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Storm Deposition of Pisoids in the Humboldt Oolite Member of the Gilmore City Formation (Mississippian), North-Central Iowa

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Pisoids (concentrically laminated carbonate grains, > 2 mm in diameter) are abundant in the upper Humboldt Oolite Member of the Gilmore City Formation (Mississippian). Their cortices are isopachous and nuclei include both intraclasts and fragments of preexisting pisoids. They occur both as floating grains in a fine grainstone matrix and concentrated at the bases of distinct layers that may be crudely graded beds. Sorting characteristics and the presence of broken and abraded pisoids suggest not only their origin as primary free grains, but also storm influence in the deposition of local pisolite layers. Regionally, the upper Humboldt Oolite is characterized by pisolite with birdseyes, fenestrae, evaporite cements, evaporite solution-collapse breccias and tepee structures, a recurrent facies association that has been documented in both ancient and modern arid, peritidal, carbonate depositional environments.

INDEX DESCRIPTORS: pisoids, peritidal carbonate facies, storm deposits.

Ooids are coated, carbonate grains in which a nucleus of variable composition is surrounded by a cortex of concentric lamellae. They are spheroidal or ellipsoidal and typically medium to coarse sand-sized (0.25–1.0 mm). A sediment or sedimentary rock composed chiefly of ooids is an oolite. The term pisoid has been defined variously, but it is most often used to denote ooid-like grains larger than 2 mm in diameter. Pisolite is a sediment or sedimentary rock made up mostly of pisoids. Insofar as the terms ooid and pisoid are purely descriptive, ooids and pisoids are a polygenetic group of grains. They form both under the influence of biologic processes and as purely chemical precipitates in a variety of environments ranging from shallow marine to lagoons, lakes, rivers, caves and calcareous soils (Tucker and Wright 1990).

The origin of marine ooids is reasonably well understood. Most form by the accretion of concentric lamellae in saturated, wave- or current-agitated subtidal environments (Tucker and Wright 1990). In contrast, the origin of pisoids has been more controversial. Early workers considered ooids and pisoids to be qualitatively different because oolites are typically very well sorted with an upper size limit near 1 mm (Bathurst 1975). Apparently, few grains were known to bridge the gap between 1 and 2 mm. In fact, intermediate-sized grains do occur and in certain deposits (e.g., this study) there exists an uneven continuum of grain sizes from ooid to pisoid range. In modern carbonate environments, however, pisoids have been observed forming without ooids in arid, restricted, peritidal settings such as the Persian Gulf (Purser and Loreau 1973, Evamy 1973, Scholle and Kinsman 1974) and Western Australia (Handford et al. 1984), so not all pisoids are simply large ooids. The famous Middle Permian pisolite in the Guadalupe Mountains of west Texas and New Mexico consists almost entirely of large pisoids to the exclusion of other grains (Esteban and Pray 1983). Perhaps another source of confusion regarding the origin of pisoids is the fact that certain ones have experienced two quite different phases of growth. In the first phase they develop an evenly lamellar (isopachous) cortex as a consequence of accretion on the traction carpet of a mobile sediment. This is followed by a second phase in which the sediment becomes stationary and continued growth of pisoids is characterized by downward (gravitational) elongation of lamellae, polygonal fitting of grains, perched inclusions and bridge-like or laminar cements (Esteban and Pray 1983). Failure to recognize characteristics of the first growth phase can and has led to the misinterpretation of once mobile pisoids as vadose diagenetic features (Dunham 1969).

In this paper we describe a distinctive pisolite occurrence in Mississippian rocks of north-central Iowa. Evidence is presented for interpreting the pisoids as primary free grains that were introduced into a fine peloidal-oolitic grainstone matrix most likely as a consquence of storm activity that suspended and mixed grains of widely disparate sizes. We also review evidence of associated birdseye and fenestral fabrics, evaporites, solution-collapse breccias and tepee structures that strongly suggests formation and deposition of the pisoids in a hypersaline peritidal setting.

