Teacher's Guide to Geology at Meadowcroft Rockshelter

A Component of First Peoples: Archaeology at Meadowcroft Rockshelter

Contents

Why Geology in *First Peoples*?

When a visitor stands in the parking lot facing Meadowcroft Rockshelter, their first observations are usually one of two things: the looming **sandstone** cliff that contains the Rockshelter and towers over the landscape, or the steep incline of the **slope** leading up to the **excavation** enclosure (which they know they must ascend – nearly 70 steps – it's a long way up). Here they are, standing at the feet of one of the most significant **prehistoric archaeological** sites in North America, and their first intake is over rocks. Something about those rocks just calls people to investigate the space.

Today's visitors need not be embarrassed about their reaction; for thousands of years people shared the desire to climb the **slope** (or the steps if they arrived any time after 2008). Albert Miller, the farmer who discovered the first **archaeological evidence** at the site, and Dr. Adovasio, the principle investigator of the famous **archaeological excavation**, both commented on the geologic setting *before* they knew the **archaeological** significance. In fact, when Dr. Adovasio first encountered Meadowcroft Rockshelter in 1973, the floor of the site was littered with garbage and charcoal from recent campfires. The site was clearly an attractive hangout for local teens. Just a few inches below the 1973 campfire was another firepit, this time associated with colonial-era glass, and just below that yet another fire site associated with flint projectile points.

What is the magnetic quality of the rocks at Meadowcroft? At the most basic, perhaps it is the suggestion of protection: the overhanging rocks and the surrounding cliff embrace the landscape, while the elevation holds the advantage over the surrounding landscape. The rock formation also offers southern exposure (warmth), cross winds for ventilation, and proximity to water but high outside of the flood zone, **features** that promise, if not comfort, conveniences, particularly for **prehistoric** visitors. The magnetic aura is the Rockshelter itself.

In **archaeology**, **closed- sites** like **rockshelters** or caves are often predictable sites for **cultural evidence**. Once discovered, sites such as Meadowcroft, become part of the marked landscape, drawing humans repeatedly as long as the Rockshelter exists.

Thus, **geology** is a natural theme for inclusion in the *First Peoples: Archaeology at Meadowcroft Rockshelter* curriculum. Students are not immune to the attraction to the rocks at Meadowcroft, and their casual observations generate many conversations. They often ask how old the Rockshelter is, why the rocks are pockmarked, and, most frequently is it going to fall on us? These questions can all be answered through **geology**.

Teaching Geology at Meadowcroft Rockshelter

The **excavation** at Meadowcroft used **geoarchaeological** methods to inform the process of **archaeology**. Using the Geology GigaPan image activity guide and the resources in this curriculum guide, students will gain an appreciation for the **multi-disciplinary** approach and will understand how a geologic formation witnessed 16,000 years of human activity.

Intersection of Geology Theme with Disciplines

The table below summarizes how the Geology theme of the *First Peoples: Archaeology at Meadowcroft Rockshelter* curriculum can be used to explore various academic disciplines.

First Peoples Theme	Major Disciplines addressed in First Peoples				
	Science	History	Environment and Ecology	Geography	Technology and Engineering
Geology	Natural **stratigraphy** explains the evolution of the Rockshelter over time. Physical **features** suggest the origins of the landscape.	Throughout 16,000 years, **geology** has served as the foundation for all human activity at the site. At the most basic, the rocks around Meadowcroft anchor all aspects of the landscape from which humans meet their basic needs.	The geologic processes that created the Cross creek drainage impacted the flow of water throughout the **watershed**. The **slope** of the land and proximity to water dictate the **ecology** of the **watershed**.	Topography influenced how prehistoric peoples moved through the landscape. In the 20th and 21st centuries, energy extraction resulted in drastic human alteration to the landscape.	**Lithic** (stone) tools were the backbone of the Paleo- toolkit. Coal extraction in the 20th century and natural gas extraction today are major industries.

Geology GigaPan Inquiry

The First Peoples Geology GigaPan inquiry addresses the following points of inquiry with students.

