EVALUATION OF FUGITIVE DUST EMISSIONS FROM MINING

TASK 1 REPORT

IDENTIFICATION OF FUGITIVE DUST SOURCES ASSOCIATED WITH MINING

PEDCo ENVIRONMENTAL

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1. INTRODUCTION

This evaluation of fugitive dust air pollution from mining operations was undertaken to identify and compile currently available information on emission sources, regulatory approaches, control techniques, and research programs related to mining activities. An analysis of the assembled information will then be used as the basis for recommending near-term research and development programs which might be implemented by IERL/Cincinnati to fill gaps in the data base and further document effective control techniques for fugitive dust from mining operations. For the more promising recommended R & D efforts, proposed technical approaches will also be developed.

The project is composed of three tasks, each of which will have its own task report:

Task 1 - Identification of fugitive dust sources associated with mining activities.

Task 2 - Assessment of current status of the environmental aspects of fugitive dust.

Task 3 - Recommendation of promising research areas.

The project is similar in scope to a study recently completed by Monsanto Research Corporation.[1] However, the intent of the present contract is to provide recommendations for specific research programs while the Monsanto Research study was designed to compile preliminary data on fugitive dust emissions from open sources and to recommend other sources for testing. Therefore, only the first of the three tasks overlaps to any extent with this previous work; their work has been utilized in preparing the Task 1 report.

The present Task 1 report summarizes current knowledge concerning fugitive dust sources at mines and ranks the identified sources in order of relative importance from the standpoints of air quality impact and need for further research. Data for the report were obtained from a literature search and from PEDCo's files on fugitive dust sources. The literature search was not intended to be exhaustive, but to be thorough enough to uncover all studies in which fugitive dust emissions from mining operations were quantified by a reasonably accurate procedure. In this task, primary importance was attached to the identification of all mining activities that are major dust sources and the estimation of representative emission rates from these various sources.

The scope of the project includes both surface and underground mining plus related operations normally performed at the mine sites, such as crushing and storage. It does not include dust that is generated and remains underground or in an enclosed area--only emissions that affect ambient air quality. Also, it does not include emissions which occur off-site during shipping or at distant processing plants. Almost all particulate emissions at mines would be categorized as fugitive dust since they are generally emitted at ground level as a result of equipment activity or material transfer rather than from stacks.

This report is divided into three chapters following the Introduction. Chapter 2 describes four major mining industries (coal, copper ore, rock quarrying, and phosphate rock) and the sizes and geographic distribution of their mines. Chapter 3 describes 11 different mining operations which are responsible for significant fugitive dust emissions in one or more of the major mining industries, and presents estimates of emissions from each of these operations. The final chapter summarizes those operations which have the greatest air quality impacts and those for which additional emission data are most needed.

2. MAJOR MINING INDUSTRIES

The four mining industries which are probably the largest sources of fugitive dust nationally are coal, copper, crushed stone, and phosphate rock mining. These industries are each described briefly in this chapter to provide a basis for evaluating the extent and impacts of fugitive dust air pollution from mining operations.

All four of these materials are mined primarily in surface mines, which have far more potential for fugitive dust emissions than underground mines. In addition, the tonnages removed from these mines are generally greater than for other minerals and ores. Some other materials which were also considered because of their large tonnages and surface operations are iron, oil shale, and sand and gravel. Iron ore mining was eliminated because ferrous metals are not within the purview of the Resource Extraction and Handling Division of the Cincinnati Industrial Environmental Research Laboratory, EPA, the sponsoring group for this work. Oil shale was not included because there are presently no large-scale oil shale surface mines in operation. Sand and gravel mining was not included because much of this material is mined and processed wet and is therefore non-dusting.

Mines other than the four types used as examples here can certainly be major fugitive dust sources. They have the same unit operations and points of dust release, so their emissions can be estimated by comparison with any one of the four mining industries for which data have been assembled.

2.1 COAL MINING

There were 603.4 million tons of bituminous coal and lignite mined in the U.S. in 1974 in a total of 5,247 mines. Of these mines, 3,208 were surface mines and 2,039 were underground. Production from surface mines surpassed underground mines in 1974 for the first time, accounting for 54 percent of the total.[2]

The 50 largest coal mines and their 1973 and 1974 production rates are listed in Table 2.1. These mines, 34 surface mines and 16 underground, produced 24.6 percent of the coal mined in 1974. Their locations are shown in Figure 2.1. They are concentrated in the coal mining areas of Appalachia, the Central states, the Northern Great Plains, and the Four Corners area. All of the Western mines shown, plus those in Indiana, Ohio, and most of those in Kentucky are surface mines.

Although total coal production has been relatively stable for several years, there has been a definite shift from the East and from underground mines to the strip mines of low sulfur coal in the West. This trend is expected to accelerate in the future with the opening of giant new mines in Powder River Basin, northwestern Colorado, the Four Corners area, and the lignite fields of North Dakota and eastern Montana. Many of these mines will be used to supply coal gasification plants and mine-mouth power plants.

The most unique aspect of surface coal mining is the huge amount of earth moving associated with it. The overburden removal operations to get to the coal seams dwarf previous major earth moving projects such as canals and dams. A new generation of larger earth moving equipment was developed to handle this task.

Trucks are used at almost all surface mines to transport the coal from the mine to the processing area or loading ramp. For shipment to consumers, railroads are the most

Table 2.1 LARGEST U.S. COAL MINES

Company	Mine	State	Est. production, 10^3 ton/yr 1974	1973
Utah International	Navajo[s]	NM	6955	7389
Decker	Decker No. 1[s]	MT	6786	4159
Peabody	River King[s]	IL	6474	6526
Peabody	River Queen[s,u]	KY	4703	4172
Southwestern Illinois	Captain[s]	IL	4347	4451
Peabody	No. 10[u]	IL	4132	4147
C&K	Fox[s]	PA	4000	2620
Peabody	Black Mesa[s]	AZ	3933	3247
Washington Irrigation Dist.	Centralia[s]	WA	3890	3229
Clinchfield Div., Pittston	Moss No. 3[u]	VA	3679	3903
Peabody	Sinclair[s]	KY	3529	5291
Central Ohio	Muskingum[s]	OH	3367	3668
Amax	Belle Ayr[s]	WY	3313	898
Consolidation, Central Division	Egypt Valley[s]	OH	3253	4257
Peabody	Lynnville[s]	IN	3232	4065
Western Energy	Colstrip[s]	MT	3213	4254
Arch Minerals	Seminoe No. 1[s]	WY	3142	2865
Amax	Leahy[s]	IL	2834	2942
Peabody	Universal[s]	IN	2833	3044
U.S.Steel	Robena	PA	2815	2871
Peabody	Ken[s,u]	KY	2793	3202
Pacific Power & Light	Dave Johnston[s]	WY	2687	2897
Amax	Ayrgem[s]	KY	2685	3206
Arch Minerals	Seminoe No. 2[s]	WY	2590	1498
Peabody	Camp No. 1[u]	KY	2528	2620
Peabody	Kayenta[s]	AZ	2515	-
Monterey	No. 1	IL	2480	2695
Inland Steel	Inland	IL	2469	2588
Kemmerer	Sorensen[s]	WY	2437	2546
Amax	Ayrshire[s]	IN	2404	250
Consolidation, Mountaineer Div.	Robinson Run[u]	WV	2380	2401
Old Ben	Old Ben No. 1[s]	IN	2345	2396
Peabody	Big Sky[s]	MT	2229	1972
Peabody	Homestead[s]	KY	2194	2449
Island Creek	Pevler No. 1[s,u]	KY	2189	1733
Consolidation, Christopher Div.	Humphrey No. 7[u]	WV	2155	2692
Consolidation, Mountaineer Div.	Loveridge[u]	WV	1985	2185
Rosebud	Rosebud[s]	WY	1963	1510
Old Ben	No. 24[u]	IL	1960	2377
Freeman	Orient No. 3[u]	IL	1919	2207
Consolidation, Ohio Valley Div.	Ireland[u]	WV	1860	2343
Peabody	Vogue[s]	KY	1814	2412
Mathies	Mathies[u]	PA	1809	2036
Peabody	Star[u]	KY	1808	1999
Amax	Wright[s]	IN	1790	2097
Amax	Minnehaha[s]	IN	1790	2012
Mountain Drive	Mountain Drive[s]	KY	1765	1663
Old Ben	No. 26[u]	IL	1739	2100
Peabody	Baldwin[u]	IL	1727	1291
Knife River	Beulah[s]	ND	1722	1726

[s] strip mines
[u] underground mines

Source: Bituminous Coal Data, 1974 Edition, National Coal Association, Washington, D.C., 1975.

