Climate-Induced Changes in Fluvial Ichnofossil Assemblages of the Pennsylvanian-Permian Appalachian Basin

Jennifer K. Crowell and Daniel I. Hembree
Department of Geological Sciences, Ohio University, Athens, Ohio

PURPOSE

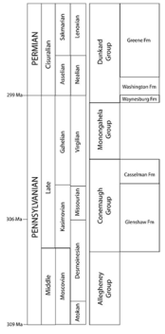
- Use ichnofossils to investigate the long-term response of terrestrial communities to shifting climatic conditions.

HYPOTHESES

- Ichnofossil diversity, density, and abundance will increase from the Allegheny to Dunkard groups.
- Ichnofossil composition will reflect an up-section change to a community composed of opportunistic generalist organisms.
- These changes likely resulted from a trend toward more reduced primary productivity due to the shift to a drier, more seasonal climate.

BACKGROUND

- Five outcrop localities were investigated in Ohio and West Virginia.
- Allegheny group – shale, limestone, sandstone, coal
- Conemaugh group – shale, sandstone, limestone, coal
- Monongahela group – shale, mudstone, sandstone, limestone
- Upper and Lower Dunkard group – shale and mudstone with some sandstone, limestone, and coal



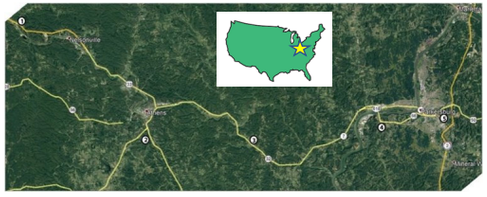


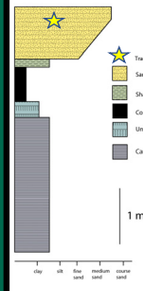
Figure 1. Study sites in southeastern Ohio and West Virginia. Stratigraphic units present at each site include: 1. Middle Pennsylvanian Allegheny Group; 2. Upper Pennsylvanian Conemaugh Group; 3. Upper Pennsylvanian Monongahela Group; 4. Lower Permian Lower Dunkard Group; 5. Lower Permian Upper Dunkard Group.

METHODS

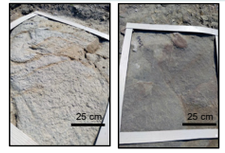
- Stratigraphic sections measured and ichnofossil assemblages identified in point bar sandstones.
- Abundance, density, diversity and composition of assemblages assessed in multiple 0.5x0.5-m grids along bedding planes.
- Assemblages compared with ANOVA and Dunn's post hoc test.

RESULTS

Allegheny – Site 1



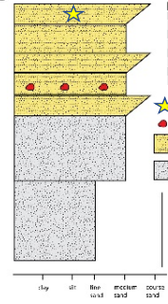
Location	Block	Grid	Abundance	Diversity	Density	Complexity	MW	Behaviors
Site 1	1	1	0	0	0	0	0	NA
Site 1	2	2	0	0	0	0	0	NA
Site 1	3	3	0	0	0	0	0	NA
Site 1	4	4	0	0	0	0	0	NA
Site 1	5	5	0	0	0	0	0	NA
Site 1	6	6	0	0	0	0	0	NA
Site 1	7	7	0	0	0	0	0	NA
Site 1	8	8	0	0	0	0	0	NA



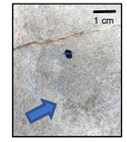
- **Abundance Mean: 0**
- **Diversity Mean: 0**
- **Density Mean: 0**
- **Complexity Mean: 0**
- **Mean Width: 0**

No ichnofossils were observed at Site 1.

Conemaugh – Site 2



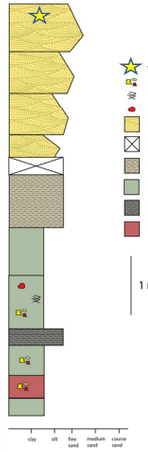
Location	Block	Grid	Abundance	Diversity	Density	Complexity	MW: Vert. Tun.	MW: Long Tunnel	Behaviors
Site 2	1	1	0	0	0	0	0	NA	Dwelling, deposit feeding
Site 2	2	2	2	1	1	1	1	NA	Dwelling, deposit feeding
Site 2	3	3	3	1	1	1	NA	NA	Dwelling, deposit feeding
Site 2	4	4	2	1	1	0.3	NA	NA	Dwelling, deposit feeding
Site 2	5	5	0	0	0	0	NA	NA	Dwelling, deposit feeding
Site 2	6	6	3	2	1	0.5	1	1	Dwelling, deposit feeding
Site 2	7	7	0	0	0	0	NA	NA	Dwelling, deposit feeding
Site 2	8	8	3	1	1	1	NA	NA	Dwelling, deposit feeding



