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Cover Photo: A shovel loads a Terex truck. Huge equipment is necessary
to make modern surface coal mining efficient and economical.

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SURFACE MINING OF COAL

WHAT IS SURFACE MINING?
Surface mining is an efficient method for mining some minerals, especially coal, from deposits near the surface. It uses very large equipment to strip away overlying material, extract the coal, and then fill in the mined valleys. Reclaiming the mined area is also an important and required part of the surface mining operation.

The procedure that was often called "stripmining" is the most common form of surface mining. Some ore deposits are huge and involve excavating ore from a huge pit. Such "open pit mining" differs because it is worked "open-to-the-sky" and not continuously backfilled.

Coal surface mining involves a series of steps: 1) explore for deposits of coal near the surface, 2) prepare the surface for the mining operation, 3) drill, 4) blast, 5) remove the overburden, 6) load the coal, 7) haul the coal, and 8) reclaim the surface of the land to what it was like before mining.

WHERE IS THE COAL SURFACE MINING DONE?
Coal deposits underlie large areas of the Western and Midwest United States (see Figure 3). To locate coal deposits near the surface, geologists can measure changes in gravity (earth density), magnetic field, electrical resistivity, and radioactivity. Along with an understanding of the geological history of an area, this allows a coal explorer to only suspect deposits. To be more certain, sound waves are set off with dynamite blasts and echo back to sound trucks; this helps detect underlying beds of minerals. If a substantial coal deposit is suspected, a drill rig is brought in to drill out a core sample of the layers beneath the locality. Only after coal samples reveal a valuable coal seam will a company commit expensive equipment to begin surface mining.

HOW DO THEY BEGIN COAL SURFACE MINING?
First, trees and vegetation are removed. Topsoil is relatively soft and is scraped up by large bulldozers or scrapers and stockpiled for later use during reclamation. Topsoil is important in restoring the land after mining and may also contain seeds for native vegetation. Underneath the topsoil is the overburden.

WHAT IS "OVERBURDEN"?
Layers of poor subsoil, shale and other deposits above the coal seam must be removed before the coal can be taken out. This material is the "overburden." Removing overburden is a major cost in surface mining. If some of the overburden contains acid or base compounds, exposing this overburden can lead to surface and stream pollution; managing such overburden becomes the main concern in reclaiming the mined area.

Sometimes there are several layers of coal with other material in between; this is called "interburden" and is

This issue is written by Dr. John Richard Schrock, Associate Professor of Biology at Emporia State University. Dr. Schrock received his doctorate from the University of Kansas in entomology and studied the succession of insects on coal spoilbanks. He has authored six science journal articles involving the biology of surface coal mine reclamation.
A "ripper bulldozer" is used both to prepare a site for removal of overburden, and in restoration of the contour of land following mining. Overburden usually has to be broken apart by drilling holes in it and placing charges to blast it apart. Depending on the nature of the overburden, the drilling and blasting is done at special depths and spacing to break it into the proper size for the removal equipment being used.

WHAT DETERMINES IF A COAL SEAM IS WORTH MINING?

Two main factors are the 1) thickness and grade of the coal seam and 2) how deep the seam is buried. A thin seam near the surface may not repay the cost of removing the shallow soil above it, but it may be very worthwhile to dig deeper to mine a thick coal deposit. The comparison of the depth-of-overburden to thickness-of-coal-seam is called the overburden ratio and determines if it is profitable to mine a deposit. (Also see page 10.)

WHAT ARE "SPOILBANKS"?

The overburden materials are deposited in a valley left by the previous mine cut. In the first half of this century, spoilbanks were sometimes left exposed and such barren ridge-and-valley sites remain some people's memory of "spoilbanks."

Today, mine companies must bury the toxic spoils deep and place the topsoils on top in accordance with 1970's mining regulations.

WHY WERE SOME OLD SURFACE MINES TOXIC?

Mines vary by the amount of acidic and alkaline chemicals in the coal and overburden, and in the climate—all of
these factors are important.