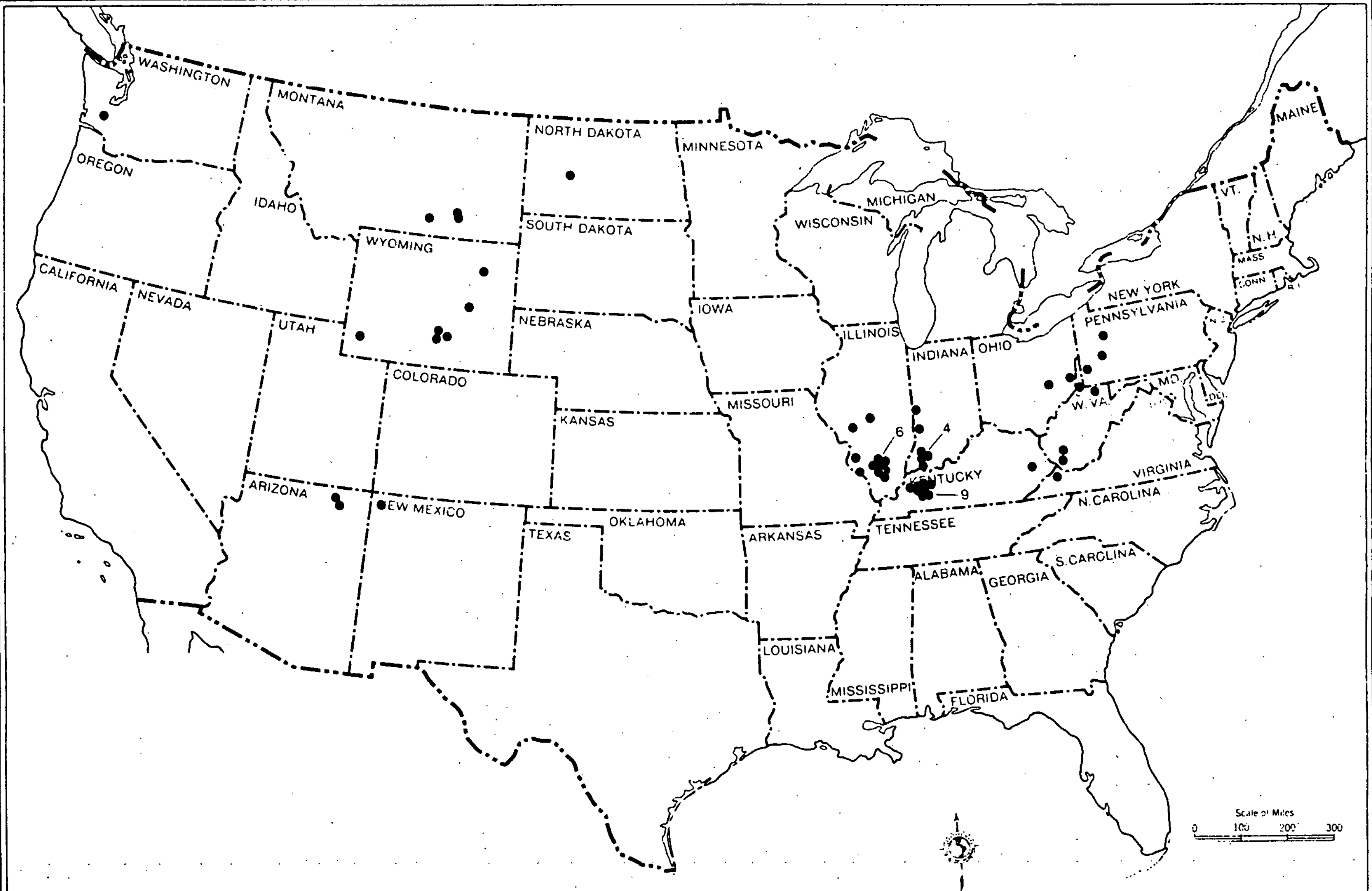

Figure 2.1. Locations of largest U.S. coal mines.

common means with 66 percent of the tonnage in 1974. Almost 40 percent of this amount was in unit trains. The remainder of coal shipment is evenly divided among barges, trucks, and mine-mouth operations (with 11 percent each). All other modes of transportation account for less than one percent.[2]

2.2 COPPER MINING

Domestic mine production of recoverable copper in 1975 was 1.41 million tons, down sharply from the 1.60 million tons in 1974 and 1.72 million tons in 1973 as a result of decreased demand for copper products. The principal copper-producing states were Arizona, with 56.6 percent of the total, Utah (12.7%), New Mexico (10.4%), Montana (7.2%), Nevada (5.6%), and Michigan (5.2%).[3] The largest 25 copper mines, which provided 89 percent of the total production in 1973, are listed in Table 2.2. Their locations are shown in Figure 2.2.

Open pit mines accounted for 83 percent of mine output and underground mines for 17 percent. The production of copper from leach pads and in-place leaching (mainly recovered by precipitation with iron) was 160,000 tons in 1973, or 9 percent of the output from the mines.[3]

As indicated from the above data, copper mining is characterized by very large mines of relatively low grade ore rather than many small mines in rich veins. The average yield nationally of copper in copper ore was only 0.53 percent. This low grade ore necessitates the handling of large quantitites of material in the mining and processing steps. Also, wide variations in copper content within the ore body may require the mining and handling of additional amounts of waste material that is too low in copper content to justify recovery.

Table 2.2 LARGEST U.S. COPPER MINES, 1973

Company/Mine	Estimated production, tons	State	County
Kennecott Copper Utah Copper	255,000	Utah	Salt Lake
Magma Copper San Manuel	158,300[a]	Arizona	Pinal
Phelps Dodge Morenci	119,500	Arizona	Cochise
Anaconda Berkeley Pit	127,800[a]	Montana	Silver Bow
Phelps Dodge Tyrone	104,000	New Mexico	Grant
Kennecott Copper Ray Pit	98,900	Arizona	Pinal
Cyprus Mines Pima	88,100	Arizona	Pima
White Pine Copper White Pine	76,600	Michigan	Ontonagon
Duval Sierrita Sierrita	NA	Arizona	Pima
Kennecott Copper Chino	67,800	New Mexico	Grant
Anamax Mining Twin Buttes	73,600	Arizona	Pima
Phelps Dodge New Cornelia	53,800	Arizona	Pima
Inspiration Copper Inspiration	43,100	Arizona	Gila
Asarco Mission	46,600	Arizona	Pima
Kennecott Copper Ruth	50,000	Nevada	White Pine
Anaconda Yerington	35,800	Nevada	Lyon
Asarco Silver Bell	23,800	Arizona	Pima
Anaconda Butte Hill	NA	Montana	Silver Bow
Cities Service Copper Cities	NA	Arizona	Gila
Duval Mineral Park	NA	Arizona	Mohave
Magma Copper Magma	NA	Arizona	Pinal
Phelps Dodge Copper Queen	NA	Arizona	Cochise
UV Industries Continental	NA	New Mexico	Grant
Bagdad Copper Bagdad	NA	Arizona	Yavapai
Duval Esperanza	NA	Arizona	Pima

[a] This figure includes underground as well as open pit production.

NA = not available

Source: Preprint from the 1973 Bureau of Mines Minerals Yearbook, Copper, U.S. Department of the Interior, Bureau of Mines, Washington, D.C., 1973, pp 2-5.

Source: Fugitive Dust from Mining Operations, Monsanto Research Corporation, Dayton, Ohio, prepared for U.S. Environmental Protection Agency, 1975.

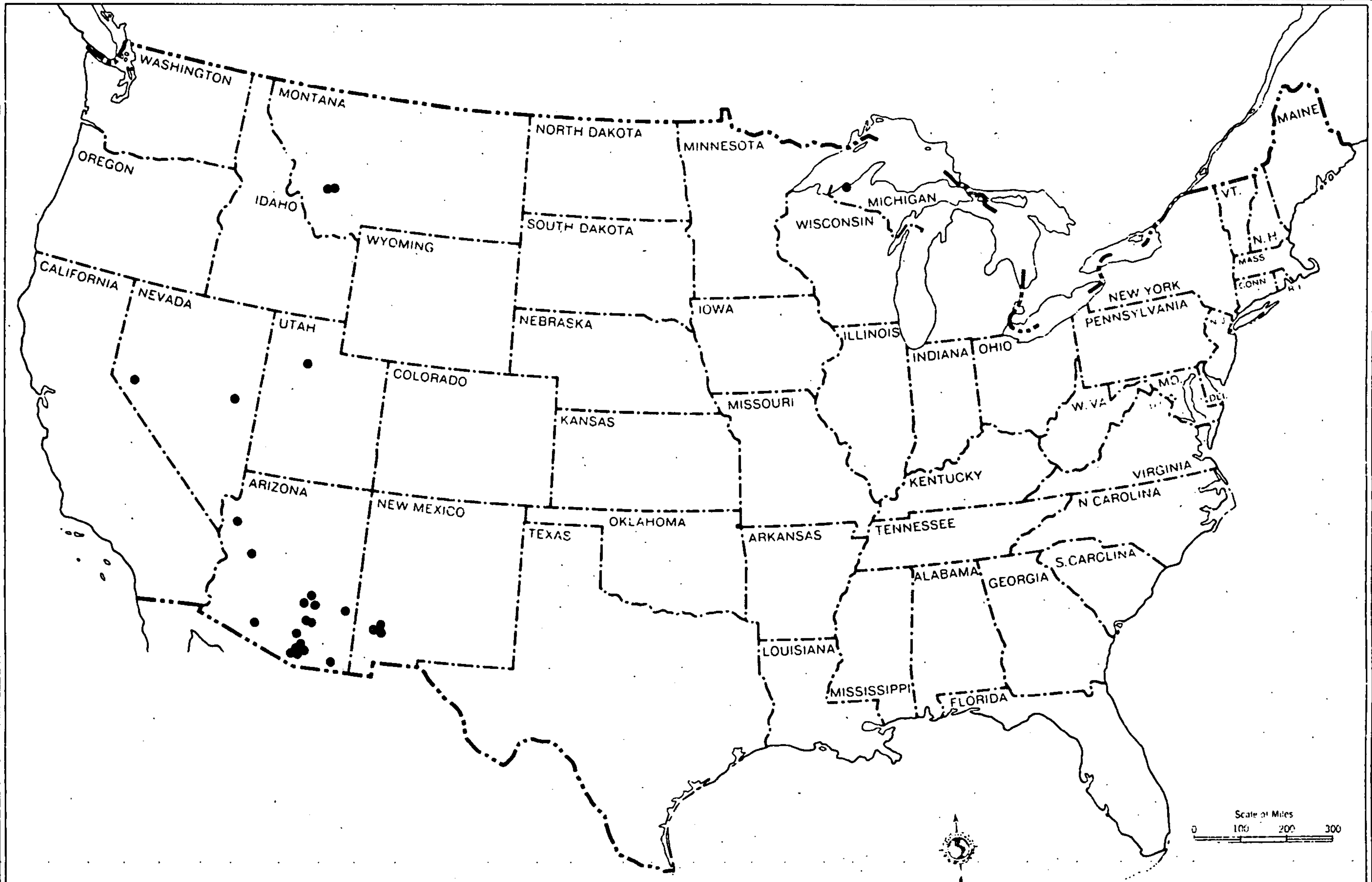

Figure 2.2. Locations of largest U.S. copper mines.

Approximately 94 percent of the ore is concentrated before it is smelted. The concentration (by froth flotation) usually occurs at the mine site because of the reduction that can be obtained in the amount of material to be shipped to the smelter. The smelters are located in proximity to the major ore deposits; most of the concentrated ore is shipped via unit trains on private tracks owned by the copper companies. The smaller mining companies that do not have their own smelters send their ore to custom smelters, which may involve longer shipping distances.

2.3 STONE QUARRYING

Production of stone in 1974 totaled 1.044 billion tons of which 1.042 billion were crushed.[4] Crushed stone was produced in every state except Delaware, with the six states of Florida, Illinois, Missouri, Ohio, Pennsylvania, and Texas accounting for more than one third of the national total. The percentage of total crushed rock quarried in each state with significant production is shown in Figure 2.3.

There were 5,431 active quarries in the country in 1974. Of these, 228 mined at least 900,000 tons during the year and accounted for 37 percent of the domestic production.[4] Stone quarrying tends to be an industry of smaller operations serving local and regional needs.

Almost all stone quarries are open pit mines. Blasting is normally used in quarrying crushed rock. Other equipment such as rippers and hydraulic excavators may be used to break the rock loose. Surge piles between the quarrying and the crushing/sizing operations are also quite common.

