Redefinition of the Osagean-Meramecian Boundary in the Mississippian Stratotype Region

THOMAS W. KAMMER

Department of Geology and Geography, West Virginia University, Morgantown, WV 26506

PAUL L. BRENCKLE

Amoco Production Company, Research Center, P.O. Box 3385, Tulsa, OK 74102

JOHN L. CARTER

Section of Invertebrate Paleontology, Carnegie Museum of Natural History, 4400 Forbes Avenue, Pittsburgh, PA 15213

WILLIAM I. AUSICH

Department of Geology and Mineralogy, Ohio State University, Columbus, OH 43210

PALAIOS, 1990, V. 5, p. 414–431

Analysis of fossil occurrences in late Osagean-early Meramecian stratotype beds of the upper Mississippian River Valley shows that major faunal changes occur within the Warsaw Formation, not at the underlying Keokuk-Warsaw formational contact where the Osagean-Meramecian serial boundary is presently placed. Relying on this evidence, we propose raising this boundary to the base of the informal upper Warsaw member described herein. The boundary is recognized by the first occurrence of the brachiopods Warsawia lateralis, Planalvus densa, Crossacanthia perlamellosa, Setigerites altonensis, and Tetra-camera subcuneata, the blastoid Pentremites comoideus, and the calcareous foraminifer Globoendothrya baileyi. Use of these fossil appearances provides a more rigorous definition of the serial boundary and permits correlation beyond the Mississippi River Valley. Foraminifers suggest that the boundary falls within the middle Visean of western Europe.

The stratotype section for the proposed boundary is located near the type locality of the Meramecian Series at Meramec Highlands, St. Louis County, Missouri. The lithostratigraphy of the late Osagean and early Meramecian is reviewed in key areas within the Mississippi River Valley and a new member, the Peerless Park, is proposed for a shoaling unit within the middle of the Keokuk Limestone.

INTRODUCTION

The Osagean and Meramecian series are widely used chronostratigraphic divisions of the Middle Mississippian in North America, but recognition of the Osagean-Meramecian boundary outside the stratotype region is tenuous because it is presently defined on lithostratigraphic rather than biostratigraphic criteria. Ulrich's (1904) designation of the Meramec Group, in effect, fixed the boundary at the base of the Warsaw Formation at Meramec Highlands, St. Louis County, Missouri (see Figs. 1, 8, and Appendix 2, section 9 for location). Ulrich did not describe the Warsaw at that locality but presumably followed Hall's (1858) widely accepted concept of the type Warsaw from western Illinois (Figs. 1, 2). Weller (1908) miscorrelated the type Warsaw to the St. Louis area, lowering the base of the formation at Meramec Highlands relative to Hall's original definition. Later, Van Tuyll (1925) redefined the type Warsaw of Hall (1858) as the “Upper Warsaw” and designated the underlying shaly Geode Bed as the “Lower Warsaw,” which on faunal evidence had been considered part of the Keokuk Limestone (Fig. 2). This redefined Keokuk-War-
saw contact coincided with Weller's (1908) placement at Meramec Highlands and has generally been adopted as the position of the Osagean-Meramecian serial boundary in the Mississippi River Valley (Weller et al., 1948; Thompson, 1979; Shaver, 1985). There has not been total agreement with this definition, however. The Iowa Geological Survey (Avcin and Koch, 1979) puts the boundary at the top of the Warsaw. The Illinois and Indiana surveys (Atherton and Palmer, 1979; Gray, 1979), influenced by lack of agreement on the position of the Osagean-Meramecian boundary (e.g., Weller et al., 1948, p. 99, and “Discussion” later in this text), adopted the term Valmeyeran (Weller and Sutton in Moore, 1933) for the combined Osagean and Meramecian, and the Genevievian Stage of Swann (1963). Van Tuyl's redefinition of the Warsaw is justifiable on lithologic grounds in that he united two similar siliciclastic-carbonate units (Warsaw Limestone of Hall and the Geode Bed) into a single formation. His Keokuk-Warsaw formalization contact, however, is an inappropriate position to define the Osagean-Meramecian boundary not only because the contact is potentially regionally diachronous but also because significant faunal changes first occur at or above the base of the upper part (upper Warsaw), rather than the lower part (lower Warsaw), of the Warsaw. The start of these changes coincides with the base of Hall's (1857) original Warsaw Limestone and defines the level we propose for the Osagean-Meramecian boundary (Fig. 2).

The purpose of our paper is to review the lithostratigraphy and biostratigraphy of the Warsaw and adjacent
**FIGURE 2**—Stratigraphic nomenclature and age assignments of late Osagean-Meramecian rocks within the Mississippi River Valley. The position of the top of the Meramecian in the far right column follows Maples and Waters (1987).

**FIGURE 3**—Ranges of brachiopods, *Pentamerites concodus*, and microfossils (right end) in the type Keokuk-War saw area (Appendix 2, sections 1–5); numbers keyed to Table 1. Ranges are subdivided no finer than middle and upper Keokuk, lower and upper lower Warsaw, and lower and upper upper Warsaw for macrofossils. Macrofossils were not collected from the lower Keokuk. Keokuk microfossil ranges excerpted from Brenckle et al. (1974, fig. 2) at Gray’s Quarry (Appendix 2, section 1). Warsaw and Sonora occurrences based on unpublished collections from Geode Glen (Appendix 2, section 2).

Formations at key localities within the Mississippian stratotype region (Fig. 1). Traditional formational names are retained although a new member of the Keokuk Limestone, the Peerless Park, is established (Appendix 1). The fossil succession at these localities (Figs. 3–6) demonstrates that typical Meramecian assemblages began to replace late Osagean faunas within the Warsaw Formation. Documentation of these changes provides a more rigorous paleontologic definition of the Osagean-Meramecian boundary and now offers a means to correlate more confidently to areas outside the type region.

The improved time resolution will aid in more precise reconstruction of Middle Mississippian events, particularly in the Midcontinent. Such events include the progradation of the Borden delta complex into the Illinois Basin, the subsequent infilling of the Illinois Basin, and the later transgression recorded by an extensive package of carbonate rocks including the upper Warsaw, Salem, and St. Louis formations. It was also during this time that rapid evolutionary changes took place within crinoid and blastoid lineages, as camerocid-dominated faunas were replaced by advanced cladid-dominated ones (Lane, 1972),
and blastoids underwent periods of habitat-specific extinction and radiation (Ausich et al., 1988). Paleooecologic and biogeographic analysis of crinooids (e.g., Kammer and Ausich, 1987) and other fossil groups requires precise time resolution.

BOUNDARY POSITION AND REFERENCE SECTIONS

We concentrated our investigations in the three Mississippi River Valley areas with the best outcrops of upper Osagean-Meramecian rocks. From north to south, these are: A) the type Keokuk-War saw area in Lee County, Iowa, and adjacent Hancock County, Illinois; B) the type Meramecian area in St. Louis County, Missouri, and adjacent counties in Illinois; and C) Ste. Genevieve County, Missouri (Fig. 1). Each area offers continuous or nearly continuous exposures of the Keokuk, Warsaw and Salem/Sonora formations which are the focus of this study.

References for important measured sections of these rock units are given in Appendix 2.

