60th Annual Meeting of the American Institute of Professional Geologists

Celebrating 60 years of professional geoscientists exchanging information and technology in the many facets of geoscience.

September 16-19, 2023 | Covington, Kentucky

Industrial Mineral Production and Quarry Operations in Northern Kentucky

Field Trip, Monday, September 18, 2023

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West view of Petersburg Quarry with loess capped highwall and bedrock hills in background (STOP 2).

Close up view of loess capped highwall and stratified glacial outwash deposit (STOP 2).

South view of pit showing conveyor route from dredge to screen shaker feed to jaw crusher (STOP 2)

South view of dredge in pit (STOP 2).

South view of 2-yard capacity fixed bucket dredge adjacent to pit (STOP 2).

South view of sieve screen and wash assembly on left and density separator on right (STOP 2).

East view of Butler crushed stone quarry pit and pond and highwall section (STOP 4).

West view of highwall near base of 430 ft. deep pit (STOP 4).

View of interburden (Logana Sh.) overlain by Grier Ls. and underlain by Curdsville Ls. in pit (STOP 4).

West view of finish screen assembly and final product stockpiles at plant (STOP 4).

West view of loading operation at plant (STOP 4).

Photo of some of the sample size gradations produced at Butler Quarry (STOP 4).

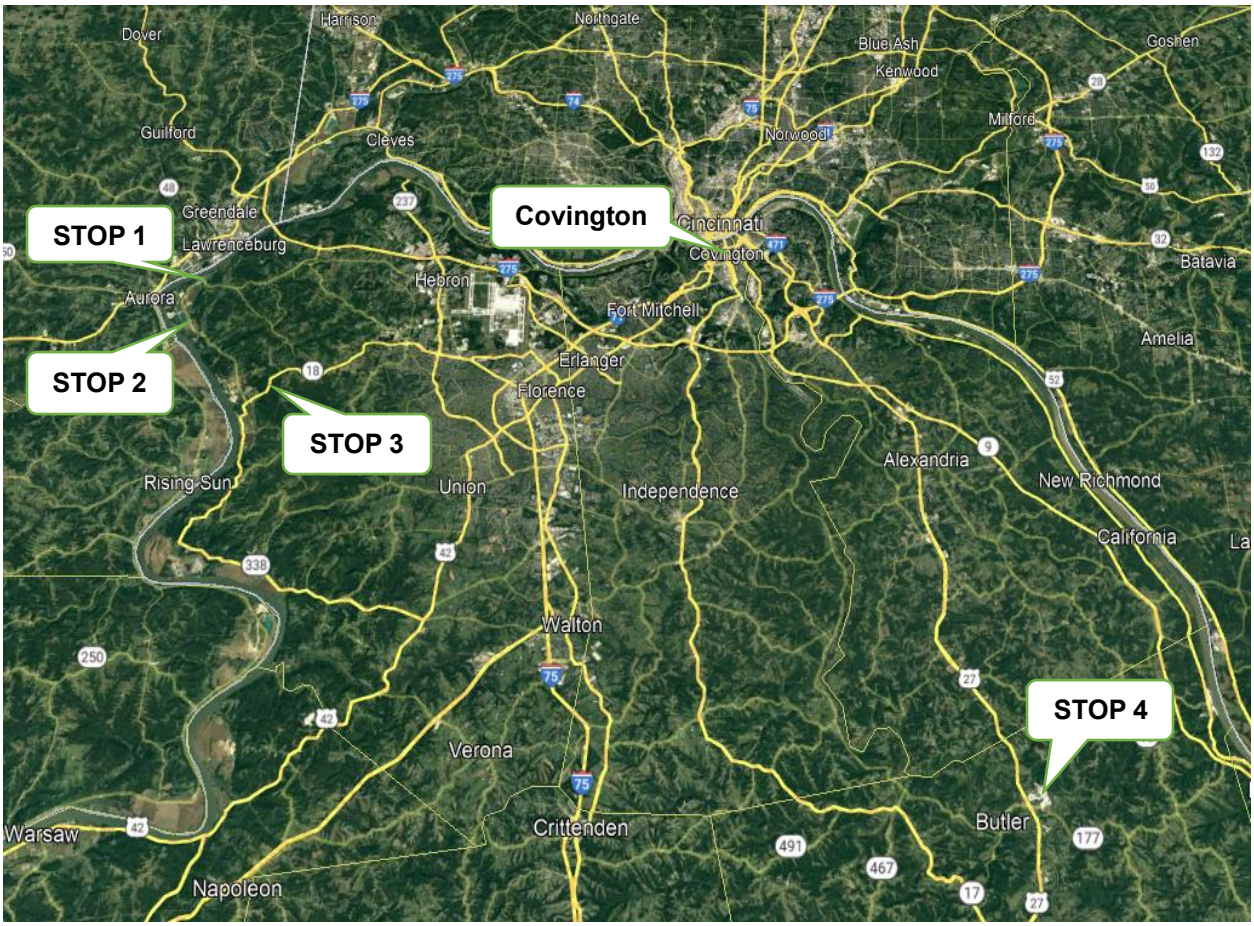
Acknowledgements

The authors gratefully acknowledge Northern Kentucky Aggregates, LLC and Hilltop Stone, LLC for permission to visit and observe the quarry operations and plant. Mr. Tyler Jordan, Geologic Technician, and Mr. Dave Abdon, Operations Manager of Northern Kentucky Aggregates, and Mr. Mark Faulhaber, Professional Engineer, and Mr. Terry Figgins, Operations Manager of Hilltop Stone provided valuable geologic and engineering information regarding the historic and ongoing quarry operations. Without their contributions and assistance, this field trip would not have been possible.

Field Trip Itinerary (All times Eastern Daylight Time)
Monday, September 18, 2023

8:00 a.m. Depart Covington Radisson Hotel
8:40 a.m. Arrive **STOP 1**, View of Ohio River, Petersburg, KY
9:00 a.m. Depart STOP 1
9:05 a.m. Arrive **STOP 2**, Northern Kentucky Aggregates Sand & Gravel Quarry, Petersburg, KY
10:50 a.m. Depart STOP 2
11:00 a.m. Arrive **STOP 3 (Lunch)**, Dinsmore Homestead, Burlington, KY
12:15 p.m. Depart STOP 3
1:15 p.m. Arrive **STOP 4**, Hilltop Stone Quarry, Butler, KY
3:00 p.m. Depart STOP 4
4:00 p.m. Arrive Radisson Hotel Covington

Aerial Image of Field Trip Stop Locations



Field Trip Route

The field trip route from the AIPG conference hotel in Covington, Kentucky to the quarry sites is a 102-mile-long, counterclockwise circular loop in northern Kentucky along a combination of urban divided highways and rural two-lane public roads. The field trip road log and mileage are listed below.

Route	**Mileage**
(BEGIN) Radisson Hotel to KY Hwy. 8 (5th Street), Covington, KY	0.05
KY Hwy. 8 (5th Street-one way) East to Philadelphia Street	0.10
Philadelphia Street North to KY Hwy. 8 (4th Street)	0.10
KY Hwy. 8 (4th Street-one way) West to Junction I-71/I-75 (Exit 192)	0.20
I-71/I-75 South to Junction I-275 (Exit 185), Erlanger	6.00
I-275 West to Junction KY 3608 (Exit 11), Idlewild	12.00
KY 3608 South to KY Hwy. 20 (Petersburg Road)	1.00
KY Hwy. 20 (Petersburg Road) West to Market St, Petersburg,	4.30
Market Street North to Front Street and Petersburg Park **(STOP 1)**	0.20
Front Street East to Main Street	0.05
Main Street South to 3rd Street	0.20
3rd Street West to KY Hwy. 20	0.05
KY Hwy. 20 West to Northern KY Aggregates Quarry Entrance **(STOP 2)**	1.55
KY Hwy. 20 South (Bellview Road) to Junction KY Hwy. 18, Bellview	5.10
KY Hwy. 18 (Burlington Pike) East to Densmore Homestead **(Lunch; STOP 3)**	0.80
KY Hwy. 18 East (Burlington Pike) to Junction I-71/I-75 (Exit 181), Florence	10.80
I-71/I-75 North to Junction I-275 (Exit 185), Erlanger	3.00
I-275 East to Junction KY Hwy. 9 (Exit 77), Wilder	7.00
KY Hwy. 9 (AA Highway) South to US Hwy. 27, Cold Spring	3.90
US Hwy. 27 South to KY Hwy. 177 (Alexandria Pike), Butler	16.60
KY Hwy. 177 East to Hilltop Stone Quarry Entrance **(STOP 4)**	0.40
KY Hwy. 177 West to US Hwy. 27	0.40
US Hwy. 27 North to KY Hwy. 471 (Alexandria Pike), Highland Heights	19.75
KY Hwy. 471 North to Junction I-471 (Exit 1)	0.70
I-471 North to Junction I-71 (Exit 0), Cincinnati, OH	5.10
I-71 South to Junction/Merge I-75, (Exit 1) Cincinnati	1.40
I-71/I-75 South to KY Hwy. 8 (5th Street; Exit 192), Covington, KY	0.70
KY Hwy. 8 East to Radisson Hotel, Covington **(END)**	0.05
TOTAL	**101.50**

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Introduction

Industrial Minerals are non-fuel, non-metal, and non-gemstone quality geological materials mined for their use in various physical and chemical applications in industrial and agricultural processing, road and building construction, commercial products, and personal care products. Industrial minerals are ubiquitous geological resources, derived from igneous, metamorphic, and sedimentary bedrock, hydrothermal, placer, residual, and unconsolidated deposits, mined and produced in all 50 U.S. States and throughout the world. Industrial minerals can be grouped into four broad product categories: (1) processed minerals, which requires a mineral separation process by physical or chemical processes prior to sale and use, (2) dimension stone, where natural stone or rock is finished (e.g., drilled, cut, trimmed, polished) to specific sizes or shapes, (3) crushed stone, or those minerals that require a size reduction by mechanical processes, and (4) sand and gravel, which require only a size sorting process. Crushed stone and sand and gravel are often collectively referred to as aggregates by the mining and construction industries.

The product range of industrial minerals is large, varying from low value, locally used bulk products to high value niche products (e.g., those used in nanotechnology; Lehtinen et al., 2015). The U.S. Geological Survey (USGS) collects and reports statistical data of the domestic production, consumption, and economic trends of 84 non-fuel mineral commodities in the U.S. and lists key production states, international resource locations, imports and exports in annual Mineral Commodity Summaries (USGS, https://pubs.usgs.gov/periodicals/mcs2023/mcs2023.pdf). The USGS has identified and listed 50 mineral commodities on the 2022 List of Critical Minerals based upon reviews of international market supply chains and domestic vulnerabilities to potential disruptions affecting the national economy and development of infrastructure (USGS, https://www.usgs.gov/news/national-news-release/us-geological-survey-releases-2022-list-critical-minerals). Of the Critical Minerals, 17 are classified by USGS as Rare Earth Elements (REE's) which are all metallic, and 32 are other metallic minerals. The only non-metallic (and non-fuel) industrial mineral included on the Critical Minerals list is barite, which is not produced in the Greater Cincinnati area.