Most of the crushed rock is used for construction-related purposes such as roadbases, concrete aggregate, or cement manufacture. In many cases, pits or quarries may be

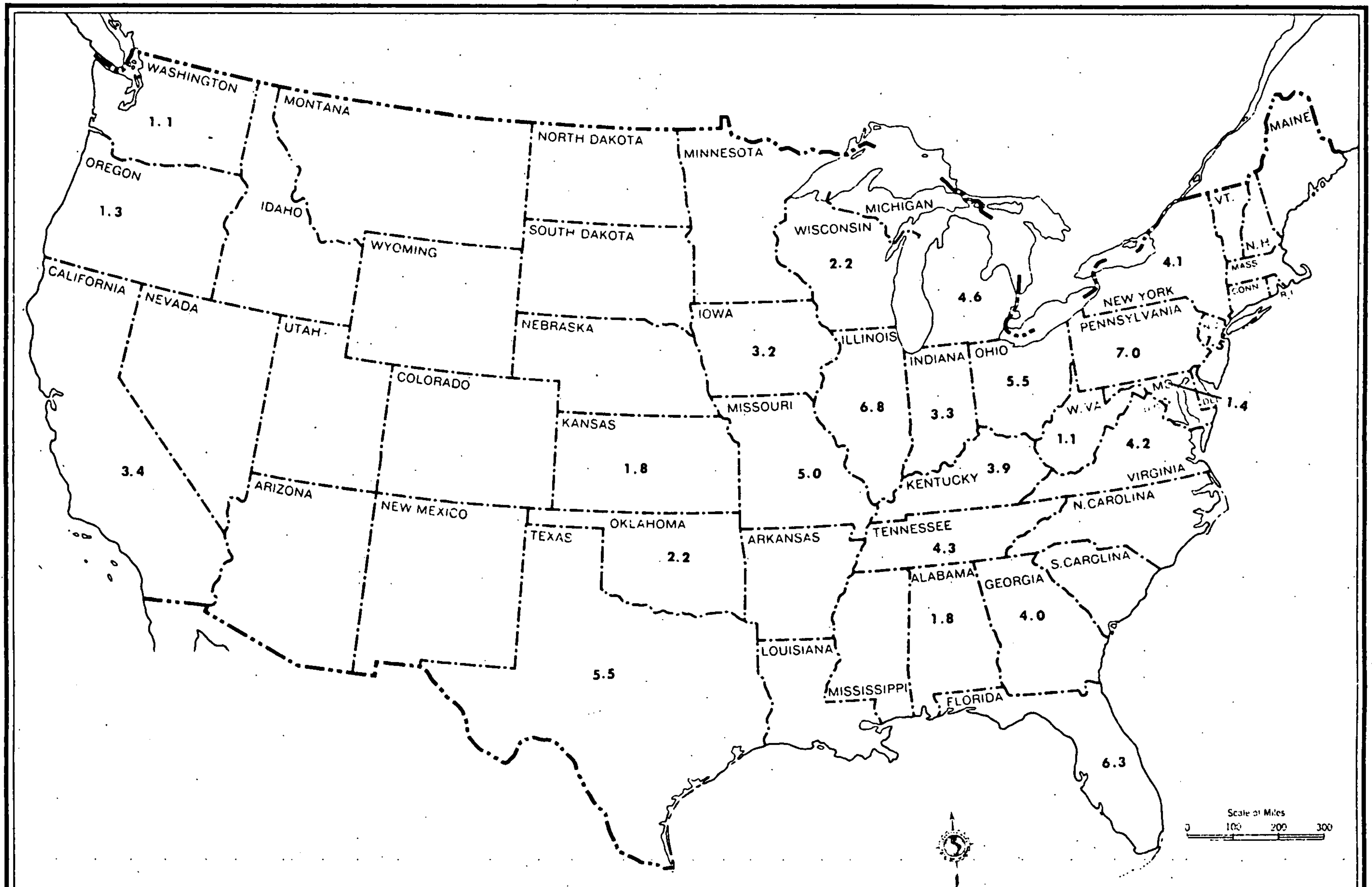

Figure 2.3. Production of crushed rock by state, percent.

operated in conjunction with specific construction projects and mined only intermittently. The crushing plants are often portable and may be used to service as many as 10 different quarries.

Because it is desirable to have quarries located close to the points of usage for the stone, quarries are more likely to be located in or near populated areas than are other types of mines. This proximity has also caused more concerns about the environmental impacts of quarries than the more remote mines--noise, dust, truck traffic, blasting, and inadequate site reclamation after mining have all created local problems at some quarries.

2.4 PHOSPHATE ROCK MINING

Marketable phosphate rock production in 1975 was 48.8 million tons, an increase from the 45.7 million tons of 1974 and 42.1 million tons of 1973. Mining of phosphate rock is concentrated in Florida, which accounted for 77.7 percent of the total output in 1975, and particularly in Polk County in west central Florida. Locations of the largest 24 mines are shown in Figure 2.4, and their estimated production rates are presented in Table 2.3. These 24 mines accounted for 77 percent of phosphate rock mined in 1975.[5]

Mining procedures are somewhat different for the different types of phosphate rock deposits found in Florida, Tennessee, and the Western states. The Florida land pebble deposits are contained in a matrix of sandy clay averaging 16 ft in thickness, overlain by a 20 ft overburden of sandy soil.[6] Prior to mining, the land is drained and vegetation is removed. Draglines with 35 to 55 cubic yd buckets strip the overburden and mine the matrix simultaneously. The overburden is dumped into an adjacent mined-out area or stacked on natural ground adjacent to the cut. The matrix

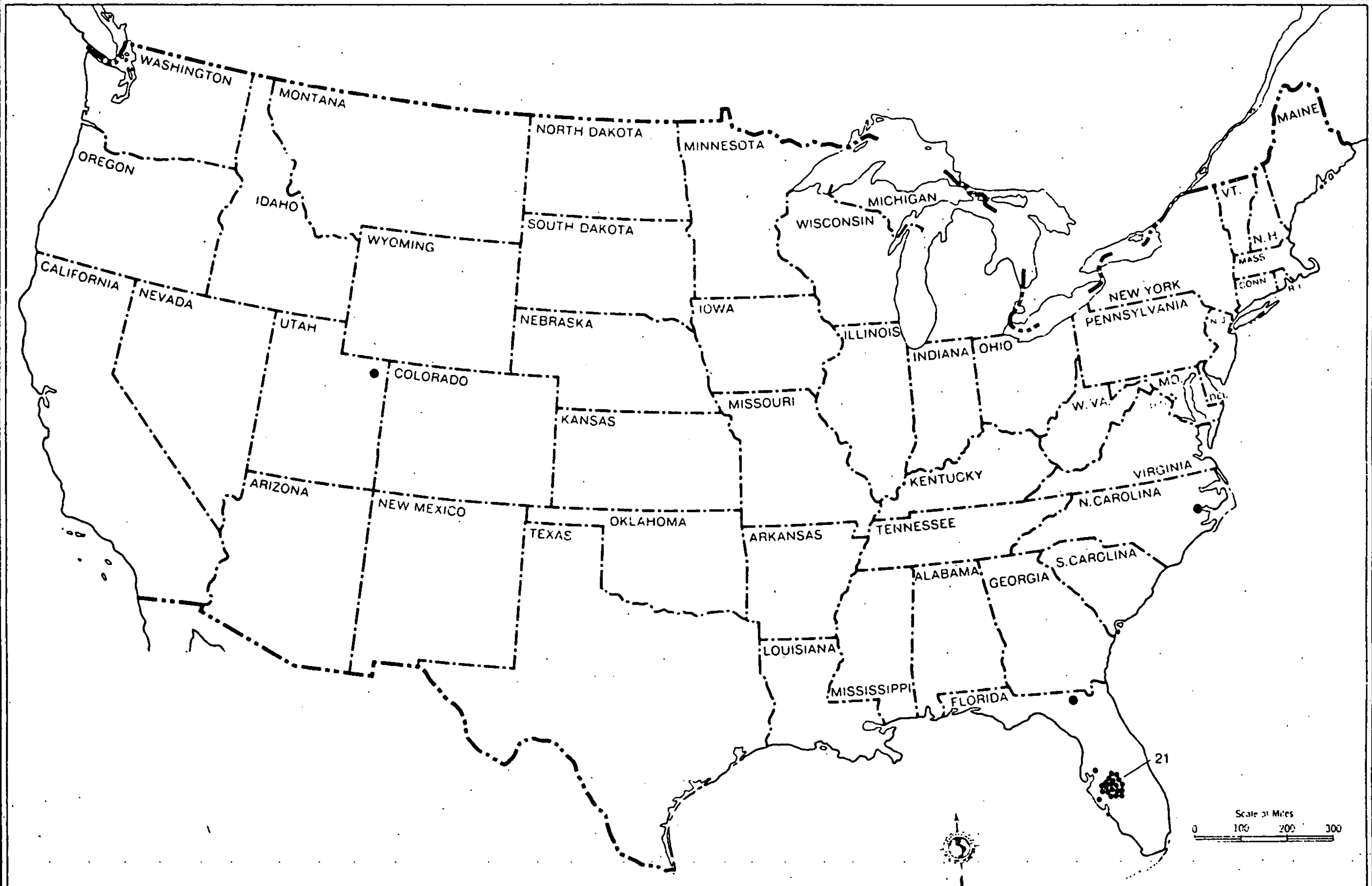

Figure 2.4. Locations of largest U.S. phosphate rock mines.

Table 2.3. LARGEST U.S. PHOSPHATE ROCK MINES, 1975

Company/Mine	Estimated production, 10^6 ton/yr	State	County
IMC	11.0	Florida	Polk
Clear Springs			
Noralyn			
Homeland			
Phosphoria			
Achan			
Kingsford			
Agrico	7.0	Florida	Polk
Palmetto			
Payne Creek			
Saddle Creek			
Fort Green			
Mobil			
Fort Meade	3.3	Florida	Polk
Nichols	1.2		Polk
Occidental	3.5[a]	Florida	Hamilton
Suwannee			
Swift	2.6	Florida	Polk
Silver City			
Watson			
W. R. Grace	2.5	Florida	Polk
Bonny Lake			
Brewster	1.8	Florida	Polk
Haynsworth			
Gardinier	1.8	Florida	Polk
Fort Meade			
USS-AgriChemicals	1.2	Florida	Polk
Rockland			
Lake Hancock			
Texasgulf	0.5[a]	N. Carolina	Beaufort
Lee Creek			
Borden	0.4	Florida	Hillsborough
Tenoroc			
Beker	0.4	Florida	Manatee
Manatee			
Stauffer	0.4[a]	Utah	Uintah
Vernal			

[a] This figure is 1973 data, Preprint from the 1973 Bureau of Mines Minerals Yearbook, Phosphate Rock, pp. 3-5.