Lane and Brenckle (1977) described the upper Keokuk through lower St. Louis interval from outcrops around the junction of Interstate highways 44 and 270 near Meramec Highlands (see Fig. 8 for location). We designate this area to be the primary reference for our proposed Osagean-Meramecian boundary, which is located specifically at the base of unit 24 in the middle of the Cragwood Road section (Lane and Brenckle, 1977, fig. 8; Appendix 2, section 8). The base of this unit is also the level at which Weller (1908) and the above authors placed the Warsaw-Salem contact, i.e., at the appearance of thick-bedded carbonates. We, instead, consider this contact to mark the base of the upper Warsaw because of the heterogenous lithologies of the overlying beds. Typical Salem grainstones do not appear until very near the top of the Cragwood Road section, where we place the Warsaw-Salem contact (Fig. 2). This stratigraphic horizon is the same one chosen by Rexroad and
TABLE 1—Summary of ranges of common or biostratigraphically important brachiopods, the blastoid Pentremites conoides, and calcareous microfossils from the Keokuk, Warsaw, and lower Salem or Sonora formations within the Mississippi River Valley. See Figures 3–6 for details of ranges. Brachiopod ranges that extend into the Salem Limestone of Indiana, Kentucky, Illinois, and Missouri are also listed (Carter and Carter, 1970; Feldman, 1987). K = Keokuk, LW = lower Warsaw, UW = upper Warsaw, S = Salem or Sonora.

<table>
<thead>
<tr>
<th>Brachiopods</th>
<th>K</th>
<th>LW</th>
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<tbody>
<tr>
<td>1. Actinoconchus “lamellosus” (Leveille)</td>
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<td>2. Acuminothyris keokuk Carter</td>
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<td>3. Anthracospirifer brencleii Carter</td>
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<td>4. Anthracospirifer keokuk (Hall)</td>
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<td>5. Avonia williamsana Girty</td>
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<td>6. Brachythyrus suborbicularis (Hall)</td>
<td>X</td>
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<td>7. “Camarotoechia” nutata (Hall)</td>
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<td>9. Cleothyrina obsaxima (McChesney)</td>
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<td>10. Cleothyrina parviostris (Meek &amp; Worthen)</td>
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<td>12. Composita globosa Weller</td>
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<td>13. Composita trinuclea (Hall)</td>
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<td>14. Cranacea sulcata Weller</td>
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<td>15. Crossacanthia perlamellosa Gordon</td>
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<td>16. Dimgelasma neglecta (Hall)</td>
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<td>18. Eumetria verneuilliana (Hall)</td>
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<td>19. Girtyella indianensis (Girty)</td>
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<td>20. Girtyella turcida (Hall)</td>
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<td>22. Imbrizia mortonana (Miller)</td>
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<td>24. Keokukia sulcata Carter</td>
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<td>25. Labri productus wortheni (Hall)</td>
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<td>26. Marginirugus magnus (Meek &amp; Worthen)</td>
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<td>27. Orthotetes keokuk (Hall)</td>
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<td>28. Ovatia ovata (Hall)</td>
<td>X</td>
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<td>29. Ozora crawfordswillensis (Weller)</td>
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<td>30. Ozora genevievensis Carter</td>
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<td>32. Planarulus densa (Hall &amp; Clarke)</td>
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<td>33. Plectospira juvenis Carter</td>
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<td>34. Productus mesialis Hall</td>
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<td>35. Prospira bifurcata (Hall)</td>
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<td>37. Pseudosyrinx gigas Weller</td>
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<td>38. Pseudosyrinx keokuk Wellers</td>
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<td>39. Punctospirifer monroensis Carter</td>
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<td>40. Punctospirifer salemensis (Weller)</td>
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<td>41. Rotaia subtrigona (Meek &amp; Worthen)</td>
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<td>42. Rhyncopora beecheri Greger</td>
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<td>43. Scoaloncha indianaensis (Hall)</td>
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<td>44. Setigerites altonensis (Norwood &amp; Pratten)</td>
<td>X</td>
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<td>45. Setigerites setigerus (Hall)</td>
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<tr>
<td>46. Skelidorygna subcardiformis (Hall)</td>
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<td>47. Spirifer grittyi Carter</td>
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<tr>
<td>48. Spirifer incertiformis Girty</td>
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TABLE 1—Continued.

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<td>49. Spiroceras logani Hall</td>
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<td>51. Spiroceras subquadratus Hall</td>
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<td>53. Spiroceras washingtonensis Weller</td>
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<td>55. Subglobosochonetes planumbona (Meek &amp; Worthen)</td>
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<td>57. Tetracameria subcuneata (Hall)</td>
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<td>58. Tolmatchoffia keokuk (Hall)</td>
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<td>59. Tomophractus kollari Carter</td>
<td>X</td>
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<td>60. Tornyi ceres pseudolineatus (Hall)</td>
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<tr>
<td>61. Tornyi setigerus (Hall)</td>
<td>X</td>
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<tr>
<td>62. Warsania lateralis (Hall)</td>
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<td>63. Yagonia collinsoni Carter</td>
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</table>

Blastoid

64. Pentremites conoides Hall

Calcareous microfossils

65. Endotaxis and/or Tetraxis spp. | X | X | X |
66. Eoendothyranopsis scitula (Toomey) | X | X | X |
67. Eoendothyranopsis scitula and/or E. spongios (Zeller) | X | X |   |
68. Eoendothyranopsis spp. | X |    |    |   |
69. Globoendothyra baileyi (Hall) | X | X |   |   |
70. Globoendothyra piaiae Breckle | X | X | X |   |
71. Koninckopora tenuiramosa Wood | X |    |    |   |
72. Koninckopora? sp. | X |    |    |   |
73. Paraarchaeidiscus spp. | X | X |   |   |
74. Planoarchaeidiscus and/or Viseidiscus spp. | X | X |   |   |
75. Principia cf. P. "donbassica" (Kosenko) | X |    |    |   |
76. Skippella redwalliensis (Skipp) | X |    |    |   |
77. Viseidiscus spp. | X | X |   |   |

† Occurs in formations above the Salem.
* Occurs only in the very base of the upper Warsaw at locality 14 (Appendix 2).

Collinson (1965) for the base of the Salem in the nearby Marshall Road section (Appendix 2, section 10).

Other boundary reference sections include the type Warsaw Formation at Geode Glen, Warsaw, Illinois, and Tower Rock Quarry North at Ste. Genevieve, Missouri (Appendix 2, sections 2 and 14). At both these localities the Osagean-Meramecian boundary coincides with the lower-upper Warsaw contact.

LITHOSTRATIGRAPHY

The Warsaw Formation in the Mississippi River Valley is a mixed siliciclastic-carbonate interval lying between cherty Keokuk Limestone crinoidal grainstones and packstones and relatively thick-bedded Salem Limestone or sandy Sonora Formation grainstones. Both formational contacts are gradational, with the lower one placed at the position where shale and/or dolomite become dominant over limestone, and the upper where the beds become continuous calcarenitic grainstones.

Two informal Warsaw members can be traced throughout the stratotype region. The lower member is comprised of intercalated shales and crinoidal limestones or dolomitized packstones/wackestones that change upward into shaly-silty, dolomitic beds. The latter are highly geodifferent locally, hence the name “Geode Bed” that was originally applied to this interval (Fig. 2). The maximum thickness of this member is in and around Ste. Genevieve County where almost 30 m have been measured in cores taken from the Tower Rock Quarry (Fig. 1 and Appendix 2, section 14).

Hall (1857) recorded a Magnesian Limestone (dolomite) bed above the Geode Bed in western Illinois and in 1858 included it as part of the overlying (upper) Warsaw. However, the bed is discontinuous and limited to the type
Warsaw area and because of its dolomitic composition is most likely allied with the Geode Bed as part of the lower Warsaw (Fig. 2). The bed is less than 2 m thick at Geode Glen (Appendix 2, section 2). Fossils within the Magnesian Limestone are too poorly preserved for identification.