In the Midwest, some coal surface mines uncover large amounts of iron pyrites in the coal and the overburden above the coal. When iron pyrite (FeS$_2$) is exposed to weathering and rain, it produces sulfuric acid (H$_2$SO$_4$). Other surface mines dig up minerals that weather into basic compounds. Both acid and base compounds are relatively inert and harmless when sealed inside the ground, but form a toxic topsoil and can pollute drainage streams if exposed.

Before reclamation was required, and some mining companies left the overburden exposed in ridges and valleys, the bottom overburden just above the coal seam—often the most toxic layer—was the last to be cast on the surface. Such exposed surfaces were sometimes so acidic on unreclaimed spoilbanks that plants could not grow and stream runoff was yellow from the toxic acid and rust.

Today, not only is the topsoil set aside, but equipment is used to separate layers with acid spoils and place them near the bottom and keep subsoils near the top.

WHAT IS "BACKFILLING"?

Filling in the valley formed by excavating the coal deposit, usually with overburden from the next mine cut, is called "backfilling." Today this restores the contour of the land to what existed before mining. It does not include the restoration of topsoil or revegetation which is part of the reclamation process.

WHAT IS A "HIGHWALL"?

The only way to see a "highwall" today is to visit an active surface mine. Each pass of the shovel or dragline will
excavate a new valley, leaving a vertical cut—the highwall—on one side and depositing the overburden as spoilbanks in the previously cut valley. Today, when a mine is finished, the whole area is then filled and leveled. However, in old unreclaimed mines, the last cut is never filled and often forms a deep cool lake. The vertical cliff side of these “strip pits” was the highwall.

HOW IS THE MATERIAL LOADED?

How overburden and coal is removed depends on the locality and hardness of the materials and the size of the mine operation.

It usually involves giant shovels or draglines and end-loaders. Usually, a shovel or dragline digs a trench and works its way along the bottom of the trench. To one side it faces a vertical highwall of overburden yet to be dug away. On the other side is the sloping bank of spoils.

WHAT EQUIPMENT IS USED?

A shovel resembles the crane many people are familiar with at construction sites, but the long derrick is replaced with a short arm holding a square dipper that scrapes forward and up “into the toe.” The loaded shovel often can contain 21 cubic yards of overburden or coal from one upward scrape. The bottom of the dipper is a trapdoor that spills the contents onto the spoilbank or into a large truck.

A dragline does have a long derrick that suspends a huge bucket. Unlike the shovel, the bucket swings free, held by lines. This huge bucket is thrown out
Figure 4. A large surface mine dragline is working above a coal seam. Overburden is being removed from above the coal and layered into the trench formed in the previous pass to the right. The highwall is on the left.

and drag backward "into the heel." A dragline can overcast shallow subsoil on the top of a spoil bank two rows away, and then place the deeper toxic spoils on the bottom of the first row spoilbank. The long reach of a dragline has made it the most common excavator in surface mining in the eastern United States.

Huge shovels and draglines occasionally must move across a large interstate highway that crosses a coal field. Because of the enormous weight, a thick layer of earth is applied over the highways to prevent the weight of the shovel or dragline from crushing the roadbed.

In Europe, a huge bucket-wheel excavator is common. A circular wheel at the tip of the derrick arm chews like an upward cutting buzz-saw into the overburden; from the surface down about 50 feet. Material is dumped from the bucket-wheel much like a waterwheel, and conveyed along a long belt conveyor and overcast out over the spoilbanks. It may also load soft brown coal seams near the surface. Otherwise, a smaller shovel follows to remove overburden from 50 feet down to the coal seam.

Coal is usually loaded by a loading shovel. If the coal is hard, the shovel must have a powerful cutting force. It should also leave a clean level mine floor.

The dipper on a shovel could bury a standard-sized truck. Therefore, coal is usually hauled by huge specially-built Terex trucks. Large surface mines use both huge bottom-dump and rear-dump trucks. These special trucks are several stories tall and are so large they are

Figure 5 (centerfold). An outline of coal surface mining operations. Revised extensively from Grim and Hill, EPA 1974.
WHY IS SURFACE MINE EQUIPMENT SO BIG?