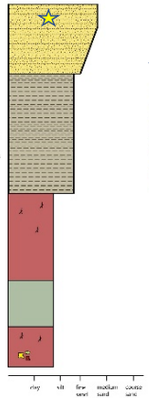
- **Abundance Mean: 1.6**
- **Diversity Mean: 0.8**
- **Density Mean: 0.6**
- **Complexity Mean: 0.6**
- **Mean Width: 0.4 mm**

Typical ichnofossil morphology from Site 2 was single vertical shafts with circular openings (*Skolithos*).

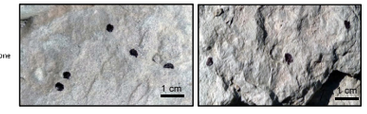
Monongahela – Site 3A



Monongahela – Site 3B



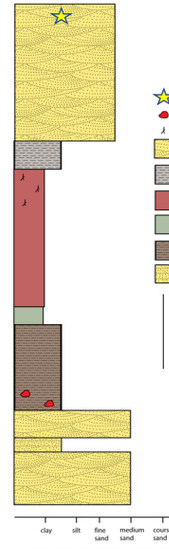
Location	Block	Grid	Abundance	Diversity	Density	Complexity	MW: Vert. Tun.	MW: Cir.ring Tun.	MW: Sq.Vert.Tun.	Behaviors
Site 3	1	1	8	1	1	1	NA	NA	NA	Deposit feeding, dwelling
Site 3	2	2	7	1	1	1	NA	NA	NA	Deposit feeding, dwelling
Site 3	3	3	10	2	1	0.6	0.5	0.4	NA	Deposit feeding, dwelling
Site 3	4	4	3	1	1	1	0.5	NA	NA	Deposit feeding, dwelling
Site 3	5	5	11	1	1	1	NA	NA	NA	Deposit feeding, dwelling
Site 3	6	6	3	1	1	1	NA	NA	NA	Deposit feeding, dwelling
Site 3	7	7	7	1	1	0.5	NA	NA	NA	Deposit feeding, dwelling
Site 3	8	8	22	2	1	0.5	NA	NA	NA	Deposit feeding, dwelling
Site 3	9	9	16	1	1	1	NA	NA	NA	Deposit feeding, dwelling
Site 3	10	10	20	1	1	1	5	NA	NA	Deposit feeding, dwelling
Site 3	11	11	4	1	1	1	3	NA	NA	Deposit feeding, dwelling
Site 3	12	12	4	1	1	1	4	NA	NA	Deposit feeding, dwelling
Site 3	13	13	9	1	1	1	8	NA	NA	Deposit feeding, dwelling
Site 3	14	14	12	2	1	1	4	NA	3.5	Deposit feeding, dwelling
Site 3	15	15	14	1	1	1	7	NA	NA	Deposit feeding, dwelling
Site 3	16	16	10	1	1	1	7	NA	NA	Deposit feeding, dwelling

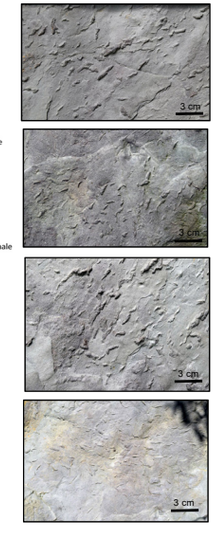


- **Abundance Mean: 11.6**
- **Diversity Mean: 1.3**
- **Density Mean: 1**
- **Complexity Mean: 1**
- **Mean Width: 2.8 mm**

Typical ichnofossil morphologies from Site 3 were single to paired vertical shafts with circular openings (*Skolithos, Arenicolites*).