Objectives Students will . . .	Grade Bands	Indicators of Mastery Students will be able to . . .
• Define, describe, analyze, and evaluate the use of **geomorphology** at Meadowcroft Rockshelter • Identify, describe or evaluate how **stratigraphy** and the **Law of Superposition** can be used to date geologic **features** • Explain the geological processes that formed Meadowcroft Rockshelter; Describe the lifecycle of a rockshelter • Identify, define, explain or analyze the geological processes that formed the **stratigraphy** inside the Rockshelter • Define **geoarchaeology** and explain how the study of Meadowcroft Rockshelter benefitted from this **multi-disciplinary** approach	11^{th} -12^{th} Grade	• Analyze the use of **geomorphology** in the Meadowcroft Project • Explain the role of **stratigraphy** in **relative dating** • Analyze the lifecycle of Meadowcroft Rockshelter; describe the geologic processes involved • Analyze the benefits of using stratigraphic principles to excavate an **archaeological** site • Evaluate the use of a **geoarchaeological** approach at Meadowcroft
	8^{th}- 10^{th} Grade	• Describe how **geomorphology** contributes to **archaeology** at Meadowcroft • Describe how **stratigraphy** and the **Law of Superposition** can be used to discuss **chronology** • Explain the geologic processes that created Meadowcroft Rockshelter • Explain how Meadowcroft's **stratigraphy** formed • Evaluate the use of a **geoarchaeological** approach at Meadowcroft
	5^{th}-7^{th} Grade	• Define **geomorphology** and give an example of how it informs the **excavation** of sites • Describe how geologists use the **Law of Superposition** and **stratigraphy** to date geologic **features** • Explain how Meadowcroft Rockshelter formed • Explain how the **stratigraphy** formed; identify **erosion** as a source for sediment • Explain how **geoarchaeology** is **multi-disciplinary**
	• K- 4^{th} Grade	• Recognize that **archaeologists** need to understand how **excavation** sites formed • Recognize that **stratigraphy** examines layers; describe **chronology**: deeper is older • Recognize that geological processes created the **rockshelter** • Recognize that the **stratigraphy** is made up of sediments deposited by **erosion** • Recognize that **archaeologists** used **geology** to understand the **excavation** site

Major Terms and Concepts

Scattered throughout the curriculum guide and GigaPan exploration are terms highlighted in bold. These include key vocabulary terms, concepts, and items of significance. Teachers can incorporate the terms in vocabulary and spelling lists

Terms	Concepts	Identification Significance
Geoarchaeology	Landforms in the Ohio drainage	Appalachian Sea
Geomorphology	Ancestral Ohio River drainage	Allegheny Mountains
Geology	Geologic Time Chart	Appalachian Allegheny Plateau
Matrix	Geologic Map	Appalachian Mountains
Sedimentary	Physiographic Regions	Appalachian Basin
Lithologies	Lithologies and Geologic Dating	Eastern Continental Divide
Shale	Rockshelter Formation and lifecycle	Ohio River
Sandstone	Stratigraphy and the Law of Superposition	Cross Creek
Limestone		Atlantic Ocean
Deposition		Casselman formation (Upper Conemaugh)
Tributary		Pennsylvanian Period
Strata		Monongahela-Beaver River System
		Teays-Mahomet River System

Geology of the Meadowcroft Rockshelter and the Cross Creek Drainage

Adapted from D.Benyon and J.Donahue, "The Geology and Geomorphology of Meadowcroft Rockshelter and the Cross Creek Drainage," in Meadowcroft: Collected Papers on the Archaeology of Meadowcroft Rockshelter and the Cross Creek Drainage, edited by R. C. Carlisle and J.M. Adovasio, 31-51. 47th Annual Meeting of the Society For American Archaeology, Minneapolis, Minnesota, April 1982.

From prior experience with **closed-site excavation**s, Dr. Adovasio recognized that Meadowcroft Rockshelter was the ideal site for applying **geoarchaeological** methodologies. **Geoarchaeology** is a **multi-disciplinary** approach that uses the techniques and subject matter of **geography**, **geology**, and other earth sciences to examine topics which inform **archaeological** knowledge. Generally, **geoarchaeology** involves studies of the natural processes that impact the area in and around an **archaeological** site. A major branch of **geoarchaeology** is **geomorphology**, the study of how sites formed through geological processes and the subsequent impact of those processes on **cultural material**s buried within the sites.

Dr. Adovasio's teams needed a firm grasp on the site's **geomorphology** if they were to successfully inform the **archaeological** process. Their first task was to understand the evolution of the landscape so they could determine how and when the Rockshelter formed. This information would indicate when the Rockshelter might have first been available for human use. Secondly, **geomorphology** would explain how the **stratigraphy** of the site formed, including the composition of the **matrix**, **depositional** mode, force, and rate. This **evidence** would help **archaeologists** anticipate how long people had used the site, but also any geologic events that may have transported **cultural materials**.

