Chapter 14.3
OPEN CAST (STRIP) MINING

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14.3.0 SURFACE MINING—CONCURRENT RECLAMATION

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Surface mining in which reclamation is carried out contemporaneously with extraction may be classified as either area mining or contour mining. *Area mining* is often referred to as *open cast* or *strip* (furrow) *mining.* It is frequently practiced on a large scale, which results in low unit cost, high productivity, high recovery, and greater safety compared to underground mining. *Contour* (or collar) *mining* progresses in a narrow zone following the outcrop of a coal seam in mountainous terrain. The specific methods used in contour mining are referred to as haulback, box-cut, and block-cut mining (Anon., 1979). The unique aspect of both area and contour mining is that overburden, removed to gain access to the mineral commodity, is immediately placed in the previously mined area.

Coal of bituminous rank as well as lignite are the principal products of area mining. Phosphate and most oil sands are also mined in this manner. To a lesser extent anthracite, bauxite, and bentonite are also mined by area methods (Hartman, 1987). Contour mining is reserved almost exclusively for removing the thin coal beds of the Appalachian region.

In area mining, removal of overburden is accomplished with large draglines, stripping shovels, or bucket wheel excavators (BWEs). These machines excavate and deposit material in one continuous operation. The same function can be accomplished, in part, through the use of explosives (cast blasting). Often removal of soil and overburden is accomplished using a combination of casting machines to maximize the width of the mining area. Conventional excavation and haulage techniques (truck and shovels, scrapers, or dozers) are also used by themselves, or in conjunction with one or more casting machines. Conventional excavation and haulage may be dedicated to topsoil removal only, or it may be employed in removing both topsoil and overburden.

Area mining usually progresses in a series of parallel, deep trenches referred to as furrows or strips that may exceed several thousand feet (1 km or more) in length (Fig. 14.3.0.1). Material is removed from the undisturbed area on the highwall side forming a deep trench. It is then placed in the open pit at the angle of repose forming a spoil ridge. The width of the open pit is typically 75 to 150 ft (23 to 46 m), the height of the highwall may be up to 200 ft (61 m), and the height of the spoil ridge may be up to 250 ft (76 m). Typical highwall angles range from 50° to vertical. Typical spoilpile angles range from 30 to 45° measured from the horizontal. Angles steeper than 37°, which is the angle of repose for most materials, can be obtained by allowing the spoil to compact under its own weight then excavating the material a second time to an oversteepened condition. Experience has shown that oversteepened spoil, in some locations, is capable of standing long enough to extract the mineral and begin backfilling the pit before major instability occurs.

Haulback mining proceeds in a series of nearly square rectangular pits following the outcrop for as much as several miles (kilometers) (Fig. 14.3.0.2). The pit width is dictated by the economic stripping ratio and steepness of topography. Since mining roughly follows a contour, the path of mining is generally sinuous with both outside and inside curves. Mining progresses by first removing a box cut and hauling the overburden to a suitable disposal site. Thereafter, overburden is broken, excavated, and hauled by truck, scraper, or conveyor to fill previously mined-out pits with little or no waste deposited on the outslope. In this manner waste moves in a direction opposite to the direction of mining and hence the name “haulback.”

Box-cut contour mining (Fig. 14.3.0.3) is practiced in moderately sloping terrain. It is essentially the same as area mining where the total number of strips is limited to two or three. The strips are oriented parallel to the outcrop line and progress uphill into the highwall. The first strip is a consecutive series of box cuts, which provides an open pit for spoil cast from the second strip.

A dozer is normally employed to clear vegetation over the box cuts and down-slope from the outcrop line. Overburden is then pushed from the box cuts to the outslope area. Once the coal is uncovered, it is removed, and the dozer establishes a level bench upslope from the box-cut line. From this bench, a dragline then excavates the overburden and deposits it into the adjacent box cut. In place of the dragline, a shovel can be used to remove overburden from the second cut thus eliminating the need to create an upslope bench. Upon reaching the economic limit of mining, dozers push the spoil uphill to cover the highwall before revegetation commences.

Block-cut mining can be applied to either area or contour mining. This method differs from conventional area and contour mining in that blocks of overburden in excess of 70 ft (20 m) wide are removed as a unit and deposited in mined-out areas either perpendicular to the direction of advance (area mining) or along the outcrop direction (contour mining). If the mineral commodity is relatively shallow with more or less uniform cover, the overburden can be removed by front-end loader (FEL) or pushed by dozer to the disposal site in one operation.

If a coal seam is close to flat lying and occurs near a mountain top, the deposit can be mined from outcrop to outcrop in series of strips as practiced in conventional area mining. In some cases, the spoil is leveled rather than contoured to approximate the original topography. This method is referred to as mountaintop removal (Anon., 1979). This modification, however, differs from mountaintop removal as described in Chapter 14.1. In the previous section, mountaintop removal was identified as a “deferred reclamation” technique because overburden was hauled to a disposal site away from the mining area. In the above case, overburden is deposited in the open pit adjacent to the seam being uncovered and reclaimed as mining progresses.

The cycle of operations includes clearing vegetation, soil removal, drilling and blasting overburden, stripping, removal of coal or other mineral commodity, and reclamation. In the case of area and contour mining, reclamation should be considered as a unit operation since it is repetitive and concurrent with mining.

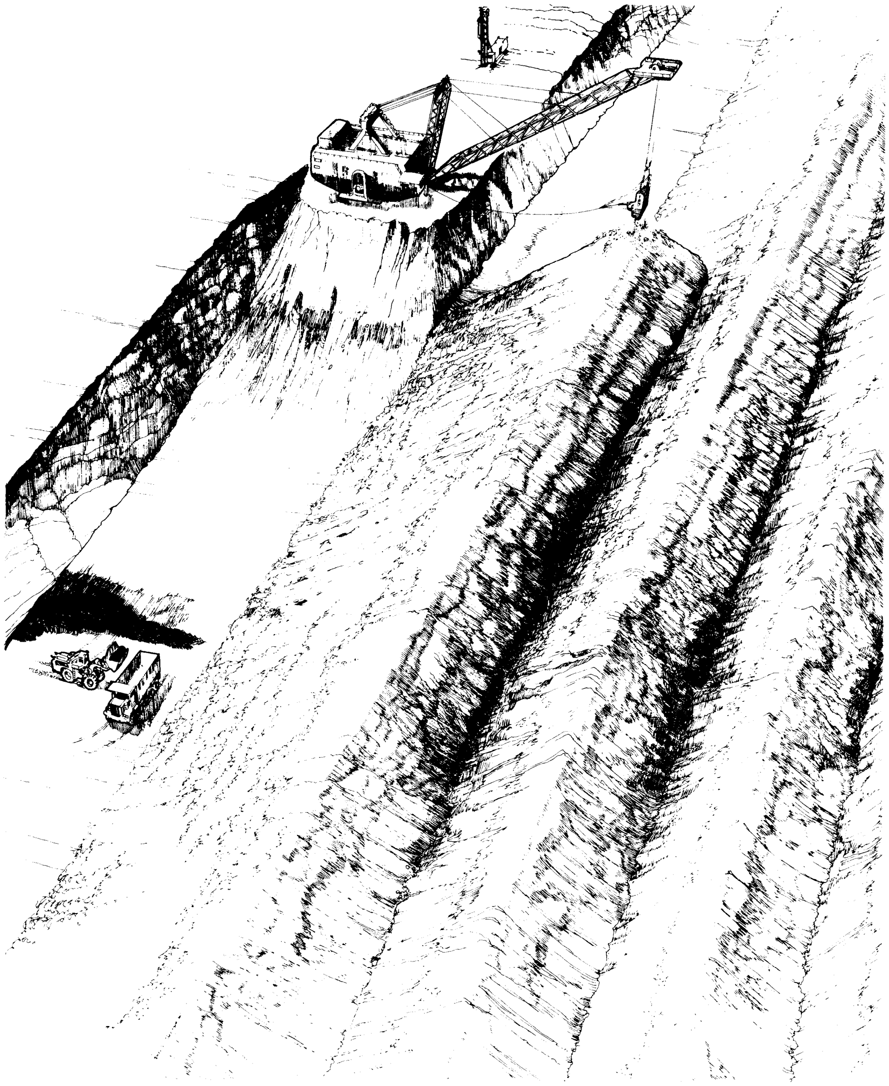

Fig. 14.3.0.1. Conventional area mining utilizing a dragline. (Anon.,1979; illustration by Frank Kulczak. By permission from Skelly and Loy, Harrisburg, PA.)

Clearing vegetation is nearly always accomplished with track-mounted dozers. Soil removal is often assisted by dozers but more commonly achieved with scrapers and dozers, or trucks and FELs. Overburden can be broken with dozers equipped with rippers if the rock is weak or drilled and shot if it is more competent. Drilling may be done with drag bits, rotary bits, or percussion. Holes are usually vertical, but occasionally inclined holes are used to achieve better highwall stability and more uniform fragmentation especially if the highwall is not vertical. The explosive of choice is ANFO unless water precludes its use.

Selection of an appropriate excavator is usually dictated by the properties of the overburden and mineral commodity as well as the deposit geometry. Stripping shovels are able to exert maximum digging effort and are the best choice for blocky material. They also have a shorter cycle time compared to draglines. The main disadvantage is that they must work on top of the seam to be mined. If this material is friable, fines are created by movement of the excavator, and the fines may contribute to poor recovery or poor product specifications. In addition, shovels must reach from the top of the seam to the top of the spoilpile rather than from the original ground surface to the top of the spoil pile as is the case for draglines.

Effective use of draglines requires well-broken and disaggregated material. The main advantage of the dragline over stripping shovels is flexibility. It usually has greater reach for a given set of circumstances and can operate on either the highwall side or on the spoil side. In addition, it can cope better with adverse pit conditions such as slides and flooding that would be difficult for a shovel. It can also dig a deeper box cut and can dig both above and below its position on the overburden. The cost per cubic yard (cubic meter) is slightly higher for bucket (dipper) sizes less than 70 yd^3 (54 m^3) compared to shovels but about the same for the larger sizes (Weimer, 1968).

Bucket wheel excavators perform best in material which is well fragmented and void of large boulders and buried vegetation. They are particularly well adapted to hard pottery clays, phosphates, tar sands, and bauxite. Often they are able to handle these materials without blasting. The advantage of BWEs is a more even power demand compared to either shovels or draglines. They also tend to provide more stable pit slopes, more uniform spoil piles, and greater control in selective mining of interbedded deposits. BWEs are able to excavate both above and below the elevation of the base of the machine. The major

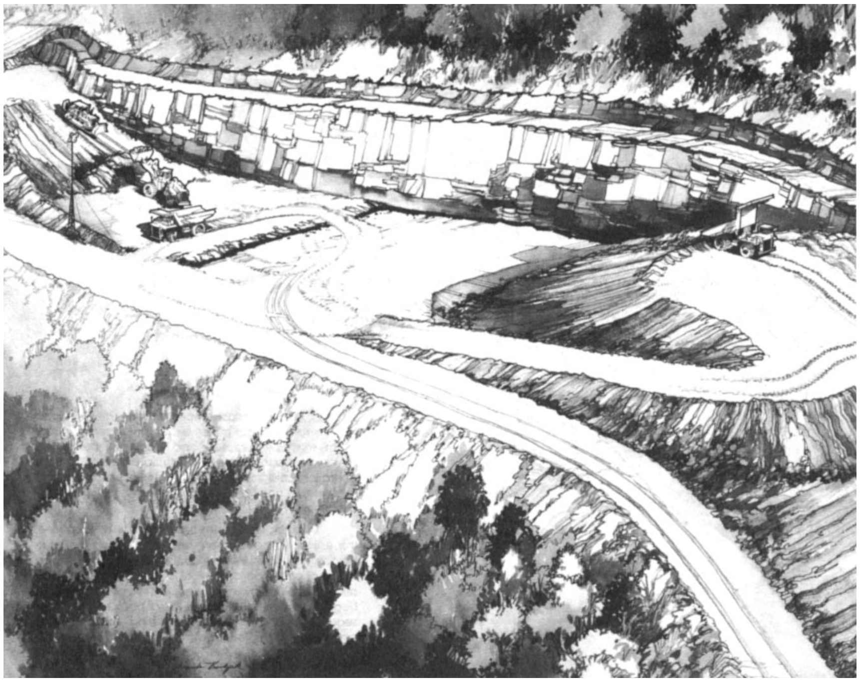

Fig. 14.3.0.2. Conventional haulback mining utilizing trucks, dozers, and front-end loaders. (Anon., 1979; illustration by Frank Kulczak. By permission from Skelly and Loy, Harrisburg, PA.)

