Geologic Resources Inventory Scoping Summary
Cuyahoga Valley National Park, Ohio

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January 25, 2010

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US Department of the Interior

The Geologic Resources Inventory (GRI) provides each of 270 identified natural area National Park System units with a geologic scoping meeting and summary (this document), a digital geologic map, and a geologic resources inventory report. The purpose of scoping is to identify geologic mapping coverage and needs, distinctive geologic processes and features, resource management issues, and monitoring and research needs. Geologic scoping meetings generate an evaluation of the adequacy of existing geologic maps for resource management, provide an opportunity to discuss park-specific geologic management issues, and if possible include a site visit with local experts.

The National Park Service held a GRI scoping meeting for Cuyahoga Valley National Park on October 5, 2009 at the Boston Store Visitor Center in Boston Township, Ohio. A site visit at the park was conducted on October 5-6, 2009. Tim Connors (NPS-GRD) facilitated the discussion of map coverage and Lisa Norby (NPS-GRD) led the discussion regarding geologic processes and features at the park. Mike Angle from the Ohio Department of Natural Resources (ODNR) presented a brief geologic overview of the park and surrounding area. John Szabo, from the University of Akron, presented a brief glacial history of northern Ohio. Anthony Gareau from Cuyahoga Valley National Park presented a slideshow of some of the more distinctive geologic features within the park as well as a status of some of the GIS projects currently underway in the park including repeat photography of geologic sites done by Charles Prosser in 1912. Participants at the meeting included NPS staff from the park and Geologic Resources Division, geologists from the Ohio Department of Natural Resources, academics from University of Akron, Kent State University, and Bowling Green State University, and cooperators from Colorado State University (see table 2). This scoping summary highlights the GRI scoping meeting for Cuyahoga Valley National Park including the geologic setting, the plan for providing a digital geologic map, a prioritized list of geologic resource management issues, a description of significant geologic features and processes, lists of recommendations and action items, and a record of meeting participants.

Park and Geologic Setting

First established as a national recreation area on December 27, 1974, Cuyahoga Valley National Park was redesignated as a national park by Congress on October 11, 2000. The park protects 13,354 ha (33,000 ac) in Cuyahoga and Summit counties of northern Ohio, preserving a 35-km (22-mi) stretch of the Cuyahoga River between Cleveland and Akron, Ohio within the greater Ohio & Erie Canal National Heritage Corridor. Of this land, approximately 7,284 ha (18,000 ac) are federally owned with the remainder owned by local public agencies, private landowners, or private land with National Park Service easements. Human interest and uses of the valley began over 12,000 years ago and it has served as a vital transportation corridor for centuries. The Portage Trail was a major Native American trade and migration route. The Ohio & Erie Canal opened in 1827 between Cleveland and Akron parallel to, and with water supplied by the Cuyahoga River. The

Valley Railway followed some 40 years later. The rugged geology and lack of reliable groundwater sources prevented development within the valley that occurred in surrounding areas. The geologic setting (i.e. rugged topography, lack of adequate groundwater) contributed to the preservation of the land that has been set aside as Cuyahoga Valley National Park.

The Cuyahoga River and its tributaries including Yellow Creek, Furnace Run, Tinkers Creek, West Creek (formerly Skinners Run), Brandywine Creek, and Chippewa Creek, are downcutting through mid- to late- Paleozoic sedimentary rocks overlain by Pleistocene-age glacial deposits. The park lies within the Glaciated Allegheny Plateau, Huron-Erie Lake Plains, and Till Plains physiographic regions of Ohio. As such, the park is in a transitional area between sediments and rocks affected by the mountain building (orogenies) of the Appalachian Mountains and the relatively undeformed landscape of the plains.

Gently dipping Paleozoic-age sedimentary rocks are exposed within Cuyahoga Valley National Park. These units include the Devonian Chagrin Shale, Cleveland Shale, Bedford Formation, and Berea Sandstone; the Mississippian Cuyahoga Formation; and the Pennsylvanian Sharon Conglomerate. These sedimentary rocks were deposited within a longstanding epicontinental sea east of the Cincinnati Arch. This area was a bay-like environment with periodically restricted water circulation. Source areas for sediments included the Canadian Shield to the north and east as well as the rising Appalachian Mountains to the east. The depositional environments at this time were shifting and complex; geologists continue to decipher the depositional features within the rocks exposed at Cuyahoga Valley. The Chagrin Shale, Cleveland Shale, and Bedford Formation accumulated primarily in shallow, intermittently anoxic seas. They consist of layers of fine-grained, organic shale interbedded with coarser grained storm deposits. The Berea Sandstone was deposited in a shifting, fluvio-deltaic environment. Throughout the Mississippian, the depositional environments changed from offshore marine, to coastal, to fluvial, and back to marine. The sedimentary members of the Cuyahoga Group (ascending upwards: Orangeville, Sharpsville, Strongsville, and Meadville members) reflect these depositional settings. The overlying, coarse-grained, quartz-pebble-rich Pennsylvanian Sharon Conglomerate formed in a high-energy, braided stream environment.

Stream incision carved a deep valley through the Paleozoic sedimentary rocks prior to the formation of the present Cuyahoga Valley. This paleo-valley filled with sediments during Pleistocene glaciations. Evidence of prior glaciations is obscured by the vast landforms of the late Wisconsinan glacial maximum. The glacial history of the area is extremely complex. Glacial landforms include ground moraines, end moraines, dissected outwash terraces, glacio-lacustrine deposits, and kames and eskers that are found primarily south of the park boundary. Glacial drift tends to be thicker in valleys and thinner on upland areas.

The landscape at the park varies from relatively flat, open floodplain areas along the flanks of the Cuyahoga River and its larger tributaries, to near vertical cliffs of sandstone and conglomerate atop less resistant shale layers. Modern alluvium lines the river valleys and some tributary valleys. Colluvial deposits (rock debris that collects at the base of a slope by mass wasting) are common along the steep valley slopes. There are more than 65 individual soil types mapped within the park. According to Tom Nash, nearly 800 soil phases (subdivisions mapped within soil types based on erosion, slope, stoniness, or soluble mineral content) attest to the geographic complexity of soils in Summit County, Ohio.

Geologic Mapping for Cuyahoga Valley National Park

During the scoping meeting, Tim Connors (NPS-GRD) showed some of the main features of the GRI's digital geologic maps, which reproduce all aspects of the original paper maps, including notes, legend, and cross sections, with the added benefit of being geographic information system (GIS) compatible. The GRI geology geodatabase data model incorporates fundamental GIS design principles and methods to provide a uniform digital map production standard and rigorous quality control for each dataset and map produced throughout the NPS. Staff members digitize maps or convert digital data to the GRI digital geologic map model using ESRI ArcGIS software. Final digital geologic map products include data in geodatabase and shapefile format, layer files complete with feature symbology, Federal Geographic Data Committee (FGDC)-compliant metadata, an Adobe Acrobat PDF help document that captures ancillary map data, and a map document that displays the map, and provides a tool to access the PDF help document directly from the map document. Final data products are posted at http://science.nature.nps.gov/nrdata/. The data model is available at http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm.

When possible, the GRI Program provides large scale (1:24,000) digital geologic map coverage for each park's area of interest, which is often composed of the 7.5-minute quadrangles that contain park lands (fig. 1). Maps of this scale (and larger) are useful to resource managers because they capture most geologic features of interest and are spatially accurate within 12 m (40 ft). The process of selecting maps for management begins with the identification of existing geologic maps (table 1) and mapping needs in the vicinity of the park. Scoping session participants then select appropriate source maps for the digital geologic data or develop a plan to obtain new mapping, if necessary.

