9-19-2015

Field Trip #1 – “Stratigraphy and Sedimentology of the Upper Ordovician in Southeastern Indiana”

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Stratigraphy and Sedimentology of the Upper Ordovician Southeastern Indiana

Field Trip Leader: Ben Dattilo, Indiana University Purdue University Fort Wayne

Contributing Authors
Christopher Aucoin, Carlton Brett, University of Cincinnati, Thomas J. Schramm, Louisiana State University
Stratigraphy and Sedimentology of the Upper Ordovician in Southeastern Indiana

Saturday, September 19, 2015 8:00 AM to 6:30 PM

Field Trip Leader: Benjamin F. Dattilo

Contributing Authors: Christopher Aucoin, Carlton Brett, Thomas Schramm

This trip will cover the high-resolution sequence stratigraphy, depositional environment, process sedimentology, and paleontology of four spectacularly fossil-rich exposures of the Cincinnati Upper Ordovician (internationally the Katian Stage; in North America the Cincinnatian Series) in southeastern Indiana. Stops include Madison (Richmonedian through Silurian), Lawrenceburg (Edenian and Maysvillian), Southgate Hill (Deeper water Richardmonian), and Brookville Dam (Maysvillian). The Cincinnatian is characterized by alternating beds of shell-rich limestones (shell beds) and fossil poor, mudstones. Limestone-rich and mud-rich intervals define meter scale and 10-meter-scale cycles.

The sedimentological processes that generated these beds and cycles are the subject of recent research. We will discuss the role of high energy events and fluctuating sediment supply in generating these strata, and discuss the possibility of correlating meter-scale cycles across facies transitions over tens of kilometers of distance using physical, paleontological, and geochemical techniques. We will also discuss how sedimentological processes lead to the destruction of organic matter in a succession of obviously fossil-rich strata. There will be ample opportunity to collect a spectacularly fossil-rich slab, and perhaps even a perfect trilobite! The trip will depart from the Crowne Plaza Indianapolis at 8:00 AM and return at 6:30 PM. Attendees are urged to be flexible in scheduling Saturday evening activities.
## Contents

Road Log.................................................................................................................................................. 3

Fossils and Strata of the Cincinnatian........................................................................................................... 6
  Cincinnati Fossils ...................................................................................................................................... 6
  Stratigraphy.............................................................................................................................................. 6
  Sedimentology—the origin of shell beds ..................................................................................................... 6

Fossil Identification Charts .......................................................................................................................... 7

Stop Descriptions ....................................................................................................................................... 17
  Stop 1: Madison ....................................................................................................................................... 17
  Stop 2. Lawrenceburg .............................................................................................................................. 24
  Stop 3. South Gate Hill ............................................................................................................................ 29
  Stop 4. Brookville Dam Spillway ............................................................................................................. 31

References ................................................................................................................................................... 34
Road Log

Map showing the route of the field trip

Start: Crowne Plaza Indianapolis 123 West Louisiana Street, Indianapolis

Leave 8:00

1. Head north on S Illinois St toward W Louisiana St (0.2 miles)
2. Turn right onto W Maryland St (0.4 miles)
3. Slight right onto E Maryland St (0.1 miles)
4. Slight right onto E Washington St (0.3 miles)
5. Turn right onto the Interstate 65 S/Interstate 70 W ramp to Louisville/St. Louis (0.4 miles)
6. Merge onto I-65 S/I-70 W (0.4 miles)
7. Keep left at the fork to continue on I-65 S, follow signs for Louisville (73.6 miles)
8. Take exit 36 for US-31 toward Austin/Crothersville (0.4 miles)
9. Turn left onto US-31 S (3.0 miles)
10. Turn left onto IN-256 E/E Main St Continue to follow IN-256 E (19.5 miles)
11. Turn left onto IN-56 E/Ohio River Scenic Byway (3.9 miles)
12. Turn left onto US-421 N/Jefferson St. Follow US 421 north to large roadcut (3.2 miles)