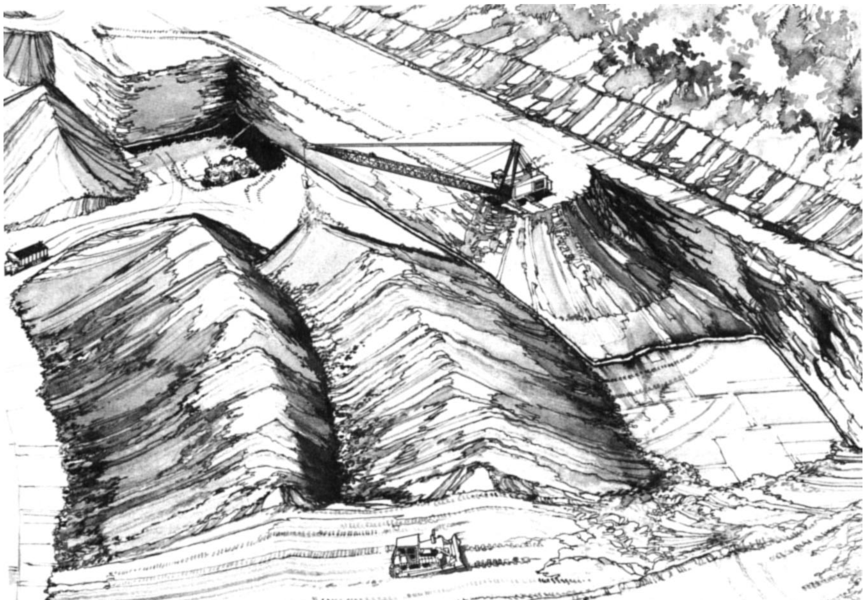

Fig. 14.3.0.3. Box-cut contour mining employing dozers and dragline. (Anon., 1979; illustration by Frank Kulczak. By permission from Skelly and Loy, Harrisburg, PA.)

disadvantages are the higher capital cost and lower maneuverability (Aiken and Wohlbier, 1968).

Proper selection of a casting machine (or combination of casting machines) is determined through use of a range diagram. This diagram represents the configuration of highwall and spoil pile in cross section. It allows graphical estimation of overburden "bank" volume and the equivalent volume of broken waste (swell is commonly 25 to 30%). This diagram allows planning of cuts and excavator moves. Careful planning is necessary to ensure that a spoil pile of given width, height, and slope angle can accommodate the volume produced by a highwall excavation of given width and depth of cover (Phelps, 1973).

Once the commodity is exposed by stripping, loading of coal or other materials may be done directly with BWEs, FELs, electric shovels, hydraulic shovels, or backhoes. Stronger material may require ripping or blasting for efficient loading. In the case of Florida-type phosphate deposits, high-pressure jets of water can be used to slurry the ore and transport it to a sump where it can be pumped to processing facilities.

Common applications for surface mining with concurrent reclamation can be subdivided on the basis of the deposit geometry and type. Area mining may be applied to deposits where (1) the overburden is thick and uniform down to a single, near-horizontal coal seam or down to several coal seams separated by thin parting; (2) the overburden is shallow and the coal seam is thick and near horizontal; (3) the layers of overburden are interspersed with numerous nearly horizontal coal seams; and (4) the overburden is of variable thickness covering coal seams which are dipping. Contour mining is applicable where nearly-horizontal, thin seams are exposed in mountainous terrain. Area mining can also be applied to lignite, tar sands, and phosphate. Case studies of each of these situations are presented in Chapters 14.3.1 through 14.3.8.

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14.3.1 MONOLITHIC OVERBURDEN, HORIZONTAL COAL SEAMS: BRIDGER MINE

MARK L. BRICKER

14.3.1.1 Mine Description

The Jim Bridger mine is operated by Bridger Coal Co. and is located in Sweetwater County, 35 miles (56 km) northeast of Rock Springs, WY. The general location of the mine site is shown on Fig. 14.3.1.1 and an aerial overview on Fig. 14.3.1.2.

Bridger Coal is a joint venture of the operator, NERCO Coal Corp., and Idaho Energy Resources Co. The permit boundary encompasses in excess of 20,000 acres (81 km^2) and is nestled against the western side of the Continental Divide.

Production started on July 3, 1974, and by the end of 1989, the mine had produced 83 million tons (75 Mt). Annual production averages 5 to 7 million tons (4.5 to 6.4 Mt) of run-of-mine coal. Coal is consumed on site by the Jim Bridger Power Plant, a 2000-MW generating station, and the electricity is transmitted to the Pacific Northwest power grid (Oregon, Idaho, Northern California, etc.).

Dragline stripping operations are scheduled around the clock, two 12-hr shifts/day, seven days/week, 356 days/year (nine holidays are observed). A dragline crew works a 12-hr shift each day for four days and then has the next four days off. The remaining operations are scheduled for three 8-hr shifts/day, five days/week, 251 days/year. Some maintenance and warehouse personnel work the same schedule as the draglines.

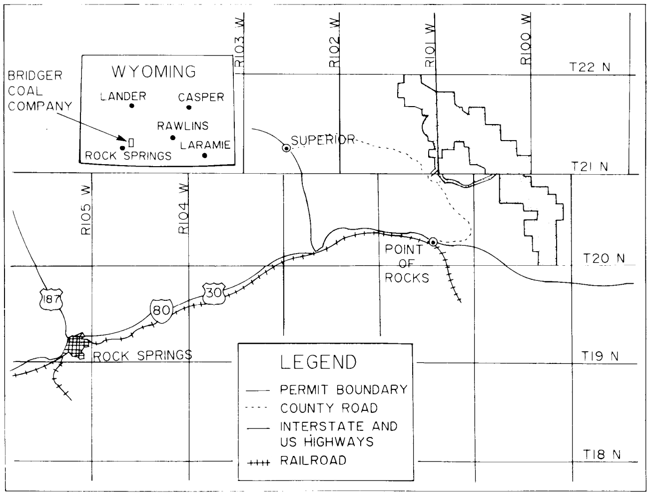

Fig. 14.3.1.1. General location map.

Fig. 14.3.1.2. Aerial overview of mine site and power plant.

The mine employs four draglines and one shovel for casting operations and two front-end loaders (FELs), one shovel, and one hydraulic backhoe for five to six active production faces. The total number of employees at the mine is 422. Of this number approximately 109 are in supervisory or administrative positions.

14.3.1.2 Deposit Description and Geology

The Jim Bridger mine is located on the northeastern flank of the Rock Springs uplift, a broad, asymmetrical anticlinal feature about 60 miles (97 km) long and 35 miles (56 km) wide with a north-trending axis. This uplift separates the Green River Basin to the west and the Great Divide and Washakie Basins to the east.

Precambrian rocks on the apex of the uplift are estimated to be 17,000 ft (5200 m) above the Precambrian rocks in the Green River and Washakie Basins. Normal faults with generally less than 100-ft (30-m) vertical displacement cut through the uplift. The dip of strata on the flanks is generally between 3 to 15°.

The coal seams occur in the Deadman Coal Zone of the Fort Union Formation, which is Paleocene in age. This zone is about 60 to 80 ft (18 to 24 m) above the contact with the underlying Lance Formation. The Fort Union Formation is about 1500 ft (460 m) thick, and the Lance Formation is about 900 ft (270 m) thick. There are five coal seams exposed in the mine; they are designated D5 through D1 from top to bottom. Various combinations of these seams exist throughout the field forming single-seam, two-seam, three-seam, and four-seam areas. The seams generally dip 2 to 5° to the northeast.

Sedimentary rocks of the Fort Union Formation represent depositional processes of a fine-grained, fluvial-flood-basin complex with extensive swampy conditions and minor lacustrine influence. Recognized depositional environments within the three-dimensional framework include poorly drained swamps, well-drained swamps, crevasse splays, and fine-grained channel sandstone deposits.

Overburden and interburden materials consist of interstratified sandstones, siltstones, claystones, and minor shale and thin, discontinuous limestone stringers. These stratigraphic units exhibit a high degree of rock variability, both laterally and vertically.

Table 14.3.1.1. Coal Reserves

Lease	Acres (km^2)	Tons × 10^6 (t × 10^6)
Federal Coal	8595.68 (34.79)	91.5 (83.0)
State Coal	1280.00 (5.18)	0.4 (0.36)
Union Pacific Coal	8579.46 (34.71)	103.8 (94.2)
Totals	18,455.14 (74.69)	195.7 (177.5)

Stripping ratio: 8 bank yd^3/ton (6.7 m^3/t)

Table 14.3.1.1 is a summary of reserves and stripping ratio for the mine. Coal leases are held by the federal government, the State of Wyoming, and the Union Pacific Railroad.

The coal resource is classified as subbituminous. The energy content averages 9400 Btu/lb (21,864 kJ/kg) with 18% moisture, 9.5% ash, and 0.59% sulfur.

14.3.1.3 Mine Development

Soil is removed from areas prior to stripping operations. In the early years of the mine, reclaimed areas were not available for direct application of soil. Therefore, soil was placed in stockpiles at various locations. This stockpile practice is not preferred because of the loss of soil fertility and the microbiological community. Use of stockpiled soil on reclaimed areas requires fertilization, while direct-applied soil has reduced fertilization costs over 50%. Direct-applied soil is hauled from the highwall side of the pit across or around the pit and distributed on reclaimed areas. Soil depths at Bridger range from 0 to 60 in. (0 to 1524 mm) with a field average of 15 in. (381 mm). A buffer of 600 ft (180 m) is maintained from the highwall for operational flexibility.

Once soil is removed, the overburden material is drilled and blasted. Outcrop development is generally accomplished by a scraper or truck and shovel fleet. The outcrop overburden material is placed to minimize out-of-pit spoil. After outcrop is developed, the draglines remove overburden by simple side casting or extended bench methods up to approximately 80 ft (24 m) in depth. Depths greater than 80 ft (24 m) require a multiple-pass, spoil-side, dragline stripping method.

Highwall angles generally range from 50 to 70°, with an average of 65°. The angle of repose for the spoil material is 36°.

General pit development is northwest to southeast along the strike of the coal beds. Each successive pit is farther down the dip of the coal seams. Pit widths vary greatly throughout the mine, but generally outcrop pits are 200 to 250 ft (61 to 76 m) in width. Where the overburden is less than 150 ft (46 m), the pit width varies from 150 to 200 ft (46 to 61 m). For overburden depths greater than 150 ft (46 m) in depth, pit width ranges from 120 to 150 ft (37 to 46 m) in width. An overall average pit width is 150 ft (46 m).

The active pit is approximately 9 miles (14.5 km) in length. Spread across this area are four draglines, a truck fleet and shovel operation, and a scraper fleet operation. Therefore, as many as six faces are operative at any time.

Pit access is available through a series of ramps or entries spaced at approximately 4000-ft (1220-m) intervals. Since the mine is located to the northeast of the power plant, the ramps start at the pit floor and advance through the spoil side of the pit up a 3 to 5% grade to a haul road network ending at the power plant truck dump.

Table 14.3.1.2. Drilling Equipment

Drill Name	No.	Bit Size in. (mm)	Purpose
Bucyrus-Erie 60R	1	12¼ (311)	Overburden
Drilltech D60K	1	10⅝ (270)	Overburden/ Parting
Schroeder Twin Mast	1	5¼ (133)	Coal
Drilltech D50K	1	9⅞ (251)	Overburden/ Parting
Marion M-3	1	12¼ (311)	Overburden
Drilltech D25K	1	6 (152)	Parting/ Coal

Future mine development will consist of opening the remaining southern portions within the permit boundary, which will extend the pit approximately 6 miles (9.7 km). As the southern expansion is started, final reclamation will begin in the currently active area. This development philosophy minimizes the total area disturbed and allows portions of the mine to return to its original livestock and wildlife land use as soon as possible.

14.3.1.4 Unit Operations

DRILLING AND BLASTING. Drilling is accomplished by six different makes and models of drills. Table 14.3.1.2 identifies the drill fleet at the mine.