Table 1. GRI Mapping Plan for Cuyahoga Valley National Park (CUVA)

Covered Quadrangles	Relationship to the park	Citation	Format	GRI Action
Chagrin Falls OH 7.5'	Non-intersecting qoi	(2490) Larsen, G.E. and Slucher, E.R., 1996, Reconnaissance bedrock geology of the Chagrin Falls, Ohio, quadrangle, Ohio Division of Geological Survey, Open-File Map 1:24000 scale	Digital GIS (ESRI)	Already have digital bedrock in GRI format; intersects watershed of interest supplied by CUVA
Shaker Heights OH 7.5'	Intersects CUVA	(2493) Larsen, G.E. and Slucher, E.R., 1996, Reconnaissance bedrock geology of the Shaker Heights, Ohio, quadrangle, Ohio Division of Geological Survey, Open-File Map 1:24000 scale	Digital GIS (ESRI)	Already have digital bedrock in GRI format: ; intersects watershed of interest supplied by CUVA
Cleveland South OH 7.5'	Intersects CUVA	(2486) Larsen, G.E., 1996, Preliminary bedrock geology of the Cleveland South, Ohio, quadrangle, Ohio Division of Geological Survey, Open-File Map 1:24000 scale	Digital GIS (ESRI)	Already have digital bedrock in GRI format; ; intersects watershed of interest supplied by CUVA

Covered Quadrangles	Relationship to the park	Citation	Format	GRI Action
Lakewood OH 7.5'	Non-intersecting qoi	(2487) Larsen, G.E., 1996, Preliminary bedrock geology of the Lakewood, Ohio, quadrangle, Ohio Division of Geological Survey, Open-File Map 1:24000 scale	Digital GIS (ESRI)	Already have digital bedrock in GRI format
Twinsburg OH 7.5'	Non-intersecting qoi	(2494) Larsen, G.E. and Slucher, E.R., 1996, Reconnaissance bedrock geology of the Twinsburg, Ohio, quadrangle, Ohio Division of Geological Survey, Open-File Map 1:24000 scale	Digital GIS (ESRI)	Already have digital bedrock in GRI format; intersects watershed of interest supplied by CUVA
Northfield OH 7.5'	Intersects CUVA	(2491) Larsen, G.E. and Slucher, E.R., 1996, Reconnaissance bedrock geology of the Northfield, Ohio, quadrangle, Ohio Division of Geological Survey, Open-File Map 1:24000 scale	Digital GIS (ESRI)	Already have digital bedrock in GRI format; intersects watershed of interest supplied by CUVA
Broadview Heights OH 7.5'	Intersects CUVA	(2488) Larsen, G.E. and Slucher, E.R., 1996, Preliminary bedrock geology of the Broadview Heights, Ohio, quadrangle, Ohio Division of Geological Survey, Open-File Map 1:24000 scale	Digital GIS (ESRI)	Already have digital bedrock in GRI format; intersects watershed of interest supplied by CUVA
Hudson OH 7.5'	Intersects CUVA	(2496) Slucher, E.R., 1996, Reconnaissance bedrock geology of the Hudson, Ohio, quadrangle, Ohio Division of Geological Survey, Open-File Map 1:24000 scale	Digital GIS (ESRI)	Already have digital bedrock in GRI format; intersects watershed of interest supplied by CUVA
Peninsula OH 7.5'	Intersects CUVA	(2492) Larsen, G.E. and Slucher, E.R., 1996, Reconnaissance bedrock geology of the Peninsula, Ohio, quadrangle, Ohio Division of Geological Survey, Open-File Map 1:24000 scale	Digital GIS (ESRI)	Already have digital bedrock in GRI format; intersects watershed of interest supplied by CUVA
West Richfield OH 7.5'	Intersects CUVA	(2489) Larsen, G.E. and Slucher, E.R., 1996, Preliminary bedrock geology of the West Richfield, Ohio, quadrangle, Ohio Division of Geological Survey, Open-File Map 1:24000 scale	Digital GIS (ESRI)	Already have digital bedrock in GRI format; intersects watershed of interest supplied by CUVA
Akron East OH 7.5'	Non-intersecting qoi	(2495) Slucher, E.R., 1996, Reconnaissance bedrock geology of the Akron East, Ohio, quadrangle, Ohio Division of Geological Survey, Open-File Map 1:24000 scale	Digital GIS (ESRI)	Already have digital bedrock in GRI format; intersects watershed of interest supplied by CUVA
Akron West OH 7.5'	Intersects CUVA	(4081) Slucher, E.R. and Larsen, G.E., 1996, Reconnaissance bedrock geology of the Akron West, Ohio, quadrangle, Ohio Division of Geological Survey, Open-File Map 1:24000 scale	Digital GIS (ESRI)	Already have digital bedrock in GRI format; intersects watershed of interest supplied by CUVA

Covered Quadrangles	Relationship to the park	Citation	Format	GRI Action
Wadsworth, OH 7.5'	Non-intersection qoi	Slucher, E. R., and K. E. Vorbau. 1997. Reconnaissance bedrock geology of the Wadsworth, Ohio quadrangle, Ohio Division of Geological Survey, Open-File Map 1:24000 scale	Digital	Convert to GRI digital geologic-GIS map datamodel; intersects watershed of interest supplied by CUVA
Cleveland South 30x60	Intersects CUVA	(75183) Pavey, R.R., Schumacher, G.A., Larsen, G.L., Swinford, E.M., and Vorbau, K.E., 2000, Surficial geology of the Cleveland South 30 x 60 minute quadrangle Digital Map Series SG-2, 1: 100000 scale	Digital	Convert to GRI digital geologic-GIS map datamodel
Summit County, OH (not a quadrangle)	Intersects CUVA	(21061) White, G. W. 1984. Glacial geology of Summit County, Ohio. Scale 1:62,500. Report of Investigations 123, Ohio Division of Geological Survey	Paper?	Need to obtain map scans, digitize, and incorporate into GRI CUVA digital geologic map coverage.
Cuyahoga County, OH (not a quadrangle)	Intersects CUVA	(21071) Ford, J. P. 1987. Glacial geology of Cuyahoga County, Ohio. Scale 1:62,500. Report of Investigations 134, Ohio Division of Geological Survey	Paper?	Need to obtain map scans, digitize, and incorporate into GRI CUVA digital geologic map coverage.
Quaternary Geology of Ohio	Intersects CUVA	Pavey, R. R., R. P. Goldthwait, C. S. Brockman, D. N. Hull, E. M. Swinford, and R.G. Van Horn. Scale 1:500,000. Map No. 2, Ohio Division of Geological Survey	Digital	Shapefile sent by Jim McDonald?
Glacial Geology of Northeastern Ohio	Intersects CUVA	G. W. White, 1982. Map scale 1:250,000. Bulletin 68, Ohio Division of Geological Survey	Paper	Copy sent by Mike Angle
Bedrock Geologic Map of Ohio	Intersects CUVA	E. R. Slucher, E. M. Swinford, G. E. Larsen, G. A. Schumacher, D. L. Shrake, C. L. Rice, M. R. Caudill, and R. G. Rea, 2006. Map Scale 1:500,000. Map No. BG-1, Ohio DIvison of Geological Survey	Paper or Digital	