Total Leg: 106 mi / 1 h 50 min

Arrive 10:00

Stop 1: Madison, Indiana US 421 near Indiana 62 (38.778182, -85.365295)

Leave 11:30

13. Head northwest on US-421 N toward IN-62 E (22.4 miles)
15. Turn left onto Bielby Rd (354 feet)

Total Leg: 46.6 mi / 53 min

Arrive 12:23 (Lunch)

Stop 2: Lawrenceburg, Beilby Road (Indiana 48) and US 50 (39.092605, -84.872221)

Leave 13:15

16. Head northwest on IN-48 W/Bielby Rd toward Tower Rd (2.6 miles)
17. Turn right onto Pribble Rd (3.0 miles)
18. Turn left onto IN-1 N, drive north to the large road cut (15 miles)

Total Leg: 20.7 mi / 28 min

Arrive 13:45

Stop 3: St Leon/Southgate Hill, 3001-3099 Indiana 1, West Harrison, Indiana (39.343371, -84.954095)

Leave 15:00

19. Head north on IN-1 N toward Old Indiana 1 (1.6 miles)
20. Turn left onto US-52 W (5.9 miles)
21. Continue straight onto State Rte 101 N/Main St, Continue on Rte 101 N (1.3 miles)
22. Turn left (0.2 miles)
23. Slight left (0.2 miles)

Total Leg (9.2 mi / 16 min)
Arrive 15:20

Stop 4: Brookville Dam Spillway (39.439262, -84.999815)

Leave 17:00

28. Slight left onto IN-244 W (21.8 miles)
29. Turn right onto the I-74 W/US-421 N ramp to Indianapolis (0.2 miles)
30. Merge onto I-74/US-421 N (24.4 miles)
31. Take the Interstate 465 N exit toward Shadeland Ave. (0.2 miles)
32. Keep left at the fork, follow signs for Interstate 465 S/Interstate 74 W and merge onto I-465 S (4.6 miles)
33. Take the exit onto I-65 N (3.9 Miles)
34. Take exit 110A for Morris St toward Prospect St (0.3 miles)
35. Slight right toward Leonard St (371 feet)
36. Continue onto Leonard St (0.2 miles)
37. Turn left onto Virginia Ave (0.6 miles)
38. Turn left onto E South St (0.6 miles)
39. Turn right onto S Illinois St (371 feet)

Total Leg: 76.1 mi / 1 h 26 min

Arrive 18:30

End: Crowne Plaza Indianapolis 123 West Louisiana Street, Indianapolis
Fossils and Strata of the Cincinnatian

Cincinnati Fossils
Given the lack of economic deposits, the Upper Ordovician rocks in and around the Cincinnati region, including southeastern Indiana, have received remarkably consistent attention from geologists since the mid to late 1800s. This is, largely, because they are among the most richly fossiliferous deposits in the world. Fossils are intrinsically interesting if for nothing more than their beauty. The following plates include some of the most common fossils and some of the most sought-after fossils that might be encountered on the fieldtrip. With the exception of two photos, the fossil figures were taken from Cummings (1907). The abundance of fossils makes the deposits a convenient natural laboratory, and recent studies include the ecological dynamics of species migration (the Richmondian invasion; e.g. Stigall, 2010), the exploration of continent-scale evolutionary relationships (e.g. Jin 2001; 2012), and the day-to-day interactions of extinct forms (Dattilo et al. 2010; Freeman et al. 2013).

