General Geological Information for the Tri-States Of Kentucky, Virginia and Tennessee

Southeastern Geological Society (SEGS) Field Trip to

Pound Gap Road Cut U.S. Highway 23 Letcher County, Kentucky

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SECTION 1 - PHYSIOGRAPHIC PROVINCES OF THE REGION

REFERENCES INCLUDE: 1,3,5, 26 AND 27

Appalachian Plateau Province (Figure 1)

Within the state boundaries of Kentucky, this province is known as the Eastern Kentucky Coal Fields and The Knobs Region, with the latter on the boundary of the Appalachian Plateau and Interior Low Plateau to the west. The Appalachian Plateau includes portions of the states of New York, Pennsylvania, West Virginia, Kentucky, Tennessee and Alabama from the northeast to the southwest.

Surface exposures of rock are generally Pennsylvanian sandstones, which are relatively erosion resistant, shales and coal seams. The rock strata lie in a structural basin (Appalachian Basin) and are uniformly flat with gentle dips, undulations and minor faulting. The rock's resistance to erosion being uniform due to lithology and structure, has allowed for the development of a dendritic drainage pattern. The terrain is visually punctuated with steep-sided valleys and hills due to the presence of sandstones in the upper stratum.

Along the western front of the Appalachian Plateau the boundary is marked by an erosional escarpment that extends through several states. Known as the Pottsville Escarpment, this boundary is readily visible when approached from the west due to the sudden change in visual topography.

Along the eastern front of the Appalachian Plateau the distinction is not quite as obvious to an untrained eye. Again, the front extends through several states and is marked by numerous thrust faults bearing various locale names. The Pine Mountain Thrust Fault, Jacksboro and Russell Fork strike slip faults represent this boundary in the vicinity of the field trip.

Ridge and Valley Province

The Ridge and Valley Physiographic Province is generally represented by anticline valleys and syncline ridges. The folded and faulted sedimentary strata extend from Alabama in the south to Quebec, Canada in the north. The province belt curves, widens and narrows at various points along its general northeast and southwest trend. From an aerial perspective this province can be distinguished easily by both topography and drainage.

The ridges are supported by Pennsylvanian sandstones and quartzites, and Mississippian sandstones and carbonates. The valleys are usually composed of less resistant carbonates, shales and other clastic deposits ranging from Devonian to Cambrian in age. The drainage developed in the Ridge and Valley province is strongly controlled by the rock's folded structure and represented by trellis surface drainage patterns.

When traversing (northwest – southeast trend) the Ridge and Valley province, the rock sequences often will repeat themselves along with the topography. The western boundary (with the Appalachian Plateau province) is characterized by repetitious thrust faults and hogback topography. Many of the highways parallel these hogbacks where deeply-dipping strata are easily viewed. To the east the repeating thrust faults give way to an often uniform folding pattern where ridges and valleys repeat both elevation and lithology. Along the eastern side of the Ridge and Valley province the Pre-Cambrian crystalline rocks of the Blue Ridge Physiographic Province are separated by a thrust fault belt.

The structure of the Ridge and Valley province is likely due to continental collisions during the late Paleozoic, between Africa and North America. Where the province belt is narrow, the repetitious folding is generally replaced by southeast-dipping thrust faults and block sequences that repeat.

Blue Ridge Province

Although not immediately adjacent to the field trip's tri-state region, the Blue Ridge Physiographic Province has structural influence over the two provinces to the west or northwest. Because the rocks in the Blue Ridge province are metamorphic and exhibit crystalline lithologies they form the mountain backbone of eastern North America from Tennessee and North Carolina in the south to Newfoundland, Canada in the north.

Rocks in the Blue Ridge province consist of metamorphosed sedimentary and volcanic rocks overlying gneisses and granites that represent the Pre-Cambrian continental basement rocks.

Other Provinces of Kentucky (Figure 1)

The Bluegrass Region is divided into an "inner" and "outer" Bluegrass Region. The lithology of the Bluegrass Region is primarily Ordovician carbonates and clastics bound by thin bands of Silurian and Devonian strata. Structurally, the Bluegrass Region represents the surface expression of the Cincinnati Arch which has a general north to north-northeast trending axis. The limestones have elevated phosphate content so the developed soils are more fertile than in other areas of the state. The Bluegrass Region is best known for the horse industry.

The Knobs Region borders the Bluegrass Region and is easily recognized when approached from the Bluegrass Region. As the name implies, the terrain consists of steep-sided hills or "knobs" that have a distinguished lumpy appearance from a ground view. These hills are erosional remnants of the outlying provinces and their associated escarpments (Pottsville Escarpment, Dripping Springs Escarpment and Muldraughs Hills). The knobs are usually capped with resistant Mississippian strata and Mississippian shales form the sharp slopes. Devonian black shales often are located in the base areas of the knobs.

The Mississippian Plateau or Pennyrile Region separates the Bluegrass Region from the Western Kentucky Coal Field and bounds the latter to the south and west. The Pennyrile Region is a well developed karst limestone plain that exhibits many of the characteristic dolines, disappearing streams and caves. Mammoth Cave National Park and Carter Cave State Park are located within this state physiographic province.

The Western Kentucky Coal Field is the province that represents the Illinois Basin, a regional structural low that trends generally to the north-northwest into the state of Illinois. The Illinois Basin is the counterpart to the Appalachian Basin that bounds the eastern side of the Cincinnati Arch, and as such has similar lithology. The surface exposures are usually Pennsylvanian in age and as the name suggests, coal is a major resource. In this region of Kentucky the coal is often mined by strip operations that use methodologies similar to the phosphate industry in Florida.

The Jackson Purchase or Mississippi Embayment has the youngest rocks and sediments exposed in Kentucky. The province represents the northern most extension of the Gulf Coastal Plain Physiographic Province that bounds the Mississippi River from the Gulf of Mexico to the confluence of the Ohio River. The New Madrid Fault Zone is located below this province, and, is considered the most active fault zone in the central United States.