The upper Warsaw member contains mostly fossiliferous shale and limestone with lesser amounts of dolomite. It is equivalent to Hall's (1857) original Warsaw Limestone in the type Warsaw area. There, shale predominates over limestone, but in the type Meramecian the opposite is true. The preponderance of carbonate in the upper Warsaw around Meramec Highlands may explain why the unit was initially assigned to the Salem (see discussion in previous section). The limestones, however, are mostly argillaceous. Subordinate lithologies include dolomitic wackestones to packstones interbedded with shales and dolomites. This lithology is unlike the usual shale-free, clean skeletal grainstones of the Salem. Toward Ste. Genevieve the upper Warsaw grades laterally into the Salem Limestone (Fig. 1) and only 2 m of upper Warsaw are present at the Tower Rock Quarry North section (Appendix 2, section 14).

The name Warsaw is applied only to lower Warsaw rocks in the Mississippi River Valley of southern Illinois. Lineback (1966, 1968, 1969, 1972, 1981a) referred the upper Warsaw and lower Salem of our Ste. Genevieve County usage to the Ullin Limestone (Fig. 2), and he equated the lower Warsaw (his Warsaw Shale) to the upper part of the Borden Siltstone throughout the Illinois subsurface. The overlying Ramp Creek Member of the Ullin Limestone in southern Illinois may also be age-equivalent in part to the lower Warsaw because it contains the Marginirugus magnus brachiopod zone (Wilman et al., 1975, p. 140) and is overlain by the Meramecian Harrodsburg Limestone Member.

The upper Warsaw in southeastern Iowa is mostly missing because of pre-St.Louis erosion (Van Tuyl, 1925, p. 210), and to the southwest at Boonville in central Missouri it becomes dominantly carbonate as in the type Meramecian.

**FIGURE 6**—Summary of ranges of brachiopods, Pentremites concideus, and microfossils (right end) from the Keokuk Limestone and Warsaw Formation within the Mississippi River Valley (Figs. 3–5); numbers keyed to Table 1. Macrofossil ranges are subdivided no finer than middle to upper Keokuk, lower Warsaw, and upper Warsaw. Most microfossil taxa range at least into the upper Meramecian.
REDEFINITION OF THE OSAGEAN-MERAMECIAN BOUNDARY

The Warsaw Formation has been extended into southwestern Missouri (e.g., Moore, 1928; Thompson, 1979), but the almost completely calcareous lithology does not support use of that formal name.

BIOSTRATIGRAPHY

The Osagean-Meramecian boundary is best recognized on outcrop by the ranges of brachiopods and the blastoid Pentremites conoides Hall, which are abundant and relatively easy to identify. Many (if not all) of these fossils also occur in Indiana, Kentucky, and central and southwestern Missouri. Calcareous microfossils may be useful in extending the boundary outside of the eastern and central United States. Bryozoans are abundant in the Keokuk-Warsaw-Salem interval, but their taxonomy and biostratigraphy are poorly understood. Other fossil groups are rare and not well preserved, or are apparently not sensitive to the boundary, such as conodonts (Rexroad and Collinson, 1965).

Brachiopods

Brachiopod ranges for the three Mississippi Valley study areas of this report (type Keokuk-Warsaw area, type Meramecian, and Ste. Genevieve County) are shown in Figures 3–6 and Table 1. These range charts are not comprehensive and include only common brachiopod species. Most of the brachiopods discussed below are illustrated in Weller (1914) or Carter (1990).

The best index fossil for the late Osagean in the type Meramecian and Ste. Genevieve County areas is the large distinctive productid Marginirusus magna (Meek and Worthen). However, it is absent in the type Keokuk-Warsaw area. Its greatest range is in Ste. Genevieve County where the species first occurs in the bed just below the mid-Keokuk Peerless Park Member (see Appendix 1) and continues upward throughout the upper Keokuk and entire lower Warsaw. Its highest known occurrence is at Tower Rock Quarry North (Appendix 2, section 14) where it occurs with Warsowia lateralis in a grainstone 75 cm thick, 1.4 m below the base of the Salem. This is the only known locality in the Mississippi River Valley where these two brachiopods overlap in their stratigraphic ranges, and is the basis for extending M. magna into the basal Meramecian in Figures 5 and 6 and Table 1. This slight overlap does not invalidate the usefulness of either species but, in fact, can be considered to mark precisely the Osagean-Meramecian boundary. The same situation occurs in Harrison County, Indiana (Locality 13 of Noll and Rexroad, 1975) where M. magna and W. lateralis occur together in the basal meter of the Harrodsburg Limestone.

The base of the Meramecian is recognized by the first occurrence of the following brachiopods: Warsowia lateralis (Hall), Planalbus densa (Hall and Clarke), Setigerites altonensis (Norwood and Pratten), Crossanthis parallelosa Gordon, and Tetracamera subcuneata (Hall). Brachiopod assemblages containing some or all of these species occur in the Quapaw Limestone of southwestern Missouri (Gordon in McKnight and Fischer, 1970, p. 56) and in the Warsaw Formation of western Kentucky (Butts, 1917, p. 30). Hirt (1991) reported that W. lateralis and P. densa first appear in the middle of the Ramp Creek Formation, above the highest M. magna, in Monroe County, Indiana. Feldman (1989) reported W. lateralis from the base of the Ramp Creek Formation, in Monroe County, Indiana, an occurrence we were unable to confirm in the field in April, 1990.

The data from Table 1 indicate that about two-thirds of the Keokuk brachiopod species range into the lower Warsaw or higher. More than half of the lower Warsaw species range into the upper Warsaw, and 80 percent of upper Warsaw species range into the Salem or above. It is very clear that the upper Keokuk and lower Warsaw brachiopods are closely similar. In fact, only the introduction of the distinctive spiriferid Skelidorygna subcardiformis (Hall) near the Keokuk-Warsaw boundary, in the type region of these formations, allows faunal discrimination of these units. Similarly, the upper Warsaw brachiopod fauna is nearly the same as that of the Salem.

The most important faunal change in this sequence occurs between the lower and upper Warsaw, although this change does not represent a major brachiopod extinction event.

Results of the present study require modification of the megafaunal zones erected by Weller (1926) and revised by Dutro et al. (1979). For example, Weller's Productus magnus Zone, now the Marginirusus magna Zone, was said by these authors to mark the base of the Meramecian. Weller (1926, p. 326) stated that this species was not found in the Keokuk Limestone, being restricted to lower Warsaw beds in the Mississippi Valley region. However, Weller and St. Clair (1928, p. 188, 192, 197) reported this species from two localities in the Keokuk of Ste. Genevieve County. J. M. Weller (1948, p. 114) later indicated only a late Keokuk age for this species. As discussed above, we find that this species ranges throughout the upper half of the Keokuk and the lower Warsaw. In other words, it characterizes the upper part of the Osagean Stage as defined herein, not the lower Meramecian.

Less important changes in Weller's zonal scheme are as follows. The Spirifer grimesi-logani Zone terminates in the upper Keokuk, not at the base of the Warsaw as Weller indicated. In the Mississippi Valley region the total range of the zonal name givers is from the lower, but not basal, Burlington to approximately the middle part of the Keokuk. The Productus crawfordsvillensis Zone, originally restricted to the upper Keokuk, now should be referred to as the Zone of Ozora crawfordsvillensis. The genus Ozora consists of two species, O. genevievesnici Carter and O. crawfordsvillensis (Weller). The former is restricted to the middle Keokuk of Ste. Genevieve County, and the latter occurs in the lower Warsaw of southeastern Iowa, the Edwardsville Formation (Crawfordsville beds) of Indiana, and the New Providence Shale Member of the Borden Formation in Kentucky (Kammer, 1985). The precise chronostratigraphic range of this species is not known.