Stratigraphy
In this guidebook you will see hints of a complex history of stratigraphic nomenclature. Early stratigraphic work by Cummings (1907) in Indiana and others in the immediate area of Cincinnati (summarized by Caster et al., 1955) relied heavily on fossil content to correlate relatively thin units over large areas. In the 1960s (e.g. Peck, 1966; Brown & Lineback, 1966), an emphasis on the facies concept and the strict separation of lithostratigraphy and biostratigraphy inspired a proliferation of new named units that tend to follow political boundaries like state lines. The resulting correlation chart (Cuffey, 1998: copied herein) is a bit confusing, in part because it reflects the concept that lithologic units are facies mosaics and that tracing thin units for long distances is impossible. With the advent of event stratigraphy and sequence stratigraphy, the concept of “stratigraphic surfaces” was added to the geologist’s lexicon. Older stratigraphic approaches were revived and revised in a new sequence stratigraphic system (e.g. Holland and Patzkowski, 1996). Ongoing work is sequence stratigraphic in basis and has resulted in the extension and refinement of the earlier stratigraphic system, as well as the elimination of “state line stratigraphy” (e.g. Brett & Algeo. 2001).

Sedimentology—The origin of shell beds
Underlying stratigraphy is sedimentology, and the key sedimentological question in the Cincinnatian is the origin of shelly limestone beds intercalated with mudstone beds, as well as small scale cycles that consist of alternating limestone and mudstone rich phases. If these meter-scale cycles are so extensive that they can be traced individually across the Ohio, Kentucky and Indiana outcrop area, how are they generated and how is it that they don’t disappear into a mosaic of facies. Since most shell beds contain abundant evidence of reworking, and since the area was in the tropical storm belt during the Ordovician, these beds and cycles have long been interpreted as storm beds or “tempestites” that formed from storm winnowing (Kreisa, 1981). More recently arguments have been made in support of basin-scale fluctuations in the supply of mud from the Taconian Orogen (Brett et al., 2008; Dattilo et al., 2008, 2012) as the principle cause of bedding, with ubiquitous storm (or tsunami?) reworking playing only a minor role.
**Fossil Identification Charts**

**Brachiopods (assorted)**

**Glyptorthis insculpta**

**Hebertella**

**Plaesiomys subquadrata**

**Retrorsirostra carleyi**

This distinctive species is restricted to a narrow zone near the base of the Richmondian. One of the Richmondian invaders that failed to thrive. Look for it at the first bench at Southgate Hill.

**Platystrophia ponderosa**

*P. ponderosa* is the most recognizable of the various named species. It has recently been reassigned to the genus *Vindlandostrophia* by someone from Northern Europe (of course). There is some grumbling about this by North American Paleontologists. Look for it at the top of the Lawrenceburg outcrop.

**Cincinnetina**

The Brachiopod f.k.a. *Omnella*, *Dalmanella*, or *Resserella*, several species, each of which can be found in some abundance at one stratigraphic level, have recently been reassigned to *Cincinnetina*. North Americans like this new name.

**Zygospira**

Look like little bitty baby *Platystrophia* but are not even close—examine particularly the classic “lamp shell” pedicle opening in the dorsal valve. Can be very abundant.

**Platystrophia**

There are many smaller variants of *platystrophia* that appear to differ from *P. ponderosa* in being attached throughout life. There are a few different named species, but taxonomy is almost as bad as for *Rufinesquina*.

**Hiscobecus capax**

a.k.a. *Lepidocyclus*. Similar to *Platystrophia* in appearance, but entirely different ancestry. Descended from earlier forms of *Rhynchothere*. This is a Richmondian species.

**Rhynchothere dentatum**

Resemble *Zygospira*, but more triangular. Look for them at the U.S. 27 cut near Richmond.
Strophomenate Brachiopods

Rafinesquina
arguably the most common large brachiopod in the world, life mode long disputed, species taxonomy nearly hopeless.

Leptaena
An extremely long-ranging form known for colonizing after mass extinction, marks Maysvillian-Richmondlbian boundary

S. sinuata
(marker species in the Fairview at Lawrenceburg)

Holtedahlina sulcata

Strophomena
(several species and variants)
Trepostome Bryozoans
Ramose forms

same species
different species
Gross surface characteristics are unreliable. The three specimens on the left are the same species (middle specimen shows two patterns), while the three on the right are different species, but show the same pattern (yes, I included the one in the middle twice—intentionally).