Blast patterns are rectangular or square and vary with depth and type of material. An emulsion-product mix is used, which is a blend of 33% emulsion and 67% ANFO. In extremely wet areas, the product mix is raised to 50% emulsion and 50% ANFO. Powder factors average between 0.6 to 0.8 lb/yd^3 (0.36 to 0.47 kg/m^3) for overburden, 0.4 lb/yd^3 (0.24 kg/m^3) for coal, and 0.8 lb/yd^3 (0.47 kg/m^3) for parting.

OVERBURDEN REMOVAL. After outcrop development, draglines remove overburden by simple side casting or extended bench methods up to approximately 80 ft (24 m) in depth. These methods are illustrated in Fig. 14.3.1.3 for simple side casting and Fig. 14.3.1.4 for extended bench methods.

Depths greater than 80 ft (24 m) require a multiple-pass, spoil-side, stripping method. The overburden is split into two lifts of approximate equal depth and the first or upper lift is drilled and stripped by simply sidecasting the material into the empty pit (Figs. 14.3.1.5 and 14.3.1.6).

Next the dragline maneuvers from the highwall elevation down a ramp (cut out of the upper lift) to the lower lift elevation. Prior to cutting the ramp with the dragline, the lower lift material is drilled and blasted. The dragline strips a key cut that establishes the lower portion of the highwall and places that material behind the upper lift spoil.

Finally, the entire upper lift and lower lift key-cut spoils are leveled, and the dragline maneuvers onto the spoil-side pad. From this position, the dragline strips the remaining lower lift material and spoils the material in its final position.

Since mining operations occur in multiple-seam areas, supplemental stripping operations usually remove the interburden materials. In areas where the parting and overburden materials are approximately equal, the multiple-pass dragline operation described above is altered to allow the dragline to remove interburden materials. These interburden materials must be tested prior to mining to ensure they are not toxic. Only nontoxic materials can be deposited with dragline spoil.

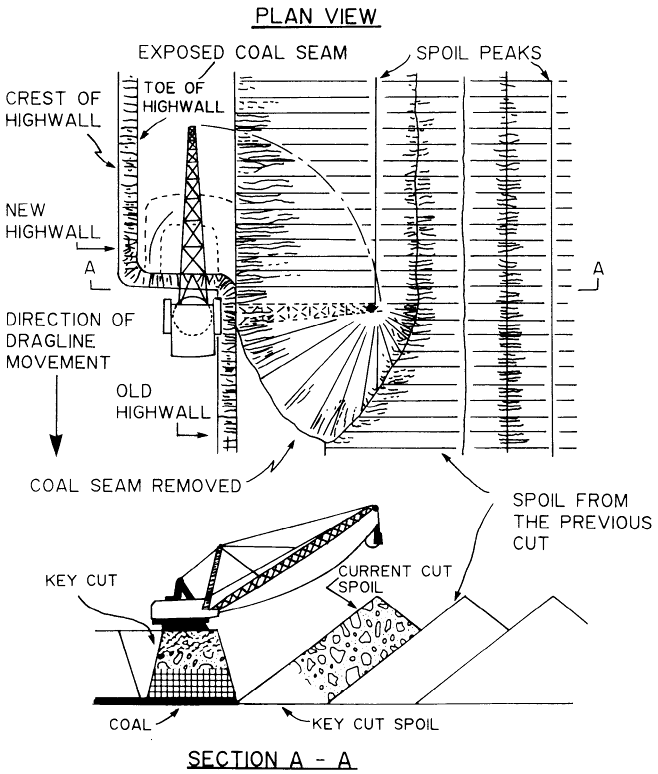

Fig. 14.3.1.3. Simple side casting.

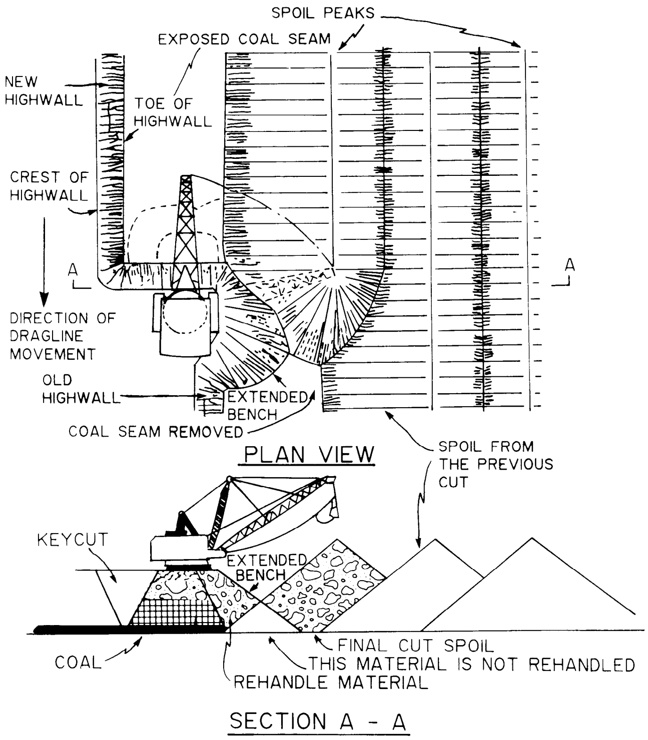

Fig. 14.3.1.4. Extended bench stripping.

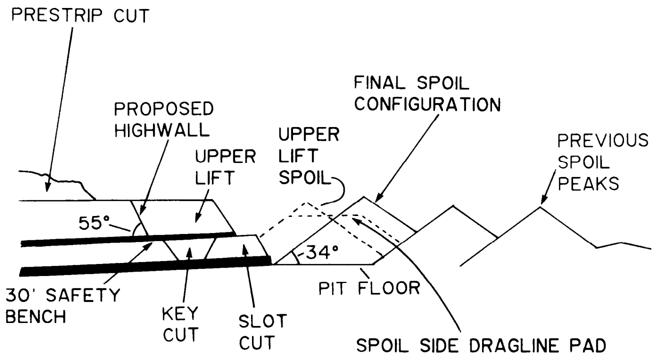

Fig. 14.3.1.5. Multiple-pass, spoil-side stripping. Conversion factor: 1 ft = 0.3048 m.

Fig. 14.3.1.6. Dragline on the spoil side.

Table 14.3.1.3. Stripping Equipment

Description	No.	Size yd^3 (m^3)	Rate yd^3/shift (m^3/shift)
Marion 8200 dragline	2	75 (57.3)	16,000 (12,234)
Page 757 dragline	1	60 (45.9)	13,000 (9940)
Page 732 dragline	1	20 (15.3)	5000 (3823)
Bucyrus-Erie 195B shovel	1	12 (9.2)	3000 (2294)
777B Caterpillar 90-ton truck	3	130 (99)	N/A
657 Caterpillar scraper	4	32 (24.5)	4500 (3441)

Note: All production rates are expressed in terms of 8-hr shifts.

Supplemental stripping operations consist of a truck-and-shovel fleet or a scraper fleet. These operations provide added flexibility to the mine by selectively handling toxic materials, performing advance benching of the highwall for the dragline, or removing interburden materials in multiple-seam areas.

Table 14.3.1.3 summarizes the stripping equipment as of 1989.

Fig. 14.3.1.7. Coal loading operations.

Table 14.3.1.4. Coal Loading and Support Equipment

Description	No.	Size yd^3 (m^3)	Rate yd^3/shift (m^3/shift)
Dart 600 C FEL	1	23 (17.6)	7100 (5429)
Caterpillar 992 FEL	1	13 (9.9)	4100 (3135)
Koehring 1266E hydraulic backhoe	1	15 (11.5)	6600 (5046)
Bucyrus-Erie 195B shovel	1	18 (13.8)	7800 (5964)
Michigan 380 RT dozer	3	N/A	N/A
Caterpillar 16G blade	3	N/A	N/A
Caterpillar 633 scraper	1	34 (26)	N/A
Caterpillar 777B truck	5	130 (99)	N/A

COAL PRODUCTION. Once the overburden and/or interburden has been removed and the top surface of the coal seam exposed, the coal surface is cleaned by rubber-tired dozers, blades, or scrapers. The coal is then drilled using twin-mast auger drills employing 5 1/4-in. (133-mm) bits. The material is lightly blasted to facilitate loading operations.

Coal loading is accomplished by FELs, electric shovels, or hydraulic backhoes (Fig. 14.3.1.7). Table 14.3.1.4 summarizes the coal loading equipment as well as the major pieces of support equipment.

HAULAGE. Prior to 1989, coal was hauled 11 miles (17.7 km) from the mine to the power plant by a fleet of thirteen 120-ton (109 t) bottom-dump trucks. Due to length of haul, a 42-in. (1067-mm) conveyor system was installed in 1989 to reduce the distance for truck haulage. Five 90-ton (82-t) end-dump trucks replaced the bottom-dump trucks. These new trucks shuttle coal a distance of approximately 4 miles (6.4 km) round trip from the pits to two truck dump sites feeding the conveyor system. Each truck dump site uses a feeder-breaker to size the coal to – 6 in. (– 147 mm) prior to loading the belt.

The conveyor system consists of a 13,000-ft (3962-m) main belt and an 8000-ft (2438-m) northern wing. The belt runs at 825 ft/min (244 m/s) and conveys coal at a rate of 1500 tph (1361 t/h). Coal is discharged at the power plant's newly constructed transfer building.

RECLAMATION. Reclamation consists of spoil pile leveling and grading, soil application, fertilization, and mulching. Spoilpile leveling is initiated by dozers and completed by the scraper fleet. The regraded area is deep-ripped with a dozer prior to soil application. Generally, in order to meet approximately original contour (AOC) criteria, as defined by the Wyoming Department of Environmental Quality (WDEQ), spoil material must be moved several hundred feet (meters), thereby requiring use of the scraper fleet.

Once an area has been regraded, soil is applied directly from the highwall or from soil stockpiles. Soil is applied to regraded areas at an average thickness of 15 in. (381 mm). A survey of elevations and results of chemical analyses of samples from the regraded area are submitted to the WDEQ for evaluation prior to soil application.

After soil is applied, the area is lightly ripped with a blade or a chisel plow along the contour, and native seed mixes are drill-seeded. Finally, most areas are mulched with hay to provide additional protection from erosion. Presently, there are over 1130 acres (4.6 km^2) of reclaimed land on the mine site, and the WDEQ has rated 90% of Bridger's reclamation as fair to good.

14.3.1.5 Product Control

Coal quality is monitored by an in-pit sampling program of cuttings from production drillholes in coal. Short proximate analyses and sodium oxide content in the ash analyses are performed at the mine utilizing the power plant's coal lab. These data are used for daily and weekly forecasts as well as actual daily quality delivery estimates. Minimal in-pit blending is required, as the coal generally exceeds the contractual quality restrictions. Long-term coal quality projections are based upon core drilling on 500- to 1000-ft (152- to 301-m) spacings. These coreholes are gridded and modeled on the computer, resulting in values for the life-of-mine plan.

14.3.1.6 Maintenance Facilities

Maintenance is performed onsite in a large diesel shop and small gas vehicle shop. These facilities are located adjacent to the power plant and main mine office. The diesel shop is 30,000 ft^2 (2787 m^2) and consists of four repair bays, one lube bay, one wash bay, a warehouse, three welding bays for dragline buckets, and offices for maintenance and warehouse personnel. Additional satellite facilities are located closer to the pit for large pieces of equipment, such as shovels and drills.