The value of industrial minerals produced in the U.S. far exceeds that of metals and coal. In 2022 the value of industrial minerals produced in the U.S. was $63.5 billion, whereas the value of metals was $34.7 billion and coal $21.3 billion. (USGS, https://pubs.usgs.gov/periodicals/mcs2023/mcs2023.pdf). Of the industrial minerals, natural aggregates (crushed stone and sand and gravel) had a value of $ 31.4 billion and all other industrial minerals had a value of $32.1 billion.

Crushed stone is a high-volume, low value commodity. The crushed stone industry is highly competitive and is characterized by many operations serving local or regional markets. The only type of crushed stone produced in the greater Cincinnati area is limestone (and dolostone), sourced from surface and underground mines works in Middle and Late Ordovician sedimentary strata. Online records retained by the U.S. Mine Safety and Health Administration (MSHA; https://www.msha.gov/data-and-reports/mine-data-retrieval-system) list at least ten (10) active crushed stone mines in the region.

Sand and gravel is also a high volume, low value commodity. Sand and gravel production and consumption is classified and reported by the USGS into two categories: industrial use and construction use. Examples of industrial uses include hydraulic fracturing sand (frac-sand), silica sand (glass sand) and foundry sand. Examples of construction uses include Portland cement manufacture for concrete, road base and bituminous/asphalt coverings, mortar sand, and landscaping or recreation. Virtually all sand and gravel produced in the greater Cincinnati area is for construction use, sourced from Quaternary alluvium deposits of the Ohio River floodplain or its tributaries. According to MSHA records, there are at least ten (10) active or intermittent sand and gravel quarries in the region.

Free on Board (FOB) sale price and transportation cost to delivery site are the major factors considered by consumers of crushed stone and sand and gravel. Most sale product is transported via public roads and highways by contract trucking firms to local consumers and their delivery sites in the greater Cincinnati area. Depending on the sale product volume and quality, the general “rule of thumb” considered for maximum road distance to delivery site is 40 miles, or alternatively within a 30-mile radius. Property frontage and access to the Ohio River and barge loadouts are used by some of the regional quarry operators. A significant amount of crushed stone is shipped as far as the U.S. Gulf Coast. A lesser amount of crushed stone is shipped by rail.

The purpose of this field trip is to visit and observe an example of an active crushed stone mining operation and a sand and gravel operation in the greater Cincinnati area. Field trip participants will have an opportunity to observe and discuss the host geologic and overburden materials, mine excavation and equipment, mine processing and storage, and product types and sizing. The crushed stone operation is in Butler, Pendleton County, Kentucky and is owned by Hilltop Stone, LLC. The sand and gravel operation is near Petersburg, Boone County, Kentucky and owned by Northern Kentucky Aggregates, Inc.

Field trip participants are respectfully asked to wear safety hard hats and boots, and to obey all posted and verbal safety rules issued by the mine operator or its employees. AIPG is an invited guest, so please comport yourself in an appropriate manner.

Regional Physiography and Geologic Setting

Both quarry sites are located within the Interior Low Plateaus Physiographic Province, a region dominated by horizontal to gently dipping sedimentary plateaus incised by dendritic streams and river valleys. The Interior Low Plateaus region is south of the Central Lowland and southern limit of glaciation. It includes the Cincinnati Arch, a broad north-northeast striking domal feature and the northeast striking Nashville Dome to the south, and an intervening Cumberland Saddle region in southern Kentucky **(Figure 1)**.

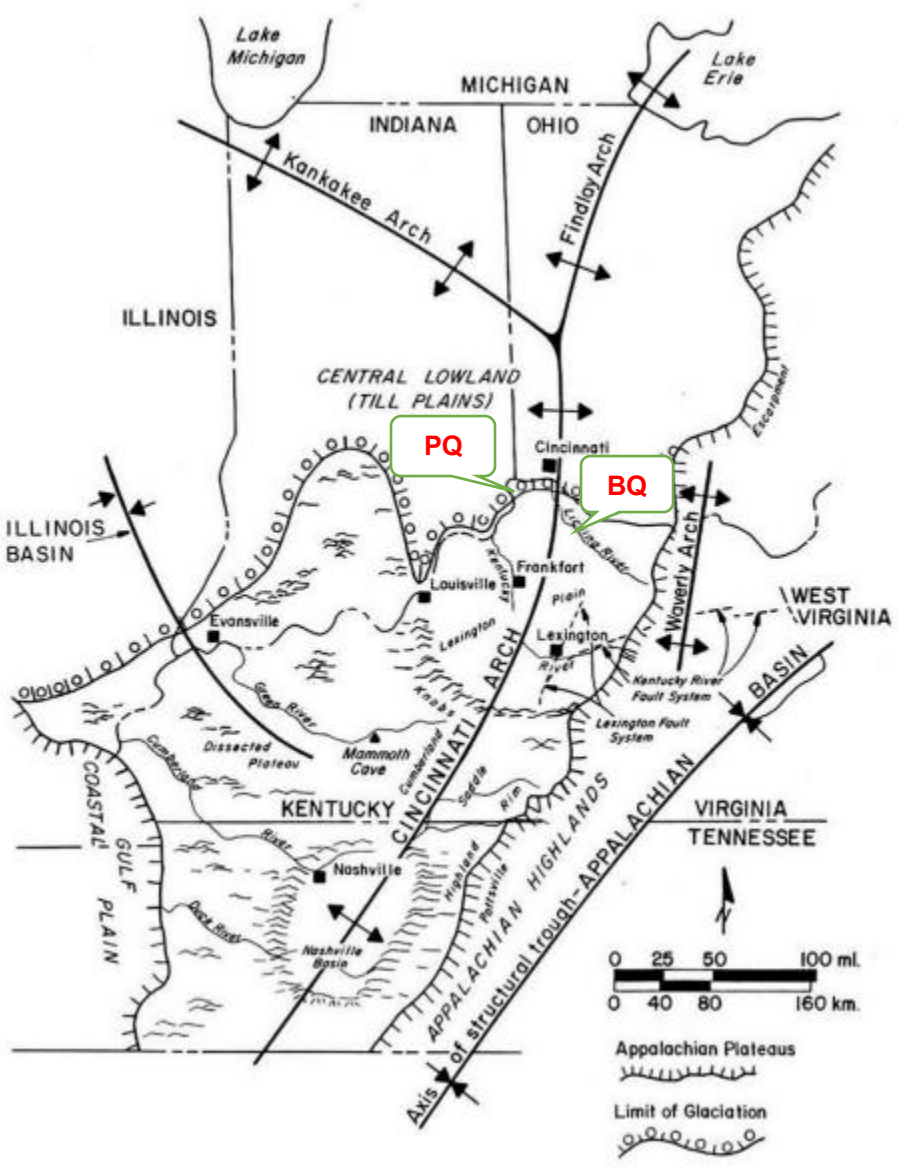


Figure 1. Regional structure map of the Cincinnati Arch showing the relationship between adjacent structural and physiographic features. **BQ** = Butler Quarry; **PQ** = Petersburg Quarry (modified from Hunt, 1974).

Both quarry sites are in the Outer Bluegrass Region, a subdivision of the Bluegrass Region of the Interior Low Plateaus. The Outer Bluegrass is distinguished by moderate to steeply rolling topography and deep, steep sided stream valleys, with little flat land on upland areas or floodplains. The bedrock in this subregion is composed of interbedded Upper Ordovician limestones and shales that are more easily eroded than the limestones of the Inner Bluegrass, the latter of which is composed of Middle Ordovician limestones on gently to moderately rolling topography, with small stream valleys.

The Northern Kentucky Aggregates Petersburg Quarry is sited on an inside meander bend and floodplain of the Ohio River, which is approximately 1 mile wide at the quarry site. The surface elevation at the quarry varies from approximately 465 to 475 feet MSL in waterfilled pits to 520 feet MLS at the undisturbed portions of the property. Hence the upper surface of the floodplain is 45 to 55 feet above the normal pool elevation of the Ohio River. A prominent steep sloped bluff forms the valley walls on Kentucky side and Indiana side of the Ohio River. The bluff is locally 200 feet high, and further inland from the Ohio River, the upland area is 300 feet higher, and moderately rolling to deeply incised and steeply sloping.

The Hilltop Stone Butler Quarry is also sited within a floodplain of a river valley, albeit a much smaller one of the Licking River. The Licking River is a northwest flowing, 303-mile-long meandering tributary of the Ohio River, which drains a large area of northeastern Kentucky. The quarry site, at an elevation of 510 to 530 ft MSL, was selected for the shallow depth to higher purity limestone beds of the Lexington Limestone Group, which are below drainage in the Ordovician outcrop area of northern Kentucky. The Quaternary sediments consist of sandy terrace deposits underlain by alluvium of the Licking River. The depth of cover is less than 20 feet in the area. The surrounding upland area is locally 350 feet higher, and moderately rolling to deeply incised and steeply sloping.

The quarry sites straddle the axis of the Cincinnati Arch, which has a structural relief of up to 1,500 feet based upon regional mapping of the New Albany-Ohio Shale (Devonian-Mississippian). The Cincinnati Arch evolved in Late Ordovician to Early Silurian time, with significant upwarping during Early to Middle Devonian time (McDowell, 1980). The arch remained a positive feature throughout much of the remainder of Paleozoic time. The present structural relief of the arch results from Late Paleozoic or post-Paleozoic movement (McDowell, 1983). Late Ordovician shale and limestone interbeds crop out along the axis in the Cincinnati area, whereas Pennsylvanian sandstone and shale crop out along the distant flanks. A prolonged episode of subaerial erosion was succeeded by multiple episodes of Pleistocene glaciation which modified the regional landscape and drainage. The modern course of the Ohio River was established at the close of the Illinoian Stage with aggradation occurring during the Wisconsinan Stage (Ray, 1974).

Geologic Bedrock and Unconsolidated Deposits

A generalized geologic map of extreme northern Kentucky shows the aerial extent of geologic bedrock units and unconsolidated sediments for the region and the field trip quarry sites **(Figure 2)**, and an associated lithostratigraphic column shows the complex lateral relationships and nomenclature for the Middle and Upper Ordovician of the Cincinnati Arch-Tri State region and Nashville Dome-Central Tennessee region exhibited on the following page **(Figure 3).** The pink colored map pattern displays the youngest bedrock of the Cincinnati Arch as the Bull Lake Formation (map symbol "Obl", Richmondian Series-Upper Ordovician) and successively younger formations on the flanks (map symbol "Oaf", Maysvillian-Richmondian Ashlock Formation, Fairview Formation, Grant Lake and Calloway Creek Limestone undifferentiated), Kope Formation (map symbol "Ok", Edenian-Maysvillian). Unconsolidated sediments are composed of Quaternary age glacial outwash (map symbol "Qow") and alluvium (map symbol "Qal").

