The Type Section of the Pendleton Sandstone

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Abstract

The Pendleton Sandstone (middle Devonian) at its type section at Falls Park, Pendleton, Madison County, Indiana, consists of 7 feet 7 inches of very fine-grained, very well-sorted, subrounded to subangular, dolomitic quartz sandstone. The sandstone disconformably overlies finely crystalline dolomite of the Wabash Formation (Silurian, Niagaran) of which the upper 8 inches contain a conodont fauna of the *Polygnathoides siluricus* Zone. The basal bed of the Pendleton contains rounded clasts of finely crystalline dolomite as well as reworked Silurian conodonts. The upper boundary of the Pendleton is the contact between sandstone and Jeffersonville Limestone, some beds of which are distinctly arenaceous.

Introduction

This study of the Pendleton Sandstone in its type area presents a detailed description of the only known good exposures of this Devonian rock unit. During the 100 years since the sandstone was first examined, several geologic reports concerning the exposures at Pendleton have been inconsistent regarding thickness, vertical succession, lithologic variation within the sandstone, and correlation of the Devonian rocks present. This paper summarizes previous investigations of the outcrops at Pendleton, interprets the above-mentioned inconsistencies regarding these exposures, presents a measured and described section of the Silurian and Devonian rocks present, and describes petrographic characteristics of the sandstone beds.

The best outcrop of the Pendleton Sandstone is located just north of C S ½ SW ¼ Sec. 16, T18N, R7E (Anderson South 7½ quadrangle), at the falls of Fall Creek in Falls Park at the north edge of Pendleton, Madison County, Indiana. The upper part of the sandstone crops out near the top of the water-filled quarry several hundred feet south of the falls. Small exposures of the sandstone may also be seen along the north bank of Fall Creek at water level in C SW¼ SW¼ Sec. 16, several hundred yards downstream from the falls.

The Pendleton Sandstone was named in 1869 by E. T. Cox (3).

Cox (4) in 1879 first published a measured and described section of the Pendleton Sandstone "from the bed of Fall Creek to the top of the drift" and reported 15 feet of sandstone. This section, divided into 4 numbered units, also appeared in 1901 (9) as follows:

1) Drift . . . 50 feet.
2) Ash colored rough weathering, cherty magnesian limestone, alternating with soft sandy, greenish colored, pyritous layers, in all about 4 feet.
3) Buff sandy magnesian limestone, *Pleurotomaria* and coral bed, 4 feet.

4) Heavy bedded and soft, white sandstone, upper part fossiliferous, 15 feet.

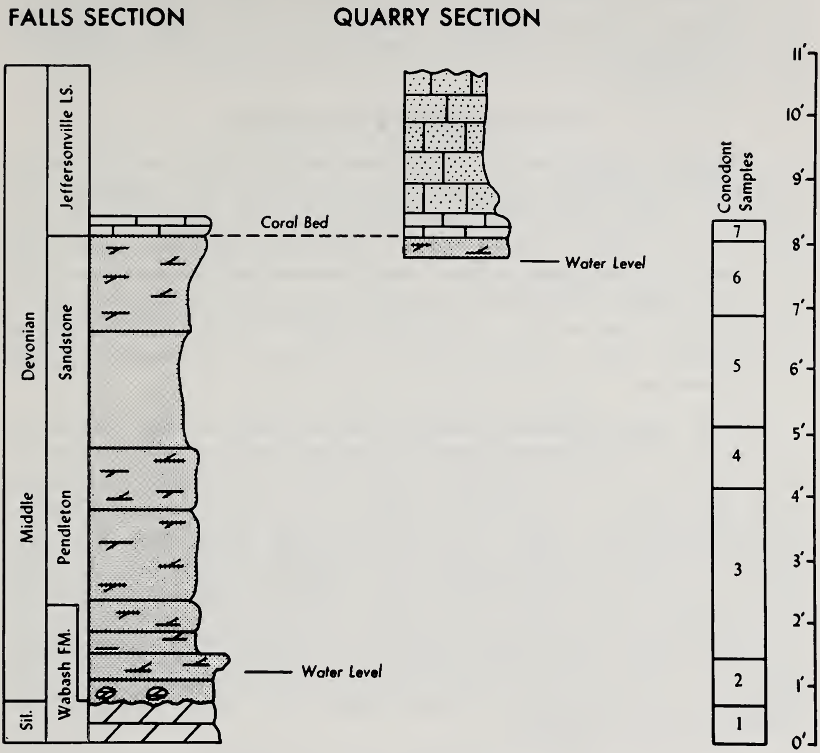

FIGURE 1. *Columnar sections of strata at Falls Park, Pendleton. The falls section is the type section of the Pendleton Sandstone. Conodont sample intervals are shown at the right.*