Upper Dunkard – Site 5



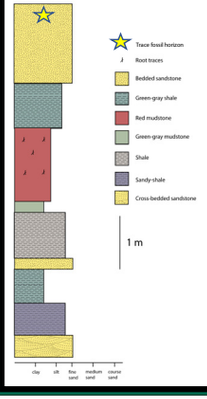


Location	Block	Grid	Abundance	Diversity	Density	Complexity	MW: Small	MW: Medium	MW: Large	MW: Circular	MW: Simple	MW: Bilobed	MW: Tunnel	Behaviors
Site 5	1	1	150	1	2	3	1	3	8	NA	NA	NA	NA	Deposit feeding
Site 5	1	2	130	1	2	2	1	3	NA	NA	NA	NA	NA	Deposit feeding
Site 5	2	3	110	2	2	4	1	3	5	4	NA	NA	NA	Deposit feeding; dwelling
Site 5	2	4	75	3	2	3	1	2	10	NA	NA	NA	NA	Deposit feeding
Site 5	3	5	<30	3	1	1	NA	NA	NA	15	5	10	NA	Detritus feeding; locomotion
Site 5	3	6	<20	3	1	1	NA	NA	NA	10	5	NA	3	Detritus feeding; locomotion; deposit feeding
Site 5	4	7	<30	3	4	1	NA	NA	NA	3	5	NA	10	Detritus feeding; locomotion; deposit feeding
Site 5	4	8	<15	2	1	1	NA	NA	NA	10	5	NA	NA	Deposit feeding

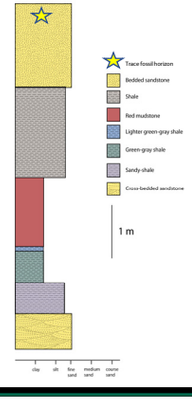
- **Abundance Mean: 72.5**
- **Diversity Mean: 2.3**
- **Density Mean: 1.9**
- **Complexity Mean: 2**
- **Mean Width: 8.4 mm**

Typical ichnofossil morphologies from Site 5 were vertical shafts with circular openings, horizontal tunnels, and segmented tunnels (*Skolithos, Scoyenia, Treptichnus*).

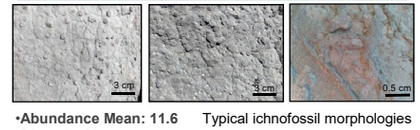
Lower Dunkard–Site 4A



Lower Dunkard–Site 4B



Location	Block	Grid	Abundance	Diversity	Density	Complexity	MW: Circular	MW: Narrow	MW: Irregular circles	MW: Concave	MW: Wide	MW: Thick-cemented	Behaviors
Site 4	1	1	60	4	2	1	3	10	5	NA	NA	NA	Deposit feeding
Site 4	2	2	110	3	3	1	1	3	20	NA	NA	NA	Deposit feeding
Site 4	3	3	130	1	3	1	NA	3	NA	NA	NA	NA	Deposit feeding
Site 4	4	4	200	1	3	1	NA	3	NA	NA	NA	NA	Deposit feeding
Site 4	5	5	200	3	4	1	0.4	NA	NA	NA	0.4	NA	Deposit feeding; resting
Site 4	6	6	400	2	5	1	0.3	NA	NA	NA	0.4	NA	Deposit feeding
Site 4	7	7	120	2	3	1	0.3	0.5	NA	NA	NA	NA	Deposit feeding
Site 4	8	8	140	1	3	1	0.3	0.4	NA	NA	NA	NA	Deposit feeding
Site 4	8	9	120	1	3	1	NA	0.5	NA	NA	NA	NA	Deposit feeding
Site 4	8	10	200	2	3	1	0.3	0.5	NA	NA	NA	NA	Deposit feeding
Site 4	9	11	100	3	3	2	0.4	0.5	NA	NA	NA	NA	Deposit feeding; locomotion
Site 4	10	12	300	2	3	1	NA	0.3	NA	NA	0.3	NA	Deposit feeding
Site 4	11	13	200	2	5	1	NA	0.5	NA	NA	NA	NA	Deposit feeding
Site 4	12	14	75	1	2	1	NA	0.5	NA	NA	NA	NA	Deposit feeding
Site 4	13	15	300	2	4	1	NA	0.5	NA	NA	NA	NA	Deposit feeding
Site 4	14	16	280	2	6	1	0.4	0.3	NA	NA	NA	NA	Deposit feeding



- **Abundance Mean: 11.6**
- **Diversity Mean: 1.3**
- **Density Mean: 1**
- **Complexity Mean: 1**
- **Mean Width: 2.8 mm**

Typical ichnofossil morphologies from Site 4 were single to paired vertical shafts, trails, and tunnels (*Skolithos, Arenicolites, Cruziana, Scoyenia*).

DATA ANALYSIS

- ANOVA indicates significant differences between quantitative properties of ichnofossil assemblages.
- Dunn's post hoc suggests assemblages of Allegheny and Conemaugh are distinct from Monongahela and Dunkard.