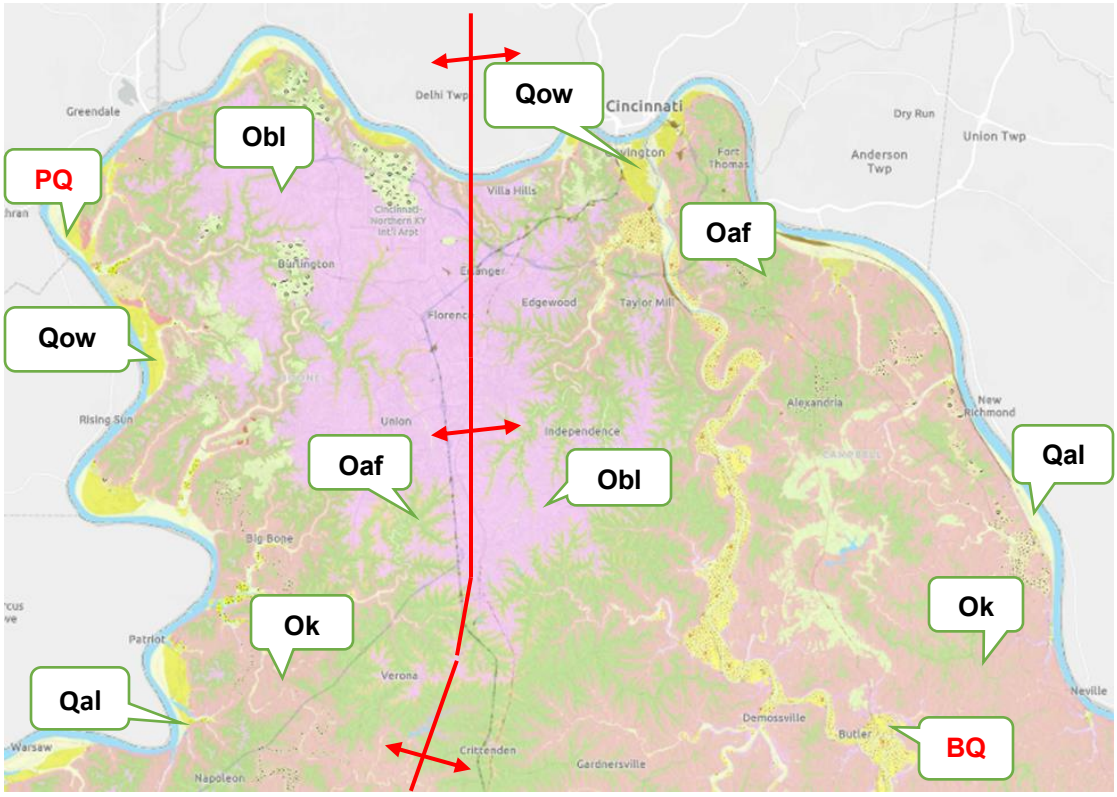


Figure 2. Generalized geologic map of northern Kentucky showing the location of the field trip quarry sites (Butler Quarry ="**BQ**", Petersburg Quarry = "**PQ**"; "Obl" = Bull Fork Formation; "Oaf" = Ashlock Formation, Fairview Formation, Grant Lake and Calloway Creek Limestone undifferentiated; "Ok" = Kope Formation; "Qow" = Quaternary outwash; "Qal" = Quaternary alluvium (from Kentucky Geological Survey, https://kgs.uky.edu/kgsmap/kgsgeoserver_dep/viewer.asp); Map Scale 1 in = 7 mi.

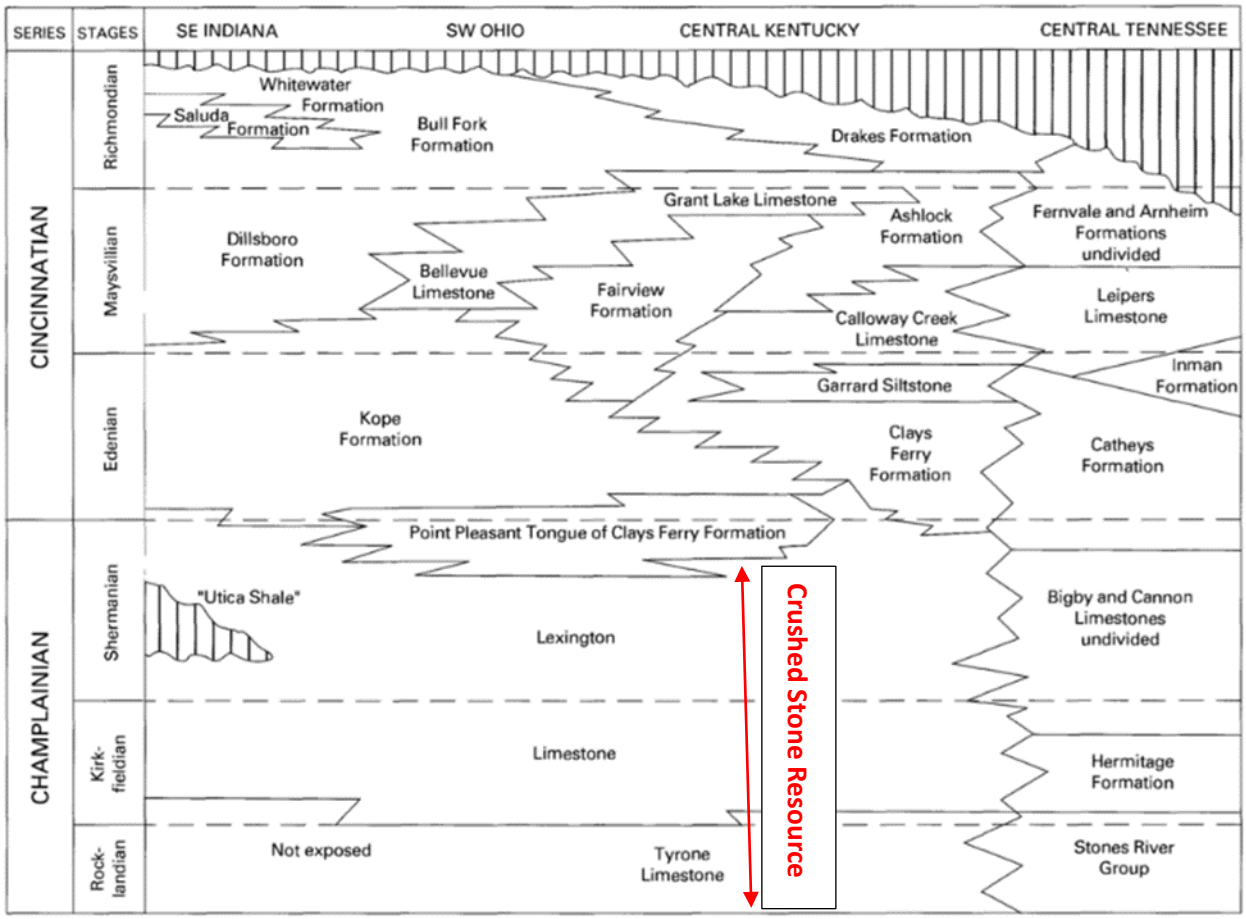


Figure 3. Lithostratigraphic relations of the Middle (Champlainian Series) and Upper Ordovician (Cincinnatian Series) in the Cincinnati Arch region of Ohio, Indiana, Kentucky, and Tennessee (modified from Wahlman, in Pojeta, 1992, after Sweet, 1979).

The details of the Middle and Upper Ordovician lithostratigraphic correlations and nomenclature are beyond the scope of this field trip. However, the principal point is that the strata assigned to the Upper Ordovician, which is locally up to 300 feet thick in the region, is considered as overburden cover of the unexposed formations of the Middle Ordovician Lexington Limestone Group and High Bridge Group below. The Upper Ordovician is primarily composed of thick calcareous shales with thin interbeds of argillaceous limestone, the latter typically less than 1.5 feet thick. Hence, owing to the abundant shale and high clay content of limestone beds, these formations are not commercial quality. In contrast, the Middle Ordovician Lexington Limestone Group, which is below stream drainage in most of the Tri-State region, is up to 200 feet of relatively pure, slightly argillaceous limestone, is the primary target for crushed stone production in the region. The limestone is only accessible below deeply entrenched stream valleys such as the Ohio River and its principal tributaries. Therefore, the locations of crushed stone mines are typically sited in these valley areas and most are underground works.

Market Area and Demographics of the Greater Cincinnati Area

Field trip participants will observe a marked change from the dense urban industrial, commercial, and residential land use types of the Covington area to low density, single-family residences, agricultural farms, and recreational uses of wooded, vacant land near the quarry areas. These urban and rural land use types are natural and compatible, and the demarcation between urban and rural in the Greater Cincinnati region is primarily based upon the local topography. Level areas along the floodplain or moderately sloping areas within 5 miles of the Central Business District (CBD) are urban and high density residential, as are mostly level upland areas within 15 miles of the CBD. In moderately sloping areas further away from the CBD, the development is much less.

The quarry sites and production are influenced in a general manner by the economic, political, physical, and social characteristics of the Cincinnati, OH-KY-IN Metropolitan Statistical Area (MSA). A MSA is a geographic area with a significant population nucleus, along with any adjacent communities that have a high degree of economic and social integration with that nucleus. The Cincinnati MSA includes 16 counties in the states of Ohio, Kentucky, and Indiana **(Figure 4)**.

