CHAPTER ONE

DIGGING UP THE PAST

For centuries, humans have struggled to extract ***coal*** from below the earth's surface in order to provide a cheap and plentiful source of energy. During this time, technology was continually being developed to improve the way this resource was to be mined and used. Many inventions that affect our daily lives are the result of this perpetual search for an efficient source of energy.

The story behind the universal use of coal is a testament to the human spirit filled with perseverance and dedication.

Coal carts exiting a drift mine in Butler county
(Photo courtesy of Sam Brydon)

Fueling History

Using coal as a source of fuel spawned important technological advancements that unlocked the mineral's true energy potential and ultimately improved our way of life.

It is not precisely known when the energy value of coal was first discovered. Evidence suggests that several ancient civilizations knew that coal burned but this discovery played only a small role in the advancement of their cultures.

The Chinese were thought to have first pioneered the use of coal as fuel during the Han dynasty (206 BC to 220 AD). Upon returning to Italy following his visit to China, Marco Polo wrote of these people using unusual black stones as fuel.

The first use of coal in Europe was by the Romans when they occupied Scotland. The coal was referred to as "sea coal" for it was found washing onto the beaches. Actually the coal did not come directly from the sea. It had been dislodged from exposures found along the coast by the relentless pounding of waves.

When the Romans withdrew from Scotland in the fifth century AD, the unique resource they had discovered and used was left behind and forgotten.

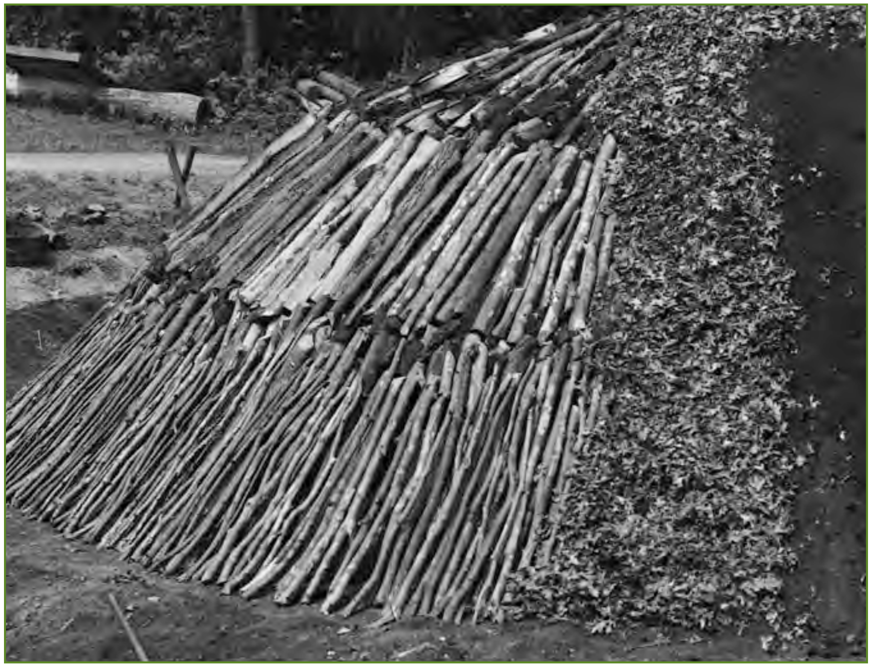
Centuries later the use of coal slowly resurfaced in Britain. At first, little use could be found for coal. It was not used to heat homes because most houses had no chimney, but had simply a depression in the floor for a fireplace. The noxious smoke and fumes released by the burning coal proved to be unbearable.


Charcoal Making Video Part 1


Part 2


Part 3


Part 4



Neatly stacked logs covered by leaves and soil create the slow smolder necessary to produce charcoal.
(Photo courtesy of National Park Service, Hopewell Furnace NHS)

It was not until the iron industry had exhausted the forests of Europe did a real interest in coal develop, raising the price of wood and ***charcoal***, which is made by partially burning wood using only a small amount of oxygen. Soon, as coal became cheaper than wood, chimneys became a common addition to most homes.

