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Cuyahoga Valley National Park

Paleontological Resource Inventory (Public Version)



An exposure of shale and sandstone from the Lower Mississippian Cuyahoga Group in Cuyahoga Valley National Park.

NPS / AUSTIN SHAFFER

Cuyahoga Valley National Park: Paleontological resource inventory (public version)

Science Report NPS/SR—2024/210

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Abstract

Cuyahoga Valley National Park (CUVA) was established as Cuyahoga River National Recreation Area on December 27, 1974, to preserve and protect the Cuyahoga River Valley and its historic, scenic, natural, and recreational values. While not explicitly mentioned in the park's mission statement, paleontological resources preserved at CUVA are nevertheless of importance, particularly when considering the significant fossil discoveries made elsewhere across northeast Ohio.

The upper Paleozoic geologic strata of CUVA encompass sedimentary rocks dating from the Late Devonian to the Early Pennsylvanian, recording a series of shallow marine and coastal riverine environments. Within these rocks, a diverse assortment of fossil organisms is preserved at the park, including corals, bryozoans, brachiopods, bivalves, cephalopods, gastropods, arthropods, crinoids, early land plants, fish, and more.

To comprehensively assess the paleontological resources at CUVA, a field inventory was conducted from April to June 2024. Fifteen notable paleontological localities were documented in the park during this inventory, with several potentially significant new fossil discoveries made as well, such as rare Early Mississippian tetrapodomorph material. A review of published and gray literature supplemented the 2024 fieldwork. Between the fossil discoveries of the 2024 field inventory and previous research conducted within the park, it is clear that significant paleontological resources occur within CUVA. Future research on these fossils holds a high likelihood of yielding important scientific information as well as potential new species.

This report provides foundational data on the scope, significance, and distribution of paleontological resources at CUVA and provides recommendations to support the management, interpretation, and research of these resources.

List of Terms or Acronyms

Actinopterygian: A member of the class Actinopterygii, the ray-finned fish, including the great majority of living fish.

Alluvial (adjective), **alluvium** (noun)**:** A general term for unconsolidated terrestrial sediment moved by water and not attributed to a more specific process (i.e., not fluvial, glacial, or lacustrine).

Anoxic: When applied to bodies of water, this refers to waters depleted of oxygen.

Arthrodire: A member of the extinct order Arthrodira, a group of armored jawed fish known from the Devonian.

Arthropod: A member of the phylum Arthropoda, a diverse group of invertebrates with exoskeletons, segmented bodies, and jointed appendages. Insects, arachnids, and crustaceans are modern examples.

Artifact (archeology)**:** Objects made or modified by humans.

Basal (geology)**:** Located near or at the bottom of a specific geologic unit.

Bashkirian: The Early or Lower Pennsylvanian, approximately 323 to 315 Ma.

Basin (geology)**:** A geologic downwarp formed by folding and faulting; geologic basins can often be identified by rock strata dipping to a central point, a bullseye pattern of rocks in a geologic map with the youngest rocks at the center, or an anomalous area of young rocks at the same elevation as older rocks in the vicinity. An eroded geologic basin does not necessarily form a depression.

Bedrock (geology)**:** A general term for the rock that underlies soil or other unconsolidated, surficial material.

Benthic: Of, relating to, or occurring at the bottom of a body of water, such as the seafloor.

Biostratigraphy: Using fossils to identify the relative positions and relative ages of rocks.

Biostrome: A stratified sedimentary deposit built by sedentary marine organisms, such as corals, brachiopods, and crinoids.

Bioturbation: Disturbance of sediment by organisms to the extent that sedimentary features such as bedding and stratification are destroyed.

Bivalve: A member of the class Bivalvia, mollusks with two shells. Historically referred to as pelecypods. Examples include clams, oysters, mussels, and scallops.

Body fossil: Fossilized remains of the body of past organisms, including bones, teeth, skin, shells, wood, and leaves.

Brachiopod: A member of the phylum Brachiopoda, marine filter-feeding animals with two shells, resembling bivalve mollusks but more closely related to bryozoans. Brachiopods are sometimes known as "lamp shells" due to the resemblance of some taxa to ancient oil lamps.

Bryozoan: A member of the phylum Bryozoa, filter-feeding aquatic colonial animals. Bryozoans are sometimes called "moss animals" because they often encrust objects.

Calcareous: Mostly or partly composed of calcium carbonate; lime-rich.

Calcite: A mineral made of calcium carbonate. Found in limestone and some fossils.

Calcium carbonate: $CaCO_3$, a mineral-forming compound. Calcite is a common form.

Carbonate (geology)**:** A general term for minerals containing carbonate ions (CO_3^{-2}), such as calcite, and rocks containing these minerals, such as limestone.

Carboniferous: Internationally, the fifth geologic period of the Paleozoic Era, often divided into the Mississippian and Pennsylvanian in North America. Lasted from approximately 359 to 299 Ma.

Cenozoic: A geologic era, dated approximately 66 Ma to the present, noted for the diversification of mammals. The term means "new life".

Cephalopod: A member of the class Cephalopoda, a group of mollusks with a prominent head fringed by tentacles. Examples include squids, octopuses, *Nautilus*, and many extinct forms, especially ammonoids.

Chlorophyte: A member of the clade Chlorophyta, a type of green algae.

Chondrichthyan: A member of the class Chondrichthyes, the cartilaginous fish. Examples include sharks, rays, and chimaeras.

Chordate: A member of the phylum Chordata, a group of animals with notochords. The vast majority of chordates are vertebrates.

Chronostratigraphy: A branch of stratigraphy that examines the relationship between strata and time. Isotope geology and geochronology are heavily utilized to determine the precise age of certain rocks.

Cladistics: A biological classification method grouping organisms in groups (**clades**) based on the proportion of shared measurable derived characteristics (**synapomorphies**). Cladistics is the most commonly utilized method for classifying organisms.

Clast: A rock fragment of any size. A rock made up of clasts, such as sandstone or shale, is called clastic.

Clay: Can be used to refer to clay minerals or as a sedimentary fragment size classification (less than 1/256 mm [0.00015 in]).

CMC: Cincinnati Museum Center.

CMNH: Cleveland Museum of Natural History.

CMP: Cleveland Metroparks.

Colluvial (adjective), **colluvium** (noun)**:** a general term for unconsolidated terrestrial sediment deposited at the base of a slope through various means (e.g., mass wasting).

Conformable (geology)**:** A successive, continuous sequence of strata deposited without interruption or disturbance.

Conglomeratic (adjective), **conglomerate** (noun)**:** A clastic sedimentary rock comprised of a significant proportion of gravel-sized clasts (>2 mm [0.08 in]) and a finer grained matrix.

Conodont: A member of the extinct class Conodonta, a group of eel-like chordates known primarily from jaw elements.

Consolidant (paleontology)**:** a dilute adhesive used to penetrate a fossil specimen and adhere internally in order to prevent damage.

Contact (geology)**:** The boundary that separates two bodies of rock; the horizon or plane where two formations meet.

Conulariid: A member of the clade Conulariida, an extinct group of distant relatives of corals that formed flat-sided conical structures from small mineralized rods.

Crinoid: A member of the class Crinoidea, an echinoderm known as a sea lily, featuring a cup-like body with feathery tentacular arms, usually but not always attached to a surface with a stalk.

Cross-bedding or **cross-stratification:** Uniform to highly varied sets of inclined sedimentary beds deposited by wind or water that indicate flow conditions such as deposition direction and depth/height.

Ctenacanth: A member of the extinct order Ctenacanthiformes, a group of predatory cartilaginous fish which filled a similar ecological role and are near to the ancestry of sharks.

CUVA: Cuyahoga Valley National Park.

Decapod: A member of the order Decapoda, a group of crustaceans that includes prawns, shrimp, lobsters, crayfish, and crabs.

Devonian: The fourth geologic period of the Paleozoic Era. Lasted from approximately 419 to 359 Ma.

Dinoflagellate: A member of the clade Dinoflagellata, a group of single-celled organisms with two whip-like flagella. Dinoflagellates are known in the fossil record from their resistant cysts.

DOI: Department of the Interior or, in references, digital object identifier.

Early-diverging: A lineage that diverges from another lineage early in their collective history.

Echinoderm: A member of the phylum Echinodermata, a group of invertebrates noted for their five-fold symmetry. Sea stars, sea urchins, sea lilies, and sea cucumbers are some examples.

Epibiont: An organism that lives attached to another organism.

Eurypterid: A member of the extinct order Eurypterida. A group of Paleozoic invertebrates, commonly referred to as sea scorpions, that includes some of the largest known arthropods.

Eutrophication: A condition that occurs in bodies of water when abundant nutrients permit blooms of microorganisms that deplete oxygen in the water.

Extinct: A group of organisms that no longer exists.

Extirpated: A species or larger group of organisms that is unable to live in part of its former geographic range. Applied in areas where the organism no longer lives.

Facies: A body of rock that is distinct from the surrounding rock, due to specific aspects of deposition and setting. Facies are generally invoked when there are differences within a formation or member that are not suitable for mapping (i.e., not laterally persistent).

Famennian: The latest or uppermost Devonian, approximately 371 to 359 Ma.

Float (geology)**:** Eroded material resting on the surface, not attached to an outcrop.

Fluvial: Of or pertaining to a river or rivers.

Form genus: A classification based on similarity of general form, for example in paleobotany due to the rarity of complete fossil plants (e.g., form genera for fossil wood or leaves). Fossils assigned to a form genus have similarities but may not be closely related.

Formation (geology)**:** Fundamental rock-stratigraphic unit that is mappable, lithologically distinct from adjoining strata, and has definable upper and lower contacts. The basic unit of stratigraphy.

Fossiliferous: A rock or deposit that yields fossils.

Gastropod: A member of the class Gastropoda, a group of mollusks including snails and slugs (snails without shells), known from the Cambrian to the present.

Geochronology: A branch of geology dedicated to determining the age of rocks, sediments, fossils, and geologic events. A number of different types of geochronology exist based on the use of varying dating methods.

GRD: Geologic Resources Division of the National Park Service.

GRI: Geologic Resources Inventory.

Group (geology)**:** A lithostratigraphic unit comprising several related formations classified together.

Gymnosperm: A member of the clade Gymnospermae, a group of seed plants that includes conifers, cycads, gnetophytes, and ginkgophytes.

Hederelloid: A member of the extinct suborder Hederelloidea, a group of colonial tube-building invertebrates often found encrusting the surface of other marine organisms and which are likely related to modern horseshoe worms.

Holocene: The second and most recent epoch of the Quaternary Period, following the Pleistocene and the last glacial maximum, beginning approximately 11.7 ka and continuing to the present.

Holotype: A specimen that serves as the basis for an organism's scientific name and is ideally representative of the given taxon, although this is not necessarily the case. Other "types" exist for specific situations, such as a paratype or a neotype.

Hyperpycnite: A sedimentary deposit produced by dense sediment flows outflowing from rivers.

Ichnofossil or **trace fossil:** Fossilized remains of the biological activity of past organisms, including traces of burrows, tracks, root traces, feeding marks, fossilized dung, and layers produced by microbial mats.

Ichnogenus, ichnospecies, ichnofamily, ichnotaxon: A scientific name used for a trace fossil, existing in parallel to the names used for body fossils.

Ichnology: The study of traces of biological activity beyond an organism's remains. Sometimes divided into **paleoichnology** (the study of trace fossils or ichnofossils) and **neoichnology** (the study of modern traces).

In situ (geology)**:** When describing fossils, this means found in place at an outcrop.

Index fossil: A widespread, distinctive fossil organism that corresponds to a specific geologic age and is used to date and correlate rock strata.

Interbedding (geology)**:** Rock layers of a specific lithology lying between or alternating with those of a different lithology.

Isostatic rebound: Upward movement of Earth's crust in response to glacial retreat removing the weight of ice sheets.

Ka: An abbreviation for "kiloannum" or "kilo-annum" meaning "thousand years."

Lacustrine: A lake as a depositional environment or mode of transport.

Lepidodendralean: A member of the extinct order Lepidodendrales, tree-like lycophytes related to modern quillworts, spikemosses, and clubmosses, commonly referred to as scale trees. Lepdidodendraleans were the dominant plants of Carboniferous coal-swamp forests.

Limestone: A sedimentary rock consisting mainly of calcium carbonate, primarily in the form of the mineral calcite.

Lithified: A sedimentary deposit that has become rock.

Lithology: The variety or varieties of rock in a formation, member, bed, or other division.

Locality: A distinct site, especially one known to field fossils or other unique features.

Lycopod: A member of the class Lycopodiopsida, a group of plants containing clubmosses and firmosses, quillworts, and spikemosses. While modern examples are relatively small, giant lycopods were abundant during the Carboniferous.

Ma: An abbreviation for "megaannum" or "mega-annum" meaning "million years."

Matrix (geology)**:** A fine-grained mass of rock in which larger grains, clasts, crystals, and/or fossils are embedded.

Member (geology)**:** A lithostratigraphic unit with definable contacts; a subdivision of a formation.

Mesiodistal: An anatomical orientation describing teeth: "mesial" is toward the front of a jaw, where the two halves meet, and "distal" is toward the opposite end.

Mesozoic: A geologic era, dated approximately 252 to 66 Ma, noted for the dominance of dinosaurs on land and the appearance of birds, mammals, and flowering plants. The term means "middle life."

Microfossil: A fossil, typically 1 mm (0.04 in) or less in size, that must be studied with a microscope.

Miospore: Small fossil plant spores.

Mississippian: In North America, the de facto fifth geologic period of the Paleozoic Era (internationally a subperiod of the Carboniferous Period). Lasted from approximately 359 to 323 Ma.

Mollusk: A member of the phylum Mollusca, a diverse group of invertebrates noted for their combination of a muscular foot, a shell, and a mantle that covers the innards and secretes the shell. Examples include bivalves, cephalopods, and gastropods.

MWAC: Midwest Archeological Center.

Nautiloid: A member of the subclass Nautiloidea, a group of shelled cephalopod mollusks represented today by species of chambered nautilus, but in the past including various straight (orthoconic) and coiled forms.

Noeggerathialean: A member of the extinct order Noeggerathiales within the class Progymnospermopsida. Enigmatic woody plants resembling modern tree ferns, and which were close to the ancestry of all seed-bearing plants.

NPS: National Park Service.

Organic: Made of organic compounds (i.e., molecules of carbon, hydrogen, nitrogen, and oxygen); pollen, spores, and cysts, all of which can be fossilized, have organic walls.

Orthocerid: A member of the extinct order Orthocerida, a group of nautiloid mollusks generally having elongate straight shells.

Osteichthyan: A member of the clade Osteichthyes, the bony fish. Osteichthyans include ray-finned fish, lobe-finned fish, and technically tetrapods, although this last group is usually excluded in practice.

Paleoecology: The study of interactions among organisms and between organisms and their environments on a geologic timescale.

Paleogeography: The study, description, and reconstruction of the physical landscape from past geologic periods.

Paleozoic: A geologic era, dated approximately 539 to 252 Ma, noted for the diversification of invertebrates and the appearance of vertebrates and land plants. The term means “early life”.

Paludal: Of or pertaining to a marshland.

Palynomorph: An organic-walled microfossil. Pollen and spores are common examples. Other types include tests (hard spherical shells) of some microorganisms and the jaw elements of worms.

Pennsylvanian: In North America, the de facto sixth geologic period of the Paleozoic Era (internationally a subperiod of the Carboniferous Period). Lasted from approximately 323 to 299 Ma.

Permian: The seventh and last geologic period of the Paleozoic Era, ended by the largest mass extinction in Earth's history. Lasted from approximately 299 to 252 Ma.

Placoderm: A member of the extinct class Placodermi, a group of armored jawed fish.

Pleistocene: The older of two epochs in the Quaternary, noted for extensive glaciation. Lasted from approximately 2.58 Ma to 11.7 ka.

Progymnosperm: A member of one of several lineages of extinct plants close to the ancestry of modern seed plants.

PRPA: Paleontological Resources Preservation Act (2009).

Quaternary: The most recent geologic period, third and last in the Cenozoic Era, noted for extensive glaciation and numerous glacial/interglacial periods, beginning approximately 2.58 Ma and continuing to the present.

(Marine) Regression (noun), **regressive** (adjective)**:** A marine retreat, exposing land.

Reworked (geology)**:** A fossil or other object that has been eroded from an older rock unit and redeposited in a younger unit.

Rostroconch: A member of the extinct class Rostroconchia, a group of mollusks that had "taco"-like single folded shells.

Rugose coral: A member of the extinct subclass Rugosa, a group of corals that included both colonial and solitary forms, with the solitary forms known as horn corals.

Sand: A clastic particle smaller than a granule and larger than a silt grain, having a diameter in the range of 1/16 mm (0.0025 in) to 2 mm (0.08 in).

Sandstone: Clastic sedimentary rock of predominantly sand-sized grains.

Scaphopod: A member of the class Scaphopoda, a group of mollusks with elongate conical shells, also known as "tusk shells".

Sediment: An eroded and deposited, unconsolidated accumulation of rock and mineral fragments.

Sedimentary: Refers to a consolidated and lithified rock consisting of clastic and/or chemical sediment(s). One of the three main classes of rocks, alongside igneous and metamorphic.

Sessile (zoology)**:** Refers to an organism which is permanently affixed to a substrate; not free moving.

Silt: Clastic sedimentary material intermediate in size between fine-grained sand and coarse clay (1/256 to 1/16 mm [0.00015 to 0.002 in]).

Siltstone: A clastic sedimentary rock composed of silt-sized grains.

SMP: Summit Metro Parks.

Soil: Surface accumulation of weathered rock and organic matter capable of supporting plant growth and often overlying the parent material from which it formed.

Stratification: The accumulation or layering of sedimentary rocks in strata. Tabular, or planar, stratification refers to essentially parallel surfaces. Cross-stratification refers to strata inclined at an angle to the main stratification.

Stratigraphy: The geologic study of the origin, occurrence, distribution, classification, correlation, and age of rock layers, especially sedimentary rocks.

Stratotype: The standard (original or subsequently designated), accessible, and specific sequence of rock for a named geologic unit that forms the basis for the definition, recognition, and comparison of that unit elsewhere.

Stratum (singular), **strata** (plural)**:** A layer of rock/sediment distinguished by specific lithological characteristics.

Stromatoporoid: A member of the class Stromatoporoidea, a group of reef-building layered sponges. They are regarded as extinct, although some modern sponges are similar.

Syntype: One of a group of specimens designated as a name-bearing series for an organism.

Taxonomy: The study of naming, defining, and classifying organisms into groups. Taxonomic groups or **taxa** (singular: **taxon**) are provided a taxonomic ranking (the main ranks utilized are **domain, kingdom, phylum/division, class, order, family, genus,** and **species**, although additional ranks exist).

Tectonics: The movements and interactions of Earth's plates.

Tempestite: A sedimentary structure produced by storms.

Tentaculitid: A member of the extinct order Tentaculitida, conical-shelled marine invertebrates that likely embedded themselves in soft sediment of the seafloor.

Tetrapod: A member of the superclass of Tetrapoda, meaning "four feet", although some members have lost some or all four limbs (e.g., snakes). Tetrapods include amphibians, reptiles, birds, and mammals.

Tetrapodomorph: A member of the clade Tetrapodomorpha, including tetrapods and their closest lobe-finned fish relatives. Tetrapodomorphs were the first vertebrate animals to transition from an aquatic to a terrestrial lifestyle.

Tournaisian: The Early or Lower Mississippian, approximately 359 to 347 Ma.

(Marine) Transgression (noun), **transgressive** (adjective)**:** A marine encroachment, submerging land.

Turbidite: A sedimentary deposit produced by density flow.

Unconformity: A general term for any erosional or non-depositional surface between two rock units.

USGS: United States Geological Survey.

USNM: United States National Museum of Natural History.

Viséan: The Middle Mississippian, approximately 347 to 331 Ma.

Weathering: The physical, chemical, and biological processes by which rock is broken down.

Acknowledgments

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We also thank the staff members at Cleveland Metroparks and Summit Metro Parks for their help in coordinating fieldwork efforts on co-managed properties. Special thanks to Nathan Byer and Ella McLaren for their assistance with fieldwork. Thanks to Jenn Grieser, Connie Hausman, and Eric Shaffer of Cleveland Metroparks, and Rob Curtis, Mike Johnson, and Megan Shaeffer of Summit Metro Parks for their support.

Paleontologists from local institutions, such as the Cleveland Museum of Natural History and Kent State University, as well as those from further afield provided valuable input and information during this project. We thank Caitlin Colleary, Ted Daeschler, Russell Engelman, Nick Gardner, Joe Hannibal, Amanda McGee, Roy Plotnick, and Carrie Schweitzer for all of their assistance.

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Finally, we thank Bob Carr, Carrie Schweitzer, Ryan Trimbath, and Kelsey Voit for their reviews of this work. The useful feedback provided by these individuals helped to improve the final product.

Dedication

We dedicate this paleontological resource inventory report to paleontologist Dr. Rodney Feldmann, whose contributions to the paleontology of northeast Ohio and to the field as a whole are tremendous.

Rod was born in Steele, North Dakota in 1939. He went on to receive education in geology at the University of North Dakota, pursuing a career of scientific discovery and wonder. Throughout his life, he sought to share his excitement about paleontology with others, work with students to prepare them for their own successful careers, and maintain a job that felt more like a hobby than work.

In 1965, Rod moved to northeast Ohio and began working in the Department of Geology at Kent State University. In the subsequent decades, he taught and mentored a great number of students alongside conducting a wealth of paleontological research. With more than 450 scientific publications on fossils, primarily focused on decapod crustaceans (lobsters, crabs, and shrimps), Rod's paleontological work placed him among the most highly cited scientists in the world and will certainly leave a lasting impact on the field.

His work in northeast Ohio, in particular, was crucial in the production of this inventory report, including some of the only paleontological work to occur in Cuyahoga Valley National Park since federal protection was established. Rod loved Cuyahoga Valley National Park and, alongside his wife and fellow paleontologist Carrie Schweitzer, conducted geological field trips to the park for Kent State students each semester.

Rod died at the age of 84 on May 1, 2024. He spent his final days writing sections of the Treatise of Invertebrate Paleontology, doing what he loved and never working a day in his life.



Rod Feldmann collecting fossil specimens in the Solnhofen Limestone of Germany. © CARRIE SCHWEITZER

Introduction

Cuyahoga Valley National Park (CUVA) preserves approximately 33,000 acres (132 km^2; 51 mi^2) of the Cuyahoga River Valley ecosystem between the metropolitan centers of Akron and Cleveland in northeast Ohio (Figure 1) as the Cuyahoga River flows northward into Lake Erie. The park was established by Congress on December 27, 1974, in order to preserve and protect the historic, scenic, natural, and recreational values of the Cuyahoga River Valley (National Park Service 2013). Initially designated as Cuyahoga Valley National Recreation Area, the park was redesignated Cuyahoga Valley National Park on October 11, 2000. CUVA consistently ranks among the top ten most visited national parks in the country, attracting millions of local, national, and international visitors each year. The mosaic landscape of CUVA, co-managed by the National Park Service, Cleveland Metroparks, Summit Metro Parks, and other public and private partners, contains mixed deciduous forests, wetlands, urban and historic infrastructure, and other abundant cultural and natural resources, including a diverse assortment of Paleozoic fossils.

This report provides detailed information on the paleontological resources of CUVA, including the history of paleontological work in the lands now within the park, geologic units, taxonomic groups, localities, museum collections, research, interpretation, and management and protection. In addition to the main body of text, there are six appendices: Appendix A (tables of paleontological taxa arranged by stratigraphy); Appendix B (museum collections data); Appendix C (contact information for repositories); Appendix D (paleontological resource law and policy); Appendix E (paleontological locality data); and Appendix F (a geologic time scale).