There are more bryozoans and more different kinds of bryozoans than there are of any other Cincinnatian fossil. Unfortunately they are rather difficult to identify.
This page shows you a range of external shapes that you might encounter. Sometimes these shapes help identify genus, more often they are a result of environment. Generally bryozoans look like corals with much smaller openings.

The gumdrop shape is usually the same genus, *Porospora*. With a few months work, you might be able to identify ten additional genera

Massive colony
Frondose forms
Corals (&stuff)

- **Streptasma**
- **Cyathophylloides**
  - Septae are well developed
- **Tetradium**
  - Is it a coral? sponge? algae? everyone has an answer, nobody knows. However, it forms large heads that look
- **Grewingkia canadensis**
- **Calapoezia**
- **Protarea**
  - Often found encrusting shells.
- **Longitudinal section through Tetradium**

Bryozoans

cyclostomes
- Very tiny lace like encrusters on shells and other bryozoans
- Photographs much enlarged

- Actual size
- Enlarged
- Actual size

cryptostomes
- (enlarged) Cryptostomes are common and commonly overlooked

cystoporids

**Constellaria**
- This is one of the most easily identified bryozoans characterized by its flower or star-like surface pattern. These can be found below the uppermost bench of the Lawrenceburg cut, where they are a marker for the Fairview Formation.
Echinoderms
Articulated echinoderms are always worth keeping, or turning over to the Field Trip Leader. He can keep them.

Anomalocrinus incurvus
Look for this in the Lawrenceburg cut, Bellevue Member, at the top of the exposure. It is by far the largest Cincinnati crinoid.

Cincinnaticrinus pentagonus
It is very easy to overlook whole specimens, because the cup is as small as the stem.

Cupulocrinus polydactylus
You might find this one anywhere in the Richmondian.

C. varibrachialis

Glyptocrinus decadactylus
This form is restricted to the fairmount, near the top of the Lawrenceburg cut.

Plicodendrocrinus casei
Mostly in the Waynesville and Liberty Formations.

Ectenocrinus simplex
Common in the Kope, near the base of the Lawrenceburg outcrop.

Pychnocrinus dyeri
Maysvillian and lower Richmondian

Sea stars
Very, very, very, rare. It is best not to let anyone know that you found one until months later. Could lead to violence.

Edrioasteroids
Edrioasteroids look like sea stars on a coin. They are usually attached to the brachiopod Ratinesquina. They are rare, but not extremely rare. I found this one at the top of the Lawrenceburg cut. Complete specimens (not pictured) are spectacular.

Crinoids (sea lillies)
Crinoids are consist of an attachment base, a column (stem) a cup and arms together making the 'head'. They look a bit like flowers.

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Snails

Cyclonema

Cyclonema is the only genus of gastropod with an originally calcitic shell, so its shell is preserved more readily than the shells of other snails. It is often found attached to the anal opening of cnoids, and may have been capable of boring.

Loxoplocus bowdeni

Hormotoma

Clathrospira

Cyrtolites

Lophospira

Trochonema

Ambonychia

Anomalodonta gigantea

Anomalodonta costata

Ctenodonta

Ischyrodonta ovalis

Cymatontota

Ischyrodonta elongata

Caritodens

Like both the scallops and the oysters that descended from it, this bivalve had an outer calcite shell and an inner aragonite shell. It is the only one whose shell is regularly preserved.
Cephalopods

Gyroceras

“Cyrtoceras”

Gomphoceras

These are rather rare.

Actinoceroids
Generally straight shells with these "beaded"-looking siphuncles.

Treptoceras duseri
One of the more common Cincinnati an orthoconic actinoceroids.

Endoceroids
Endoceroids are characterized by straight shells with flat cone-shaped siphuncles.