Source: Particulate and Sulfur Dioxide Area Source Emission Inventory for Duval, Hillsborough, Pinellas, and Polk Counties, Florida, PEDCo-Environmental Specialists, Inc., Cincinnati, Ohio, prepared for U.S. Environmental Protection Agency, June 1975.

is deposited in a previously prepared sluice pit where hydraulic guns slurry it. The slurry is pumped for distances up to six miles to a washing plant.

Phosphate rock ore in Tennessee is stripped and mined from consolidated deposits with 2 or 3 cubic yd draglines, then trucked to the processing plant.

In Western states, all phosphate ore is strip mined except for two underground mines in Montana. Mines in southeastern Idaho use scrapers, bulldozers, or power shovels to remove overburden and mine the ore. Phosphate rock in Utah is quarried after an overlying limestone layer is drilled, blasted, and removed. Ore mined in Western states is either hauled by truck or moved by rail to processing plants.

In the period 1971 to 1975, demand for phosphate rock worldwide exceeded production capacity, reversing a condition of oversupply that characterized the industry for the previous five years. Indications of reduced demand and resistance to higher prices were noted in 1975. Mining capacity now appears capable of satisfying anticipated demands. Florida output is projected to steadily increase to a level of about 55 million tons per year by 1980 and remain near that level for 10 to 20 years.[6]

3. MINING OPERATIONS WITH POTENTIAL FOR FUGITIVE DUST

There is no established classification of mining operations. The Council on Environmental Quality Report to Congress[7] on coal surface mining and reclamation identified nine discrete operations associated with surface mining: construction of access roads, scalping or clearing of vegetation, drilling and blasting to fracture the overburden, removal and placement of overburden, removal of the coal, rehandling and grading of the overburden, revegetation, water drainage control, and sediment basin construction. In an air quality study of mining,[8] Environmental Research and Technology described the operations somewhat differently: topsoil removal and placement, overburden removal and redistribution, coal removal and transport, conveying, sorting, crushing, storage, vehicular traffic on unpaved roads, and coal fires.

The breakdown of operations used in this report is oriented toward isolation of specific dust-producing activities. For each of the 11 operations identified (see Table 3.1), the operation is described and all available emission estimates compiled and compared. Also, variables on which the emission rate is dependent are discussed, e.g., climate and size of material being handled.

All of the 11 operations are not found in every type of mine, and in some cases the operation is only a significant dust source at one type of mine. The operations that are usually dust sources within a particular mining industry are shown in Table 3.1.

Table 3.1. DUST-PRODUCING OPERATIONS BY MINING INDUSTRY

Operation	Mining industry Coal	Copper	Rock	P_2O_5 rock
Overburden removal	x	+	+	x
Blasting	+	x	x	o
Shovels/Truck loading	x	x	x	o
Haul roads	x	x	x	o
Truck dumping	+	x	x	o
Crushing	+	+	x	o
Transfer & conveying	+	+	+	x
Cleaning	o	o	o	o
Storage	+	+	x	x
Waste disposal	+	x	o	+
Reclamation	x	o	+	x

x = usually a major source

\+ = a minor or occasional source

o = usually not a dust source

In estimating the total fugitive dust emissions from a mine, it is preferable to identify the dust-producing activities present and estimate emissions for each one separately rather than to use a single emission factor for the entire mine. The former procedure permits direct determination of the major source areas--the ones needing control--and results in accurate assessments even if the mine has some atypical processes.

3.1 OVERBURDEN REMOVAL

Description

Overburden removal is an operation in almost all surface mining and entails removal of all topsoil, subsoil, and other strata overlying the deposit to be mined. Significant advances in methods of surface mining have occurred in recent years with the development of giant excavating and hauling equipment designed specifically for these operations.

In 1965, coal surface mining was not considered feasible unless the overburden depth to seam thickness was 10:1 or less--i.e., a coal seam five feet thick to justify removal of 50 ft of overburden. With introduction of the larger equipment, this range of overburden to seam thickness has increased to as much as 30:1. Removal of up to 200 ft of overburden is now feasible for coal mining, while the average in 1965 was 48 ft.[9]

There are three major types of coal strip mining--area, contour, and auger. Area strip mining is used where the terrain is relatively flat. Large-scale excavation equipment, usually draglines, remove the overburden material and deposit it in spoil banks in a trench left by the previous strip. Thus, only the initial strip produces waste overburden that must be disposed of or stored for land reclamation. Trenches excavated by draglines are normally about 100 to 200 ft wide.

On land to be mined with slopes greater than about 15 degrees, contour strip mining is usually employed. In this mining method, the overburden is removed from the slope to create a flat excavation, or bench, resulting in a vertical highwall on one side and a downslope pile of spoils on the other side. The exposed deposit is then mined and the land reclaimed by backfilling the previously worked area with newly removed overburden. If a pattern of backfilling to the original or similar contour is carried out concurrently with the mining and the backfilled land is revegetated, the mined area can usually be successfully reclaimed. Leaving the spoils on the downslope can result in landslides and prevent reclamation.

The third type of strip mining--auger mining--is usually done in conjunction with contour mining. The deposit exposed in the highwall by the contour method is mined by using large drills or augers to pull the deposit horizontally from the seam.

A national bill to regulate surface mining of coal has been passed by the Congress on two different occasions. However, because of steep slope performance standards contained in both bills, the President has vetoed them. The two states where the majority of contour and auger coal mining methods are used, Pennsylvania and West Virginia, have laws prohibiting spoils on downslopes. In West Virginia, all but the last 20 feet of the highwall must be covered and in Pennsylvania all of the highwall must be re-covered.

Increasingly, as demand for complete land reclamation grows, the overburden material is segregated by removing topsoil and other subsoil components suitable for revegetation, storing them separately, and then covering the contoured spoil banks with these two layers during the reclamation process. This greatly increases the ability to revegetate and reclaim the land. It also increases the time and cost of overburden removal, with the need for bulldozers and scrapers for removing up to five feet each of topsoil and other subsoil strata and transporting this soil to storage areas.

For other types of surface mining such as open pit mining and quarrying, overburden removal may be only a one-time or occasional operation rather than continuous. For these types of mines, the deposit to be removed is of the same magnitude or larger than the overburden volume and the location of the mining activity is relatively fixed. Therefore, the overburden is removed permanently and may be transported off-site for disposal.

In excavating overburden, three kinds of equipment are used in typical surface mining operations:

- Draglines
- Shovels
- Small mobile tractors, including bulldozers, scrapers, and front-end loaders

Most surface mining operations use these equipment items in varying combinations.

Draglines are electrically powered equipment capable of moving large amounts of material with a bucket capacity ranging from 30 to 220 cu yd (overburden has an average density of 1.3 ton/cu yd). The dragline moves along the surface or bench, positions its bucket on the overburden to be removed, and loads it by dragging it toward the machine. The loaded bucket is then lifted, the machine rotated, and the bucket dumped in an area that has already been mined.

Alternately, the excavated material may be temporarily stockpiled and moved to a final disposal site by loading onto trucks.

Shovels are large diesel or electrically powered stripping equipment used in surface mines for a number of years and specifically designed for a particular mine operation. These machines proceed along a bench scooping up fragmented overburden in buckets with capacities of up to 130 cu yd. In the largest surface mines, shovels are often used in conjunction with draglines.

Tractors are typically used either in small mines or in conjunction with larger, more specialized equipment in large mines. The principal advantages of tractors are their maneuverability, ability to negotiate steep grades, and capability to dig and transport their own loads. They are used for a variety of tasks, including clearing, topsoil removal, preparing benches, and leveling spoil piles.

A fourth type of excavation equipment, the bucket wheel excavator, is seldom used in this country. It has a rotating bucket wheel mounted at the end of a boom up to 400 ft long. As the wheel rotates, the buckets along the perimeter are loaded when they cut into the deposit with an upward motion. Continuing rotation causes the buckets to be inverted and empty onto a conveyor which then transports the material to a disposal area. Only very large mines with suitably soft overburden material can justify the expense of this equipment.

Emission Estimate

The two primary fugitive dust sources associated with overburden removal are:

- Dumping of dragline buckets or shovels full of overburden material into adjacent trenches or spoil banks, as shown in Figure 3.1.
- Operation of scrapers and bulldozers in topsoil and subsoil removal and transfer.

If the overburden material must be transferred to trucks for removal, the emissions from loading, travel on haul roads, and dumping are considered under these other mining operations.

No sampling specifically for either of these two sources has been done. However, some emission estimates have been made. Hittman estimated 0.002 lb/ton of coal mined as the average emission factor nationally for excavation at coal surface mines where area stripping was used, and 0.003 lb/ton of coal with contour stripping.[9] For uncontrolled mining in the Southwest (primarily the Four Corners area), their estimate was 0.26 lb/ton of coal; with controls (assumed to be watering), fugitive dust emissions were estimated to be 0.009 lb/ton of coal. Battelle estimated the total fugitive dust emissions from surface mining of coal in Western states to be 0.1 lb/ton of overburden removed and indicated that overburden removal was the largest emission source at these mines.[10] Considering the common ratios of overburden removed to coal mined (5:1 to 20:1), Battelle's factor appears to be an order of magnitude higher than Hittman's value. From both of these references, it can be concluded that emissions from strip mining and particularly the overburden removal process vary considerably geographically, presumably because of the much drier climate in the Western states.