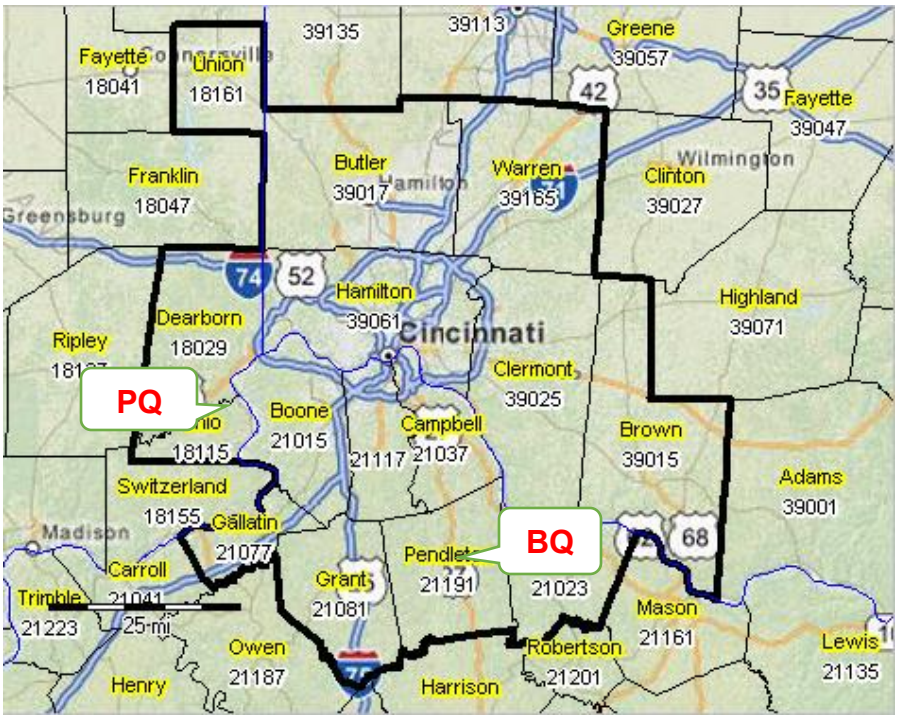


Figure 4. Map showing the counties (and county codes) included within the Cincinnati, OH-KY-IN MSA and locations of the Butler Quarry (**BQ**) and Petersburg Quarry (**PQ**). Both quarry sites are located within the Cincinnati MSA. (from Proximity One, http://proximityone.com/metros/2013/cbsa17140.htm#3.1).

It is of critical importance to understand the current population figures and projected growth trends to project and support long-term mining operations and supply needs of a market area. The Cincinnati, OH-KY-IN MSA has a current (2022) population of approximately 2.2 million and the State of Kentucky has a population of approximately 4.5 million. Online data indicates the Cincinnati MSA is expected to have an annual population increase of 0.2% and Kentucky an increase of 0.1% through 2027 **(Table 1)**.

Cincinnati, OH-KY-IN MSA
Population Data

	MSA		Kentucky		USA	
	Pop.	% Annual	Pop.	% Annual	Pop.	% Annual
2027 Estimate	2,290,408	0.2%	4,569,772	0.1%	339,902,796	0.2%
2022 Total	2,256,884	0.5%	4,537,160	0.4%	335,707,897	0.7%
2010 Census	2,137,667	0.6%	4,339,367	0.7%	308,745,538	1.0%
2000 Census	2,016,981		4,041,769		281,421,906	

Source: *US Census, Site To Do Business, June 2023 (https://stdb.com)*

Table 1. Population data for the Cincinnati, OH-KY-IN MSA, Kentucky, and USA (from Site To Do Business (https://stdb.com).

An employment sector is defined as the grouping of companies that are engaged in similar business activities, products, or services. Classifying an economy of an MSA or State into different sectors helps economists analyze the economic activity within those sectors. As a result, sector analysis provides an indication as to whether an economy is expanding or contracting (Investopedia, https://www.investopedia.com/terms/s/sector.asp).

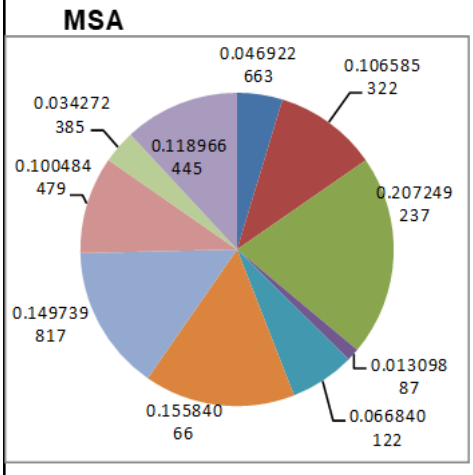
Sectors are generally classified into four main groups: (1) Primary Sector, which consists of companies and their “red collar” employees which extract or harvest natural resources or raw materials (mining, agriculture, fishing, forestry, construction); (2) Secondary Sector, which consists of companies and their “blue collar” employees that manufacture goods from the natural resources or raw materials produced from the Primary Sector (automobile production, textiles, shipbuilding, energy utilities); (3) Tertiary Sector, which consists of companies and their “white collar” employees that provide services (retailers, restaurants, tourism, transportation and distribution, insurance and banking, healthcare, legal services), and (4) Quaternary Sector, which consists of companies and their “white or gold collar” employees that are involved in knowledge based activities and services (higher education, research and development, information technology, professional consulting services; (Investopedia, https://www.investopedia.com/terms/s/sector.asp).

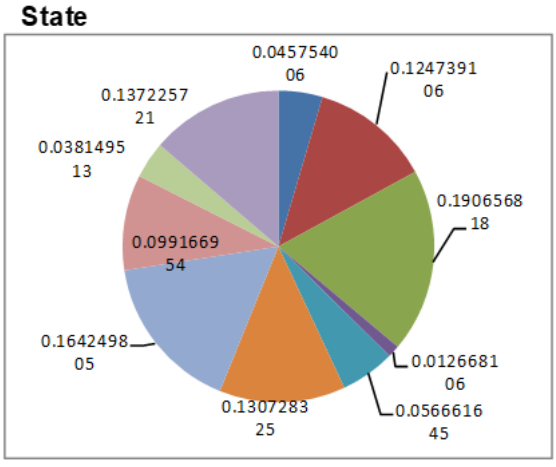
The tertiary sector is the largest sector in the United States since the service industry represents the largest share of the economy. Sector employment data from the U.S.

Bureau of Labor Statistics indicates the Cincinnati MSA and Kentucky are average or slightly above average in the tertiary sector **(Table 2)**. A review of annual economic trends by the senior author indicates that there has been a slight growth of the MSA and State economy in the several years prior to the declaration of the outbreak of the Coronavirus (COVID-19) pandemic by the World Health Organization (WHO) on March 11, 2020, and that the economy is rebounding in 2022 after a two-year contraction from the pandemic, which officially ended on May 5, 2023 (https://www.who.int/news/item/05-05-2023).

Cincinnati, OH-KY-IN MSA
Sector Employment

	MSA		State (Kentucky)	
Natural Resources/ Mining/ Construction	52,300	4.7%	86,000	4.4%
Manufacturing	121,400	10.9%	247,900	12.6%
TTU	236,500	21.2%	425,900	21.6%
Information	14,600	1.3%	22,000	1.1%
Financial	74,600	6.7%	97,300	4.9%
Professional Services	171,400	15.4%	221,400	11.2%
Edu & Health Services	165,600	14.9%	294,800	15.0%
Leisure & Hospitality	111,700	10.0%	201,900	10.3%
Other Services	39,200	3.5%	63,700	3.2%
Government	126,600	11.4%	307,300	15.6%
Total	**1,113,900**	**100.0%**	**1,968,200**	**100.0%**





Source: *US Bureau of Labor Statistics (Dec. 2022)*

Table 2. Sector employment data for the Cincinnati MSA and Kentucky. The decimal amounts depicted in the pie chart correspond with the percentages listed in the table for the respective sector type (U.S. Bureau of Labor Statistics, https://www.bls.gov/).

A list of the major employers of the Cincinnati OH-KY-IN MSA below amplifies the overall predominance of tertiary and quaternary sector employers, and a subordinate but important base of secondary and primary sectors **(Table 3)**.

Cincinnati, OH-KY-IN MSA
Major Employers

Rank	Company	# of Employees
1	Kroger	20,000
2	Cincinnati Children's Hospital Medical Center	16,742
3	Cincinnati/Northern Kentucky International Airp	14,602
4	TriHealth Inc.	12,000
5	University of Cincinnati	10,530
6	UC Health	10,551
7	St. Elizabeth Healthcare	10,048
8	Procter & Gamble	9,700
9	GE Aviation	9,000
10	Fifth Third Bancorp	7,500
11	Mercy Health - Cincinnati	7,500
12	City of Cincinnati	6,600
13	Cincinnati Public Schools	6,500
14	Amazon.com LLC	6,000
15	Baker Construction Enterprises, Inc.	5,500
16	Fidelity Investments	4,800
17	Hamilton County	4,500
18	Miami University	3,804
19	Anthem Blue Cross Blue Sheild	3,700
20	Boone County School District	3,500
21	RDI Corporation	3,500
22	Cincinnati Financial Corp	3,298
23	Kings Island	3,000
24	Total Quality Logistics	3,000
25	US Bank	3,000

**Cincinnati Business Journal 2022*

Table 3. List of major employers of the Cincinnati, OH-KY-IN MSA (Cincinnati Business Journal, https://www.bizjournals.com/cincinnati/).

The list shows that the major employers are predominately health care services and providers, banking and investment firms, public and private school districts and universities, transportation-distribution facilities (Cincinnati Airport, Amazon). Some regional industrial manufactures (Kroger, GE Aviation, Proctor & Gamble) provide a stable base of secondary sectors. Absent from the list are natural resource-based employers (mining, agriculture, and forestry) which suggests there is an overall market demand for raw materials including lumber and construction aggregates for the Cincinnati area.

Aggregate Production in the Greater Cincinnati Area

The Petersburg Sand & Gravel Quarry is one of several competing quarries and suppliers of sand and gravel in the Cincinnati area. The quarry is owned and operated by Northern Kentucky Aggregates, Inc. The map below shows the Petersburg Quarry is located approximately 1.3 aerial miles and 2 road miles south-southwest of Petersburg, Boone County, Kentucky and 20 aerial miles and 26 road miles west-southwest of the Cincinnati, CBD; **Figure 5**). The subject quarry has frontage on KY Hwy. 20 and a direct barge loadout on the adjacent Ohio River.