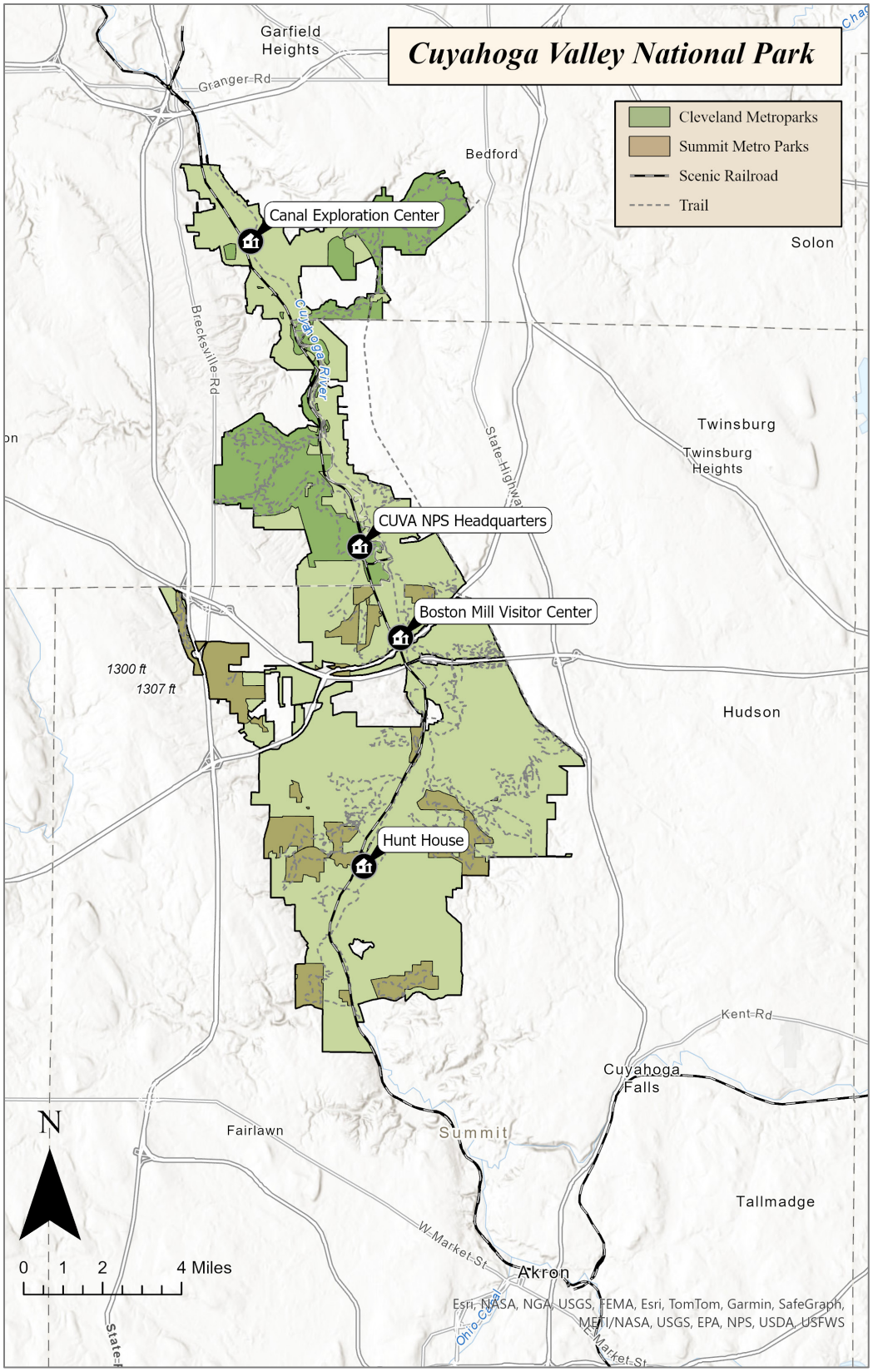


Figure 1. Park map of CUVA with co-managed properties, trails, scenic railroad route, and certain park facilities indicated. NPS / AUSTIN SHAFFER

Significance of Paleontological Resources at CUVA

Northeast Ohio has produced numerous important fossils from its upper Paleozoic geologic strata, including diverse Devonian marine organisms and terrestrial taxa of the Carboniferous. While the same geologic units and many of their constituent fossils have been identified from CUVA, the scope, significance, and distribution of the park's paleontological resources have hitherto not been thoroughly understood. A paleontological resource inventory of CUVA provides a comprehensive look at these park resources which will support future research, interpretation, and management.

Purpose and Need

The NPS is required to manage its lands and resources in accordance with federal laws, regulations, management policies, guidelines, and scientific principles. Those authorities and guidance directly applicable to paleontological resources are cited in Appendix D. Paleontological resource inventories have been developed by the NPS in order to compile information regarding the scope, significance, distribution (both geospatial and temporal), and management issues associated with fossil resources present within parks. This information is intended to increase awareness of park fossils and paleontological issues in order to inform management decisions and actions that comply with laws, directives, and policies. Options for paleontological resource management are locality-specific and may include: surveys; site monitoring; cyclic prospecting; stabilization and reburial; shelter construction; excavation; closure; patrols; alarm systems or electronic surveillance; and no action. See Appendix D for additional information on applicable laws and legislation.

Project Objectives

This park-focused paleontological resource inventory project was initiated to provide information to CUVA staff for use in formulating management activities and procedures that would enable compliance with related laws, regulations, policy, and management guidelines. Additionally, this project will facilitate future research, proper curation of specimens, and resource management practices associated with the paleontological resources at CUVA. Methods and tasks addressed in this inventory report include:

- Locating, identifying, and documenting paleontological resource localities through field reconnaissance and perusal of archives, photography use, and GPS data.
- Assessing collections of CUVA fossils maintained within park collections and in outside repositories.
- Documenting current information on faunal assemblages and paleoecological reconstructions.
- Interviewing park staff to gather information on the current status of paleontological resources, to aid in formulating plans for management, ideas for interpretation, and recommendations.
- Conducting a thorough search for relevant publications, unpublished geologic notes, and outside fossil collections from CUVA.

History of Paleontological Work at CUVA

Records of paleontological and associated geological work taking place in the fossiliferous geologic units of northeast Ohio, including areas within CUVA, date back to the late 1800s. J. S. Newberry (1873, 1875) reports the discovery of multiple fossil fish taxa (see Appendix A for a list) from the Cleveland Member of the Ohio Shale Formation near Bedford, Ohio, likely within the current park boundaries. If such fossils were indeed found in CUVA, they would represent the earliest reported paleontological resources from what is now the park. In the 150 years or so since these discoveries, occasional paleontologically relevant research has been conducted in and around CUVA. Several works significant to the assessment of paleontological resources at CUVA are briefly outlined here.

Charles S. Prosser's 1912 publication on the Devonian and Mississippian formations of northeastern Ohio details the author's work conducted in the region beginning in 1901 and dedicates a 167-page chapter strictly to the geology and paleontology of the Cuyahoga Valley (Prosser 1912). This chapter references five general locations where fossils were found within the modern park boundaries and describes a diverse assortment of invertebrate taxa from these locations, including conulariids, brachiopods, bivalves, cephalopods, and gastropods; all of these fossils are reported to occur within either the Ohio Shale or Bedford Formations (see Appendix A for a list of these taxa and their stratigraphic occurrence in the park).

A 1947 publication by Wilbert H. Hass describes five conodont zones from the Devonian and Mississippian in Ohio, including conodont fossils from within modern CUVA (Hass 1947). While a number of different conodont taxa are listed as occurring within the Ohio Shale Formation, Bedford Formation, and basal Cuyahoga Group, this publication does not report which specific taxa were identified from which sites, only which geologic units produced conodont fossils generally at each site. This precludes the recognition of any specific conodont taxa as occurring in the rocks of CUVA. Nevertheless, the findings of Hass remain relevant to considerations of the paleontological resources of CUVA.

In 1962, Marcia R. Winslow provided a detailed report on plant microfossils (i.e., spores) from Devonian and Mississippian strata of Ohio (Winslow 1962). This work included samples taken from Ohio Shale Formation and Bedford Formation rocks within modern CUVA. A large number of fossil plant taxa were described from these sites by Winslow (see the "Museum Collections and Curation" section and Appendix A for lists of these taxa), including holotypes designated for 14 species from within the park.

A 1990 study by Barbara A. Schwimmer and Rodney M. Feldmann documented the brachiopod-dominated fauna of two sites in CUVA (then the Cuyahoga Valley National Recreation Area) and represents the first significant paleontological field survey in the park since federal protection under the NPS was established (Schwimmer and Feldmann 1990). Nineteen brachiopod taxa and four bivalve taxa were described by Schwimmer and Feldmann from the Chagrin Member of the Ohio Shale Formation, expanding upon and revising the earlier work of Prosser (1912) that included invertebrate fossil taxa from these areas.

In October 2022, a reconnaissance survey of paleontological resources at CUVA was undertaken through collaboration between paleontologist John-Paul Hodnett, CUVA staff members Megan Hulbreck and Ryan Trimbath, and Nathan Byer of Cleveland Metroparks (CMP). Several different fossil locations and many taxa were observed during this work, with the recommendation made that a formal Paleontological Resource Inventory, such as conducted here, take place. The results of the 2022 survey helped lay the groundwork for this inventory.

Summary of 2024 Paleontological Survey

This paleontological resource inventory report for CUVA was produced through a combination of fieldwork and data compilation conducted by Austin B. Shaffer in 2024. Previous reports of fossil occurrences in CUVA were compiled from published sources and gray literature. Field surveys of CUVA were conducted in order to identify fossiliferous locations in the park, with survey emphasis placed upon streamside outcrops. On occasion, fieldwork was assisted by staff from CUVA (Ryan Trimbath) and CMP (Nathan Byer and Ella McLaren). Significant fossil localities were documented using GPS, photographs, and field notes. Data management occurred through the use of Excel spreadsheets and ArcGIS Pro.

Documentation and report writing were assisted through examination of relevant published literature, allowing for tentative identification of fossil taxa and specimens. Regional paleontologists were consulted on the identification of certain specimens. Lists and tables containing 2024 inventory data can be found in Appendices A, B, and E (CUVA taxa, collections, and localities, respectively). Additional information may be accessed by qualified researchers through the NPS at CUVA.

Geology

Geologic History

The fossil-bearing geologic strata of CUVA record depositional environments of the late Paleozoic, from the Late Devonian to the middle Carboniferous, alongside more recent sediments from the Quaternary. (Note that "early" and "late" refer to geochronological age, whereas "lower" and "upper" refer to stratigraphic position, and "middle" applies to either; these terms are capitalized if officially defined, lowercase if not, e.g., Early Mississippian, late Tournaisian. A glossary containing definitions for much of the terminology used in this report can be found near the beginning of this report.)

The time interval of the late Paleozoic preserved at CUVA is characterized by marine regressions and transgressions associated with the onset of the Late Paleozoic Ice Age (LPIA). While most of the Devonian saw consistent greenhouse conditions, the late Famennian stage, around 365 Ma (million years ago), experienced the initial glaciation of the LPIA (Brezinski et al. 2010; Lakin et al. 2016). This early transitional phase of the ice age, which lasted until the Mississippian subperiod of the Carboniferous (about 359 Ma), seems to have seen an intermittent series of glacial episodes during the shift to full icehouse conditions (Lakin et al. 2016). During the latest Devonian, midlatitude glaciers likely existed in the Acadian Highlands east of the Appalachian Basin (and CUVA), with icebergs possibly rafting glacial debris out into the shallow marine environment of the uppermost Ohio Shale Formation (Brezinski et al. 2010; Lakin et al. 2016; Dunkel et al. 2022). As global sea level dropped and glaciers advanced, the Appalachian Basin experienced a regression of the marine shoreline, captured at CUVA in the stratigraphic sequence of the Bedford and Berea Formations (Figure 2) (Brezinski et al. 2010). The deltaic and shallow-marine prodeltaic environments of these two units received sediment via northerly rivers that flowed from highlands in eastern Canada down to the shoreline of the shallow ancient Ohio Bay (Figure 3) (Pepper et al. 1954; Lewis 1988; Dunkel et al. 2022). The climatic and environmental fluctuations seen in the transitional early LPIA likely placed the floral and faunal communities of the time under strain (Pfefferkorn et al. 2017).

At the end of the Devonian, a multiphase biological crisis known as the Hangenberg Event lasted for several hundred thousand years and affected the entire world. This first-order mass extinction saw substantial losses of diversity in both the terrestrial and marine realms with multiple major taxonomic clades (including phacopid trilobites, stromatoporoid sponges, and placoderms) disappearing entirely (Kaiser et al. 2015). This event also saw severe impacts to global ecosystems and surviving taxa. The terrestrial *Archaeopteris*-dominated forests and diverse marine reef-building communities that had characterized the Late Devonian collapsed during this event and the body size of vertebrates such as sharks, other fish, and tetrapods shrank significantly (most taxa in the wake of the event being under 1 m/3.3 ft in length), with the slow recovery from these impacts occurring over tens of millions of years (Kaiser et al. 2015; Sallan and Galimberti 2015; Yao et al. 2020). The exact drivers of the end-Devonian extinction event remain heavily debated; hypotheses range from eutrophication via increased continental weathering facilitated by the expansion of land plants (Qie et al. 2023) to volcanism (Rakocinski et al. 2020; Kaiho et al. 2021) to a nearby supernova explosion (Fields et al.

2020; Marshall et al. 2020). At CUVA, the Hangenberg Event spans the strata of the uppermost Ohio Shale Formation, the Bedford Formation, and the Berea Formation (Blood et al. 2019).

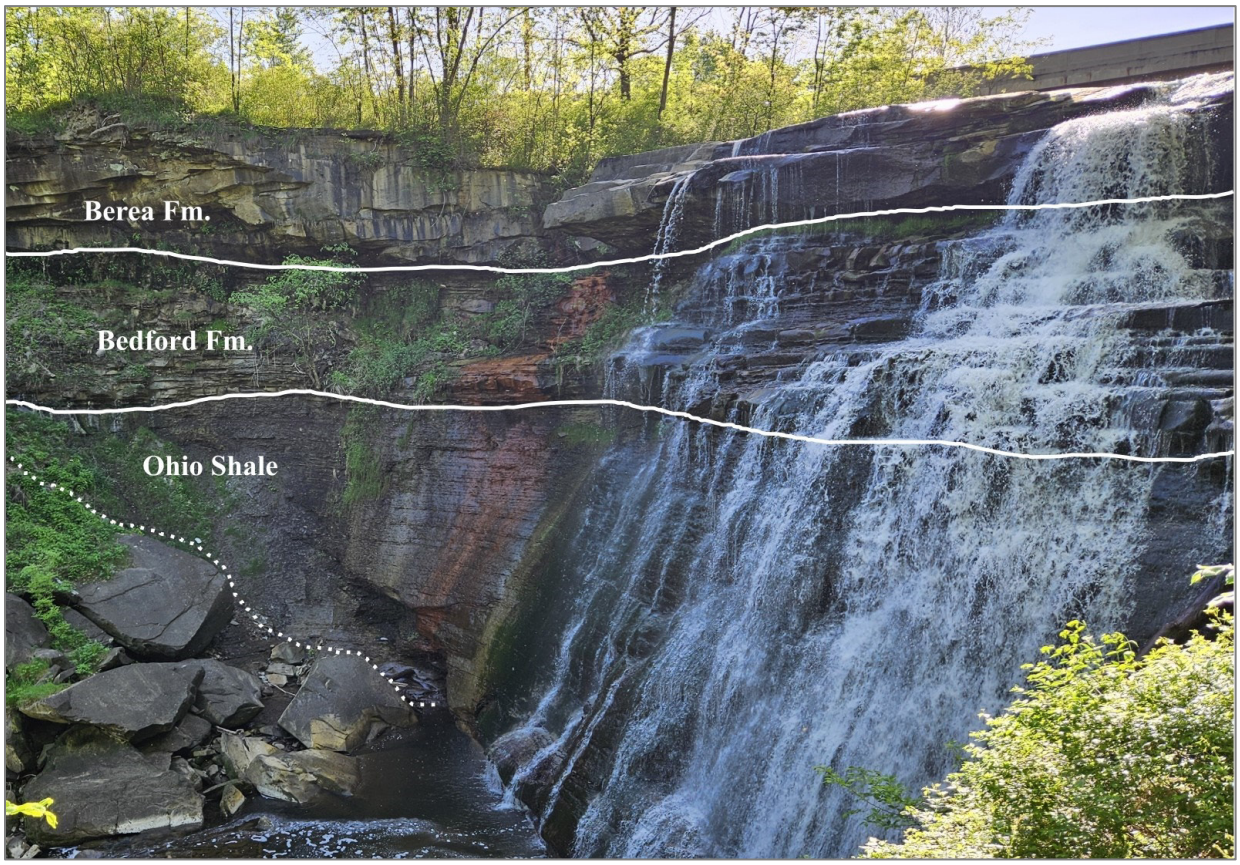


Figure 2. Upper Devonian geologic units visible at CUVA's Brandywine Falls with stratigraphic contacts roughly marked by solid white lines. Fallen sandstone blocks from the Berea Formation are abundant near the base of the falls, as visible in the bottom-left of the image below the dotted white line. NPS / AUSTIN SHAFFER

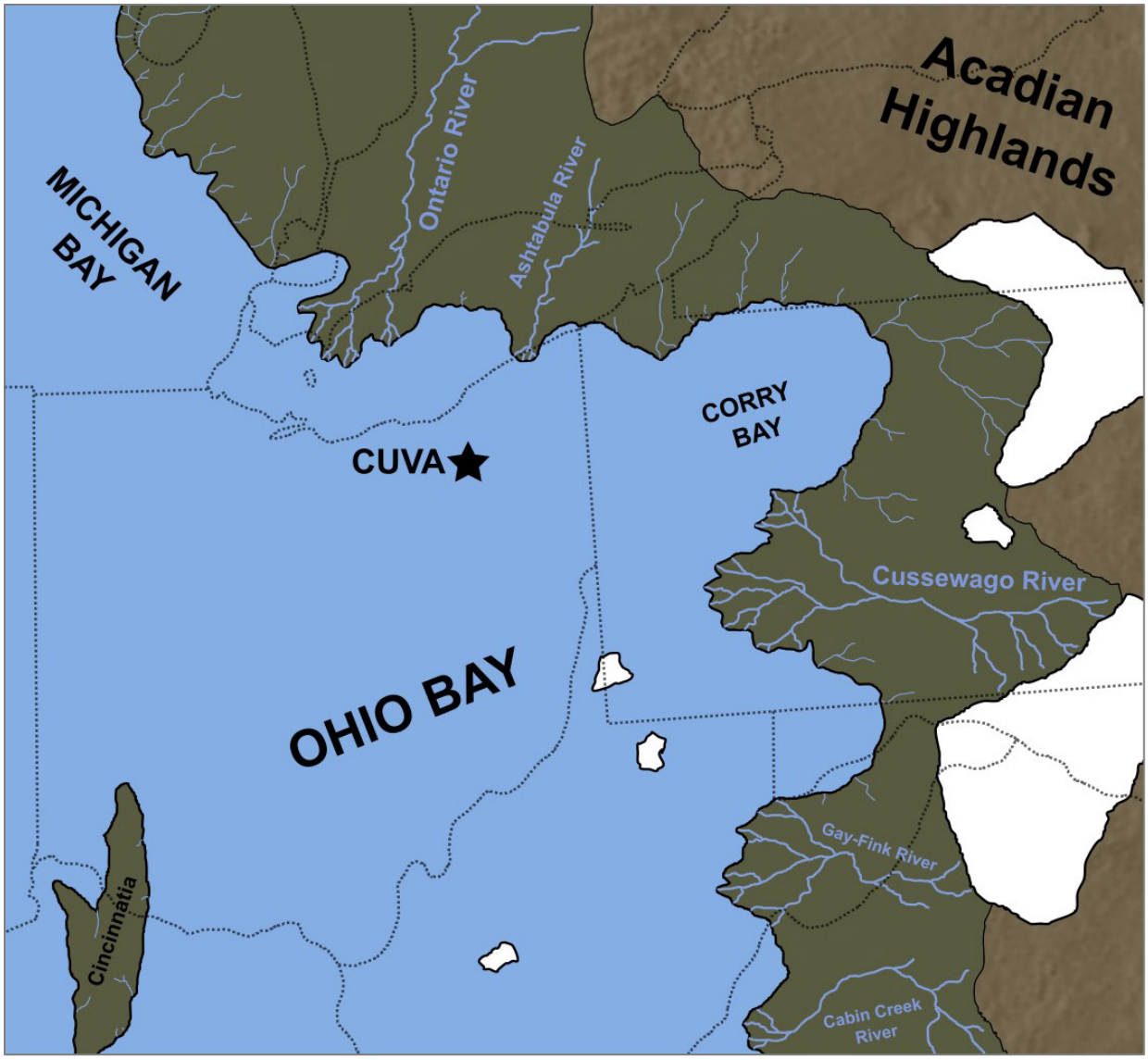


Figure 3. General paleogeographic map of the Appalachian Basin during the Late Devonian (Famennian) at the onset of Bedford Formation deposition. Modern state boundaries are shown with dotted lines. Location of CUVA indicated by star south of the Ontario and Ashtabula deltas in the Ohio Bay. Possible occurrence of glaciers and icebergs in this region during the Late Devonian is indicated by the white areas (included for the purposes of illustration and not necessarily corresponding to actual glacial extent). Map created using information from Pepper et al. (1954) and Brezinski et al. (2010). NPS / AUSTIN SHAFFER

The earliest Carboniferous, specifically the Tournaisian and Viséan stages of the Mississippian (Early and Middle Mississippian, roughly 359 to 331 Ma), has long been characterized by a globally sparse fossil record, especially among tetrapodomorphs (for which this time is known as Romer's Gap). While still little understood, recent discoveries of fossil localities from this time interval, particularly from Scotland, have produced important discoveries, shedding light on the recovery of ecosystems following the end-Devonian extinction event, the terrestrialization of tetrapods and arthropods, and the development of the later Carboniferous forests of the Pennsylvanian (Clack et al.

2016; Otoo et al. 2018). The Cuyahoga Group at CUVA corresponds to this time interval (Tournaisian), with deposition of sediment in coastal deltaic and prodeltaic environments (Bork and Malcuit 1979; Clayton et al. 1998), and therefore holds the potential to provide significant paleontological and paleoecological insights.

Later in the Carboniferous, a period of pronounced erosion created incised river valleys, within which sediment deposition by braided streams would eventually produce the strata of the Early Pennsylvanian (Bashkirian; about 323 to 315 Ma) Sharon Formation (Meckel 1967; Mrakovich and Coogan 1974; Wells et al. 1993; Foos et al. 2003). These sediments and the streams that carried them likely originated to the northeast in the highlands of eastern Canada (Fuller 1955; Meckel 1967). Deposition of the Sharon Formation occurred near the height of icehouse conditions in the LPIA, with the associated climatic changes likely leading to significant environmental and vegetational restructuring (Pfefferkorn et al. 2017).

Following the deposition of the Sharon Formation, a vast span of geologic time (roughly 315 million years) is not preserved at CUVA. This missing time, covering the Late Pennsylvanian, Permian, the entire Mesozoic, and most of the Cenozoic, would have seen the area of the park experience a multitude of changes geographically, environmentally, climatically, and taxonomically. Any sediments that may have been deposited during this timeframe at CUVA have since been eliminated through erosion, such as through fluvial or glacial forces.

The youngest sediments present at CUVA document the recent geologic history of the Quaternary Period. This geologic period, beginning 2.58 Ma and continuing to the present, is characterized by glacial and interglacial periods of the Quaternary glaciation, a component of the larger Late Cenozoic Ice Age. The Illinoian and Wisconsin Glacial Periods, the most recent two glacial periods within the Quaternary glaciation, saw much of North America (including CUVA) covered by expansive ice sheets over the last few hundred thousand years, advancing and retreating multiple times before finally retreating from northeast Ohio around 14.5 ka (thousand years ago) (Larson and Kincare 2009; Szabo et al. 2011). Following the retreat of the Laurentide Ice Sheet, the level of early Lake Erie was substantially lower than present (about 40 m/130 ft lower), leading to substantial downcutting by the early Cuyahoga River and other drainage systems flowing into the lake (Szabo et al. 2011). Eventually isostatic rebound of the region raised the topography of the Great Lakes, leading to Lake Erie filling to modern levels and the Cuyahoga Valley floodplain closely approaching its modern elevation by around 7 ka (Szabo et al. 2011). Within this glacial context across the Quaternary, a variety of different sediments were deposited at CUVA by means of fluvial, glacial, lacustrine, and other processes, representing the youngest strata present at the park.