Kindle (9) redescribed the section "at the quarry and in the bank of the creek" as follows: 10 inches+ of "bluish drab calcareous fine-grained sandstone" overlain by 6 feet 8 inches of "massive white sandstone with 10 to 12 inch strata" succeeded by 3 feet 6 inches of "hard gray limestone." Kindle pointed out that Unit 2 in Cox's "evidently a connected section" had not been found anywhere resting directly on Unit 3 at Pendleton, that Unit 2 is of Niagaran age with a fauna containing *Sphaerexochus romingeri*, and was shown in incorrect stratigraphic succession. During our study of the Pendleton exposures we did not see any cherty limestone (Cox's Unit 2 lithology). Kindle's section, representing 7½ feet of sandstone, is essentially the same one measured and described by us in 1972 (Fig. 1). Kindle (9) described a chert pebble conglomerate of "local development in the upper part of the Pendleton sandstone" on the north side of Fall Creek several hundred yards downstream from the falls. When we visited this spot we found numerous chunks of concrete containing pebbles of dark-colored chert. We suspect that these slabs of concrete, which are embedded in alluvium several feet above sandstone bedrock at water level, were interpreted as conglomerate by Kindle. At the falls only the basal several inches of the sandstone contain pebbles, which consist of finely crystalline dolomite. No chert is present and the upper part of the sandstone is not conglomeratic.

Stratigraphy of the Type Section

Although Falls Park on Fall Creek is the type locality of the Pendleton Sandstone, a specific type section has not formally been designated. In the late 1800's the sandstone was well exposed in the then active quarry south of Fall Creek as well as in the banks and bed of the creek. In 1972, the quarry was abandoned and full of water and only the highest beds of Pendleton Sandstone were present above water level. We designated the outcrop at the falls (Fig. 1) as the type section of the Pendleton. This is both the largest and thickest exposure of the unit in the type area.

At the type section the Pendleton forms massive ledges in the bed and banks of Fall Creek. The lip of the falls is located near the top of the sandstone, which is exposed in the bed of Fall Creek immediately above the falls, as are several inches of the overlying fossiliferous, arenaceous limestone. The bed of Fall Creek below the falls was developed on the Wabash Formation (Silurian, Niagaran). Although below water level in 1972 (Fig. 1), the upper 8 inches of the Wabash are accessible at the base of the falls on the south side and blocks can be obtained that indicate the nature of the contact with the Pendleton Sandstone. Total thickness of sandstone at the falls is 7 feet 7 inches. This is the only outcrop where both lower and upper contacts of the sandstone may be observed.

Type Section of the Pendleton Sandstone

		ft	in.
Jeffersonville Limestone			
11	Limestone, gray, arenaceous, thin to medium-bedded; wackestone. This unit is visible only along south edge of old water-filled quarry about 25 feet north of picnic shelter.	2	10
10	Limestone, gray with limonite surficial straining; tetracoral packstone or biosparite. The corals lie horizontally and are tubular, ¼-½ inch in diameter. Observable below Unit 11 at the quarry and above the falls of Fall Creek; conodont sample 7.	0	4
Pendleton Sandstone			
9	Sandstone, white, dolomitic, very fine-grained, very well-sorted, subangular to subrounded; has manganese oxide concretions, brachiopod and trilobite fragments near top of unit; conodont sample 6.	1	6
8	Sandstone, white, very friable, very fine-grained, very well-sorted, subangular to subrounded, burrowed. See Figure 2 for grain size analysis; conodont sample 5.	1	10
7	Sandstone, red and white, dolomitic, very fine-grained, very well-sorted, subrounded to subangular, thin-bedded, burrowed; has mottled lamination; conodont sample 4.	1	0
6	Sandstone, red and white, dolomitic, very well-sorted, subrounded to subangular; conodont sample 3.	1	5