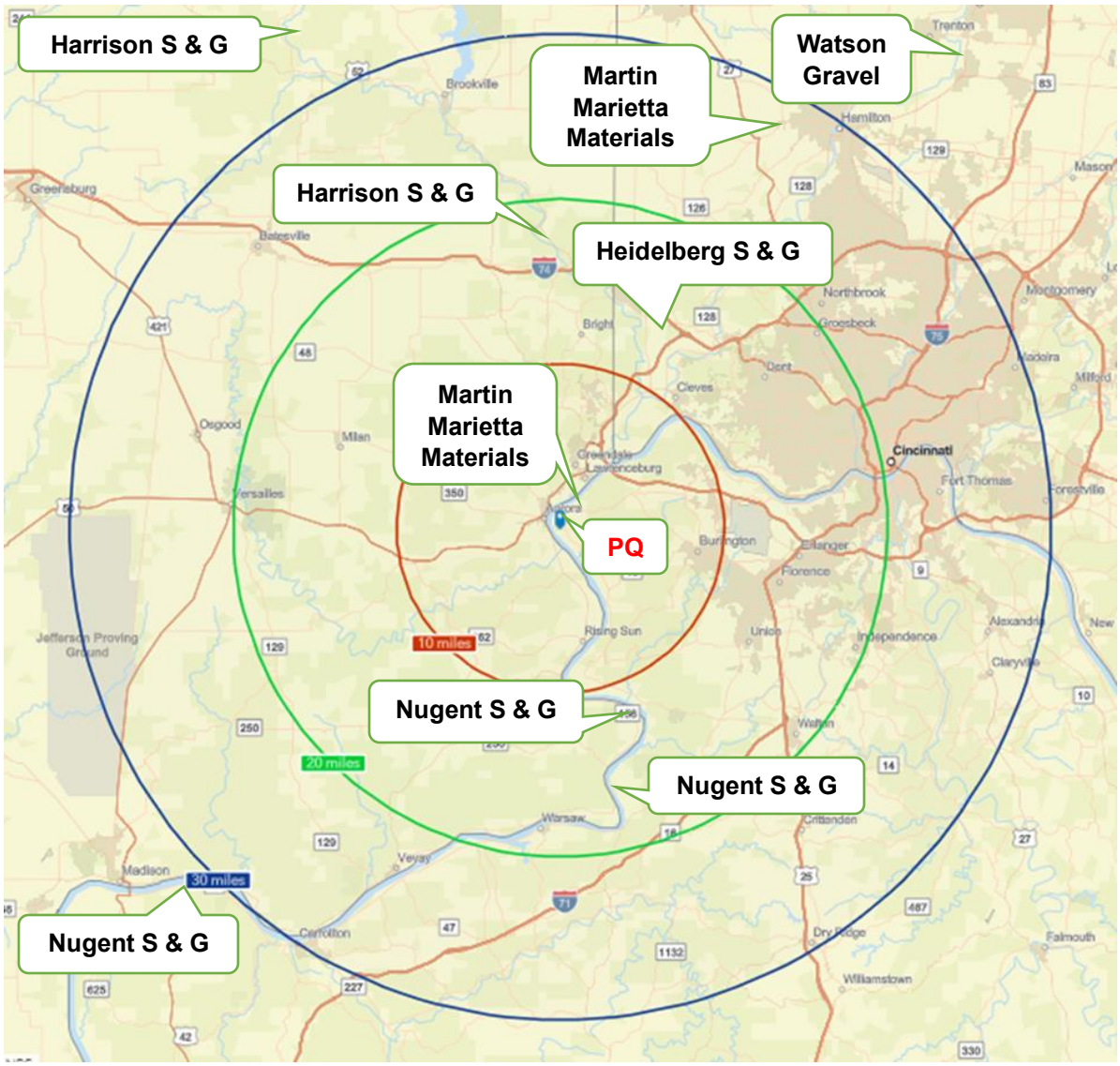


Figure 5. Map showing the location of the Petersburg Quarry (**PQ**) and competitor sand and gravel operations and associated 10-mile (red ring), 20-mile (green ring), and 30-mile (blue ring) market distance radii from the subject quarry.

The Butler Quarry is one of several competing quarries and suppliers of crushed stone in the Cincinnati area. The quarry is owned and operated by Hilltop Stone, LLC. The map below shows the Butler Quarry is located approximately 1.3 aerial miles and 1.5 road miles east-northeast of Butler, Pendleton County, Kentucky and 23 aerial miles and 27 road miles south-southeast of the Cincinnati CBD; **Figure 6**). The subject quarry has frontage on KY Hwy. 177 and nearby access to U.S. Hwy. 27.

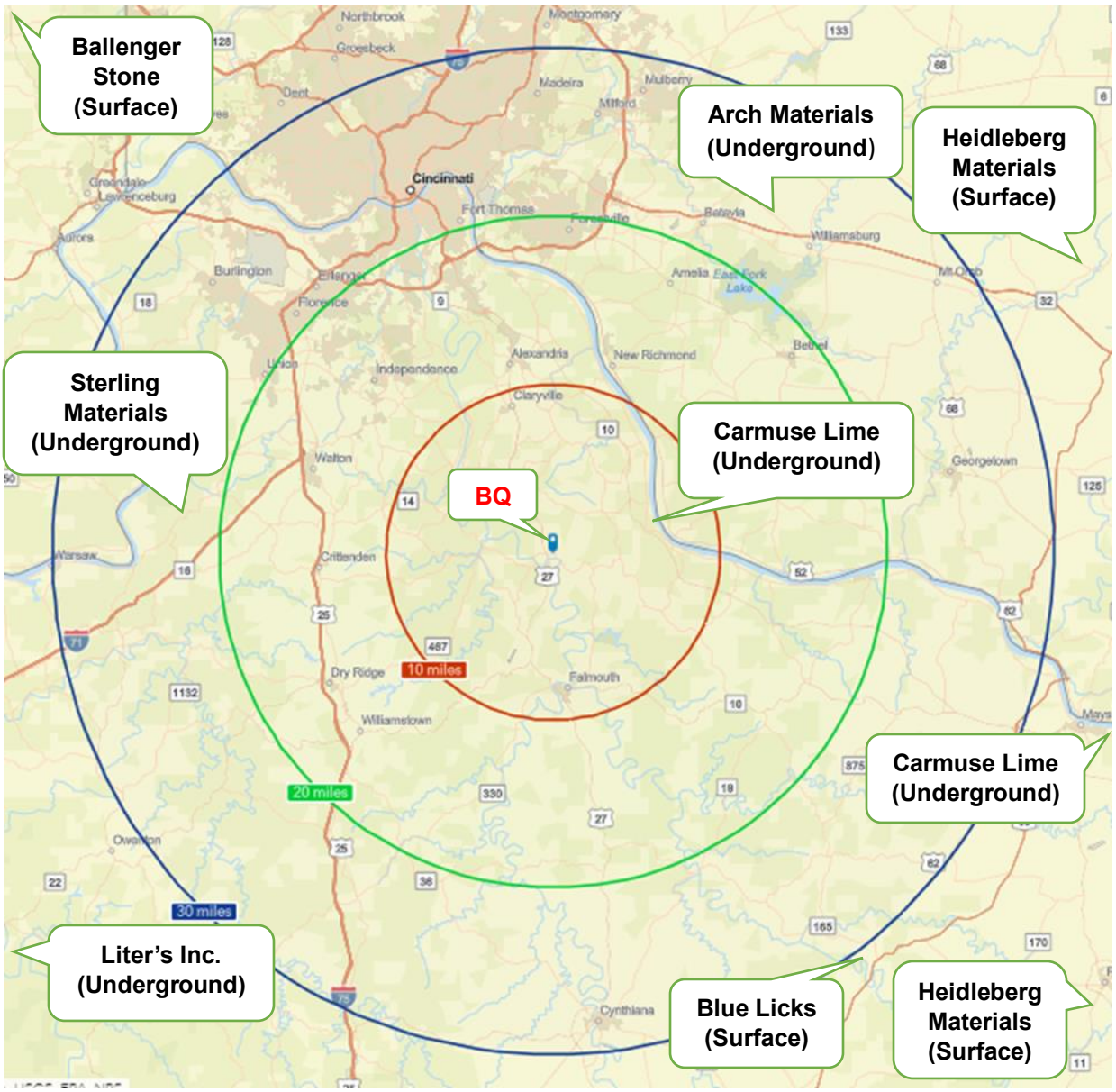


Figure 6. Map showing the location of the Butler Quarry (**BQ**) and competitor crushed stone operations and associated 10-mile (red ring), 20-mile (green ring), and 30-mile (blue ring) market distance radii from the subject quarry.

STOP 1: View of Ohio River at Petersburg, Kentucky

The first stop of this field trip is a northward view from the south bank of the Ohio River at Petersburg Riverfront Park, Boone County, Kentucky. Peterburg (2023 population 418) is sited at approximately 500 feet MSL, and 50 feet above the normal pool elevation of the Ohio River on a Quaternary stream terrace deposit of a floodplain **(Figure 7)**.

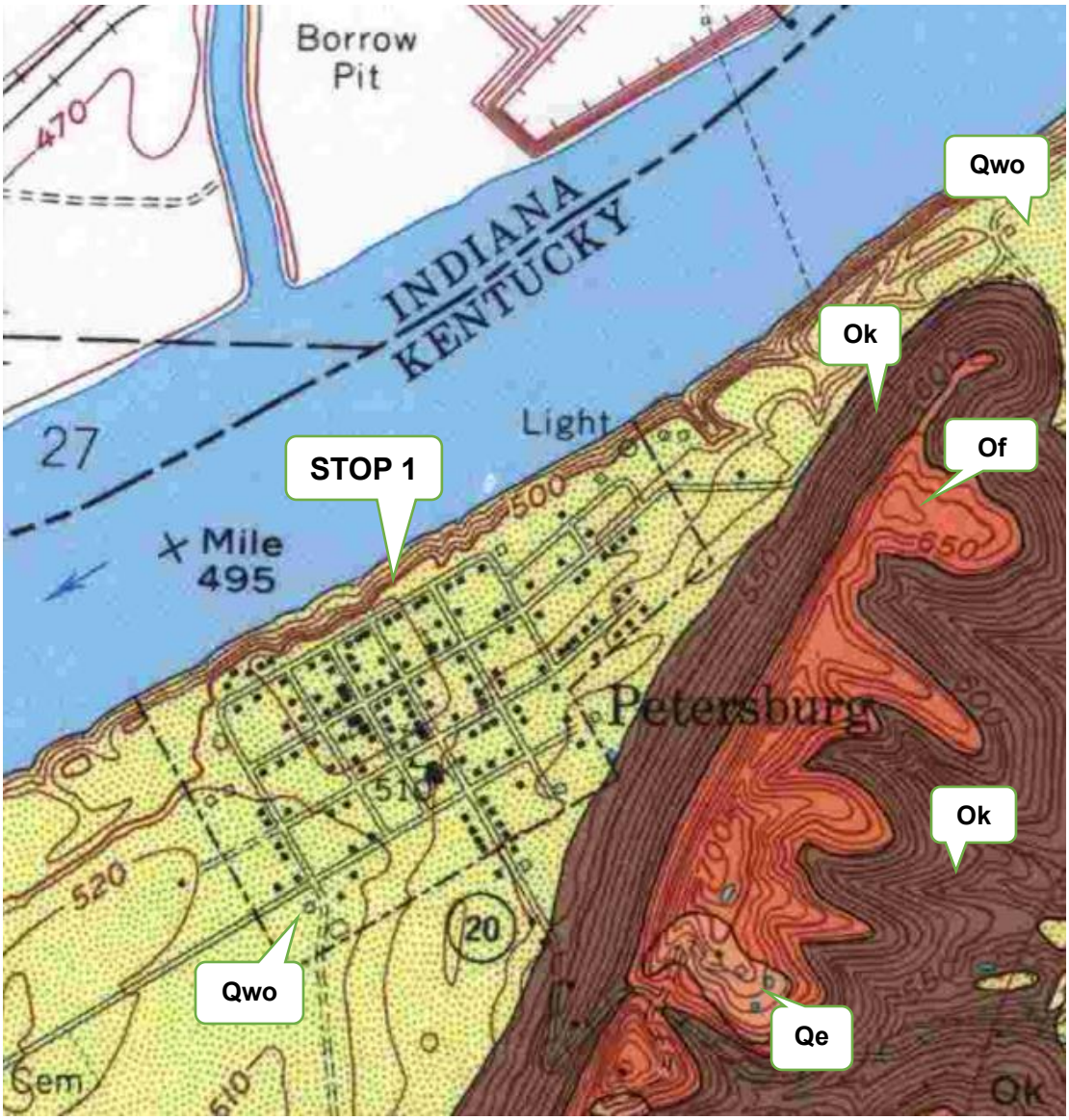


Figure 7. Geologic map of part of the Lawrenceburg, IN 7.5' quadrangle showing the juxtaposition of the northeast narrowing Ohio River floodplain and the upland river bluffs near Petersburg, Kentucky (Map symbol "Qe" = Quaternary eolian sand; "Qwo" = Quaternary glacial outwash; "Of" = Ordovician Fairview Formation; "Ok" = Ordovician Kope Formation; Map scale 1" = 0.25 mi. approx. (from Swadley, 1972).