GEOLOGIC SETTING

The stratigraphic section on which this study is based was measured and described along the eastern face of the active Martin Marietta Corporation Pedersen Quarry, immediately west of the East Fork of the Des Moines River, approximately two miles east-northeast of the town of Humboldt, Humboldt County, Iowa (Fig. 2 in Brenckle and Groves 1987). The Pedersen Quarry is approximately one-half mile due east of the abandoned and flooded P&M Stone Company Hodges Quarry (later operated by Martin Marietta), which was the focus of numerous sedimentologic and paleontologic investigations (Harper 1977, Gerk and Levorson 1982, Glenister and Sixt 1982, Sixt 1983, Carter 1983, Brenckle and Groves 1987). Strata exposed in the Pedersen Quarry are assigned to the Humboldt Oolite Member of the Gilmore City Formation. Sixt (1983) and Woodson and Bunker (1989) discussed the complex nomenclatural history of the Gilmore City and Humboldt intervals. The name Humboldt Oolite had fallen from use in recent years (Woodson and Bunker

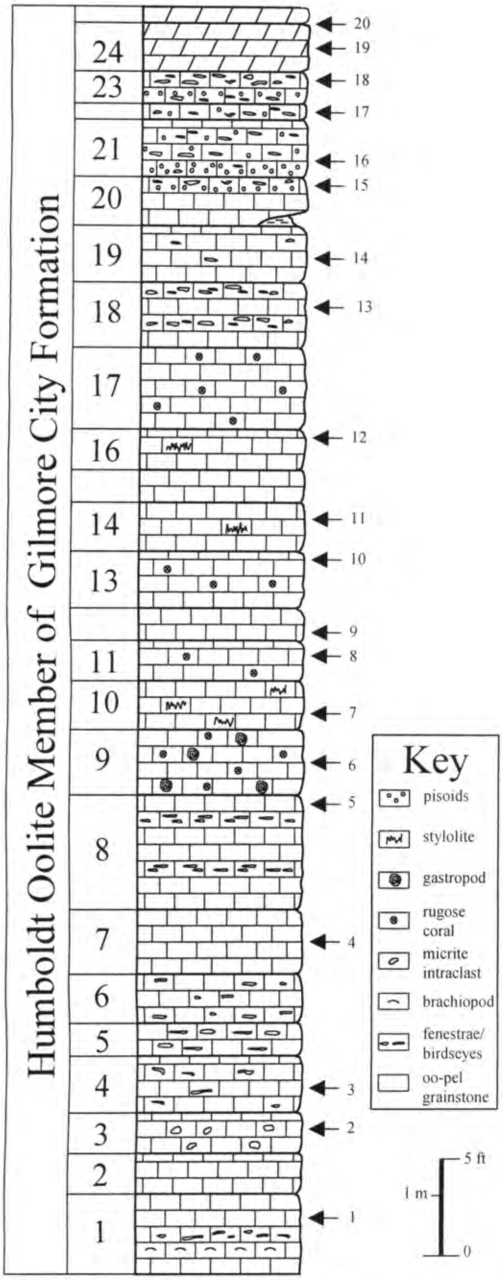

Fig. 1. Columnar stratigraphic section of Humboldt Oolite exposure at Pedersen Quarry (SE¼ NW¼ sec. 32, T92N, R28W, Humboldt County, Iowa). Numbers left of rock column denote stratal units (bedsets) discriminated on the basis of field observations. Numbered arrows show positions of rock samples.