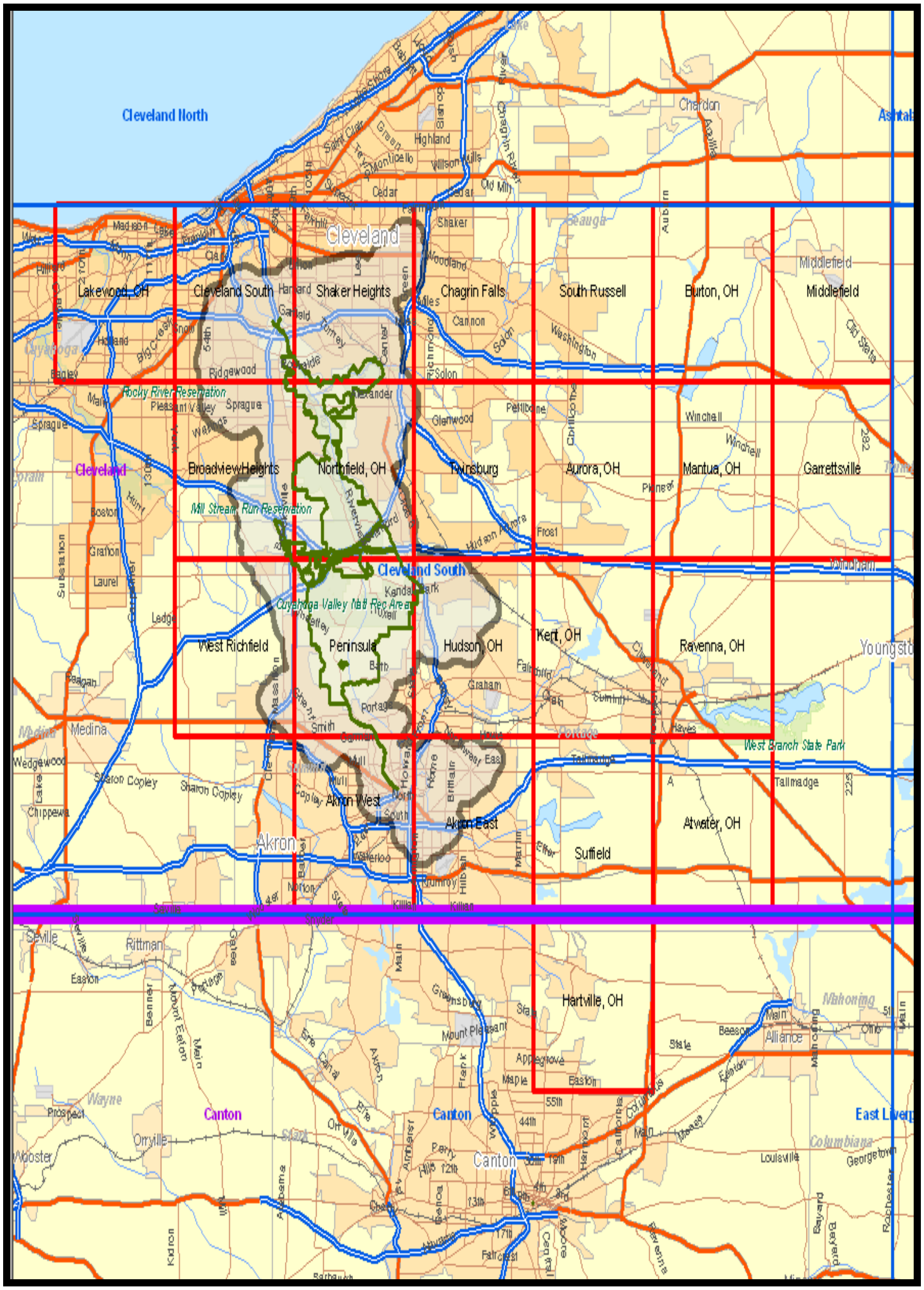

Figure 1. Area of interest for Cuyahoga Valley National Park, Ohio. The 7.5-minute quadrangles are labeled in black; names and lines in blue indicate 30-minute by 60-minute quadrangles, whereas names and lines in purple indicate 1x2 degree quadrangles. Green outlines indicate park boundaries and thick gray lines indicate the boundary of the watershed area of interest.

The GRI digital geologic bedrock map coverage is currently available as ESRI shapefiles at 1:24,000 scale for Cuyahoga Valley National Park and include the Lakewood, OH, Cleveland South, Shaker Heights, Chagrin Falls, Broadview Heights, Northfield, OH, Twinsburg, West

Richfield, Peninsula, Hudson, OH, Akron West, and Akron East quadrangles of interest (fig. 2). These data are available at:
http://science.nature.nps.gov/nrdata/quickoutput2.cfm?UnitSearch=&Action=Search&nps_quicksearch=%2B

The park is also interested in obtaining digital geologic bedrock map coverage for the Wadsworth, Ohio quadrangle to provide coverage of all watershed sub-basins, which drain into the Cuyahoga River within the park.

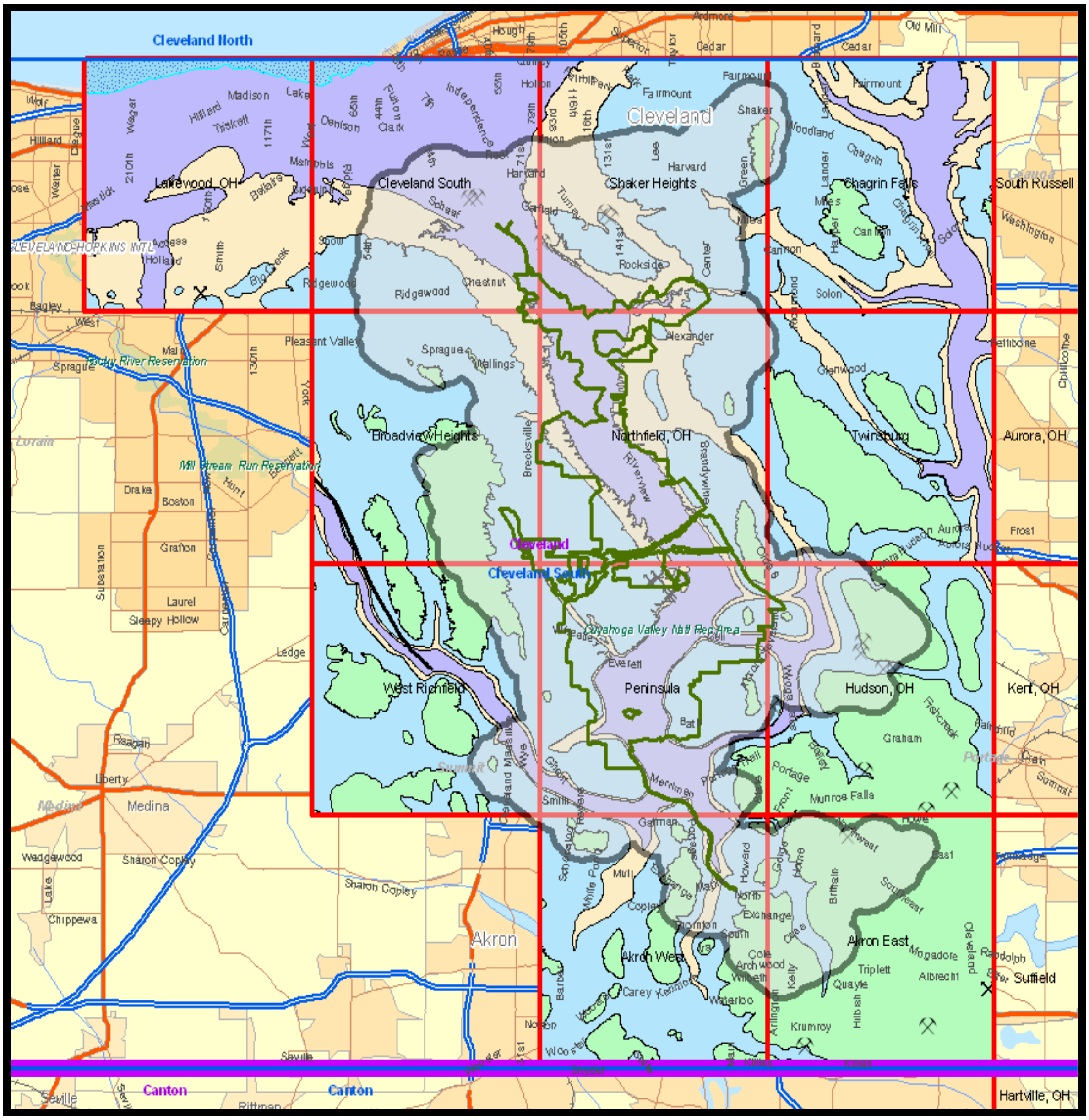

Figure 2. Existing GRI digital geologic bedrock map for Cuyahoga Valley National Park. The watershed of interest areas are covered by this map with the exception of a small area within the Wadsworth quadrangle to the southwest (not labeled).