14.3.2 MONOLITHIC OVERBURDEN, THICK HORIZONTAL COAL SEAMS: JACOBS RANCH MINE

G. PAUL ANDERSON AND STEVEN J. KIRK

14.3.2.1 Mine Description

Kerr-McGee Coal Corporation's Jacobs Ranch mine is a two-pit operation located approximately 52 miles (84 km) southeast of Gillette, WY, and 11 miles (18 km) east of Wright, WY. It is one of 15 coal mines currently (1989) operating in the Powder River Basin of Wyoming (Fig. 14.3.2.1). The mines in the Powder River Basin are typified by thick coal seams and relatively thin overburden. This mine, along with the majority of surrounding mines, employs the truck-shovel method as the sole means of overburden stripping and coal mining. Two pits

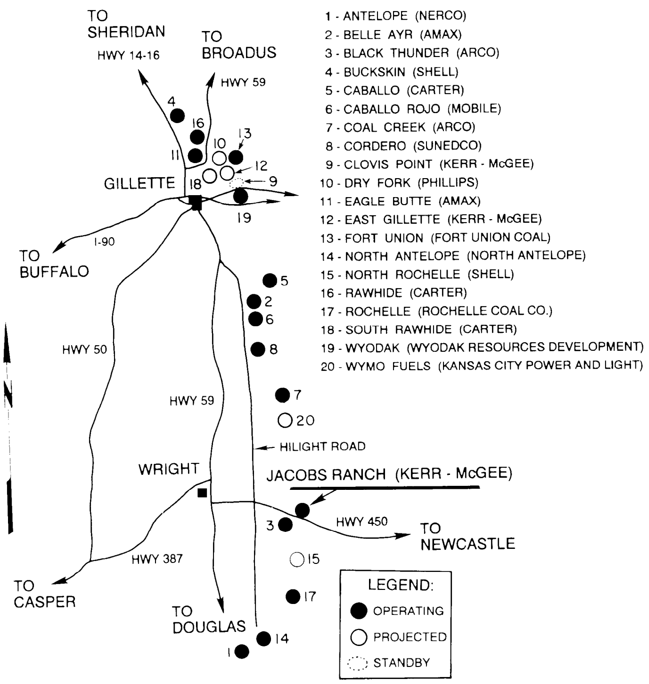

Fig. 14.3.2.1. Campbell County coal mine locations.

Fig. 14.3.2.2. Aerial photograph of Jacobs Ranch mine.

are mined so that coal can be blended to meet coal quality needs of customers (Fig. 14.3.2.2).

Construction began at Jacobs Ranch mine in 1975. Kerr-McGee erected the first shovel at Jacobs Ranch mine and began stripping overburden in August 1976. Coal shipments began in February, 1978 and are currently scheduled through the year 2009.

Annually, the mine produces 15 million tons (13 Mt) of subbituminous, low-sulfur coal that is used to generate electricity in Texas, Louisiana, Arkansas, and Oklahoma. Stripping and mining are currently conducted during three 8-hr shifts, 7 days/week, 355 days/year. Trains are loaded every day of the year, at any hour.

14.3.2.2 Deposit Description and Geology

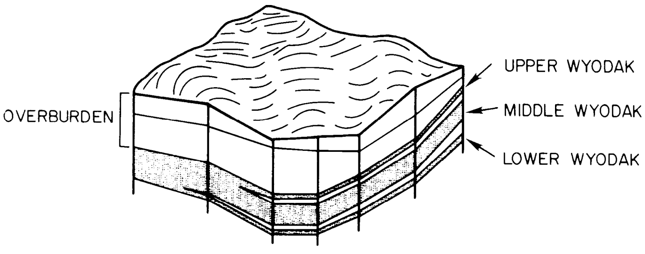

Fig. 14.3.2.3. Geologic cross section of Jacobs Ranch mine.

The 12,000-mile^2 (31,000-km^2) Powder River Basin contains an estimated 22.8 billion tons (20.7 billion t) of subbituminous coal that can be economically recovered using surface mining methods. In general, the coal increases in heating value from north to south. The coal north of Gillette averages 7900 Btu/lb (18,375 kJ/kg). Coal in the southernmost portion of the Powder River Basin has an average heating value of 8900 Btu/lb (20,700 kJ/kg) (Glass, 1982).

Bounded by the Big Horn Mountains on the west, the Black Hills on the east, and the Laramie Range and accompanying highlands on the south, the Powder River Basin stretches across northeast Wyoming in the form of a syncline. The sediments that fill the basin were deposited over a 500-m.y. period, but the structure itself is a product of Laramide folding that began about 70 m.y. ago. At that time, the land folded to create a system of rivers, flood plains, and swamps (Ayers, 1986). Streams originating in the highlands to the south and the southwest carried sand and mud into the basin, where they were deposited in channels and on flood plains. The swampy areas between the channels supported a dense growth of grasses. The remains of these plants constitute some of the thickest coal deposits in the world (Ayers, 1986).

The deposit at Jacobs Ranch mine consists of 375 million tons (340 Mt) of recoverable subbituminous coal. The coal averages 8600 Btu/lb (20,000 kJ/kg), 0.46% sulfur, and 5.58% ash. Over 125 million tons (113.4 Mt) have been shipped since 1978. The 5000-acre (20.23-km^2) coal deposit is located on the 15,000-acre (60.70-km^2) Jacobs Ranch, an active cattle property.

The formation being mined at Jacobs Ranch mine is the Wyodak coalbed. This horizontal seam is continuous throughout the lease area except near the eastern and southern boundaries and in Burning Coal Draw, where it has naturally burned in the geologic past. The coalbed is comprised of up to three separate coal seams referred to as the Upper, Middle, and Lower Wyodak. Only in the southwestern part of the lease do the three seams merge to form a coal unit 50 to 60 ft (15 to 18 m) thick (Fig. 14.3.2.3). The bed is contained within the Fort Union Formation.

The Upper Wyodak coal is the uppermost coal being mined. It is present as a separate unit over all the lease, except where it merges with the Middle Wyodak Seam. The Upper Wyodak Seam ranges from 0 to 7.5 ft (0 to 2.2 m) in thickness and shows no discernible trends.

Separating the Middle Wyodak Seams from the Upper Wyodak Seam is Split A, a carbonaceous shale parting 0 to 38 ft (0 to 12 m) thick. Below Split A is the Middle Wyodak coal. The seam is approximately 40 to 55 ft (12 to 17 m) thick over much of the lease and shows no trends, except for a gradual decrease in thickness that begins about 1000 to 1500 ft (305 to 457 m) from the geologic burnline.

The Lower Wyodak coal ranges in thickness from 0 to 8.5 ft (0 to 2.6 m) over the lease. It merges with the other two coal seams in the southwest and is separated from the Middle Wyodak toward the northeast by a shaley parting. This parting, referred to as Split B, varies from 0 to 73 ft (0 to 22 m) in thickness,

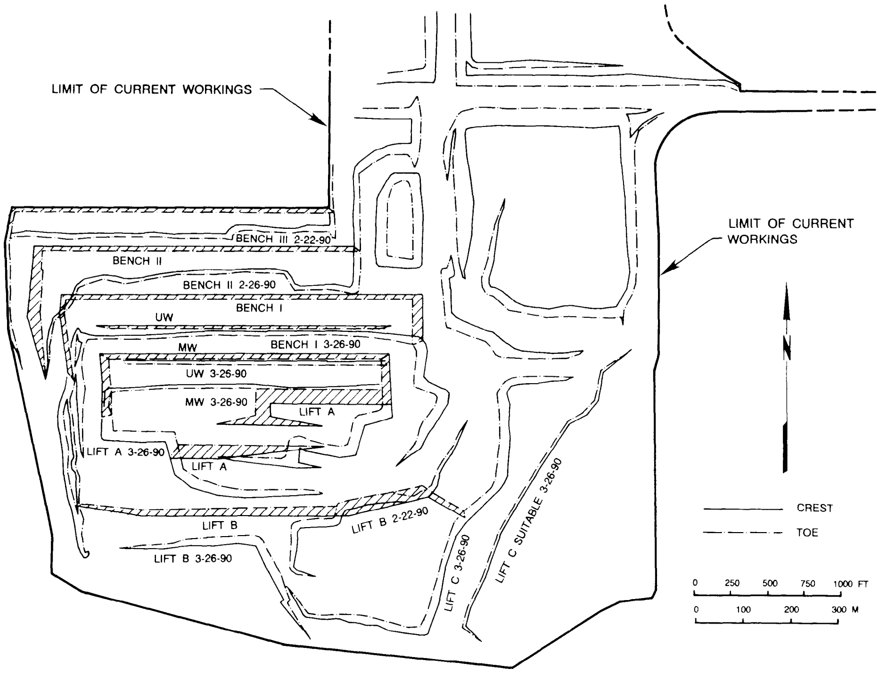

Fig. 14.3.2.4. Monthly mine plan.

averaging between 5 to 10 ft (1.5 to 3.0 m) thick over most of the lease.

About 70% of the Jacobs Ranch coal lease is rolling upland. This upland consists principally of shale and sandstone of the Wasatch Formation. Playas in scattered depressions occur on the plateau. These intermittent lakes, varying in size from less than a few yards (meters) to about 0.5 miles (0.8 km) in diameter, may be caused by local structure of the underlying strata. The remainder of the lease area is either shale slope or alluvial terrace.

The overburden-to-coal ratio varies throughout the Powder River Basin. Ratios range from 0.80:1 to almost 3.00:1. In general, overburden is thinner in the northern part of the Basin; however, stripping ratios vary from mine to mine and throughout individual deposits.

14.3.2.3 Mine Development

As is typical with surface coal mines in the United States, no surface disturbance can occur without the proper permits. Jacobs Ranch mine is regulated by several federal and state agencies. The Office of Surface Mining, the Bureau of Land Management, and the Forest Service all oversee activities at the mine. In addition, the Wyoming Department of Environmental Quality (WDEQ) requires that a mining permit be renewed every five years. An annual report also is required for WDEQ.

In order to reclaim the land successfully after mining, topsoil must be categorized, removed, stockpiled, and planted. The categorization of topsoil types and quantities is accomplished by augering on a grid with a maximum spacing of 200 ft (60 m). An environmental technician analyzes the topsoil and recommends the depth to which it should be removed. Scrapers then remove the topsoil and transport it to strategically located stockpiles or place the topsoil directly on recontoured overburden surfaces. If the topsoil is placed in a stockpile, it is seeded with a quick growing, perennial crop to hinder wind and water erosion.

The initial stripping at Jacobs Ranch mine was made in an area of low-overburden depth. The "box-cut" material was placed in permanent overburden piles adjacent to the initial openings. Due to marketing demands, the mine soon became a two-pit, blended-coal operation.

The pit and backfill design must be performed concurrently. Optimal pit design minimizes haul distance, while taking into account the after-mining contours. The overburden highwall stands at an angle of 1:1, horizontal to vertical. The backfill angle of repose is 1.5:1.

Because of the complex, three-seam coal deposit at Jacobs Ranch mine, the pit geometries are "stair-stepped" in both lateral directions from the pit floor. As mentioned previously, the coal thickness averages between 50 and 60 ft (15 to 18 m). The pit width averages approximately 2000 feet (610 m). The total disturbed length, at any time, varies between 2400 and 4000 ft (730 to 1200 m) along the axis of advance.

Haulage for overburden occurs on roads built into overburden benches (Fig. 14.3.2.4). Coal haulage to the preparation plant is on semi-permanent haul roads.

14.3.2.4 Unit Operations

DRILLING AND BLASTING. Virtually all the coal and overburden is drilled and blasted to maintain high truck and shovel productivities and low operating costs. Drillholes are spaced on approximate 50-ft (15-m) centers and are loaded with ANFO explosives if the holes are dry, and ANFO-based slurries if the holes are wet.

LOADING. The unit weight of overburden at Jacobs Ranch mine averages 111 lb/ft^3 (1778 kg/m^3) and is loaded with stripping shovels that have bucket capacities up to 36 yd^3 (27.5 m^3) (Fig. 14.3.2.5). In addition, front-end loaders (FELs) perform waste removal on an as-needed basis. The diesel/electric loaders can load 15 yd^3 (11.5 m^3) per pass.

The stripping equipment is used on an around-the-clock basis. (A shovel operates up to 6000 hr/yr after allowing for mechanical breakdowns and operating inefficiencies. FELs are used one-half that time.) The thick coal seams and homogeneous overburden contribute to high productivities and economies of scale.

Fig. 14.3.2.5. Stripping operations: 36-yd^3 (27.5m^3) shovel loading 170-ton (154-t) end-dump truck.

Fig. 14.3.2.7. Continuous-miner loading a 170-ton (154-t) bottom-dump truck.

Fig. 14.3.2.6. Production face: 40-yd^3 (30.6-m^3) shovel loading 170-ton (154-t) bottom-dump truck.

Fig. 14.3.2.8. Preparation of topsoil for reclamation.

Coal mining is normally conducted during 2 shifts/day, 5 days/week. One coal shovel is assigned to each of the two pits. Bucket capacities for the coal shovels range up to 40 yd^3 (31 m^3) (Fig. 14.3.2.6). The output from each of these shovels is regulated, on a shift-by-shift basis, in order to blend the coal properly.