The Brachythyris (=Skelidorygna) subcardiformis
Zone was said by Weller (1926, p. 327) to be characteristic of, but not restricted to, the Salem Limestone in southern Missouri and Illinois (in today's terminology this would be an acme zone). Following Van Tuyl (1925, p. 153), we have found this species as low as the uppermost Keokuk in southeastern Iowa and nearby Illinois and, in addition, we have found it in the lower Warsaw in the type Meramecian area and in the upper Warsaw in Ste. Genevieve County. Therefore, it is not a reliable indicator of Salem age and its occurrence should be interpreted with caution. The first occurrence of this species may be a useful guide to the late Osagean, but no verification of this is at hand for areas outside the Mississippi Valley region.

Echinoderms

Echinoderms are an abundant component of Osagean and Meramecian rocks. Although articulated crinoid calyces are not common enough for use as effective index fossils, crinoids did evolve rapidly during the Osagean and Meramecian (Laudon, 1948, 1973; Lane, 1972) leaving behind a succession of distinctive faunas. It was recognition of the nearly complete dissimilarity between lower and upper Warsaw crinoids that drew our attention to the Osagean-Meramecian boundary problem.

The systematics of all late Osagean and early Meramecian crinoids from the stratotype area are currently being revised by Kammer and Ausich. Preliminary results of this work indicate that of the 21 species of crinoids in the lower Warsaw (Geode Bed) of the type Keokuk-War saw area, 62 percent (13/21) occur in the underlying Keokuk and only 14 percent (3/21) in the upper Warsaw. Fourteen percent (3/21) are also in early Meramecian rocks at Boonville, Missouri (upper Warsaw), and at Canton, Indiana (Harrodsburg Limestone). These data suggest a major change in crinoid faunas between the lower and upper Warsaw corresponding to the Osagean-Meramecian boundary as defined in this study. However, the Warsaw crinoids cannot be used to define the boundary because most species are rare and commonly represented only by single specimens.

Of all echinoderms, the blastoid *Pentremites conoideus* Hall is the most useful for recognizing the Osagean-Meramecian boundary. It is the sole member of this genus to occur in the upper Warsaw and Salem of the Mississippi River Valley. We have found it at every upper Warsaw and Salem outcrop investigated, except for the 2 m of upper Warsaw at the Tower Rock Quarry North section (Appendix 2, section 14). *Pentremites conoideus* also occurs in the Ramp Creek (Feldman, 1989), Harrodsburg, and Salem formations of Indiana (Galloway and Kaska, 1957) and equivalent rocks in Kentucky (Weller, 1931). Illustrations of *P. conoideus* are in Hall (1858, pl. 22, figs. 8–11), Galloway and Kaska (1957, pl. 2, figs. 8–11, 11, figs. 1–19), Waters et al. (1985, fig. 4), and Feldman (1989, fig. 3.2). *Pentremites* is unknown from the Keokuk Limestone and lower Warsaw of the Mississippi Valley. However, two species, *P. elongatus* Shumard and *P. kirki* Hambach, do occur in the Burlington Limestone (Macurda, 1975).

In November 1989 Kammer and Ausich examined outcrops of the Boone Formation at Springfield, Missouri that contained a population of *Pentremites* in late Osagean rocks well below the Short Creek Oolite. (The late Osagean age is based on the occurrence of many crinoid species typical of the Keokuk Limestone.) Eighteen specimens were collected and approximately 50 additional specimens were studied. A small percentage of individuals are morphologically indistinguishable from *P. conoideus*, but the majority of individuals show characteristics more similar to *P. elongatus*. A sample of several individuals from this population would not be mistaken for *P. conoideus*. Workers attempting to extend the biostratigraphy of the present study into southwest Missouri should be aware of this new population of *Pentremites* in the late Osagean.

It is quite likely that the late Osagean *Pentremites* in the Springfield, Missouri area is a transitional population between *P. elongatus* and *P. conoideus*. Waters et al. (1985) inferred an ancestral-descendant relationship between these species. If this evolutionary relationship is substantiated, the widespread occurrence of *P. conoideus* at the base of the Meramecian in the Mississippi River Valley represents the later geographic expansion of the species following its development to the southwest.

Calcereous Microfossils

Although the ranges of calcareous foraminifers, algae and problematic microfossils are strongly facies-dependent, the distribution of selected taxa (Figs. 3–6) permits an operational definition of the late Osagean and early Meramecian both within and outside the stratotype region. Except for the Peerless Park Member (Appendix 1), the Keokuk and lower Warsaw microbiota is generally sparse. It is dominated by long-ranging tetraxiid, earlandiid, and small endothyrid foraminifers with rare occurrences of globoendothyrids and archaeiscids (*Paraarchaeiscus*, *Viusediscus*, *Planarchotheiscus*). The low diversity reflects the inhospitable environments of the relatively deeper water crinoidal-bryozoan beds. Calcareous microfossils disappear with the lower Warsaw at the onset of continuous clastic-dolomite deposition only to reoccur in the upper Warsaw with the return of favorable limestone facies.

Many of the Peerless Park genera and species are in the upper Warsaw along with *Globoendothrya baileyi* (Hall). The appearance of this species provides the best foraminiferal evidence to define the Osagean-Meramecian boundary and, because of its widespread distribution, *G. baileyi* potentially offers a means to extend the boundary beyond the Mississippi River Valley. The utility of the species, however, is tempered by the fact that its incoming within the upper Warsaw is most likely facies-dependent and may not be synchronous with appearances elsewhere.

The present report of *G. baileyi* from the base of the upper Warsaw in the St. Louis and Ste. Genevieve areas is a downward extension of the range reported in Baxter and Brenckle (1982, fig. 3). Most specimens that those authors identified as *Globoendothrya tomiliensis* group in the Salem and St. Louis limestones should be reassigned.
to *G. baileyi* (sensu Henbest, 1931, and Scott et al., 1947). *Globoendothyrea piasae* Brencle, a seeming precursor to *G. baileyi*, first occurs within the upper Keokuk Limestone. It is similar to *G. baileyi* except for differences in septal morphology and less robust dimensions. *Globoendothyrea piasae* is the first representative of the smaller globoendothyroids known throughout the Meramecian in the Middlecontinent. Comparative studies may show that it is conspecific with "*Plectogyra" plectogyra* described by Zeller (1950) from the St. Louis Limestone at St. Louis, Missouri.

The Keokuk-Warsaw occurrences contradict many previous North American and intercontinental microfossil correlations within the Middle Mississippian. Peerless Park taxa, such as the foraminifers *Eoendothyranopsis spiroides* (Zeller), *E. scitula* (Toomey), *Skippella redwallensis* (Skipp), *Globoendothyrea* and *Archaediscidae* (*Viseidiscus*), the alga *Fourstonella* and the problematic *Koninckpora*, have been considered Meramecian indicators in many published microfossil zonations (e.g., Zeller, 1957; McKay and Green, 1963; Skipp, 1969; Mamet and Skipp, 1970a, b). Obviously, this age assignment is untenable because the Peerless Park Member, lying within the middle Keokuk Limestone in the Meramecian stratotype region, is by definition late Osagean. Alternative microfossil correlations for the Osagean and Meramecian have been proposed by Brencle et al. (1982), Baxter and Brencle (1982) and Brencle and Groves (1987).