PEDCo estimated that the dragline operation at a lignite surface mine in North Dakota had an emission rate of 0.05 lb/ton of overburden removed, primarily resulting from

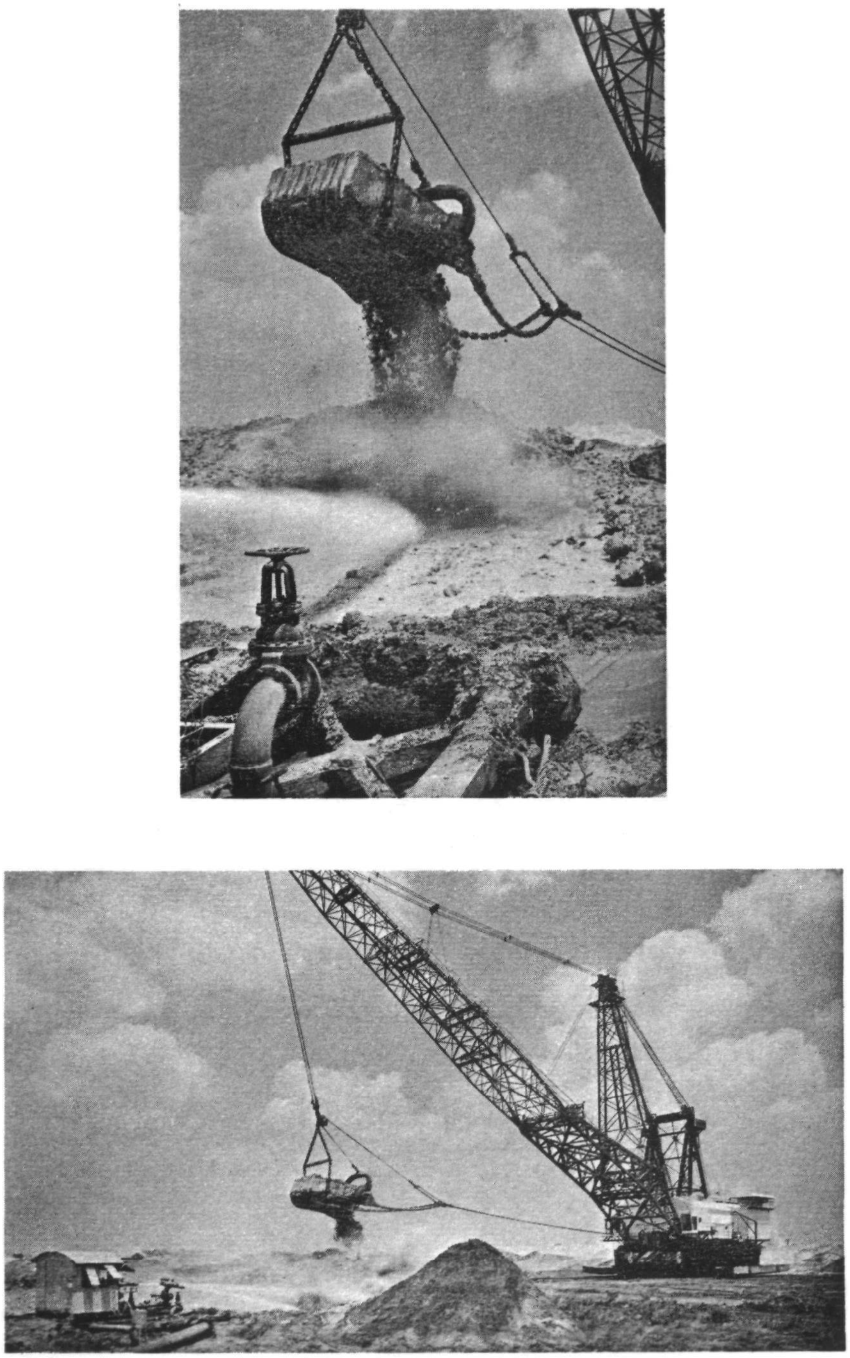

Figure 3.1. Overburden removal.

Source: Phosphate, Florida Phosphate Council, p 6.

dumping of the excavated material from a height of at least 100 feet into the trench. For the particular mine surveyed, this was equivalent to 0.42 lb/ton of lignite mined. In addition, three scrapers stripping the topsoil and subsoil layers were estimated to each produce fugitive dust emissions of 16 lb/hr of operation, or a total of 0.03 lb/ton of lignite mined on an annual basis. These estimates were made by comparison with emission rates from similar fugitive dust sources, such as construction and aggregate handling, which had been tested. The resulting emission estimates of 0.45 lb/ton of lignite or 0.054 lb/ton of overburden removed compare well with Battelle's average factor if it is assumed that about half of the total strip mining emissions result from the overburden removal operation (the value was 63 percent for the particular mine that PEDCo surveyed).

Engineering Research and Technology (ERT) has provided input[8] to the Bureau of Land Management on the air quality aspects of coal development in northwest Colorado for an environmental impact statement.[11] They proposed an emission factor of 0.0024 percent of the material moved (0.048 lb/ton) for topsoil removal, overburden removal, or coal removal, including a correction for climatic conditions and control measures (watering) at the mines. This emission rate was obtained by applying a published emission factor[12] for aggregate handling and storage to the overburden handling operation, but reducing that emission rate by a factor of three because the material at the mines is coarse broken rock containing few fines rather than aggregate. This emission rate was further reduced to account for lack of fugitive dust on wet or frozen days. The resulting factor agrees quite well with the PEDCo value for mining in a similar climatic area, especially considering the rather crude methods of approximation used in both cases.

Overburden removal for copper mining, rock quarrying, and phosphate rock mining may be much less of a fugitive dust source than in coal mining for several reasons:

- Much less overburden material is handled in open pit mines and quarries.
- If the overburden material is to be removed permanently, no segregation and separate handling of topsoil fractions is required.
- Phosphate rock deposits in Florida and other Southeastern states are generally mined in areas where the water table is near the surface and the overburden has a high moisture content and therefore does not produce dust when moved. Average overburden depths in Florida are about 20 ft.
- If the overburden depth is fairly shallow, the excavated material will not be dropped as far from the dragline bucket or shovel to the trench or spoil bank, creating less of an impact and less opportunity for dispersion of airborne material.

PEDCo estimated particulate emissions from dragline operations at an open pit copper mine in Butte, Montana to be 29 ton/yr.[13] No data were obtained on the amount of overburden removed annually; the emission rate per ton of ore mined was 0.0008 lb, almost negligible in comparison with the factor for coal mining. The excavation area was noted to be moist and nondusting; emissions were estimated by assuming the active dragline operation of 2 acres to be equivalent to an active construction site, using an emission factor of 1.2 ton/acre/month.

The Battelle, PEDCo, and ERT data show that overburden removal is potentially one of the largest fugitive dust sources at surface mines. It is also one of the most variable. The dust losses from this operation vary with the composition and texture of the overburden material, its moisture content, excavation procedures, equipment employed, etc. For any specific mine, the emission rate is probably most closely related to the amount of overburden moved.

3.2 BLASTING

Description

Drilling and blasting are done to fracture hard, consolidated material so it can be removed more easily and efficiently by the excavating equipment. Blasting may be needed for certain impenetrable overburden or for partings between the seams being mined, but more commonly to loosen the deposit itself. This operation is a routine part of open pit mining and quarrying; its use in surface coal mining is dependent on the depth and hardness of both the overburden and the coal bed; it is almost never required with phosphate rock mining.

The blastholes are drilled from the surface of the rock layer or deposit to the depth to which the deposit is to be broken. Shelves of 30 to 50 ft depth are often used if a deposit of greater thickness is being mined. A flat bench is first prepared for the drilling rig, which is mounted on a tractor or truck. The holes are drilled in a predetermined pattern by an electrically-powered rotary drill 4 to 15 inches in diameter. Larger holes (containing more explosives) are drilled for fracturing rock than for breaking coal. Typical blasting patterns range from 20 ft by 20 ft to 50 ft by 100 ft, with the blasthole spacings varying with the material to be fractured. When a particularly resistant rock formation is encountered, a pneumatic drill may be required.

Normally, the explosive is a mixture of ammonium nitrate and fuel oil. Either dynamite or metalized mixtures such as ammonium nitrate and aluminum can be used when a more powerful explosive is required. From 300 to 11,000 lb of explosives are charged into each hole, depending on its depth, location in the pattern, and the material encountered in drilling. Millisecond delays in the blasting sequence are programmed to maximize the breaking effect and to minimize seismic shock. Mats may be used with small blasts to reduce the scattering of rock fragments during the blast.

The frequency of blasting is rarely more than once per day and may be much less often. For reasons of safety and to minimize disruption of other mining activities, blasting is usually conducted between work shifts. The area to be blasted must also be cleared of equipment and workers during the time that the holes are being charged and wired for detonation, so drilling and blasting are generally as isolated from the other active mining operations as possible.

Emission Estimate

Sampling of drilling and blasting operations at one granite quarry indicated emission rates of 0.0008 lb/ton of granite quarried for drilling and 0.16 lb/ton due to blasting.[14] Of 11 different processes sampled at the quarry (not the same 11 mining operations described herein), blasting produced the most emissions, accounting for 63 percent of the total fugitive dust emissions from the quarry and crushing plant. More explosive charge is required for blasting granite than other ore. Based on the results of this study, the research firm that conducted the sampling, Monsanto Research, has scheduled further field testing of emissions from blasting.

Monsanto says

PEDCo estimated emissions from daily blasting at a large open pit copper mine to be about 200 lb of suspended material per blast, or about 0.001 lb/ton of ore. This estimate was based on visual observation and was noted to be only an order of magnitude value. The large difference between the two available emission factors could be due to unreliability of the PEDCo estimate or to actual differences between the amounts of dust generated by the two blasting operations. The additional scheduled testing may resolve this question.

Blasting is a difficult operation to sample because of its short duration and the danger of placing sampling equipment or men close enough to the area of the expected plume prior to the blast. Also, the force of the blast throws much material into the air that is larger in particle size than suspended particulate. Distinction of this settleable material (which may have a much greater mass) from the suspended fraction may not be possible at the time of the sampling; particle sizing analysis on the collected sample and correction for the percent by weight of settleable particulate may be necessary. Observation of film footage of blasting shows that much of the fine dust that remains airborne is actually generated as the blasted rock returns to the surface after being lifted by the force of the blast, not by the initial explosion.[15] The drilling part of this operation is amenable to conventional open source sampling methods, but these emissions are probably negligible compared to emissions from blasting.

The dust plume from a blasting operation is shown in Figure 3.2. Blasting is not similar to any other fugitive dust source, so development of an emission factor cannot be accomplished by comparison or extrapolation of data from other operations.