Geologic Time Scales and Geologic Maps

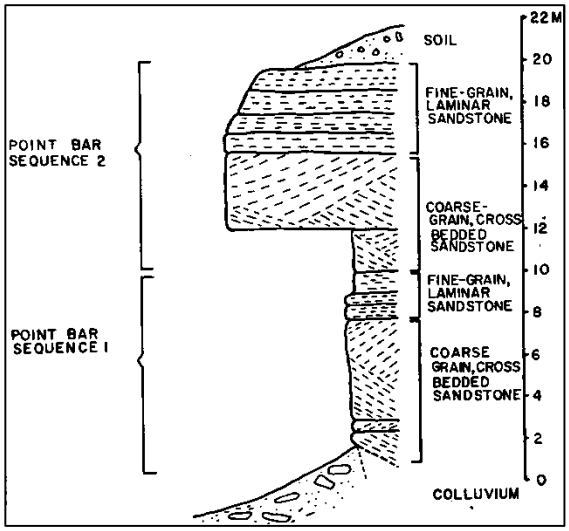
Geologists study the earth and its history through the natural features of the planet. The evidence geologists study is in rocks and landforms. Like archaeologists studying artifacts, geologists look for patterns that tell them about the passage of time. Generally, geologists talk about very large amounts of time since the earth is approximately 4.5 billion years old.

Geologists use specific words to refer to the passage of time. They separate these huge amounts of time into smaller divisions and refer to the divisions by name, similar to the way that archaeologists use cultural periods. The passage of geologic time can be explained using a geologic time chart. Similarly a geologic map shows the age and type of bedrock closest to the surface. Geologic Maps for the region of Pennsylvania where Meadowcroft Rockshelter is located demonstrate that the bedrock dates to the Pennsylvanian Period (299-318 million years). Geologic Time can help us understand and describe what happened at Meadowcroft before people arrived at the site.

Geography, Geologic Origins, and Physiography

To understand the formation of Meadowcroft Rockshelter, geomorphologists first looked to the physical **geography** (physiography) of the site. Geologically, Meadowcroft Rockshelter is located on the unglaciated portion of the **Appalachian or Allegheny Plateau**, west of the valley and

ridge province of the **Appalachian Mountains**, and northwest of the **Appalachian Basin**. This unglaciated southern portion of the Appalachian Allegheny Plateau is drained by the westward flowing **Ohio River watershed**, of which Cross Creek is a small **tributary**. The surface rocks of this region are layered **sedimentary** rocks of Middle to Upper Pennsylvania Age (Casselman Formation), 299 to 359 million years old. The predominant **lithologies** are **shale**, quartz, **sandstone**, **limestone**, and coal in decreasing order of abundance.



ure 1 Sketch of Morgantown-Connellsville sandstone Meadowcroft Rockshelter showing the change in limentary structure and grain size through the two nt-bar sequences (Image from Collected Papers: 2, 5.).

Meadowcroft Rockshelter itself is formed beneath a cliff of Morgantown-Connellsville **sandstone**, a thick fluvial or channel **sandstone** within the **Casselman formation (Upper Conemaugh)** (See Figure 1), dating to the **Pennsylvanian Period**. It is an immature **sandstone** composed predominantly of quartz grains with minor amounts of mica, feldspar, and rock fragments. The rock underlying the Morgantown-Connellsville **sandstone** is a less resistant lithology, most likely **shale**. The **sandstone** and **shale** that make up the Rockshelter formation began as alluvial deposits on the shifting plain of the Appalachian Sea some 299 to 359 million years ago during the Carboniferous Pennsylvanian Period of the Paleozoic Era. The **sandstone** was deposited as two superimposed sandbar (or point- bar) **sequences**. The rock within each **sequence** changes from cross-bedded, coarse-grained **sandstone** to laminated, fine-grained **sandstone**. The cliff above the Rockshelter is 72.2 feet high, with the **sandstone** decreasing in thickness along the Cross Creek valley both to the east and west; it has its maximum thickness at the Rockshelter.