Coal eventually found a place in early industry thanks to a significant advancement in technology. In 1612, the invention of a special furnace, known as a ***reverberatory furnace***, allowed coal to replace wood as the primary fuel for separating, or ***smelting***, copper, tin, and lead from ***ore***, and for making glass. Unlike previous furnaces, this innovative furnace could heat the material to be smelted without mixing it directly with the fuel. Separating the fuel from the ore prevented any impurities normally associated with coal from tainting the smelted material. Although this new invention worked well for producing tin, copper, and glass, it could not generate the intense heat needed to produce iron. A ***blast furnace*** was the

Buried Sunshine

Reading layers of earth and rock like a complicated mystery novel, geologists are able to piece together the 4.5 billion-year history of our planet. Coal has a short but fascinating chapter near the end of this long and complex reference book called Earth.

365 million years ago, during what is referred to as the Carboniferous Period, Pennsylvania would have been a very interesting place to visit. A bathing suit and sunscreen would have been in order for Pennsylvania was located near the equator and enjoyed a tropical climate, much like the Everglades in southern Florida. Most of western Pennsylvania was covered by vast swamps rich with vegetation consisting mainly of ferns and fern-like plants. These were no ordinary plants, some may have reached heights of 75 feet. These lush, tropical forests created tons of debris, such as leaves, twigs, branches and trunks, which fell into the warm, murky water below. This sluggish stew of decaying plant material slowly formed a thick mat of organic material called peat. Sand and silt gradually accumulated on top of this peat. Over time, the heat and pressure created by the weight of this overlying sediment compacted the peat, squeezing out virtually all the water, forming a hard, black concentrated carbon-rich material.

This "living fossil", called coal, has stored the sun's energy beneath the earth for millions of years. When burned, this concentrated energy is released. Coal burns much hotter and longer than wood, which makes it such an extremely valuable energy resource.


Coal Formation Video 1


Coal formation Video 2


Coke Ovens Video 1


Iron Furnace Video 1


Steel Making Video 1


Electricity Video 1


Coke Ovens Video 2


Iron Furnace Video Part 2


Steel Making Video 2


Electricity Video 2

only furnace capable of producing such extreme temperatures. Blast furnaces are named for the loud roar that is heard when air is violently introduced to the fire with large bellows to create the intense heat necessary to melt iron. Coal could not be used in a blast furnace. It is much softer than charcoal, and would "slump" into a dense mass under the intense heat and choke the furnace. In addition, the impurities found in coal, such as sulfur, caused the iron that was produced to be very brittle.

Not until the practice of charring coal was developed in 1642 was the full potential of coal realized. Charring coal by partly burning it in covered heaps, similar to the way charcoal is made, produced a hard cinder of almost pure carbon that would burn with a clean, smokeless heat. This cinder, called ***coke***, revolutionized the industrial uses for coal and spawned the Industrial Revolution in Europe.

With the settlement of the New World, coal was again basically ignored as a fuel source. The virtually unlimited

Remains of an iron furnace *(Photo courtesy of Steve Smith)*

Did Beer Change The World?

By the end of the 1600's industrial and economic growth in Europe, ironically an area laden with coal, had become stagnant. Mass deforestation had driven the cost of wood and charcoal out of the reach of many struggling industries. The brewing industry was among those desperately in need of an alternative fuel. Brewers tried using coal-fired ovens to dry malt, a "stew" of grain, usually barley, that is steeped in water until it sprouts; however, the coal's foul smoke and many impurities affected the taste of the beer, just as it had affected the quality of iron when used in blast furnaces. Frustrated, brewers tried charring coal just as wood is charred to form charcoal. When the resulting coal cinders, or coke, were used in the malt ovens, the best beer England had ever tasted was produced.

Abraham Darby, an English Quaker familiar with both the brewing industry and the iron industry, determined what was good for malt must be good for iron. In 1709, using a leased blast furnace and coke he prepared himself, Mr. Darby produced the first quality iron ever made from coal. This monumental event proved that iron could be made by using England's seemingly limitless coal fields rather than its vanishing forests. The Industrial Revolution had begun.