The vista from Petersburg Riverfront Park enables field trip participants to see the local topography, characterized by an inside meander bend of a 1.5-mile-wide floodplain, a sharp north facing river bluff to the south, a 1,500-foot-wide Ohio River channel, and the terminus of a 200-foot-wide tributary stream (Tanners Creek) on the opposite side of the Ohio River, downstream from Lawrenceburg, Dearborn County, Indiana.

The astute observer will note the absence of a man-made levee or flood control barriers. This is because the stream terrace is a natural levee, about 50 feet higher than the normal pool level. The Ohio River is naturally a shallow river that was artificially deepened by a series of dams, which now number 20 along its 981-mile length. The average depth is approximately 15 feet along much of its length but reaches 168 feet deep west of the McAlpine Locks and Dam west of Louisville, Kentucky. At Petersburg, the channel shape is slightly asymmetric and convex, and up to 46 feet deep within 400 feet of the Kentucky shoreline (Fishermap.org, https://usa.fishermap.org/depth-map/ohio-river/).

The published geologic map of the Lawrenceburg, IN 7.5' Quadrangle indicates the floodplain surface is mapped as glacial outwash of Wisconsinan (Late Pleistocene) age **(Figure 5)**. The outwash is described as well to poorly sorted gravel and sand, and borehole data indicate a total thickness of at least 170 feet in the Petersburg area. Some of the Wisconsinan sediments overlie older Illinoisian sediments (Swadley, 1972). The river bluff is steeply sloping bedrock of the Kope Formation (Upper Ordovician), a 200+ foot thick calcareous shale and subordinate siltstone, with thin interbeds of sparsely to abundantly fossiliferous limestone, commonly less than 12 inches thick (Swadley, 1972).

The origin of the glacial outwash sediments and depositional history of the Ohio River Valley has been thoroughly studied and described. In brief, the present course of the Ohio River was established by the end of Illinoian time (~130,000 to 125,000 years BP), following complex modifications of the pre-Pleistocene landscape and northward drainage patterns from prior Nebraskan and Kansan glaciations that extended into the Midwest and Greater Cincinnati region (Ray, 1974). By the close of the Yarmouth interglacial (~380,000 to 200,000 years BP), local topographic relief was greater than at any other time during the Quaternary. Major valley aggradation began during Illinoisan time and extended onto surrounding upland areas. The Wisconsinan ice sheets did not reach the main Ohio River valley at any point, but the river provided a sluiceway for glacial meltwater and deposition of fluvioglacial sediments. Aggradation and degradation during glacial fluctuations led to the formation of two prominent river terraces (Ray, 1974).

The Ohio River makes an abrupt 90-degree bend from southwest to southeast approximately 1.5 miles downstream from STOP 1. An active sand and gravel quarry along this river bend will be the focus of the next field trip stop.

STOP 2: Petersburg Sand & Gravel Quarry, Petersburg, Kentucky

The Petersburg Sand & Gravel Quarry is located approximately 1.3 aerial miles and 2 road miles south-southwest of Petersburg, Boone County, Kentucky and 20 aerial miles and 26 road miles west-southwest of the Cincinnati, Ohio Central Business District (CBD; **Figure 8**). The subject property address is 3743 Belleview Road (KY Hwy. 20), Petersburg, Kentucky 41080.

Figure 8. Boone County property tax map showing the location of the Petersburg Quarry and vicinity. The controlled property (fee simple) boundary is outlined in red colored lines (Map Scale 1 in. = 0.25 mi).

The Petersburg Quarry is operated by Northern Kentucky Aggregates (https://www.jrjnet.com/nka/), a subsidiary enterprise of the Jurgensen Companies (https://www.jrjnet.com/), which was established in 1934 in Cincinnati and has a

controlling interest of 16 construction aggregate quarries, porous and hot mix asphalt production plants, construction paving equipment and services, and transportation terminals in the Tri-State region. The Mine Safety and Health Administration (MSHA) Mine ID listed for the Petersburg Quarry is 15-00030, and the Kentucky Division of Mine Reclamation and Enforcement (DSMRE) Permit Number is 015-9605.

According to MSHA records and conversation with the mine operations manager, the mine began operation in 1976 or 1977 under an unknown owner on land formerly used for row crop production. The quarry was sold to Jurgenson Companies in 1979. Historical editions of topographic maps aerial images indicate extraction commenced in a now abandoned pit set back about 1,500 feet southwest of Belleview Road and northwest of the current primary access road to the scale house and plant. This pit expanded north toward Old Horsley Ferry Road and depleted most of the productive area of the glacial outwash, approximately 22 acres, and was abandoned in the late 1980's **(Figure 9)**. The remnant water filled pit is 17 acres and can be distinguished on current topographic base maps and aerial images. The present operation located on the southeast side of the primary access road began in the late 1980's. Using a water borne dredge, the pit developed to the southeast, set back about 600 feet from Belleview Road, and developed the area closest to and parallel to Belleview Road, and about the same time, a second parallel pit, using a fixed bucket dredge moored to the shoreline, commenced closer to the Ohio River, and progressed to the southeast. The two separate pits were segregated by the current peninsula conveyor belt until the early 2000's, then united near the southeastern margin of the property boundary. During the past 20 years, the extraction has gone deeper and enlarged the depletion area closer to Belleview Road. The dredge uses a 10-yard clam shell bucket and the depth of the working pit is 50 feet below water level. The current working pit measures approximately 74 acres and reached its limit surface footprint. In 2019 an idle sand and gravel quarry, plant and barge loadout located about 4 miles to the south and formerly known as the Belleview Quarry, was purchased by Jurgensen Companies. This mine has not been resurrected to operational status and is currently used for receiving barge shipments and stockpiling of other aggregate products. The management is currently under negotiations with the property owner(s) to the southeast of the current mining operation to purchase the adjoining farm property and expand the ongoing mining operation.

The quarry produces approximately 300,000 to 380,000 sale tons per year of mostly asphalt sand, concrete sand, "top deck" 3/8" size "pea gravel", and to a lesser extent, larger sized #67 and #57 sizes. The sale product is delivered by truck throughout the Cincinnati region as far as Winchester, Kentucky, 110 miles to the south. The 8-man crew currently works 5 day, 12-hour shifts, and an 8-hour shift on Saturday. The work crew is cross trained on all operational aspects of quarry operations to maintain daily production.

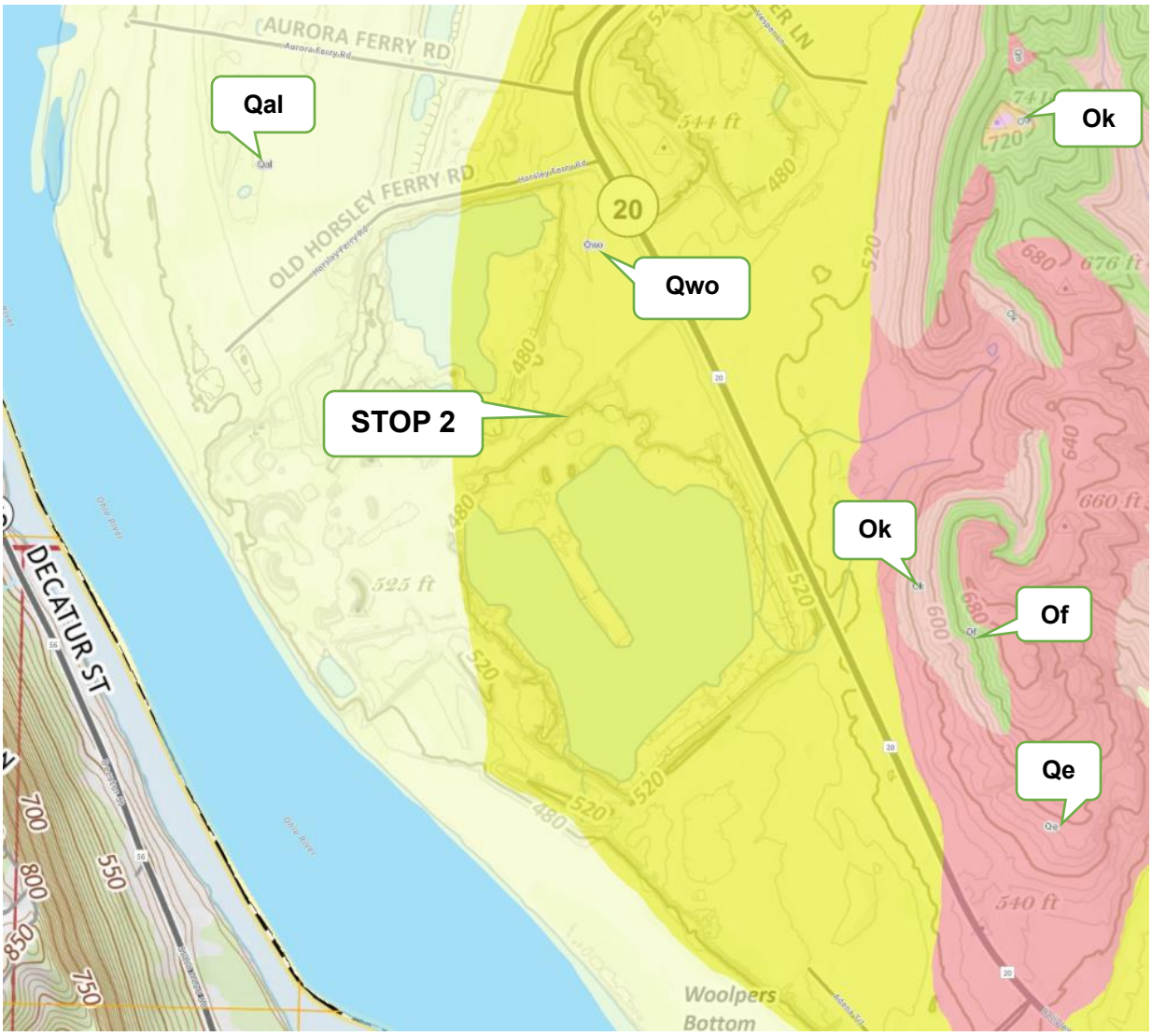


Figure 9. Geologic map of part of the Aurora and Lawrenceburg 7.5' quadrangles showing the aerial extent of the Petersburg sand and gravel quarry and vicinity, Petersburg, Boone County, Kentucky. Map symbols: "Ok" = Ordovician Kope Formation, "Of" = Ordovician Fairview Formation, "Qe" = Quaternary eolian deposits, "Qwo" = Quaternary glacial outwash, "Qal" = Quaternary Alluvium (from Swadley, 1972, Map Scale: 1 in. = 0.25 mi. approx.).

