to highly stressed, euryhaline marine conditions. However, there is great variability in conodont distributions, both vertically and laterally.

Conodonts are more abundant in the upper gray shale of Location A than they are in the lower black shales of all locations (fig. 3). But the opposite is true of Location B, in which the upper gray shale is almost barren. Thus the gray shales do not represent a uniform

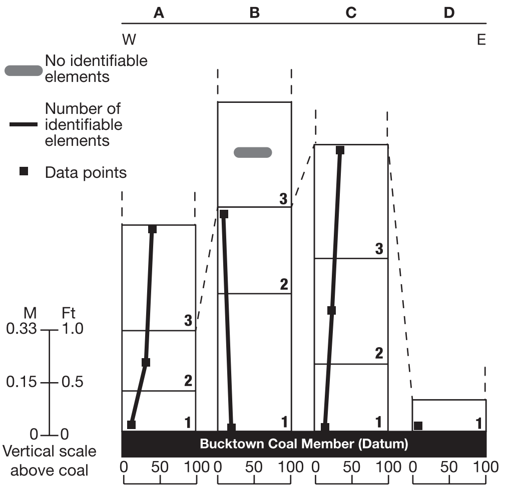

Figure 5.—Percentage of *Adetognathus* Pa's as a part of the total Pa's by sampling interval. Approximately 60 m separate each sampling location.

depositional environment, but instead environmental conditions vary in a relatively short distance such as between Location A and B. This lateral variation resulted in an environment inhospitable to conodonts in Location B. Further, the conodonts in Locations A, B, and C increase in abundance upward in the black shale. We interpret this distribution to show marine conditions above the coal changing from the relatively anoxic and restricted conditions that produced the lower black shales to very quiet low-energy conditions represented by the gray shales.

Adetognathus tolerates stressed euryhaline environmental conditions (Merrill and von Bitter, 1976) and is uncommonly abundant in this locality. We recovered *Adetognathus* from all but one sample. Its abundance indicates a very restricted, low-energy, shallow-water environment, possibly lagoonal or perhaps representing a small embayment; we interpret its presence to indicate moderately stressed to harsh conditions. *Adetognathus* Pa elements comprise from 9 percent to 52 percent of Pa elements in nine samples and this element is the dominant genus in two samples (fig. 5). If one accepts assignment to the *Adetognathus* biofacies on the basis of its Pa elements being approximately 10 percent or more of the total Pas, all but one of our samples belong in that biofacies. *Adetognathus* increases in abundance upward from the base of the black shale overlying the coal to the top of the black shale in Locations A and B and increases to the middle of the black shale in Location C. We interpret this to indicate progressively harsher environmental conditions, perhaps with progressively greater freshwater influence.

Adetognathus continues to increase in abundance in the gray shale overlying the black shale in Location A. This distribution supports our view that the gray shale at this location generally represents a shallow-water, harsh euryhaline environment, perhaps a lagoon or a small embayment.

Also suggesting a shallow-water, restricted environment, such as a lagoonal setting, is the high ratio of juvenile to adult specimens of *Idiognathodus* in all samples. Juvenile idiognathodids comprise 88 percent to 100 percent of *Idiognathodus* Pas. This ratio suggests that the paleoenvironment was harsh and resulted in a high juvenile mortality rate. But our previous studies (for example, Brown and others, 1991) suggest that juveniles prefer shallow, quiet water. Based on that observance, we attribute the higher proportion of juveniles relative to adults in this area to quiet water rather than to harsh conditions.

The rare *Idioprioniodus* elements further suggest low-energy, reducing conditions (Merrill and von Bitter, 1976). But the fragmentation and rarity of *Hindeodus* and *Neognathodus*, both of which are representative of normal, nearshore, open water conditions (Merrill and von Bitter, 1976), may indicate introduction of these genera into the depositional site by irregular storm events.

SUMMARY

In summary, we collected conodonts from a geographically restricted gray and black shale marine lens that was lying directly above the Bucktown Coal Member of the Dugger Formation in a Solar Sources pit 3 km south of Petersburg in Pike County, Indiana. Pa elements of *Idiognathodus* dominated the collection and we were able to document an excellent example of ontogenetic growth stages of this genus. We do not recognize *Streptognathodus* in the Desmoinesian. Conodont distribution in numbers and in communal diversity is not uniform either vertically or laterally. Thus we conclude that environmental conditions were varied. We interpret the geographically restricted black and gray shales overlying the Bucktown Coal in this locality to represent a very nearshore, restricted, deltaically influenced coastal plain environment. We further interpret the basal black shales overlying the coal to be of flotant marsh origin and to represent a localized flooding event. Distributary channels associated with a deltaic system subsequently delivered fresh water that resulted in very localized deposition of brackish water gray shales.

Restricted bays and possibly lagoons developed post-coal black and gray shales as the deltaically influenced depositional environments shifted from swamp to shallow marine settings. We think that migrations of delta lobes allowed local incursions of euryhaline marine waters sporadically and that this conodont community distribution generally indicates a nearshore deltaically influenced coastal plain environment rather than a normal middle to outer shelf open marine one. The evidence supports a model of localized control on sedimentation rather than sedimentation controlled by glacially influenced eustatic sea level change and we think that glacially controlled sea level changes were not a contributing factor to post-Bucktown Coal sedimentation patterns.