The bigger the equipment, the cheaper it is to retrieve minerals from the ground. Along with larger loaders and trucks, there have been improvements in explosives and larger drill rigs. Bigger equipment means greater productivity and cheaper coal. This makes it economical to dig to deeper coal seams, or as mine specialists would say, it increases the “overburden ratio.”

WHAT IS THE "OVERBURDEN RATIO"?

Coal beds are usually flat deposits. The cost of surface mining depends upon the thickness and hardness of the overburden to be removed, and the thickness and quality of the coal seam.

Obviously, thick coal seams near the surface are easy and cheap to mine ..., and most have been exhausted. And a thin coal seam that is very deep isn’t worth the cost to reach it. So a surface miner must calculate the ratio of costly overburden to valuable coal.

For example, the cost limit for stripping coal is set at an overburden ratio of 12:1 in Kentucky. This means that it is worthwhile to mine downward for up to 36 yards to reach a 3-yard-thick seam, but is not economical to remove 14 yards of overburden to extract a 1-yard-thick seam.

OLD SPOILBANKS

In the first half of this century, unreclaimed spoils were often left in 80-foot tall washboard-like patterns sometimes with acidic sulfur spoils at the surface.

Spoilbanks were expected to heal naturally over time in a process called succession where grasses, pine trees, shrubs and eventually forests slowly overgrow the barren area. In wetter

Figure 6. A shovel loads coal into a large Terex truck. Notice that the working floor is kept flat. From 80% to 95% of the coal is extracted, the loss being mainly at the edges of layers where rock is intermixed.
Figure 7. Various designs of huge trucks operate solely on the mine roads at the surface mine site.

areas, this often occurred, but dry spoilbanks were often slow to "return to nature."

Even where forests regrew, if reclamation efforts were not made, natural revegetation has sometimes been slow to return and the soil remains very shallow and subject to erosion, especially in the U.S. Appalachians and in Eastern Europe.

An area the size of the state of Connecticut was mined in the United States and left mostly unreclaimed before the 1970s; most of this area has revegetated to some degree. But since 1977, over 100,000 acres of abandoned mines have been reclaimed.

DOES MODERN MINING DAMAGE THE LAND?

Abandoned barren spoilbanks are now mainly history. Today, mining companies must reclaim the land, and some retain ownership or lease it for farming and other uses.

Is the soil as "good" as before surface mining? In one German study*, a natural area with ancient compacted soils could only grow an incomplete shrubland before surface mining. After mining and reclamation, the area grew to a full canopy forest, now that tree roots could penetrate the looser restored subsoil! While people's definition of "good" may vary, today's modern surface mining and extensive reclamation no longer leaves open scars on the earth as it sometimes did.

NEW MINING LAWS

Some mine companies realized the importance of reclaiming the spoilbanks and restoring the topsoils and conducted reclamation and related research long before it was required by law.

In 1977, the Surface Mining Control and Reclamation Act required that surface mined lands be generally restored to pre-mining conditions of contour, topsoil, and drainage. To date, over 2.5 million acres of coal mine land has been reclaimed, an area about the size of the State of Delaware.

Today, the cost of restoring contour,

restoring topsoil, planting seeds or seedlings, etc. is a major factor in the final price of surface coal mining. Soil scientists, hydrologists, engineers, botanists, and ecologists are an important part of reclamation science.

HOW ARE SURFACE MINES "RECLAIMED"?

Reclamation is the final stage of surface mining and involves backfilling, grading, surface stabilization and revegetation. Backfilling was accomplished when the dragline or shovel spread the overburden onto the spoilbanks, burying the toxic spoils and layering the subsoils. Sometimes, grading and compaction is needed during backfilling and may be done again to restore pre-mining slopes or contours if backfilling was roughly done.

Special bulldozers are usually used in regrading. To ensure that the surface is stable, layers of high-sulfur acidic spoils must be sealed and water quality maintained in the restored drainage. Soil is a complex layer that is rebuilt by: mulching, disking, harrowing, fertilizing and liming. The topsoil was usually stockpiled; this is retrieved and spread by scrapers, end-loaders, or dump trucks.