In addition to the shovels and FELs, Jacobs Ranch mine recently purchased a continuous loader (Fig. 14.3.2.7). The loader employs a rotating drum that cuts coal in horizontal slices. The coal is discharged directly into trucks by a movable conveyor belt. A typical coal crew consists of a shovel operator, an oiler, and truck drivers. Support equipment includes rubber-tired dozers, crawler tractors, road graders, and water trucks. It is commonplace to have overburden and coal shovels operating simultaneously.

Productivity at Powder River Basin mines ranges between 100 and 300 tons of coal (76 and 272 t)/employee-shift. Productivity also is measured by total units produced. A unit is considered to be either a cubic yard (0.76 m^3) of overburden or a ton (0.91 t) of coal. The unit productivity in the basin ranges between 300 and 700 units/employee-shift.

HAULAGE. All material transported at Jacobs Ranch mine is moved by trucks. The overburden is hauled mainly by 170-ton (154-t) end-dump trucks that have a capacity of 104 yd^3 (80 m^3) of overburden per trip (Fig 14.3.2.5). The mine is also using four 240-ton (218-t) trucks in an attempt to further increase production efficiency. Coal is hauled primarily by 170-ton (154-t) bottom-dump trucks (Fig 14.3.2.6).

RECLAMATION. Kerr-McGee Coal's philosophy toward reclamation is straightforward: make the land more productive than it was when mining began. This simple goal translates into many hours spent planning, testing, and restoring the Wyoming range lands in an efficient and effective program, at the lowest possible cost. Recognition of these efforts includes the National Reclamation Award given by the Department of the Interior in 1988.

At Jacobs Ranch mine, reclamation is continuous. The mining process is similar to a "moving hole," as overburden removed ahead of mining is placed behind the advancing pit. Once the backfilled overburden has been contoured to match the surrounding terrain, topsoil is spread on the site. The ground is planted with blends of up to 14 types of grasses and shrubs (Fig. 14.3.2.8). The blend ensures vegetation hardy enough to withstand harsh Wyoming winters. Fences protect the lands until the grasses are healthy and established.

In addition, employees erect natural rock habitats that provide cover for small animals and vantage points for birds of prey.

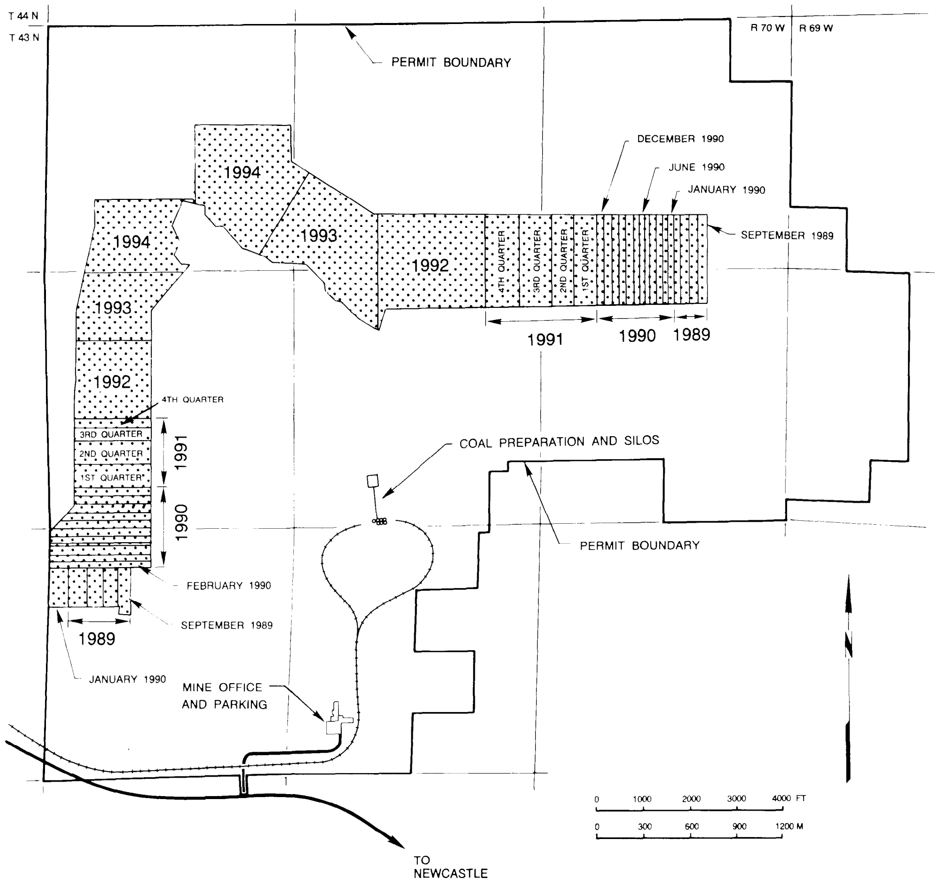

Fig. 14.3.2.9. Five-year mine plan.

Before completing reclamation, crews dig ditches and ponds to prevent run-off water from eroding topsoil.

The best testimonies to Kerr-McGee Coal's success in reclamation are the deer and antelope grazing on the protein-rich grasses growing on acreage that has yielded its coal. Studies carried out at Jacobs Ranch mine document that reclaimed areas are more productive than surrounding undisturbed range land.

14.3.2.5 Product Control

As mentioned previously, coal quality at Jacobs Ranch mine varies throughout the deposit. The challenge for the engineers at Kerr-McGee Coal Corporation was to determine an ultimate mine plan that would ensure quality coal over the life of the mine.

Every year an updated five-year mine plan is completed (Fig 14.3.2.9). Monthly mine plans shown in Fig. 14.3.2.4, are prepared in accordance with the five-year outline.

On a daily basis, a quality control engineer inspects the pit and ensures that proper grade control is maintained for the shovels and loaders. The quality control engineer is responsible for blending the coal into the silos and, eventually, into the coal trains. Onsite proximate analyses are performed for all coal shipments.

14.3.2.6 Ancillary Facilities

MAINTENANCE. Jacobs Ranch mine's ongoing maintenance program emphasizes inspections and repairs of mining equipment before a major failure hampers coal production. This effort requires two teams of diesel mechanics, welders, and maintenance electricians. The maintenance shop is large enough to accommodate 24-ft (7.3-m) tall haul trucks. Equipment too large and slow to be brought to the shop is serviced in the field. This equipment includes bulldozers, drills, and shovels.

COAL PREPARATION. The preparation plant at Jacobs Ranch mine has two parallel circuits that are each capable of producing coal at 2000 tph (1815 t/h). The coal delivered to the preparation plant hopper ranges up to 15 in. (381 mm) in diameter. A dual stage crusher in each circuit reduces the coal to its final 2-in. (51-mm) size.

Coal is sampled as it is placed in one of seven, 14,000-ton (12,700-t) silos. Coal is loaded into two unit trains using automatic train loading and top-off systems. The 115-car unit trains are loaded to within ±0.2% of the desired weight.

Individuals with supporting skills such as accounting, engineering, and computer science help ensure that Kerr-McGee Coal meets its goals. The company strives to provide the safest working environment, to deliver high-quality coal, and to continue operating as a responsible corporate citizen in the Powder River Basin.

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14.3.3 VARIABLE INTERBURDEN, HORIZONTAL MULTIPLE COAL SEAMS: COLOWYO COAL COMPANY

DAVID B. MCDONALD

14.3.3.1 Mine Description

The Colowyo Coal Co., a 50-50 partnership of W.R. Grace & Co. and M.A. Hanna Co., started coal production on March 11, 1977. The mine (Fig. 14.3.3.1) is located at Axial, CO, which is 26 miles (42 km) southwest of Craig, in Moffat County, CO. The elevation of the mine site is 7000 ft (2100 m). Colowyo operates on federal and state coal leases with some private ownership of the surface. The logical mining unit (LMU) is 11,405 acres (46 km^2).

Colowyo's 1989 production rate is 4.1 million tpy (3.7 Mt/a) of coal that requires the removal of 27 million yd^3 (21.4 million m^3) of virgin overburden and 3.8 million yd^3 (2.9 million m^3) of rehandle. The mine is designed and permitted to operate at a maximum production rate of 4.4 million tpy (4 Mt/a). In order to produce at this rate, Colowyo operates 323⅔ days/year, 3 shifts/day. Twenty shifts/week are scheduled in operations, with the 21st shift being a maintenance shift. The remaining days not worked are 14 days for a vacation shutdown, 10 holidays, and 17⅓ days that comprise the 21st shift.

14.3.3.2 Deposit Description and Geology

GEOLOGIC SETTING.

Formation—The coal measures mined at Colowyo are contained in the Williams Fork Formation, part of the Late Cretaceous Mesa-Verde Group deposited approximately 70 m.y. ago. In the western United States, the Mesa-Verde Group contains several coal-bearing formations. The Williams Fork Formation consists of alternating beds of sandstone, siltstone, shale, and coal, typical of deposits along a linear clastic shoreline. The Williams Fork Formation is approximately 1600 ft (490 m) thick in the vicinity of the Colowyo mine.

Structure—The predominate regional structure is influenced by the White River/Sierra Madre uplift to the east, the Uinta Uplift to the west, and the Sand Wash Basin to the north. Within

1 - Primary coal crusher
2 - 37 yd^3 (28.5 m^3) dragline
3 - 27 yd^3 (20.5 m^3) dragline
4 - 25 yd^3 (19.2 m^3) electric shovel
5 - 28 yd^3 (21.6 m^3) electric shovel
6 - Overburden drill
7 - Equipment parking lot
8 - Explosive storage
9 - In-pit rock crusher
10 - Coal cleaning
11 - Overburden shot-rock inventory
12 - Topsoil removal
13 - Topsoil replacement - final reclamation
14 - Active waste dumps - truck and shovel

Fig. 14.3.3.1. Aerial view of the Colowyo mine looking eastward.

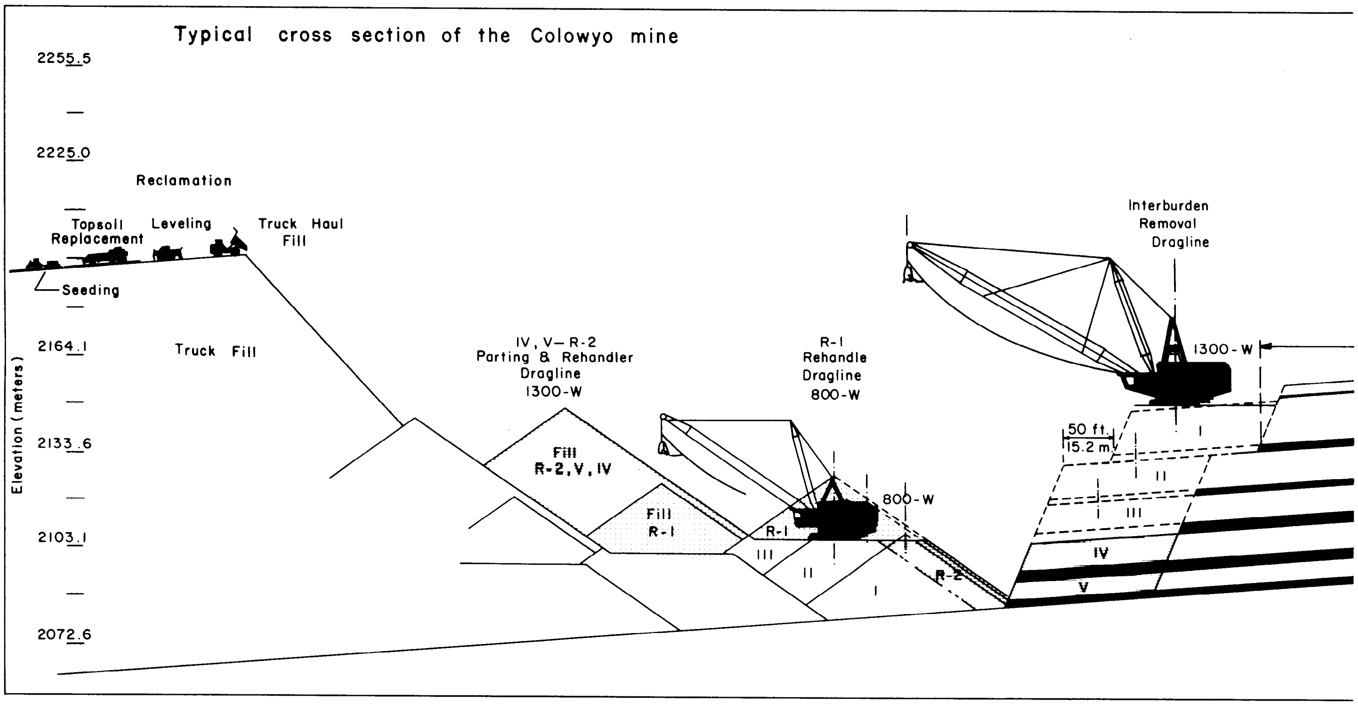

Fig. 14.3.3.2. Typical cross section of Colowyo mine.

the mine area, the geologic attitude of the overburden and coal seams strike at an orientation of N70°W and dip 4 to 6° north. Minor interruptions in the local attitude are seen through the effects of differential compaction linked to changes in interburden material and thickness. Local structural anomalies surrounding the Colowyo leases cause abrupt changes in attitude beyond the Colowyo lease boundaries.