Other Provinces of Virginia

The Coastal Plains Physiographic Province extends from the Gulf of Mexico to the New England Atlantic coastlines and generally extends inland to some significant topographical change. The geology consists of young terrestrial and marine sediments deposited or reworked along the continental margin. In Virginia (and the other Atlantic coast states) the inland extent of the Coastal Plains province is to the fall line. It is at this point that the rock become more crystalline and resistant to erosion, thus, waterfalls are present in most river systems at this lithologic change. The rocks present in the fall line are often low-grade metamorphics.

The Piedmont Physiographic Province extends from the fall line on the east to the Blue Ridge province on the west. The metamorphic rocks generally grade from low-grade slates and phyllites to high-grade schists and gneisses east to west, respectively. Carbonate derived marbles and sandstone derived quartzites are also present. The Piedmont strata dip gently to the east with topography expressed through low hills and shallow sloping valleys.

Section 2 – Regional Geologic Structure

References include: 12, 15,17, 18, 30 and 32

Kentucky's Structural Setting (Figure 2)

The structural geology of Kentucky and the surrounding area is reasonably straight-forward. Continental collisions in the late Paleozoic, produced horizontal compression that was relieved through a series of thrust faults that dip to the southeast. The more altered areas are in the Blue Ridge province and decrease altering extends into the Ridge and Valley and Appalachian Plateau provinces, respectively.

Two basins (Appalachian to the east and Illinois to the west) are separated by the Cincinnati Arch. All three are regionally large structural features that extend into several adjoining states. The Appalachian Basin is truncated to the east by thrust faults, but is regionally large, extending from Alabama to Pennsylvania. The Illinois Basin in western Kentucky and southern Illinois is complete with all sides represented. These basins have significant down-warping with Ordovician rocks about 3000 and 4000 feet below land surface in the Appalachian and Illinois Basins, respectively.

The Cincinnati Arch, which structurally separates the two basins, has Ordovician and Devonian rocks exposed at the surface. The Cincinnati Arch fold axis is represented on the surface by the Lexington Fault System. The axis trend is generally to the north-northeast. Two fault systems extend from the Lexington system to the northeast and east-northeast. The Kentucky River Fault Zone is to the north, and the Kentucky River is located in portions of this trace. The Irvine-Paint Creek Fault Zone parallels the Kentucky River Fault Zone approximately 20 or 30 miles to the south.

In southeastern Kentucky a large block of Devonian through Pennsylvanian rock was pushed upward and westward during the building of the Appalachian Mountains in the late Paleozoic. The topographic ridge formed by this thrust fault plate and offset is approximately 125 miles long, trends northeast – southwest, and is locally known as Pine Mountain.

SECTION 3 – MINERAL RESOURCE OF THE REGION

REFERENCES INCLUDE: 3, 5, 6, 8, 10, 17, 19, 20, 21, 25, 30, AND 32

Virginia's Geological Mineral and Mineral Fuel Resources Figure 3

Economic minerals are abundant in Virginia and tend to be in zones defined by the physiographic provinces.

- The Coastal Plains have been mined for sand, gravel, heavy minerals, diatomaceous earth, marl and clay.
- The Piedmont produces architectural stones, along with feldspar, slate, kyanite, soapstone and vermiculite.
- The Blue Ridge province has been mined for copper, iron, tin and manganese along with a generous supply of quarry stone and some gem stones.
- The Ridge and Valley province has a developed tourist following that is associated with the mountainous structure and the extensive cave systems developed in the limestones of this province. Other mineral resources include crush stone, lime, lead, zinc, iron, manganese, gypsum, coal, oil, gas, barite, clay and salt.
- The Appalachian Plateau province is best known for coal, oil and gas and in local areas river sand and gravel. Crushed stone is often a bi-product of coal mining.

Virginia has more than 3000 caves developed in the carbonate rocks of the Ridge and Valley province. All caves are protected by state law along with the speleothems, animals, and historic/archaeological artifacts they contain. Caves have been used by man for various endeavors. Shelter was an early plus, but, they have also been used for mining of minerals, distilling beverages, attractions, water resources and education/research to name a few. Most of Virginia's caves are privately owned.

Karst terrain is located in Virginia where carbonate rocks are exposed at or near the land surface. Sinkholes, subsidence, flooding and pollution are all natural or man induced hazard in karst regions. Heavy rainfall, as well as, over-pumping can create catastrophic collapse sinks to localized subsidence of unconsolidated surface soils. Sinkholes have been used for the disposal of solid waste and storm water runoff which has created ground water contamination concerns or problems.

Coal is Virginia's "black gold" and is mined from approximately 40 coalbeds which range from 4 to 5 feet thick. Coal is most abundant in the southwestern part of the state and is associated primarily with the Appalachian Plateau province. The first documented coal mining was from the Richmond basin in 1748. Coal analysis would typically show <1 % sulfur, < 10 % ash, < 30 % volatiles, and 13,000 BTU per pound. One ton of coal with a BTU value of 11,000 is equivalent to 22,000 cubic feet of natural gas, 158 gallons of distilled fuel oil or one cord of dried hardwood.

Commercial hydrocarbon production began for Virginia near Bristol in 1931. This area became known as the Early Grove Field and produced from 1935 to 1957 and 1983 to 1994. Since 1994, the field has been used for natural gas storage. Oil and natural gas production is generally from the Ordovician and Devonian shales and "black" shales of the Appalachian Basin in western Virginia. In Virginia, natural gas is the second most valuable fossil fuel, with coal as the leader.