This operation is an obvious dust source wherever it occurs. While its appearance indicates that it is a major

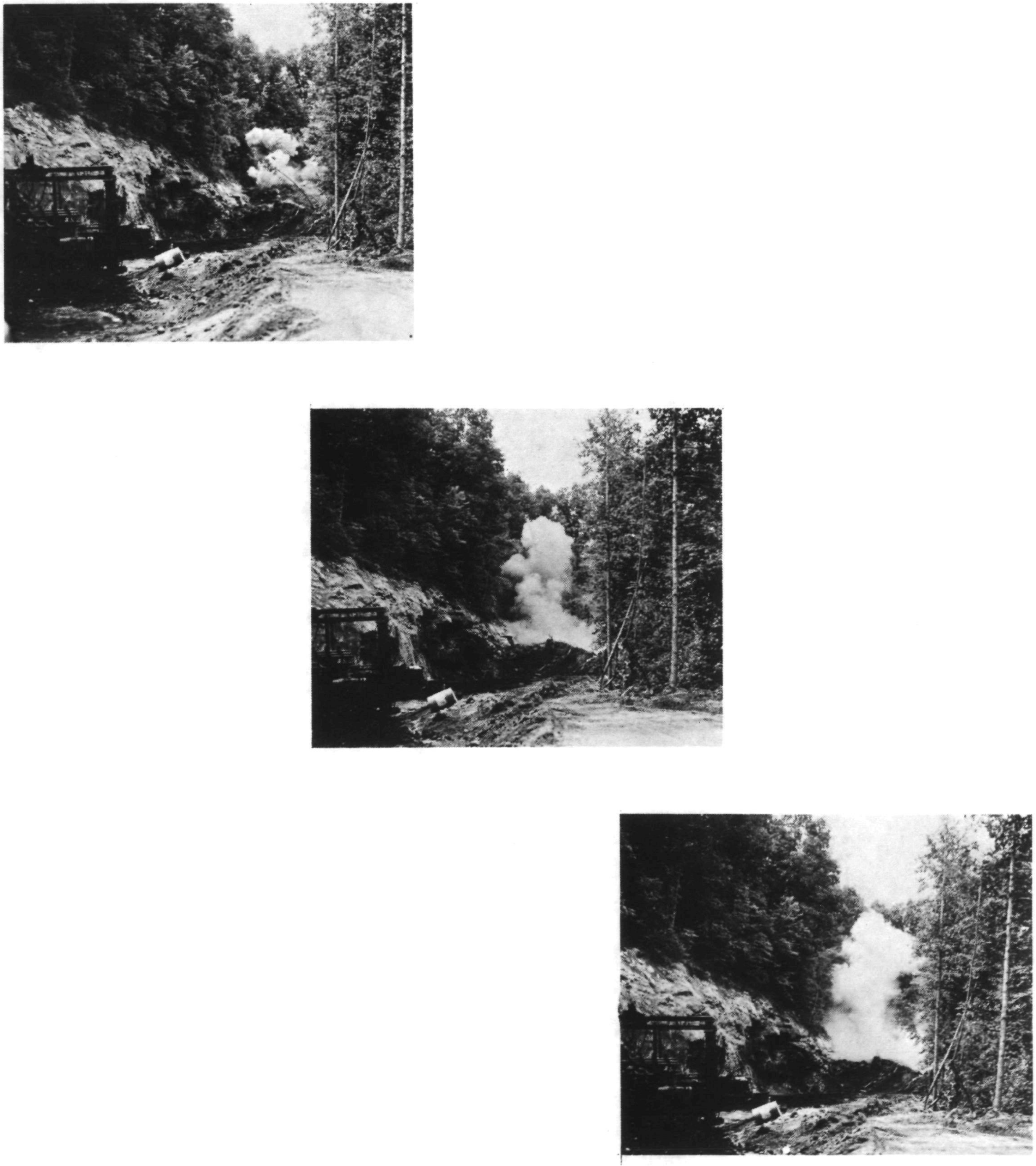

Figure 3.2. Blasting.

source of mining emissions, its time-averaged contribution may be quite small because the emissions occur for only a few seconds per day or week.

3.3 SHOVELS/TRUCK LOADING

Description

In most surface mines, the ore or material being mined is loaded onto off-highway trucks for transport from the point where it is removed to a central transfer location or processing area at the mine site. The material can also be transported within the mine in a mechanical or hydraulic conveyor system, but this method is rarely used except in phosphate rock mining, where the deposit is usually pumped as a slurry through a pipeline to the processing area. Another seldom used alternative to shovel and truck operation is the mobile storage bin into which material can be loaded directly by dragline, then crushed and loaded into trucks.

Any of the excavation equipment described in Section 3.1 can be used to excavate the deposit and load it onto trucks. However, electric powered, crawler-mounted shovels are most often employed for this purpose because they can load the trucks more quickly. The shovel breaks the fractured deposit loose, scoops the bucket full of material, lifts the bucket and swings it over the truck bed, and releases the load through the hinged bottom of the bucket. When the truck is full, it drives off and another moves into position while the shovel is scooping another bucket of material.

The newer haul trucks at mines usually have load capacities of 100 to 200 tons and are diesel-electric powered. The trucks may be either end dumping or the gondola-shaped bottom dumping, depending on the configuration of the tipple, or dumping area. The same trucks may also carry low grade ore or unmarketable material in the deposit to a separate dump area for disposal. The loading operation and fugitive dust potential for scooping and loading this waste material is identical to that for the material being mined.

A small front-end loader may be assigned to the area being worked by the shovel to remove spilled material that could cause damage to truck tires and to move materials that cannot be easily reached by the less maneuverable shovel. For irregular deposits and smaller mines, a front-end loader may be used instead of an electric powered shovel.

The area where the shovel is working is normally freshly exposed, so the material has almost the same moisture content as the unexposed deposit. However, the position where the trucks are loaded may dry rapidly as a result of the traffic movement. It is difficult for watering trucks or other control equipment to gain access to truck loading areas because of the danger of driving near the mining equipment or haul trucks (which have poor close range visibility) and because the shovel, the deposit, and the power line for the shovel often block access from all but one direction.

Emission Estimate

Dust is generated at many points in the truck loading operation, but mainly by the scooping of loose material by the shovel, dumping from the shovel bucket into the truck bed, and movement of trucks into position to be loaded. Dust generation from truck loading is shown in Figure 3.3. Several emission estimates have been made for the entire operation. Midwest Research Institute sampled the loading of crushed rock by front-end loaders and determined an

Figure 3.3. Truck loading.

Source: Draft EIS, Eastern Powder River Coal Basin, 1974, p I-74.

average emission rate of 0.05 lb/ton of rock.[12] This emission factor was also applied by PEDCo to loading of copper ore by shovels as the differences in the two operations were thought to offset one another:[13]

- the shovel must break the fractured rock loose instead of just scooping it out, resulting in higher emissions than for loading of aggregate;
- the shovel is not as maneuverable as a front-end loader and therefore drops the rock a greater distance into the truck;
- the crushed rock tested was very dry and contained a substantial amount of fines, in comparison with moderate moisture content and few fines for the shovel operation; and
- the crushed rock loading was exposed to higher wind speed conditions than the copper ore loading.

The effect of the shovel's larger bucket size on emission rate could not be determined.

The PEDCo emission factor estimate for loading lignite coal in North Dakota is 0.02 lb/ton loaded. This lower estimated emission rate was based on comparison with loading of crushed rock, considering the higher moisture content and fewer fines in the lignite. The lower value also appears reasonable in comparison with emissions from other operations at the lignite mine, such as truck dumping and grader operation.

The ERT air quality analysis for Colorado coal mines cited in Section 3.1 proposed the same emission factor for coal removal and loading as for overburden removal, 0.048

lb/ton. This value is almost the same as those developed for crushed rock and copper ore, and may be a function of lower moisture content in the coal beds in northwest Colorado than in North Dakota lignite.

Monsanto Research's sampling at a crushed granite plant indicated that loading onto haul trucks produced negligible emissions,[14] reportedly because of the large aggregate size, i.e., the absence of fine granite dust.

The Hittman report included an emission factor of 0.04 percent due to "windage losses" in truck hauling at coal mines.[9] It was indicated that most of these emissions occurred at the two ends of the hauling trip--loading and dumping--and that most of the weight loss was probably as airborne particulate. However, much of the airborne particulate could still be due to settleable material. If it is assumed that half of the total "windage losses" of 0.8 lb/ton (0.04 percent) occur during loading and that 25 percent of this material remains suspended, the emission estimate for truck loading would be 0.10 lb/ton. This is higher than the other estimates, but certainly close enough to confirm the relative magnitude of these other values.

Independent emission estimates for the truck loading operation cover a fairly wide range, possibly indicative of the many variables involved in this operation. The most important of these variables are the moisture content and amount of fines in the material being loaded, the number and types of equipment working in the loading area, and climatic conditions at the mine.

3.4 HAUL ROADS

Description

Haul roads, mostly temporary unpaved roads between the active mining areas, tipple, waste disposal areas, and equipment service areas, are common to all surface mines. In a typical mine, these roads constitute about 10 percent of the total area directly disturbed by the mining.[16] Because of the size of the trucks and crawler-mounted equipment that use these roads, they are normally constructed at least 40 ft wide. In mines opened in recent years, particularly those in the West that use 100 to 200 ton capacity trucks, the roads may be as wide as 100 ft.

Some of the haul roads at the mine lead from bench level at the bottom of the deposit to undisturbed surface elevations, which may be 200 to 300 ft higher. Therefore, these haul roads either have a steep grade or follow a circuitous route to the higher elevation. In areas where contour mining is practiced and lighter equipment is used, the roads generally exhibit poor alignment and drainage, low durability, and marginal maintenance. Where area mining is practiced with its attendant heavy equipment, roads are necessarily better engineered.

Road surfaces vary according to the terrain, type of operation and size of equipment used. Road surfaces may be graveled but more commonly they are just graded. In areas of flat open terrain, the roads are graded with berms thrown up at the road edges from excess material generated during grading or maintenance. In Eastern states, where mine operations are located in hilly or forested terrain, the use of berms is often prohibited or discouraged because of its adverse drainage effect.

Haul roads are normally cleared of spilled material and regraded frequently while in use. Heavy equipment tends to rut and compact the surface. Continuous maintenance of haul roads for the heavy equipment makes higher speeds possible and provides greater usage time of the roads. Generally, the haul roads are built and maintained as cheaply as possible while still not slowing down production from the mine. At any given time, only a portion of the roads at the mine site will be active, but the abandoned roads are left as is for possible reuse when the active mining area moves again. In the interim period, they serve a definite purpose in providing good access throughout the mine.

In addition to the haul trucks, other vehicles use the haul roads regularly--water trucks, fuel and service trucks, pickup trucks, motor graders, bulldozers, and explosives trucks. The vehicle miles traveled (VMT) per day on haul roads can be estimated from the numbers of each type of vehicle in operation at a mine and their respective driving patterns (e.g., round trip distance from loading area to tipple and number of loads per shift per truck). Alternatively, the VMT can be estimated from total gasoline and diesel fuel usage and average fuel consumption rates for the different vehicles.