The geologic map shows that the quarry pits have been developed on Quaternary glacial outwash deposits, which includes Wisconsinan and Illinoisian sand and gravel. Aggregate composition varies with grain size for both sand and gravel. Percentage of limestone and dolomite particles is highest in the coarsest grades of both sand and gravel. Quartzite, igneous, and metamorphic rocks comprise 10 to 20 percent of all coarse aggregate, but in the sand size ranges they form only a small percentage (Amaral, 1994).

STOP 3: (Lunch), Dinsmore Homestead, Burlington, Kentucky

The Dinsmore Homestead provides field trip participants a quiet, shaded respite for an outdoor picnic lunch and an opportunity to join a guided tour of a furnished antebellum home, outbuildings, and grounds. The site is located approximately 5.2 aerial miles and 6.2 road miles west-southwest of Burlington, Boone County, Kentucky and 17.4 aerial miles and 22 road miles west-southwest of the Cincinnati, Ohio CBD. The subject property address is 5656 Burlington Pike, Burlington, Boone County, Kentucky 41005.

The Dinsmore Homestead is sited on 30 acres near the western base of a steep sloping upland area along Middle Creek, one of many steep sided, west flowing streams that drain the larger upland area. The site is currently owned and managed by the Dinsmore Homestead Foundation Board. The mission of the Board is to preserve and maintain the home, outbuildings, furnishings, artifacts, and grounds, to provide educational opportunities for youth and adults, and to support cultural and historic research (Dinsmore Homestead Foundation, https://www.dinsmorefarm.org/preservation/the-foundation/).

The main residence is a wood frame, two-story 4,500 SF farmhouse built circa 1842 in Greek Revival Style. The house was occupied by the namesake James Dinsmore (1790-1872), his family and subsequent heirs, who with the help of tenant hands grew various row crops and raised livestock until 1960. In 1987, the property ownership was legally transferred to the Dinsmore Homestead Foundation, which was created by a governing Board charged with preserving and maintaining the historic property and its legacy.

Figure 10. North view of Dinsmore Homestead, rural Burlington, Kentucky.

STOP 4: Butler Crushed Stone Quarry, Butler, Kentucky

The Butler crushed stone quarry is located approximately 1.3 aerial miles and 1.5 road miles east-northeast of Butler, Pendleton County, Kentucky and 23 aerial miles and 27 road miles south-southeast of the Cincinnati, Ohio CBD (**Figure11**). The subject property address is 1405 KY Hwy. 177, Butler, Kentucky 41006.

Figure 11. Pendleton County property tax map showing the location of the Butler Quarry and vicinity. The controlled property boundary (fee simple) is outlined in red colored lines and the mineral lease area is outlined in blue colored lines (Map Scale 1 in. = 0.25 mi.).

The Butler Quarry is operated by Hilltop Stone, LLC, a subsidiary enterprise of Hilltop Basic Resources, Inc. established in 1941 in Cincinnati as a building material and ready-mix concrete supply company (Hilltop Stone, History https://hilltopcompanies.com/history/). The company owns and operates one sand and gravel quarry, two surface crushed stone quarries, two barge and rail transportation terminals, and two Ready Mixed concrete plants, with concrete truck delivery, within the

Tri-State region. The Mine Safety and Health Administration (MSHA) Mine ID listed for the Butler Quarry is 15-04255, and the Kentucky Division of Mine Reclamation and Enforcement (DSMRE) Permit Number is 096-9400. The Mine Information retained on the MSHA Mine Data Retrieval System is included in the Addendum.

According to MSHA records and conversation with the mine operations manager, the mine began operation in 1954 under the ownership of Gohagan and Mathis, Inc., was sold to Medusa Aggregates Company in 1979, and sold to Southdown, Inc. in 1998 and in turn to Cemex, Inc. in 2001. Hilltop purchased the operation in 2001.

Beginning at the ground surface elevation of 550 ft. MSL, the initial surface mining operations stripped off approximately 20 to 30 feet of overburden consisting of Quaternary alluvial and terrace deposits of sand and gravel mantling the bedrock in the Licking River Valley, and an additional 20 feet of weathered bedrock of the Point Pleasant tongue of the Clays Ferry Formation (Upper Ordovician; **Figure 12)**. A scaled stratigraphic profile shows the nomenclature and relative thicknesses of the bedrock units currently exposed in the pit **(Figure 13)**. In descending order, the uppermost 20 feet of bedrock is an overburden caprock of thin bedded shaly limestones of Point Pleasant Formation (Upper Ordovician). The upper producing target beds consisted of approximately 50 feet of argillaceous and silty limestones of the Point Pleasant Formation and underlying 55 feet of flaggy bedded Cane Run Bed and Grier Member of the upper part of the Lexington Limestone Formation. Beneath the latter, is the uppermost bench setback and the top of a prominent interburden layer of up to 50 feet of shaly limestone identified as the Logana Member. The latter is excavated and moved to a waste storage area in the northern part of the property. Below the Logana Member is 35 feet of relatively pure Curdsville Limestone Member, the base of the Lexington Limestone Formation. A bench setback is developed at the top of the underlying Tyrone Limestone, marked by a 1-to 2-foot-thick regional greenish gray bentonite claystone bed identified as the “Mud Cave”, which has been interpreted from petrographic and mineralogical assemblages as a volcanic ash layer. The “Mud Cave” and the “A seam” and “Pencil Cave” bentonites below weather to chert and are deleterious material. The Tyrone Limestone forms a sheer rock wall up to 125 feet thick in the pit and consists of light-colored crystalline, fossiliferous limestone. Below the Tyrone Limestone, another bench is developed on the top of the Oregon Limestone, a very fine grained, slightly darker colored, mostly non fossiliferous algal dolostone, up to 20 feet thick.

The current pit size is 60 acres, and the mining operation is down to 120 ft MSL, or 420 feet below the top surface. The works at the base are currently extracting the upper part of the Camp Nelson Limestone of the Highbridge Group (Middle Ordovician). The Camp Nelson is a massive bedded, light colored algal limestone that generally lacks fossils.

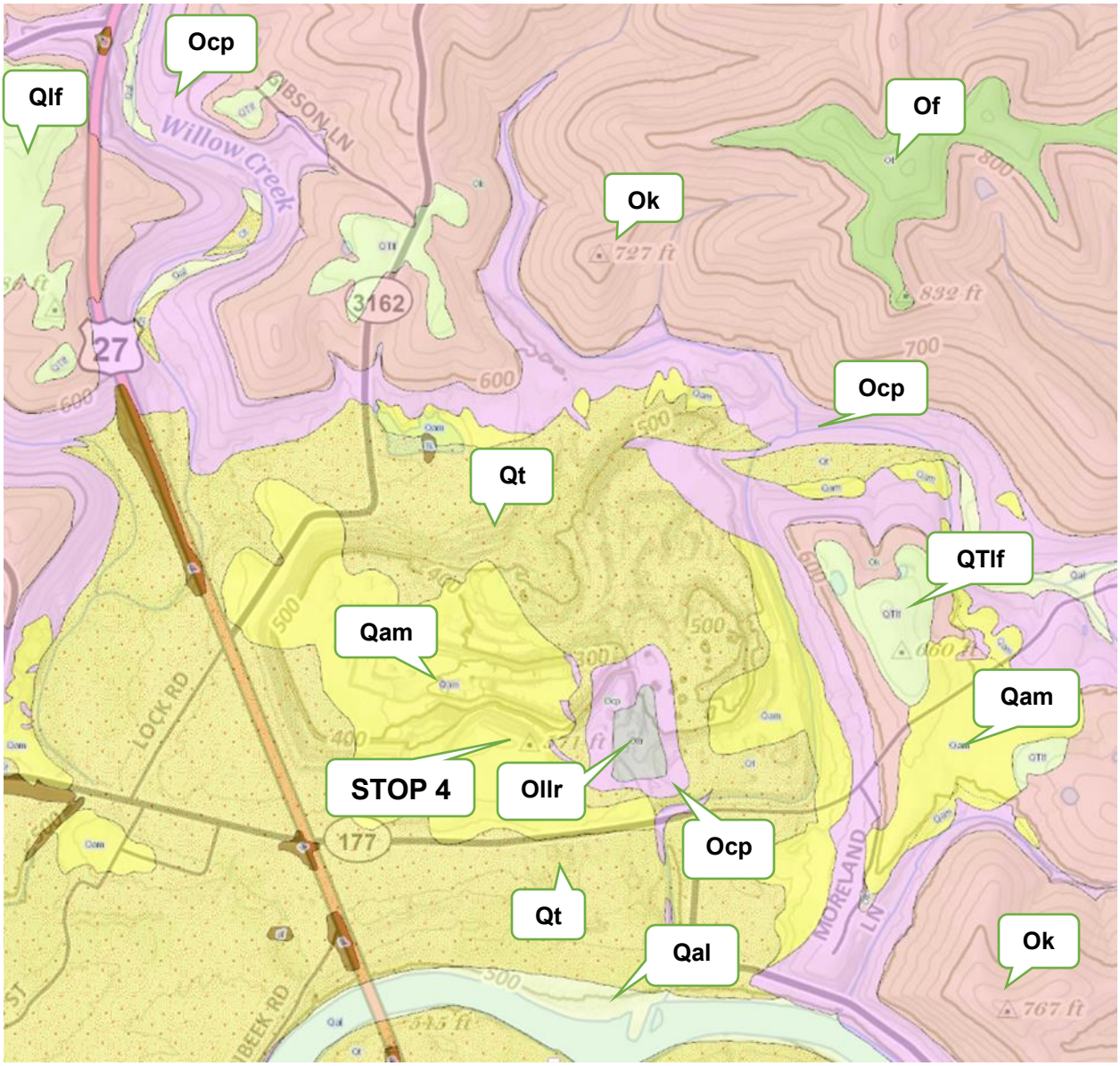


Figure 12. Geologic map of part of the Butler 7.5' quadrangle showing the location of the general location of the active pit and pre-disturbance geologic bedrock and unconsolidated deposits (Map symbols: "Ollr" = Ordovician Lower part of Lexington Limestone, "Ocp" = Ordovician Point Pleasant tongue of the Clays Ferry Formation, "Ok" = Ordovician Kope Formation, "Of" = Ordovician Fairview Formation, Qlf = Quaternary Lacustrine and fluvial deposits (pre-Illinoisan), "Qila" = Quaternary Lacustrine deposits (Illinoisian), "Qld" = Glacial drift (Illinoisian), "Qt" = Quaternary-Tertiary Terrace deposits, "Qam" = Quaternary alluvium of valley sides, meander cores, cut-off meanders, and abandoned channels, "Qal" = Quaternary alluvium (From Luft, 1972, Map Scale: 1 in. = 0.25 mi. approx.).