In summary, the geologic formations present at CUVA include (in ascending order of age, oldest to youngest) the Ohio Shale Formation (Late Devonian), the Bedford Formation (Late Devonian), the Berea Formation (Late Devonian), the Cuyahoga Group (Early Mississippian), the Sharon Formation (Early Pennsylvanian), and Quaternary sediments (Pleistocene–Holocene) (Figure 4). The ages, fossil content, and depositional environments of these units at CUVA are summarized in Table 1.

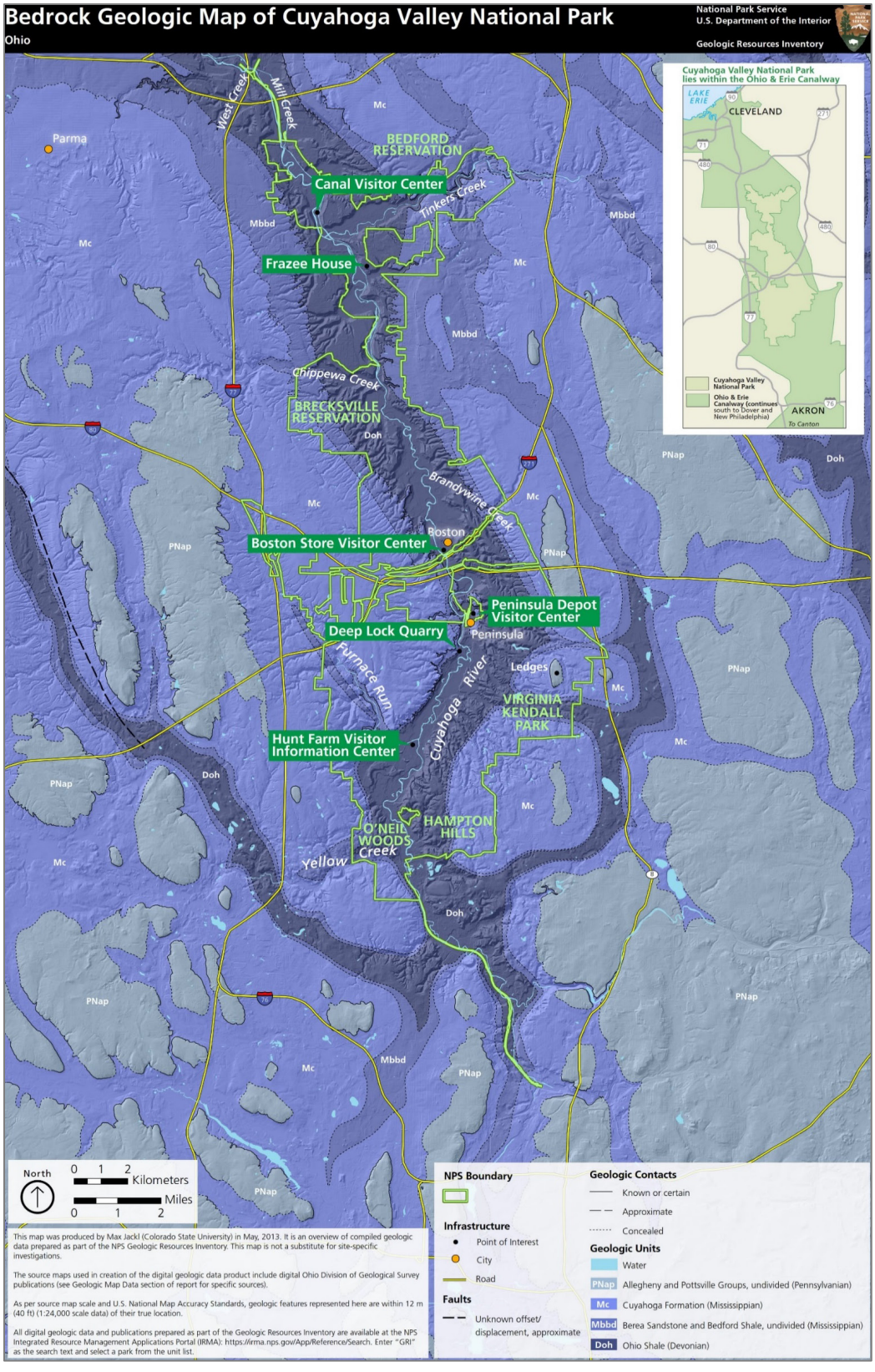


Figure 4. Bedrock geologic map of CUVA. Digital map data is available at https://irma.nps.gov/DataStore/Reference/Profile/2171326. NPS

Table 1. Summary of CUVA stratigraphy, fossils, and depositional settings in descending order of age, from youngest to oldest. See text for details and references.

Formation	Age	Fossils Within CUVA	Depositional Environment
Quaternary sediments	Pleistocene–Holocene	None to date	Alluvial, colluvial, fluvial, glacial, lacustrine, and paludal deposits
Sharon Formation	Early Pennsylvanian	None to date	Braided streams within incised valleys
Cuyahoga Group	Early Mississippian	Plants including lepidodendraleans and possible noeggerathialeans, rugose corals, bryozoans, brachiopods, orthocerid cephalopods, gastropods, crinoids, conodonts, and a possible tetrapodomorph	Deltaic and shallow-marine prodeltaic environments
Berea Formation	Late Devonian	Plant fragments and a possible brachiopod	Deltaic system
Bedford Formation	Late Devonian	Dinoflagellates, chlorophytes, plant palynomorphs, progymnosperm wood, rugose corals, conulariids, bryozoans, brachiopods, hederelloids, tentaculitids, bivalves, cephalopods, gastropods, a probable eurypterid, crinoids, conodonts, a ctenacanthiform shark, probable osteichthyan fish, and invertebrate trace fossils	Prodeltaic shallow-marine environments
Ohio Shale Formation	Late Devonian	Dinoflagellates, chlorophytes, plant palynomorphs including spores of lycopods and ferns, rugose corals, bryozoans, brachiopods, tentaculitids, bivalves, cephalopods, gastropods, conodonts, fish teeth and fragments, and invertebrate trace fossils	Nearshore shallow-marine

Geologic Formations

Ohio Shale Formation (Upper Devonian)

Description: The Ohio Shale Formation consists predominantly of gray and black shales (Figure 5) and is divided into three members in northeast Ohio, in ascending order the Huron, Chagrin, and Cleveland Members (Baird et al. 2023). The Huron and Cleveland Members are dominated by black shales whereas the Chagrin Member is primarily gray shale. Deposition of these shales likely occurred within nearshore shallow-marine environments, black shale deposition occurring in localized anoxic zones offshore of active deltas and gray shale deposition occurring between these active deltas or offshore of abandoned channel complexes (Dunkel et al. 2022). The presence of certain sedimentary structures such as wave-modified turbidites, tempestites, and hyperpycnites supports the attribution of these black shales as having been deposited under shallow prodeltaic conditions (Alshahrani and Evans 2014; Dunkel et al. 2022). The Ohio Shale Formation is reliably dated to the Late Devonian, with the Hangenberg extinction event likely beginning near the end of the formation's deposition (Blood et al. 2019).



Figure 5. Ohio Shale Formation exposed along Sagamore Creek at CUVA. NPS / AUSTIN SHAFFER

Fossils found within CUVA: The fossils found in the Ohio Shale Formation at CUVA are similar to those found elsewhere in the unit across northeast Ohio, including invertebrates, chordates, plants, and microfossils. Invertebrate fossils found in the Ohio Shale Formation of the park include indeterminate trace fossils, rugose corals, bryozoans, brachiopods, tentaculitids, bivalves, orthocerid cephalopods, and gastropods (Prosser 1912; Hannibal and Feldmann 1987; Schwimmer and Feldmann 1990). Chordate fossils from this unit at CUVA include conodonts, various chondrichthyans ("*Orodus*"*, Polyrhizodus,* Ctenacanthidae indet., and "*Cladodus*"), and indeterminate ray-finned fish pertaining to Palaeonisciformes (Newberry 1873, 1875; Hass 1947). Possible plant fragments were observed during 2024 fieldwork, and microfossils of dinoflagellates, chlorophytes, lycopods, and ferns have also been reported (Winslow 1962).

Fossils found elsewhere: The Ohio Shale Formation and its subunits have produced a diverse assortment of plant, invertebrate, and vertebrate fossil taxa across its extent. The fossil flora of the Ohio Shale Formation includes wood of the progymnosperm *Callixylon* (Chitaley and Cai 2001), the arborescent lycopsid *Clevelandodendron* (Chitaley and Pigg 1996), and the enigmatic giant fungus *Prototaxites* (Chitaley 1992). Invertebrate fossils of various groups occur in this unit, such as

brachiopods and bivalves (Prosser 1912; Schwimmer and Feldmann 1990), cephalopods (Prosser 1912; House et al. 1986), arthropods (Hannibal and Feldmann 1983; Weidner and Feldmann 1985; Feldmann and Schweitzer 2019), and the enigmatic shelled invertebrates *Coleolus* (Yochelson and Hlavin 1985) and *Sphenothallus* (Neal and Hannibal 2000). The Ohio Shale Formation is particularly well-known for its fossil fish fauna, one of the most diverse Late Devonian assemblages worldwide, which includes conodonts, arthrodire placoderms, chondrichthyans, and osteichthyans (Newberry 1873, 1875, 1889; Hass 1947; Carr and Hlavin 2010; Carr and Jackson 2010; Boyle and Ryan 2017; Carr 2017).

Bedford Formation (Upper Devonian)

Description: The Bedford Formation, often referred to as the Bedford Shale, consists of shale (Figure 6), very fine-grained sandstone, and siltstone deposited under shallow-marine prodeltaic conditions (Lewis 1988; Dunkel et al. 2022). This unit is lithologically variable and thins to the east and west of Cleveland, Ohio (Lewis 1988). The type locality for this unit occurs within CUVA along Tinkers Creek (Henderson et al. 2022); however, it has been proposed that, due to the incomplete thickness present in the area of Tinkers Creek, the exposure of the Bedford Formation along Chippewa Creek (also within CUVA), which contains a complete stratigraphic interval with contacts, should be designated as a stratotype for the unit (Henderson et al. 2022). The strata of the Bedford Formation may record major climatic and environmental shifts (e.g., glaciation and sea level drop) coinciding with the initial phase of the Hangenberg extinction event (Blood et al. 2019).



Figure 6. The shale-dominated Bedford Formation exposed at the unit's type locality along Tinkers Creek at CUVA. NPS / AUSTIN SHAFFER

Fossils found within CUVA: The marine deposits of the Bedford Formation at CUVA contain an abundance of different taxa from the Late Devonian. Within the park, microfossils of dinoflagellates and chlorophytes, various plant palynomorphs, and progymnosperm (*Callixylon*) wood have been reported (Winslow 1962). Numerous fossils of invertebrates have also been reported (Prosser 1912; House et al. 1986) and/or observed during the 2024 inventory, including invertebrate traces, rugose corals, conulariids, bryozoans, brachiopods, hederelloids, tentaculitids, bivalves, cephalopods, gastropods, a probable eurypterid, and crinoids. Chordate fossils have also been found in the Bedford Formation of the park, namely conodonts (Hass 1947), a new ctenacanthiform shark (CMNH 6323), and probable osteichthyan fish remains discovered in 2022.

Fossils found elsewhere: Across the Bedford Formation of northern Ohio, a diverse assemblage of brachiopods, bivalves, cephalopods, and gastropods has been reported (House et al. 1986; Pashin and Ettensohn 1992). The taxonomic composition of this Bedford fauna corresponds well with that observed in the formation at CUVA.

Berea Formation (Upper Devonian)

Description: The Berea Formation, often referred to as Berea Sandstone or Berea Grit, consists predominantly of fine- to medium-grained calcareous sandstone (Figure 7) deposited under deltaic conditions with localized interbeds of shale (Lewis 1988; Dunkel et al. 2022). The sandstone of the

Berea Formation has been extensively studied and quarried for use as building stone (Hannibal 2020). Deposition of this unit likely occurred near the end of the Devonian during the glaciation of the Hangenberg extinction event (Blood et al. 2019).



Figure 7. Sandstone of the Berea Formation exposed along the boardwalk near Brandywine Falls at CUVA. NPS / AUSTIN SHAFFER

Fossils found within CUVA: The Berea Formation rarely contains fossil material at CUVA. At the park, fossils are limited to occasional plant fragments (potentially fossil wood) and one possible brachiopod. The brachiopod specimen, having been found in float away from any outcrop, may alternatively have originated from sandstone of the Bedford Formation or the Cuyahoga Group.

Fossils found elsewhere: Near Amherst, Ohio, fossil wood of the form genus *Callixylon* has been described from the Berea Formation (Beck et al. 1982). Fossils of invertebrate traces, the plant form genus *Annularia*, brachiopods, ctenacanth shark spines, and the actinopterygian fish *Gonatodus brainerdi* have also been reported from this unit in northeast Ohio (Corbett and Manner 1988; Hannibal 2020).

Cuyahoga Group: Orangeville Formation (Lower Mississippian)

Description: At CUVA and across northeast Ohio, the Cuyahoga Group consists of interbedded siltstone, sandstone, and gray and black shale (Figure 8) of the Orangeville Formation; the basal Sunbury Member of this formation is shale-dominated and represents the oldest Carboniferous deposits in the area (Baird et al. 2023). Traditionally, the Cuyahoga Group has also been characterized as a formation (with the Orangeville Formation instead representing a member);

however, the most up-to-date stratigraphic nomenclature of these units (Baird et al. 2023) is followed herein. The overlying Meadville Formation of the Cuyahoga Group, which occurs in northwest Pennsylvania, is not present in northeast Ohio (Baird et al. 2023). The deposits of the Logan Formation, which overlie the Cuyahoga Group in Wayne County, Ohio and southward, were eroded in northernmost Ohio prior to the deposition of the Pottsville Group in the area (Szmuc 1957). Miospore assemblages identified from the Cuyahoga Group support an Early Mississippian (Tournaisian) age of deposition for the unit (Clayton et al. 1998). The Cuyahoga Group and the overlying Logan Formation have been interpreted as representing deltaic and shallow-marine prodeltaic environments (Bork and Malcuit 1979).



Figure 8. Exposure of the Cuyahoga Group showing interbedded shale, siltstone, and sandstone along Spring Creek at CUVA. NPS / AUSTIN SHAFFER

Fossils found within CUVA: The Cuyahoga Group has yielded fossils of plants, invertebrates, and chordates from marine and terrestrial environments at CUVA. Assorted plant fragments, including lepidodendralean and possible noeggerathialean material, were discovered alongside potential tetrapodomorph remains in deltaic deposits of this unit during 2024 fieldwork. As also observed in 2024, marine facies of the Cuyahoga Group at CUVA preserve fossils of rugose corals, bryozoans, brachiopods, orthocerid cephalopods, gastropods, and crinoids. Conodonts have also been reported from this unit within the park (Hass 1947).

Fossils found elsewhere: The fauna of the Cuyahoga Group consists of a diverse assortment of invertebrate taxa, including ichnofossils, sponges, corals, conulariids, bryozoans, brachiopods, bivalves, cephalopods, gastropods, rostroconchs, scaphopods, and trilobites (Szmuc 1957; Bork and Malcuit 1979; Wilson 1979; Hoare 1990; Willis 1996; Ausich and Roeser 2012; Kammer and Roeser 2012; Ausich and Wilson 2023). Miospores are also known from this unit in northeast Ohio (Clayton et al. 1998). Chondrichthyan fossil material has been recovered from shale of the Sunbury Member in northeast Ohio (Williams 1979; R. Carr, pers. comm., August 2024).

Pottsville Group: Sharon Formation (Lower Pennsylvanian)

Description: The basalmost unit of the Pottsville Group in northeast Ohio, the Sharon Formation (often referred to as the Sharon Conglomerate) is predominantly composed of sandstone and conglomerate. The unit unconformably overlies the Cuyahoga Group at CUVA, only being present at Ritchie Ledges (Figure 9) in the Virginia Kendall portion of the park. The Sharon Formation is largely unfossiliferous, with only rare occurrences of Pennsylvanian (Bashkirian) plant fossils and reworked Devonian marine invertebrates (Mrakovich and Coogan 1974; Hannibal and Feldmann 1987; Foos et al. 2003). Deposition of the Sharon Formation has been inferred to have occurred via braided streams within incised valleys, producing the abundant cross-bedding found in this unit (Mrakovich and Coogan 1974; Wells et al. 1993; Foos et al. 2003).



Figure 9. Sandstone and conglomerate outcrop of the Sharon Formation as seen at Ritchie Ledges at CUVA. NPS / AUSTIN SHAFFER

Fossils found within CUVA: None to date.

Fossils found elsewhere: Plant fossils, while rare, represent the primary fossils observed in the Sharon Formation. A handful of Pennsylvanian plant form genera have been identified from this formation near Cuyahoga Falls, Ohio (roughly 8 km or 5 mi southeast of CUVA); these taxa include *Lepidodendron, Sigillaria, Calamites,* and *Trigonocarpus* (Newberry 1874; Foos et al. 2003). Fragmentary reworked Devonian marine fossils have also been identified from conglomerate of the Sharon Formation, including rugose corals, brachiopods, trilobites, and *Tentaculites* (Fuller 1955).

Quaternary sediments (Pleistocene–Holocene)

Description: A heterogeneous assortment of Quaternary sediments (Figure 10) covers much of CUVA, including alluvial, colluvial, fluvial, glacial, lacustrine, and paludal deposits (Thornberry-Ehrlich 2020).



Figure 10. Quaternary sediment along Adam Run at Hampton Hills Metro Park. NPS / AUSTIN SHAFFER

Fossils found within CUVA: None to date.

Fossils found elsewhere: Pleistocene vertebrate fossils are found across much of Ohio, with sites preserving an assortment of different large mammals depending on their location within the state (Terry 2013). This includes various extinct and extirpated taxa across northeast Ohio, such as helmeted muskox (*Bootherium bombifrons*), Ohio giant beaver (*Castoroides ohioensis*), stag-moose (*Cervalces scotti*), elk (*Cervus canadensis),* American mastodon (*Mammut americanum*), woolly

mammoth (*Mammuthus primigenius*), flat-headed peccary (*Platygonus compressus*), and muskox (*Ovibos moschatus*) (McDonald 1994; Redmond et al. 2021). While some of these fossil records are from Summit and Cuyahoga Counties nearby CUVA, no such paleontological resources have yet been identified from within the boundaries of the park.

Taxonomy

A diverse array of fossil taxa has been documented from CUVA, including various plants, invertebrates, and vertebrates. See Appendix A for full lists of taxa. Locality data for fossil sites can be found in Appendix E. A glossary containing definitions for much of the terminology can be found near the beginning of this report.

Plants

Class Lycopodiopsida (scale trees, clubmosses, spikemosses, and quillworts)

Taxa of the class Lycopodiopsida often dominate fossil floras of similar age to those at CUVA and have been found in multiple geologic units of the park. Fossil spores from lycopod taxa have been reported from the Ohio Shale and Bedford Formations of CUVA (Winslow 1962). These include multiple taxa of spikemoss (Selaginellales).

Macrofloral lycopod remains have also been observed at CUVA. Stem material of a scale tree (cf. *Lepidodendropsis*) was discovered in the Cuyahoga Group of the park during the 2024 inventory (Figure 11). The presence of this taxon in Lower Mississippian rocks of CUVA, while significant, is unsurprising given the prevalence of *Lepidodendropsis* at macrofloral fossil sites of this age across eastern North America and Europe—the Euramerican floral realm (Chandra and Keqin 1996; Falcon-Lang 2004; Gensel and Pigg 2009).



Figure 11. A scale tree (cf. *Lepidodendropsis*) stem segment found in the Cuyahoga Group of CUVA. NPS / AUSTIN SHAFFER

Class Polypodiopsida (ferns and horsetails)

Fossil fern spores, including those of taxa from the orders Equisetales (horsetails) and Sphenophyllales, have been described from the Late Devonian-age uppermost Ohio Shale Formation and Bedford Formation at CUVA (Winslow 1962). No other diagnostic fossils of this clade have yet been identified from the park.

Class Progymnospermopsida

Progymnosperm fossils at CUVA are currently limited to wood of the form genus *Callixylon* reported from the Bedford Formation and a possible noeggerathialean leaf specimen observed in the Cuyahoga Group (Figure 12). Plants of the order Noeggerathiales have been historically enigmatic; however, recent well-preserved fossils support the placement of this clade as derived progymnosperms (Wang et al. 2021). Given the rarity of noeggerathialean fossils in the Carboniferous Euramerican floral realm (Pfefferkorn and Wang 2016), the specimen observed in the Mississippian sandstone of CUVA would hold significance, if the identification is accurate.



Figure 12. Possible progymnosperm (cf. Noeggerathiales) fossil material from the Cuyahoga Group at CUVA. Scale not available. NPS / AUSTIN SHAFFER

Other Plants

Additional assorted fossil plant spores not confidently assignable to any of the aforementioned groups have been reported from the Ohio Shale and Bedford Formations at CUVA (Winslow 1962). Isolated indeterminate plant fragments were observed within the Ohio Shale and Berea Formations.

Most notably, sandstone of the Cuyahoga Group at CUVA (also containing the previously discussed lepidodendralean and noeggerathialean specimens) was found to preserve a layer of abundant plant fragments (Figure 13), many of which may be identifiable to specific taxa upon further analysis.



Figure 13. Fragmentary plant material in sandstone of the Cuyahoga Group at CUVA (this layer is also shown in Figure 12). Scale not available. NPS / AUSTIN SHAFFER

Invertebrates

Phylum Cnidaria (corals, sea anemones, jellyfish, etc.)

The marine strata of CUVA preserve assorted cnidarian fossils, namely conulariids and corals. Conulariids, an extinct sessile group related to modern jellyfish and hydrozoans, have been reported from the Bedford Formation of the park (Prosser 1912). Their fossils are elongate four-sided pyramidal structures made up of small mineralized rods. Corals, particularly those of the order Rugosa, are relatively common fossils at CUVA, occurring in the Upper Devonian Ohio Shale and Bedford Formations as well as the Lower Mississippian Cuyahoga Group. Examples of these corals at CUVA include both solitary ("horn coral") and colonial forms (Figure 14). The strata in which fossil corals are found at the park were deposited in the context of the end-Devonian Hangenberg extinction event and the onset of the Late Paleozoic Ice Age (LPIA). This geologic interval represents a significant time in the evolution of reef-building corals, a time of ecosystem collapse and recovery (Yao et al. 2020). The occurrence of fossil corals at CUVA is therefore useful to understand the evolutionary and ecological dynamics of this clade. Of particular interest is the observation of biostromes of colonial rugose corals in the Cuyahoga Group of the park (Figure 15). Such fossils are rare from the Early Mississippian, with similar biostromes not found elsewhere until the late Viséan (Yao et al. 2024). Further research on the colonial corals of the Tournaisian Cuyahoga Group at

CUVA may therefore yield important information on the recovery of reef ecosystems during the early LPIA.