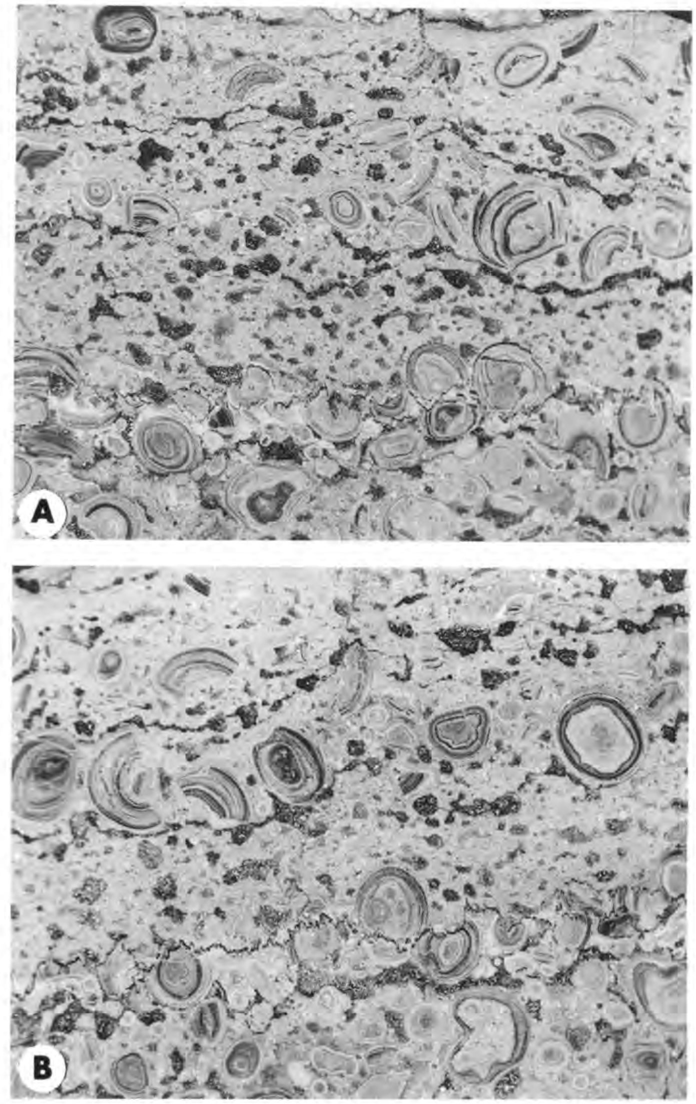

Fig. 2. *A and B*, Polished slabs of fenestral pisolite facies, upper Humboldt Oolite (unit 21, sample 16), actual size. Pisoids occur in layers separated by pisoid-poor matrix. Note broken and abraded pisoids as well as abundant birdseyes and fenestrae.

1989, Witzke et al. 1990, Anderson 1998), but it is now recognized by the Iowa Geological Survey Bureau as an official stratigraphic subdivision corresponding to the upper Gilmore City Formation (B. J. Witzke, written communication 2001). We employ it in this paper to distinguish the clean, light-colored limestones of the upper Gilmore City from underlying, more typical Gilmore City beds that contain shale stringers and interspersed dolomite.

The Humboldt Oolite at Pedersen Quarry is approximately 65 feet (~20 m) thick and consists mostly of medium- to very fine-grained oolitic and peloidal packstone to grainstone with occasional bioclastic debris, fenestrae and isolated birdseyes (Fig. 1) (see Appendix for petrographic descriptions of samples). The uppermost exposed beds (units 24 and 25) are finely crystalline dolomite, which are overlain by glacial till containing erratic cobbles. Freshly blasted (October 2000) rubble from the north face of the quarry contains a significant amount of sublithographic, laminated limestone breccia, but this lithology was not observed in place. The breccia is identical to that described by Sixt (1983) from the top of the Humboldt at the Hodges Quarry and interpreted as a syndepositional or early postdepositional collapse feature caused by the dissolution of evaporites interbedded with lime mudstone. Evaporite cements in the upper Humboldt at the Hodges Quarry were noted by Sixt (1983) and Brenckle and Groves (1987).

Pisoids and associated fenestrae and birdseyes that are particularly well developed in the upper Humboldt were assigned by Sixt (1983) to an informally designated "fenestral pisolitic facies." An exposure of this facies near Rutland, immediately northwest of Humboldt,