GRI scoping participants discussed several options for surficial map coverage of Cuyahoga Valley National Park. The Ohio DNR's Division of Geological Survey website (http://www.dnr.state.oh.us/tabid/7105/Default.aspx) has digital map coverage at a variety of scales and types. Options include geomorphic maps, materials maps, and stack maps which convey the surficial topographic expression with depth of unconsolidated material (derived by subtracting the depth to bedrock from the surficial elevation). Additionally, their website at http://www.ohiodnr.com/tabid/7841/Default.aspx details online "interactive map" themes that may be useful for NPS resource management including some of the following:

- Abandoned Underground Mines with Address Locator
- Map of Ohio Earthquake Epicenters
- Mineral Industries Map of Ohio
- Oil and Gas Map of Ohio with Address Locator
- Emergency Oil and Gas Well Locator
- Lake Erie Geology and Shore Erosion Map of Ohio with Address Locator
- Midwest Regional CO2 Sequestration Partnership (MRCSP)

Ohio has 1:62,500 scale glacial geology maps for Summit, Cuyahoga, and Medina counties. The Ohio Department of Natural Resources, Division of Soil & Water Resources has glacial and bedrock aquifer maps, and county-based Ground Water Resources Maps and Ground Water Pollution Potential Maps that the park may find useful in managing groundwater resources. Desired derivative products include landslide hazard maps. These only exist for southeastern Ohio, but would be a valuable dataset especially in light of the mountain biking lobbyists currently seeking access to trails within the park. Other potential map resources include the Cuyahoga River Remedial Action Plan (RAP) website (www.cuyahogariverrap.org) for water quality data, and county websites (www.co.summit.oh.us, and www.cuyahogacounty.us) for waterway maps, and slope maps.

GRI scoping participants agreed to use the surficial geologic map of the Cleveland South 30 x 60 minute quadrangle which covers the park. This map is in digital format and will be converted to the GRI digital geologic-GIS map datamodel. The GRI will also obtain the glacial geologic maps at 1:62,500 for Cuyahoga and Summit counties. There is also a regional bulletin of Glacial Geology of northeastern Ohio (White, 1982) at 1:250,000 scale. Park staff stated that they would like to obtain coverage for the entire Ohio & Erie Canal National Heritage Corridor for future planning.

Geologic Resource Management Issues

The scoping session for Cuyahoga Valley National Park provided the opportunity to develop a list of geologic features and processes, which will be further explained in the final GRI report. During the meeting, participants prioritized the most significant issues as follows:
(1) Flooding and fluvial processes,
(2) Hillslope processes, and
(3) Disturbed lands.

Other geologic resource management issues discussed include seismicity, groundwater, lacustrine and wetland features, and caves.

Flooding and fluvial processes

The Cuyahoga River and its tributaries define Cuyahoga Valley National Park, are central to the establishment of the park, and fluvial processes continue to shape its landscape. The park has both bedrock confined channels such as at Pinery Narrows and Peninsula, and floodplain dominated channels in broader sections of the Cuyahoga Valley such as the area from Hillside Road northward. Numerous dams in the park (e.g., Virginia Kendall Dam, dams creating Armington and Horseshoe Ponds) have affected natural fluvial processes in the park.

Natural river processes have eroded streambanks and threatened the stability of natural and cultural resources along the banks of the Cuyahoga River and its tributaries. Undercutting of the riverbanks in some places has caused riverbank erosion and trees to fall into the river channel. Unstable glacial deposits on terraces along the river are prone to fail as riverbanks and steep slopes are undercut. Meandering streams also forms cutoffs and oxbow lakes – creating vital wetland habitat in the park such as at Beaver Marsh and Stumpy Basin.

Resource managers are concerned about the lateral migration of the Cuyahoga River and its affect on infrastructure adjacent to the river. In order to protect resources adjacent to the riverbank such as the Ohio & Erie Canal, Towpath Trail, and the Cuyahoga Valley Scenic Railroad, the river has been stabilized, and in these certain areas no longer meanders naturally across its floodplain. Riverbank stabilization projects such as riprap are visible along the river at places such as the confluence with Chippewa Creek (fig. 3). A piecemeal approach to riverbank stabilization has resulted in problems adjacent to and downstream of the projects and is creating a hardened, rather than naturally flowing stream. The park currently follows a Riverbank Management Program that incorporates both the historic preservation mandates and the natural resource objectives of the park. The program includes monitoring and action plans for riverbank problems; the preference is to use less intrusive techniques, engineered and non-engineered measures at locations where the progress of riverbank erosion has not yet presented an imminent threat to the Towpath Trail, Valley Railway, or other features. Some techniques used are engineered log jams, utilization of root wads, planting of deep rooting trees between the top of the bank and the resource; removing trees that are severely threatened by erosion before they are felled during a flood event; encouraging channel cutoffs or reestablishing of meanders where appropriate. The Riverbank Management Program also includes expansion of the Riverbank Erosion Monitoring Program using an array of techniques to provide a more comprehensive and accurate assessment of the progression of stream meandering and erosion (Programmatic Environmental Assessment for Riverbank Management of the Cuyahoga River, 2004). The park employs two engineers to assess the need for stabilization to protect the infrastructure within the floodplain. When the river erodes too close to the Towpath Trail, the natural hydraulic head drives water through the packed clays underlying the towpath. Water flows towards the canal, destabilizing the towpath and locally increasing erosion.

High terraces perched along some stretches are evidence of inflated floodplain deposits caused by increased erosion and subsequent sedimentation in local waterways from poor land use practices prior to the establishment of the national park. The river naturally meanders across its floodplain and in some areas, is threatening park infrastructure. Maintaining a balance between preserving park resources and allowing the natural meandering processes of the river to continue is a constant resource management issue at Cuyahoga Valley National Park.

Flooding is very common along the Cuyahoga River and its tributaries at any time of year. Floods can follow spring snowmelt, seasonal storms, or be caused by ice dams forming near the mouth of the river along Lake Erie. In 1913, a flood covered archaeological sites along the river and deposited silt in the rafters of historic buildings along the canal such as the Canal Visitor Center. The July 2003 flood caused over $3 million in damages to Cuyahoga Valley National Park's railway, Towpath Trail, and other historic structures. In 2004 a 500-year flood occurred on Yellow Creek causing widespread erosion, instability, and landslides. In 2005, flooding along the Cuyahoga River threatened the towpath trail near Chippewa Creek. Additional flooding in 2006 along the Cuyahoga River and its tributaries caused additional damage to park resources.

Land use practices within the watershed and upstream of the park can strongly impact park resources. Forty-four communities impact streams flowing into Cuyahoga Valley National park and more impact the river. Adjacent development usually leads to more impervious surfaces–areas that water cannot infiltrate such as buildings, parking lots, roads, and sidewalks. Cuyahoga Valley National Park research indicates that areas with higher imperviousness have decreased watershed quality. Other scientific data show increases in stormwater runoff, erosion, sedimentation, stream channelization, and degradation of stream habitat and biodiversity with increased impervious surfaces in surrounding areas. At Furnace Run, privately owned areas include a catchment basin and stream stabilization upstream from the park boundary. At Yellow Creek (near the O'Neill Woods), a tributary that has better water quality than most other streams within the park is being negatively impacted by outside development.

As climate change occurs, flooding events may become more frequent and sediment loading in streams will likely increase. This trend makes understanding the hydrogeologic system and having sound river stabilization practices in place critical for resource managers at the park. The National Oceanic and Atmospheric Administration (NOAA) has been tracking climate change since the 1950s. The Great Lakes region has experienced above average temperature increases. Today, Lake Erie typically freezes for one month instead of three months each winter. Thirteen cm (5 in.) less snow falls each winter. Vegetation leafs out earlier in the spring than in past years. Understanding the outcomes of these changes is crucial to protecting the natural and cultural resources at the park.

In an attempt to understand how specific reaches of the river are changing with time, the park is currently in the process of a 12-year riverbank monitoring program. Rebar positioned at approximately 25 sites serve as baseline positions to monitor the channel change along the river corridor. The park is also considering creating designated overflow areas to accommodate increased flow.