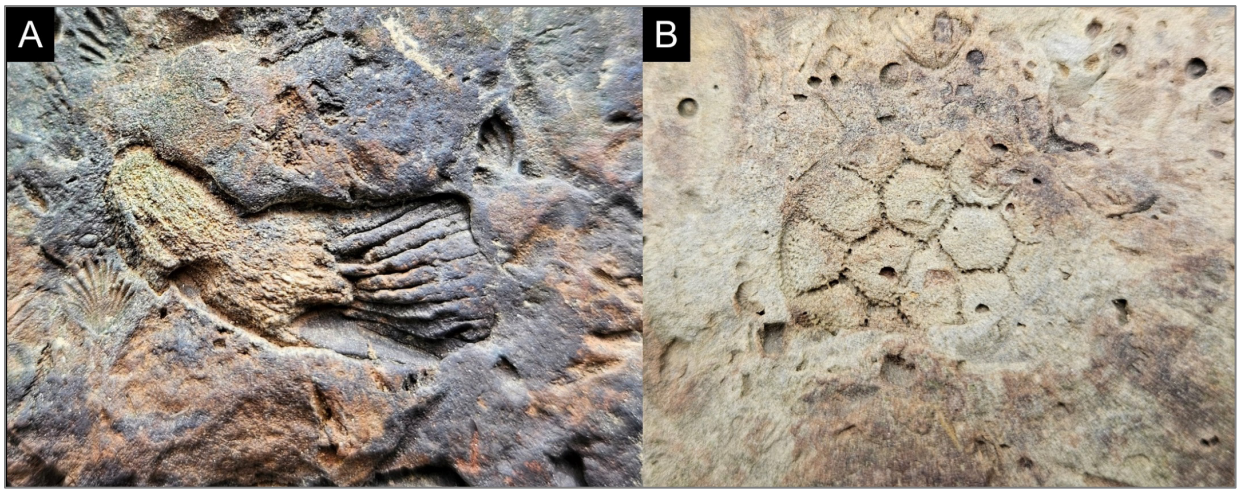


Figure 14. Solitary (**A**) and colonial (**B**) rugose corals from sandstone of the Bedford Formation at CUVA. Scale not available. NPS / AUSTIN SHAFFER

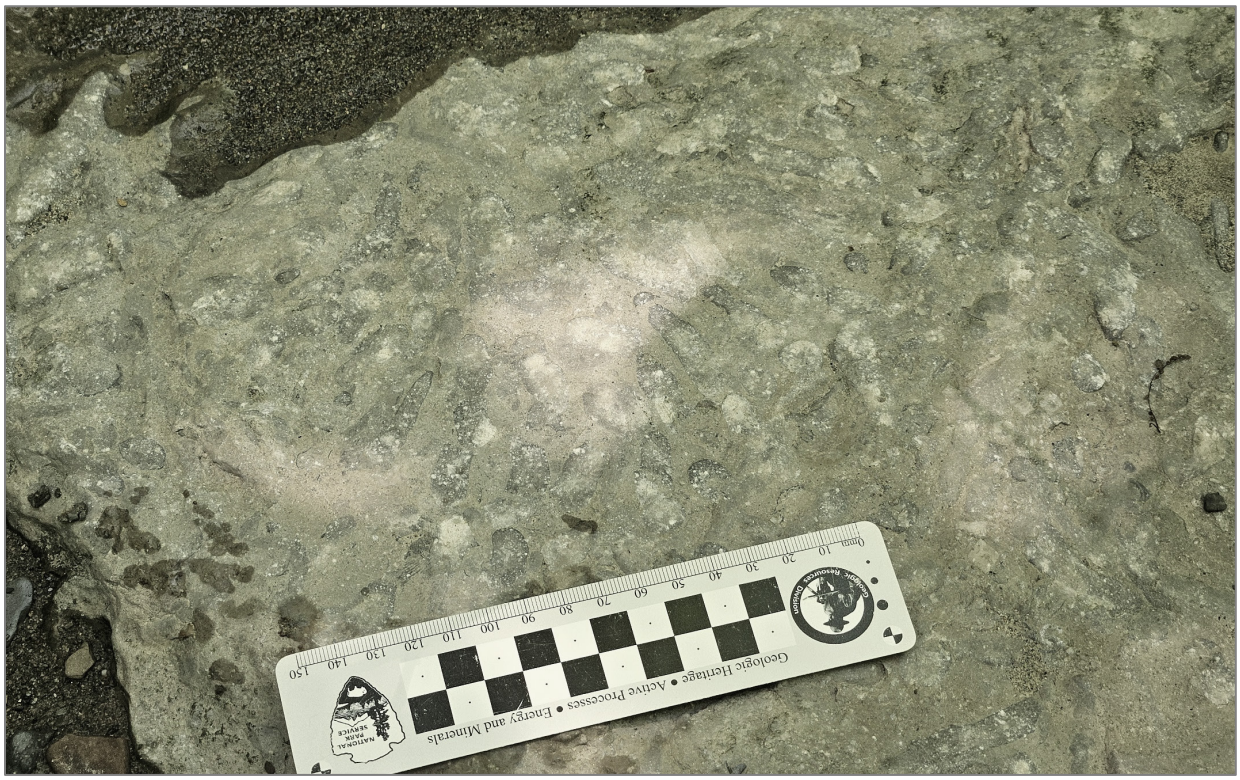


Figure 15. Biostrome of colonial rugose corals in the Cuyahoga Group at CUVA. NPS / AUSTIN SHAFFER

Phylum Bryozoa (moss animals)

Bryozoans, colonial aquatic invertebrates, are some of the most abundant and diverse Paleozoic marine fossils. Remains of these organisms have been observed in each of the marine units of CUVA: the Ohio Shale Formation, the Bedford Formation, and the Cuyahoga Group (Figure 16). While retained as Bryozoa indet. until an in-depth assessment of fossil bryozoan diversity in the park can occur, fossils of this clade occur in a number of different forms and can regularly be found in rich assemblages at CUVA.

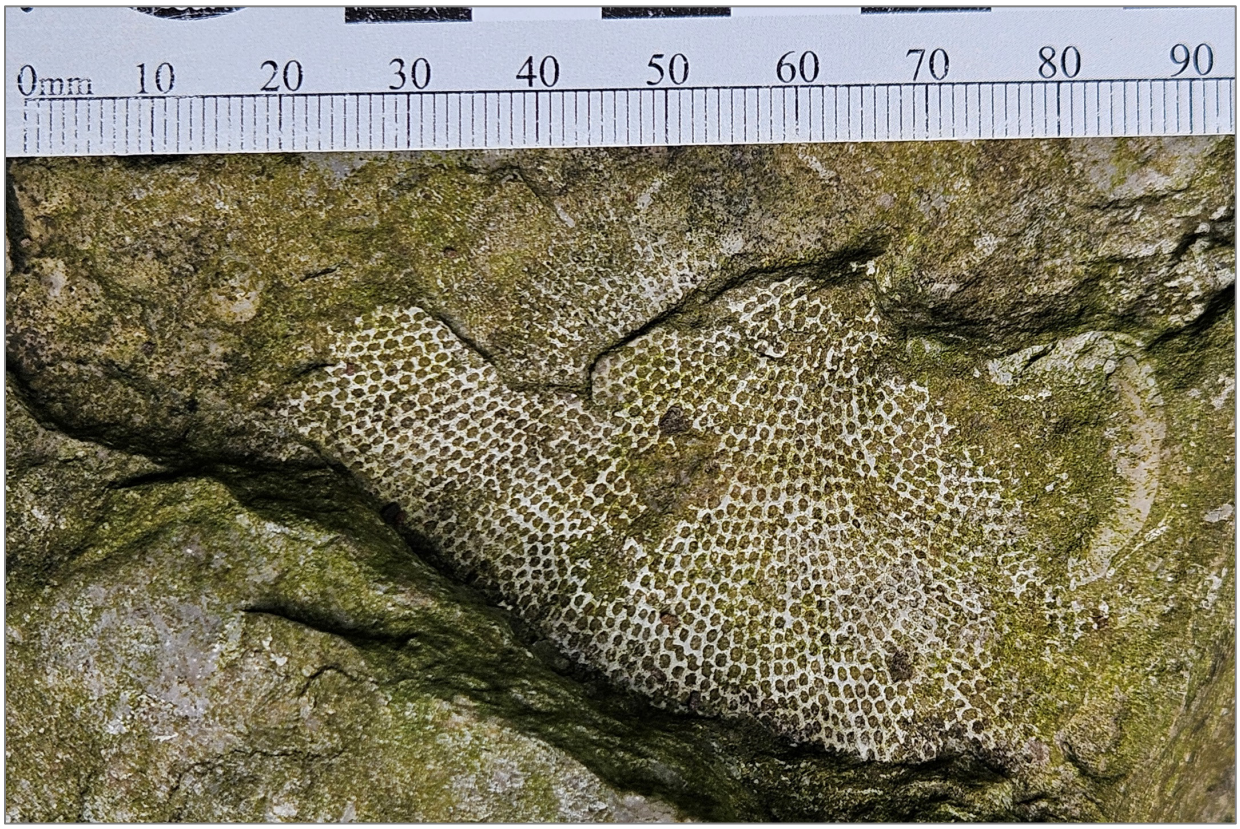


Figure 16. Fenestrate bryozoan fossil from the Cuyahoga Group at CUVA. NPS / AUSTIN SHAFFER

Phylum Brachiopoda (lamp shells)

Brachiopod fossils represent the most abundant and diverse paleontological resources at CUVA, being found in the Ohio Shale Formation (Figures 17 and 18), the Bedford Formation, possibly the Berea Formation, and the Cuyahoga Group. While most of the brachiopods observed during the 2024 field inventory are retained as Brachiopoda indet. until thorough assessment can take place, prior research conducted within the park has identified more than 24 Late Devonian brachiopod taxa (Prosser 1912; Schwimmer and Feldmann 1990). A full list of these taxa, their corresponding stratigraphic positions, and relevant references can be found in Appendix A. It is likely that further work on the brachiopod fauna of CUVA will identify a number of additional taxa.



Figure 17. Brachiopods observed in the Ohio Shale Formation at CUVA. NPS / AUSTIN SHAFFER



Figure 18. A brachiopod (*Cyrtospirifer*) in the Ohio Shale Formation at CUVA. NPS / AUSTIN SHAFFER

Phylum Mollusca: Class Bivalvia (clams, oysters, mussels, etc.)

Bivalves are another common fossil component of the Paleozoic units at CUVA, with more than 14 taxa previously identified from the Ohio Shale and the Bedford Formations (Figure 19) (Prosser 1912; Schwimmer and Feldmann 1990). A full list of these taxa, their corresponding stratigraphic positions, and relevant references can be found in Appendix A. Despite resembling brachiopods, the two clades are not closely related, with brachiopods related to bryozoans and bivalves belonging to the mollusks. An in-depth assessment of fossil bivalve diversity at CUVA is likely to identify additional taxa.



Figure 19. Partially pyritized bivalve (cf. *Palaeoneilo*) observed in the Bedford Formation at CUVA. NPS / AUSTIN SHAFFER

Phylum Mollusca: Class Cephalopoda (squids, nautiloids, etc.)

Fossil cephalopods, specifically orthocerid nautiloids, occur in both Devonian and Mississippian units of CUVA. Prosser (1912) reported the occurrence of *Orthoceras* from the Ohio Shale

Formations within the park (*Orthoceras* is a "wastebasket taxon" known in strict terms from significantly older rocks, so this record should be understood as a similarly straight, gently tapered shell ["orthoconic"]), and 2024 fieldwork identified the occurrence of Orthocerida in the Cuyahoga Group of CUVA (Figure 20). Ammonoids have also been reported from the Bedford Formation of the park (House et al. 1986).

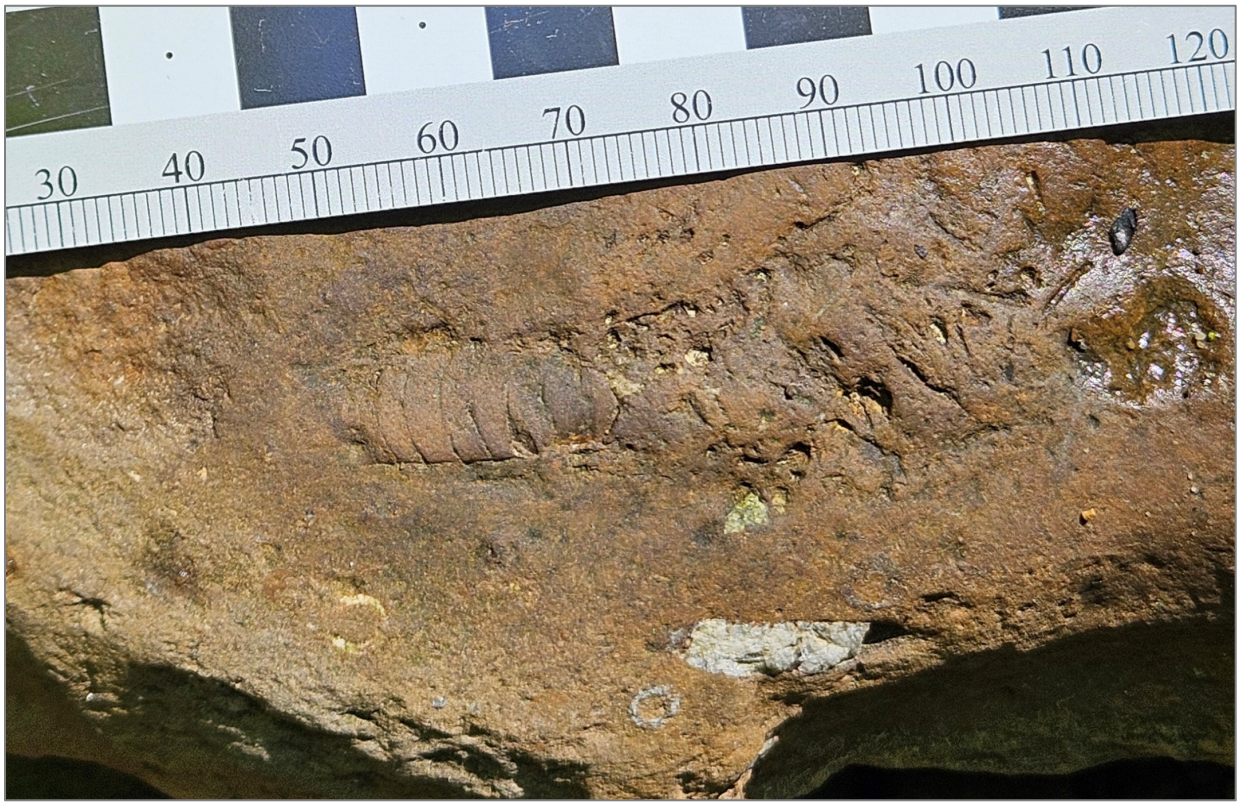


Figure 20. An orthocerid cephalopod in sandstone of the Cuyahoga Group at CUVA. NPS / AUSTIN SHAFFER

Phylum Mollusca: Class Gastropoda (snails and slugs)

Marine gastropod fossils have been identified from the Ohio Shale Formation, Bedford Formation, and Cuyahoga Group at CUVA. Occurrences of *Bellerophon* in the Ohio Shale Formation and *Euomphalus* in the Ohio Shale and Bedford Formations were reported by Prosser (1912). *Bellerophon* shells coil in a flat plane and flare at the aperture, appearing to swallow previous whorls, whereas *Euomphalus* shells usually have a nearly flat coil but do not significantly flare. During the 2024 field inventory, *Euomphalus* was observed in both units reported by Prosser (Figure 21) as well as in the Cuyahoga Group of the park. Potential revision of Devonian/Carboniferous gastropod taxonomy is beyond the scope of this work and therefore a traditional identification of *Euomphalus* is retained herein.



Figure 21. A marine gastropod (*Euomphalus*) in the Ohio Shale Formation at CUVA. NPS / AUSTIN SHAFFER

Phylum Arthropoda (trilobites, chelicerates, myriapods, crustaceans, etc.)

One notable fossil arthropod occurrence has been documented from CUVA: a possible eurypterid from the Famennian Bedford Formation (Figure 22). This specimen was collected during the 2022 fossil reconnaissance survey of the park. Eurypterid fossils from the Late Devonian are rare, with only a handful of examples known from nearby Pennsylvania (Plotnick 2022). The CUVA specimen is not particularly well-preserved, but it may provide a view of the underside of the organism (possible interpretation included in Figure 22B). The small size of the fossil and its occurrence in Upper Devonian deltaic/prodeltaic strata suggest that the specimen might represent a juvenile, akin to recently described fossils from the Famennian of Belgium (Lamsdell et al. 2019). We refrain from making any conclusive remarks on the taxonomy or growth stage of this specimen until a more in-depth assessment can occur. The rarity of eurypterids from the Late Devonian, particularly juveniles, indicates that the articulated CUVA specimen potentially holds significance for understanding the ecology and evolution of eurypterids during the Devonian–Carboniferous transition.

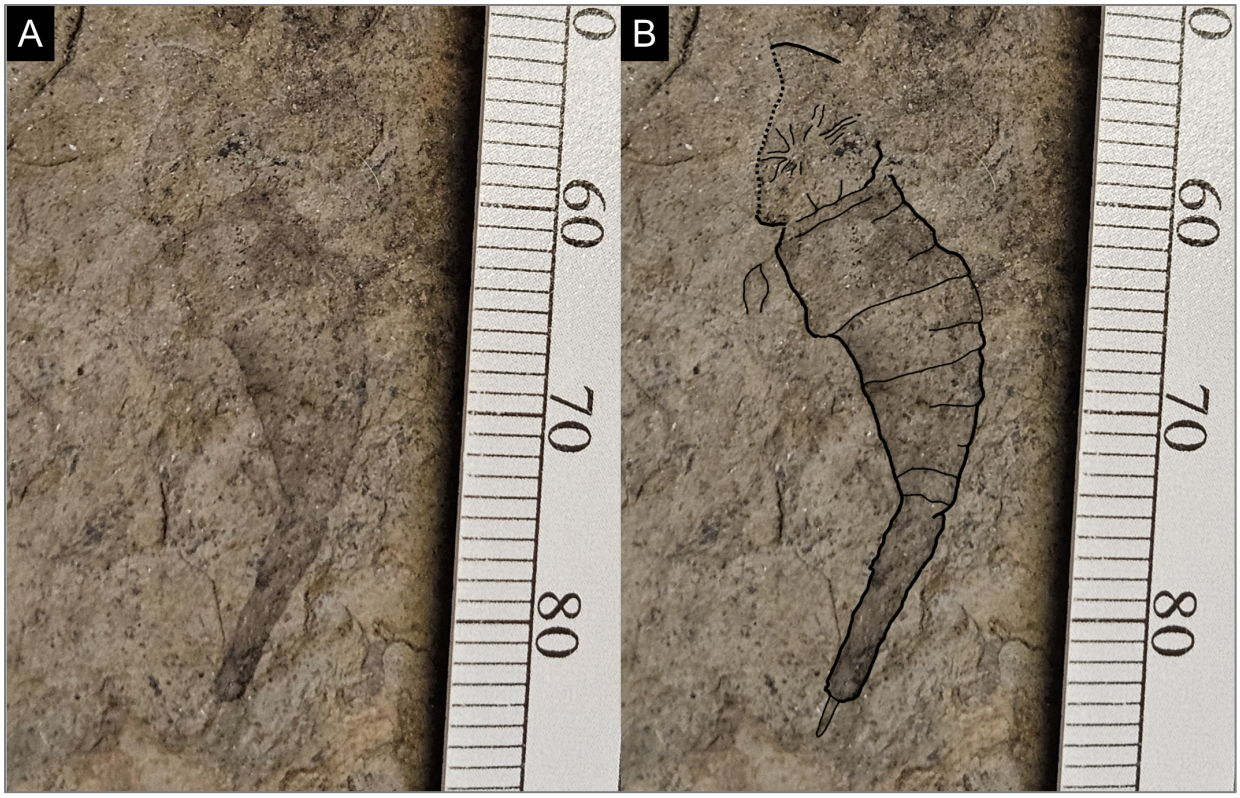


Figure 22. Photograph (**A**) and rough interpretation (**B**) of a possible eurypterid collected from the Bedford Formation at CUVA. NPS / AUSTIN SHAFFER

Phylum Echinodermata: Class Crinoidea (sea lilies and feather stars)

Crinoids are a diverse group of echinoderms whose stalked forms (known as "sea lilies") represent a common component of Paleozoic marine assemblages. Therefore, it is unsurprising that disarticulated fragments of crinoids, herein retained as Crinoidea indet., were observed in the Bedford Formation and Cuyahoga Group at CUVA during the 2024 field inventory (Figure 23). These fragments are typically whole or partial rings representing segments of stems ("columnals"), and generally cannot be attributed to particular genera or species. Future research may illuminate the taxonomic diversity of crinoids present within the strata of the park, particularly if preserved plates from the body ("calyx") and/or crowns (calyx plus arms) are discovered.



Figure 23. Fossiliferous sandstone of the Bedford Formation at CUVA containing abundant crinoid stem fragments alongside bits of bryozoans and brachiopods. NPS / AUSTIN SHAFFER

Invertebrate Ichnotaxa

Invertebrate ichnofossils (Figures 24 and 25) are regularly observed in the Upper Devonian shale-dominated units of CUVA (Ohio Shale and Bedford Formations), and possibly also occur within the Berea Formation and Cuyahoga Group. These various trace fossils are not referred to specific ichnotaxa herein, instead maintaining a more general identification until thorough assessment of Paleozoic ichnotaxonomic diversity at the park can occur.



Figure 24. Invertebrate traces in the Ohio Shale Formation of CUVA. NPS / AUSTIN SHAFFER

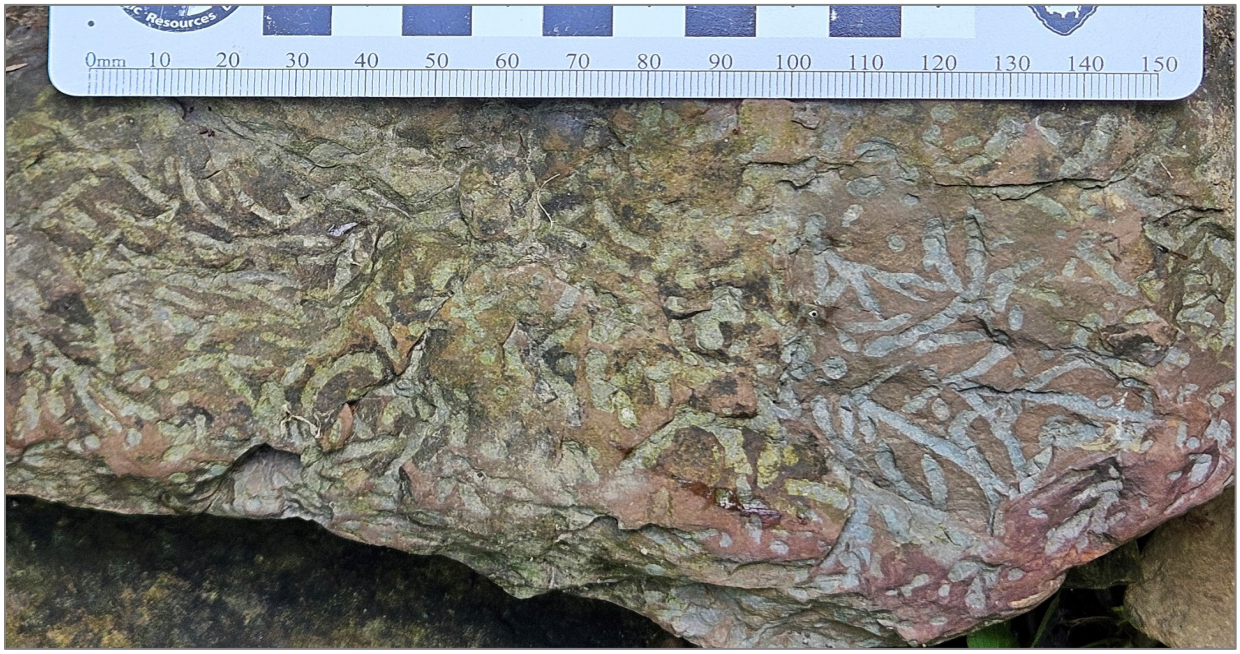


Figure 25. Invertebrate traces in the Ohio Shale Formation of CUVA. NPS / AUSTIN SHAFFER

Other Invertebrates

Various additional invertebrate fossils, not attributable to the aforementioned clades, have also been observed at CUVA.

Epibiont tubes were seen on a brachiopod specimen in the Bedford Formation (Figure 26) that are referrable to the clade Hederelloidea, extinct colonial marine animals that are typically found encrusting other hard marine organisms. Hederelloids have historically been included among bryozoans but have recently been interpreted as a distinct group with probable relation to modern horseshoe worms of the phylum Phoronida (Taylor and Wilson 2007).