Emergence of Western Pennsylvania Landforms

Between 251 million and 299 million years ago, the continent of Africa slammed into North America, creating the super-continent Pangea. The collision put the eastern seaboard under tremendous stress, forming the **Allegheny Mountains** in an event known as the **Allegheny Orogeny**. This event pushed the land of western Pennsylvania to its highest elevation and initiated a long period of **erosion** (250 million years and counting) that has produced the landscape that we see today. Most of this **erosion** happened during the Mesozoic Era (66 million to 251 million years ago).

During the Tertiary Period (1.8 to 66 million years ago) geologic events caused Pennsylvania's water systems to take their present form. The **watersheds** east of the Eastern Continental divide (such as the Susquehanna, Potomac and James rivers) flowed to the Atlantic Ocean, while those west of the divide (including the ancestral Ohio) generally cut across the **Appalachian Allegheny Plateau** toward the center of the continent.

Early in this pre-glacial period, the Plateau drainage was significantly different than that seen today. Topographic relief was lower and drainage flowed north and northwest to the area that would later be occupied by the Great Lakes. Two primary river systems drained the Appalachian Plateau: the **Monongahela-Beaver** (Figure 2) flowed north toward the Lake Erie Basin, while the **Teays-Mahomet River** flowed from Virginia into West Virginia and northward into Central Ohio, Indiana, and Illinois. At this time, Cross Creek was a **tributary** of the north-flowing Ohio, which, with the Lower Allegheny, was a **tributary** of the Monongahela-Beaver (Upper Ohio).

Stratigraphy and Geologic Evidence

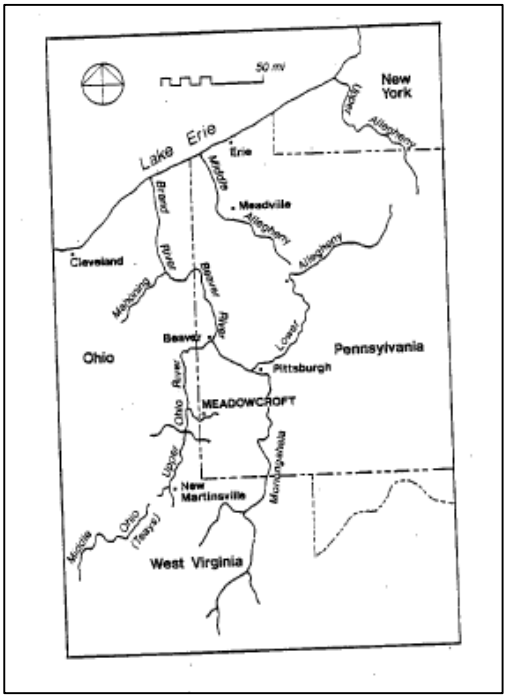
Landscapes are built in layers; each layer is a record of individual geologic events that occurred at some point in the past. These layers are referred to as **strata** and they are studied through **stratigraphy**.

Stratigraphy is a geology that deals with the origin, composition, distribution, and succession of **strata**. The **Law of Superposition** illustrates a basic principle of **stratigraphy**: layers that are deposited first are oldest, while layers on the surface are newest.

Geologists use the **Law of Superposition** to interpret landscapes; they study outcroppings and core samples to understand the **sequence** of geologic events. Generally, the rocks at the lowest point of a formation are oldest, while the uppermost rocks are newest.

The appearance of the rocks often reveals how they formed; in Pennsylvania, the most common rocks are **sedimentary**. **Sedimentary** rocks are formed from small sediments (sand gravel or clay) that have become naturally cemented together. **Sandstone** consists of visible layers of hardened sand. **Shale** consists of layers that split easily because they are simply hardened layers of clay or mud. **Limestone** is a **sedimentary** rock that formed from calcium and magnesium carbonates that were produced by ancient organisms in the sea. These **sedimentary** rocks can also contain fossil evidence that can be used to interpret life at a period when the sediments in the rocks were not yet cemented together.

In a sense, **sedimentary** rocks and rock formations are like mini-archaeological sites: they are composed of layers that contain evidence of earlier life and events. In short, **stratigraphy** is a tool for investigating **sequences**, be they geological or cultural.



ure 2 Pre-glacial Monongahela-Beaver Drainage
age From Collected Papers: 1982, 34).