The Cuyahoga River was once considered a highly polluted and disturbed waterway. The sources of past and present pollution to the river include wastewater facility discharges, inactive hazardous waste sites, combined sewer overflows, sanitary sewer overflows, and other point and non-point sources. In 1988, the Cuyahoga River Remedial Action Plan (RAP) was established as part of a bi-national effort to restore the Great Lakes. Today, after 40 years of continuing restoration the recovery of the lower Cuyahoga River is not only evident in the improvement in the aquatic assemblages that inhabit the river water, but in the terrestrial wildlife associated with the riparian habitat of the river corridor. Efforts to improve water quality and preserve wetlands have transformed a once polluted river into an attractive place for wildlife. Much of the main stem of the Cuyahoga River and it's tributaries throughout the park are in attainment with the State of Ohio's water quality standards for warm water habitat.

Slope processes

The steep-walled Cuyahoga Valley and its tributaries with highly variable, unstable glacial deposits (particularly the glacial lake deposits) are inherently prone to mass wasting and hillslope processes. This ruggedness helped to preclude urban development in the area, preserving the area for the future national park. The resistant rocks that form the caprock for many of the upland areas and waterfalls are also prone to block fall when undercut on steeper slopes. Pervasive joint sets (often intersecting at 90° angles) form natural spall surfaces. Frost- and root-wedging cause blockfall locally (fig. 4). Blockfall was a recent concern along the Blue Hen Falls trail at Boston, Ohio. Blockfall also occurred recently at The Glens area of Tinkers Creek within the Bedford Reservation. Rockfall processes and resulting landforms are obvious at the Ritchie Ledges area of the park. Mass wasting within the Devonian shales at Station Road Bridge Trailhead (near the Brecksville Depot) causes slumping over the railroad tracks.

Historically, slope processes have damaged homes in the vicinity of the park. Structures built along slopes near the edges of gorges have failed as gravity and undercutting eroded the steep slopes. State Route 303 is susceptible to damage from slope processes and high silt content; it is constantly being stabilized and rebuilt. Homes along Riding Run experienced "exploding" windows due to the internal stresses on the structures caused by mass wasting. The Yellow Creek area is particularly unstable.

Throughout much of Cuyahoga Valley National Park, thick glacial-deltaic and glacial-lacustrine deposits frequently form active slumps and debris flows (fig. 5). These slumps supply sediment to the valley causing narrowing of the downstream floodplain. Slope creep has caused closures of horse trails in the Wetmore system. The Old Carriage Trail is prone to severe erosion and slumping. Slump areas frequently knock down trees and create openings in the canopy that allow successional vegetation to flourish. These slump block communities are evident throughout the park.

Disturbed Lands

Oil and gas exploration began in the vicinity and within the park in the 1930s. Most of the production comes from the Devonian shales and Berea Sandstone. Deeper wells have been drilled into carbonate Salina and Clinton formations at approximate depths of 900 m (3,000 ft) below the surface to the base of the Silurian-age rocks. In the park, Precambrian crystalline basement rocks are ≈1,500 m [5,000 ft] below the surface. There are 90 active oil and gas wells within Cuyahoga Valley National Park. Of these, 37 are on NPS lands, 4 are on NPS/less than fee lands, and 49 are on private lands. Seventeen wells within the park remain orphaned (no owner) and in need of plugging. Of these, only eight are on NPS surface estate. The most recently plugged well (in 2009) was within the floodplain of the Cuyahoga River north of the Boston Mills Ski Area. Between 1986 and 2009, 53 orphaned wells were plugged by the NPS. Three wells are currently proposed for plugging in 2010. Park staff monitors the wells in the park to assess potential impacts on park resources. The Ohio DNR website has a record of historical complaints related to oil and gas activities and the NPS maintains a database of case incident reports regarding oil and gas wells.

Because of a lack of reliable groundwater in the area, many early settlements created earthen dams and ponds to use as their water supply. Natural flooding processes have removed some smaller farm pond and tributary dams in the past. Many valleys have dams that have failed such as Haskell Run that has had five or six failed dams impounding it in the past. The Ohio DNR website has dam safety information and data on over 600 dams in the Cuyahoga region. The park has GPS data on dams for a dam hazard assessment. There are an estimated 15 dams within park boundaries (most of these are on farm ponds). There are nearly 60 dams located within the Cuyahoga River watershed, with five dams located on the main stem of the Cuyahoga River. These dams are likely acting as sediment sinks, trapping material that would otherwise be transported to Cleveland Harbor. Notably, the Gorge Metropark (Ohio Edison) Dam, approximately 8 miles upstream of the park boundary, is believed to be a significant sediment sink. In cooperation with the Ohio EPA, the cities of Kent and Monroe Falls recently removed two concrete, lowhead dams on the Cuyahoga River. These dams were located several miles upstream from the park boundary. Within the park there are two lowhead dams located on the river - the Peninsula Dam and the Brecksville Dam (also known as the Canal Diversion Dam). The Brecksville Dam and the Gorge Dam have been identified by the Ohio EPA as sources of impairment to water quality. Both dams are being considered for removal. In July, 2009 the Ohio EPA in cooperation with the National Park Service issued a notice of intent to prepare an EIS for the removal/modification of the Brecksville Dam.

In one flooded stretch of Beaver Marsh (an area that used to be a salvage yard), beavers built a dam creating a large marsh area within an area that the park restored. Riparian wetland habitat such as that at Stumpy Basin (an area containing rare plants) along the canal is considered endangered.

There are several historic and one active quarries within the park boundary. DeGeronimo Aggregates in Independence, currently produces “haydite”, an expanded shale light aggregate. Haydite is used for landscaping and is formed by heating shales. The NPS has an easement to protect the cultural resources at this 5-ha (13-ac) quarry. The Euclid Bluestone, a coarser facies in the Bedford Formation, was quarried off Granger Road (Independent Excavating company) (see fig. 6). Indigo Lake in the park is a former quarry that is now filled with groundwater. Other quarries include several in the Hemlock area, in the Virginia Kendall Ledges area, and Deep Lock quarry. The Berea Sandstone (also called the Berea Grit) was widely quarried for flagstone, building material, and to make marbles and gristmill wheels. Huge, expansive Berea Sandstone quarries are located throughout the region. This stone was exported as far away as Germany. Most of these quarries are to the northeast of the park. The locations of active quarries are included on the Ohio DNR website.

Forty major disturbed sites covering over 178 ha (440 ac) have been restored since 1984 at the park. These features include sand and gravel pits, borrow pits, quarries, flyash dumps, and topsoil mines. A sand and gravel pit, once a dump, at Snowville Road has been remediated as has an old topsoil mine near Brandywine Ski Resort. The 16-ha (39-ac) Krejci dumpsite is still under restoration at Hines Hill Road east of the Boston Store area. This site was a former salvage yard and site of an industrial waste dump for many years. Large companies such as the Ford Motor Company have been legally obligated to help fund the cleanup effort. There are 25 months left to complete the clean-up. The Ipsaro site, adjacent to the Rockside Road Station in Independence, is currently under restoration as part of wetland mitigation.

At least 11 agricultural leases exist within several areas of the park. Most of these are small-scale, private operations raising cash crops, and pasturing animals. As part of their lease agreements, the park established a 30-m (100-ft) riparian buffer zone to protect these fragile stream and wetland areas from impacts from grazing or farming.

Because the location of the park is within a heavily urbanized area, several transportation corridors traverse the park with adjacent right-of-ways. Easements also exist for power lines, buried pipelines, and cables.