Figure 26. Epibiont hederelloid tubes on a brachiopod (cf. *Lingula*) surrounded by bryozoan fragments in sandstone of the Bedford Formation at CUVA. Scale not available. NPS / AUSTIN SHAFFER

Another enigmatic clade of extinct organisms with fossils preserved at CUVA is Tentaculitida. Tentaculitids are known from cone-shaped shells with prominent ridges, somewhat resembling screws. These shelled organisms likely occupied a benthic lifestyle, embedding themselves in soft sediment of the seafloor, and may be most closely related to the phyla Brachiopoda and Phoronida (Vinn and Zatoń 2012; Tsujita and Baird 2024). Fossils of tentaculitids are known from the Upper Devonian Ohio Shale and Bedford Formations at CUVA (Figure 27), from shortly before their abrupt extinction at the end of the Devonian.



Figure 27. A partial tentaculitid (Tentaculitida indet.) observed in the Bedford Formation at CUVA. NPS / AUSTIN SHAFFER.

Chordata

Class Conodonta

The cosmopolitan fossils of conodonts are often utilized as index fossils for Paleozoic geologic strata. At CUVA, conodont fossils have been found in the Ohio Shale Formation, Bedford Formation, and Cuyahoga Group. The fossils of these early-diverging chordates have been reported from rocks of the park since the 1870s (Newberry 1873, 1875).

A 1947 publication by W. H. Hass details the biostratigraphic zones of conodonts in Upper Devonian and Lower Mississippian strata of Ohio, including fossils from localities both inside and outside the boundaries of CUVA. While Hass reports a number of conodont taxa from the three aforementioned geologic units, the publication does not specify which conodont taxa were recovered from which locality, thereby precluding determination of the specific provenance of any given taxon. As such, no specific conodont taxa reported by Hass are here attributed to CUVA (instead maintaining a broader attribution of Conodonta spp.). A list of the conodont taxa reported by Hass and which may occur in CUVA is included in Appendix A; it should be reiterated that these taxa may or may not have been observed within the park.

Class Chondrichthyes (cartilaginous fish)

Chondrichthyan fossils are a rare but known occurrence in the Upper Devonian shale-dominated units of CUVA. The earliest paleontological research to have likely occurred in the park reported a

handful of chondrichthyan taxa from the Ohio Shale Formation, including a possible orodontiform, the petalodontiform *Polyrhizodus*, and ctenacanthiforms (Newberry 1873, 1875).

On August 10th, 1934, F. K. Morris and J. E. Hyde collected a large nodule within the Bedford Formation near Bedford, Ohio. This nodule contained the anterior end of a partial skeleton of a ctenacanthiform shark, a rare find for the region and from a geologic horizon which makes it among the youngest Devonian representatives of this clade from northeast Ohio. The fossil is currently housed at the Cleveland Museum of Natural History (CMNH 6323) and preserves the upper and lower jaws, branchial (gill) arches, left and right scapulocoracoids (shoulder girdles), pectoral fin elements, and the anterior dorsal spine. The specimen is catalogued as "*Ctenacanthus clarki*" and has yet to be formally described.

Recently, JP Hodnett, along with Nicholas Gardner (Potomac State University, WV) and Russell Engelman (Case Western Reserve University, OH) assessed, measured, and photographed the Bedford ctenacanth at CMNH. Since its discovery in 1934, the specimen had seen mechanical preparation, and the nodule was broken down into more than 20 individual pieces before being stored as a jumble of segments. The nodule was reassembled into its original articulated state by Hodnett, Gardner, and Engelman (Figure 28).

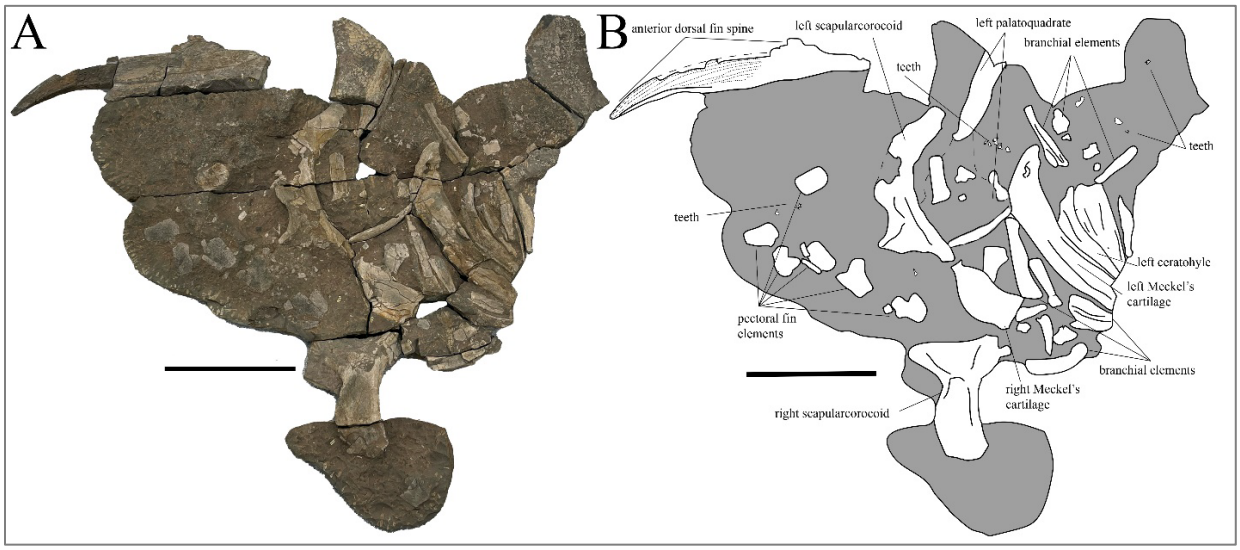


Figure 28. The ctenacanth specimen (CMNH 6323) from CUVA. **A)** Photo of the reassembled nodule containing the partial skeleton. **B)** Line diagram of the large anatomical elements seen within the block. Scale equals 15 cm (6 in). © JP HODNETT

Examining the specimen, it was determined that the Bedford ctenacanthiform differs significantly from *Ctenacanthus*, a taxon well-known from the earlier Cleveland Member of the Ohio Shale Formation (Ginter 2010; Ginter et al. 2010). The Bedford ctenacanth differs from *Ctenacanthus* in having proportionately longer and narrower upper and lower jaws, a less expanded quadratic process of the palatoquadrate (upper jaw), and enlarged basipterygia (plate-like cartilage) of the pectoral fin (Hodnett et al. 2021). The long and narrow jaws are similar to *Cladodus elegans* from the Middle

Mississippian of Scotland, but *Cladodus* has a more elongated quadrate compared to the Bedford ctenacanth (Ginter and Maisey 2007). A number of ctenacanth spine taxa are known (Maisey 1981, 1982, 1984), and the Bedford ctenacanth is identified as having the "*Ctenacanthus clarki*" type; however, as it is now evident that ctenacanth spine types can be shared between multiple taxa, the validity of spine taxa has been challenged (Hodnett et al. 2021).

Dentally, the Bedford ctenacanth teeth (Figure 29) differ significantly from those seen in *Ctenacanthus* and *Cladodus* by the lack of longitudinal cristae (ridges), a tooth base less expanded mesiodistally, and the presence of numerous small vascular openings between the crown and the tooth base (Ginter 2010; Ginter et al. 2010). This latter character is seen in the Middle Mississippian ctenacanthids *Goodrichthys* and *Troglocladodus* (Ginter 2009; Hodnett et al. 2024). Based on the above differences between the Bedford specimen and *Ctenacanthus*, we propose that the Bedford ctenacanth represents a new taxon. Based on data from complete specimens of other ctenacanthids (Hodnett et al. 2016, 2021), we estimate the overall body length of the Bedford ctenacanth to be approximately 180 cm (71 in) (Figure 30).

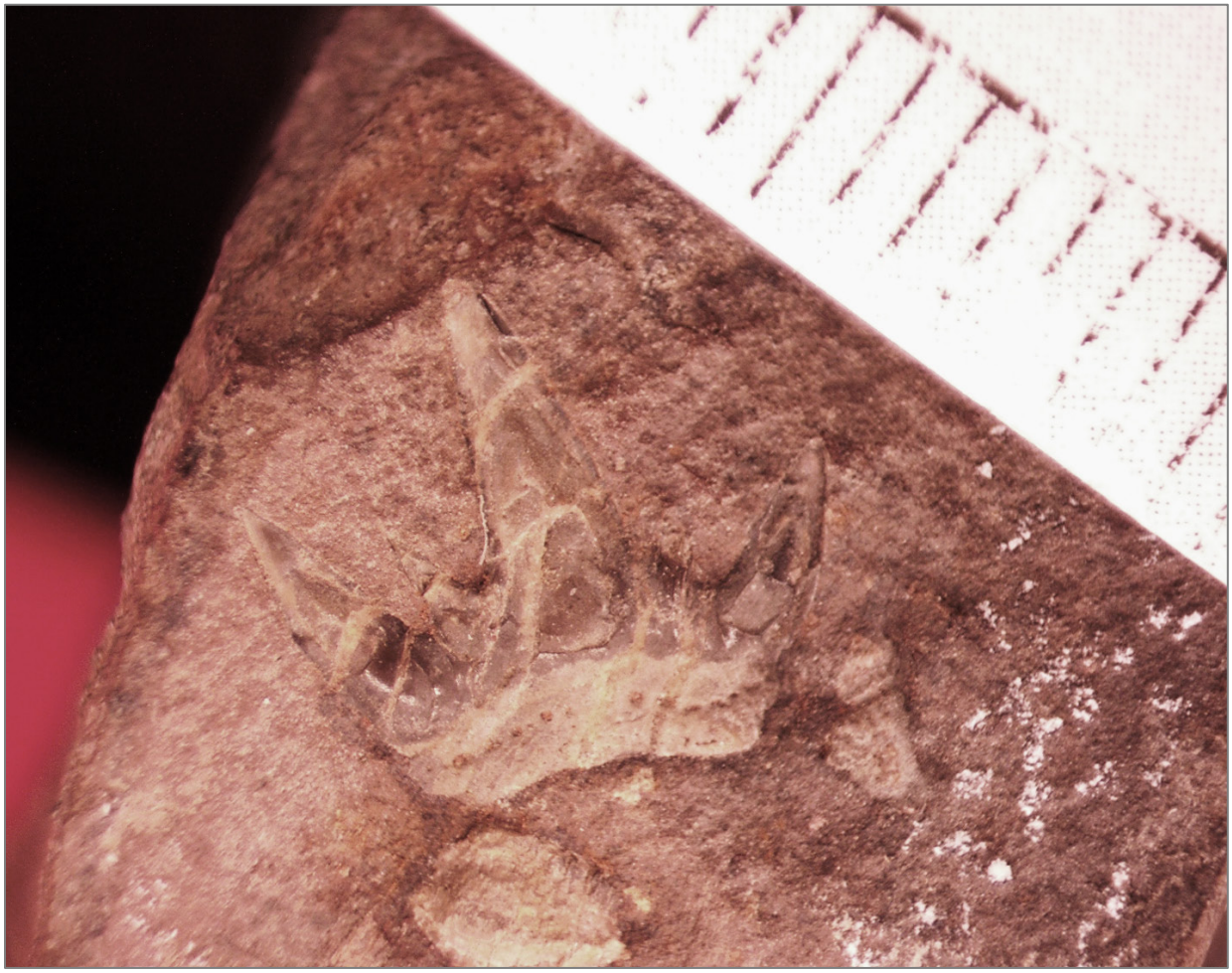


Figure 29. Tooth from the Bedford ctenacanth. Scale in mm. © JP HODNETT

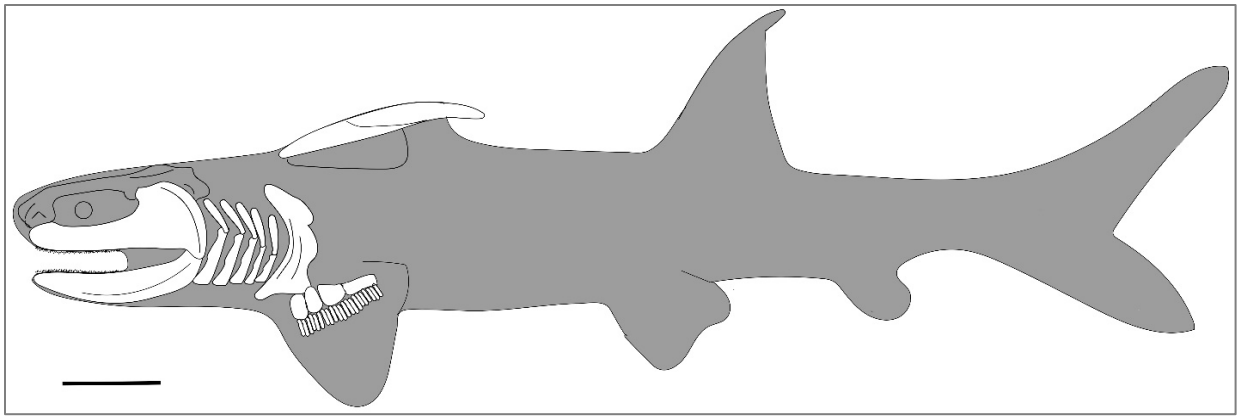


Figure 30. Tentative reconstruction of the Bedford ctenacanth. Scale equals 15 cm (6 in). © JP HODNETT

Superclass Osteichthyes (bony fish)

Rare fossils of bony fish have been reported from the Upper Devonian strata of CUVA. The occurrence of Palaeonisciformes in the Ohio Shale Formation near Bedford, Ohio was briefly mentioned by Newberry (1873, 1875). During the 2022 CUVA reconnaissance survey, two specimens tentatively attributable to Osteichthyes were collected from the Bedford Formation of the park: a possible actinopterygian tooth in the same slab as the aforementioned eurypterid (Figure 22), and an osteichthyan fish scale (Figure 31). Bony fish remains are rare in this unit and further discoveries and analysis would be necessary to clarify the taxonomic relationships of these specimens.

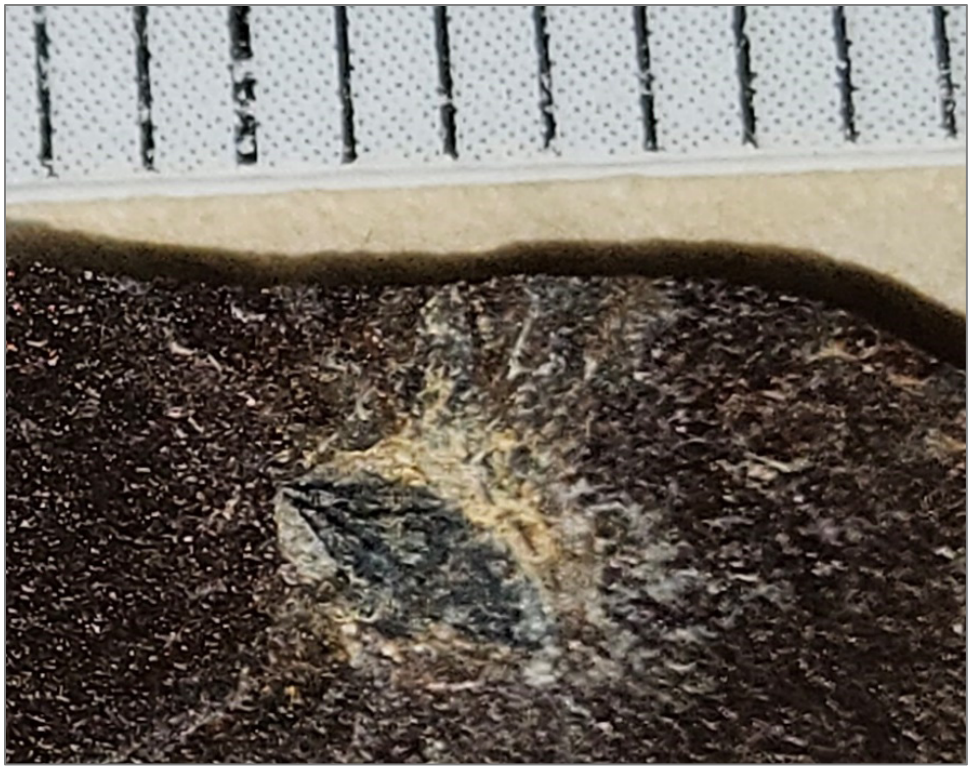


Figure 31. Osteichthyan fish scale collected from the Bedford Shale of CUVA during the 2022 fossil reconnaissance survey. Scale in millimeters. NPS / AUSTIN SHAFFER

Infraclass Tetrapodomorpha (tetrapods and allies)

Fossils of tetrapodomorphs are a rare occurrence in strata of the age exposed at CUVA. A single possible tetrapodomorph occurrence in the Cuyahoga Group of the park was discovered during the 2024 inventory. This fossil (Figure 32) consists of a partial dentary bone of a lower jaw, found within Lower Mississippian sandstone. This fossil falls within Romer's Gap, a worldwide period noted for scarce tetrapod fossils which has only recently begun to be filled by remains found at sites in Scotland (Clack et al. 2016; Otoo et al. 2018). As such, this fossil discovery at CUVA holds substantial scientific significance. Further assessment of this material is necessary in order to confirm a tetrapodomorph identity and determine whether the specimen represents a new taxon.

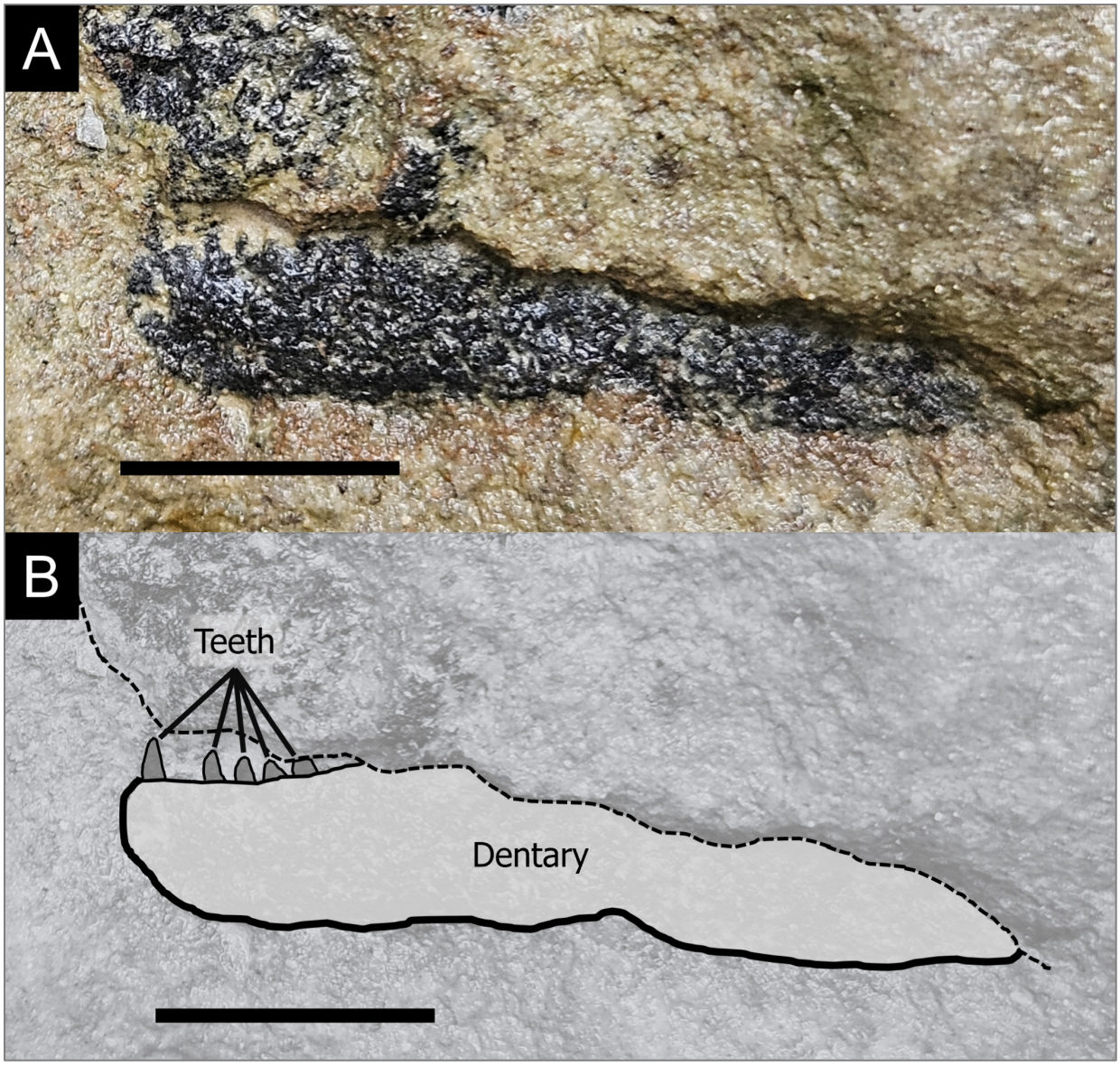


Figure 32. Possible tetrapodomorph dentary found alongside fossil plants in the Cuyahoga Group at CUVA. **A.** Field photo of specimen. **B.** Rough interpretive diagram highlighting dentary and teeth. Scale equals 1 cm (0.4 in). NPS / AUSTIN SHAFFER

Paleontological Localities

Paleontological Localities Within CUVA

During the 2024 inventory, a total of 15 localities containing paleontological resources were documented within the boundaries of CUVA. These localities were confirmed to either currently possess or to have previously produced substantial and/or significant fossils. Paleontological localities are herein documented at CUVA from the Ohio Shale Formation, the Bedford Formation, and the Cuyahoga Group. Additional fragmentary fossil occurrences were sporadically observed as float throughout much of the park's stream channels; however, these were not documented as official localities due to their ubiquity and lack of significant specimens.

A breakdown of CUVA paleontological localities and associated data can be found in Appendix E. Information regarding specimen collection from CUVA can be found in Appendix B. A glossary containing definitions for much of the terminology used can be found near the beginning of this report.

Cultural Resource Connections

There are many ways for paleontological resources to have connections to cultural resources. Examples of paleontological resources in cultural contexts include, but are not limited to: fossils used by people for various purposes, such as petrified wood used for tools, spear points, and other artifacts, or fossil shells picked up as charms or simply because they looked interesting; associations of prehistoric humans with paleontological resources, such as kill sites of mammoths, prehistoric bison, and other extinct animals; incorporation of fossils into cultural records, such as fossils in Native American lore, "tall tales" of mountain men, and emigrant journals; and fossils in building stone. Kenworthy and Santucci (2006) presented an overview and cited selected examples of National Park Service fossils found in cultural resource contexts. At CUVA, fossils have been observed in stones used to demarcate trails as well as within the building stone of park signage.

Museum Collections and Paleontological Archives

Museum Collections and Curation

Park Collections

The museum collections facility at CUVA does not currently contain any paleontological specimens. All fossils collected from locations within the park are currently housed at other repositories, as such collections largely occurred prior to the establishment of CUVA museum collections or of the park itself.

Collections in Other Repositories

Six repositories are currently recorded as housing specimens likely from CUVA: the Cincinnati Museum Center (CMC; Cincinnati, Ohio); the Cleveland Museum of Natural History (CMNH; Cleveland, Ohio); the Cleveland Metroparks (CMP; Cleveland, Ohio); Kent State University (KSU; Kent, Ohio); the Midwest Archeological Center (MWAC; Lincoln, Nebraska); and the National Museum of Natural History (USNM; Washington, D.C.). See Appendix C for contact information.

The CMNH currently houses 116 fossil specimens from within the modern boundaries of CUVA. 115 of these specimens were collected, described, and figured by Schwimmer and Feldmann (1990). The other fossil specimen from CUVA housed at CMNH is a partial skeleton of a new ctenacanthiform (CMNH 6323), detailed elsewhere in this report.

MWAC, an NPS repository serving the Midwest Region, has 23 items catalogued under 14 numbers that are reported as containing fossils (some of the items in the lots themselves are not fossils). These specimens are all invertebrate fossils uncovered during archeological and other investigations, and include rugose corals, a bryozoan, brachiopods, a possible gastropod, and crinoids.