Formation of Meadowcroft Rockshelter

Geomorphologists study changes in the formation of the land; once land is built up (in the case of Meadowcroft, it happened with the Allegheny Orogeny), it begins to erode. Much of the **erosion** occurs as bodies of water down cut through earlier formations. To understand how and when the Rockshelter formed, specialists looked at the size, shape, age, and composition of landforms such as **terraces** and **floodplains**, remnants of lakes, and sediment in **valleys** of the Cross-Creek **watershed.** They used this data to reconstruct the paleo-topography of the Cross Creek drainage. By correlating the landforms of the Cross Creek valley with those of the Greater Ohio **watershed**, they could create a very precise **sequence** for the development of the Cross Creek and the Meadowcroft Rockshelter. They discovered that glacial episodes during the Pleistocene (1.8 million years ago, ending within the past 12,000 years) triggered geologic processes that shaped the modern Ohio **watershed** and carved Meadowcroft Rockshelter.

During the Pre-Illinoisan Period (A and B in Figure 3), Cross Creek formed a broad terrace bounded by a steeper ascending **slope** as it flowed northwest to the Ohio River. Glacial advances eventually stopped the northern flow of the Mon-Beaver, which ponded forming Lake Monongahela. During this period, all valleys in the system ponded; many of the terraces seen in the Cross Creek valley are **evidence** of this event. The lake gradually increased in volume (twice) until it eventually breached a divide at New Martinsville, WV, causing the Upper Ohio to join the Lower Ohio (Teays-Mahomet) in flowing toward the Mississippi. The outpouring of water from the lake resulted in rapid downcutting throughout the system; at Meadowcroft, this created a constricted valley through the Casselman formation.

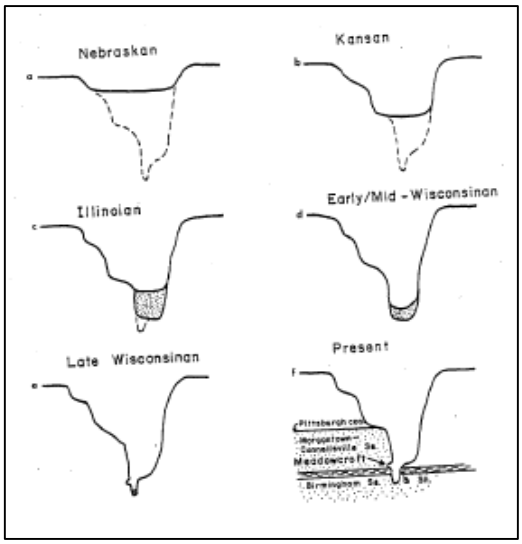


Figure 3 Formation of Meadowcroft Rockshelter (Image From: Meadowcroft: Collected Papers on the Archaeology of Meadowcroft Rockshelter and the Cross Creek Drainage

With the Illinoisan Glacial Advance (C in Figure 3), the Ohio and Cross Creek filled with alluvial deposits to a depth of 100 feet (approximately the roof level of the Rockshelter today). During the interglacial period,

stream action from Cross Creek cut through the fill. The scouring action cut back into the hillside under the **Morgantown-Connellsville sandstone** and formed a **re-entrant,** or **rockshelter**, over **shale** bedrock. The **sandstone** then remained as a roof to the Rockshelter, with the creek flowing through it.

During the Early Middle Wisconsinan Glacial Advance (21,000-31,000 years ago), a period of quiet water **deposition** resulted in a fine, silty blue clay on the floor or the Rockshelter (D in Figure 3). This floor would eventually serve as Strata 1 during the **archaeological** investigation of the Rockshelter. With the final glacial advance (Wisconsinan, 21,300YBP), Cross Creek cut a final terrace through the valley, roughly corresponding to the modern **floodplain** of the creek,10-30 feet above the present stream level (E in Figure 3). Gradually, the creek entrenched further. By 11,000 YBP, the Meadowcroft Rockshelter stood high, safe, and dry above the **floodplain** of Cross Creek (F in Figure 3), an ideal campsite for any humans walking past.

Formation of Meadowcroft Stratigraphy

From the start, Dr. Adovasio recognized that the Rockshelter on the cliffs of the Cross Creek was an ideal site for an **excavation** because it was a **closed site**, a **rockshelter**. Rockshelters are often located above the path of moving water and they are protected from wind. Generally, the roof-like structure of a **rockshelter** protects the underlying landscape from outside forces. At open-air **archaeological** sites, alluvial **deposition** from bodies of water and aeolian **deposition** from the wind, can cause large amounts of sediment to bury and drastically move cultural **artifacts**. In some cases, alluvial and aeolian forces can completely scramble the **stratigraphy** of a site. By contrast, at a **rockshelter**, the **stratigraphy** is generally intact because it has not been acted upon by outside forces. Any **cultural materials** deposited in the layers under a **rockshelter** are generally undisturbed by human or geological forces until they are excavated by an **archaeological** team.