Iron In Our Veins Part 1

Iron In Our Veins Part 3

Iron In Our Veins Part 2

Iron In Our Veins Part 4

supply of timber made it unnecessary to pursue the difficult and dangerous practice of mining coal. But wood eventually became scarce and expensive. The same situation that had occurred in England a century before, occurred in the United States. The New World now had to look beneath the surface of the earth for an alternative energy source.

Commercial coal mining in the U.S. began in the mid 1700's in Virginia. The first coal production in Pennsylvania began in 1761 at Coal Hill, what is now Mt. Washington in Pittsburgh. Coal once again became the principle fuel of choice for use in iron furnaces and glass works, and eventually provided fuel for James Watt's monumental invention of the 1800's, the steam engine.

Coal in Pennsylvania, as in the rest of the United States, fueled the American Revolution, the Industrial Revolution, two World Wars and thrust the United States to the forefront as the industrial capital of the world. Today, the United States is the second largest global consumer of coal. Most of this coal is used to satisfy our increasing demand for electricity. Eight out of every ten tons of coal consumed nationwide is used by an electric generating plant. Pennsylvania is the third largest consumer of coal in the United States. Electric generation consumes 90% of all coal used in the state. In addition to electric generation, coal remains the primary fuel for the iron industry and for the production of chemicals, paper, cement and even food.

Mining Through Time

The rise in popularity of coal as an energy source greatly increased the demand for its mass production. Improved methods of extraction and transportation have led to the methods used today, as well as several inventions we now take for granted.

During more than 200 years of mining, Pennsylvania has produced nearly a fourth of all the coal ever extracted in the United States. In 1918, Pennsylvania exceeded the production of 276 million tons of coal, more than any state has ever produced in one year.

Thousands of men have lost their lives during the slow and painful evolution of mining. It took hundreds of years for technology to improve the working conditions and efficiency of a coal mine. To this day, removing a mineral from below the earth's surface is a difficult and dangerous task.

Mule driver and his mule. On average, a mule would haul 100 tons of coal per day.
(Photo courtesy of the Historical Society of Western Pennsylvania)

Underground Mining

As the supply of coal easily accessible from the earth's surface dwindled it became necessary to venture underground.

Conventional Mining

Underground mining began by "tunneling" into a hillside. These types of mines are called ***drift mines.*** Using picks, bars, and hammers, miners would tunnel through the coal seam, leaving pillars of coal behind to support the mine roof. As the miners retreated from the mine they would remove these supporting pillars and let the mine collapse. The practice of leaving pillars of coal to support the mine roof is still employed today but several other techniques are used that have greatly improved mine safety. Using wooden timbers to support the mine roof was common well into the 1940's. Eventually steel beams replaced wooden timbers, but often the weight of the roof is enough to bend even steel beams. ***Roof bolting*** is a modern method of strengthening the mine roof.

Roof bolts compress the layers of rock that make up the roof into one strong layer, much the way that many layers of plywood are bonded together to produce one strong sheet. Powerful electrically powered, hydraulic driven machines drill holes, insert, and tighten the roof bolts.

Breaking coal from the seam with a pick was difficult and exhausting work. Blasting coal with explosives requires much less effort. Early advancements in drilling and blasting, or "shooting the coal" greatly improved the efficiency and productivity of a mine.