In western European chronostratigraphic terms, the Peerless Park microbiota is no older than late early Visean and may be younger (Brencle et al., 1982). Conodont evidence (Lane and Ziegler, 1983) suggests that the Tournaissian-Visean boundary in the Mississippi River Valley falls within the upper Burlington Limestone beneath the Keokuk. This placement, which complements the present microfossil data, does not support previous foraminiferal correlations (e.g., Sando et al., 1969; Mamet and Skipp, 1970b) that equated the Tournaissian-Visean boundary with the Warsaw-Keokuk formational contact.

Paraarchaediscoid foraminifers in the Warsaw exhibit an oscillating to sigmoidal coiling pattern and a wall structure at the "involutus" evolutionary stage (Pirlet and Conil, 1977). This morphology is prevalent in middle Visean archaediscids of western Europe (Pirlet and Conil, 1977), suggesting that the Osagean-Meramecian boundary of this report falls within that chronostratigraphic interval. The first occurrence of *Paraarchaediscus* (= *Archaediscus* of Baxter and Brencle, 1982) was thought to be a reliable Meramecian indicator, but its discovery in the lower Warsaw during this study extends the generic range into the upper Osagean as defined herein. *Paraarchaediscus* probably migrated from Eurasia since ancestral forms (*Glomo-discus*) have not been reported in North America.

**DISCUSSION**

In redifining the Osagean-Meramecian boundary it is important to consider Ulrich's (1904) concept of the Warsaw Formation when he established the Meramec Group. If Ulrich used Hall's concept rather than Van Tuyl's (Fig. 2), then the placement of the Osagean-Meramecian boundary at the Keokuk-Warsaw formational contact was not what Ulrich intended. Ulrich never provided any explicit lithostratigraphic or biostratigraphic data for separating the Osage and Meramec groups. We suspect, however, that he used Hall's definition of the Warsaw (our upper Warsaw) in defining his Meramec Group. Ulrich was surely aware of Hall's (1857, 1858) work on the stratigraphy and paleontology of Iowa. In Ulrich's (1890) monograph on Paleozoic Bryozoa he distinguished between the Keokuk Limestone, Keokuk Group, and Warsaw beds in reporting the stratigraphic occurrences of bryozoans. The Keokuk Group included both the Keokuk Limestone proper and the Geode Bed (Worthen, 1866). Later, Ulrich (1911, p. 594) listed what he considered to be Meramecian species from the Warsaw at its type locality (Geode Glen, Appendix 2, section 2). The list includes *Spirifer (= Warsavia) lateralis* and the bryozoans *Fenestella tenax* Ulrich and *Polypora varsoviensis* Prout, which first occur in the upper Warsaw, not the Geode Bed.

An indirect statement by Ulrich (1905, p. 28) also suggests he defined the Warsaw according to Hall. In describing the Meramec Group of western Kentucky, Ulrich stated: "The lowest division, the Warsaw formation, is possibly in part equivalent to the lower part of the Spergen [Salem] limestone, but as the occurrence of rocks of that horizon [Warsaw] in the outcrops of Spergen limestone southeast of Ste. Genevieve, Mo., can not now be either definitely denied or affirmed it seems best provisionally to regard the Warsaw as restricted to areas north of Ste. Genevieve". The upper Warsaw (Hall's Warsaw) is essentially restricted to areas north of Ste. Genevieve (Fig. 1). The presently recognized Warsaw in the Ste. Genevieve area contains abundant geodes throughout its entire thickness (including the thin upper Warsaw), so Ulrich probably considered it correlative with the Geode Bed.

The position of the Osagean-Meramecian boundary in the type area of the Warsaw was lowered by Van Tuyl (1925) when he redefined the Warsaw to include both the clastic-dominated Geode Bed of the Keokuk Limestone and the Warsaw Limestone of Hall (1858). He referred these two units to the Lower Warsaw and Upper Warsaw, respectively (Fig. 2). The lower Warsaw (Geode Bed) consists of siltstones, silty shales, dolomitic siltstones, argillaceous dolostones, and thin limestones. It is approximately 9m thick on average and is characterized by common to abundant geodes, although geodes are not present in every bed or at every locality in the type area. Hall (1858, p. 96) defined the Geode Bed as the upper limit of the Keokuk Limestone (Fig. 2). Fossils from the Geode Bed were reported as being from the Keokuk Limestone or Group, a practice continued until Van Tuyl's (1925) revision. Worthen (1866, p. 98), who was Hall's assistant and apparently did most of the field work (Clarke, 1921, p. 276), stated that "usually the geode bed is destitute of fossils, but at some localities there are thin bands of limestone intercalated in it, which contain the same species which characterize the Keokuk limestone proper". We agree
with Worthen's statement based on our collections from the lower Warsaw (Fig. 3). The same situation is true in the St. Louis area where the lower Warsaw shales directly above the Keokuk Limestone contain a late Osagean fauna with species typical of both the Keokuk of Iowa and the Borden Group of Indiana (Fig. 4). Fenneman (1911, p. 21) also noted the Keokuk affinities of fossils from the lower Warsaw in the St. Louis area.

Thus, the top of Hall's and Worthen's Geode Bed member of the Keokuk Limestone or Group, or the top of the discontinuous Magnesian Limestone (present only in the type Warsaw area), coincides with the top of the Osagean as used herein. From 1858 until Van Tuyl's (1925) work, all fossils collected from both the Keokuk Limestone proper and the Geode Bed were labeled as either Keokuk Group or Keokuk Limestone. This practice includes Weller's (1914) monograph on Mississippian brachiopods and all works on crinoids (e.g., Wachsmuth and Springer, 1897). Many older museum collections have specimens from Iowa and Illinois labeled as being from the Keokuk, but the specimens are preserved in siltstone typical of what is now called lower Warsaw. Also, late Osagean fossils from the Borden Group and Ramp Creek Formation of Indiana and Kentucky are also labeled as Keokuk in older museum collections. The Keokuk was thus synonymous with late Osagean and used as a biostratigraphic, rather than lithostratigraphic, unit by many 19th century workers.

Van Tuyl's (1925) reassignment of the Geode Bed to the Warsaw Formation began the confusion about the age of the Warsaw and the position of the Osagean-Meramecian boundary. Van Tuyl (1925, p. 185) thought the fauna of the Geode Bed to be more similar to Hall's Warsaw than to the underlying Keokuk Limestone. This opinion appears to be subjective as inspection of Van Tuyl's faunal lists (p. 152-154, 208-210) shows the Geode Bed fauna to have strong similarities with both the Keokuk and Warsaw of Hall. As previously noted, 62 percent of the Geode Bed crinoid species also occur in the Keokuk. In any event, Van Tuyl (1925, p. 182-185) placed the base of the Meramecian at the base of the newly defined Warsaw. This placement apparently followed the practice of other early workers who assumed that chronostratigraphic boundaries should coincide with formational boundaries. Weller (1908) unwittingly put the Osagean-Meramecian boundary at the same level as Van Tuyl by his miscorrelation of the Warsaw-Salem interval at Meramec Highlands.

Stuart Weller (1926), who was Van Tuyl's dissertation advisor, accepted Van Tuyl's conclusions and included the Geode Bed in the Warsaw and the Meramecian, thus reversing his earlier usage (Weller, 1914). Moore (1928), also a student of Weller, followed Van Tuyl in placing the Geode Bed in the Warsaw, but he thought the Warsaw was completely Osagean. Moore (1928, p. 230) correctly recognized that the Osagean crinoid fauna became extinct within the Warsaw rather than at the top of the Keokuk Limestone (same conclusion of Laudon, 1973). Weller and Sutton (1940) placed the Osagean-Meramecian boundary at the Keokuk-Warsaw boundary of Van Tuyl because the Warsaw contained the "Pentremites-Composita" fauna so characteristic of the Meramecian and Chesterian". They thought this "to be of more importance than the presence of many hold-over Keokuk species" (p. 811). Clearly, Weller and Sutton (1940) did not make a distinction between the faunas of the lower Warsaw (Geode Bed) and upper Warsaw (Hall's Warsaw), treating them as one. Pentremites occurs only in the upper Warsaw.