Other geologic resource management issues

Seismicity

According to geologists at the Ohio DNR, the risk for earthquakes at Cuyahoga Valley National Park is small. The Ohio DNR website contains a record of earthquake epicenters over the past 50 years. The U.S. Geological Survey (USGS) also maintains constant monitoring of seismic activity for the area. Minor quakes have occurred near the park. An M_w 3.3 earthquake occurred near Twinsburg on March 12, 2007, just 10 km (6 mi) east of the park. Earthquakes tend to occur in an area near Lake County, 64-80 km (40-50 mi) northeast of the park, including a 1986 M_w 5.0 event. Even moderate seismic shaking could trigger mass wasting resulting in slumps, landslides, and blockfalls. Susceptible areas would include those with unconsolidated glacial deposits exposed on steep and/or undercut slopes, or those with large blocks of jointed rocks perched precipitously on the edge of steep slopes or cliffs.

Groundwater

According to groundwater resource maps from the Ohio DNR website, there is little water well data available for the central part of the Cuyahoga Valley. Aquifers include poor quality shale aquifers, and glacial (clay-rich) aquifers. In general, groundwater resources are scarce for Cuyahoga Valley. However, one aquifer site at the former Jaite Mill historically pumped 500 gallons/minute. There are abundant groundwater resources south of Cuyahoga Valley National Park, across an ancient drainage divide, within a buried valley at Akron. Early settlers pumped water from streams and built small, earthen dams for farm ponds to use for their water supplies. This lack of abundant groundwater precluded heavy settlement of the area and ensured a tract of relatively natural land was available for the formation of the national park.

Understanding vulnerability to groundwater contamination is an important resource management goal at Cuyahoga Valley National Park. Knowledge of the hydrogeologic system of the valley is needed. To this end, knowledge of the presence and extent of buried valleys and the composition of the glacial deposits is critical. Geophysical techniques including resistivity and seismic surveys are used to determine the depth of unconsolidated material over bedrock in areas where reliable water well or oil and gas well data are lacking.

When blasting occurred to build the Ohio Turnpike through the park, the local groundwater paths changed. The groundwater essentially drained out through the newly blasted roadcuts. According to John Szabo, a similar situation occurred in the Montrose area when it was suburbanized 20 years ago, forcing the City of Akron to build a water tower to compensate for the change in the hydrologic system.

Lacustrine and wetland features

Though only a few natural oxbow ponds exist, there are over 70 human-made ponds within Cuyahoga Valley National Park. Many of these ponds were created- by farmers to obtain a reliable water source. The park has had a Pond Management Plan in place since the 1990s.

Geologists consider the mud-rich deposits within a pond or oxbow lake to be like a book of the health and history of the ecosystem. An oxbow lake preserves a former river course, and gives a snapshot look at a previous channel substrate. The pollen in these deposits can be used to reconstruct the past climatic history of the area. Geologists also use these types of deposits to measure the success of soil conservation programs.

Over 485 ha (1,200 ac) of wetland areas exist within the park. Approximately 350 riverine wetlands exist along the floodplains and tributaries of the Cuyahoga River including wetlands such as Stumpy Basin, Beaver Marsh, and Fawn Pond. These wetlands generally have alluvial soil characteristics. About 700 unique groundwater wetland systems also exist along the hillsides and valley walls and generally contain peat-rich soils. Other depressional wetlands totaling about 350, exhibit clay-like soils which are typical for the region. Numerous vernal pools provide seasonal wetland habitat vital to amphibian reproduction (Sonia Bingham, pers. comm.. 1/19/2010).

Caves

Several sandstone rock overhang caves exist within the park boundary including Deer Lick Cave in the Brecksville Reservation, and Ice Box Cave in the Virginia Kendall Ledges area of the park. Deer Lick Cave has cave formations that could be subject to damage and vandalism. Ice Box Cave has a square-shaped opening formed along joints and fractures within the Sharon Conglomerate (fig. 7). It formed where a seep emerged along joints and bedding and the blocks of rock pulled apart. It has approximately 18 m (60 ft) of passageway. It becomes very narrow and treacherous and visitors have been known to become trapped in the cave and have had to be rescued.

GRI scoping participants knew of no karst-related issues at the park. Karst-susceptible limestone typically occurs as float within the park, possibly carried downstream from exposures to the east. Some limestone may also have been transported by ice activity (interred in glacial ice or rafted on calved ice as erratics). Limestone was heated to make lime for mortar that was sold throughout the region.

Figure 3. Riprap along the Cuyahoga River near the confluence with Chippewa Creek. The riverbank stabilization project was done to protect a stretch of the towpath trail from flood damage. Photograph is by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 4. Root wedging within the Sharon Conglomerate at Gorge Metropark. Photograph is by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 5. Slumping of unconsolidated glacial lake deposits over the Cuyahoga Formation along Chippewa Creek near the confluence with the Cuyahoga River. Photograph is by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 6. Euclid Bluestone (a coarse facies of the Bedford Formation) exposed on a quarry wall near Rockside Road. Photograph is by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 7. Opening to Ice Box Cave within the Sharon Conglomerate at the Ledges area of Cuyahoga Valley National Park. Photograph is by Trista L. Thornberry-Ehrlich (Colorado State University).

Features and Processes

Cuyahoga River valley

The Cuyahoga River dominates the landscape at Cuyahoga Valley National Park. The river carved a deep and scenic valley that geologists refer to its "Grand Canyon effect". The river was called "Ka-ih-ogh-ha" or "Crooked River" by Native Americans. In contrast to other rivers that flow into Lake Erie, the Cuyahoga River initially flows south, away from the lake near its origin in Geauga County until it reaches the water divide near Akron at which point it turns abruptly northward. Though some 145 km (90 mi) long, as the crow flies, the river empties into Lake Erie only 48 km (30 mi) west of where it begins. Stretches of the river are confined by bedrock such as at Pinery Narrows and Peninsula. These stretches tend to be narrower and straighter with incised meanders trapping the river course. Most streams within the watershed are immature with rapids and waterfalls. The closely spaced ravines can drop nearly 180 m (600 ft) in a few miles. They developed as the last glacial ice retreated. Some of the drainage is controlled by regional joint patterns in the bedrock.

Several good examples of the ancient post-glacial Gilbert delta sequences occur along the length of the river. At Mud Brook, one such example is well-exposed. These types of deposits make good local aquifers. During glacial times, many deltas were deposited along the margins of the Cuyahoga River in a series of ice-dammed, pro-glacial lakes including Lake Cuyahoga and Lake Independence (M. Angle, written communication 2009). Later, near the mouth of the Cuyahoga River (in the "flats" region of the city of Cleveland), numerous deltas were created by the ancestral Cuyahoga River sediments where it entered ancestral Lake Erie during the Maumee, Whittlesey, and Warren stages (M. Angle, written communication 2009).

The geologic setting at Cuyahoga Valley is conducive to the formation of waterfalls. The resistant Berea Sandstone was deposited atop less resistant shales of the Bedford Formation. These shales erode away leaving ledges of sandstone. Waterfalls exist on many tributary streams within Cuyahoga Valley National Park. Examples of waterfalls include Mudcatcher Falls (east), Blue Hen Falls (west), and Brandywine Falls (east).

Glacial features

The glacial history of the Cuyahoga Valley, which geologists continue to refine with new fieldwork and mapping, is extremely complex. Prior to the Pleistocene glacial advances, the north- to northwest-flowing Teays River system used to drain a large part of Ohio. Similar to the Teays River system, pre-glacial streams draining Summit County also flowed northwards. Southward advancing continental ice sheets dammed the river and buried much of the existing river valley with glacial sediments. Drainages were reversed and exhibited strong elbows of capture–a right-angled bend formed when a stream taps and quickly "captures" the flow of a neighboring stream. South-flowing courses incised into the bedrock up to 25 m (80 ft) lower than the present Cuyahoga River. Glaciers advanced, retreated, and readvanced several times during the major glacial periods. During the most recent glaciation–the Wisconsinan event, glacial ice flowed from north to south and wedged up against the Allegheny Plateau just east of Cuyahoga Valley National Park and melted in place. For thousands of years the ice sheet advanced, retreated, and readvanced in ≈1,000-year cycles. During the Erie interstade, the ice melted back to Canada, formed a large depositional basin, and then readvanced in a northeast to southwest direction. This readvance of glacial ice entrained lake clays and dropped clay-rich till deposits.