Maximum overburden depth, including the thickness of the coal seams, is about 400 ft (120 m). Near outcrop locations, where the upper coal seams have eroded, the minimum depth of the pit will be about 275 ft (85 m). Interburden depths range from 12 ft (4 m) to 90 ft (30 m).

NUMBER AND THICKNESS OF SEAMS. Colowyo mines coal from eight major seams. In addition to the eight-seam operation, two of the major seams split within the area of the pit, bringing the total number of coal seams currently recovered to ten. Fig. 14.3.3.2 is a typical cross section showing the geometry and distribution of the coal seams mined at Colowyo.

PROPERTIES OF MATERIALS. The coal rank is subbituminous ‘A’ and ‘B’. The coal averages 10,700 Btu/lb (24,888 kJ/kg), 0.2 to 0.4% sulfur, 4 to 6% ash, and 14 to 16% moisture. The overburden and interburden consists of sandstone, siltstone, shale, and claystone.

STRIPPING RATIO. The in-place stripping ratio is 6.5 yd^3/ton (5.5 m^3/t) and will increase to 7.5 yd^3/ton (6.3 m^3/t) due to coal splits and subsequent loss in recovery.

ESTIMATED RESERVES. The recoverable reserves amenable to surface mining include 138 million tons (125 million t). The recoverable underground reserves are estimated at 74 million tons (67 Mt) as of 1989.

14.3.3.3 Mine Development

The eight major seams can be mined by either of two different scenarios: (1) all truck and shovel or (2) a combination of truck and shovel and draglines. The latter system was used in the mine design due to the inherent cost advantage of draglines. The mine is separated into two areas using different types of mining equipment but still integrally tied together. The interburden for the first three coal seams is mined by standard truck and shovel mining methods and has a stripping ratio of approximately 10 yd^3/ton (8.4 m^3/t). The remaining five coal seams are mined with draglines, with a stripping ratio of approximately 4:1. The mining cuts are 150 ft (46 m) wide in both mining areas, and the two mining areas are separated by at least two mining cuts (Fig. 14.3.3.2). This mining configuration of five dragline seams and three truck-and-shovel seams is designed for a nominal 4 million tpy (3.6 Mt/a) of coal production. Increasing or decreasing annual production requires lowering or increasing the vertical height of the dragline highwall and a corresponding addition or reduction in the truck and shovel area. In all production scenarios, the two mining systems must move through the deposit at the same rate. The constant rate keeps the truck haulage cycle distance approximately the same, which, in turn, stabilizes the required haulage truck fleet. In this scenario, the mine is a moving V, which removes approximately three mining cuts per year.

The mine design incorporates an in-pit or stockpile coal reserve of two-months production. The dragline area of the mine has no significant in-pit coal reserves, as sequencing of the mining process does not allow coal to be left behind the draglines without limiting dragline production. The coal must be removed and the next lower bench shot before the dragline can be moved to the next bench. The mining sequence of removing interburden—cleaning, drilling and blasting coal, mining and hauling coal, drilling and blasting overburden for the next bench, and then reconstructing the coal haul road without delaying the dragline—requires careful pit planning and engineering. Two draglines working within a pit less than 1 mile (1.6 km) in length also increases the critical nature of dragline scheduling.

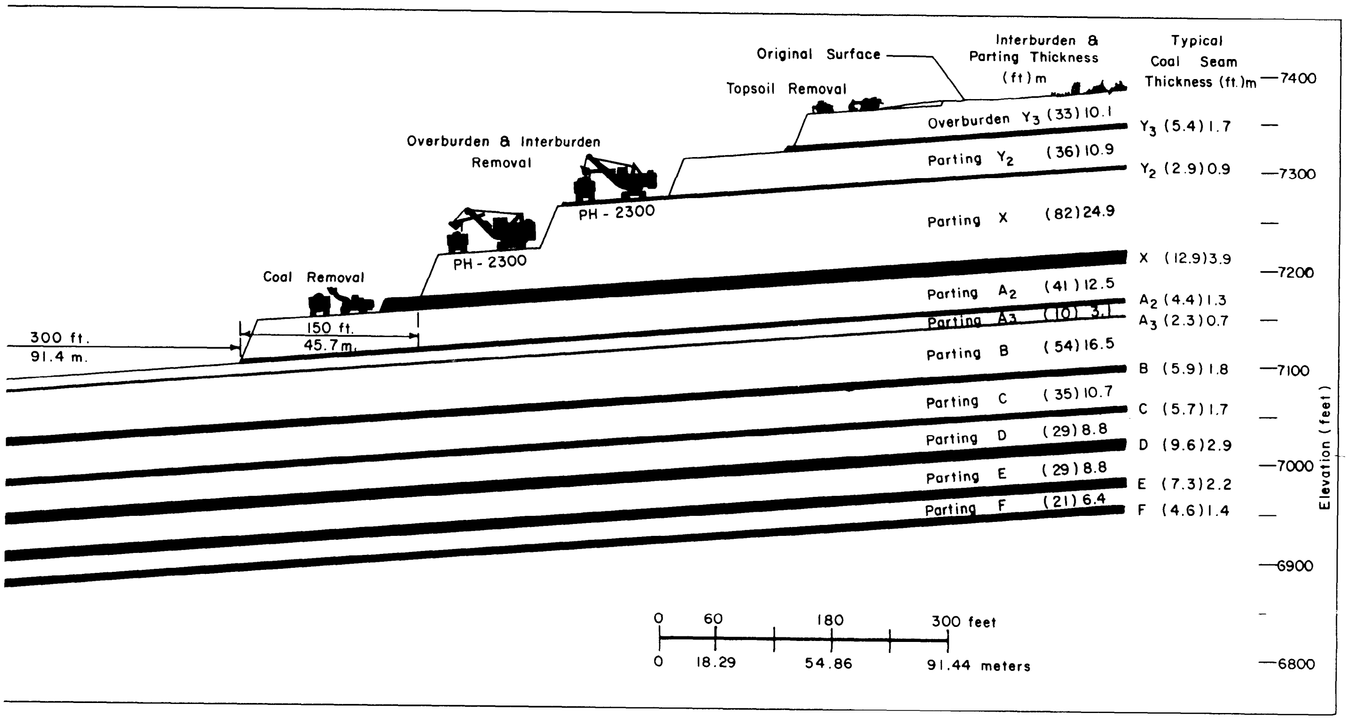

Fig. 14.3.3.2. (cont.)

In-pit reserves are maintained on the 'X' coal seam in the truck and shovel area.

The coal seams dip about 6%. The mature pit is 4600 ft (1400 m) long and 2000 ft (610 m) wide, with highwalls at an average angle of 63.5°. The swell factor for the dragline dump is approximately 25% and only 14 to 15% for the truck-and-shovel dump. The average truck haulage distance is 8400 ft (2560 m).

14.3.3.4 Unit Operations

DRILLING. All overburden is drilled and blasted. Overburden drilling is accomplished with three rotary drills. One electric drill is capable of drilling 10 5/8-in. (270-mm) holes and is used mainly in the truck and shovel area. The other two drills are used in the dragline area of the mine, where maneuvering room is limited and numerous holes are required due to the limited thickness of overburden. The two diesel machines drill 9 7/8-in. (250-mm) holes. All drills use 8 5/8-in. (219-mm) steel, medium formation tricone button bits and are capable of angle-drilling a 15° hole. Scheduling of drills in the dragline area of the mine requires advance planning due to the limited time available to keep the dragline supplied with broken material. Drill availability and utilization is critical for the cast blasting of 'B' level and requires maximum utilization of all drills. The hole size, drill pattern, and average depth of each level is shown on Table 14.3.3.1.

Coal drilling is accomplished with one Schroeder Brothers 4-in. (102-mm), twin-auger drill mounted on a John Deere tractor. The drill averages about 1500 ft (457 m) per shift and is used 5 shifts/week.

BLASTING. Blasting is accomplished daily using either ANFO or heavy ANFO. Heavy ANFO is a mixture of 25% emulsion to ANFO by weight in dry holes, while a 35% emulsion is used in dewatered wet holes. The 25% blended heavy ANFO has a specific gravity of 1.18, while the 35% blended heavy ANFO has a specific gravity of 1.28. Regular ANFO has a specific gravity of 0.85.

The 'Y,' 'X,' 'A,' and 'B' overburden benches have about 50% wet holes; therefore, these areas use the majority of the heavy ANFO. The lower overburden area, 'C,' 'D,' 'E,' and 'F' benches, rarely have wet holes and use the regular ANFO for blasting.

Table 14.3.3.1 lists the drill patterns, powder factors, tie-in and direction, and type of explosives used for each bench. Cast blasting is utilized only on 'B' level. Fig. 14.3.3.3 shows a typical cast blasting pattern.

LOADING. From the original surface to the 'A_3' seam (Fig. 14.3.3.2), overburden and interburden are removed by two 25-yd^3 (19.2-m^3) shovels and one 15-yd^3 (11.5-m^3) shovel. The two 25-yd^3 (19.2-m^3) shovels are scheduled 20 shifts/week. The 15-yd^3 (11.5-m^3) shovel is a spare. The mining cut is 150 ft (45 m) wide, which allows enough working area for double spotting of haulage trucks.

Interburden removal below the 'A_3' seam is accomplished with Bucyrus-Erie walking draglines (one 800W and one 1300W) with capacities of 27 yd^3 (20.8 m^3) and 37 yd^3 (28.5 m^3), respectively. Both units work from either the highwall or spoilpile locations. Beginning with the interburdens over the 'B' seam, the 800W dragline, located on the east end of the pit, mines toward the west; the 1300W (37-yd^3) (28.5-m^3) dragline, located on the west end of the pit, mines toward the east.

After 'B' interburden is removed, the 800W moves down the ramp to remove the 'C' interburden, mining to the east. The 1300W then mines the 'B' ramp and removes the remaining 'C' interburden from west to east.

In the 'D' seam interburden, the 800W moves down the ramp and mines a small portion of the 'D' interburden on the east end of the pit, while the 1300W completes removal of the 'C' interburden. The 1300W then replaces the 800W and com-

Table 14.3.3.1. Drilling and Blasting

Bench or Area	Hole Size in. (mm)	Drill Pattern ft (m)	Average Hole Depth ft (m)	Tie-in and Direction	Explosive	Powder Factor lb/yd^3 (kg/m^3)
'X' and 'Y'[a]	10⅝ (270 mm)	37 × 42 staggered (11.3 × 12.8)	50 (15.2)	30° echelon to outside	Heavy ANFO	0.63 (0.37)
'A'	9⅞ (251 mm)	30 × 35 staggered (9.1 × 10.7)	45 (13.7)	30° echelon to outside	Heavy ANFO	0.63 (0.37)
'B'	10⅝ (271 mm)	variable burden staggered	64 (19.5)	Echelon to outside	Heavy ANFO	1.25 (0.74)
'C' West	9⅞ (251 mm)	18 × 24 staggered (5.5 × 7.3)	15 (4.6)	Rows to outside	ANFO	0.55 (0.33)
'C' East	9⅞ (251 mm)	25 × 30 staggered (7.6 × 9.1)	35 (10.7)	Rows to outside	Heavy ANFO	0.75 (0.44)
'D' West	9⅞ (251 mm)	25 × 30 staggered (7.6 × 9.1)	30 (9.1)	Rows to outside	Heavy ANFO	0.65 (0.39)
'D' East	9⅞ (251 mm)	18 × 24 staggered (5.5 × 7.3)	20 (6.1)	Rows to center	ANFO	0.65 (0.39)
'E'	9⅞ (251 mm)	21 × 26 staggered (6.4 × 7.9)	30 (9.1)	Rows to center	ANFO	0.72 (0.43)
'F'	9⅞ (251 mm)	14 × 20 rectangular (4.3 × 6.1)	10 (3.0)	Rows to center	ANFO	0.50 (0.30)
All coal seams	4 (102 mm)	12 × 12 square (3.7 × 3.7)	6 (1.8)	No delays	Packaged gel	0.14[b] (0.06)[c]

[a] Upper bench has 6 ft (1.8 m) of subdrilling and is drilled to a grade. Lower bench is drilled to coal.
[b] lb/ton of coal.
[c] kg/t of coal.

pletes the removal of the 'D' interburden, moving once more from west to east. At this point, the 800W rehandles a portion of the 'B,' 'C,' and 'D' interburdens, preparing the spoilpile from west to east so the 1300W can remove 'E' and 'F' interburdens. The 1300W digs a coal ramp for 'E' and 'F' coal removal on the west end of the pit and then proceeds west to east again, removing 'E' interburden from the spoil side and casting spoil 180° against the previous cut spoil. Meanwhile, the 800W removes a necessary portion of the previous cut spoil, starting in the center of the pit and proceeds from west to east to make room for the 1300W to spoil 'E' interburden.