ACKNOWLEDGEMENTS

The authors thank Dr. G. K. Merrill, University of Houston – Downtown, for his continuing efforts in helping us to understand and interpret Pennsylvanian conodont taxonomy and paleoecology. Drs. Derek Wright and David Myton of Lake Superior State University provided the expertise for SEM photography. Publication is authorized by the State Geologist, Indiana Geological Survey.

LITERATURE CITED

Brown, L.M. & C.B. Rexroad. 2009. Conodont paleontology of the West Franklin Limestone Member of the Shelburn Formation (Pennsylvanian) in the southeastern part of the Illinois Basin, Indiana Geological Survey Special Report 68:34, 3 pls.

Brown, L.M., C.B. Rexroad, D.L. Eggert & A.S. Horowitz. 1991. Conodont paleontology of the Providence Limestone Member of the Dugger Formation (Pennsylvanian, Desmoinesian) in the southern part of the Illinois Basin. Journal of Paleontology 65:945–957.

Burger, A.M. & C.E. Wier. 1970. Bucktown Coal Member; Providence Limestone Member, Pp. 27–28 and 135. *In* R.H. Shaver & others, *Compendium of rock-unit stratigraphy in Indiana*, Indiana Geological Survey Bulletin 43:203.

Greb, S.F., D.A. Williams & A.D. Williamson. 1992. Geology and stratigraphy of the Western Kentucky Coal Field. Kentucky Geological Survey Bulletin 2:77.

Greb, S.F., W.M. Andrews, C.F. Eble, W. DiMichele, C.B. Cecil & J.C. Hower. 2003. Desmoinesian coal beds of the Eastern Interior and surrounding basins: The largest tropical peat mires in Earth history, Pp. 127–150. *In* M.A. Chan & A.W. Archer (Eds), *Extreme depositional environments: Mega end members in geologic time*. Geological Society of America Special Paper 370:264.

Hopkins, M.E. & J.A. Simon. 1975. Pennsylvanian System, Pp. 163–201. *In* H.B. Willman, E. Atherton, T.C. Buschbach, C. Collinson, J.C. Frye, M.E. Hopkins, J.A. Lineback & J.A. Simon, 1975. *Handbook of Illinois stratigraphy*, Illinois Geological Survey Bulletin 95:261.

Lambert, L.L., P.H. Heckel & J.E. Barrick. 2003. *Swadelina* new genus (Pennsylvanian Conodonta) a taxon with potential chronostratigraphic significance. Micropaleontology 49:151–158.

Merrill, G.K. 1972. Taxonomy, phylogeny, and biostratigraphy of *Neognathodus* in Appalachian Pennsylvanian rocks. Journal of Paleontology 46: 817–829.

Merrill, G.K. 1975. Pennsylvanian conodont biostratigraphy and paleoecology of northwestern Illinois. Geological Society of America Microform Publication 3:130.

Merrill, G.K. 1999. *Neognathodus* and the species concept in conodont paleontology. *In* E. Serpgali & C. Corradini (Eds), *Studies on Conodonts*, p. 465–473, Bollettino della Societa Paleontologica Italiana 37, no. 2–3:265–473.

Merrill, G.K. & P.H. von Bitter. 1976. Revision of conodont biofacies nomenclature and interpretations of environmental controls in Pennsylvanian rocks of eastern and central North America. Royal Ontario Museum Life Sciences Contribution 108: 46.

Rexroad, C.B., J.A. Wade, G.K. Merrill, L.M. Brown & P. Padgett. 2001. Conodont biostratigraphy and depositional environments of the Mecca Quarry Shale Member and the Velpen Limestone Member of the Linton Formation (Pennsylvanian, Desmoinesian) in the eastern part of the Illinois Basin. U.S.A. Indiana Geological Survey Special Report 63:19, 2 pls.

Sweet, W.C. 1988. The Conodonta—morphology, taxonomy, paleoecology, and evolutionary history of a long-extinct animal phylum. Oxford University Press, Oxford Monographs on Geology and Geophysics 10:212.

Tri-State Committee on Correlation of the Pennsylvanian System in the Illinois Basin. 2001. Toward a more uniform stratigraphic nomenclature for rock units (formations and groups) of the Pennsylvanian System in the Illinois Basin. Illinois Basin

Consortium Study 5, Illinois State Geological Survey, Indiana Geological Survey, Kentucky Geological Survey, 26 pp., 1 pl.

Van den Boogaard, M. & M.G.M. Bless. 1985. Some conodont faunas from the Aegiranum marine band. Proceedings of the Koninklijke Nederlandse Academie van Wetenschappen, series B, 88:133–154.

Wier, C.E. 1950. Geology and coal deposits of the Jasonville Quadrangle, Clay, Greene, and Sullivan Counties, Indiana. U.S. Geological Survey Coal Investigation Map C-1.

Wier, C.E. 1952. Geology and mineral deposits of the Jasonville Quadrangle, Indiana. Indiana Geological Survey Bulletin 6:34.

Wier, C.E. & H.H. Gray. 1961. Geologic map of the Indianapolis 1° and 2° quadrangle, Indiana and Illinois, showing bedrock and unconsolidated deposits, Indiana Geological Survey Regional Geological Map 1.

Manuscript received 19 April 2012, revised 29 October 2013.