Tennessee's Geological Mineral and Mineral Fuel Resources (Figure 4)

Energy minerals in Tennessee include coal, oil-shales, natural gas, radioactive minerals and oil. Only coal, oil and natural gas are presently recovered economically. Coal is generally of high quality and is mined from the Appalachian Plateau province rocks. There are undeveloped energy mineral resources in west Tennessee when lignite and oil-shales are considered. Their development will be dependent on the ability to protect surface and ground water resources in the region. Coal represents about 13 % of Tennessee's mineral industry and oil and gas about 2 %.

Sand, gravel, clay, limestone, dimension stone and crushed stone are quarried or mined in Tennessee. Collectively, these earthen resources account for about 45 % of Tennessee's mineral industry.

Kentucky's Geological Mineral and Mineral Fuel Resources (Figures 5, 6, 7, 8 and 9)

Dr. Thomas Walker in 1750 was recorded as the first person to discover and use Kentucky coal. Commercial mining began in 1820 and peaked in 1990 at 170 million tons. Kentucky's coal is used in 25 states to produce electricity and exported to 15 countries. The Western Kentucky Coal Field is noted for large-area surface mining and slope and shaft mining. The Eastern Kentucky Coal Field is mountainous and therefore, supports contour surface mining and drift underground mining. Mountain-top mining is used where economics support this method. About 85 % of Kentucky's original coal resources are left.

With names like Burning Springs and Oil Valley it is evident that hydrocarbons have been known from Kentucky's early European immigration. The first oil producing well was drilled in 1818 while searching for salt brine. Western Kentucky has historically produced oil and eastern Kentucky natural gas. Most of the oil is produced from Mississippian-age limestone and sandstone in the eastern and western regions of the state. The south and central regions of Kentucky have production from the Ordovician-age limestones and dolostones. Most of the natural gas is recovered from Devonian-age black shales in the eastern region of the state. These Devonian reservoirs have a successful completion rate of about 97 %.

The potential for coal-bed methane exists in both the Kentucky coal fields. To release the methane from the saturated coal seams, large quantities of water must be pumped and environmentally acceptable disposal is a problem. As future coal production enters these saturated seams coal-bed methane may be an economic bi-product.

Kentucky ranked 5th nationally in 1992 for the production of crushed stone and lime. Road construction is the major user of this material followed by other industries, such as, bridge and building construction, riprap, and railroad ballast. There are about 90 crushed stone quarries in the state with an average life of 50 years.

Industrial minerals from Kentucky include limestone, clay, sand and gravel, iron, titanium, phosphate and vein minerals such as fluorite, barite, galena, sphalerite and calcite.

Limestones are used as sulfur sorbents for acid mine drainage and lime, a product of limestone, is used in desulfurization of flue gas at electric generating plants and water treatment. Low silica limestone dust is used for fire and explosion control in coal mines. Carbonate rocks are exposed on 25 % of Kentucky's land surface and come from Ordovician, Silurian and Mississippian-age strata.

Clays are used in the production china, tile and bricks. Kitty litter and other absorbents are produced and clays also serve as extenders and fillers in numerous products. Expansive clays are used in oil drilling muds.

Sands and gravels are used in construction materials and the glass industry. Some of Kentucky's sands and gravels are produced from glacial outwash plains.

In the early 1900's mining of iron, phosphate, barite, galena and sphalerite were major industries, but larger and more economic sources have closed these mineral industries in the state.

Section 4 – General Information on Coal Resources of the Region

References include: 3, 5, 6, 12, 13, 17, 22, 29, 30 and 32

Coal Wisdom

Coals mined today throughout most of the United States were deposited during the Mississippian and Pennsylvanian Periods. Partially decomposed vegetation accumulating in fresh or brackish water under reducing conditions develops into peat. With continued burial and increasing heat and pressure the peat is chemically altered to lignite, then sub-bituminous, bituminous and finally anthracite coal. This process is called coalification. Coal seams can range form less than an inch too greater than 100 feet in thickness. However, ratio estimates range from 3 : 1 to 10 : 1 feet, of compacted peat to seam coal. A pure black variety of lignite is jet, or black amber. Jet is usually found as isolated masses in bituminous shale. It will take a high polish and has a conchoidal fracture leading to its use as jewelry stock.

Coal is a combustible organic rock which is generally massive and relatively pure in carbon. When visually inspected, coal has dull areas, called escinite, which are the resistant parts of the original plant material like leaves, spores and root hairs. The remainder of the mass has shiny areas are called vitrinite, which are composed of the woody cell walls.

A product produced form coal and used in the production of iron and steel is coke. Coke is produced by heating coal in an oven that is sealed so the atmosphere is oxygen deficient. Volatile gases are driven off (and often captured as a fuel source or flared) and what remains is a lump of coke. Industrial coke is about 2 inches or less in size somewhat porous with a semi-shiny metallic appearance.

Coal quality is dependent upon the conditions of deposition and subsequent chemical alteration. The water quality of the coal swamp, the type of plant material and the amount of inorganic matter all play into the quality of coal reserves. For combustion coal, ash, nitrogen, sulfur and BTU are important analytes. The BTU's determine the energy release when burned while the other components of the analysis define emissions and solid waste results.

Coal resources are the estimated amounts of coal in the ground, without regard to the feasibility of recovering the mineral. Coal reserves are the amount that can be extracted profitably under existing economic conditions. The reserve can change drastically when variable such as, extraction methodologies, interest rates, market prices, taxes, and etc. change.

Because the coastal swamp depositional environment was dynamic, coal seam deposits can be disrupted by channel cuts and fills, splitting, parting, rider seams and subseams. All of these depositional situations create mining yield changes that can be opportunities or difficulties.

Splits occur when high-energy and low-energy depositional environments are in close proximity. Seasonal influx of clastics from a channel into a back swamp or breach of a natural levee could be an examples of splitting deposition. If the split is thin, and the interburden is tolerable, it is considered parting at the mine face and the split or parting seam is mined along with the primary seam. Parting can also create mine design and engineering issues controlled by the thickness of the parting and composition of the interburden.