5	Sandstone, red and white, dolomitic, very well-sorted; has disrupted laminae, vertical fractures filled with ferrugenous oxides; conodont sample 3.	0	6
4	Sandstone, red, dolomitic, very fine-grained, very well-sorted, subangular to subrounded; has sparse pyrite; conodont sample 3.	0	4
3	Sandstone, reddish brown, dolomitic, very fine-grained, very well-sorted, subrounded to subangular; displays faint lamination; conodont sample 3; base of unit at water level 25 May 1972.	0	5
2	Sandstone, gray, dolomitic, very fine-grained, very well-sorted, subrounded to subangular; lacks lamination; conodont sample 2.	0	4
1	Sandstone, gray, dolomitic, very fine-grained, very well-sorted, subrounded to subangular; has undulatory lamination, possible bioturbation, rounded pebbles of dolomite (½-1 inch in diameter) at base; conodont sample 2.	0	3
Total Thickness of Pendleton Sandstone		7	7
	Disconformity—irregular jagged surface suggests rocks below this unit must have been lithified prior to deposition; black to brown coating covers molds of unit 1 into the unconformity surface.		
Wabash Formation			
	Dolomite, gray, very finely crystalline; crinoidal packstone to wackestone; has fissures filled with pyritic quartz sand; conodont sample 1.	0	3
	Dolomite, gray, very finely crystalline, crinoidal; conodont sample 1.	0	3
	Dolomite, gray, very finely crystalline; crinoidal packstone to grainstone; has moldic porosity (5%) after crinoid plates; conodont sample 1.	0	2

In the early reports of Cox (4) and Kindle (9) the top of the Pendleton Sandstone as a rock unit was not defined, although the limestone beds above the sandstone were consistently separated as a distinct lithologic unit ("*Pleurotomaria* and coral bed" of Cox). Sutton (15), however, designated both the sandstone and the superjacent limestone beds the "Pendleton formation." Since the relation of the limestone beds, arenaceous in part, to higher rocks is not evident from the exposures at Pendleton, there is no satisfactory top to Sutton's "Pendleton formation". We believe that the top of the Pendleton Sandstone as a formal rock-stratigraphic unit of formational rank should be placed at the base of the lowest carbonate rocks overlying sandstone, whether or not these carbonates are arenaceous. This is a contact that can be mapped, although admittedly in a small area at Pendleton, and recognized in the subsurface. We advocate restriction of the Pendleton to sandstone at the base of middle Devonian limestones or dolomites. On this basis we assign rocks superjacent to the sandstone at Pendleton to the Jeffersonville Limestone. W. J. Wayne (unpublished data) regards the Pendleton as a member of the Jeffersonville, which alternate interpretation merits consideration. Regardless of the rank of the unit, we prefer using the name Pendleton Sandstone for sub-Jeffersonville or sub-Geneva sandstones, which may be discontinuous, in central and southern Indiana. If basal middle Devonian rocks overlying Silurian strata in this region are arenaceous carbonates, we prefer designation of these beds as Geneva Dolomite or Jeffersonville Limestone, respectively.

Paleontology and Correlation

The Pendleton Sandstone and the overlying limestone beds contain an invertebrate megafauna composed mostly of corals, brachiopods, trilobites, stromatoporoids, and gastropods. The fossils were initially studied by Cox (4) who presented a faunal list and named the coral-rich limestone immediately overlying the sandstone the "*Pleurotomaria* and coral bed" and Hall (7) who correlated the beds exposed at Falls Park with the Scoharie Formation (upper lower Devonian) of New York on the basis of faunal similarity. Kindle (9) identified additional taxa from the sandstone and "*Pleurotomaria* and coral bed" and supported Hall's correlation.

A different correlation was made by Sutton (15) who interpreted the Pendleton as equivalent to the lower parts of the Geneva and Jeffersonville Formations (lower middle Devonian) and considered the sandstone as one of three lithologic facies of this stratigraphic interval. Weller (19) similarly interpreted the Pendleton and indicated it is "comparable to and may be correlated with the Dutch Creek [Sandstone Member of the Grand Tower Limestone] of Illinois." Cooper *et al.* (2) also correlated the Pendleton with the Geneva and Jeffersonville. On the basis of paleontologic, sedimentologic, and paleogeographic considerations we support the interpretations of Sutton and Weller regarding the stratigraphic position of the Pendleton as low in the middle Devonian.