Fossil specimens described by Girty (1939), Winslow (1962), and House et al. (1986) are reposited at the USNM. Several unpublished brachiopods from the Ohio Shale Formation of Brandywine Creek are also catalogued at the CMC. The collection date(s) of the CMC brachiopods is unknown.

Two additional fossil specimens were collected from CMP property within CUVA during the 2022 paleontological reconnaissance survey of the park: a bony fish scale and a slab containing a probable eurypterid alongside a possible fish tooth. These specimens are currently maintained by CMP staff with eventual transfer plans to an established local repository (e.g., CUVA or CMNH).

Unfigured brachiopod/bivalve specimens collected by Schwimmer and Feldmann (1990) were supposedly reposited at Kent State University in the Department of Geology; however, these specimens were not located during this inventory.

Type Specimens

Twenty paleontological taxa have been named from specimens collected within what is now CUVA (Table 2). Sixteen taxa were named by Winslow (1962) for palynomorph fossils recovered from localities in CUVA, 14 of which were new species and two that were designated as new variants. All

of them come from the Upper Devonian units of the park. The specimens were reposited with the USGS office in Columbus, Ohio, but it is not known if they are still there.

Girty (1939) named three species of the brachiopod genus *Lingula* (*L. arcta, L. eriensis*, and *L. limatula*) on the basis of multiple specimens including some recovered from the Ohio Shale Formation of Bedford, Ohio and Brecksville, Ohio. No catalogue numbers were provided alongside the description of these taxa; syntypes follow the listing in the USNM online collections database. Another species, *Lingula papyracea*, was named by Girty (1939) from specimens that were collected from a Bedford Formation locality that may have been within CUVA (USNM 180560.A, 180607, 180608, and 180609). Because of the uncertainty, it is not included in Table 2.

A species of phyllopod crustacean, *Spathiocaris chagrinensis*, was named by Ruedemann (1916) based on a type specimen from the Ohio Shale Formation from what is now CUVA. This holotype was lost, leading to the designation of CMNH 3745 from Big Creek in Cleveland, Ohio as a neotype (Frye and Feldmann 1991). However, it has become evident that the fossils of this taxon (as well as those similar to it) represent the aptychi (jaw plate) of cephalopods, possibly Orthocerida, and *S. chagrinensis* has also since been transferred to the genus *Sidetes* (Frye and Feldmann 1991; Goolaerts et al. 2017; Mironenko 2020).

Table 2. Fossil taxa named from specimens found within CUVA. Holotypes from Winslow (1962) are verbatim except for the omission of the geologic unit; plates and figures are found in that document.

Taxon	Geologic Unit	Reference(s)	Type Specimen	Notes
Anapiculatisporites retusus	Bedford Fm.	Winslow 1962	Plate 18, figure 15, maceration 159, slide 12, collection 7-12-6-53-b	Palynomorph
Canthospora cracens	Bedford Fm.	Winslow 1962	Plate 15, figure 3, maceration 40B, slide 13, collection 4-11-1-52	Palynomorph
Canthospora patula	Bedford Fm.	Winslow 1962	Plate 15, figure 6, maceration 40C, slide 27, collection 4-11-1-52	Palynomorph
Cirratriradites hystricosus	Bedford Fm.	Winslow 1962	Plate 18, figure 5, maceration 162, slide 10, collection 17-12-6-53	Palynomorph
Convolutispora tuberosa	Bedford Fm.	Winslow 1962	Plate 17, figure 21, maceration 162, slide 8, collection 17-12-6-53	Palynomorph
Dicrospora bedfordi	Bedford Fm.	Winslow 1962	Plate 10, figures 2, 2a, maceration 40A, slide 13, collection 4-11-1-52	Palynomorph
Endosporites? *crassaspinosus*	Bedford Fm.	Winslow 1962	Plate 18, figure 10, maceration 163, slide A, collection 9-12-6-53	Palynomorph
Endosporites? *pseudoradiatus*	Bedford Fm.	Winslow 1962	Plate 16, figure 7, maceration 40C, slide 10, collection 4-11-1-52	Palynomorph
Lingula arcta	Ohio Shale Fm.	Girty 1939	Syntypes including USNM 180624, 180571, and 180577 from CUVA	Brachiopod
Lingula eriensis	Ohio Shale Fm.	Girty 1939	Syntypes including USNM 180564, 180620, 180625, 180626, and 180627 from CUVA	Brachiopod
Lingula limatula	Ohio Shale Fm.	Girty 1939	Syntypes including USNM 180579 from CUVA	Brachiopod
Reticulatisporites? *fimbriatus*	Bedford Fm.	Winslow 1962	Plate 14, figures 1, 1a, 1b and Plate 22, figure 21, maceration 40B, slide 16, collection 4-11-1-52	Palynomorph

Table 2 (continued). Fossil taxa named from specimens found within CUVA. Holotypes from Winslow (1962) are verbatim except for the omission of the geologic unit; plates and figures are found in that document.

Taxon	Geologic Unit	Reference(s)	Type Specimen	Notes
Reticulatisporites? *fimbriatus* var. *spathulatus*	Bedford Fm.	Winslow 1962	Plate 14, figures 4, 4a, and plate 22, figure 22, maceration 40B, slide 15, collection 4-11-1-52	Palynomorph
Sidetes chagrinensis	Ohio Shale Fm.	Ruedemann 1916; Frye and Feldmann 1991	Western Reserve University d 600	Cephalopod aptychi (previously considered phyllopod crustacean shield)
Tasmanites sinuosus	Ohio Shale Fm.	Winslow 1962	Plate 20, figure 1, maceration 156, slide 1, collection 1-12-6-53	Chlorophyte alga
Triletes aries	Bedford Fm.	Winslow 1962	Plate 9, figures 3, 3a, maceration 163, slide 1, collection 9-12-6-53	Palynomorph
Triletes auritulus	Bedford Fm.	Winslow 1962	Plate 3, figures 1, 1a, maceration 40C, slide 1, collection 4-11-1-52	Palynomorph
Triletes catenulatus	Bedford Fm.	Winslow 1962	Plate 6, figures 3, 3a, 3b, maceration 161, slide 25, collection 8-12-6-53	Palynomorph
Triletes catenulatus var. *marginatus*	Bedford Fm.	Winslow 1962	Plate 5, figures 8, 8a, maceration 40A, slide 13, collection 4-11-1-52	Palynomorph
Triletes globulus	Bedford Fm.	Winslow 1962	Plate 8, figures 4, 4a, 4b, maceration 161, slide 2, collections 8-12-6-53	Palynomorph

Archives

NPS Paleontology Archives

All data, references, images, maps, and other information used in the development of this report are maintained in the NPS Paleontology Archives and Library. These records consist of both park-specific and service wide information pertaining to paleontological resources documented throughout the NPS. If any resources are needed by NPS staff at CUVA, or additional questions arise regarding paleontological resources, contact the NPS Senior Paleontologist and Paleontology Program Coordinator Vincent Santucci, vincent_santucci@nps.gov. Park staff are also encouraged to communicate new discoveries to the NPS Paleontology Program, not only when support is desired, but in general, so that this information can be incorporated into the archives. A description of the Archives and Library can be found in Santucci et al. (2018).

E&R Files

E&R files (from "Examination and Report on Referred Fossils") are unpublished internal USGS documents. For more than a century, USGS paleontologists identified and prepared informal reports on fossils sent to the agency by other geologists, for example to establish the relative age of a formation or to help correlate beds. The system was eventually formalized as a two-part process including a form sent by the transmitting geologist and a reply by the survey geologist. Sometimes the fossil identifications were incorporated into publications, but in many cases the information is unpublished. These E&R files include documentation of numerous fossil localities within current NPS areas, usually predating the establishment of the NPS unit in question and frequently unpublished or previously unrecognized. Extensive access to the original files was granted to the NPS by the USGS beginning in 2014 (Santucci et al. 2014). No E&R files are yet known for CUVA.

Park Paleontological Research

Current and Recent Research

At the time of writing, only two permits have been issued for paleontological work at CUVA: one prior project on Devonian vertebrates and the 2024 paleontological resource inventory. These are listed below in chronological order by research permit number.

- COLM-2011-SCI-0010, principal investigator Robert Carr of Ohio University, project "*Late Devonian Vertebrate Biogeography and Biodiversity*", issued for 2011–2013.
- COLM-2024-SCI-0002, principal investigator Vincent Santucci of National Park Service, project "*Cuyahoga Valley National Park Paleontological Resource Inventory*", issued for 2024.

Paleontological Research Permits

See the National Park Service Natural Resource Management Reference Manual DO-77 section on Paleontological Resource Management, subsection on Scientific Research and Collection (https://irma.nps.gov/DataStore/Reference/Profile/572379). NPS Management Policies 2006, section 4.8.2.1 on Paleontological Resources, states that

> *The Service will encourage and help the academic community to conduct paleontological field research in accordance with the terms of a scientific research and collecting permit.*

Any collection of paleontological resources from an NPS area must be made under an approved research and collecting permit. The NPS maintains an online Research Permit and Reporting System (RPRS) database for researchers to submit applications for research in NPS areas. Applications are reviewed at the park level and either approved or rejected. Current and past paleontological research and collecting permits and the associated Investigator's Annual Reports (IARs) are available on the RPRS website (https://irma.nps.gov/rprs/). Additional information on NPS law and policy can be found in Appendix D.

Recommended Research

Potential future research topics concerning CUVA paleontological resources were identified during the 2024 inventory. These topics are listed below:

- Thorough assessment of invertebrate fossil diversity at CUVA (e.g., corals, bryozoans, brachiopods, mollusks, crinoids, ichnofossils).
- Detailed analysis of the Bedford Formation eurypterid specimen collected in 2022.
- Description of the new ctenacanthiform taxon represented by the Bedford Formation skeleton.
- Examination of the Early Mississippian paleobotanical site in the Cuyahoga Group at CUVA (including the potential tetrapodomorph material found therein).

- Analysis of the putative Tournaisian colonial coral biostrome from the Cuyahoga Group at CUVA and comparison with similar biostromes in the Devonian–Carboniferous transition.
- Documentation of the presence of the Skinner's Run Pyrite Bed at the contact of the Chagrin and Cleveland Members of the Ohio Shale Formation at CUVA and exploration of this horizon for important vertebrate fossil material.
- Continued survey of Upper Devonian and Lower Mississippian strata in the park for additional fossil material.

Interpretation

At the time of writing, interpretation and education related to paleontology currently exists at CUVA. Regular programming provided by park staff takes places throughout the year which highlights the paleontological resources of the park (e.g., horn corals, brachiopods, crinoids) and provides important education on what fossils are and how they are formed (J. Bates, CUVA, pers. comm., July 2024). Activities for children available through the Junior Ranger program include field excursions near Everett Covered Bridge at Furnace Run, viewing example fossils, and making plaster casts. Across these programs, a message is conveyed emphasizing the importance of leaving fossils in place and informing what to do if a fossil is found in the park (J. Bates, pers. comm., July 2024). Programs and interpretive signs focused on geology also occur at Ritchie Ledges, Brandywine Falls (Figure 33), and Boston Mill Visitor Center.



Figure 33. Interpretive sign describing the geologic history of Brandywine Falls at CUVA. NPS / AUSTIN SHAFFER

Efforts such as those currently in place at the park provide an important foundation for paleontological education and may be bolstered by the expansion of interpretive programs across CUVA, the development of paleontology-related interpretive media for the park (website content, brochures, wayside exhibits, etc.), and the celebration of National Fossil Day (perhaps in collaboration with local partners such as the CMNH and regional paleontologists).

Current Long-Range Interpretive Plan

A long-range interpretive plan is in development for CUVA at the time of writing (R. Trimbath, CUVA, pers. comm., May 2024). Development and use of at least one formal paleontological interpretive theme should occur in conjunction with the interpretive themes found in the CUVA foundation document (National Park Service 2013). The CUVA foundation document does not address the presence of paleontological resources in the park.

Recommended Interpretive Topics

I. General Paleontological Information

All of the following interpretation topics include a section instructing visitors how to be paleontologically aware while in the park. The ranger will provide the visitor with advice on why fossils are important, how paleontologists look for fossils, what to do if fossils are found, and reminders to be aware that fossils exist and should be respected within park boundaries.

- Fossils are non-renewable resources that possess scientific and educational information and provide insight into what Earth was like thousands and even hundreds of millions of years ago.
- When paleontologists survey for paleontological resources, the most important tool for planning is a geologic map. Paleontological resources are more common in certain geologic units, so knowing where those units are exposed is important for a successful search. Other tools that a paleontologist takes into the field include a field notebook for recording data and observations, small picks and brushes, consolidants to stabilize fossils, GPS unit, camera, topographic maps, and appropriate First Aid and safety equipment. It might be helpful to provide examples of these items for visitors when giving an interpretive talk.
- If fossils are found in the park by a visitor, the visitor should photograph it and notify a ranger of where the resource was found, but most importantly, they should leave the fossil where they found it. It is extremely important for scientific and resource management purposes for contextual information to be preserved. Visitors should be informed that park fossils are protected by law.

II. Fossils of CUVA

- Interpretation and education programs could be developed to educate the public on what types of fossils are present in CUVA and what they tell scientists about Earth's dynamic history. The goal of these programs would be to increase visitors' understanding of local geology and paleontology. Therefore, information regarding fossils from the vicinity of CUVA can be included. Programs should not disclose the locations of sensitive fossil resources.

III. Further Interpretation Topics

Staff at CUVA should promote their paleontological resources and provide additional opportunities or programs for visitors to learn about fossils on National Fossil Day, celebrated annually on Wednesday of the second full week in October (National Earth Science Week). For more information

on this event visit: https://www.nps.gov/subjects/fossilday/index.htm. The NPS coordinates the National Fossil Day partnership and hosts fossil-focused events across the country. Conducting one or more paleontology-focused activities on this day would be a perfect opportunity to not only increase public awareness about paleontological resources in CUVA, but also to connect with other parks and museums that are also participating in this national event. The NPS Geologic Resources Division can assist with planning for National Fossil Day activities and provide Junior Paleontologist Program supplies including activity booklets, badges, posters and other fossil-related educational resources (https://www.nps.gov/subjects/fossils/junior-paleontologist.htm).

Paleontological Resource Management and Protection

Fossils have scientific, aesthetic, cultural, educational, and tourism value, and impacts to any of these values impairs their usefulness. Effective paleontological resource management protects fossil resources by implementing strategies that mitigate, reduce, or eliminate loss of fossilized materials and their relevant data. Because fossils are representatives of adaptation, evolution, and diversity of life through deep time, they have intrinsic scientific values beyond just the physical objects themselves. Their geological and geospatial contexts provide additional critical data concerning paleoenvironmental, paleogeographic, paleoecologic, and a number of other conditions that together allow for a more complete interpretation of the physical and biological history of the earth. Therefore, paleontological resource management must act to protect not only the fossils themselves, but to collect and maintain other contextual data as well.

In general, losses of paleontological resources result from naturally occurring physical processes, by direct or indirect human activities, or by a combination of both. These processes or activities influence the stability and condition of in situ paleontological resources (Santucci and Koch 2003; Santucci et al. 2009). The greatest loss of associated contextual data occurs when fossils are removed from their original geological context without appropriate documentation. Thus, when a fossil weathers and erodes from its surrounding sediments and geologic context, it begins to lose significant ancillary data until, at some point, it becomes more a scientific curiosity than a useful piece of scientific data. A piece of loose fossil "float" can still be of scientific value, however, when a fossil has been completely removed from its original context, such as an unlabeled personal souvenir or a specimen with no provenance information in a collection, it is of very limited scientific utility. Similarly, inadvertent exhumation of fossils during roadway construction or a building excavation may result in the loss or impairment of the scientific and educational values associated with those fossils. It is not necessary to list here all of the natural and anthropogenic factors that can lead to the loss of paleontological resources; rather it is sufficient to acknowledge that anything that disturbs native sediment or original bedrock has potential to result in the loss of the paleontological resources that occur there, or the loss of associated paleontological resource data.

National Park Service Laws, Regulations, and Policies

Paleontological resources are non-renewable remains of past life preserved in a geologic context. At present, there are 431 official units of the National Park System, plus national rivers, national trails, and affiliated units that are not included in the official number. Of these, 286 are known to have some form of paleontological resources, and paleontological resources are mentioned in the enabling legislation of 18 units. Fossils possess scientific and educational values and are of great interest to the public; therefore, it is exceedingly important that appropriate management attention be placed on protecting, monitoring, collecting, and curating these non-renewable paleontological specimens from federal lands. In March 2009, the Paleontological Resources Preservation Act (PRPA) was signed into law as part of the Omnibus Public Land Management Act of 2009. The new paleontology-focused legislation includes provisions related to inventory, monitoring, public education, research and collecting permits, curation, and criminal/civil prosecution associated with fossils from

designated Department of Interior (DOI) lands. More information on laws, policies, and authorities governing NPS management of paleontological resources is detailed in Appendix D. Paleontological resource protection training is available for NPS staff through the NPS Paleontology Program. The Paleontology Program is also available to provide support in investigations involving paleontological resource theft or vandalism.

Between 2009 and 2022 an interagency coordination team including representatives from the Bureau of Land Management (BLM), Bureau of Reclamation (BOR), National Park Service (NPS) and U.S. Fish & Wildlife Service (FWS) developed the DOI final regulations for PRPA. In 2022, the DOI Paleontological Resources Preservation Act final regulation was published in the Federal Register and was subsequently made available online: https://www.federalregister.gov/documents/2022/08/02/2022-16405/paleontological-resources-preservation. For more information regarding this act, visit https://www.nps.gov/subjects/fossils/fossil-protection.htm.

2006 National Park Service Management Policies (section 4.8.2.1) state

> *... Paleontological resources, including both organic and mineralized remains in body or trace form, will be protected, preserved, and managed for public education, interpretation, and scientific research. The Service will study and manage paleontological resources in their paleoecological context (that is, in terms of the geologic data associated with a particular fossil that provides information about the ancient environment).*
>
> *Superintendents will establish programs to inventory paleontological resources and systematically monitor for newly exposed fossils, especially in areas of rapid erosion. Scientifically significant resources will be protected by collection or by on-site protection and stabilization. The Service will encourage and help the academic community to conduct paleontological field research in accordance with the terms of a scientific research and collecting permit. Fossil localities and associated geologic data will be adequately documented when specimens are collected. Paleontological resources found in an archeological context are also subject to the policies for archeological resources. Paleontological specimens that are to be retained permanently are subject to the policies for museum objects.*
>
> *The Service will take appropriate action to prevent damage to and unauthorized collection of fossils. To protect paleontological resources from harm, theft, or destruction, the Service will ensure, where necessary, that information about the nature and specific location of these resources remains confidential, in accordance with the National Parks Omnibus Management Act of 1998.*
>
> *All NPS construction projects in areas with potential paleontological resources must be preceded by a preconstruction surface assessment prior to disturbance. For any occurrences noted, or when the site may yield paleontological resources, the site will be avoided or the resources will, if necessary, be collected and properly cared for before construction begins.*

Areas with potential paleontological resources must also be monitored during construction projects.

Paleontological Resource Management at CUVA

The paleontological resources at CUVA are typically exposed by and at risk of damage via erosion. Most of the fossils found in the park occur along and in streams where erosion has allowed them to be observed, however this same process threatens eventual damage of the fossils, particularly those preserved in soft shale. The risk of erosion must be considered when determining whether paleontological specimens at CUVA warrant collection.

Alongside erosion, unauthorized collection and vandalism pose significant threats to paleontological resources at CUVA. High levels of visitation to the park, the close proximity of protected lands to populous urban areas of northeast Ohio, and the presence of fossils along and near roads and trails all contribute to the risk of illegal fossil collection. A variety of different terms are used to describe this practice, such as looting, theft, and poaching. Regardless of the terminology used, the unauthorized collection of fossils is nevertheless a concern at CUVA. While little direct evidence of unauthorized fossil collection is known from the park, there are locations in CUVA where, during the 2024 inventory, clear public awareness of fossil resources was evident. Such areas, alongside other locations in the park containing abundant or scientifically important fossils, should be monitored to protect these resources.

Baseline Paleontology Resource Data Inventories

A baseline inventory of paleontological resources is critical for implementing effective management strategies, as it provides information for decision-making. This inventory report has compiled information on previous paleontological research done in and near CUVA as well as taxonomic groups that have been reported within CUVA boundaries. This report can serve as a baseline source of information for future research, inventory reports, monitoring, and paleontological decisions. The Paleontological Resource Inventory and Monitoring report for the Heartland I&M Network completed by Hunt et al. (2008) and the references cited within were important baseline paleontological resource data sources for this CUVA-specific report.

Paleontological Resource Monitoring

Paleontological resource monitoring is a significant part of paleontological resource management, and one which usually requires little to implement beyond time and equipment already on hand, such as cameras and GPS units. Monitoring enables the evaluation of the condition and stability of in situ paleontological resources (Santucci and Koch 2003; Santucci et al. 2009). A monitoring program revolves around periodic site visits to assess conditions compared to a baseline for that site, with the periodicity depending on factors such as site productivity, accessibility, and significance of management issues. For example, a highly productive site that is strongly affected by erosion or unauthorized collection, and which can be easily visited by park staff, would be scheduled for more frequent visits than a less productive or less threatened site.

A monitoring program is generally implemented after an inventory has been prepared for a park and sites of concern have been identified, with additional sites added as necessary. Because each park is different, with different geology and paleontology among other factors, ideally each park which has in situ fossils or significant accumulations of reworked fossils would have its own monitoring protocol to define its monitoring program. Data accumulated via monitoring is used to inform further management decisions, such as the following questions: Is the site suitable for interpretation and education? Does the site require stabilization from the elements? Is collection warranted? Is there a need for some form of law enforcement presence?

Collection is recommended to be reserved for fossils possessing exceptional value (e.g., rare or high scientific significance) or at immediate risk of major degradation or destruction by human activity and natural processes. Therefore, paleontological resource monitoring is a more feasible potential management tool, informing when fossil collection is merited.

The first step in establishment of a monitoring program is identification of localities to be monitored, as discussed previously. Recommended monitoring of paleontological localities at CUVA developed through this inventory can be found in Appendix E. Locality condition forms are then used to evaluate factors that could cause loss of paleontological resources, with various conditions at each locality rated as good, fair, or poor. Risks and conditions are categorized as Disturbance, Fragility, Abundance, and Site Access. “Disturbance” evaluates conditions that promote accelerated erosion or mass wasting resulting from human activities. “Fragility” evaluates natural conditions that may influence the degree to which fossil transportation is occurring. Sites with elevated fragility exhibit inherently soft rapidly eroding sediment or mass wasting on steep hillsides. A bedrock outcrop that is strongly lithified has low fragility. “Abundance” judges both the natural condition and number of specimens preserved at the locality as well as the probability of being recognized as a fossil-rich area by non-paleontologists, which could lead to unpermitted collecting. “Site Access” assesses the risk of a locality being visited by large numbers of visitors or the potential for easy removal of large quantities of fossils or fossil-bearing sediments. A locality with high access would be in close proximity to public use areas or other access (along trails, at roadcuts, at beach or river access points, and so on).

Each of the factors noted above may be mitigated by management actions. Localities exhibiting a significant degree of disturbance may require either active intervention to slow accelerated erosion, periodic collection and documentation of fossil materials, or both. Localities developed on sediments of high fragility naturally erode at a relatively rapid rate and would require frequent visits to document and/or collect exposed fossils in order to prevent or reduce losses. Localities with abundant or rare fossils, or high rates of erosion, may be considered for periodic monitoring in order to assess the stability and condition of the locality and resources, in regard to both natural processes and human-related activities. Localities that are easily accessible by road or trail would benefit from the same management strategies as those with abundant fossils and by occasional visits from park staff, documentation of in situ specimens, and/or frequent law enforcement patrols. Further information on paleontological resource monitoring can be found in Santucci and Koch (2003) and Santucci et al.

(2009). A comprehensive suite of management actions is described in NPS Management Policies 2006 and summarized in Appendix D.