Rider coal seams are above the primary coal seam. In underground mining, rider seams create an incompetent zone where horizontal slippage or roof collapse can occur. In surface mining operations, rider coal is considered a spoil and is usually discarded with overburden. Because of the cleat structures in coals, they are often good aquifers, and rider seams with water can create additional engineering headaches to be overcome.

Subseams occur near the base of a primary seam and because of water content and composition of fine clastics create engineering and equipment problems that must be considered in the mine design.

There are several methods used to extract coal from the surrounding rock. The method chosen depends upon factors such as, the size of the seam (lateral and vertical), overburden (volume and rock type) and reclamation plan . There are generally two categories, surface mining and underground mining.

Surface Mining (Figure 10)

When the coal seams are exposed and observable, as they often are in surface mining operations, run-of-mine coal is often an economic consideration. Run-of-mine coal is coal shipped directly from the mine, which does not require the added cost of preparation or washing. The quality of the coal is also improved since the moisture content is not increased by the washing process.

Dragline mining methods are common in the western U.S. (Powder River Basin) and western Kentucky. This technique uses a dragline in a pit or on the surface to relocate overburden and extract coal from the target seam. Overburden is then returned to commence the reclamation process.

Mountain-top removal mining, like the name implies, removes the mountain-top rock overburden to expose a coal seam or seams. The technique requires explosive loosening of the overburden and relocating this material by very large front-end loaders and very large haul (dump) trucks. When the coal seam is exposed it is often cleaned of debris with a street sweeper and then "chipped up" with a front-end loader and placed in trucks for transportation. After a work area is initially established, the mining and subsequent reclamation moves across or through the mountain top in tandem.

Contour mining advances around the side of a mountain following the coal seam. In the Appalachian Plateau the coal seams are reasonably parallel to the elevation contour so the mining follows the "contour". Overburden is removed by bull dozer or front-end loader and a "bench" (a working surface) is formed. The mining advances along the contour, extracting coal and completing the reclamation almost simultaneously.

Auger mining is a method used to increase the recoverable coal on a highwall or contour job. Once the bench has been established and the coal on the bench extracted and loaded, screw-augers (up to 3 feet in diameter) are used to drill the coal seam up to about 100 feet into the mountain. The coal rides to the bench on the auger flights and is recovered by a conveyor which belts the coal to a pile. The pile is loaded for transportation by a front-end loader.

Underground Mining (Figure 10)

Coal that cannot be recovered economically with surface means is often extracted using underground methods. Room and pillar mining is the most common method employed for underground mining. The process begins with the highwall face-up and establishment of a work area in the vicinity of the mine portal. The ventilation system installation also begins at this time and is continuously expanded as the working face advances. Fresh air is delivered to the mine face with fans and dedicated passages for the movement of air. The fresh air is used to control the breathing air quality and maintain any encountered methane below the explosive limit of the gas.

Because the seams are narrow, so is the mining equipment used to extract and transport the coal and mine workers. The continuous miner is equipped with a rotating cutter head that can be hydraulically raised or lowered to grind the coal from the seam. As the coal is cut, it is transported along the cutter head by auger-like flights to the center of the miner and onto a short conveyor. The conveyor delivers the coal from the head of the miner to the tail section where it is transferred to a shuttle or ram car. The continuous miner advances about 3 feet or more into the seam per pass, with a room width of about 20 feet. Dimensions and advancing rates are controlled by the mining characteristics of the coal and competency of the roof and floor rock.

The shuttle car receives the coal from the continuous miner directly, or a ram car collects the coal from the mine floor like an enormous dust pan. The coal is then driven from the working face by either piece of equipment to the feeder breaker. The feeder breaker, crushes the coal and meters it onto a conveyor belt at a manageable rate. The beltline then transports the coal to the work area outside the mine portal. The mine plan usually calls for enough miners and shuttle (or ram) cars to keep the beltline operating at maximum capacity. The coal stock piles outside the mine (run-of-mine coal is not common in underground operations) by use of a radial stacker. The stock pile is loaded into truck for transport by front-end loaders.

The mine face advances in parallel rooms with coal separating them. When sufficiently advanced the separating coal fin is mined on the back side connecting the two rooms and leaving a coal pillar. The spacing of rooms and pillars is designed to sufficiently support the roof.

Roof bolters are also used as a room advances. This machine enters a freshly mined room (while the continuous miner has moved to another room) to secure the roof rock. Usually equipped with tandem roof jacks, the jacks are hydraulically placed between the floor and roof while the roof is drilled to competent rock. The drill is extracted and an epoxy cartridge is rammed up the hole followed by the bolt which is then spun and pushed hydraulically into the epoxy cartridge. As the bolt spins the two part epoxy is mixed and fills the voids around the bolt shaft. The epoxy cures in seconds (various cure rates are used depending on roof conditions) and the jacks are released and the roof bolter is advanced to the next set of bolt locations.

As the mine equipment moves forward in the mine the constant supply of coal dust creates and explosive hazard. The ventilation system is the first-line engineering control for the reduction of this hazard. Equally important, is the suppression of dust generated from the walls and pillars of the mine. This is controlled by spraying on a coating of low-silica limestone dust (rock dust) to trap the coal particles and prevent them from becoming airborne.

After a coal seam has been sufficiently depleted and a full complement of rooms and pillars exist, it is time to back out and recover the pillars. As the continuous miner extracts the coal in the roof supporting pillars, the equipment retreats in the direction of the main beltline. The roof is allowed to collapse or crush any remaining pillars.

Coal leaving an underground mine is rarely run-of-mine coal and contains rock debris and occasionally parts of the mining equipment (i.e. continuous miner teeth).