Haul roads at mines are routinely watered for dust suppression during all periods when water on the road surface does not create a safety hazard (generally when temperatures are above freezing). The water is usually applied by large tank trucks equipped with a pump and directional nozzles which spray the road surface and adjacent shoulders and berms. Fixed pipeline spray systems have also been used on main haul roads that are relatively permanent. Various chemicals may be added to the water or applied separately to the road surface to improve binding and reduce dusting. Over 100 dust suppressant materials are now marketed, and many of them have been proven effective for short periods in tests on mining haul roads.[17] As a result of the frequent watering, heavy bearing loads on the road surfaces, and chemical applications, mining haul roads usually have the appearance of oiled or crudely paved roads rather than rural gravel roads.

Emission Estimate

There have been several studies during the past few years of emission rates from unpaved roads. However, as indicated above, emissions from mining haul roads may be much different than those from normal unpaved roads because of the larger vehicles, compacted surfaces, and frequent watering. Figure 3.4 shows a large-capacity truck on a well-controlled haul road. Close observation of well-controlled haul roads reveals that much of the dust is generated near the edges of the roads, where the surface is composed of looser material, and in areas where the surface has dried. Also, haul roads have fugitive dust emissions that result from movement other than traffic--road construction and repair, loss of fines from the open bed trucks during transit, and wind erosion on abandoned and seldom used roads. Vehicle exhaust contains particulate emissions, but it is not considered to be fugitive dust and is therefore not included in the emission estimates.

There have been at least three different emission estimates made specifically for traffic on unpaved haul roads. The first of these was by PEDCo. It was developed from EPA's published emission factor for unpaved roads:[18]

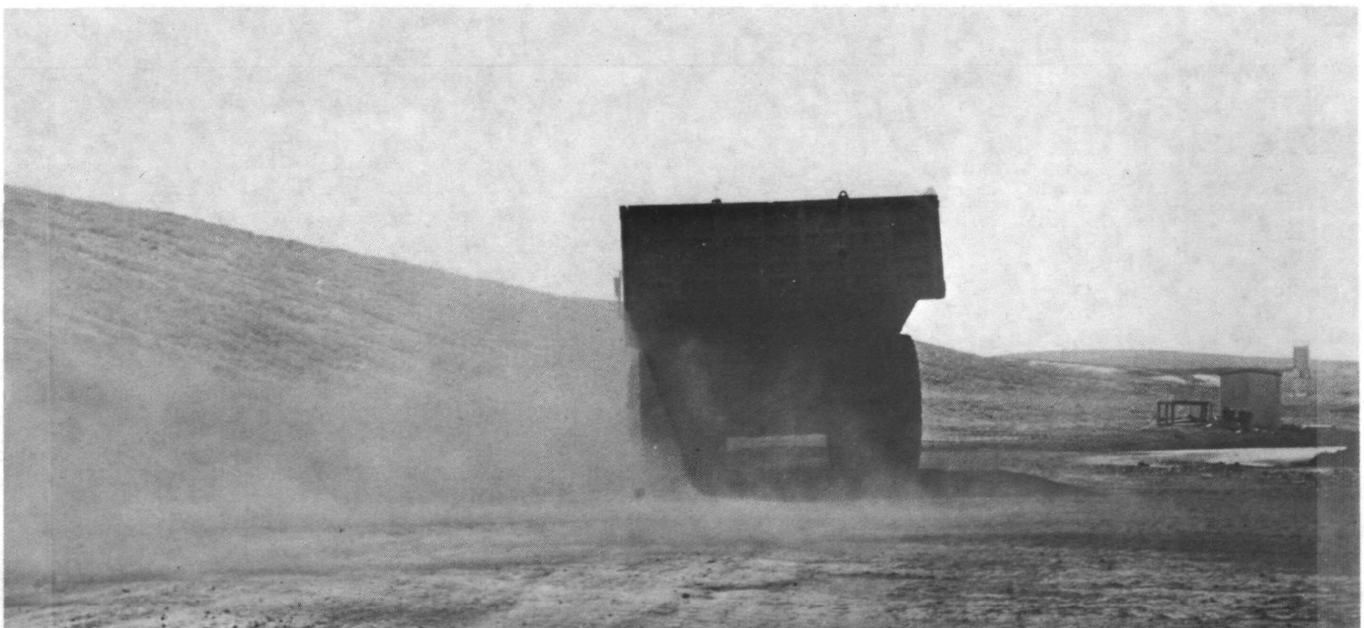

Figure 3.4. Haul roads.

$$EF = (0.60)(0.81)(s)(S/30)(1-W/365) \qquad \text{(eq.1)}$$

where EF = emission factor, lb/VMT

0.6 = average fraction of emitted particulate in the suspended particulate size range (less than 30 μ diameter)

s = silt content, percent

S = average vehicle speed, mph

W = days with 0.01 inch or more of precipitation or reported snow cover

This emission factor was modified to account for the much larger surface area of the road in contact with the truck tires. It was assumed that the relative emission rates for off-highway trucks, even though they have only four tires, would be two and one-half times as great as for light duty vehicles, based on the comparative widths of tire faces. Other input data used to calculate the emission factors for two different mining operations are summarized below:

Parameter	For open pit copper mine	For lignite surface mine
Average vehicle speed, mph	15	20
Days/yr with no rain or snow cover	274	166
Emission reduction due to watering and chemicals, percent	80	50
Emission factors, lb/annual VMT		
Haul trucks	1.1	2.2
Pickup trucks	0.4	0.9

In addition, an uncontrolled emission factor of 32 lb/hr was proposed for grader operations in these PEDCo studies, and the same control efficiencies were assumed for the graders working on the haul roads as for the truck traffic. Windage losses in transit were thought to be negligible in comparison with emissions from the road surfaces in these two instances, but for some materials the emissions from the moving trucks could be significant. Wind erosion emissions from the haul roads were assumed to be indistinguishable from wind erosion of other exposed areas at the mines and were therefore considered in another source category.

Monsanto Research's study of a granite quarry showed emission rates from "vehicular movement on unpaved roads" of 0.048 lb/ton of material processed, or about 2.4 lb for each round trip to the crusher, assuming 50 ton capacity trucks and only haul truck traffic on the roads. A conscientious haul-road watering program was reportedly being implemented at the mine during the test program. Since the dimensions of the quarry and hauling frequency were not described, it is not possible to compare this value directly with the other available emission factors. However, it appears to be somewhat lower.

ERT used a base emission factor of 3.7 lb/VMT (obtained from an early study of fugitive dust emission sources)[17] for both haul trucks and light duty vehicles at surface mines in northwestern Colorado. This factor was then reduced by multiplying by a climatic correction of 0.44, the fraction of days when the surface was not wet or frozen, and a control factor of 0.50 to account for watering of the roads on dry days. The resulting net emission factor was 0.8 lb/VMT for total annual travel at the mine. This value is near the weighted average of emission rates for the copper mine and employed the same rationale as the PEDCo study in applying correction factors to account for differences between emission rates from normal unpaved roads and mining haul roads.

The available emission factors for this mining operation are in fairly close agreement. Using any of these values, haul roads are shown to be a major fugitive dust source at all surface mines, even with the relatively high control efficiencies obtained with frequent watering and use of chemical dust suppressants. The calculation procedures used to derive the factors indicate that variables which affect emissions from this operation most are vehicle speed, estimated control efficiencies, and climatic conditions at the mine.

3.5 TRUCK DUMPING

Description

Truck dumping is the simplest operation at the mine to describe--it involves only the dumping of the mined material from the truck into a tipple or receiving hopper for the primary crusher. The same operation may also occur at the edge of a spoils slope if the truck is dumping waste material or overburden. While the operation is quite simple, it has been identified as a significant fugitive dust source at many different mines,[13,19] as shown in Figure 3.5.

Emission Estimate

Dust is generated as the material tumbles from the truck bed and strikes the ground or side of the hopper. Three different estimates of the emission rate from this operation were located. Midwest Research Institute, in a sampling study of aggregate handling operations, estimated that dumping of crushed rock or gravel onto storage piles accounted for about 12 percent of the total emissions of 0.33 lb/ton from handling, or 0.04 lb/ton. The truck dumping operation was not sampled in isolation from the other

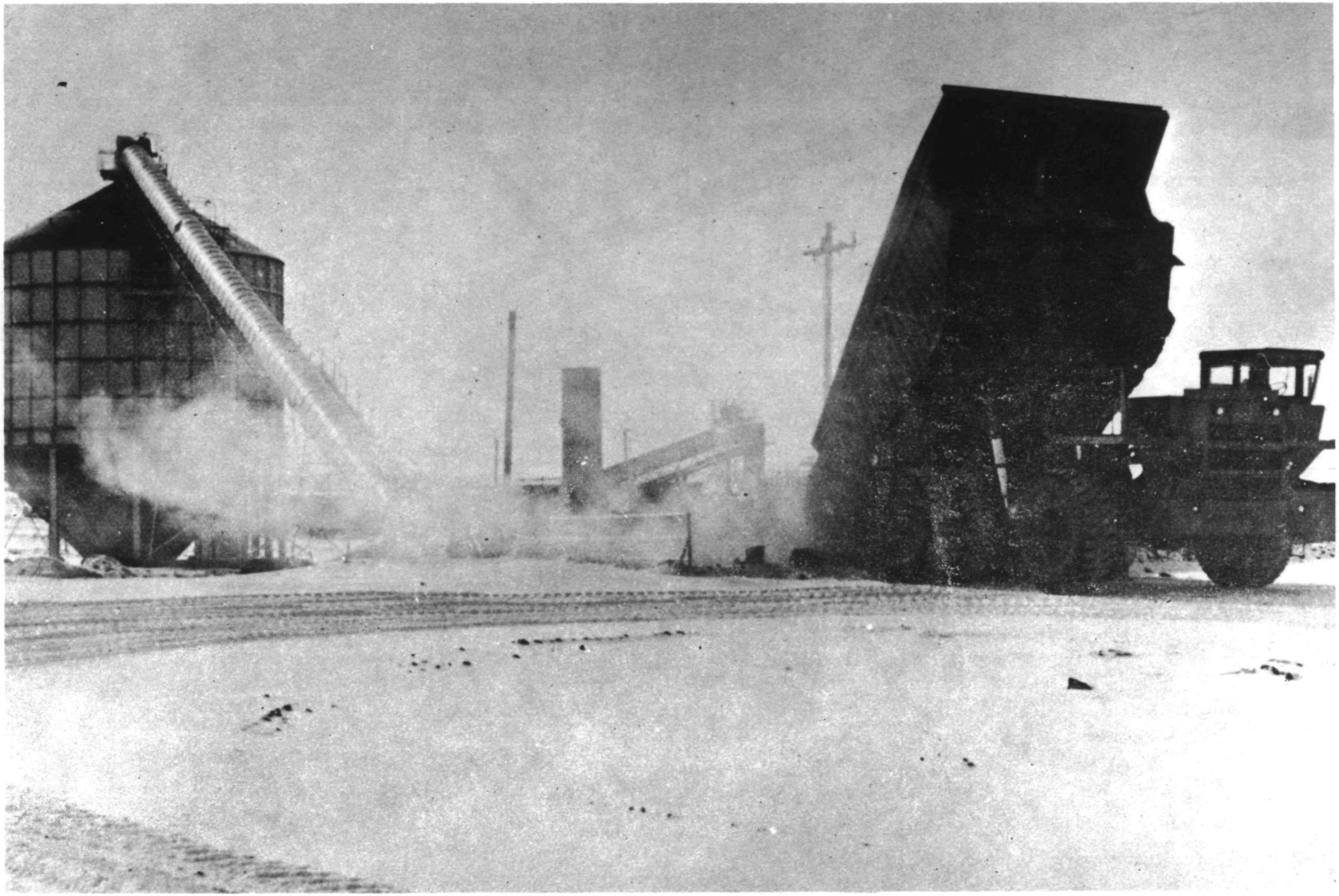

Figure 3.5. Truck dumping.