Laudon (1948) assembled what appeared to be strong evidence for an Osagean age for the Warsaw. He concluded that 27 out of 30 species in the Warsaw were also in the Keokuk Limestone; only Pentremites conoides was also found in the overlying Salem Limestone. Laudon made his collections at Soap Factory Hollow (Appendix 2, section 3), south of the town of Warsaw, Illinois. Kammer and Ausich visited Soap Factory Hollow in 1989 and found Van Tuyl's (1925, p. 188) formation assignments to be erroneous, which may have misled Laudon. The majority of exposures along the creek are those of the Keokuk Limestone proper, with limited exposures of the lower Warsaw (Geode Bed) and an approximately 1 m section of upper Warsaw. Apparently Laudon did most of his collecting from the Keokuk Limestone assuming the limestones to be from the Warsaw. Unfortunately, Laudon did not collect at Geode Glen (Appendix 2, section 2), which is the type section of Hall's Warsaw (Van Tuyl, 1925, p. 203-204) and only about 1 km northeast of Soap Factory Hollow. In an obvious misquote that has added to the confusion, Weller et al. (1948, p. 99) stated "Laudon believes that the greatest stratigraphic break in the whole Mississippian occurs at the top of the Keokuk and that the fauna of the overlying Warsaw is almost entirely strange to the Osage."

Some authors (e.g., Ulrich, 1911, p. 588; Laudon, 1948) have postulated that major stratigraphic breaks were associated with Warsaw deposition. While our evidence is not conclusive, several observations suggest the possibility that the lower-upper Warsaw contact marks a disconformable sequence boundary with a stratal hiatus increasing from south to north. Our evidence includes: 1) the abrupt turnover of macrofossil taxa at or near the proposed Osagean-Meramecian boundary; 2) the progressive restriction (greatest to the north) of lower Warsaw environments reflected by the vertical change from limestones to siliciclastics and dolomites, followed abruptly by normal marine beds in the upper Warsaw; 3) the lateral change of upper Warsaw, near-shore shales and limestones in the type Warsaw area to open marine Salem limestones around Ste. Genevieve; 4) the greatest thickness of lower Warsaw around Ste. Genevieve, probably indicating either more continuous sedimentation and/or less extensive erosion than to the north; and 5) the overlap in ranges of Marginirus magnus and Warsawia lateralis near Ste. Genevieve, suggesting that sedimentation was more continuous here than to the north where the overlap is unknown.

The Warsaw, therefore, would seem to be part of a regional regressive-transgressive cycle. The older phase, represented by the lower Warsaw, recorded the westward progradation of Borden terrigenous clastics over the eastern edge of the Burlington-Keokuk Shelf, while the upper
Warsaw marked the gradual return of clear water conditions culminating in widespread deposition of Salem-St. Louis carbonates across the upper Midcontinent (Collinson et al., 1979). The changeover from regressive to transgressive conditions may have been accompanied by a hiatus of variable duration at the lower-upper Warsaw contact. The present biostratigraphic data, however, cannot unequivocally prove either the existence or duration of such a break, which must be considered in the context of a regional Osagean-Meramecian boundary study.

If a significant break should exist between the lower and upper Warsaw, the Osagean-Meramecian boundary stratotype should be moved from the Mississippi River Valley to an area of more continuous sedimentation. The biostratigraphic information presented in this paper could then serve as a focal point for identifying the proper stratigraphic interval in which to relocate the serial boundary.

The problem surrounding the placement of the Osagean-Meramecian boundary centers on confusion between application of lithostratigraphic and biostratigraphic data to corresponding stratigraphic units. In general, the stratigraphic units were initially defined on the contained faunas, and today these represent chronostratigraphic units. Subsequent revision retained earlier stratigraphic names but redefined them on lithostratigraphic data. Commonly, lithostratigraphic and chronostratigraphic units were regarded to be equivalent. The revisions that we propose decouple lithostratigraphic and chronostratigraphic units and will allow a more precise deciphering of Middle Mississippian history in the midcontinental United States and elsewhere.

CONCLUSIONS

Faunas do not change significantly across the present Osagean-Meramecian boundary at the Keokuk-Warsaw formational contact. Consequently the boundary cannot be readily correlated beyond the stratotype sections in the Mississippi River Valley. However, a widely recognizable change occurs within the Warsaw Formation that corresponds precisely with the base of Hall’s (1857) Warsaw Limestone and probably with Ulrich’s (1904) concept of the base of the Meramec Group. We recommend that this latter horizon serve as the Osagean-Meramecian boundary, recognized by the first occurrence of Pentremites conoides, Warsaviala lateralis, Planalavus diffusa, Crossacanthia pellamellosa, Setigerites altonensis, Tetracamera subcuneata, and Globoendothrya baileyi.

ACKNOWLEDGMENTS

We thank the following people for their gracious help. H. Richard Lane, James Baxter, Albert Kollar, Julie Wulf, and Scott Rodeheaver provided assistance in the field. James F. Miller showed us the Osagean stratigraphy of southwestern Missouri and allowed us to study his collection of Pentremites. Ronnie Inman provided access to the Tower Rock Quarry and provided Warsaw cores. John Groves reviewed Appendix 1. H. Richard Lane and Carl B. Rexroad improved an earlier draft of this manuscript by their careful reviews. We acknowledge support of this research by the National Science Foundation; EAR-8705331 (TWK) and EAR-8706430 (WIA).

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APPENDIX 1
THE PEERLESS PARK MEMBER (NEW MEMBER) OF THE KEOKUK LIMESTONE

PAUL L. BRENCLE and JOHN L. CARTER

DEFINITION

The Peerless Park Member is a discontinuous but persistent carbonate unit within the middle of the Keokuk Limestone, extending from the Mississippi River Valley into central Illinois (Fig. 7-1). It is named herein for exposures (Fig. 8) located near Peerless Park, southern St. Louis County, Missouri. Around Ste. Genevieve and St. Louis, the member is tabular to lenticular, varies from less than 0.5 m to about 4 m thick, and consists of predominantly chert-free, sandy, smooth-weathering, cross-beded limestone. This lithology contrasts with the rubbly-weathering, cherty encrinites typical of the Keokuk and provides a correlative horizon consistently at the same stratigraphic level beneath the Keokuk-Warshaw formational contact. At some localities the beds change laterally into typical Keokuk facies and become indistinguishable from the surrounding layers.

Grainstones are most common in the Peerless Park although a variety of lithologies are present. In the type area (Figs. 8, 9, 10), foraminifers and abraded crinoidal, algal and bryozoan fragments are
the dominant algae with subordinate amounts of ooids, coated grains and pellets. Around Ste. Genevieve the unit is mostly peloidal-coccolith.