Section 5 – Activities Incidental to Coal Mining in the Region

References include: 3, 5, and 6

After the Coal is Mined - Benefication, Quality Control, Transportation and Reclamation

Benefication / Preparation

After the coal is stockpiled outside the underground mine or transported by truck from a surface mine, it often needs to be improved in quality for sale. In the coal industry this benefication process is termed preparation and sometimes washing. Run-of-mine coal skips this step and moves directly to transportation or market. The objective of coal preparation is to remove non-coal material and improve the coal quality in one or more parameters.

Coal generally enters a preparation plant near the top and gravity is used to move the coal down through the plant. Magnets are used on the head of the beltline to draw off metal debris before the coal and rock enters the process. Next the coal is separated from the rock debris through a series of shaker screens and tables. Water is initially introduced at this point in the process to control the dust and recover the coal fines. The scalped rock is transported by conveyor to a refuse storage area.

The coal continues to be washed and sized through various screens. Stoker coal usually 2 inch to ¾ inch in size is often separated during preparation, as it brings a premium price and has uses for metallurgical or coke production. Smaller coal lumps and fines are the remainders that often are used for fuel. Fuel coals are stockpiled or delivered for transportation independent of the stoker.

The coal fines are recovered as a liquid slurry and pumped back to the top of the plant where they are separated from rock fines by flotation methods. Magnetite is often used as the density control agent because it can be recovered on magnetic drums and re-used in the flotation process. These coal fines are separated from the water fraction by various drying methods and moves to a stockpile area outside the preparation plant. Any fine rock debris is separated from the water, often with flocculent or cyclones, and handled as a refuse waste similar to the larger rock fraction segregated at the beginning of the process.

Water in large quantities is a difficult commodity to come by in mountainous regions, and like most other areas water withdrawal permits are required for ground water or surface water industrial uses. Most of the time, preparation plants recycle and re-use their process water. Water recovered in the flocculation tank may require pH adjustment prior to reuse. The wet rock fines are stored in impoundments designed to collect and capture the water as the fines de-water. This captured water is returned to the plant for use, where its pH may also be adjusted for use.

Quality Controls

The quality of coal is initially considered when the resources are evaluated, and refined when the reserves are calculated. The reserves reflect current and predicted market conditions for a particular type of coal. Important attributes of the coal are the BTUs, ash, sulfur and nitrogen content when the coal is considered for a fuel.

Laboratory analysis begins with the first core sample and continues throughout the mining, preparation, transportation and consumption step. Once the coal leaves the mine and generally meets a customer's specifications, it undergoes preparation and blending processes to bring it inline with a customer's specifications. These added steps to meet the customer's specification can occur anywhere along the transportation leg of the coal's journey to market.

Weights are collected along with quality control samples as coal enters and leaves a transloading facility. Quality samples from a beltline are collected by an in-line sampler that makes a swipe across the belt at a predetermined sampling interval, based on the tonnage per minute being conveyed. If a truck is being sampled a screw auger inside a sampling barrel is advanced into the coal while in the trailer. Usually on a small portion of the collected sample is saved for analysis. If it is a large customer order then several samples may be bagged together and the samples treated as a composite that represent the whole or a percentage of a customer's order. Generally, coal is sampled and weighed a minimum of six times from mine to consumer.

Transportation

Transloading facilities transfer coal from one form of transportation to another. Often ground storage is required as an intermediate step, but there are some facilities that go directly from one transportation method to another. Examples are, truck to rail, truck to barge, rail to barge, barge to truck, etc.

Coal begins its transportation on a conveyor belt or with a front-end loader, but trucks get it from the mine to market or to transloading facilities. Tractor-trailer transportation is currently the most common method to move coal short distances with typically a load capacity of 50 tons. When traveling in coal country watch out! These trucks creep up hill and scream down hill. There is nothing that can clear your lower digestive system like meeting head-on a fast moving coal truck on a narrow mountain lane…..at 30+ MPH.

As distances or the required coal volume increases so does the size of the transportation. Trains are another method used for transportation but require an additional handling step in most cases to get from truck to train. Open top hopper cars are most commonly used. These cars have two methods of unloading, bottom dump or rotary dump. Bottom dump cars have been around for years and as the name implies, the doors on the bottom of the car open and the coal falls by gravity into a hopper below the tracks. Rotary dump cars are clamped to a large rotating section of rail and turned upside down over a hopper. Rotary dump cars can be recognized by color coding, where one end of the car is painted a unique color. The colored end of the car has a rotary coupler. Rotary dump cars also have a "belly" without hopper doors. A third type of hopper car is a hybrid car with bottom doors and a rotary coupler.

When coal is transported by train it usually occurs in what is termed, a "Unit Coal Train". These trains are dedicated to the transportation of coal and, in the eastern U.S., typically consist of 90 rail cars. In the western U.S. unit coal trains may consist of up to 125 rail cars. If the rail cars are constructed of steel they have a capacity of 85 to 90 tons. Aluminum rail cars have a capacity of 105 to 107 tons, are resistant to corrosion (steel cars rust due to pH of wet or damp coal), but are more easily damaged. The locomotive arrangement changes with the terrain. On low grades and straight runs two or three locomotives may be used. In steeper terrain, additional locomotives may be placed at the end of the train (pushing) and sometimes in the middle.

Unit coal trains are usually loaded at the preparation plant or a yard specifically designed for loading trains. The coal is usually weighed into a bin or hopper above the railcars by conveyor. Coal quality sampling is usually requested at this point. When the car is positioned by the operator the coal gravity feeds down a chute and into the car. The operator advances the car along the rails to evenly distribute the coal. In cold climates the coal is sometimes treated with a freezing inhibitor to facilitate the removal of the coal from the railcar at its destination.