Dr. Adovasio also acknowledged that Meadowcroft Rockshelter would challenge even the most practiced **closed-site geoarchaeologists**. Despite the protection, **rockshelters** often have complicated geologic and sedimentologic histories because **erosion** and attrition are constantly at work in these **environments**. Essentially, the formation of a **rockshelter** is also the start of its demise: **erosion** shapes the initial landform and attrition and **erosion** ultimately wear it down. These geologic processes deposit numerous layers of materials on the floor of **rockshelters**. Great attention to detail, requiring painstaking **excavation** and documentation is essential for sifting through the numerous layers inside these sites. To compound matters at Meadowcroft, **evidence** of roof spalls in the distant past indicated that the shelter was originally much larger. A larger shelter suggested a higher probability of long-term cultural site use, but the spalls indicated that the **excavation** crew would constantly encounter rocks (some the size of vehicles) as they dug. Once again, the **archaeological** team applied **geomorphology** to the study of the **rockshelter**, this time focusing their effort on **stratigraphy**.

Methodology

Geomorphologists used four methods to study the **stratigraphy**. Each method applied a different sampling technique to determine the source, mode, and composition of sediments. The first sampling method collected stratigraphic sediment columns (or cores) from all major areas of the site from east to west and north (inside) to south (outside) of the **dripline**. To collect the cores, geomorphologists cut vertically from the surface of the site through all **strata** to culturally sterile Stratum I. The samples were then analyzed for composition and origin.

Geomorphologists were also interested in establishing the modern rates of sedimentation at the Rockshelter. They placed a sampling tray on the roof of the **excavation** enclosure but under the rock overhang beginning in 1974 and continuing until 1978. The roof was swept daily to collect the fragments dropping from the ceiling (**colluvium**) and wall of the Rockshelter. This procedure demonstrated the sedimentation mechanisms and rate of accumulation impacting the site.

Third, geomorphologists gauged the effects of **sheetwash** from **upland** sources of the site by placing a large holding tank and drainage system on the eastern margin of the Rockshelter in 1976. The tank trapped all sediment and water moving across the roof during rainstorms. The procedure demonstrated the kind and volume of **upland** materials transported during rainstorms and another method for studying the accumulation of the Meadowcroft Colluvial pile.

Last, the geomorphologists extracted a column of rock samples from the base to the top of the Morgantown-Connellsville cliff at 20-50 cm (ca. 8-20 inch) intervals to compare the grain size and composition of the cliff face to samples from roof spalls the colluvial pile. The comparisons permitted the study of the patterns of **erosion** of the Rockshelter face.

Sources and Mode of Sediments

During the **excavation**, **archaeologists** could differentiate between the stratigraphic layers based on the color, composition, and texture, among other factors. They found eleven major stratigraphic layers within the site.

Field examination by geomorphologists and laboratory analysis of samples indicate that the sediments that make up the **stratigraphy** have four sources: 1) the silty clay of Stratum I which was deposited on the **shale** floor of the Rockshelter during a period of quiet water **deposition**, 2) rock fall from the Morgantown-Connellsville cliff ranging from granules to large boulders, 3) grain-by-grain **attrition** from the **sandstone** cliff, and 4) sheetwash from **upland** sources during rainstorms. The fine, blue silty clay located in Stratum I is the only **evidence** of stream or lake deposits underneath the Rockshelter. All other sediment derives from **erosion**. Essentially, the **stratigraphy** is a colluvial pile under the **sandstone** cliff. **Colluvium** results when sediment moves downslope and piles up. These deposits lie flat, forming smooth interfaces between **strata**.