**PALEONTOLOGY**

**Calcareous Microfossils**

The open marine, shallow-water deposition of the Peerless Park Member provided an exceptionally favorable environment for development of late Osagean foraminifers, algae and problematic microfossils. Many of the taxa within the member are absent elsewhere in the Keokuk, but reoccur in overlying Meramecian beds (Figs. 3-6). Brenckle et al. (1982) described a typical Peerless Park assemblage from the so-called "Fork Bed" at Elsah, Illinois, including *Koningiophyra tenuiramosa* Wood, *Principia cf. P. "donbasica"* (Kosenko), *Fourstonella, Epistoechoides, Skippella reduvallensis* (Skipp), *Eoendothyranopsis scitula* (Toomey), *E. spiroidea* (Zeller) and *Globoendothyrpa piasae* Brenckle. In addition, specimens of the primitive archaeocyclus genus *Vaseidicus* (illustrated in Brenckle, 1990, fig. 5A-C) were found in the bed immediately underneath the Peerless Park Member at the Waterslide section (Fig. 10). This occurrence is the oldest for the Archaeocyclusidae in the Mississippi River Valley and possibly in all of North America.

Fenneman (1911, p. 21, 40) commented about a chert-free limestone bed within the Keokuk at Peerless Park that he thought contained a megaflora allied to the Meramecian Spergen (Salem) Limestone. His observations, which undoubtedly refer to the Peerless Park Member, could be applied as well to the calcareous microfossils. Were it not for their isolation within the Keokuk, the foraminifers and associated microbiota could be mistaken for a Salem or age-equivalent assemblage. Indeed, many of the Peerless Park microfossils traditionally have been used as Meramecian guides. Weller (1895, p. 185-196) came to the same conclusion as Fennemann about the megafauna in the Short Creek Oolite from southwestern Missouri and adjacent states (Fig. 7-2). That unit is a thin, cross-bedded, oolithic-bioclastic grainstone lying within cherty Osagean encrinites of the Boone Formation. It contains calcareous microfossils very much like those in the Peerless Park. Weller (1895) surmised that the similar lithofacies of the Short Creek and Spergen (Salem) accounted for the similarity in megaflora. The same argument also explains the close relationship of the Peerless Park, Short Creek and Meramecian microfossils.
REDEFINITION OF THE OSAGE-MERAMECIAN BOUNDARY

Top of outcrop approximately 15m above base of section. Beds above 4.3m are mostly inaccessible and were not measured or described.

Limestone, buff to brown, dolomitic, slightly sandy, composed of crinoidal-fine-grained fossil debris wackestone; abundant nodular and layered chert, white to gray, speckled; solitary rugose corals.

Limestone, buff, very sandy, dolomitic, stromatolitic at base, composed of coarse-grained, abraded, crinoidal-laminar-coral packstone, glauconitic, solitary rugose corals.

Limestone, light gray, sandy, smooth weathering, cross-bedded, composed mostly of coarse-grained, abraded, crinoidal-laminar-algal grainstone; scattered gray chalk nodules near base; stromatolitic at base with up to 2 cm thick shaly parting; brachiopods, snails, corals.

Limestone as below, buffy to blocky weathering, capped by discontinuous, most of crinoidal-bryozoan-spicle packstone with shaly parting at base. (Section offset 10m to west)

Limestone, light gray to brown, gray, rubby weathering, stromatolitic, composed mostly of fine to coarse grained, crinoidal-bryozoan grainstone and packstone, slightly glauconitic: abundant lenticular and nodular bedded chert, gray to white, speckled, fossiliferous; shaly partings between some stromatolites.

Weathered limestone, chalk and soil cover.

Limestone, light to medium gray, rubby weathering, dolomitic, slightly bioturbated, composed of crinoidal-bryozoan-peloidal packstone, abundant white and buff chalk nodules and layers.

Limestone, light gray, sandy, smooth weathering, prominently cross-bedded, composed mostly of coarse-grained, abraded, crinoidal-laminar-algal-bryozoan-peloidal grainstone.

Limestone, medium-dark gray, rubby weathering, composed of fine to coarse-grained, bryozoan-crinoidal-spicle-lamellar packstone, abundant, interbedded gray nodular chert.

Limestone, gray, blocky weathering, composed of fine to coarse-grained, bryozoan-crinoidal packstone; abundant, light gray chert in lower part.

Limestone, gray, rubby weathering, crinoidal packstone with very abundant gray to buff chalk nodules.

Brachiopods

The megafauna of the Peerless Park Member in its type area (Fig. 8) is dominated by articulate brachiopods, both in numbers of individuals and in taxonomic diversity. Well over 20 species in as many genera occur in the type Peerless Park, but none is confined to the member. The productids Avonia williamsana Girty, Keokukia rotunda Carter, Echinococoncha alternatus (Norwood and Pratten), Setigerites setigerus (Hall), Tolmatchoffia keokuk (Hall), Tomipteris kolarii Carter, and Stegacanthia biseriata (Hall) dominate the assemblage. Another important group is the spiriferids, including Anthracospirifer breckleli Carter, Spirifer tenuicoatus Hall, Brachythyris subplicularis (Hall), and Tornyifuer pseudolineatus (Hall). Other common species include Orthotetes keokuk (Hall) and Cranaea sulcata Well.

Our collections from the Peerless Park Member in Ste. Genevieve County have yielded only specimens of Orthotetes keokuk and an unidentified terebratulid. Well and St. Clair (1928, p. 189), however, listed 11 brachiopod species in their equivalent bed 14 at the Clement section of Ste. Genevieve County.

Contrary to Preneman's (1911) opinion, we think that the brachiopods of the Peerless Park Member are of normal Osagean aspect, not to be mistaken easily for a Salem assemblage. Many of the Peerless Park species also occur in the Short Creek Oolite of southwestern Missouri, although the latter bears a much less diverse fauna.
Short Creek-Peers Park Correlation

Baldwin (1953), Voss (1963) and Thacker and Satterfield (1977) tentatively or otherwise assigned the Peers Park beds of eastern Missouri to the Short Creek Oolite, and Weller and St. Clair (1928) thought both units were age-equivalent. We agree that they are most likely coeval based on similarities in the megafaunal and microfossil successions. The Peers Park clearly lies within the middle of the Keokuk Limestone throughout its areal extent, but the Short Creek proper has generally been correlated to the uppermost Keokuk or basal Warsaw. The latter correlation in part stems from the interpretation of the brachiopod Marginirusus (formerly Productus) magnus, which first occurs in beds directly beneath both the Short Creek and Peers Park. Weller (1914 and in Weller and St. Clair, 1928) correctly identified that fossil in the Keokuk and Warsaw formations of the Mississippi River Valley, but in a 1926 paper restricted its occurrence to the Warsaw. Using Weller's 1926 correlation, Moore (1928) equated the Short Creek to the lower Warsaw and Gordon (in McKnight and Fischer, 1970) did the same. In a later paper, Moore et al. (1989) reassigned the Short Creek to the upper Keokuk.

Thompson (1986) thought that faunal evidence in southwestern Missouri was equivocal for correlating the Osagean-Meramecian boundary and, following the position of Thompson and Anderson (1976), arbitrarily put the Short Creek at the top of the Keokuk. Thacker and Satterfield (1977) applied this correlation to eastern Missouri. They placed the Peers Park beds (their Short Creek Oolite) at the Keokuk-Warshaw contact in Ste. Genevieve County, although more than 10 m of typical Keokuk limestone separate the Peers Park from the overlying Warsaw shales and siltstones in that area.

REGIONAL RELATIONSHIPS

The lithology, sedimentary structures and areal distribution suggest that the Peers Park Member represents a narrow band of discontinuous shoals and channels deposited along the eastern edge of the Burlington-Keokuk Shelf adjacent to the Illinois Basin (Lineback, 1966, fig. 9; Lane, 1978; Whitehead, 1984, p. 284). The shoaling environment possibly continued around the southern end of the shelf, connecting with the Short Creek deposits to the west. Subsequent erosion associated with the Ozark Uplift (Fig. 7), however, removed any physical evidence of continuity between the eastern and western shelf edge. For that reason we prefer to distinguish the Peers Park as a separate lithostratigraphic unit.