Soft Coal Video Part 1

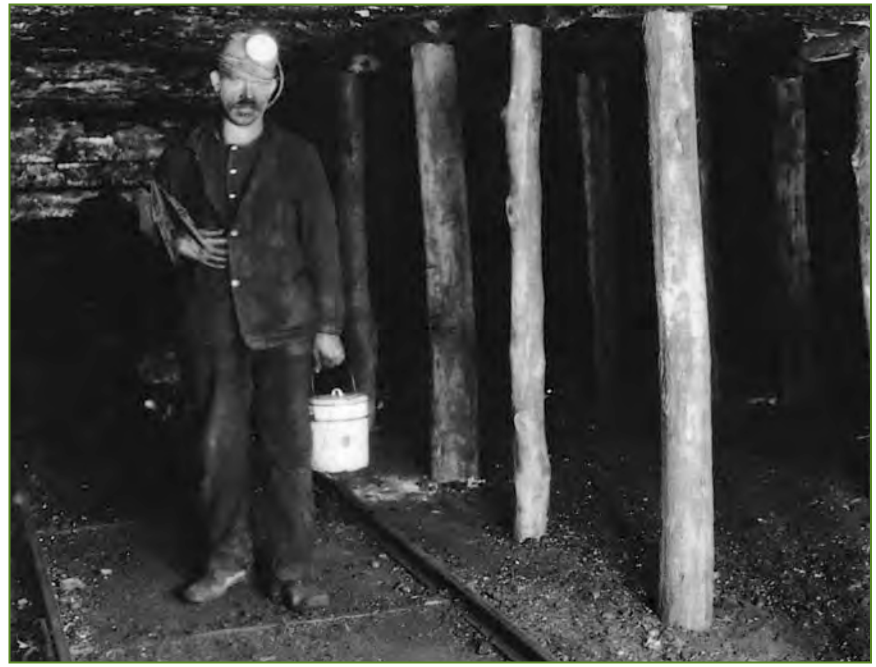
Hard Coal Video Part 1

Soft Coal Video Part 2

Hard Coal Video Part 2

1920's Anthracite Mine Video

Hard Coal Video Part 3

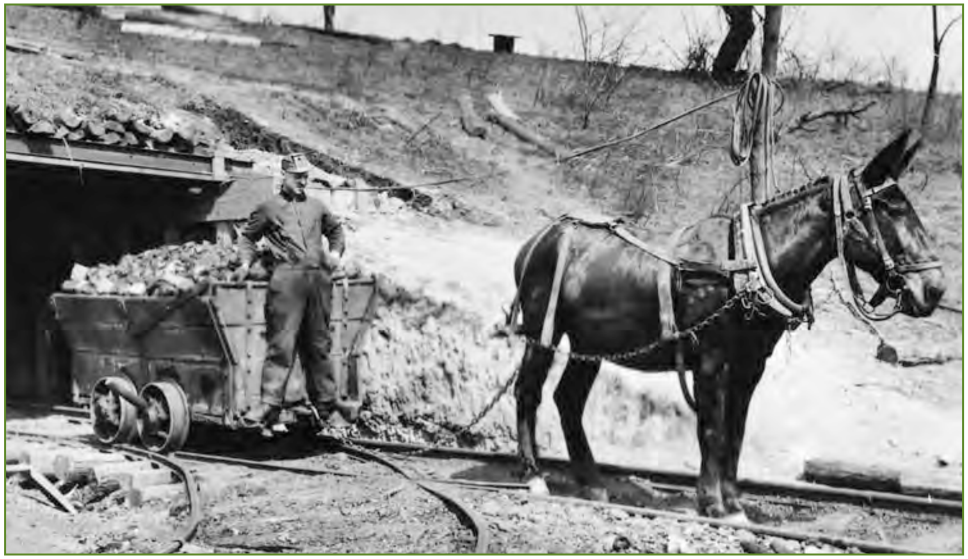


Miner with lunch pail inside a mine supported by wooden timbers
(Photo courtesy of the Historical Society of Western Pennsylvania)

To shoot the coal, a hole must be drilled to receive the explosive. A ***coal auge***r was a primitive tool used to drill the hole. It resembled a brace and bit commonly used by carpenters. This was slow and grueling work. Eventually hand held electric drills made this job easier. Now miners use hydraulic drilling machines on wheels that can be easily "driven" to the working face of the coal seam to quickly drill a hole.

Once a hole is drilled, the "shot fireman" loads the hole with explosives and detonates it. The coal shatters and falls to the floor where it can be loaded and transported out of the mine. To improve the effectiveness of each blast, the ***cutting machine*** was developed in the 1930's. This machine, resembling a huge chainsaw on wheels, undercuts the coal, making a space for the coal to expand during blasting. This allows more coal to be shattered with each blast.