The single most important factor controlling the mode and rate of sedimentation that composes the **stratigraphy** is the evolution of the Rockshelter itself. The physical changes in the Cross Creek valley and the configuration of the Rockshelter determine sedimentation style. Climatic variation impacts the rate of sedimentation, but the geological forces at play around and in the Rockshelter are what creates the sedimentation. For instance, the ceiling of the Rockshelter is gradually migrating upward and cliff-ward as **erosion** occurs both on the Rockshelter ceiling and the cliff face. The freezing, thawing, and movement of water and the penetration of roots in cracks in the Morgantown-Connellsville **sandstone** overhang trigger periodic roof falls. The rate of fall is increased by higher amounts of rainfall and lower temperatures, but the decay of the rock itself is what causes sediment to enter the Rockshelter. The timing of the Old Roof Fall (ca. 14,900 YBP) and the New Roof Fall (between ca. 1290 and 1665 YBP) are triggered by gradual enlargement of fractures in the **sandstone** overhang to a point where the blocks were no longer stable and fell. All **rockshelters** experience this cyclical process; it is inevitable that someday, thousands of years from now, the remaining overhang of the Meadowcroft Rockshelter too will fall. However, the current enclosure and conservation efforts by Meadowcroft Museum have greatly slowed the process and ensure the safety of the site and visitors for many years to come.

Tables

Ancient Geological Activity at Meadowcroft Rockshelter

Years Ago	Era or Eon	Period	Epoch	Activity affecting Pennsylvania	Types of Rock or Deposits	Activity Affecting the Cross Creek Drainage
0 to 1.8 million	Cenozoic Era	Quaternary	Holocene			We are here!
			Pleistocene	Glaciation	Sand, Silt, Clay, Gravel	Over thousands of years Cross Creek cuts through the Morgantown-Connellsville **sandstone** to form the Rockshelter. The first People arrive.
1.8 million to 66 million		Tertiary		Weathering & Erosion; creation of present landscape	Sand, silt, gravel	System of rivers, creeks, and rivulets that drain water from Pennsylvania today are in place. The Ohio (and Cross Creek) and Lower Allegheny rivers are tributaries of the Monongahela-Beaver drainage network which flows north to the Lake Erie Basin.
66 million to 146 million	Mesozoic Era	Cretaceous		Separation of North America from Africa as the Atlantic Ocean Opens; Intense Erosion and Weathering	Clay, sand	
146 million to 200 million		Jurassic			Diabase	
200 million to 251 million		Triassic			**Shale**, **Sandstone**, Diabase	
251 million to 299 million	Paleozoic Era	Permian		Allegheny Orogeny changes Pennsylvania from a depositional basin receiving sediment to an area above sea level that has	**Sandstone**, **shale**	

				been eroding ever since.		
299 million to 359 million		Pennsylvanian and Mississippian (Carboniferous)		Alluvial **deposition** as Appalachian basin retreats east-ward	**Sandstone**, siltstone, **shale**, coal, **limestone**	Alluvial sediments are deposited as the shoreline of the Appalachian Sea migrates. These sediments will form the **sandstone** rock formation that becomes Meadowcroft Rockshelter. Formation of the region's great coal seams as the alluvial plain shifts, burying carbon-rich peat that will become coal.

Pleistocene Geological Activity in the Cross Creek Drainage: Formation of the Meadowcroft Rockshelter

Period		**Activity affecting the Ohio drainage**	**Impact on Cross Creek drainage**	**Impact on Rockshelter**
Wisconsinan Glacial Period	Late Wisconsinan	The Ohio experiences a final glacial outwash.	Cross Creek forms a low terrace 10-30 feet above modern stream level, 10-20 feet below the top of Stratum I.	The **rockshelter** is available for human occupation and sits "high and dry" above the high-water level of Cross Creek. (21,300 YBP)
	Early Middle Wisconsinan (21,000-31,000 years ago)	Streams draining the glaciers introduce meltwater and sediment into the Ohio.	Cross Creek further erodes the valley and deposits fine silty blue clay during a period of quiet water **deposition**, followed by active downcutting.	The silty-blue clay is deposited on the floor of the re-entrant (this will become Strata I of the Rockshelter **excavation**). Afterwards the Rockshelter enlarges and is never again exposed to fluvial **deposition**.
Sangamon Interglacial Period			Cross Creek down cuts the Illinoisan alluvial fill below the present channel, undercutting the **shale** beneath the	Downcutting initiates a re-entrant beneath the Morgantown-**Sandstone** cliff.