We systematically channel sampled the beds at Pendleton for conodonts. One kilogram of rock was processed from each of the 7 stratigraphic intervals shown in Figure 1. Sample 1 from the top 8 inches of the Wabash Formation (Silurian, Niagaran) contained a moderate conodont fauna assigned to the *Polygnathoides siluricus* Zone (mid-Silurian, Ludlow Stage of Europe) (17). The fauna was dominated by panderodids and contained as important elements *Ozarkodina media* and *O. simplex* identified by Carl B. Rexroad, Indiana Geological Survey. Sample 2 from the basal pebbly sandstone of the Pendleton contained a few specimens of Silurian panderodids which we interpreted as reworked from older rocks and some of which might be included in the pebbles of finely crystalline dolomite that are present immediately above the Siluro-Devonian disconformity. Sample 3 from a sandstone interval contained only two fragmentary amber-colored conodonts, one possibly a hindeodellid, that appeared to be Devonian but were undiagnostic. Samples 4-7 were barren of conodonts.

Although sandstones may yield small numbers of identifiable conodonts, diagnostic faunas have been recovered from other sandstones by several workers. The Dutch Creek Sandstone Member of the Grand Tower Limestone of southern Illinois occupies a similar stratigraphic position as the Pendleton (1, 2, 19). The Dutch Creek contains a sparse conodont fauna containing as diagnostic elements several subspecies of *Icriodus latericrescens* (1). One, *I. latericrescens robustus* Orr, is an index for the lower middle Devonian and is also known from the Jeffersonville Limestone of southern Indiana and the Onondaga Limestone of New York (10).

Sandstone or arenaceous carbonate rocks typically occupy a stratigraphic position at or near the base of the middle Devonian throughout the craton in central and eastern United States (14). In the

Devonian outcrop belt of southern Indiana, basal middle Devonian carbonates are generally only slightly arenaceous. They become increasingly so westward into the Illinois Basin where beds of sandstone are discontinuously present throughout much of the western part of the southern half of the state (12, 14).

According to Summerson and Swann (14), general uplift in the Ozarks and Wisconsin highlands following deposition of the Clear Creek Chert (upper lower Devonian of southern Illinois) exposed Cambro-Ordovician clastic formations. Quartz sand drived from these lower Paleozoic units was spread eastward principally by wind under near-arid conditions. These authors suggested that the Pendleton sand body resulted from obstruction of sand movement by the gentle topography of the differentially upwarped Cincinnati Arch. The sand was then stabilized by deposition of middle Devonian carbonate rocks (Cox's "*Pleurotomaria* and coral bed" at the type section).

Petrography

In the field the Pendleton Sandstone is medium- to thick-bedded (8) having 4-inch to 22-inch beds split by partings. Mottled lamination and the oblique angle of trilobite and brachiopod tests to bedding planes suggest that the lack of internal structures, such as ripple marks and cross-bedding, is a result of bioturbation.