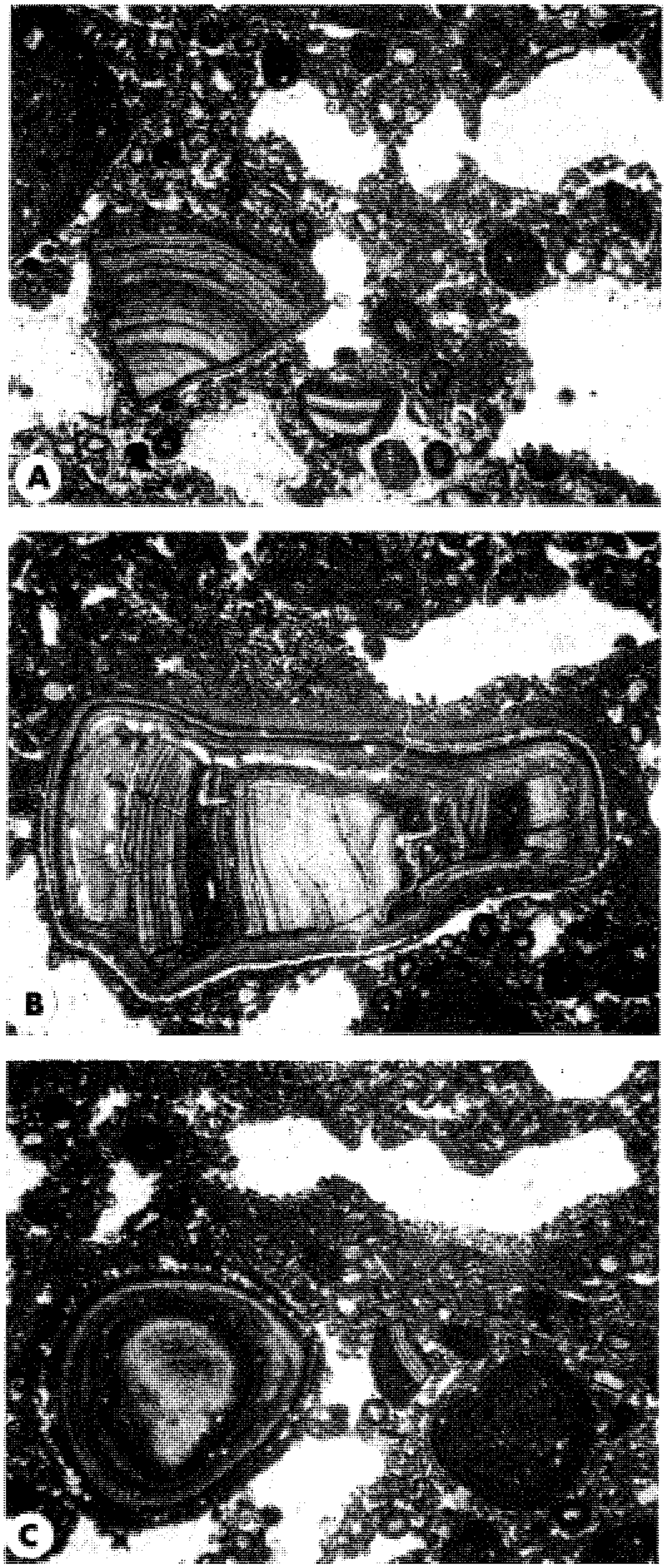

Fig. 3. Thin section photomicrographs of fenestral pisolite fabric, upper Humboldt Oolite (unit 21, sample 16), ×15. *A*, Broken pisoid fragments with incipient, secondary concentric lamellae floating in oolitic-peloidal packstone to grainstone matrix; note spar-filled birdseyes and fenestrae. *B*, Ellipsoidal pisoid exhibiting concentric lamellae developed around fragment of a preexisting pisoid. *C*, Spheroidal pisoid (lower left) and large ooid (lower right) with intraclastic nuclei; note uncoated intraclast (between pisoid and ooid) consisting of a pisoid fragment embedded in peloidal packstone matrix.

contains tepee structures that Sixt (1983) interpreted as having formed in a marine vadose environment when large-scale polygonal desiccation crusts expanded upon intermittent wetting and were then upthrust to create sheltered cavities. Although tepees have not been identified at Pedersen Quarry, their presence in the vicinity is noteworthy.

The Gilmore City Formation is Early and early Medial Mississippian (Kinderhookian and Osagean) in age as determined by studies of foraminifers and a variety of megafossil groups (Brenckle and Groves 1987). The Humboldt Oolite Member constitutes the upper part of the Gilmore City Formation. Woodson and Bunker (1989) recognized three transgressive-regressive (T-R) cycles in Kinderhookian and Osagean strata of north-central Iowa. Their upper Gilmore City (= Humboldt) was assigned to T-R cycle IIIb and interpreted as the culmination of an upward-shoaling phase of sedimentation. Paleogeographically, during Kinderhookian-Osagean time north-central Iowa lay on the eastern flank of the Transcontinental Arch, a shallowly submerged to mildly positive structural element that separated western and eastern seaways (Lane and De Keyser 1980). The upper Gilmore City has been interpreted as a peritidal equivalent to more normal marine strata of the lower Burlington Formation in southeastern Iowa (Witzke et al. 1990, Anderson 1998) near the northern limit of the Burlington Shelf (Lane and De Keyser 1980, Lane et al. 1994).

HUMBOLDT PISOIDS AND ASSOCIATED SEDIMENTARY STRUCTURES

Pisoids occur abundantly in the upper part of the Humboldt Oolite at Pedersen Quarry (units 20–23, Fig. 1). The pisoids are spheroidal to ellipsoidal, depending on the shape of the nucleus. Their diameter ranges from 2–3 mm up to 1.5 cm, with most being 4–8 mm (Fig. 2). The enclosing matrix is oolitic and peloidal packstone to grainstone with pervasive spar-filled fenestrae and birdseyes (isolated, spar-filled voids) (Fig. 3). Pisoid cortices are made up of isopachous concentric lamellae that exhibit faint radial-fibrous crystal morphology. Nuclei are both intraclasts of matrix lithology and fragments of preexisting pisoids (Fig. 3). Broken pisoids, abraded pisoid fragments and radially fractured pisoids are common (Figs. 2 and 3).