Tentaculites
Not a cephalopod! Tentaculites is... something else. Look for them, rather small things, on the first shaly bench at Southgate Hill exposure.
This range chart shows the approximate stratigraphic position of each field trip stop as well as the ranges of some standard names referred to as "Richmondlan Invasion." The range chart has been modified from field trip stops 1-4 (Barlett et al., 1955, 1960). Fossil images from Cummings (1960).

Stop 1 Madison

Stop 2 Lawrenceburg

Stop 3 South Gate Hill

Stop 4 Spillway

Abundant Corroteinaria

Abundant Parrotia

Eocene

Oligocene
**Lithostratigraphic Cross Section** of the Cincinnati Region from central Kentucky to southeastern Indiana. While this might represent the reality of a facies mosaic, there is also evidence of arbitrary differences in scale and state line limits on jurisdictions, where prominent “shazam lines” are placed. From Cuffey (1998).

**Sequence Stratigraphic Interpretation** of Cincinnatian lithostratigraphic units. Here lithostratigraphic units are interpreted as facies within a sequence stratigraphic framework. From Holland & Patzkowski (1996).
Diagram showing the development of muddy and shelly horizons in the Cincinnatian. Shell beds develop during periods of low siliciclastic sediment supply. Mud beds develop during times of high sediment supply. Storms (or other high energy events like tsunami) affect both types of beds, and do not constitute the critical difference between them: all are tempestites (Modified from Brett et al., 2008)
Stop Descriptions

Stop 1: Madison
Ben Dattilo, Carl Brett, Christoper Aucoin
38.778182, -85.365295
Road cut on US 421 near Indiana 62, Madison, Indiana

Satellite images of the Madison outcrop. A. Contextual view showing relationship to Madison and North Madison. B. Closeup view of this long outcrop.
Outcrop photos showing the interval 0.0 through 9.0 meters, Waynesville and Liberty Formations.
Outcrop photos showing intervals 9.0 m through 24.0 meters, Liberty, Whitewater, and Saluda formations.
Outcrop photos showing interval 23.0 through 33.0 meters, “Madison reefs”, Saluda Formation, Whitewater Formation, Hitz Member.
Outcrop photographs of the upper part of the Madison outcrop showing the Ordovician-Silurian unconformity and the Silurian formation.

Geologist, for scale, circled in upper photograph.
Stop 2. Lawrenceburg
Ben Dattilo, Tom Schramm, Carl Brett
39.096214, -84.875969
Roadcut on Indiana 48 at US 50 near Lawrenceburg, Indiana

Satellite images of the Lawrenceburg outcrop. A. Contextual view showing relationship to Greendale and Lawrenceburg. B. Closeup view of this large outcrop.

Outcrop photo of the Lawrenceburg cut showing nearly the entire succession from the Kope to the Bellevue.
Lawrenceburg stratigraphic column part 1
Lawrenceburg stratigraphic column part 2
Stop 3. South Gate Hill
Christopher Aucoin, Ben Dattilo
39.341100, -84.953195
Roadcut on Indiana 1, 4.4 miles north of I-74

Satellite view of the Southgate Hill outcrop. A. contextual view showing Cedar Grove to the north. B. Close up view of the extensive South Gate Hill outcrop.

Outcrop Photo showing the top of the Arnheim and the Waynesville members. Marks show Aucoin unit identifications, work in progress.
Stratigraphic Section of South Gate Hill (Hay et al., 1998). Note that terraces and road signs are included to help you find your way in the outcrop. Red annotations show stratigraphic units identified by Aucoin.
Stop 4. Brookville Dam Spillway

Ben Dattilo
39.439756, -85.005441
Indiana 101 just north of Brookville

Satellite images of outcrops in the vicinity of Brookville Dam
A. Overview of the Dam and spillway in relation to the town of Brookville. B. View of the spillway and Bon Well Hill outcrops. C. Closeup of the spillway. D. Closeup of Bon Well Hill.
Correlation of outcrops in the Brookville Reservoir area (Hay & Cuffey, 1998).
Stratigraphic column of the Brookville Dam Spillway (Hay & Cuffey, 1998)