Abundance, p=1.23x10^{-10}

	Site 1	Site 2	Site 3A	Site 3B	Site 4A	Site 4B	Site 5
Site 1		0.54	0.04	0.01	7.02E-07	2.46E-07	8.48E-05
Site 2	0.54		0.14	0.06	1.39E-05	5.48E-06	9.17E-04
Site 3A	0.04	0.14		0.7	4.00E-03	2.00E-03	0.06
Site 3B	0.01	0.06	0.7		0.01	0.01	0.14
Site 4A	7.02E-07	1.39E-05	0.004	0.01		0.84	0.3
Site 4B	2.46E-07	5.48E-06	0.002	0.01	0.84		0.22
Site 5	8.48E-05	9.17E-04	0.06	0.14	0.3	0.22	

Diversity, p=2.59x10^{-7}

	Site 1	Site 2	Site 3A	Site 3B	Site 4A	Site 4B	Site 5
Site 1		0.09	2.32E-03	0.01	4.37E-06	2.84E-04	2.95E-06
Site 2	0.09		0.18	0.37	3.83E-03	0.05	2.95E-03
Site 3A	2.32E-03	0.18		0.66	0.12	0.56	0.10
Site 3B	9.31E-03	0.37	0.66		0.05	0.30	0.04
Site 4A	4.37E-06	3.83E-03	0.12	0.05		0.34	0.94
Site 4B	2.84E-04	0.05	0.56	0.30	0.34		0.30
Site 5	2.95E-06	2.95E-03	0.10	0.04	0.94	0.30	

Density, p=1.66x10^{-14}

	Site 1	Site 2	Site 3A	Site 3B	Site 4A	Site 4B	Site 5
Site 1		0.21	0.02	0.02	3.47E-07	5.39E-08	4.03E-04
Site 2	0.21		0.32	0.32	1.27E-04	3.00E-05	0.02
Site 3A	0.02	0.32		1.00	4.65E-03	1.51E-03	0.20
Site 3B	0.02	0.32	1.00		4.65E-03	1.51E-03	0.20
Site 4A	3.47E-07	1.27E-04	4.65E-03	4.65E-03		0.73	0.12
Site 4B	5.39E-08	3.00E-05	1.51E-03	1.51E-03	0.73		0.06
Site 5	4.03E-04	0.02	0.20	0.20	0.12	0.06	

Complexity, p=0.002

	Site 1	Site 2	Site 3A	Site 3B	Site 4A	Site 4B	Site 5
Site 1		0.03	1.23E-04	1.23E-04	1.23E-04	1.02E-04	1.48E-07
Site 2	0.03		0.09	0.09	0.09	0.08	1.81E-03
Site 3A	1.23E-04	0.09		1.00	1.00	0.96	0.16
Site 3B	1.23E-04	0.09	1.00		1.00	0.96	0.16
Site 4A	1.23E-04	0.09	1.00	1.00		0.96	0.16
Site 4B	1.02E-04	0.08	0.96	0.96	0.96		0.17
Site 5	1.48E-07	1.81E-03	0.16	0.16	0.16	0.17	

Mean Width, p=1.27x10^{-5}

	Site 1	Site 2	Site 3A	Site 3B	Site 4A	Site 4B	Site 5
Site 1		0.06	0.05	2.71E-06	2.87E-03	0.12	6.47E-07
Site 2	0.06		0.83	0.01	0.52	0.45	0.01
Site 3A	0.05	0.83		9.04E-04	0.27	0.51	3.16E-04
Site 3B	2.71E-06	0.01	9.04E-04		0.01	3.24E-05	0.70
Site 4A	2.87E-03	0.52	0.27	0.01		0.06	0.01
Site 4B	0.12	0.45	0.51	3.24E-05	0.06		2.37E-06
Site 5	6.47E-07	0.01	3.16E-04	0.70	0.01	2.37E-06	

Figure 2. Dunn's post hoc tables in which pink boxes represent significant differences between compared sites. White represents no differences between compared sites.

DISCUSSION

- Qualitative and quantitative aspects of ichnofossil assemblages changed from the Allegheny to Dunkard groups.
- Abundance, density, diversity, and burrow widths increase through the section.
- Ichnofabric index increased from 0-1 to 3-4.
- Abundance and density increased because organisms would have concentrated in the substrate in areas with reduced surface resources.
- Interpreted behaviors suggest a shift from stationary deposit feeding to mobile deposit feeding.
- Community composition shifted towards more opportunistic, generalist organisms.
  - More detritus and deposit feeding
- Changes in assemblage properties may have resulted from a shift to a drier, more pronounced seasonal climate.
- Short-to long-term occupation of the substrate was more advantageous as surface conditions became more unfavorable and resources limited.