In some units there is no obvious pattern to the distribution of pisoids and they are dispersed as floating grains more or less randomly throughout the fine matrix. In unit 20, however, where pisoids are most abundant, they are clearly sorted and seem to occur in well organized layers that are separated from one another by layers of pisoid-poor matrix (Fig. 2). Certain of these alternating pisoid-rich and pisoid-poor couplets may in fact be crudely graded beds. The bases of pisoid-rich layers generally are very sharp, accentuated in places by minor stylolitization (Fig. 2).

Birdseyes are most common in pisoid-poor layers of the pisolite interval, where they are evenly distributed throughout the matrix. They occur less commonly in the matrix between pisoids in pisoid-rich layers. In contrast, fenestrae seem to occur preferentially both immediately below and above pisoid layers, being somewhat less common in pisoid-poor matrix (Fig. 2).

Humboldt pisoids do not exhibit directional elongation of cortical

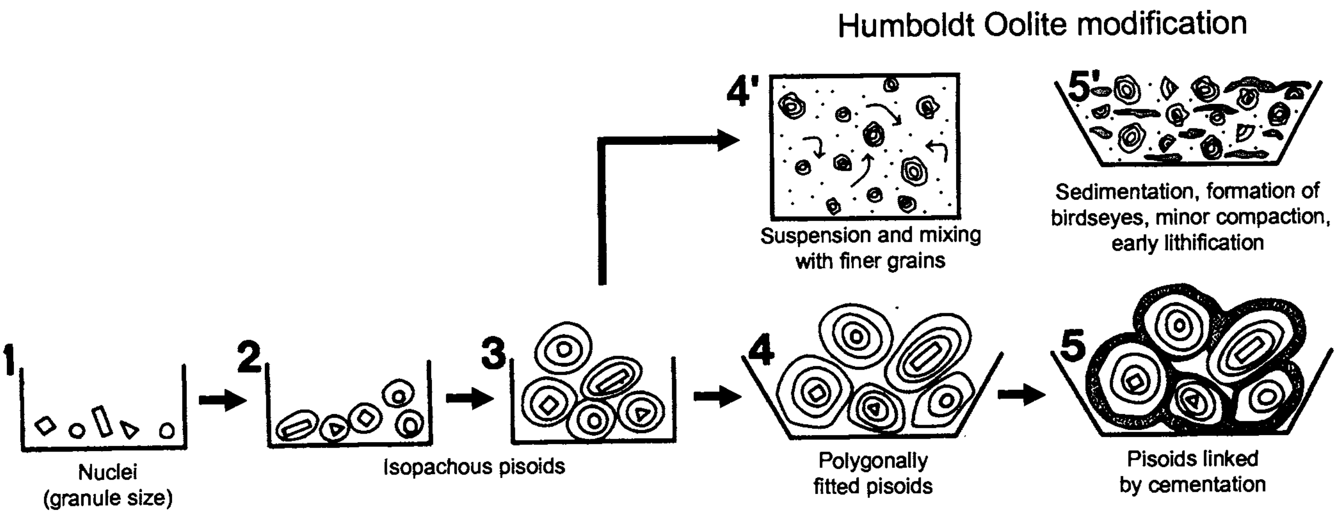

Fig. 4. Proposed model for genesis of Guadalupian pisolite (*stages 1–5*) and pisolite of the upper Humboldt Oolite (*stages 1–3, 4′, 5′*). Pisoids originate as concentrically accreted free grains (*stages 1–3*). If pisolite sediment becomes stationary, then continued lamellar growth may be directional (downward) and grains may become polygonally fitted (*stage 4*). Ultimately, laminar cements may envelop clusters of pisoids (*stage 5*). Humboldt pisoids are inferred to have been suspended and mixed with finer sediment by storms or other high-energy events (*stage 4′*). Rapid settling from suspension produced a poorly sorted pisolite or one in which pisoids and overlying finer grains constitute crudely graded beds. Birdseyes and fenestrae formed in cohesive, fine sediment that experienced only minor compaction prior to early lithification (*stage 5′*). Modified from fig. 7C in Esteban and Pray (1983).

lamellae, polygonal fitting of grains, perched inclusions, or interpisoid linkage by laminar cements.