Foundation Documents and Resource Stewardship Strategies

Foundation documents and Resource Stewardship Strategies are two types of park planning documents that may contain and reference paleontological resource information. A foundation document is intended to provide basic guidance about a park for planning and management. It briefly describes a given park and its purpose, significance, fundamental resources and values, other importance resources and values, and interpretive themes. Mandates and commitments are also identified, and the state of planning is assessed. Foundation documents may include paleontological information and are also useful as a preliminary assessment of what a park's staff know about their paleontological resources, the importance they place on these resources, and the present state of these non-renewable resources. A foundation document for CUVA has been published (National Park Service 2013).

A Resource Stewardship Strategy (RSS) is a strategic plan intended to help park managers achieve and maintain desired resource conditions over time. It offers specific information on the current state of resources and planning, management priorities, and management goals over various time frames. An RSS has not been prepared for CUVA as of summer 2024.

Geologic Maps

A geologic map is the fundamental tool for depicting the geology of an area. Geologic maps are two-dimensional representations of the three-dimensional geometry of rock and sediment at or beneath the land surface (Evans 2016). Colors and symbols on geologic maps correspond to geologic map units. The unit symbols consist of an uppercase letter indicating the age and lowercase letters indicating the formation's name. The American Geosciences Institute website (https://www.americangeosciences.org/environment/publications/mapping) provides more information about geologic maps and their uses. The NPS Geologic Resources Inventory (GRI) has been digitizing existing maps of NPS units and making them available to parks for resource management.

Geologic maps are one of the foundational elements of a paleontological resource management program. Knowing which sedimentary rocks and deposits underlie a park and where they are exposed are essential for understanding the distribution of known or potential paleontological resources. The ideal scale for resource management in the 48 contiguous states is 1:24,000 (maps for areas in Alaska tend to be coarser). Whenever possible, page-sized geologic maps derived from GRI files are included in paleontological resource inventory reports for reference, but it is recommended that GRI source files be downloaded from IRMA for use. The source files can be explored in much greater detail and incorporated into the park GIS database. Links to the maps digitized by the GRI for CUVA can be found in IRMA at https://irma.nps.gov/DataStore/Reference/Profile/2274239.

Paleontological Resource Management Recommendations

The paleontological resource inventory at CUVA has documented rich paleontological resources. This report captures the scope, significance, and distribution of fossils at CUVA and provides recommendations to support the management and protection of the park's non-renewable paleontological resources.

- CUVA staff should be encouraged to observe exposed rocks and sedimentary deposits for fossil material while conducting their usual duties. To promote this, staff should receive guidance regarding how to recognize common local fossils. For instance, when opportunities arise to observe paleontological resources in the field and take part in paleontological field studies with trained paleontologists, staff should take advantage of them, if funding and time permit. Paleontological resource guides (particularly CUVA-specific) and virtual/in-person trainings can also assist in this.
- CUVA staff should photo-document and monitor any occurrences of paleontological resources that may be observed in situ. Fossils and their associated geologic context (surrounding rock) should be documented, but left in place unless they are subject to imminent degradation. Paleontological resources at high risk of damage should be considered for collection. A Geologic Resource Monitoring Manual published by the Geological Society of America and NPS Geologic Resources Division (GRD) includes a chapter on paleontological resource monitoring (Santucci et al. 2009). Santucci and Koch (2003) also present information on paleontological resource monitoring.
- Fossil theft is one of the greatest threats to the preservation of paleontological resources and any methods to minimize these activities should be utilized by staff. Any occurrence of paleontological resource theft or vandalism should be investigated by a law enforcement ranger. When possible, incidents should be fully documented and the information submitted for inclusion in the annual law enforcement statistics.
- Fossils found in a cultural context should be documented like other fossils, but will also require the input of an archeologist or a cultural resource specialist. Any fossil which has a cultural context may be culturally sensitive as well (e.g., subject to NAGPRA) and should be regarded as such until otherwise established. The GRD can coordinate additional documentation/research of such material.
- The park may fund and recruit paleontology interns as a cost-effective means of enabling some level of paleontological resource support. The Scientists in Parks Program is an established program for recruitment of geology and paleontology interns. Local partnerships (e.g., Cleveland Museum of Natural History, University of Akron, Kent State University) may also be established to support paleontological resource management at the park. Trained volunteers are an additional option to assist with the stewardship and monitoring of paleontological localities.
- Many of the park's significant paleontological resources occur on properties co-managed with Cleveland Metroparks (CMP) or Summit Metro Parks (SMP). Collaborative efforts

between CUVA, CMP, and SMP are essential to the proper management of important fossil resources.

- Contact the NPS Paleontology Program for technical assistance with paleontological resource management issues.

If fossil specimens are found by CUVA staff, it is recommended they follow the steps outlined below to ensure proper paleontological resource management. The NPS Paleontology Program is available to provide assistance, guidance, and technical support as needed.

- Photo document the specimen without moving it from its location if it is loose. Include a common item, such as a coin, pen, or pencil, for scale if a ruler or scale bar is not available.
- If a GPS unit is available, record the location of the specimen. If GPS is not available, record the general location within CUVA and height within the outcrop, if applicable, as well as any notable landmarks. If possible, revisit the site when a GPS unit is available. Most smartphones also have the ability to record coordinates; if no GPS unit is available, attempt to record the coordinates with a phone.
- Write down associated data, such as rock type, general description of the fossil, type of fossil if identifiable, general location in CUVA, sketch of the fossil, position within the outcrop or if it is loose on the ground, any associated fossils, and any other additional information.
- Do not remove the fossil unless it is loose in an area of heavy traffic, such as a public trail, and is at risk of being taken or destroyed. If the specimen is fragile, determine whether consolidant is needed to prevent damage and if removing the fossil will cause unnecessary damage. If the fossil is removed, be sure to wrap in soft material, such as tissue paper, and place in a labeled plastic bag with associated notes.

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Appendix A: Paleontological Taxa

Paleozoic Taxa

The following tables (Tables 3–8, for plants, brachiopods, mollusks, other invertebrates, and chordates, and conodonts respectively) document the Paleozoic fossil taxa found at CUVA in stratigraphic context, as verified by personal observation in comparison with published literature.

Many of the taxonomic identifications listed below are provisional, pending in-depth assessment of the specimen(s) in question. The rows are organized systematically, placing taxa of the same taxonomic group together. The columns are organized by formation, which are presented in ascending order (oldest to youngest) left to right. If a taxon is present in a given formation at a locality that can be placed within CUVA, that cell is marked "Y"; if there is some question about the formation, the cell is marked "?". A null record is marked "–".

"[Taxon] indet." refers to fossils that are currently taxonomically indeterminate at a high level; e.g., a fragment of a brachiopod may be classified as "Brachiopoda indet." The abbreviation "cf." comes from the Latin *confer* and, when placed before a taxonomic name, means the fossil is comparable to that taxon but the identification is not certain. The abbreviation "spp." indicates multiple undetermined species.

Stratigraphic abbreviations are as follows, in descending order (youngest to oldest). In the interest of space, only units that have documented records of fossils at CUVA are included.

- Mc = Cuyahoga Group
- Dbr = Berea Formation
- Dbd = Bedford Formation
- Doh = Ohio Shale Formation

Table 3. Paleozoic paleobotanical taxa from CUVA in stratigraphic context.

Division: Class: Order	Taxon	Doh	Dbd	Dbr	Mc	Reference(s)
Chlorophyta: n/a: n/a	*Tasmanites*	Y	Y	–	–	Winslow 1962
Tracheophyta: n/a: n/a	Tracheophyta indet.	Y	–	Y	Y	Pers. observation
Tracheophyta: n/a: n/a	*Cyrtospora*	–	Y	–	–	Winslow 1962
Tracheophyta: n/a: n/a	*Radforthia*	–	Y	–	–	Winslow 1962
Tracheophyta: Lycopodiopsida: n/a	Triletes	–	Y	–	–	Winslow 1962
Tracheophyta: Lycopodiopsida: n/a	"Endosporites"	Y	Y	–	–	Winslow 1962
Tracheophyta: Lycopodiopsida: n/a	*Densosporites*	–	Y	–	–	Winslow 1962
Tracheophyta: Lycopodiopsida: n/a	*Dicrospora*	–	Y	–	–	Winslow 1962
Tracheophyta: Lycopodiopsida: Selaginellales	*Cirratriradites*	–	Y	–	–	Winslow 1962
Tracheophyta: Lycopodiopsida: Selaginellales	*Retispora*	Y	Y	–	–	Winslow 1962
Tracheophyta: Lycopodiopsida: Lepidodendrales	cf. *Lepidodendropsis*	–	–	–	Y	Pers. observation
Tracheophyta: Polypodiopsida: n/a	*Punctatisporites*	Y	Y	–	–	Winslow 1962
Tracheophyta: Polypodiopsida: n/a	*Verrucosisporites*	–	Y	–	–	Winslow 1962
Tracheophyta: Polypodiopsida: n/a	"*Anapiculatisporites*"	–	Y	–	–	Winslow 1962
Tracheophyta: Polypodiopsida: n/a	*Spermatites*	–	Y	–	–	Winslow 1962
Tracheophyta: Polypodiopsida: n/a	*Laevigatosporites*	–	Y	–	–	Winslow 1962
Tracheophyta: Polypodiopsida: n/a	*Convolutispora*	–	Y	–	–	Winslow 1962
Tracheophyta: Polypodiopsida: Equisetales	*Calamospora*	–	Y	–	–	Winslow 1962
Tracheophyta: Polypodiopsida: Sphenophyllales	*Reticulatisporites*	–	Y	–	–	Winslow 1962
Tracheophyta: Progymnospermopsida: Archaeopteridales	*Callixylon*	–	Y	–	–	Winslow 1962
Tracheophyta: Progymnospermopsida: ?Noeggerathiales	cf. Noeggerathiales	–	–	–	Y	Pers. observation

Table 4. Paleozoic brachiopod taxa from CUVA in stratigraphic context. *Sartenaerus* replaces *Centrorhynchus*, which was already in use for a worm.

Class: Family	Taxon	Doh	Dbd	Dbr	Mc	Reference(s)
Brachiopoda undetermined	Brachiopoda indet.	Y	Y	?	Y	Hodnett 2022; pers. observation
Lingulata: n/a	*Orbiculoidea*	Y	–	–	–	Prosser 1912; Schwimmer and Feldmann 1990
Lingulata: Lingulidae	*Lingula*	Y	–	–	–	Prosser 1912; Girty 1939; Schwimmer and Feldmann 1990
	Trigonoglossa	Y	–	–	–	Schwimmer and Feldmann 1990
Strophomenata: Meekellidae	*Schellwienella*	Y	–	–	–	Schwimmer and Feldmann 1990
Strophomenata: Chonetidae	*Chonetes*	Y	–	–	–	Prosser 1912
	Retichonetes	Y	–	–	–	Schwimmer and Feldmann 1990
Strophomenata: Productellidae	Productellidae indet.	Y	–	–	–	Schwimmer and Feldmann 1990
	Acanthatia	Y	–	–	–	Schwimmer and Feldmann 1990
	Productella	Y	–	–	–	Prosser 1912
Strophomenata: Strophalosiidae	*Strophalosia*	Y	–	–	–	Prosser 1912
Rhynchonellata: Dalmanellidae	*Dalmanella*	Y	–	–	–	Prosser 1912
Rhynchonellata: Onniellidae	*Aulacella*	Y	–	–	–	Schwimmer and Feldmann 1990
Rhynchonellata: Camarotoechiidae	*Camarotoechia*	Y	Y	–	–	Prosser 1912
	Leiorhynchus	Y	–	–	–	Prosser 1912; Schwimmer and Feldmann 1990
Rhynchonellata: Trigonirhynchiidae	*Sartenaerus*	Y	–	–	–	Schwimmer and Feldmann 1990
Rhynchonellata: Athyrididae	*Athyris*	Y	Y	–	–	Prosser 1912; Schwimmer and Feldmann 1990
	Composita	Y	–	–	–	Schwimmer and Feldmann 1990
Rhynchonellata: Ambocoeliidae	*Ambocoelia*	Y	Y	–	–	Prosser 1912; Schwimmer and Feldmann 1990
Rhynchonellata: Mucrospiriferidae	*Spinospirifer*	Y	–	–	–	Schwimmer and Feldmann 1990
Rhynchonellata: Cyrtospiriferidae	*Cyrtospirifer*	Y	–	–	–	Prosser 1912; Schwimmer and Feldmann 1990

Table 4 (continued). Paleozoic brachiopod taxa from CUVA in stratigraphic context. *Sartenaerus* replaces *Centrorhynchus*, which was already in use for a worm.

Class: Family	Taxon	Doh	Dbd	Dbr	Mc	Reference(s)
Rhynchonellata: Cyrtospiriferidae (continued)	*Sphenospira*	Y	–	–	–	Prosser 1912; Schwimmer and Feldmann 1990
Rhynchonellata: Elythidae	*Toryniferella*	Y	–	–	–	Schwimmer and Feldmann 1990
Rhynchonellata: Reticulariidae	*Reticularia*	Y	–	–	–	Prosser 1912
Rhynchonellata: Syringothyrididae	*Syringothyris*	Y	Y	–	–	Prosser 1912

Table 5. Paleozoic mollusk taxa from CUVA in stratigraphic context.

Class: Family	Taxon	Doh	Dbd	Dbr	Mc	Reference(s)
Bivalvia: Parallelodontidae	*Paralleolodon*	–	Y	–	–	Prosser 1912
Bivalvia: Modiomorphidae	*Palaeanatina*	Y	–	–	–	Prosser 1912
	cf. *Spathella*	Y	–	–	–	Schwimmer and Feldmann 1990
Bivalvia: Mytilidae	*Phthonia*	Y	–	–	–	Prosser 1912
Bivalvia: Malletiidae	*Palaeoneilo*	Y	Y	–	–	Prosser 1912
Bivalvia: Nuculanidae	*Nuculana*	–	Y	–	–	Prosser 1912
Bivalvia: Aviculopectinidae	cf. *Aviculopecten*	Y	–	–	–	Prosser 1912
Bivalvia: Grammysiidae	*Grammysia*	Y	–	–	–	Prosser 1912
	Sanguinolites	Y	–	–	–	Schwimmer and Feldmann 1990
	Sphenotus	Y	–	–	–	Prosser 1912
Bivalvia: Pterineidae	cf. *Actinopteria*	Y	–	–	–	Prosser 1912
	Leptodesma	Y	–	–	–	Prosser 1912; Schwimmer and Feldmann 1990
Bivalvia: Pterinopectinidae	cf. *Pterinopecten*	Y	–	–	–	Schwimmer and Feldmann 1990
Bivalvia: Schizodidae	*Schizodus*	Y	–	–	–	Prosser 1912
Cephalopoda: n/a	Orthocerida indet.	–	–	–	Y	Pers. observation

Table 5 (continued). Paleozoic mollusk taxa from CUVA in stratigraphic context.

Class: Family	Taxon	Doh	Dbd	Dbr	Mc	Reference(s)
Cephalopoda: Orthoceratidae	*Orthoceras*	Y	–	–	–	Prosser 1912
Cephalopoda: Prionoceratidae	*Prionoceras*	–	Y	–	–	House et al. 1986
Gastropoda: Bellerophontidae	*Bellerophon*	–	Y	–	–	Prosser 1912
Gastropoda: Euomphalidae	*Euomphalus*	Y	Y	–	Y	Prosser 1912; pers. observation

Table 6. Other Paleozoic invertebrate taxa from CUVA in stratigraphic context.

Phylum: Class: Family	Taxon	Doh	Dbd	Dbr	Mc	Reference(s)
n/a: n/a: n/a	Miscellaneous invertebrate traces	Y	Y	?	?	Pers. observation
Cnidaria: Hexacorallia: n/a	Rugosa indet.	?	Y	–	Y	Pers. observation
Cnidaria: Scyphozoa: Conulariidae	*Conularia*	–	Y	–	–	Prosser 1912
Bryozoa: n/a: n/a	Bryozoa indet.	?	Y	–	Y	Pers. observation
Phoronida: n/a: n/a	Hederelloidea indet.	–	Y	–	–	Pers. observation
Unknown: Tentaculita: n/a	Tentaculitida indet.	?	Y	–	–	Pers. observation
Arthropoda: n/a: n/a	Eurypterida indet.	–	Y	–	–	Hodnett 2022; pers. observation
Echinodermata: Crinoidea: n/a	Crinoidea indet.	–	Y	–	Y	Pers. observation

Table 7. Paleozoic chordate taxa from CUVA in stratigraphic context.

Class: Family	Taxon	Doh	Dbd	Dbr	Mc	Reference(s)
Conodonta: n/a	Conodonta spp.	Y	Y	–	Y	Hass 1947
Chondrichthyes: ?Orodontidae	"*Orodus*"	Y	–	–	–	Newberry 1873, 1875
Chondrichthyes: Petalodontidae	*Polyrhizodus*	Y	–	–	–	Newberry 1873, 1875
Chondrichthyes: Ctenacanthidae	Ctenacanthidae indet.	Y	–	–	–	Newberry 1873, 1875; Maisey 1984

Table 7 (continued). Paleozoic chordate taxa from CUVA in stratigraphic context.

Class: Family	Taxon	Doh	Dbd	Dbr	Mc	Reference(s)
Chondrichthyes: Ctenacanthidae (continued)	"*Cladodus*"	Y	–	–	–	Newberry 1873, 1875
	cf. *Goodrichthys*	–	Y	–	–	Hodnett 2022
Osteichthyes: n/a	Osteichthyes indet.	–	Y	–	–	Hodnett 2022
	?Actinopterygii	–	?	–	–	Hodnett 2022
	Palaeonisciformes indet.	Y	–	–	–	Newberry 1873, 1875
?Tetrapodomorpha: n/a	cf. Tetrapodomorpha	–	–	–	Y	Pers. observation

Table 8. Conodont taxa reported by Hass (1947) from stratigraphic units of CUVA. The occurrence of these taxa in their respective stratigraphic units may be from localities inside or outside of current park boundaries.

Order: Family	Taxon	Doh	Dbd	Dbr	Mc
n/a: Balognathidae	*Prioniodus*	Y	Y	–	Y
Ozarkodinida: Coleodontidae	*Hindeodelloides*	Y	–	–	–
	Lonchodina	Y	–	–	–
	Hindeodella	Y	Y	–	–
Ozarkodinida: Elictognathidae	*Siphonodella*	–	–	–	Y
Ozarkodinida: Idiognathodontidae	*Gnathodus*	–	–	–	Y
Ozarkodinida: Polygnathidae	*Polygnathus*	Y	Y	–	Y
Ozarkodinida: Spathognathodontidae	*Ozarkodina*	Y	–	–	–
	Pseudopolygnathus	–	–	–	Y
	Spathognathodus	Y	Y	–	Y
	Telumodina	Y	–	–	Y
Prioniodinida: Prioniodinidae	*Bryantodus*	Y	Y	–	–
	Prioniodina	Y	–	–	Y
	Ligonodina	Y	Y	–	Y
	Subbryantodus	Y	–	–	Y
	Trichognathus	Y	–	–	Y

Appendix B: Museum Collections Data

Collections in Other Repositories

The following tables, Tables 9–12, include information on the CUVA fossil specimens housed in the collection at CMC (Table 9), CMNH (Table 10), CMP (Table 11), and MWAC (Table 12). Geologic units have been abbreviated for space (Fm. = Formation; Mbr. = Member). See the text and Appendix E for more locality information, and Appendix A for definitions of "cf.", "indet.", and "sp.". Note that outdated names used in collections are not corrected; for example, the brachiopod genus name *Centrorhynchus* is preoccupied (the name was already in use for a modern parasitic worm) and has been replaced by *Sartenaerus* in the literature.

Table 9. CUVA paleontological specimens currently housed at CMC.

Catalog #	Locality #	Geologic Unit	Taxon
CMC IP65818	CUVA-PAL-005	Ohio Shale Fm.	*Productus* sp.
CMC IP67215	CUVA-PAL-005	Ohio Shale Fm.	*Spirifer disjunctus*
CMC IP54092	CUVA-PAL-005	Ohio Shale Fm.	*Rhynchonella* sp.
CMC IP490	?	Ohio Shale Fm.	*Spirifer disjunctus*

Table 10. CUVA paleontological specimens currently housed at CMNH.

Catalog #	Locality #	Geologic Unit	Taxon
CMNH 6323	CUVA-PAL-002	Bedford Fm.	Ctenacanthidae gen. et sp. nov.
CMNH 8401	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Orbiculoidea* sp.
CMNH 8402	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Lingula arcta*
CMNH 8403	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Trigonoglossa* sp.
CMNH 8404	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Lingula eriensis*
CMNH 8405	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Lingula eriensis*
CMNH 8406	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Aulacella* sp.
CMNH 8407	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Aulacella* sp.
CMNH 8408	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Aulacella* sp.
CMNH 8409	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Aulacella* sp.

Table 10 (continued). CUVA paleontological specimens currently housed at CMNH.

Catalog #	Locality #	Geologic Unit	Taxon
CMNH 8410	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Aulacella* sp.
CMNH 8411	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Aulacella* sp.
CMNH 8412	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Aulacella* sp.
CMNH 8413	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Schellwienella* sp.
CMNH 8414	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Schellwienella* sp.
CMNH 8415	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Schellwienella* sp.
CMNH 8416	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Schellwienella* sp.
CMNH 8417	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Schellwienella* sp.
CMNH 8418	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Schellwienella* sp.
CMNH 8419	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Retichonetes* sp.
CMNH 8420	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Retichonetes* sp.
CMNH 8421	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Retichonetes* sp.
CMNH 8422	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Retichonetes* sp.
CMNH 8423	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Retichonetes* sp.
CMNH 8424	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Retichonetes* sp.
CMNH 8425	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Retichonetes* sp.
CMNH 8426	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Retichonetes* sp.
CMNH 8427	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	Productellidae gen. indet.
CMNH 8428	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	Productellidae gen. indet.
CMNH 8429	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	Productellidae gen. indet.
CMNH 8430	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Acanthatia* sp.

Table 10 (continued). CUVA paleontological specimens currently housed at CMNH.

Catalog #	Locality #	Geologic Unit	Taxon
CMNH 8431	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Acanthatia* sp.
CMNH 8432	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Acanthatia* sp.
CMNH 8433	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Acanthatia* sp.
CMNH 8434	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Acanthatia* sp.
CMNH 8435	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Acanthatia* sp.
CMNH 8436	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Acanthatia* sp.
CMNH 8437	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Acanthatia* sp.
CMNH 8438	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Acanthatia* sp.
CMNH 8439	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Acanthatia* sp.
CMNH 8440	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Acanthatia* sp.
CMNH 8441	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Centrorhynchus* sp.
CMNH 8442	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Centrorhynchus* sp.
CMNH 8443	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Centrorhynchus* sp.
CMNH 8444	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Centrorhynchus* sp.
CMNH 8445	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Centrorhynchus* sp.
CMNH 8446	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Centrorhynchus* sp.
CMNH 8447	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Centrorhynchus* sp.
CMNH 8448	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Centrorhynchus* sp.
CMNH 8449	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Centrorhynchus* sp.
CMNH 8450	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Centrorhynchus* sp.
CMNH 8451	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Centrorhynchus* sp.

Table 10 (continued). CUVA paleontological specimens currently housed at CMNH.

Catalog #	Locality #	Geologic Unit	Taxon
CMNH 8452	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Centrorhynchus* sp.
CMNH 8453	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	"*Leiorhynchus*" sp.
CMNH 8454	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	"*Leiorhynchus*" sp.
CMNH 8455	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	"*Leiorhynchus*" sp.
CMNH 8456	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	"*Leiorhynchus*" sp.
CMNH 8457	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	"*Leiorhynchus*" sp.
CMNH 8458	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	"*Leiorhynchus*" sp.
CMNH 8459	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	"*Leiorhynchus*" sp.
CMNH 8460	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	"*Leiorhynchus*" sp.
CMNH 8461	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	"*Leiorhynchus*" sp.
CMNH 8462	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Athyris* sp.
CMNH 8463	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Athyris* sp.
CMNH 8464	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Athyris* sp.
CMNH 8465	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Athyris* sp.
CMNH 8466	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Athyris* sp.
CMNH 8467	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Composita* sp.
CMNH 8468	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Athyris* sp.
CMNH 8469	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Composita* sp.
CMNH 8470	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Composita* sp.
CMNH 8471	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Composita* sp.
CMNH 8472	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Composita* sp.