River or barge transportation is used to move excessively large volumes of material for a customer. One open top river barge can transport about 1500 to 1550 tons of coal. These barges are assembled into a river tow which typically consist of 15 barges, five deep and three abreast. In equivalent units:

- 1 Barge = 15 Hopper Railcars
- 1 Barge = 58 Tractor-trailer Trucks

- 22,500 Tons Transported = 15 Barges or 2 ½ Unit Trains or 870 Semi-trucks

If delivery is not to an inland waterway or inter-coastal waterway destination the coal must make an additional transloading stop to transfer to ocean-going barge. At this point additional weights and samplings are usually conducted.

Reclamation

The Surface Mines and Reclamation Act (SMCRA) of 1977 has had a marked improvement on the mining industry and its land stewardship. SMCRA was legislated to curb the deterioration of water quality and surface lands caused by a century of mining without concern for future environmental issues. It also established foundations for the restoration and reclamation of previously mined land. Within the industry, these lands and operations are termed "pre-law" mines or operations.

Pre-law operations are considered carefully when developing current mine plans because if these areas are disturbed they may be required to be reclaimed by the new operator. Taxes and fees collected from current mining operations are used by agencies to restore these pre-law operations.

The process of reclamation begins with the development of the mine permit which is required to be issued before any mining activity can be commenced. Within this permit, the reclamation plan is outlined even though the mine may not be expected to close for tens of years. As previously indicated, mine reclamation is generally continuous throughout the mining process.

As various stages of the reclamation process are completed and inspected by the agencies, the bonds established by the mining company before mining began are released. Generally, bond releases occur in three stages and take a minimum of seven years to get a full release.

The end use of the land is determined before mining begins and is negotiated between the landowner, the mining company and the agency. Pastureland is a popular choice for private landowners because it is not naturally common in eastern Kentucky. Company owned land is generally returned to forest conditions. In both cases the vegetative cover and density is determined in the mining permit application before mining begins.

SECTION 6 – GENERAL INFORMATION ON OIL AND NATURAL GAS RESOURCES IN THE REGION

REFERENCES INCLUDE: 10, 17, 20, 25, 30 AND 32

Oil and Natural Gas Enlightenment (Figure 11)

The development of oil and natural gas requires sedimentary deposition in conjunction with the accumulation of organic matter under reducing conditions to preserve the carbon. This sedimentary material must then be confined within the earth at sufficient depth and pressure to naturally alter the organic debris into petroleum hydrocarbons. The word petroleum means "rock oil". As the strata are buried by overlying deposits, the animal and plant remains in the sediments are converted to a substance called kerogen. As burial continues, and the pressure and temperature continues to increase, the kerogen is converted to oil and natural gas.

Oil forms with burial of organic rich sediments to a depth of approximately 1 to 1.5 miles. After a depth approximately 2 miles, the temperature gradient leads to the breaking of the carbon-to-carbon bonds and natural gas begins to increase in abundance. Below approximately 2.5 miles in depth, the thermal gradient leaves only natural gas compounds, typically methane, ethane, propane, butane and carbon dioxide.

The parent materials containing these animal and plant remains are very fine-grained muds and/or silts. Combine these fine-grained materials with reducing depositional conditions, and the results are black shales and dark-gray shales that represent the source rock for much of the earth's petroleum resources.

The genesis of oil and gas is only the beginning of its resource capacity. Trapped within these fine-grained rocks, oil or gas is not always concentrated enough to be recoverable. The rock's permeability and porosity play a key role in the recovery of oil and gas. Permeability is the ability of the rock to transmit fluids. Porosity is the storage capacity of the rock. Porosity can be "primary", the natural storage capacity based on grain spacing, or "secondary" due to fractures or voids that are post-depositional in nature. Oil and gas may remain in the pores of the source bed, or over time, migrate out of the source bed due to differential compaction, temperature and pressure gradients.

As the petroleum hydrocarbons migrate away from the source beds, they will be lost to the atmosphere unless there is some mechanism to contain the resource. Geological structures are the major traps for the containment and concentration of petroleum hydrocarbons. Folds and faults with low permeability rocks at the structural high point will trap and contain migrating oil and gas in the pore spaces of lower lying strata. Natural gas may occur as a cap over the oil in these pore spaces, and the oil will generally float above formation water.

In the tri-state area of Virginia, Tennessee and Kentucky, the dark shales of Devonian and Ordovician age are considered the source beds for much of the oil and natural gas development. Where these strata outcrop, the resources have been lost to the environment. However, in the structural low of the Appalachian Basin, these strata are sufficiently deep to retain much of the petroleum hydrocarbon resources within their layers or trap-induced reservoirs.

In eastern and western Kentucky, petroleum reservoirs are generally the Mississippian limestones and Pennsylvanian sandstones, which have relatively high porosity and serve as traps for the upward migration of oil and gas from the underlying Ordovician and Devonian source beds.

SECTION 7 – EXPOSED UPPER PALEOZOIC ROCKS OF THE REGION

REFERENCES INCLUDE: 12, 13, 17, 18, 22, 29 AND 32

Carboniferous Systems (Figures 12, 13, 14 and 15)

The Carboniferous rocks are the major source of mineral resources in the tri-state region of Kentucky, Virginia and West Virginia. While bituminous coals are the major mineral resource, the carboniferous rock units are also sources for industrial aggregates, building and architectural stone, industrial sulfide metals, and iron ore. Nearly complete stratigraphic sections of Pennsylvanian deltaic sequences are found in eastern Kentucky, particularly along U.S. Highway 23 where exposures can reach 300 feet in thickness. Mississippian sequences are exposed further to the west in Kentucky along the Pottsville escarpment.

The term Carboniferous Period is more common as a European chronostratigraphic term, spanning the geologic time scale from approximately 360 to 290 Ma. In North America, the stratigraphic sequences were developed to the extent that the Carboniferous could be divided into two periods, the Mississippian, 360 to 325 Ma., and the Pennsylvanian, 325 to 290 Ma.