For centuries coal was loaded into carts by hand. Carts were then pulled out of the mine by ponies, oxen, mules, or goats. Eventually electric locomotives replaced the hard working animals and



Mule driver exiting a mine with a full cart of coal. Notice the driver is not holding reins. Voice commands were used to guide the mule through the mine. (Photo courtesy of the Historical Society of Western Pennsylvania)

hand loading gave way to loading machines and conveyor systems, which transport coal from the mine similar to the way groceries are moved through the checkout line by a belt conveyor at the supermarket.

Approximately one quarter of all coal mined underground is still done conventionally.

Continuous Mining

Primitive cutting machines led to the invention of the ***continuous miner*** in the mid 1950's. This invention reduced the steps of drilling, cutting, blasting, and loading into one continuous operation. A continuous miner is a maneuverable machine with a turning cutting drum mounted on the front. The cutting drum has carbide-tipped teeth that literally tear the coal from the working face. A continuous mining machine is capable of removing twelve tons of coal per minute. As the coal is removed from the seam it is automatically loaded by a conveyor system and transported out of the mine. The continuous miner excavates "rooms" out of the coal seam, leaving behind pillars of coal that along with roof bolts support the roof. Because pillars of coal are left behind, only about 50 percent of the coal can be recovered using this process. Continuous coal mines account for more than half of all coal mined underground in the U.S.

Longwall Mining

The ***longwall mining machine***, also developed in the mid 1950's, is the most efficient method of removing coal from underground. A well planned longwall mining operation is capable of recovering 85 percent of the coal in a seam. Unlike conventional and continuous mining, pillars of coal are not left to support the roof, instead, as the mining machinery is moved ahead the roof is allowed to collapse.

A longwall miner consists of a large cutting wheel, called a shearer head or cutting plow, that moves back and forth on a track parallel to the working face. The ***working face*** of a longwall mine can be longer than two football fields, often 1000 feet or more, hence its name. As the shearer cuts away at the working face like a carpenter's plane removing a thin layer of wood, the coal falls into a conveyor system called a ***"pan line."*** The pan line transports the coal to coal cars or a belt conveyor to be transported out of the mine. A moveable hydraulic shield temporarily supports the roof of the mine and protects the miners and equipment. As the operation moves ahead, the shield is moved as well, allowing the roof behind the longwall miner to collapse.

Allowing the roof to collapse can cause surface ***subsidence*** problems. Very specific geologic conditions must exist for a longwall mine to be considered. For this reason longwall mining only accounts for five percent of all underground mining in the U.S.

Miners were often paid by the carts of coal they produced rather than an hourly wage.
(Photo courtesy of the Historical Society of Western Pennsylvania)

Life in the "Hole"

Around the turn of the 20th century, miners had to endure horrendous working conditions for very little money. In 1910 alone, over 500 Pennsylvania coal miners lost their lives beneath the earth. These conditions gradually improved as miners organized to demand improved safety standards.

A coal miner often began his career at a very early age. At the age of nine he may have become a ***breaker boy*** and separated slate and rock from the coal as it was brought out of the mine to the ***breaker***, a machine that "broke" coal into various sized pieces. By 12, he may have become a door boy, or ***nipper***, spending ten or twelve hours in the solitary darkness of the mine opening the mine doors whenever a mule-drawn mine car passed through. At 15, he could have become a mule driver, leading the mules through the darkness as they pulled mine cars filled with coal. After a few years, he would have graduated to mining coal.

Steaming Ahead

As mines moved further underground, flooding became an increasingly significant problem. Many methods of pumping out the mines were tried but all were stalled by one seemingly insurmountable problem. There was no source of continual and reliable power. As late as the 1700's primitive pumps had to be driven by unpredictable wind and water or the tired muscles of man or beast. This problem faced by the miners of the late 1600's and early 1700's led to arguably the most significant invention in the history of technology.

Two important discoveries led to this historic invention. First it was discovered that the earth's atmosphere exerts a surprising amount of pressure. A simple vacuum, such as a suction cup stuck to a window, illustrates this point. When air is expelled from beneath the suction cup by pressing it against the window, atmospheric pressure will hold the suction cup in place. Second, the force of steam was beginning to be recognized. An example of this is the ability of steam to lift the lid on a boiling pot of water.