Once the 'E' interburden is removed, the 1300W begins on the west end, removing 'F' interburden from the spoil side, advancing from west to east. The dragline exits the pit via a 10% ramp on the east side through the spoilpile and walks to the west end of 'B' level to start its sequence over again. During this period, the 800W pulls 'F' rehandle and incurs some idle time waiting for the east 'B' bench to be blasted. Table 14.3.3.2 shows the major equipment and corresponding productivity.

A 22-yd^3 (16.9-m^3) front-end loader (FEL) is used to load coal and to remove the overburden when dressing a coal face. This overburden comes from blasting the material directly over coal. Smaller 4- to 7.5yd^3 (3.1- to 5.8-m^3) FELs are used to load topsoil and clean the top of the coal.

HAULAGE.

Overburden—Two 25-yd^3 (19.2-m^3) class electric shovels are scheduled to remove overburden. One shovel is assigned to each side of the pit and each works to a point that is equal distance between the working face and the centroid of the truck dump. Each shovel is scheduled with six haulage trucks. The haulage profile is balanced by working one shovel on the higher benches on a long haul and the other on the lower benches with a short haul. The haulage truck fleet consists of fourteen 170-ton (154.2-t) trucks, three 120-ton (109-t) rock trucks, and four 120-ton (109-t) end-dump coal trucks.

The haulage roads for overburden have a maximum 8% grade with a preferred grade of 6%. Coal hauls from the dragline area have a maximum grade of 10%, with a preferred grade of 8%. The coal haul ramp is located on the west end of the pit.

Coal—Coal is mined with a 22-yd^3 (16.9-m^3) FEL. From the pit, coal moves in 120-ton (108.8-t) end-dump trucks to a primary crusher on the pit rim. The primary crusher is a feeder breaker that reduces pit-run coal to a 6 × 0-in. (152 × 0-mm) product. The coal is then stored in a 150-ton (136-t) surge bin. Fifty-ton (45-t) bottom-dump coal haulers are loaded from the surge bin and haul the coal 3.7 miles (5.92 km) to the rail loadout facility. These coal haulers are heavy-duty, on-highway trucks that travel loaded down a 7.5% grade to the secondary crusher at the rail loadout. The trucks' primary braking system is an electric magnetic retarder that is located in two of the three rear axles on the trailer. The trucks also have a normal braking system, and the tractors are equipped with Allison transmissions for more retarding power.

Topsoil—An average of 18 in. (457 mm) of topsoil over 50 acres (0.2 km^2) is removed each year in front of the advancing mine faces. The topsoil is dozed into piles and loaded into three 50-ton (45-t) haulage trucks by a 7.5-yd^3 (5.8-m^3) loader. The topsoil is then placed on the dump surface that has been prepared for reclamation. During the time this fleet is not moving topsoil, it is used to build haulage roads and to haul mine-made crushed rock for road surfacing.

RECLAMATION. During the years of exploration, and prior to active surface mining, Colowyo conducted extensive baseline environmental studies. In addition, a 3-acre (12,141-m^2) area was disturbed to simulate mining, and many reclamation studies (including runoff plots, shrub establishment, mulching, and planned species trials) were conducted for use in developing the Colowyo reclamation plan.

When the Colowyo mine was permitted by the State of Colorado under the permanent program of the Surface Mining Control and Reclamation Act, Colowyo submitted a complete application through the year 2017 and thereby obtained a life-of-mine approval. By obtaining a life-of-mine approval, Colowyo has the

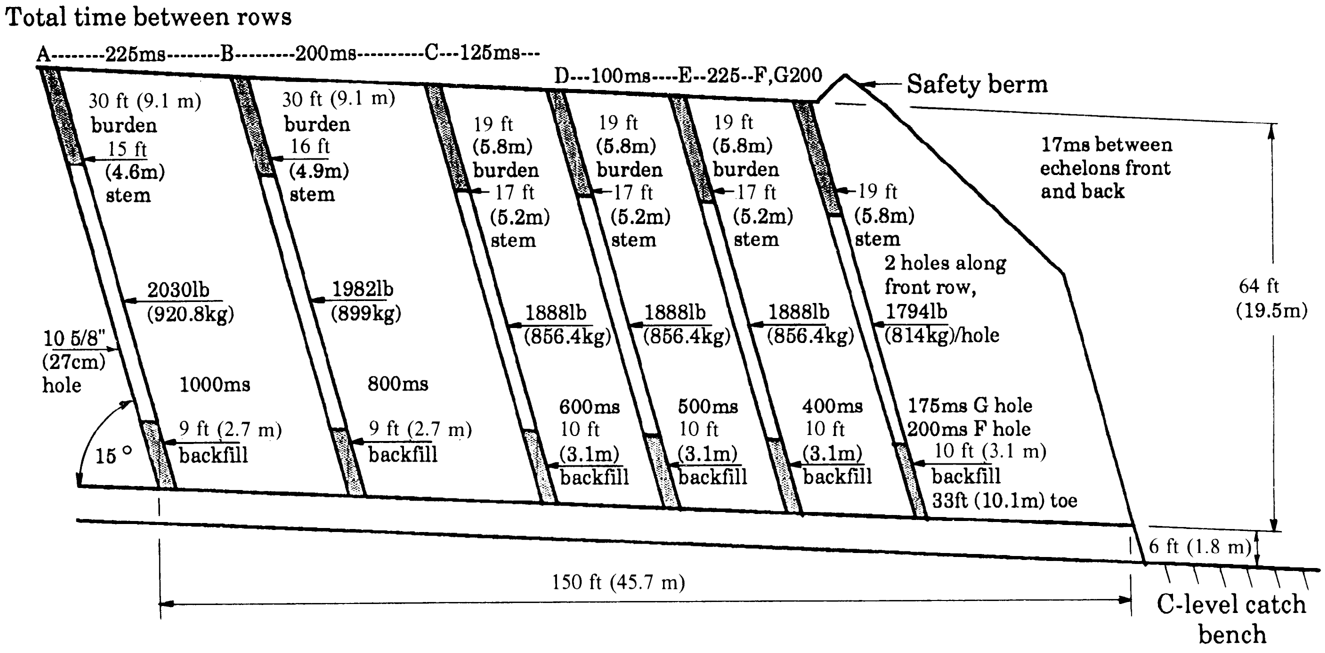

Fig. 14.3.3.3. Typical B-level cast blast pattern.

Table 14.3.3.2. Major Equipment

Equipment	No. Units	Capacity yd^3/hr (m^3/h)	Capacity tons/hr (t/h)	Annual Volume yd^3/yr × 10^6 (m^3/yr × 10^6)	Annual Volume tons/yr × 10^6 (t/yr × 10^6)
37 yd^3(28.3 m^3) dragline 285 ft (87 m) boom	1	1700 1292		9.33 7.09	
27 yd^3 (20.6 m^3) dragline 195 ft (59 m) boom	1	1070 813		4.47 3.40	
25 yd^3 (19.1 m^3) shovel	2	1400 1064		15.01 11.41	
15 yd^3 (11.5 m^3) shovel	1	900 604		1.87 1.42	
22 yd^3 (16.8 m^3) loader	2	615 467	660 599	0.72 0.55	4.10 3.72
170 ton (154 t) rock truck	14	300 228		15.37 11.68	
120 ton (109 t) rock truck	3	200 146		2.33 1.77	
120 ton (109 t) coal truck	4		255 231		4.10 3.72
50 ton (45 t) coal truck	6		125 113		4.10 3.72

“right of successive renewal” for each five-year permit term through 2017.

Reclamation activities are conducted in accordance with the approved reclamation plan which includes a “reclamation topography map” representing the approximate original contour. By survey control, overburden is dumped by trucks into the final configuration of the reclamation topography map and graded to final configuration by dozers. Where practical, the uppermost weathered overburden is placed on the surface to provide the most acceptable rooting material to enhance revegetation.

After final grading of the overburden is completed, topsoil is end-dumped with 50-ton (46-t) and 120-ton (109-t) trucks. Since the mine is in a mature configuration, the regraded area is prepared prior to topsoil removal for the next year, thereby allowing the topsoil to be hauled directly from the mining advance. The replaced topsoil is spread to a depth of 12 to 18 in. (305 to 457 mm) by dozers. Since the initial 6 in. (152 mm) of

Table 14.3.3.3. Coal Quality History

Year	Btu/lb	kJ/kg	Heat contents Ash (%)
1980	10,555	24,551	6.50
1981	10,585	24,621	6.02
1982	10,666	24,809	5.54
1983	10,714	24,921	5.38
1984	10,737	24,974	5.07
1985	10,722	24,974	4.91
1986	10,737	24,974	4.63
1987	10,713	24,918	4.73
1988	10,704	24,898	4.96

topsoil are an important source of native plant materials, that material is segregated and spread on top when practical.

The regraded topsoil is then checked for the required depth and sampled for plant nutrients. If necessary, appropriate amounts of nitrate-phosphate fertilizer are applied to the surface. After fertilizer is applied, all areas are tilled with a chisel plow to a depth of approximately 8 to 12 in. (203 to 305 mm) to reduce compaction.

A substantial amount of the Colowyo reclaimed area consists of 3:1 slopes. Newly reclaimed slopes require special attention to control erosion. Colowyo's D7 dozer has been equipped to pull farm implements, which allows the 3:1 slopes to be worked on the contour to increase erosion control. After the area has been chisel plowed, it is seeded by a rangeland drill using the approved seed mixture with approximately 30 different species of plants.

While seeding, contour furrows approximately 8 in. (203 mm) deep and 14 in. (356 mm) wide are cut into the topsoil by plowshares attached to the two outside ripper shanks on the D7 dozer. The use of contour furrows and the chisel plow are the primary reasons that Colowyo has been able to successfully control erosion on 3:1 slopes.

In addition, for every 100 ft (30 m) in elevation, a 2% ditch approximately 8 ft (2.4 m) wide and 2 ft (0.6 m) deep is constructed to carry any runoff that accumulates in the permanent drainages. The remaining reclaimed areas on flatter slopes are prepared in a similar manner by utilizing a farm tractor to pull the chisel plow, a rear blade for contour furrows, and the rangeland drill.

Most of the 3:1 slopes are outslopes of a 54,000,000-yd^3 (41,300,000-m^3) excess-spoil valley fill. The fill is a critical element of the Colowyo mine, and was constructed as an experimental practice. Existing regulations required, among other things, 4-ft (1.2-m) lifts. Colowyo's fill has been constructed in lifts that vary from 75 to 200 ft (23 to 61 m). The primary regulatory concerns have been over stability, and after 10 years of monitoring, no significant movement has been detected.

To meet permit requirements, approximately 15% of the reclaimed area on 10% or flatter slopes is revegetated to forbs and shrubs only. Shrubs are established from seed, seedlings, and by transplanting mature shrub clumps taken from the pit advance areas prior to topsoil stripping.

Reclaimed areas are monitored the first year after seeding and every three years thereafter to determine the reclamation success during the ten-year reclamation liability period.