Mississippian rocks rest conformably over Devonian rocks that are predominantly dark carbonaceous shales. The Mississippian sequence is primarily marine in origin, with depositional environments ranging from deep marine to shallow tidal and lower deltaic conditions.

The lithology of the Mississippian strata has four major depositional sequences:

1. A base composed of sandstones, shales and siltstones derived from distant terrigenous sources.

2. Marine carbonates from shallow water limestones with minor deep basin limestones.
3. Shallow water carbonates alternating with shales and sandstones that reflect an advancing delta system into the coastal marine environment.
4. Terrestrial derived shales and sandstones with minor strata of marine carbonates.

Sources for the terrigenous sediments are believed to be to the northeast in what today is the northeastern United States and southeast Canada, and to the east, beyond the present day Piedmont physiographic province of the United States.

Fossil assemblages for the Mississippian strata include: crinoids, brachiopods, bryozoans, colonial and solitary corals, echinoids, pelecypods, gastropods and trilobites in isolated areas. In the Upper Mississippian strata, fossilized plants are used to distinguish the Mississippian and Pennsylvanian units that are often similar lithologically.

The Mississippian – Pennsylvanian boundary is largely considered an unconformity. In eastern Kentucky, deep channel deposits and paleokarst features mark the boundary in the Mississippian limestones. Other models consider the depositional region to have a central beach-barrier island system that grade landward into lagoonal and deltaic environments with shales, siltstones and coals, and grade seaward into marine shales with offshore carbonate islands.

The Pennsylvanian strata are dominated by clastic rock sequences that thicken to the east and southeast. The base Pennsylvanian rocks are primarily orthoquartzite that grade upward into shales and siltstones. Coal beds representing fresh water and brackish water swamps are common and often capped with marine shales that indicate transgressing conditions.

The Breathitt Formation outcrops over much of eastern Kentucky and is characterized by large variations in thickness and lateral consistency with respect to lithology. Minable coal is found is over 30 coal seams within this formation. The paleogeographic setting established in the Mississippian is believed to have continued throughout the Pennsylvanian Period.

SECTION 8 – REGIONAL GROUND WATER RESOURCES

REFERENCES INCLUDE: 1, 2, 11, 17, 28 ABD 32

Hydrology of the Eastern Kentucky Coal Field Region

The Appalachian Plateau (Eastern Kentucky Coal Field) is underlain by a variable sequence of sedimentary rocks. Pennsylvanian clastic rocks are the dominant lithology outcropping in the region. Resistant layers of sandstone cap these gently sloping to flat plateaus that are deeply dissected by streams forming deep v-shaped valleys.

There are little to no soils or unconsolidated clastic deposits to serve as reservoirs for the storage of ground water. The Pennsylvanian rocks generally have low primary permeability and secondary permeability is confined to joints and fractures. Flow systems occur within 300 feet of land surface if the fracture system is adequately developed.

Most water supply wells drilled in valley bottoms have adequate yield for domestic use. About half the wells drilled on hillsides and less than three-quarters of those drilled on hilltops are adequate for domestic use. Yields range from approximately 0.25 to 400 gallons per minute with an average for the wells tested of approximately 104 gallons per minute. Most water from drilled wells is extremely hard and contains noticeable amounts of iron. Salty water may be obtained when the well is screened approximately 100 feet or more below the principal valley bottom.

Surface water supplies provide approximately 95% of the water used in Kentucky, originating from 13 major rivers and their associated basins and about 2,400 lakes and reservoirs. About 80% of the population is supplied by about 850 public water supply operations and approximately 94% of water used is returned to surface water sources.

Kentucky has over 200,000 water wells, accounting for about 205 gallons of ground water per day per well or 5 % of total water usage. It is estimated that half of Kentucky's private drinking-water wells are contaminated by bacteria. Pesticides were detected in about 20% of the surveyed rural domestic wells. Nitrate-nitrogen concentrations exceeded the MCL in about 5% of the surveyed domestic rural wells. Eastern Kentucky ground water often exceeds the MCL for barium, and the fluoride MCL is exceeded in ground water for much of the state.

Some known potential sources for ground water contamination include:

- 125,000 unplugged oil and gas wells
- 500,000 septic tanks
- 35,000 underground storage tanks (estimated 25% leak)
- 626 inactive landfills
- 5,000 open dumps
- 550 potentially hazardous waste sites
- 570 permitted oil-brine injection wells

Some known potential sources of surface water pollution in assessed streams that did not support swimming or fishing include:

- Agricultural runoff (30%)
- Municipal wastewater treatment plant discharges (29%)
- Runoff from mining and petroleum operations (19%)
- Runoff from urban areas and storm sewers (7 %)
- Miscellaneous sources (6%)
- Unknown sources (6%)
- Industrial discharges (3%)

Section 9 – Pine Mountain Trust Sheet

References include: 4, 15, 16 and 18

Geology and Historical Significance of the Pine Mountain Thrust Sheet (Figure 16)

The Pine Mountain Thrust Sheet is a rectangular feature that trends in a northeast – southwest direction. It is approximately 125 miles long and 25 miles wide. The long axis is bound by the Pine Mountain Thrust and Clinchport Thrust on the northwest and southeast, respectively. The narrow ends are strike-slip faults with the Russell Fork Fault and Jacksboro Fault to the northeast and southwest, respectively. Middlesboro, Kentucky is in the approximate center of the thrust sheet.

Within the thrust sheet the geology is representative of the Ridge and Valley province with anticline valleys and syncline ridges, and the Cumberland Plateau with nearly horizontal strata. Cumberland Mountain topographically separates these two physiographic provinces with beds dipping to the northwest along the shared limbs, transitioning from anticline (to the southeast, Powell Valley Anticline) to syncline (to the northwest, Middlesboro Syncline). Pine Mountain forms the northwest side of the syncline with beds dipping to the southeast. These dipping beds are the result of the upturned strata along the Pine Mountain Thrust Fault.