Table 10 (continued). CUVA paleontological specimens currently housed at CMNH.

Catalog #	Locality #	Geologic Unit	Taxon
CMNH 8473	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Spinospirifer* sp.
CMNH 8474	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Spinospirifer* sp.
CMNH 8475	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Spinospirifer* sp.
CMNH 8476	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Ambocoelia* sp.
CMNH 8477	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Ambocoelia* sp.
CMNH 8478	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Ambocoelia* sp.
CMNH 8479	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Ambocoelia* sp.
CMNH 8480	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Ambocoelia* sp.
CMNH 8481	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Cyrtospirifer leboeufensis*
CMNH 8482	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Cyrtospirifer leboeufensis*
CMNH 8483	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Cyrtospirifer leboeufensis*
CMNH 8484	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Cyrtospirifer leboeufensis*
CMNH 8485	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Cyrtospirifer leboeufensis*
CMNH 8486	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Cyrtospirifer leboeufensis*
CMNH 8487	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Cyrtospirifer leboeufensis*
CMNH 8488	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Spinospirifer* sp.
CMNH 8489	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Cyrtospirifer spicatus*
CMNH 8490	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Cyrtospirifer spicatus*
CMNH 8491	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Cyrtospirifer spicatus*
CMNH 8492	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Cyrtospirifer spicatus*
CMNH 8493	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Cyrtospirifer spicatus*

Table 10 (continued). CUVA paleontological specimens currently housed at CMNH.

Catalog #	Locality #	Geologic Unit	Taxon
CMNH 8494	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Cyrtospirifer spicatus*
CMNH 8495	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Sphenospira alta*
CMNH 8496	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Sphenospira alta*
CMNH 8497	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Sphenospira alta*
CMNH 8498	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Sphenospira alta*
CMNH 8499	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Toryniferella* sp.
CMNH 8500	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Toryniferella* sp.
CMNH 8501	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Toryniferella* sp.
CMNH 8502	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Toryniferella* sp.
CMNH 8503	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Toryniferella* sp.
CMNH 8504	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Toryniferella* sp.
CMNH 8505	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Toryniferella* sp.
CMNH 8506	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	?*Pterinopecten* sp.
CMNH 8507	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	?*Pterinopecten* sp.
CMNH 8508	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	?*Pterinopecten* sp.
CMNH 8509	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	?*Pterinopecten* sp.
CMNH 8510	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Sanguinolites* sp.
CMNH 8511	CUVA-PAL-004	Ohio Shale Fm. (Chagrin Mbr.)	*Leptodesma* sp.
CMNH 8512	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	?*Spathella* sp.
CMNH 8513	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Leptodesma* sp.
CMNH 8514	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Leptodesma* sp.

Table 10 (continued). CUVA paleontological specimens currently housed at CMNH.

Catalog #	Locality #	Geologic Unit	Taxon
CMNH 8515	CUVA-PAL-005	Ohio Shale Fm. (Chagrin Mbr.)	*Leptodesma* sp.

Table 11. CUVA paleontological specimens currently housed at CMP.

Catalog #	Locality #	Geologic Unit	Taxa	Element(s)
n/a	CUVA-PAL-002	Bedford Fm.	Eurypterida indet., ?Actinopterygii indet.	eurypterid, ?fish tooth
n/a	CUVA-PAL-002	Bedford Fm.	Osteichthyes indet.	fish scale

Table 12. CUVA paleontological specimens currently housed at MWAC. The geologic origin of all specimens listed below is unknown.

Catalog #	Taxa
CUVA 1271	Brachiopoda indet., Crinoidea indet.
CUVA 1275	?
CUVA 1332	Brachiopoda indet.
CUVA 1573	?
CUVA 8416	Bryozoa indet.
CUVA 8419	Rugosa indet.
CUVA 8435	?
CUVA 8503	Rugosa indet.
CUVA 15071	Rugosa indet.
CUVA 23657	Brachiopoda indet.
CUVA 24044	Crinoidea indet.
CUVA 24377	Crinoidea indet., ?Gastropoda indet.
CUVA 26838	Brachiopoda indet.
CUVA 31047	?Rugosa indet.

Appendix C: Repository Contact Information

Contact information for institutions known to house collections from CUVA are included below. Addresses, phone numbers, links, and email addresses to departments are included as available. This information is subject to change, particularly hyperlinks.

CINCINNATI MUSEUM CENTER (CMC)
1301 Western Ave
Cincinnati, OH 45203
(513) 287-7000
https://www.cincymuseum.org/

CLEVELAND MUSEUM OF NATURAL HISTORY (CMNH)
1 Wade Oval Dr
Cleveland, OH 44106
(216) 231-4600
https://www.cmnh.org/

CLEVELAND METROPARKS (CMP)
4101 Fulton Parkway
Cleveland, OH 44144
(216) 635-3200
https://www.clevelandmetroparks.com/

KENT STATE UNIVERSITY (KSU)
PO Box 5190
Kent, OH 44242
(330) 672-3000
https://www.kent.edu/

MIDWEST ARCHEOLOGICAL CENTER (MWAC)
100 Centennial Mall North, Room 474
Lincoln, NE 68508
(402) 437-5392
https://home.nps.gov/orgs/1740/index.htm

NATIONAL MUSEUM OF NATURAL HISTORY (USNM)
PO Box 37012
Washington, D.C. 20013
https://naturalhistory.si.edu/

Appendix D: Paleontological Resource Law and Policy

The following material is reproduced in large part from Henkel et al. (2015); see also Kottkamp et al. (2020).

In March 2009, the Paleontological Resources Preservation Act (PRPA) (16 USC 460aaa) was signed into law (Public Law 111–11). This act defines paleontological resources as

> *…any fossilized remains, traces, or imprints of organisms, preserved in or on the [E]arth's crust, that are of paleontological interest and that provide information about the history of life on [E]arth.*

The law stipulates that the Secretary of the Interior should manage and protect paleontological resources using scientific principles. The Secretary should also develop plans for

> *…inventory, monitoring, and deriving the scientific and educational use of paleontological resources.*

Paleontological resources are considered park resources and values that are subject to the "no impairment" standard in the National Park Service Organic Act (1916). In addition to the Organic Act, PRPA will serve as a primary authority for the management, protection, and interpretation of paleontological resources. The proper management and preservation of these non-renewable resources should be considered by park resource managers whether or not fossil resources are specifically identified in the park's enabling legislation.

The Paleontological Resources Management section of NPS Reference Manual 77 provides guidance on the implementation and continuation of paleontological resource management programs. Administrative options include those listed below and a park management program will probably incorporate multiple options depending on specific circumstances:

- **No action**—no action would be taken to collect the fossils as they erode from the strata. The fossils would be left to erode naturally and over time crumble away, or possibly be vandalized by visitors, either intentionally or unintentionally. This is the least preferable plan of action of those listed here.
- **Surveys**—will be set up to document potential fossil localities. All sites will be documented with the use of GPS and will be entered into the park GIS database. Associated stratigraphic and depositional environment information will be collected for each locality. A preliminary fossil list will be developed. Any evidence of poaching activity will be recorded. Rates of erosion will be estimated for the site and a monitoring schedule will be developed based upon this information. A NPS Paleontological Locality Database Form will also be completed for each locality. A standard version of this form will be provided by the Paleontology Program of the Geologic Resources Division upon request and can be modified to account for local conditions and needs.

- **Monitoring**—fossil-rich areas would be examined periodically to determine if conditions have changed to such an extent that additional management actions are warranted. Photographic records should be kept so that changes can be more easily ascertained.
- **Cyclic prospecting**—areas of high erosion which also have a high potential for producing significant specimens would be examined periodically for new sites. The periodicity of such cyclic prospecting will depend on locality-specific characteristics such as rates of sediment erosion, abundance or rarity of fossils, and proximity to visitor use areas.
- **Stabilization and reburial**—significant specimens which cannot be immediately collected may be stabilized using appropriate consolidants and reburied. Reburial slows down but does not stop the destruction of a fossil by erosion. Therefore, this method would be used only as an interim and temporary stop-gap measure. In some situations, stabilization of a locality may require the consideration of vegetation. For example, roots can destroy in situ fossils, but can also protect against slope erosion, while plant growth can effectively obscure localities, which can be positive or negative depending on how park staff want to manage a locality.
- **Shelter construction**—it may be appropriate to exhibit certain fossil sites or specimens in situ, which would require the construction of protective shelters to protect them from the natural forces of weathering and erosion. The use of shelters draws attention to the fossils and increases the risk of vandalism or theft, but also provides opportunities for interpretation and education.
- **Excavation**—partial or complete removal of any or all fossils present on the surface and potentially the removal of specimens still beneath the surface which have not been exposed by erosion.
- **Closure**—the area containing fossils may be temporarily or permanently closed to the public to protect the fossil resources. Fossil-rich areas may be closed to the public unless accompanied by an interpretive ranger on a guided hike.
- **Patrols**—may be increased in areas of known fossil resources. Patrols can prevent and/or reduce theft and vandalism. The scientific community and the public expect the NPS to protect its paleontological resources from vandalism and theft. In some situations, a volunteer site stewardship program may be appropriate (for example the "Paleo Protectors" at Chesapeake & Ohio Canal National Historical Park).
- **Alarm systems/electronic surveillance**—seismic monitoring systems can be installed to alert rangers of disturbances to sensitive paleontological sites. Once the alarm is engaged, a ranger can be dispatched to investigate. Motion-activated cameras may also be mounted to visually document human activity in areas of vulnerable paleontological sites.

National Park Service Management Policies (2006; Section 4.8.2.1) also require that paleontological resources, including both organic and mineralized remains in body or trace form, will be protected, preserved, and managed for public education, interpretation, and scientific research. In 2010, the National Park Service established National Fossil Day as a celebration and partnership organized to

promote public awareness and stewardship of fossils, as well as to foster a greater appreciation of their scientific and educational value (https://www.nps.gov/subjects/fossilday/index.htm). National Fossil Day occurs annually on Wednesday of the second full week in each October in conjunction with Earth Science Week.

Related Laws, Legislation, and Management Guidelines

National Park Service Organic Act

The NPS Organic Act directs the NPS to manage units

> *...to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such a manner as will leave them unimpaired for the enjoyment of future generations. (16 U.S.C. § 1).*

Congress reiterated this mandate in the Redwood National Park Expansion Act of 1978 by stating that the NPS must conduct its actions in a manner that will ensure no

> *...derogation of the values and purposes for which these various areas have been established, except as may have been or shall be directly and specifically provided by Congress. (16 U.S.C. § 1 a-1).*

The Organic Act prohibits actions that permanently impair park resources unless a law directly and specifically allows for the acts. An action constitutes an impairment when its impacts

> *...harm the integrity of park resources or values, including the opportunities that otherwise would be present for the enjoyment of those resources and values. (Management Policies 2006 1.4.3).*

Paleontological Resources Protection Act (P.L. 111-011, Omnibus Public Land Management Act of 2009, Subtitle D)

Section 6302 states

> *The Secretary (of the Interior) shall manage and protect paleontological resources on Federal land using scientific principles and expertise. The Secretary shall develop appropriate plans for inventory, monitoring, and the scientific and educational use of paleontological resources, in accordance with applicable agency laws, regulations, and policies. These plans shall emphasize interagency coordination and collaborative efforts where possible with non-Federal partners, the scientific community, and the general public.*

Federal Cave Resources Protection Act of 1988 (16 USC 4301)

This law provides a legal authority for the protection of all cave resources on NPS and other federal lands. The definition for "Cave Resource" in Section 4302 states

Cave resources include any material or substance occurring naturally in caves on Federal lands, such as animal life, plant life, paleontological deposits, sediments, minerals, speleogens, and speleothems.

NPS Management Policies 2006

NPS Management Policies 2006 include direction for preserving and protecting cultural resources, natural resources, processes, systems, and values (National Park Service 2006). It is the goal of the NPS to avoid or minimize potential impacts to resources to the greatest extent practicable consistent with the management policies. The following is taken from section 4.8.2.1 of the NPS Management Policies 2006, "Paleontological Resources and their contexts":

Paleontological resources, including both organic and mineralized remains in body or trace form, will be protected, preserved, and managed for public education, interpretation, and scientific research. The Service will study and manage paleontological resources in their paleoecological context (that is, in terms of the geologic data associated with a particular fossil that provides information about the ancient environment).

Superintendents will establish programs to inventory paleontological resources and systematically monitor for newly exposed fossils, especially in areas of rapid erosion. Scientifically significant resources will be protected by collection or by on-site protection and stabilization. The Service will encourage and help the academic community to conduct paleontological field research in accordance with the terms of a scientific research and collecting permit. Fossil localities and associated geologic data will be adequately documented when specimens are collected. Paleontological resources found in an archeological context are also subject to the policies for archeological resources. Paleontological specimens that are to be retained permanently are subject to the policies for museum objects.

The Service will take appropriate action to prevent damage to and unauthorized collection of fossils. To protect paleontological resources from harm, theft, or destruction, the Service will ensure, where necessary, that information about the nature and specific location of these resources remains confidential, in accordance with the National Parks Omnibus Management Act of 1998.

Parks will exchange fossil specimens only with other museums and public institutions that are dedicated to the preservation and interpretation of natural heritage and qualified to manage museum collections. Fossils to be deaccessioned in an exchange must fall outside the park's scope of collection statement. Systematically collected fossils in an NPS museum collection in compliance with 36 CFR 2.5 cannot be outside the scope of the collection statement. Exchanges must follow deaccession procedures in the Museum Handbook, Part II, chapter 6.

The sale of original paleontological specimens is prohibited in parks.

The Service generally will avoid purchasing fossil specimens. Casts or replicas should be acquired instead. A park may purchase fossil specimens for the park museum collection only after making a written determination that

- *The specimens are scientifically significant and accompanied by detailed locality data and pertinent contextual data;*
- *The specimens were legally removed from their site of origin, and all transfers of ownership have been legal;*
- *The preparation of the specimens meets professional standards;*
- *The alternatives for making these specimens available to science and the public are unlikely;*
- *Acquisition is consistent with the park's enabling legislation and scope of collection statement, and acquisition will ensure the specimens' availability in perpetuity for public education and scientific research.*

All NPS construction projects in areas with potential paleontological resources must be preceded by a preconstruction surface assessment prior to disturbance. For any occurrences noted, or when the site may yield paleontological resources, the site will be avoided or the resources will, if necessary, be collected and properly cared for before construction begins. Areas with potential paleontological resources must also be monitored during construction projects.

(See Natural Resource Information 4.1.2; Studies and Collections 4.2; Independent Research 5.1.2; and Artifacts and Specimens 10.2.4.6 in NPS 2006, available here. Also see 36 CFR 2.5.)

NPS Director's Order-77, Paleontological Resources Management

DO-77 describes fossils as non-renewable resources and identifies the two major types, body fossils and trace fossils. It describes the need for managers to identify potential paleontological resources using literature and collection surveys, identify areas with potential for significant paleontological resources, and conduct paleontological surveys (inventory). It also describes appropriate actions for managing paleontological resources including: no action, monitoring, cyclic prospecting, stabilization and reburial, construction of protective structures, excavation, area closures, patrols, and the need to maintain confidentiality of sensitive location information.

Excerpt from Clites and Santucci (2012):

Monitoring

An important aspect of paleontological resource management is establishing a long-term paleontological resource monitoring program. National Park Service paleontological resource monitoring strategies were developed by Santucci et al. (2009). The park's monitoring program should incorporate the measurement and evaluation of the factors stated below.

Climatological Data Assessments
These assessments include measurements of factors such as annual and storm precipitation, freeze/thaw index (number of 24-hour periods per year where temperature fluctuates above and below 32 degrees Fahrenheit), relative humidity, and peak hourly wind speeds.

Rates of Erosion Studies
These studies require evaluation of lithology, slope degree, percent vegetation cover, and rates of denudation around established benchmarks. If a park does not have this information, there may be opportunities to set up joint projects, because erosion affects more than just paleontological resources.

Assessment of Human Activities, Behaviors, and Other Variables
These assessments involve determining access/proximity of paleontological resources to visitor use areas, annual visitor use, documented cases of theft/vandalism, commercial market value of the fossils, and amount of published material on the fossils.

Condition Assessment and Cyclic Prospecting
These monitoring methods entail visits to the locality to observe physical changes in the rocks and fossils, including the number of specimens lost and gained at the surface exposure. Paleontological prospecting would be especially beneficial during construction projects or road repair.

Periodic Photographic Monitoring
Maintaining photographic archives and continuing to photo-document fossil localities from established photo-points enables visual comparison of long-term changes in site variables.

Appendix E: Paleontological Locality Data

During the 2024 inventory, 15 paleontological localities were documented for CUVA. These localities were confirmed to either possess substantial/significant paleontological resources currently or to have produced fossil specimens currently housed within museum collections. Table 13 below contains basic information on the verified localities, including stratigraphy, lithology, and the fossil taxa observed. Detailed information is available to qualified researchers upon request.

Table 13. CUVA paleontological locality data.

Locality #	Geologic Unit	Lithology	Taxa
CUVA-PAL-001	Ohio Shale Fm.	shale	Brachiopoda spp., Bivalvia spp.
CUVA-PAL-002	Bedford Fm.	shale/siltstone	*Conularia,* Brachiopoda spp., Bivalvia spp., *Prionoceras*, Eurypterida indet., cf. *Goodrichthys*, Osteichthyes, ?Actinopterygii, Conodonta spp., “palynomorphs”, *Callixylon*
CUVA-PAL-003	Ohio Shale/Bedford Fms.	shale	Brachiopoda spp., *Prionoceras*
CUVA-PAL-004	Ohio Shale Fm.	shale	Brachiopoda spp., Bivalvia spp., *Euomphalus*, Conodonta spp., “palynomorphs”
CUVA-PAL-005	Ohio Shale/Bedford Fms.	shale	Bryozoa indet., Brachiopoda spp., Bivalvia spp., *Prionoceras, Euomphalus*, Conodonta spp.
CUVA-PAL-006	Bedford Fm./Cuyahoga Gp.	sandstone/siltstone	Rugosa indet., Bryozoa indet., Brachiopoda spp., Hederelloidea indet., Tentaculitida indet., Bivalvia spp., *Euomphalus*, Crinoidea indet.
CUVA-PAL-007	Ohio Shale Fm.	siltstone	Rugosa indet., Brachiopoda spp., Tentaculitida indet.
CUVA-PAL-008	Bedford Fm.	shale	Brachiopoda spp., Tentaculitida indet.
CUVA-PAL-009	Ohio Shale Fm.	siltstone	Rugosa indet., Brachiopoda spp.
CUVA-PAL-010	Cuyahoga Gp.	sandstone	Tracheophyta indet., cf. *Lepidodendropsis*, cf. Noeggerathiales, cf. Tetrapodomorpha
CUVA-PAL-011	Bedford Fm.	sandstone/siltstone	Bryozoa indet., Brachiopoda spp., Crinoidea indet.

Table 13 (continued). CUVA paleontological locality data.

Locality #	Geologic Unit	Lithology	Taxa
CUVA-PAL-012	Cuyahoga Gp.	siltstone	Rugosa indet., Bryozoa indet., Brachiopoda spp., Orthocerida indet., *Euomphalus*, Crinoidea indet.
CUVA-PAL-013	Cuyahoga Gp.	siltstone	Rugosa indet., Bryozoa indet., Brachiopoda spp., Crinoidea indet.
CUVA-PAL-014	Cuyahoga Gp.	sandstone/siltstone	Brachiopoda spp., *Euomphalus*, Crinoidea indet.
CUVA-PAL-015	Cuyahoga Gp.	sandstone/siltstone	Rugosa indet., Bryozoa indet., Brachiopoda spp., Crinoidea indet.

Appendix F: Geologic Time Scale

A geologic time scale (Figure 34) is provided below for reference.

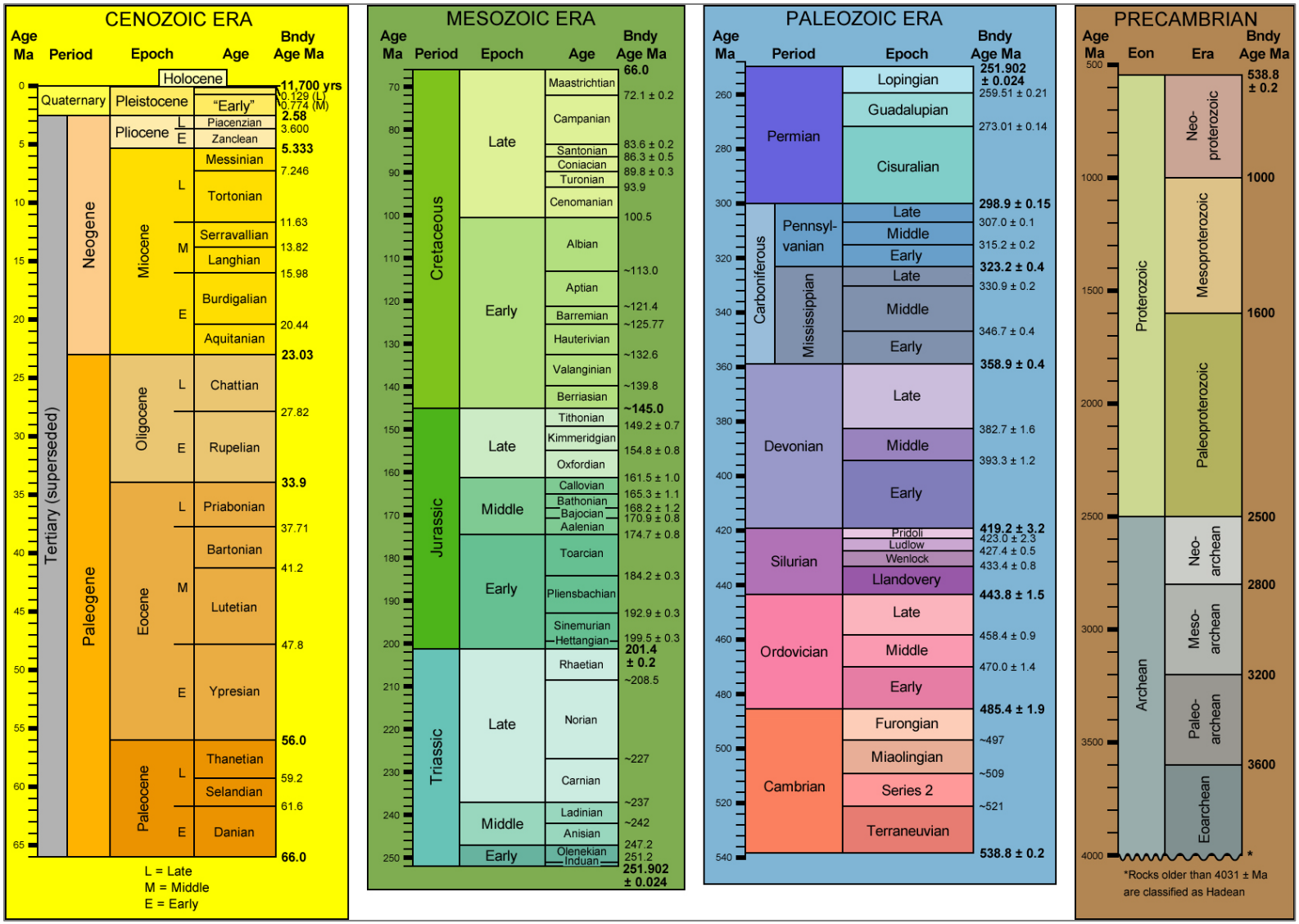


Figure 34. Geologic time scale. Ma=Millions of years old. Bndy Age=Boundary Age. Layout after 1999 Geological Society of America Time Scale (https://rock.geosociety.org/net/documents/gsa/timescale/timescl-1999.pdf). Dates after International Commission on Stratigraphy version 2023/09. NPS / JUSTIN TWEET

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