Brilliant minds of the late 1600's worked tirelessly to harness these principles. Finally, in 1712 a craftsman named ***Thomas Newcome*** built the first atmospheric steam engine. Although primitive, this ingenious apparatus provided a continuous source of power to drive a pump which removed 120 gallons of water per minute from a deep mine well over 100 feet beneath the ground. This incredible device was immediately put to work pumping out deep mines all over England.

In 1763 a young instrument maker began improving upon Newcome's legendary engine. This young instrument maker was ***James Watt*** who went on to invent the first true steam engine which forever changed industry and transportation .

Imagine what life would be like without engines, originally developed to improve coal mining, tirelessly performing countless tasks such as transporting us wherever we want to go.

Tipple and caretaker's shed at the Foltz Hill Mine, Brady Township, Butler County
(Photo courtesy of Sam Brydon)

Needless to say, spending long hours in a dark, damp, cold mine deep within the earth was uncomfortable and extremely dangerous. Often coal seams were no more than two to four feet thick, requiring miners to spend twelve or more hours a day lying on their bellies in a puddle of water. Because of their small stature, young boys were often recruited to mine thin seams. As mining technology improved, thin seams were often abandoned for thicker ones that allowed miners to stand, or at least kneel.

Miners faced deadly obstacles every minute they spent underground. There are countless stories and accounts of disasters striking virtually every mining community in Pennsylvania.

The possibility that the mine would collapse, burying those within alive, lurked in the back of every miner's mind. Often the miners' best friends were the rats that lived alongside them as they worked. Rats had the mysterious ability to sense a collapse before it occurred. If the rats evacuated the mine, the miners quickly followed. Miners often showed

their gratitude by sharing their lunch with the valuable vermin. Today, improved methods of stabilizing the mine, strict safety standards and accurate geologic surveys have drastically reduced the chances of a collapse.

Gas is yet another danger that lurks within the mine. ***Methane***, a gas with a foul odor produced naturally by humans while digesting food, commonly occurs underground. Pockets of methane, created millions of years ago by decomposing plants, are colorless, odorless and extremely flammable. Methane can fill a mine silently and a lone spark from a steel pick striking hard rock may ignite the gas causing an explosion. The resulting fire may burn for many years before it can be extinguished.

Carbon monoxide is another gas fairly common to the mine. This is the same gas that comes from the exhaust of a car. Carbon monoxide is created by mine fires and can be deadly. Canaries were used for years to detect combustible and poisonous gasses within the mine. If the canary died unexpectedly, chances are the air was not safe. Today special lamps and sophisticated detection devices monitor for the presence of dangerous gases.

Providing the miner with a source of fresh air has always been a challenge. Since the earliest days of mining it has been recognized that lives depend on proper ventilation of the mine. The Romans dug intricate ventilation shafts and lit fires beneath these air ways. The fire created strong updrafts which circulated fresh air into the mine. Fires have long since been replaced with fans and complicated ventilation systems.

Coal dust has plagued coal miners for centuries. Almost every aspect of the mining process, such as drilling, blasting and loading, creates dust, a very fine powder like the soot found in a fireplace. Coal dust causes an array of respiratory problems such as ***emphysema*** and lung cancer. Most common was the dreaded ***black lung disease***. Violent and uncontrollable coughing was its most common symptom.

"In the mining town, if you arose and went outdoors early of a summer morning, as you walked by the little wooden row houses, you would hear the miners in the morning ritual of coughing, great racking, gasping coughs, which lasted 10 or 20 minutes. This sound was as natural as the birds singing in the trees. If you became a miner, you knew that you would do "bull work", and when you reached old age

(anything past 50), you would gasp and wheeze, and spit up in the coal bucket by the coal stove. This was the life of a miner." - Eric McKeever *Tales of The Mine Country*

Strict health and safety standards now require that coal dust be contained. Drilling and mining equipment continually spray the working face with water to limit the dust that is produced. In addition to respiratory problems, coal dust is potentially explosive. ***Rock dust***, which is finely ground limestone resembling baking flour, is applied to the walls, ceiling, and floor of a mine to neutralize the explosive properties of coal dust. For this reason the inside of a working coal mine is white, not black, as might be expected.