INTERPRETATIONS

In most respects the Humboldt pisoids morphologically resemble pisoids from the Permian Reef Complex of the Guadalupe Mountains described by Newell et al. (1953), Dunham (1968, 1969), Thomas (1968), Kendall (1969), Pray and Esteban (1977) and Esteban and Pray (1983). An important difference between pisolite strata of the Humboldt and the Permian Reef Complex is the presence of matrix sediment around the Humboldt pisoids. The Guadalupian pisolite, in contrast, is composed almost exclusively of pisoids with few other grains. Although the origin of Guadalupian pisoids was controversial for decades, their interpretation as primary sedimentary grains (i.e., "clastic" pisoids) is now widely accepted. Esteban and Pray (1983) presented compelling evidence for most Guadalupian pisoids having formed as free grains within shallow (peritidal), hypersaline, intertepee depressions in a shelf-crest setting. Dunham (1968, 1969) previously interpreted the Guadalupian pisolite as paleocaliche, essentially the product of vadose diagenetic alteration of a precursor limestone. Supposed vadose diagenetic features of the Guadalupian pisolite were reinterpreted by Esteban and Pray (1983) as originating from minor in-place growth of stationary pisoids and accretion of laminar cement around primary pisoids during shallow burial in both vadose and phreatic marine diagenetic environments (Fig. 4). The environmental setting of Guadalupian pisoid genesis developed by Esteban and Pray (1983) was reinterpreted slightly by Handford et al. (1984), who observed modern pisoids forming within tepee-sheltered cavities in the vicinity of Lake MacLeod, a marine-influenced, coastal, hypersaline pond in Western Australia. Handford et al. (1984), in an attempt to explain the absence of skeletal grains in the Guadalupian pisolite, suggested that the Guadalupian pisolite-tepee facies may have been situated just landward of shelf crest shoals.

Humboldt pisoids are interpreted as having originated as free clastic grains following what we consider to be the mosr important criteria established by Esteban and Pray (1983): 1) presence of mechanically broken and abraded pisoids; 2) pisoids forming intraclastic nuclei of other pisoids; and 3) range in size of pisoids, with some being randomly distributed in the surrounding sediment and some being concentrated in distinct layers. Unlike the Guadalupian pisolite analog, however, the Humboldt pisoids probably were not deposited at their site of origin. Evidence that pisoids have been transported includes not only wear and breakage, but also their occurrence as floating grains in a much finer matrix and in apparently graded beds. These relations suggest that during storms, or other episodes of unusually high energy conditions, pisoids were suspended, mixed with finer sediment, and then deposited in a chaotic mixture (very rapid settling) or in crudely graded layers (rapid settling). Figure 4 depicts our interpretation of the genesis of the Humboldt pisolite as a modification of the model developed by Esteban and Pray (1983) for Guadalupian pisolites.

In modern carbonate environments, birdseyes and fenestrae are usually restricted to the supratidal zone, but they occasionally form in the intertidal zone (Shinn 1968). These voids form as shrinkage pores and/or when gas bubbles become trapped in cohesive sediment. Minor compaction may cause deformation of the voids, but their preservation is a reliable indicator of early lithification. Whereas true birdseyes and fenestrae typically originate in peritidal settings, Shinn (1983) documented the occurrence of large sheltered pores that closely resemble birdseyes and fenestrae in subtidal deposits on the modern Bahama Banks, and he cautioned against the use of birdseye- and fenestra-like features as rigidly constrained paleoenvironmental indicators in the absence of other criteria. The main differences between peritidal and subtidal voids are cementation of the latter by submarine, acicular (botryoidal) cements and the presence in the latter of internal geopetal sediment, neither of which was observed among our samples. Apart from the absence of botryoidal cements and internal sediment, we interpret the Humboldt features as true birdseyes and fenestrae on independent evidence of peritidal deposition, including their stratigraphic position near the top of a shoaling sequence and the lateral association of fenestrae- and birdseyebearing strata with tepees, evaporite-bearing limestone and solution-collapse breccia (Sixt 1983, Woodson and Bunker 1989).

The absence in the Humboldt pisolite of gravity-influenced features such as non-isopachous (directionally elongated) cortical lamellae and perched inclusions, and the absence of polygonally fitted grains and interpisoid linkage by laminar cements is a consequence of the pisoids resting in an oolitic-peloidal matrix rather than forming a deposit of nearly pure pisolite. Although highly porous and permeable, the pore spaces in the oolitic-peloidal matrix are comparatively small and therefore the matrix was highly confining, effectively inhibiting postdepositional growth of pisoids or laminar cement and preventing secondary accumulation of intergranular sediment (Figs. 3 and 4). The comparatively large pore spaces of the Guadalupian pisolite allowed for the postdepositional directional elongation of pisoids, polygonal fitting of grains through continued pisoid accretion, trapping of fine perched sediment and development of laminar interpisoid cements (Esteban and Pray 1983).