As the ice began to recede farther to the east and north, a series of glacial lakes formed along the glacial front at subsequently lower elevations including Lake Maumee (I, II, and III), Lake Arkona (I, II, and III), Lake Warren (I, II, and III), Lake Wayne, Lake Grassmere, and Lake Elkton. These lakes had various outlets including the Wabash River, Grand River, Mohawk River, and the Niagara River. As the ice retreated to the east and north, new outlet channels opened up and previous outlets passing through Indiana and Michigan were abandoned in favor of those draining toward New York (M. Angle, written communication 2009). Large deltaic deposits are visible along Rockside Road. Trapped outwash or a remnant beach deposit, possibly from Lake Maumee, is located north of Route 82. At 12,500 years before present, the outlet at Niagara Falls was cleared and an extreme rush of water lowered the level of proto-Lake Erie by 45 m (150 ft) going from 189 m (620 ft) to 143 m (470 ft) above sea level. The outlet at Niagara Falls was not just the result of the ice no longer physically blocking the outlet, but was also a result of that area being isostatically depressed by several hundred feet (M. Angle, written communication 2009). Geologic evidence suggests this outflow may have occurred in as little as four days. Deltas into this early Lake Erie formed deposits currently underlying the "Flats" area in Cleveland, Ohio. Glacial rebound and basin fill have brought the lake up to its current elevation of 174 m (572 ft) above sea level.

Prior to the last major glacial event, water in the Cuyahoga area was flowing northward in a drainage that trended parallel to Route 8 with a drainage divide located near Canton, Ohio. The present course of the Cuyahoga River formed during the interglacial period. During the Wisconsinan, the upper Cuyahoga followed the ice margin and at 14,800 years ago, it flowed south. When the base level dropped, the Cuyahoga River experienced extreme downcutting. It did not slowly meander to find old, buried channels, but cut a narrow, deep gorge through the national park area. These incised meanders trapped the river's course. Several southward flowing streams including Furnace Run, Yellow Creek, and Mud Brook were captured into the Cuyahoga River watershed. The system is now relatively stabilized after most of the glacial rebound (postglacial rebound is approximately 15 cm [6 in.]). However, Furnace Run continues to incise (as opposed to meander) and supplies increasing sediment loads from tributary streams to the Cuyahoga River.

At Cuyahoga Valley National Park older maps indicated that all hummocky topography was moraine deposits, but now geologists understand that the hummocky terrain could be erosional in origin. Features originally considered kame terraces are most likely dissected outwash terraces. Glaciations typically overprint earlier glacial events. Geophysical and seismic surveys reveal that the most recent Wisconsinan glaciations did not excavate to the ancestral bedrock valleys. Wisconsinan till caps interfluve areas, but does not drape down into the valleys. Sea level curves indicate the ice was relatively thin over northern Ohio during the Wisconsinan relative to the earlier Illinoian glaciation. Geologists use the presence of distinctive marker beds of till to differentiate separate glacial events. Important regional marker beds include the Mogadore Till (Illinoisan or early Wisconsinan), Kent Till, Northhampton Till, Lavery Till, and Hiram Till (late Wisconsinan).

Glacial features of the region include kames, eskers, end moraines, dissected outwash terraces, weakly-developed striations and widespread glacial erratics transported from Canada. Windblown, interglacial, loess is mixed into regional soil profiles. Other features include cyclic glacial-lacustrine deposits formed by a series of glacial lakes formed behind ice dams (glacial lobes) at the front of the continental glacier. Overprinting the depositional features are erosional features, some of which formed dramatically when an ice dam blocking the Niagara outlet finally gave way prompting a massive, scouring outflow of proto Lake Erie.

A roche moutonée (a tear-drop shaped hill that tapers in the up-ice direction) is just east of the national park. According to John Szabo, it may be the only one in Ohio. The Sharon Conglomerate caps the eroded structure.

Ecosystems remnants of colder, Pleistocene climates called Pleistocene refugia exist within the park. These tend to occur in shady, sheltered locations that remain naturally cooler than surrounding areas. Vegetation such as woodland ferns, Norway spruce, and Eastern hemlocks grow in places such as the Columbia Run watershed within Cuyahoga Valley National Park. Some care needs to be taken not to confuse shrubs planted within the Virginia Kendall Unit by the Civilian Conservation Corps projects during the 1930s with true refugia (M. Angle, written communication 2009).

Paleontological resources

Fossils are known from the bedrock units exposed within Cuyahoga Valley National Park. According to the NPS Paleontological Inventory for Cuyahoga Valley National Park (Hunt et al. 2008), the Ohio Shale, Bedford Formation, Berea Sandstone, and Cuyahoga Formation contain documented fossil resources within the park boundaries, presenting opportunities for resource management including field surveys, inventory, and monitoring, education, and interpretation. Nineteen species of brachiopods and four bivalve taxa are described from the Brandywine Falls area. Cephalopods, conodonts, burrows, and annelid worm remains occur within the Chagrin Member of the Ohio Shale. The Cleveland Member contains remains of plant spores, carbonized plants, arthropods, conodonts, and placoderm fish. The Bedford Formation and Berea Sandstone contain brachiopods, pelecypods, plants, trace fossils, and spore casings. The Cuyahoga Formation contains abundant brachiopod remains. The Meadville Member is the most fossiliferous unit in northeastern Ohio containing 125 species of sponge, coral, bryozoans, gastropods, and mollusks, ammonoids, brachiopods, crinoids, and a trilobite.

The Tinkers Creek area is especially rich in fossilized brachiopods. The southern Meadville member of the Cuyahoga Formation contains brachiopods, conularids that are well exposed at Chippewa Creek and near Route 82. Locally, fossil fish are known from the Devonian units on Interstate 71 roadcuts.

There is also potential for Pleistocene fossil remains. A mammoth was found along Barlow Road in Hudson. Mastodon remains were found at Fairlawn (Akron) south of the park within a kettle hole.

During the GRI field trip, scoping participants noticed zoophycos burrows and conularids within the Cuyahoga Formation at the Gorge Metropark as well as jumbled plant remains in the Sharon Conglomerate near Mary Campbell's Cave (fig. 8).

Unique geologic features

The Cuyahoga River itself is probably the most prominent geologic feature of the park. It cut a steep valley through thick glacial deposits in to bedrock. Its tributaries contain approximately 50 waterfalls including Blue Hen Falls, Bridal Veil Falls, Buttermilk Falls, Chippewa Falls, Brandywine Falls, Mudcatcher Falls, and Cat Falls. Newberry in 1870 used the rock exposed along the river between Akron and Cleveland to define the type section of the Cuyahoga Formation. According to the USGS Geolex database, Newberry (1870) also described the type section for the Bedford Formation, exposed along Tinkers Creek.