14.3.3.5 Product Control

Quality of the Colowyo coal has been optimized since the mine achieved a mature pit configuration. Table 14.3.3.3 illustrates this in terms of the "as shipped" Btu/lb (kJ/kg) and ash percentage. Sulfur has been maintained at a relatively constant 0.35% during this period.

Quality is evaluated through application of the principles of statistical process control. The Quality Control Department is responsible for inspection, sampling, testing, statistical evaluation, and customer feedback.

INSPECTION. Prior to drilling and blasting, the coal is cleaned by a FEL or rubber-tired dozer. This progress of cleaning is monitored and reported by the Quality Control Department. As the coal is mined, periodic inspection is conducted to observe the extent of product dilution. Also the coal is inspected at other stages of transport and stockpiling. Observations of any inferior product are reported to the coal foremen.

SAMPLING. Sampling is done before mining, during production, and upon loading of rail cars. Pre-production sampling involves the collection of drill cuttings or channel samples just prior to mining of the coal. Production samples are taken from truck tops after loading at the primary crusher for transport to the rail loadout. As rail cars are loaded, a three-stage mechanical system collects the shipment samples. A backup system is in place for car-top sampling in the event of mechanical system failure. These systems are continuously monitored for performance through statistical testing.

TESTING. The Quality Control Laboratory performs short proximate analyses, ash fusibility, Hardgrove grindability, ash elemental analysis, and other tests as needed. A mine-site lab is maintained in order to furnish timely results.

STATISTICAL EVALUATION. Production and preproduction sample data are used to define production goals. Data from each dragline and each shovel mining cut are used to predict the potential qualities for subsequent mining cuts. Causes for deviations are normally easy to track and correct; monthly production averages then are normally close to quality goals.

Control of shipment quality is based on past performance. The Quality Control Department constructs control charts to define the expected limits of variability for each customer. Two standard deviations are used for warning limits and three for rejection limits. When a shipment is in the warning region, a search for assignable cause is made. If a shipment is in the rejection area, corrective action is taken immediately by management, and the customer is informed.

CUSTOMER FEEDBACK. Customers are willing to share with Colowyo their changing needs, especially with respect to quality parameters. The most common request from the customer is for product consistency. Consistency is primarily achieved through blending.

BLENDING. A blended product with consistent qualities is achieved by tracking certain quality parameters and recommending mining, stockpiling, and coal removal in a sequence that is compatible with the mining and customer shipment schedules. The main variations in properties are a function of coal age (depth). In-pit coal reserves are not maintained in the dragline area of the mine; therefore, the five lower coal seams are always being mined. The upper three coal seams in the truck and shovel area of the mine are naturally blended into the coal flow on an "as needed" basis. Natural blending through mining meets most requirements. The use of one- or two-layered stockpiles allows this process to be fine tuned. Table 14.3.3.4 illustrates the impact of increased blending on reducing the standard deviation (sigma) in "as received" Btu/lb (kJ/kg) for one of Colowyo's customers.

14.3.3.6 Ancillary Facilities

MAINTENANCE FACILITIES. Maintenance facilities are located at the rim of the pit. The maintenance department is

Table 14.3.3.4. Blending Deviation

Year	Standard Deviation (Btu/lb)	Standard Deviation (kJ/kg)
1984	149	347
1985	133	309
1986	110	256
1987	109	253
1988	95	221

Table 14.3.3.5. Manpower

Operations	No.
Drill operator/helper	13
Powdermen	8
Dragline operator/oiler	16
Shovel operator/oiler	16
170-ton (154-t) Haulage/truck driver	66
150-ton (136-t) On-highway Coal haulage/truck driver	22
Water/truck driver	4
Equipment operator	34
Primary crusher operator	4
Train loadout operator/helper	9
Utilityman	5
Subtotal	197
Maintenance	**No.**
Mechanics	69
Electricians	20
Welders	17
Servicemen	4
Tireman	2
Steamcleaner	2
Utilityman	2
Subtotal	116
Staff and Administrative	**No.**
Administration	9
Engineering	21
Human relations	12
Finance & accounting	29
Maintenance & operation	36
Subtotal	107
TOTAL	420

divided into three areas: (1) mobile equipment, (2) field equipment, and (3) electrical. The truck shop has eight truck bays, a tire shop, and a machine shop. Near the shop is a wash building for haulage trucks and pickups. In addition, Colowyo has a welding shop, light vehicle repair bays, electrical shop, and a dozer repair bay. The warehouse, along with its outside storage area, is attached to the truck shop. The total enclosed maintenance area is approximately 67,800 ft^2 (6300 m^2).

The 21st shift is a maintenance shift and is scheduled normally on Friday during the day. One dragline is scheduled for a 16-hour preventive maintenance every other week. On the off-week, it receives electrical maintenance for eight hours. Shovels and drills are scheduled for 16 hours of preventive maintenance every two weeks. Haulage trucks receive an assembly-line, six-hour preventive maintenance check every 150 operating hours. Every 150 hours, the maintenance cycle is increased in depth and type of maintenance accomplished.

At the annual 4.1-million ton (3.7-Mt) coal production rate, the maintenance department is staffed with 116 employees. The operating department has 197 employees. Table 14.3.3.5 shows a breakdown of each department by classification, along with staff and administration.

Rail Loadout. Colowyo ships its coal by rail on the Denver & Rio Grande Western Railroad. The primary product is 1.5 × 0-in. (38 × 0-mm) crushed coal for the thermal market. The 50-ton (45.4-t) bottom-dump coal trucks deliver 6 × 0-in. (152 × 0-mm) coal to the secondary crusher located at the rail loadout. The crusher is a ring hammer mill that reduces the coal to the primary product size.

The rail loadout utilizes an open storage concept. The facility consists of a 125-ft (38-m) high stacking tube capable of stockpiling 120,000 tons (108,840 t) of coal, of which 17,000 tons (15,419 t) is live storage for direct loading into unit trains. Unit trains move through a tunnel under the stockpile and are loaded at an average rate of 5000 tph (4535 t/h), using one or two 5-ft (1.5-m) square chutes. The facility is equipped with a unit train sampling and rail weighing "in-motion" system. Stoker coal is loaded into railroad cars by a FEL on a side track and shipped weekly.

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14.3.4 MONOLITHIC OVERBURDEN, INCLINED COAL SEAMS: TRAPPER MINE

Gary M. Stubblefield and Roger W. Fish

14.3.4.1 Mine Description

The Trapper mine (Fig. 14.3.4.1), operated by Trapper Mining Inc., is located 6 miles (9.7 km) south of Craig in the northwest corner of Colorado. With an annual coal production of 2.1 million tons (1.9 Mt) delivered from a property encompassing 9600 acres (39 km^2), Trapper ranks as the third largest producing coal mine in the state (1991). Three electric draglines strip waste material from five dipping coal seams. These units work three 8-hour shifts/day, 5 days/week, except during periods when the strip ratio is greater than 10:1 yd^3/ton (8.4:1 m^3/t). In addition, stripping can occur 6 or 7 days/week when box-cutting is necessary. Coal extraction activities are performed 2 shifts/day, 5 days/week.

14.3.4.2 Deposit Description and Geology

Trapper is situated at the southern edge of the Green River Coal Field in a geologic setting of gently rolling, east-west-striking anticlines and synclines. The mine is on the southern flank of the Big Bottom Syncline where the coal dips at a fairly consist-

Fig. 14.3.4.1. Aerial view of Trapper mine looking southward.

Table 14.3.4.1. Average Seam Thickness and Run-Of-Mine Coal Quality

Pit/Seam	Thickness ft (m)	Heat Content Btu/lb (kJ/kg)	Sulfur (%)	Ash (%)	Moisture (%)
Ashmore:					
H Seam	5.4 (1.6)	9,900 (23,030)	0.47	5.1	18.4
I Seam	7.8 (2.4)	10,150 (23,610)	0.39	4.2	17.1
Colt:					
L Seam	5.4 (1.6)	9,650 (23,030)	0.64	10.0	17.1
Q Seam	7.0 (2.1)	10,100 (23,490)	0.32	7.1	17.9
Derringer:					
L Seam	3.3 (1.0)	10,150 (23,610)	0.37	6.0	17.3
Q Seam	11.6 (3.5)	9,850 (22,910)	0.33	7.2	18.2
R Seam	4.1 (1.2)	10,050 (23,380)	0.45	5.8	18.4
1986 Avg	—	9,900 (23,030)	0.39	7.5	16.6
1987 Avg	—	10,000 (23,260)	0.39	7.7	17.1

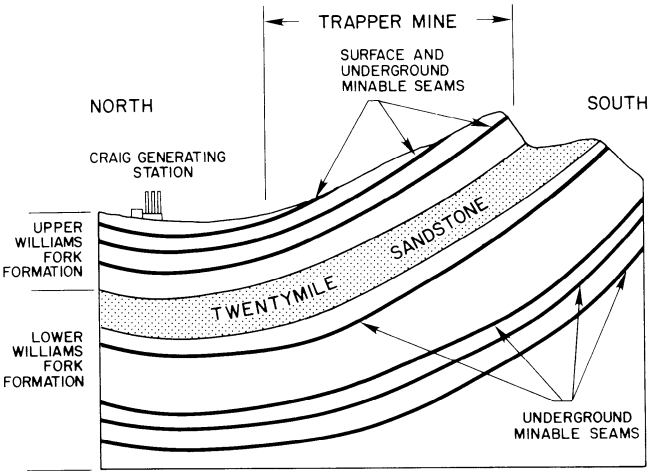

Fig. 14.3.4.2. Typical Trapper mine cross section.

ent 16% to the north, about 2% steeper than the surface of the land. There are few faults on the property. Overburden ranges from 0 to 140 ft (0 to 43 m) at the economic stripping limit. Fig. 14.3.4.2 presents a typical cross section of the mining area.

Seven major surface-minable coal seams exist within the permit boundary, with five of these seams mined from three active pits. Coal at Trapper is ranked as high-volatile subbituminous and is dedicated to steam coal application. Currently, delivered coal averages 9900 Btu/lb (23,028 kJ/kg), 0.4% sulfur, 7.5% ash, 44% fixed carbon, and 17% moisture, with a coal recovery of roughly 90%. Table 14.3.4.1 exhibits the average thickness and run-of-mine quality of the seams mined at Trapper.

Waste material (overburden and interburden) consists primarily of interbedded shale, siltstone, and sandstone layers. The waste is generally soft with an average in-place density of 3400 lb/yd^3 (2017 kg/m^3). Trapper's minable strip ratio (1991) averages 9:1 yd^3/ton (7.6:1 m^3/t).

An estimated total of 67 million tons (61 Mt) recoverable, strippable reserves remain within the permitted boundary at a minable strip ratio of 8.5:1 yd^3/ton or 7.2:1 (m^3/t). Coal recovery is expected to average 89% overall. Of the 9600 surface acres (39 km^3) of reserves controlled by Trapper, 51% is leased from the State of Colorado, 44% from the federal government, and the remaining 5% from Moffat County or private individuals. Underground reserves controlled by Trapper above the Twentymile Sandstone (Fig. 14.3.4.2) total an estimated 270 million minable tons (245 Mt) or 130 million recoverable tons (117 Mt) from five deep coal seams. An additional 300 million minable tons (272 Mt) exist below the Twentymile Sandstone.

14.3.4.3 Mine Development

TOPSOIL REMOVAL. Trapper's mining sequence begins with topsoil removal operations during the summer months of June through October. Caterpillar (Cat) D9 dozers first windrow surface vegetation onto an adjacent area where the topsoil has previously been removed. Six to eight Cat 627E scrapers are then used to remove an average of 17 in. (432 mm) of topsoil (range is 6 to 24 in., or 152 to 610 mm) from an area large enough to allow mining to continue until the following summer. After the topsoil is loaded, it is either hauled directly to previously mined and recontoured areas or stockpiled for later deposition. Topsoil is transported directly to regraded areas approximately 40% of the time by way of either across-pit ramps or haulage routes around the end of the pits.

Topsoiling productivities are 150 and 200 yd^3/hr (115 and 153 m^3/h) for direct respread and stockpiling, respectively. Over 600,000 yd^3 (459,000 m^3) are handled each year.

LAYOUT AND ACCESS TO PITS. Trapper presently has four active pits: Ashmore, Browning, Colt, and Derringer. Each extracts two major coal seams. As the Colt pit progresses to the west, it will be mined in conjunction with the Browning pit. A recently idled pit, Enfield, was a single-seam operation that