Insofar as the Humboldt pisoids at Pedersen Quarry probably have been transported, there is no local basis for judging whether they accreted on the traction carpet between tepees, within tepee-sheltered cavities, or in some other setting. Regionally, strata of the upper Humboldt Oolite include well developed fenestral carbonates, evaporites, tepees and abundant pisoids. This is a recurrent facies association that also characterizes both the Guadalupian pisolite and Holocene pisolite forming in the Persian Gulf and at Lake MacLeod, allowing us to corroborate earlier interpretations of the upper Humboldt as a hypersaline peritidal deposit that was subjected to periodic subaerial exposure. To previous interpretations we add that the upper Humboldt depositional environment was perturbed by frequent storms or other high-energy events capable of suspending and transporting large grains.

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LITERATURE CITED

ANDERSON, W. I. 1998. Iowa's geologic past—Three billion years of Earth history. University of Iowa Press, Iowa City.

BATHURST, R. G. C. 1975. Carbonate sediments and their diagenesis. Developments in Sedimentology 12. Elsevier, Amsterdam/Oxford/New York.

BRENCKLE, P. L., and J. R. GROVES. 1987. Calcareous foraminifers from the Humboldt Oolite of Iowa: key to Early Osagean (Mississippian) correlations between eastern and western North America. Palaios 1:561–581. [imprinted 1986]

CARTER, J. L. 1983. New brachiopods from the Gilmore City Limestone (Mississippian) of north-central Iowa. Annals of Carnegie Museum 52: 59–78.

DUNHAM, R. J. 1968. Asymmetrically-filled veins in Capitan reef and their genetic similatity to vadose pisolite. Geological Society of America, Annual Meeting Program, Special Paper 121:83–84.

DUNHAM, R. J. 1969. Vadose pisolite in the Capitan reef (Permian), New Mexico and Texas. Depositional environments in carbonate rocks. G. M. Friedman (ed.). Society of Economic Paleontologists and Mineralogists Special Publication 14:182–191.

ESTEBAN, M., and L. C. PRAY. 1983. Pisoids and pisolite facies (Permian), Guadalupe Mountains, New Mexico and west Texas. Pages 503–537. *In* Coated Grains. T. Peryt (ed.). Springer-Verlag, Berlin, New York, Heidelberg, Tokyo.

EVAMY, B. D. 1983. The precipitation of aragonite and its alteration to calcite on the Trucial Coast of the Persian Gulf. Pages 329–342. *In* The Persian Gulf. B. H. Purser (ed.). Springer Verlag, Berlin/Heidelburg/New York.

GERK, A. J., and C. O. LEVORSON. 1982. Unusual beach deposits in oolite carbonate envitonments, Mississippian and Recent. Ptoceedings of the Iowa Academy of Sciences 89:68–70.

GLENISTER, B. F., and S. C. SIXT. 1982. Mississippian biofacies-lithofacies trends, northcentral Iowa. Geological Society of Iowa Guidebook 37, 21 p.

HANDFORD, C. R., A. C. KENDALL, D. R. PREZBINDOWSKI, J. B. DUNHAM, and B. W. LOGAN. 1984. Salina-margin tepees, pisoliths, and aragonite cements, Lake MacLeod, Western Australia: their significance in interpreting ancient analogs. Geology 12:523–527.

HARPER, J. A. 1977. Gastropods of the Gilmore City Limestone (Lower Mississippian) of north-central Iowa. Unpublished Ph.D. dissertation, University of Pittsburgh, Pittsburgh, Pennsylvania.

KENDALL, C. G. St. G. 1969. An environmental reinterpretation of the Petmian evaporite carbonate shelf sediments of the Guadalupe Mountains. Geological Society of America Bulletin 80:2503–2526.

LANE, H. R., and T. L. DE KEYSER. 1980. Paleogeography of the late Early Mississippian (Tournaisian 3) in the central and southwestern United States. Paleozoic paleogeography of west-central United States. T. D. Fouch and E. R. Magathan (eds.). Society of Economic Paleontologists and Mineralogists, Rocky Mountain Section, West-central United States Paleogeography Symposium 1:149–162.

LANE, H. R., M. W. FRYE and G. D. COUPLES. 1994. The biothem approach: a useful biostratigraphically based sequence-stratigraphic procedure. Courier Forschungsinstitut Senckenberg 168:281–297.

NEWELL, N. D., J. K. RIGBY, A. G. FISCHER, A. J. WHITEMAN, J. E. HICKOX, and J. S. BRADLEY. 1953. The Permian Reef Complex of the Guadalupe Mountains region, Texas and New Mexico. W. H. Freeman and Co., San Francisco.