Both the Short Creek and Peers Park are part of shallowing-upward sequences, probably recording a brief, widespread regression within the Midcontinent interior seaway during the late Osagean. The depositional event was unique on the eastern shelf in that the shoaling environment was not repeated at any other stratigraphic level within the Keokuk Limestone. McKnight and Fischer (1970) reported scattered subsurface occurrences of oolitic cherts in the Boone member above the Short Creek Oolite, indicating a possible return to shoaling conditions along the western shelf edge, but Thompson (1986, p. 96) discounted reports of any other related oolitic zones in southwestern Missouri.

A similar, thin, oolitic-bioclastic unit, the Floyds Knob bed (Whitehead, 1978), occurs within late Osagean, fine-grained siliciclastics of the Borden delta complex along the eastern edge of the Illinois Basin (Fig. 7-3, 47). The Floyds Knob may be a contemporary analogue of the Peers Park beds and, if so, would extend the basin-fringing, shoal facies toward the Appalachian front. No definitive calcareous microfossils or macrofossils have yet been found in the Floyds Knob to link it unequivocally to the Peers Park, although conodont recoveries (Gates and Rexroad, 1970; Whitehead, 1978) suggest that the former unit is a Keokuk age-equivalent.

APPENDIX 2

LOCATION OF KEY SECTIONS

Type Keokuk Limestone-Warshaw Formation Area:

1. Gray's Quarry, Hamilton, Illinois, SW 1/4, NE 1/4, Sec. 31, T5N, R8W, Hancock Co., Hamilton, IL-IA Quadrangle. 38 m (124 ft) of upper Burlington Ls., Keokuk Ls., and lower Warshaw Fm. Section is figure 2 of Brenchle et al. (1974). The Warsaw-Keokuk contact of Brenchle et al. should be lowered to the base of the dolomite bed just above sample 34 on figure 2 of that paper. That level coincides with the Keokuk-Warshaw contact in Collinson et al. (1979, p. 13).


3. Soap Factory Hollow, Warsaw, Illinois, Center of Sec. 16, T4N, R9W, Hancock Co., Warsaw, IL-MO Quadrangle. The majority of exposures along the creek are Keokuk Limestone. There are limited exposures of the lower Warsaw, and only about 1 m of upper Warsaw. Laudon (1948) thought all of the exposures were Warsaw.

4. Iowan Gateway Terminal, NW 1/4, NW 1/4, Sec. 30, T6N, R4W, Lee Co., Hamilton, IL-IA Quadrangle and Keokuk, IA-MO-IL Quadrangle. 14.3 m (47 ft) of Keokuk and lower Warsaw along railroad tracks.


Type Meramecian Area:

6. Peers Park, S 1/2, NW 1/4, Sec. 20 (extended), T4N, R5E, St. Louis Co., Missouri, Kirkwood Quadrangle. Keokuk exposed along either side of Interstate Highway 44. Type area of Peers Park Member. Sections are from Appendix 1 (Figs. 9, 10) of this paper and figure 2 of Brenchle and Lane (1981).

7. Meramec River Bridge, SW 1/4, SW 1/4, Sec. 14 and NW 1/4, NW 1/4, Sec. 3, T4N, R5E, St. Louis Co., Missouri, Kirkwood Quadrangle. Upper Keokuk and lower Warsaw exposed along south side of I-44. Section is figure 7 of Lane and Brenchle (1977) and part of figure 88 of Thompson (1986).

8. Cragwood Road, NE 1/4, SW 1/4, Sec. 14, T4N, R5E, St. Louis Co., Missouri, Kirkwood Quadrangle. Upper part of lower Warsaw, upper Warsaw, and lowermost Salem in north corner of I-44 and I-270 interchange. This section, described by Lane and Brenchle (1977, p. 25–26, fig. 8), is the stratotype for the proposed Osagean-Meramecian boundary. Thompson (1986, fig. 88) combined this section with the one at Meramec River Bridge (section 7) to create a composite Warren interval. The Osagean-Meramecian boundary lies at the base of Thompson's unit 12 in figure 88 and is pictured in figure 90. Most rocks referred to as Salem in these two references are now considered
upper Warsaw. We would place the Warsaw-Salem contact at the base of unit 44 in Lane and Brencle (1977, fig. 8) and within the upper part of unit 18 in Thompson (1986, fig. 88).

9. Meramec Highlands Quarry, N¼, SE¼, Sec. 10, T44N, R5E, St. Louis Co., Missouri, Kirkwood Quadrangle. Upper Warsaw, Salem, and St. Louis exposed. Section is figure 6 of Lane and Brencle (1977), re-illustrated by Thompson (1986, fig. 92). Units 1–18 are upper Warsaw, units 19–24 are Salem, and units 25–40 are St. Louis. This section was described by Weller (1908) and Fenneman (1911), and apparently was part of Ulrich’s (1904, p. 110) Meramec Group. Ulrich’s type Meramec Group and Weller’s (1908) descriptions must have also included the Marshall Road section (10) and the Meramec River Bend section of Lane and Brencle (1977, fig. 4).

10. Marshall Road, SW¼, SE¼, Sec. 10, T44N, R5E, St. Louis Co., Missouri, Kirkwood Quadrangle. Lower and upper Warsaw and Salem exposed. Section is figure 2.2 (base of upper Warsaw is unit 26) of Rexroad and Collinson (1965) and figure 5 (base of upper Warsaw is unit 2; base of Salem is unit 27) of Lane and Brencle (1977).

11. Elshah West and Principia, NE¼, NE¼, Sec. 19 and NE¼, SE¼, Sec. 20, T6N, R11W, Jersey Co., Illinois, Elshah, IL-MO Quadrangle. Keokuk Limestone and lower Warsaw exposed. Sections described in figure 2 of Brencle et al. (1982).

12. Columbia Road Cut (IL Rt. 3), NE¼, SE¼, and SE¼, SE¼, Sec. 22, and NW¼, SW¼, and SW¼, SW¼, Sec. 23, T1S, R10W, Monroe Co., Illinois, Columbia, IL Quadrangle. This section is figure 8 of Treworgy and Norby (1989) (also in Collinson et al., 1979, p. 76).

Osagean-Meramecian boundary placed between Warsaw and Ullin (we consider their Ullin to be upper Warsaw).


Ste. Genevieve County Area:

14. Tower Rock Quarry North, Ste. Genevieve, Missouri, NW¼, NE¼, Sec. 12, T38N, R9E, Ste. Genevieve Co., Prairie Du Rocher, IL-MO Quadrangle. There are 2 m (7 ft) of upper Warsaw at this locality. 29 m (95 ft) of lower Warsaw were measured from cores taken in the main part of the Tower Rock Quarry (Sec. 18, T38N, R9E), which also contains 90 m (295 ft) of Salem Limestone.

15. Little Saline Creek, Interstate 55 mileage markers 141.7–143.0, NW¼, Sec. 2, T36N, R9E (Keokuk), and SE¼, Sec. 34, T37N, R9E (upper Keokuk and lower Warsaw) Ste. Genevieve Co., Minnith Quadrangle. At least 30 m (98 ft) of Keokuk and lower Warsaw. Thacker and Satterfield’s (1977, p. 51) units 2–5, plus overlying 8 m, are Keokuk. Their unit 4, designated the Short Creek Oolite, is the new Peerless Park Mbr.