The Pine Mountain Thrust Fault represents the western (northwestern) most escarpment of the mountain building collision between the North American Plate and the African Plate in the later Paleozoic. During this time compressional forces folded the Paleozoic strata that comprise the Ridge and Valley province and created a series of repetitive thrust faults along the western most edge of the folding.

Topographically, these thrust faults became barriers to the migration of native biota and eventually people. Small wind gaps in Cumberland Mountain and Pine Mountain at present day Cumberland Gap and Pine Mountain Gap, respectively, allowed for limited passage. First, the native buffalo traversed these gaps to the natural pastures of the Bluegrass Region. This natural concentration of the buffalo encouraged native people to follow. Between 1750 and 1775, these gaps were mapped and the Wilderness Road blazed by axe men from present day Kingsport, Tennessee to the Kentucky bluegrass, present day Lexington, Kentucky. By 1792, this 208-mile road had been used by over 100,000 people for a six to eight month torturous journey into the mid-west.

During the Civil War, the gap proved important to both sides due to its strategic position and exchanged hands on several occasions. A paved road was constructed in 1908 by the U.S. Bureau of Roads and exists as U.S. Highway 25. This highway was abandoned in the early 1990s and replaced with two tunnels constructed through Cumberland Mountain to the southwest of the natural gap. This allows for Cumberland National Park to return the gap to a more natural setting.

SECTION 10 – GEOLOGY OF SELECTED KENTUCKY LOCALE

REFERENCES INCLUDE: 9, 12, 14, 16, 17, 23 AND 24

Natural Bridge

Natural Bridge State Park is located near the town of Slade, Kentucky in Powell County along the Mountain Parkway about half way between Lexington and Salyersville, Kentucky.

The park and its namesake natural bridge (technically an arch) is situated on the boundary between The Knobs and the Cumberland Plateau (Eastern Kentucky Coal Fields) physiographic provinces along the Pottsville Escarpment.

Erosion of uplifted strata along this limb of the Cincinnati Arch has left less resistant limestones and shales exposed to the west, and more resistant sandstones exposed to the east. Where streams have head cut their way into the sandstone escarpment, the separating fins project westward as topographic highs or protruding ridges.

As these fins detach, they become isolated hills or “knobs”, but if conditions are right, an arch may form below the sandstone cap before a fin is completely detached from the escarpment. Locally these arches are known as bridges or natural bridges. Arches of this type are rare and short lived in the eastern United States due to abundant rainfall and erosion.

Cumberland Falls

Cumberland Falls State Park is located about 25 miles west of Corbin, Kentucky (home of the original Kentucky Fried Chicken) and represents the headward cutting of the Cumberland River as its' river bed transitions across rocks of differing resistance.

To the west are the Mississippian carbonate and clastic rocks, which to the east are capped with the Pennsylvanian sandstones. The boundary between the two is topographically prominent and called the Pottsville Escarpment. This abrupt change in elevation separates the Mississippian Plateau and Cumberland Plateau (Eastern Kentucky Coal Fields) physiographic provinces of Kentucky.

The falls are not along the escarpment face because headward cutting by the river has recessed the escarpment further east more rapidly than in the surrounding area. From the escarpment face, the Cumberland River is located in a recessional gorge that extends eastward to the fall line. The riverbed in the gorge is generally atop Mississippian rocks. Above the falls, the riverbed is situated atop more resistant Pennsylvanian sandstones. Somewhat softer Pennsylvanian sandstone is located in the undercut portion of the falls where aggressive erosion and cavitation have created a resistant overhang.

Falls of the Ohio

Falls of the Ohio is located on the Ohio River between Louisville, Kentucky and Clarksville, Indiana. A visitor center is located on the Indiana side, and is best reached by taking the first exit off Interstate 65 North after crossing the Ohio River, and working your way north and west along the river following the signs.

The falls are the only natural outcrop of bedrock along the entire length of the Ohio River and drop approximately 25 feet over a series of rapids. Dams and locks to support river transportation have altered the original river configuration and assist vessels and cargo barges over this natural barrier. Prior to the construction of these structures, the towns of Louisville, New Albany, Jeffersonville and Clarksville were settled to provide cargo portaging services around the falls.

The falls are best known for the abundance of Devonian and Silurian marine fossils. Specifically, horn corals were first described from this locale in the early 1800. More that 600 species of marine fossils have been cataloged from the falls including invertebrates and primitive fish. The fossils from the Falls are important in the scientific community because greater than 30% of the identified species are not known from anywhere else.

A 1,400 acre preserve has been established by the states of Indiana and Kentucky to provide for the continued protection of the Silurian and Devonian marine reefs and flats. To walk the riverbed and discover the countless fossils for yourself is truly one of geology's lifelong treasures.

Astroblemes (Figure 17)

A meteorite impact forms a roughly circular crater called an astrobleme. In the center of the impact location, may be a rebound structure where the central core of crustal rock is brought back to the surface following the impact.

Three sites in Kentucky show evidence of impact by meteorites: Jeptha Knob in Shelby County, a site near Versailles in Woodford County and a site near Middlesboro in Bell County. These sites no longer have the crater walls which eroded long ago, but do represent the remains of the eroded core. Each site has a series of radiating faults form a central core of severely fractured rock.

- Jeptha Knob is located east of Shelbyville, Kentucky between Interstate 64 and U.S. Highway 60.

- The Versailles structure is located along Big Sink Road northeast of the town of Versailles, Kentucky.
- The Middlesboro structure has the distinction of being the only astrobleme with a town (Middlesboro, Kentucky) developed within the structure. Middlesboro is just north of Cumberland Gap along U.S. Highway 25.

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