The bedrock exposures within Cuyahoga Valley National Park and surrounding Metropolitan Park Districts provide geologists with study areas in a region that is largely covered and obscured by unconsolidated glacial deposits. Geologists agree that more research is needed locally to sort the intricacies of the depositional history of the bedrock. The depositional setting of the Devonian, Mississippian, and Pennsylvanian rocks of this area was extremely complex shifting from shallow seas, to deeper water marine, to fluvial-deltaic, to braided streams. Geologists continue to refine the geologic history of these rocks and the entire region. The Bedford Formation and Berea Sandstone were long considered to be Mississippian in age, but were recently reassigned a Devonian age based on conodont remains. The Berea Sandstone (fig. 9) contains large crossbeds and other sedimentary features that appear to be channels, but could also be slumps. Theories regarding its depositional environment range from shifting, overlapping deltas forming at the mouth of rivers from the north to fluvial channels flowing from the east. This formation also locally contains excellent examples of soft sediment deformation including microfaults and mini-diapirs. The Berea is nearly devoid of fossil remains which is also enigmatic. The Chagrin Shale and Cleveland Shale (members of the Ohio Shale) contain organic muds and dark layers indicative of anoxic seas. These shales are black, fissile, carboniferous, and radioactive (pose a radon threat). Locally, these shales also may contain abundant concretions, pyrite, and may be petroliferous (M. Angle, written communication 2009). The depth of this depositional environment is a topic of debate. Some geologists consider the anoxic layers to be indicative of extreme salinity stratification whereas other geologists consider them to have formed in very cold climates. The source area for the quartz arenite of the Sharon Conglomerate is also an unusual geologic story. The Appalachian orogenies were providing source material for rocks to the east and west of the mountains, but the Sharon Conglomerate is too pure (i.e. does not contain enough feldspar or other minerals) to be realistically sourced from the east. Most geologists surmise that the quartz pebbles (fig. 10) came from the north. Similar pebbles are common to the Mississippian Blackhand Sandstone, a member of the Cuyahoga Formation found farther south in Ohio. There is some speculation that these quartzite pebbles in part may have been recycled or eroded and redeposited numerous times (M. Angle, written communication 2009). Depositional features within the Sharon Conglomerate are also confusing as they tend to appear as channels in a high energy environment, but careful study reveals these may be slump or eddy features. This unit contains classic examples of overlapping, overturned cross beds and many seep zones at the base of coarser, pebble-rich facies visible as stained areas on cliff faces.

The uniform and relatively undeformed nature of some of the exposed bedrock throughout the area made it attractive stone for building materials. The Berea Sandstone, the Euclid Bluestone (of the Bedford Formation), the shales of the Ohio Shale and Cuyahoga Formation, and the Sharon Conglomerate were all quarried locally. The Berea Sandstone was used locally in mills, knife sharpening operations, canal locks, cemeteries, and for flagstones and building materials. Many prominent buildings in northern Ohio are made from this stone. Another unique feature - petroglyphs on the face of a quarried slab of Berea Sandstone, appear inside a Lutheran Church at

Independence, Ohio. The Berea Sandstone is also used as a permeability standard in hydrogeologic studies.

Though the rocks appear undeformed, regional joint sets, often intersecting at 90° angles, are nearly omnipresent in both the shales and coarser bedrock units throughout the park. The source of stress for these joints is still a subject on debate. Theories suggest the stress may stem from Appalachian mountain building events, others suggest the joints stemmed from stresses caused by isostatic rebound following the melting of the thick continental glaciers. These joints strongly influence the permeability of the bedrock units.

The national park and surrounding Metropolitan Park Districts protect myriad areas of geologic interest including Bedford Glen–a cathedral-like natural landmark in Cleveland Metropark, Mary Campbells Cave in Summit County’s Gorge Metropark Reservation, and Deer Lick Cave containing speleothems in the Brecksville Reservation. The Boston Ledges, with an associated cave, were largely destroyed by the development of the railroad. The Virginia Kendall Ledges area including Ice Box Cave in the eastern part of the park preserve unique, moss covered, jointed blocks of Sharon Conglomerate and outcrops of unusual overturned stream deposits. Natural springs and seeps are commonly associated with jointing within the Sharon Conglomerate. Other features of geologic interest include pyrite and iron- and calcium-rich concretions in shales, iron banding (Liesegang banding–concentric, colored rings) in sandstone concretions, and honeycomb weathering in the Sharon Conglomerate.

Figure 8. Trace fossil remains (zoophycos burrows) within the Cuyahoga Formation exposed at the Gorge Metropark. Photograph is by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 9. Cliffs of stream deposits of the Berea Sandstone at the Bedford Reservation near Viaduct Park. Photograph is by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 10. Quartz pebbles within the Sharon Conglomerate exposed at Richie Ledges. Note also the honeycomb weathering on the lower surfaces. Photograph is by Trista L. Thornberry-Ehrlich (Colorado State University).

Recommendations

1. Consult U.S. Geological Survey website, and Ohio DNR website to confirm seismic activity / risk in the Cuyahoga Valley area. Mike Hanson operates the OhioSeis network.
2. Consult with NPS-GRD regarding trails management plan preparation.
3. Cooperate with local academic institutions to support student projects to develop geologic cross sections for the Cuyahoga Valley National Park.
4. Compile accurate and up-to-date geologic information for the park.
5. Pursue outreach programs with surrounding communities for responsible land and water stewardship.
6. Develop geology-specific interpretive programs for unique areas such as Pinery Narrows.
7. Study how increased visitation is impacting park resources, especially regarding trail erosion and parking lot development and use.
8. Investigate opportunities to improve geologic mapping, integrating with park GIS data.
9. Use the Ohio Division of Water Publications web site for further information about water resource management issues: http://www.dnr.state.oh.us/tabid/4079/Default.aspx..

Action Items

1. GRI report writer will obtain a copy of Manner, B. M., and R. G. Corbett. 1990. Environmental Atlas of the Cuyahoga Valley National Recreation Area. Monroeville, PA: Surprise Valley Publications to use in preparation of the final GRI geologic report.
2. GRI report writer will obtain a copy of Foos, A. (ed). 2003. Pennsylvanian Sharon Formation, past and present: Sedimentology, hydrogeology, and historical and environmental significance. A field guide to Gorge Metro Park, Virginia Kendall ledges in the Cuyahoga Valley National Park, and other sites in northeast Ohio. Guidebook No 18, prepared for the 2003 Annual Great Lakes Section SEPM/Northern Ohio Geological Society Field Conference to use in preparation of the final GRI geologic report.
3. GRI report writer will obtain a copy of Pat Pringle's thesis to use in preparation of the final GRI geologic report.
4. GRI report writer will obtain a copy of Hannibal, J. T. 1998. Geology along the Towpath: stone of the Ohio & Erie and Miami & Eire canals. Guidebook No. 14, prepared for the 1998 North-Central Section meeting of the Geological Society of America.
5. GRI report writer will find references by Peck, J. A. regarding modern sediments in Cuyahoga Valley, by Szabo, J. (1987) regarding the glacial history of the valley, and by Foos, A. regarding the bedrock of Cuyahoga Valley National Park for use in the final GRI geologic report.
6. GRI report writer will consult the OGS guidebook 20 for accurate glacial history as the deposits in the 1987 article by Szabo about the glacial stratigraphy are now placed in the Illinoian.
7. GRI report writer will use unpublished text provided by Tom Nash, as well as a list of CUVA-relevant theses provided by John Szabo (University of Akron) for use in the final GRI geologic report.
8. GRI map team and report writer will obtain a copy of RI 82 Bulletin of Northeast Ohio that includes a 50 page book.
9. GRI report writer will attempt to locate cross sections drafted by White in the 1950s.

10. GRI report writer will obtain a copy of Feldmann, R. M., and M. Hackathorn. 1996. Fossils of Ohio. Bulletin 70. Columbus, OH: Ohio Division of Geological Survey for use in the final GRI geologic report.
11. GRI report writer will contact Kim Norley and Darlene Killback at CUVA regarding restoration of abandoned quarries and dumpsites.
12. CUVA staff should contact Mike Johnson regarding geologic issues at surrounding metroparks.

References

Corbett, R. G. and B. M. Manner. 1988. Geology and Habitats of the Cuyahoga Valley National Recreation Area, Ohio. *Ohio Journal of Science* 88 (1): 40-47.

Hunt, R., J. P. Kenworthy, and V. L. Santucci. 2008. Paleontological resource inventory and monitoring—Heartland Network. Natural Resource Technical Report NPS/NRPC/NRTR—2008/132. National Park Service, Fort Collins, Colorado.

National Park Service. 2009. Cuyahoga Valley National Park. www.nps.gov/cuva (accessed October 12, 2009).

Ohio Department of Natural Resources. 2009. Division of Geological Survey homepage. http://www.dnr.state.oh.us/tabid/7105/Default.aspx (accessed October 12, 2009).

Szabo, J. P., and Angle, M. P. 1983. Quaternary Stratigraphy of Richfield Township, Summit County, Ohio. *Ohio Journal of Science* 83: 38-44.

Table 2. Scoping Meeting Participants

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