<table>
<thead>
<tr>
<th>Facies</th>
<th>Assemblage zone</th>
<th>Meters</th>
<th>General stratigraphic description</th>
<th>Formation</th>
<th>Member</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>Zone A – Rafinesquina</td>
<td>52</td>
<td>Much more shale than limestone</td>
<td>Brookville Formation</td>
<td>Station Hollow*</td>
</tr>
<tr>
<td>3a</td>
<td>Zone B – Rafinesquina</td>
<td>49</td>
<td>Prominent limestone band</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1a</td>
<td></td>
<td>46</td>
<td>Mostly shale with barren, silty limestone and siltstone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3a</td>
<td></td>
<td>43</td>
<td>Prominent band of cross-bedded limestone and sandy phosphatic fossil interbeds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2b</td>
<td></td>
<td>40</td>
<td>Lithology variable; some burrowed, massive, hard, light-gray limestone, some wavy-bedded, rather thin, fossiliferous beds; shales more calcareous than above; in lower part some shales are flaky</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1a</td>
<td></td>
<td>37</td>
<td>Mostly shale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2b</td>
<td></td>
<td>34</td>
<td>Orthograptus truncatus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2a</td>
<td>Zone A – Rafinesquina</td>
<td>27</td>
<td>Slightly more shale than above in facies 2b; Shales fissile to blocky</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3a</td>
<td></td>
<td>24</td>
<td>Prominent limestone band</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1a</td>
<td></td>
<td>21</td>
<td>High percentage of blocky shale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4b</td>
<td></td>
<td>18</td>
<td>Poorly bedded, coarsely fragmented, sorted shal-debris limestone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3d</td>
<td></td>
<td>15</td>
<td>Many barren, laminated, burrowed, thin-bedded limestones</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3a</td>
<td></td>
<td>12</td>
<td>Like above, but fewer barren beds and packed with bryozoans</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1a</td>
<td></td>
<td>9</td>
<td>Nearly all shale; more limestone beds near top</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3d</td>
<td></td>
<td>6</td>
<td>Sandy, light-gray limestone in top and thin fossiliferous limestone in thicker shales in bottom</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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*Note: Members are indicated with asterisks.
References


Field Trips
All field trips will leave from the hotel lobby

Field Trip #1
Stratigraphy & Sedimentology of the Upper Ordovician in Southeastern Indiana

Saturday Sep 19, 2015, 8:00 am to 6:30 pm

Leader:
Dr Benjamin F. Dattilo
(Indiana University-Purdue University Ft Wayne)

This trip will cover the high-resolution sequence stratigraphy, depositional environment, process sedimentology, and paleontology of four spectacularly fossil-rich exposures of the Cincinnati Upper Ordovician (internationally the Katian Stage; in North America the Cincinnatian Series) in southeastern Indiana. Stops include Madison (Richmonian through Silurian), Lawrenceburg (Edenian and Maysvillian), Southgate Hill (Deeper water Richmonian), and Brookville Dam (Maysvillian). The Cincinnatian is characterized by alternating beds of shell-rich limestones (shell beds) and fossil poor mudstones. Limestone-rich and mud-rich intervals define meter scale and 10-meter-scale cycles.

The sedimentological processes that generated these beds and cycles are the subject of recent research. We will discuss the role of high energy events and fluctuating sediment supply in generating these strata, and discuss the possibility of correlating meter-scale cycles across facies transitions over tens of kilometers of distance using physical, paleontological, and geochemical techniques. We will also discuss how sedimentological processes lead to the destruction of organic matter in a succession of obviously fossil-rich strata. There will be ample opportunity to collect a spectacularly fossil-rich slab, and perhaps even a perfect trilobite!

Note: Attendees are urged to be flexible in scheduling Saturday evening activities. Rain or shine. Bring rain gear as appropriate.

Please see the following link for more information:
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