PRAY, L. C., and M. ESTEBAN. 1977. Upper Guadalupian facies, Permian Reef Complex, Guadalupe Mountains, New Mexico and Texas. Society of Economic Paleontologists and Mineralogists, Permian Basin Section, 1977 Field Conference Guidebook 2:1–194.

PURSER, B. H., and J. P. LOREAU. 1973. Aragonitic, supratidal encrustations on the Trucial Coast. Pages 343–376. *In* The Persian Gulf. B. H. Purser (ed.). Springer Verlag, Berlin/Heidelburg/New York.

SCHOLLE, P. A., and D. J. J. KINSMAN. 1974. Aragonitic and high-magnesium calcite caliche from the Persian Gulf—a modern analog for the Permian of Texas and New Mexico. Journal of Sedimentary Petrology 44:904–906.

SHINN, E. A. 1968. Practical significance of birdseye structures in carbonate rocks. Journal of Sedimentary Petrology 38:215–223.

SHINN, E. A. 1983. Birdseyes, fenestrae, shrinkage pores, and loferites: a reevaluation. Journal of Sedimentary Petrology 53:619–628.

SIXT, S. C. S. 1983. Depositional environments, diagenesis and stratigraphy of the Gilmore City Formation (Mississippian) near Humboldt, north-central Iowa. Unpublished M.S. thesis, University of Iowa, Iowa City.

THOMAS, C. M. 1968. Vadose pisolites in the Guadalupe and Apache mountains, west Texas. Society of Economic Paleontologists and Mineralogists, Permian Basin Section, Guidebook Publication 68–77:32–35.

TUCKER, M. E., and V. P. WRIGHT. 1990. Carbonate sedimentology. Blackwell Scientific Publications, Oxfotd/London/Edinburgh/Boston/ Melbourne.

WITZKE, B. J., R. M. McKAY, B. J. BUNKER, and F. J. WOODSON. 1990. Stratigraphy and paleoenvironments of Mississippian strata in Keokuk and Washington counties, southeast Iowa. Geological Society of Iowa and 54th Tri-State Geological Field Conference, Guidebook Series 10, 105 p.

WOODSON, F. J., and B. J. BUNKER. 1989. Lithostratigraphic framework of Kinderhookian and early Osagean (Mississippian) strata, north-central Iowa. *In* An Excursion to the Historic Gilmore City Quarries. F. J. Woodson (ed.). Geological Society of Iowa Guidebook 50:3–18.

APPENDIX

Petrographic descriptions of samples

Spl. 1—bioclastic grainstone dominated by brachiopod and crinoid fragments; secondary allochems include peloids; micrite intraclasts present; irregular birdseyes present
Spl. 2—peloidal grainstone; secondary allochems include bioclastic material and ooids; micrite intraclasts abundant
Spl. 3—peloidal grainstone; secondary allochems include ooids and bioclastic material; micrite intraclasts rare; irregular birdseyes abundant
Spl. 4—peloidal grainstone; secondary allochems include ooids and bioclastic material
Spl. 5—peloidal grainstone; secondary allochems include bioclastic material and ooids; fenestral birdseyes present
Spl. 6—bioclastic grainstone dominated by brachiopod and crinoid fragments and large solitary rugose corals; secondary allochems include peloids; irregular birdseyes rare
Spl. 7—peloidal grainstone; secondary allochems include bioclastic material; irregular birdseyes rare; stylolite present
Spl. 8—peloidal grainstone; secondary allochems of bioclastic material rare
Spl. 9—peloidal grainstone; irregular birdseyes rare
Spl. 10—bioclastic grainstone dominated by brachiopod and crinoid fragments and large solitary rugose corals; secondary allochems include peloids
Spl. 11—peloidal grainstone
Spl. 12—bioclastic grainstone dominated by brachiopod and crinoid fragments; secondary allochems include peloids
Spl. 13—oolitic grainstone; secondary allochems include peloids and bioclastic material
Spl. 14—bioclastic packstone with abundant brachiopod and crinoid fragments; secondary allochems include peloids; irregular birdseyes present
Spl. 15—bioclastic packstone with abundant brachiopod and crinoid fragments; secondary allochems include peloids, ooids, and pisoids; fenestral birdseyes abundant
Spl. 16—oolitic packstone; secondary allochems include pisoids; fenestral birdseyes abundant
Spl. 17—lime mudstone; secondary allochems include ooids fenestral birdseyes present
Spl. 18—lime mudstone; secondary allochems include ooids; fenestral birdseyes present
Spl. 19—crystalline dolomite
Spl. 20—crystalline dolomite