		Morgantown-Connellsville **sandstone**.	
Illinoisan Glacial Period	Extensive Glacial sediment fills parts of the Ohio valley to 100 feet in depth. valley elevations increase (aggradation)and northern draining streams pond when glacial deposits block streams.	Cross Creek fills its valley with alluvial sediment (seen at areas about 100 feet above the current stream level and just above the modern cliff overhang at Meadowcroft Rockshelter). The stream gradient increases to 10.5 feet per mile.	The Cross Creek valley continues to erode in a deep V shape. Alluvial sediment fills the bottom of the valley to a depth of 100 feet.
Pre-Illinoisan	The glaciation periods promote the unification of pre-glacially distinct river systems draining the Appalachian Plateau, uniting them in the Ohio River. In the south, the Teays-Mahomet (Lower and Middle Ohio Rivers) system diverts southwest toward the Mississippi. Ice blocks the north flowing Monongahela-Beaver (Upper Ohio), causing the system and all tributaries to pond until the waters rise enough to breach the divide at new Martinsville, WV. A successive glacial advance recreates the ponding effect, this time when the water breaches the New Martinsville divide, it creates a permanent outlet for the system, unifying the Upper Ohio with the Middle and Lower Ohio rivers. During the Late Pre-Illinoisan period, the newly formed Ohio River entrenches, creating a deep bedrock valley similar to that seen today.	During the early Pre-Illinoisan, Cross Creek creates a broad terrace with a low gradient of 8.9 feet per mile. During the formation of Lake Monongahela I and II, Cross Creek ponds, evidenced in terraces in the drainage system. Eventually Cross Creek flows in a more constricted valley with an increasing gradient toward the Ohio. By the late Pre-Illinoisan, Cross Creek flows in a deep valley causing extensive downcutting through the Casselman Formation.	Cross Creek ends the Pre-Illinoisan as a deep V-shaped valley with the creek actively downcutting through the Casselman Formation. This downcutting shapes the land where the rockshelter will be.

Pre-Pleistocene	Topography of western PA is lower and drainage of the Appalachian Plateau region flows north and northwest toward basins that will become the Great Lakes. The Ohio River does not exist; two other river systems drain the plateau. The Teays-Mahomet River flows from Piedmont Virginia to West Virginia and northward into Central Ohio, Indiana, and Illinois. The Monongahela-Beaver drainage network (including the Ohio and lower Allegheny as tributaries) flows north to what is now the Lake Erie Basin.	Cross Creek is a **tributary** of the north flowing Upper Ohio River. Cross Creek valley exists at a high elevation and is wide and gently sloping.	

Stratigraphic Profile of Meadowcroft Rockshelter

Strata	Tag	Varying Thickness	Deposition Mode	Deposition Forces	Deposition Rate
XI	f3, f8	12-15 cm		Sheetwash	925 years
X	f25	1-5 cm	Silty clay	Sheetwash	
IX	f9	5-15 cm	Silty clay	Sheetwash	
VIII	f12	.5-5 cm	Large particles, sand	Sheetwash	
VII	f13	20-40 cm	Sandy loam	Sheetwash, Spalling	365 years
VI	f63, f129	60-140 cm	Silty clay	Spalling, Sheetwash	375 years
V	f14	20-40 cm	Sandy loam	Sheetwash, Attrition	625 years
IV	f16	30-70 cm	Sandy loam	Sheetwash, Attrition	760 years
III	f18	30-110 cm	Silty clay	Attrition, Sheetwash, Spalls	200 years
IIb	f46	40-130 cm	Sand and Silt	Attrition and High Spall	4,700 years
IIa upper	F46		Sand and silt	Attrition and High Spall	13,000 years

IIa middle	f46		Sand and silt	Attrition and High Spall	
II a lower	f46		Sand and silt	Attrition and High Spall	
I/ II	f85		Fine blue silt	Quiet water	*
1	F99	bedrock	Birmingham **shale** (300 Million Years Old)	swamp	*

Geologic Time as Related to Meadowcroft

Era or Eon	Period	Epoch		Years Ago (Approximate)
Cenozoic	Quaternary	Holocene		11,000 years ago to present
		Pleistocene	Late Wisconsinan Glacial Advance	25,000 to 11,000 years ago
			Early Middle Wisconsinan Glacial Advance	75,000 to 25,000 years ago
			Sangamon Interglacial	125,000-75,000 years ago
			Illinoian Glacial Advance	300,000 to 125,000 years ago
			Pre-Illinoian Periods (Yarmouth Interglacial, Kansan Glacial Advance, Nebraskan Glacial Advance)	425,000 to 2.5 million years ago
Mesozoic				
Paleozoic	Pennsylvanian and Mississippian (Carboniferous)			299 to 359 million years ago

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