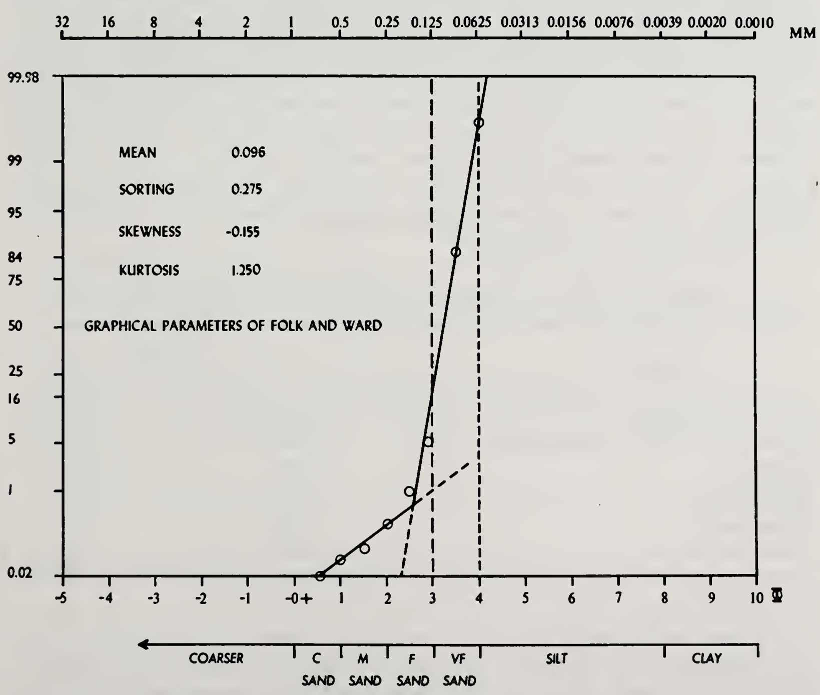

FIGURE 2. *Cumulative frequency plot and grain size parameters (5) of one representative sample from the friable interval of the Pendleton Sandstone 51 to 73 inches above the base.*

The basal contact of the Pendleton is abrupt and represents a change from the Wabash Formation (Silurian), dolomite, to Pendleton Sandstone (middle Devonian), dolomitic sandstone. Fissures filled with pyrite, dolomite, and sand extend downward into the Wabash. The unconformity surface (Fig. 1) is irregular to jagged, showing the lithified nature of the Silurian rock before Devonian sedimentation. A black to brown coating covers the surface of Devonian sandstone molds of the Silurian unconformity surface. Spherical to well-rounded lithic clasts of dolomite up to 1 inch in diameter are enclosed in a sandstone matrix above the unconformity. The Silurian conodont fauna previously cited indicates that the lithoclasts are reworked Silurian material.

The upper contact of the Pendleton can be easily mapped at the base of a key bed of coralline limestone (Fig. 1) superjacent to the sandstone in the type area.

Part of the Pendleton Sandstone from 51 to 73 inches above the base is friable, contains 20-30% porosity, lacks dolomite, and lends itself to sieve analysis (Fig. 2). The statistical parameters and grain attributes summarized in Table 1 characterize two samples of the friable zone.

Alizarine Red S (18) stains slabs dark purple indicating ferroan dolomite cement as an important constituent. In thin section the dolomite cement is euhedral and evenly distributed except for concentrations in clots and plates that probably represent replaced fossils. Most dolomite rhombs are 0.08 to 0.04 mm in diameter, but a large number of smaller rhombs range down into the silt range. Some thin sections are composed of nearly 50% dolomite. In thin section quartz appears to have been initially more rounded (0.7-0.9) (11) as overgrowths, which significantly reduce roundness, are easily recognized. Eighty-six percent of the grains have non-undulatory extinction; 14% have undulatory extinction.

TABLE 1. *Grain size parameters for two samples of the friable zone.*

Parameters	Samples	
	1	2
Mean Grain Size (5)	0.0981 mm	0.0960 mm
Maximum Grain Size of First Percentile	0.203 mm	0.203 mm
Sorting (5)	0.231	0.275
Skewness (5)	—0.514	—0.155
Kurtosis (5)	0.95	1.25
Roundness (11)	0.1-0.3	0.1-0.3
Sphericity (11)	0.7-0.9	0.7-0.9

Minor constituents are pyrite and lithic clasts of dolomite and ferroan dolomite. The pyrite is most often inset into the dolomite cement. Lithic clasts have finely disseminated pyrite concentrated in a rim around the clasts, which are aggregates of silt size, hypidiomorphic dolomite with moldic porosity.

The porosity of the cemented sandstone averages 10% in thin section. Porosity is intergranular in areas not filled by dolomite cement. Quartz grain contacts are tangential, but secondary overgrowths make many contacts appear planar to concavoconvex. Quartz-quartz contacts average 1.5 per grain.

A diagenetic history can be interpreted from thin sections. Compaction of sand grains to tangential contacts followed deposition. Quartz overgrowths formed and lengthened quartz-quartz contacts. Euhedral ferroan dolomite then cemented the rock. Pyrite may have been generated into the dolomite cement and/or have been transported in with dolomite lithic clasts that were since recrystallized.