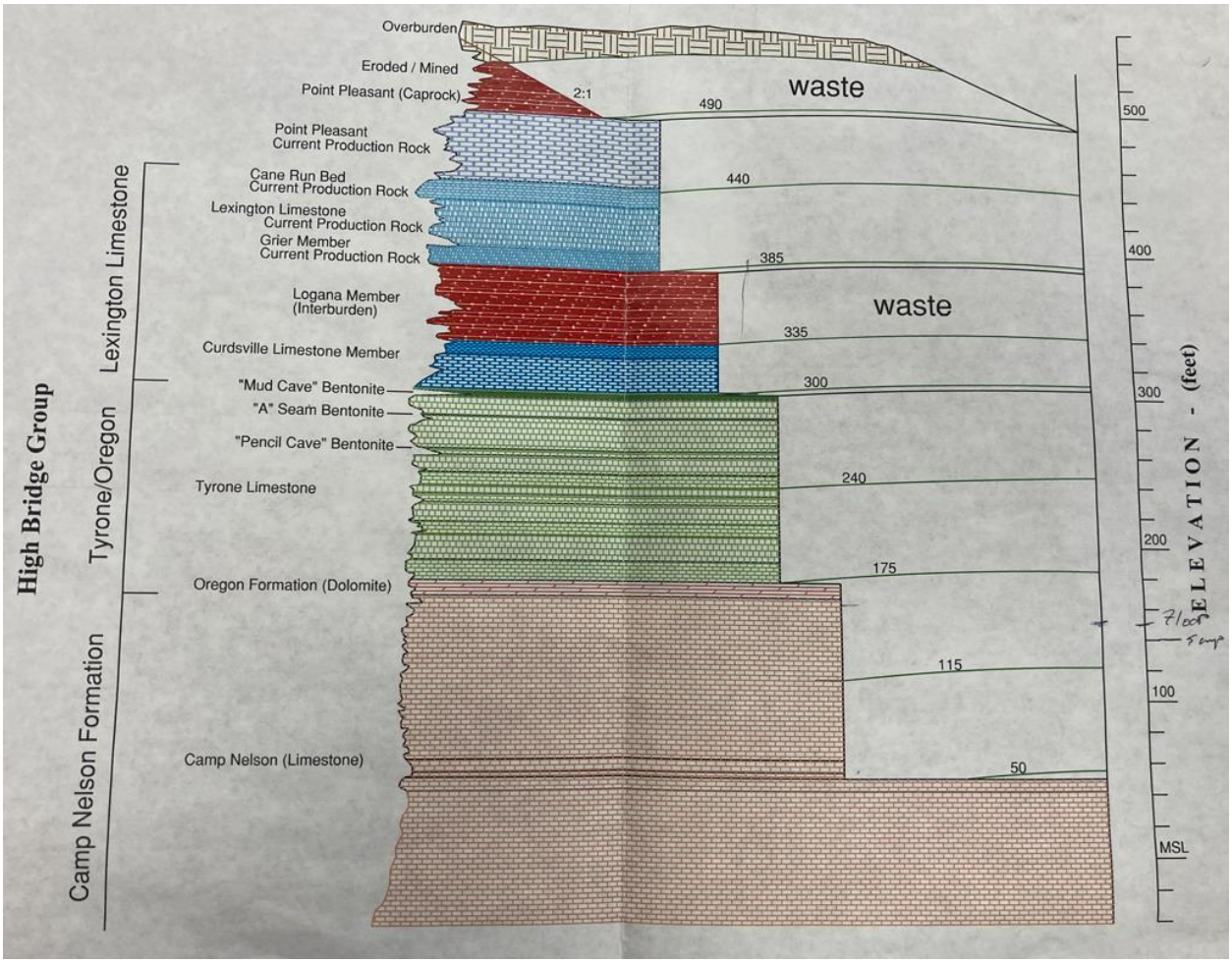


Figure 13. Stratigraphic profile and nomenclature of the exposed bedrock in the Butler Quarry with scaled reference elevation of feet Mean Sea Level (MSL). The current pit floor is at 120 ft. MSL and mining the upper part of the Camp Nelson Limestone (Middle Ordovician; figure from Hilltop Stone, 2023).

The quarry generally produces from 1.3 to 1.6 million sale tons per year. However, in the past two or three years, a significant amount of interburden tonnage (as much as 800,000 tons) of the Logana Member is being removed in the north part of the pit for the long term and expansion of the surface operation. Mine management indicated that it is technically feasible and likely that underground operations will commence from a drift portal at some time and place in the future.

The sales products include various construction sizes including “bedding sand”, #57, #8, #6, #4, and #2 Limestone, AG Lime, Dense Grade Aggregate (DGA), and Rip Rap. The products are delivered throughout the Cincinnati region and further to the south. Currently, there are approximately 25 miners working an 11-hour shift 5 days per week.

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About the Authors

Donald K. Lumm, Ph.D., C.P.G., is an owner and sole proprietor of D.K. Lumm Geological Consulting, LLC, Lexington, Kentucky since 2018, and a part time mineral appraiser for Chapman Appraisals, LLC, Louisville, Kentucky, since 2019. He earned an A.A. (1979) from Lincoln College, B.S. (Geology, 1981) from Southern Illinois University at Carbondale, M.S. (Geology, 1988) from Vanderbilt University, and Ph.D. (Geological Sciences, 1998) from the University of Kentucky. Dr. Lumm began his career in 1981 with the Coal Section of the Illinois Geological Survey where he acquired experience with geologic field mapping and subsurface mapping of the complexly faulted southern part of the Illinois Basin and resource mapping of the New Albany Shale petroleum source rock. He then worked from 1995 to 2006 as a Mineral Appraiser for the Kentucky Revenue Cabinet, Frankfort, KY and subsequently from 2006 to 2012 as a Senior Geologist for Marshall Miller and Associates, Lexington, KY and from 2012 to 2018 with ECSI, LLC, Lexington, KY. As a project geologist and private consultant, he has performed resource estimates and appraisals of coal, oil and gas, limestone, sand and gravel, clay, phosphorite, and granite in the Midwest and Southeastern U.S. He has also performed investigations of coal mine permit non-compliance violations involving landslides, mine subsidence, and stream water quality, and investigations of sinkhole collapse. He is a member of several professional organizations including AIPG, the Geological Society of America, Society of Mining Engineers, and the International Institute of Mineral Appraisers.

John T. Popp, M.S., C.P.G., retired in 2016 as Chief Geologist with Natural Resource Partners, LLC, Huntington, West Virginia, and lives in Wilmore, Kentucky. John earned a B.S. (Geology, 1972) from Eastern Illinois University and a M.S. (Geology, 1974) from Southern Illinois University at Carbondale. Mr. Popp began his diverse career with the U.S. Bureau of Mines, Pittsburgh, where he researched coalbed methane in the Appalachian Basin and Unita Basin. He joined the Coal Section of the Illinois State Geological Survey in 1977 investigating underground coal mining conditions, roof support, and coal stratigraphy, and providing support to citizen inquiries. In 1979 he joined Dames and Moore, Cincinnati, OH, and performed consulting services for the mining industry. In 1985 he joined NERCO Coal and provided technical management and advisory services in geology, whose operations were in the Appalachian, Illinois, and Powder River Basins. From 1989 to 2004 he was a coal geologist with MAPCO/Alliance Coal Lexington, KY, supporting acquisition and expansion opportunities in the Central Appalachian Basin and the Illinois Basin. In 2004 he joined Natural Resource Partners, Huntington, WV, and performed data base and reserve analysis, acquisition reviews, SEC reviews and reporting, of coal, aggregates, and other mineral commodities located in the Midwest, Southeast, and Eastern U.S.

ADDENDUM

Petersburg Quarry Mine Information from MSHA Mine Data Retrieval System
https://www.msha.gov/data-and-reports/mine-data-retrieval-system

Mine Information	
Mine ID	: 1504255
Mine Name	: PLANT #1
Mine Status	: Active
Mine Status Date	: 7/13/2015
Operator	: Northern Kentucky Aggregates Inc
Opr. Begin Date	: 1/1/1950
Current Controller	: James P Jurgensen II; Jacqueline J Alf; Jason R
Mine District	: C07
Mined Material	: Construction Sand and Gravel
Type of Mine	: Surface
Mine Site Location	: Boone, KENTUCKY
Address of Record	: 3743 Bellview Rd Petersburg KY 41080

Operator History		
Northern Kentucky Aggregates Inc	01/01/1950	--Current--

Butler Quarry Mine Information from MSHA Mine Data Retrieval System
https://www.msha.gov/data-and-reports/mine-data-retrieval-system

Mine Information	
Mine ID	: 1500030
Mine Name	: Butler Quarry
Mine Status	: Active
Mine Status Date	: 1/26/2004
Operator	: Hilltop Stone LLC
Opr. Begin Date	: 12/28/2001
Current Controller	: John F Steele Jr
Mine District	: C05
Mined Material	: Crushed, Broken Limestone NEC
Type of Mine	: Surface
Mine Site Location	: Pendleton, KENTUCKY
Address of Record	: 1994 paradise bottom road Battletown KY 40104

Operator History		
Hilltop Stone LLC	12/28/2001	--Current--
Cemex Inc	02/28/2001	12/27/2001
Southdown Inc	06/30/1998	02/27/2001
Medusa Aggregates Company	10/07/1988	06/29/1998
Medusa Aggregates Company	01/01/1979	10/06/1988
State Contracting & Materials Division	01/01/1950	12/31/1978

Author's Note: The Address of Record listed for Butler Quarry is incorrect.