Surface Mines

As mining equipment improved, coal located near the surface of the earth could be economically removed.

Surface mining is one of the oldest forms of mining in the world. Mining, in it's simplest form, began by using picks and shovels to remove coal exposed in streambeds or located beneath a few feet of soil. Inadequate technology limited the amount of surface mining done until the early twentieth century. Significant surface mining did not begin in Pennsylvania until the mid 1930's. Now, improved equipment allows operators to recover coal buried more than 200 feet underground.

A man trip transports passengers to the working face of the coal. Note the rock dust on the walls of the mine. *(Photo courtesy of Joseph Aloe, Quality Aggregates Incorporated)*

The mammoth dragline in operation *(Photo courtesy of Darrel Lewis, Allegheny Mineral Incorporated)*

Dragline buckets can hold up to 220 cubic yards of overburden. *(Photo courtesy of Steve Smith)*

Stripping shovel in the pit of an operating area mine
(Photo courtesy of Pennsylvania Department of Conservation and Natural Resources)

Today surface mines account for more than half of all coal mined in the United States.

Surface mining is attractive to coal producers for a number of reasons. It is generally cheaper to mine coal using surface techniques. In addition, the amount of coal that can be recovered from a seam is greater, averaging 85 percent compared to approximately 50 percent recovered using most underground mining techniques. Surface mining is also safer for the miners when compared to the many dangers faced underground.

Surface mining is also called "strip mining" because the surface of the land must be stripped away to reveal the coal. Restoring the land to its original form, referred to as ***reclamation***, is an important step in the surface mining process. Modern reclamation standards require all disturbed land to be returned to productive use. This commonly means that all open pits and cuts are filled, leveled, and replanted with vegetation so the site will suitably support wildlife, agriculture, recreation, or commercial and residential development.

The way in which coal is removed during surface mining depends upon the type of landscape to be mined.

Area Mining

Area mining is the preferred method if the terrain of the area to be mined is relatively flat. During area mining the soil and rock above the coal seam, called ***overburden***, is removed in a series of long narrow cuts to reveal the coal below. Today, open cuts are generally no more than 1500 feet long, but in the past they could extend for over a mile. As mining progresses to the next cut, the overburden is ***spoiled*** into the previously mined cut and bulldozers regrade the area to conform to the premining shape of the land. This allows reclamation to occur as coal is being mined.

Digging large holes requires large, powerful equipment. The monstrous ***dragline*** is often the machine of choice. This huge machine uses an enormous bucket attached to cables that are supported by a ***boom***. The bucket is lowered and dragged across the overburden effectively scooping up tons of soil and rock. The bucket is raised and the entire machine rotates to dump the spoil into the neighboring pit. One of the largest draglines has a boom as long as a football field which supports a bucket capable of holding enough spoil to fill six large semi-trucks. Draglines are best suited for relatively soft overburden.

When the overburden is hard it may be necessary to use explosives to break it into manageable pieces. Holes are drilled in the overburden to receive the explosives. Once blasted, the overburden can be excavated using a ***stripping shovel***, which is a machine mounted on crawler tracks similar to the tracks on a bulldozer. Crawler tracks allow the large machine to maneuver within the pit. The stripping shovel, so called because it "shovels" the overburden rather than dragging and scooping, has a bucket connected to an arm which is supported by a boom. Larger stripping shovels tower more than eight stories high. Smaller mines do not require such large machinery. Often bulldozers remove the overburden instead of stripping shovels.

Contour Mining

Contour mining is commonly used if the landscape to be mined is hilly or mountainous. During contour mining the side of a hill or mountain is removed. Mining begins where the coal seam intercepts the surface. This is called the cropline. Working toward the center of the hill, overburden is removed until it is no longer economically feasible to do so. A vertical cut, resembling a steep cliff, marks the final face where the mining operation stops. This cut is referred to as a ***highwall*** and is not permitted to remain. The hill must be restored to its original shape prior to mining.

Reclamation of a contour surface mining site
(Photo courtesy of US Dept. of the Interior, Office of Surface Mining Reclamation and Enforcement)