Petrology

The sequence of disconformity, sandstone, fossiliferous limestone suggests transgression by a middle Devonian shoreline with subsequent deposition in deeper water conditions represented by the Jeffersonville Limestone. Lack of appropriate sedimentary structures prohibited any study of the direction of transport of sand but directions can be taken on numerous corals on the coralline key bed (Fig. 1). A vague bimodal trend at N35E to S35W and N75E to S75W (weaker) is evident. Statistical parameter plots of Friedman (6) for sedimentary environments, CM diagrams of Passega (13), and probability plots of grain sizes of Visher (16) do not conflict with the interpretation that the Pendleton Sandstone at its type section represents sedimentation in a littoral environment.

Literature Cited

1. COLLINSON, CHARLES, L. E. BECKER, G. W. JAMES, J. W. KOENIG, and D. H. SWANN. 1968. Illinois Basin, p. 940-962. *In* CHARLES COLLINSON. Devonian of the north-central region, United States. Int. Symp. on the Devonian Sys. Calgary, Alberta. Alberta Soc. Petrol. Geol. 1:933-971.

2. COOPER, G. A., CHARLES BUTTS, K. E. CASTER, G. H. CHADWICK, WINIFRED GOLDRING, E. M. KINDLE, EDWIN KIRK, C. W. MERRIAM, F. M. SWARTZ, P. S. WARREN, A. S. WARTHIN, and BRADFORD WILLARD. 1942. Correlation of the Devonian sedimentary formations of North America. Geol. Soc. Amer. Bull. 53:1729-1794.

3. COX, E. T. 1869. First annual report of the Geological Survey of Indiana, made during the year 1869. 240 p.

4. ————.1879. Eighth, ninth, and tenth annual reports of the Geological Survey of Indiana, made during the years 1876-77-78. 541 p.

5. FOLK, R. L., and E. C. WARD. 1957. Brazos River bar: a study in the significance of grain size parameters. J. Sed. Petrol. 27:3-27.

6. FRIEDMAN, G. M. 1961. Distinction between dune, beach, and river sand from their textural characteristics. J. Sed. Petrol. 1:514-529.

7. HALL, JAMES. 1879. Footnote [Correlation of the Pendleton Sandstone]. Indiana Geol. Survey Annu. Rep. 8, 9, and 10. p. 60.

8. INGRAM, R. L. 1954. Terminology for the thickness of stratification and parting units in sedimentary rocks. Geol. Soc. Amer. Bull. **65**:937-938.

9. KINDLE, E. M. 1901. The Devonian fossils and stratigraphy of Indiana. Indiana Dep. Geol. and Natur. Resources Annu. Rep. **25**:529-758, 773-775.

10. KLAPPER, GILBERT, C. A. SANDBERG, CHARLES COLLINSON, J. W. HUDDLE, R. W. ORR, L. V. RICKARD, DIETMAR SCHUMACHER, GEORGE SEDDON, and T. T. UYENO. 1971. North American Devonian conodont biostratigraphy. Geol. Soc. Amer. Memoirs **127**:285-316.

11. KRUMBEIN, W. C., and L. L. SLOSS. 1963. Stratigraphy and sedimentation. W. H. Freeman and Co., San Francisco, Cal. 660 p.

12. LOGAN, W. L. 1931. The sub-surface strata of Indiana. Indiana Dep. Conserv. Pub. 108. 790 p.

13. PASSEGA, R. 1964. Grain size representation by CM patterns as a geological tool. J. Sed. Petrol. **34**:830-847.

14. SUMMERSON, C. H., and D. H. SWANN. 1970. Patterns of Devonian sand on the North American craton and their interpretation. Geol. Soc. Amer. Bull. **81**:469-490.

15. SUTTON, A. H. 1944. The Devonian System in Indiana. Illinois Geol. Survey Bull. **68**:162-173.

16. VISHER, G. S. 1969. Grain size distributions and depositional processes. J. Sed. Petrol. **39**:1074-1106.

17. WALLISER, O. H. 1971. Conodont biostratigraphy of the Silurian of Europe. Geol. Soc. Amer. Mem. **127**:195-206.

18. WARNE, S. J. 1962. A quick field or laboratory staining scheme for differentiation of major carbonate minerals. J. Sed. Petrology **32**:29-38.

19. WELLER, J. M. 1944. Devonian correlations in Illinois and surrounding states: a summary. Illinois Geol. Surv. Bull. **68**:205-213.