Reseeding or planting of seedlings is the final stage in reclamation. Establishing vegetation with deep roots and a developed soil layer takes time. Until plant cover is well developed, heavy rainfall can easily produce gullies, and erosion control may be necessary.

The science of reclamation is young and research trials are needed to test different methods on varying spoils and in various climates. Unlike the rapid advances in haulage truck design, good
reclamation techniques require decades to show effective results.

WHY SURFACE MINE?
Surface mining harvests more of a coal deposit (usually 80% to 95%). Underground mines leave underground pillars to support the ceiling and can rarely mine away more than half of a deposit. Surface mining also produces more coal per worker hour, about 6 tons per worker per hour compared with 2.5 tons per hour for an underground miner. In the thick western coal fields, surface mine coal production can exceed 200 tons per worker per day.

WHAT ARE THE VARIETIES OF COAL?
Lignite is a soft, brown coal that is an important fuel source in some parts of the world. It can have an almost wood-like texture and can be excavated with bucket-excavators. It is mostly used to make electricity.

Bituminous coal, also called "soft" coal is commonly mined in the Midwest and Appalachians. Bituminous and the softer "subbituminous" coal has a tarry texture and burns with a yellow flame that indicates impurities and leaves considerable soot.

Antracite is a harder coal that burns without flame color and is mostly mined in Pennsylvania.

Powerplants using high sulfur coal must use scrubbers to reduce the sulfur emissions. Some of the hard, "clean" coals, especially from Wyoming, produce little sulfur when burned. However, powerplants must weigh the cost of transportation against the cost of "scrubbing" out pollutants at the smoke stack.
COULD WE LIVE WITHOUT SURFACE MINING?

Ninety percent of all mineral products were mined by surface mining. Although the majority of surface mining is used to extract coal, bauxite (aluminum ore), phosphates, iron and copper ores, zinc, lead, nickel, and diamonds are also surface mined. Large portions of these minerals are in deposits that are near the surface and cannot be mined any other way.

POWER PLANTS AND THE PRICE OF COAL

A large portion of today's electrical power comes from coal-fired power generation plants. The dependable supply of coal to these powerplants is critical in providing electrical energy to U.S. homes and industry. Improvements in surface mining have been a major factor in keeping the cost of electricity economical.

One ton of coal produces as much heat as four and a half barrels of oil. It is estimated that the U.S. has three trillion tons of coal reserves, and over three-fourths of this reserve is in the West. This Western coal is mostly the less polluting low-sulfur coal. While the U.S. is currently dependent on overseas oil, this dependence would be far greater without the use of surface mined coal in our energy base.

When gas and oil prices are low, it decreases the demand for coal and this in turn decreases the exploration and development of coal surface mines. As oil and gas prices increase, industries convert to coal. The increased demand and price of coal then makes exploration and mining of deeper deposits profitable.

About 40 percent of Western coal (in Arizona, North Dakota, Colorado, Montana, New Mexico, and Utah) is close enough the surface to make surface mining economical. However,
these states have a dry climate and, lacking much rainfall, it will require more effort and money to revegetate the surface mined areas.

Earlier in this century, many small companies operated small surface mines and sold coal to local markets. However, changes in world politics and economics caused major fluctuations in the price of oil and gas, which in turn made coal prices undependable. And the new massive machines that more efficiently (and cheaply) moved overburden and coal were terribly expensive investments for small companies. Big equipment in turn required larger-scale mining and more specialists to manage the stages from exploration to reclamation. As a result, small companies could not remain economical. Today there are fewer but bigger surface mining companies in the United States.

IS THERE A FUTURE FOR SURFACE MINING?

The reserves of strippable coal and other minerals are enormous, but the amount of land on which mining operations are possible is rapidly decreasing. Our expanding population is building homes atop many deposits and placing zoning restrictions above more.

United States coal reserves are big enough to last 240 years at our current rate of use. As long as the need for energy does not decrease, and the alternative energy sources remain expensive, surface mining with effective reclamation remains a necessity.

FUTURE READING

"Facts About Coal" is a small 100-page illustrated booklet available from the National Coal Association, 1130 17th Street NW, Washington, DC 20036.