Source: Draft EIS, Eastern Powder River Coal Basin, 1974, p I-75.

handling operations and the estimate of 12 percent was partially subjective. This emission factor for dumping of aggregate onto storage piles was recently published in Supplement 5 of EPA's Compilation of Air Pollutant Emission Factors.[18]

Monsanto Research determined an emission rate of 0.00034 lb/ton for truck unloading at the hopper of a primary crusher.[14] The material being handled was quarried granite with very little fine material present.

For two separate studies, PEDCo used an emission factor of 0.02 lb/ton for truck dumping. This value was derived by taking half the published EPA emission factor for dumping of aggregate because of the much larger size of the broken ore and coal being handled and its higher moisture content. The 50 percent reduction was based on the estimated control efficiency of watering,[17] which is probably comparable to the effects of higher moisture content and larger material size.

Intuitively, it seems that emissions from truck dumping should be less than for the truck loading operation because dumping does not include the activity of the shovel or front-end loader in loosening and scooping the deposit. In comparison with the values presented in Section 3.3 for emissions from truck loading, the MRI and PEDCo factors for truck dumping appear to be quite reasonable. However, as with most of the mining operations, there may be a wide range of emission rates for mines of different minerals or in different climates.

3.6 CRUSHING

Description

The crushing operation is a fugitive dust source at both underground and surface mines. The material is charged to the primary crusher by means of a receiving hopper. At large mines, there may be more than one hopper or dumping bin serving separate primary crushers placed in parallel. Primary crushers are jaw crushers, set to act upon rocks larger than about six inches and to pass smaller sizes. Depending on the ultimate size requirements of the product, the material from the primary crusher may be screened with the undersize going directly to the screening plant and the oversize to secondary crushing, or all material from primary crushing may be routed to the secondary crusher. The secondary crushers are of the cone or gyratory type.

As the material is crushed, much more surface area is created. If the incoming material has a high internal moisture content (such as lignite coal), the new surfaces will be moist and nondusting. However, if the material has a low internal moisture content, the crushing greatly increases the potential for airborne dust generation. The new surfaces tend to dry out as the material continues through the process on conveyor belts and through the secondary crushers and screens. As the rock or coal becomes more finely ground and drier, the in-process dust releases become greater.

One method of suppressing the in-process dust is by adding water to keep the material moist at all stages of processing. If the use of water can be tolerated, it is usually sprayed at the crusher locations and shaker screens. The addition of water may cause blinding of the finest size screens, thereby reducing their capacity.

The crushing/screening operation is either fully enclosed or the dust emission points are hooded, with a local exhaust system, control device, and stack. This is the only operation at the mines that would not be strictly defined as a fugitive dust source, since the emissions are confined and emitted at a single point (as shown in Figure

3.6). However, most crushing operations still have some fugitive dust losses that escape the hooding system at points such as the crusher discharges and conveyor transfer points. At rock quarries, most of the crushers are portable, are not well enclosed, and therefore usually have particularly high fugitive dust emissions. One emission estimate for coal preparation assumed that half the dust generated went through a collection system to controls and half escaped.[8]

Emission Estimate

For coal crushing, EPA's published compilation of emission factors does not include a quantitative estimate, but states that "the crushing, screening, or sizing of coal are minor sources of dust."[20] The writeup on coal crushing also indicates that 95 percent control can be achieved by use of water sprays and 99+ percent control is possible with sprays followed by mechanical dust collectors. The Hittman report[9] also states that dust emissions from coal preparation plants are negligible.

Based on some data from coal processing for coke production, PEDCo estimated[21] that the uncontrolled emission rates for the three major emission points in the operation would be:

Primary crushing = 0.02 lb/ton
Secondary crushing = 0.06 lb/ton
Secondary screening = 0.10 lb/ton

In combination with the estimated control efficiencies cited above, these values appear to substantiate the non-quantitative evaluations that coal crushing is only a minor dust-producing source.

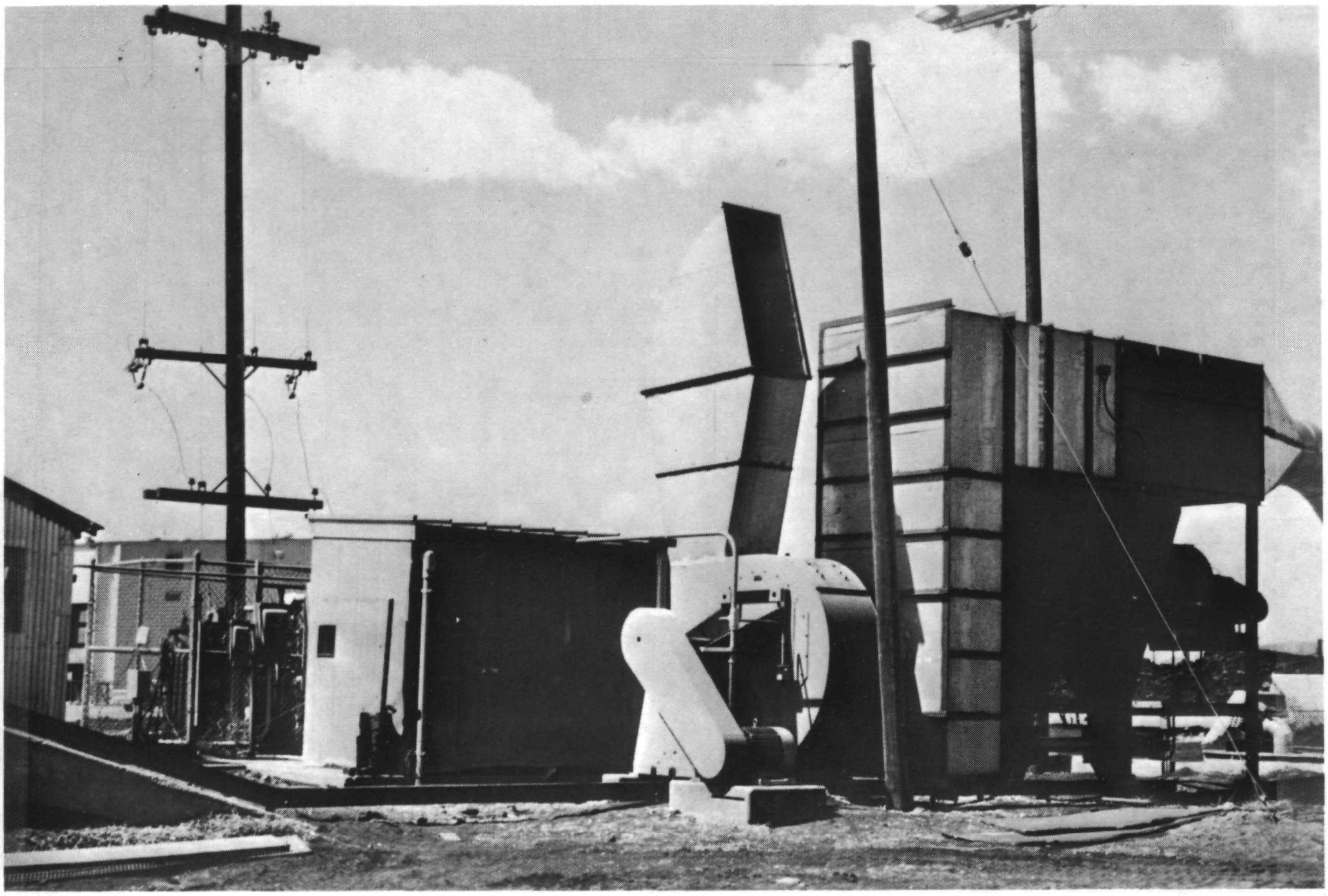

Figure 3.6. Crushing.

In contrast, the current EPA emission factors for rock crushing are quite high, as shown below:[20]

Primary crushing = 0.5 lb/ton total
= 0.1 lb/ton suspended particulate

Secondary crushing
and screening = 1.5 lb/ton total
= 0.6 lb/ton suspended particulate

It has been noted that even the lower of the two sets of emission factors often overestimates annual emissions from rock quarries in regional emission inventories, indicating that these factors are most applicable to uncontrolled portable crushers or must be combined with very high control efficiencies to produce reasonable values. It cannot be determined from the source descriptions whether the EPA emission factors include just stack emissions or both stack emissions and fugitive dust losses.

Crushing operations at a granite quarry have been sampled by Monsanto Research.[14] Their results, which include both stack emissions and fugitive dust, are more consistent with expected emission rates than the EPA values:

Primary crushing = negligible
Secondary crushing = 0.018 lb/ton
Secondary screening = 0.026 lb/ton

3.7 TRANSFER AND CONVEYING

Description

Although conveyor systems may be used to transport material from the active mining area to the processing area or to deliver the processed material to the consumer, conveying is most often found within the processing area--moving the crushed material to storage, a cleaning process, or the train loading station. This operation also includes the loading of train cars and other transfer of the material, except for conveyors within the crushing or storage operations which are considered to be integral to these operations. Because of the large tonnages that must be moved in mining, most of the transport systems are belt conveyors rather than screw, vibrating, or continuous-flow conveyors.

Generally, conveyor runs between processes are less than 1,000 ft. The average length of the few haulage conveyors between pits and crushers is about 2,100 ft,[22] and off-site delivery conveyors of up to 12 mi have been built for coal.

Loss of material from the conveyors is primarily at the feeding, transfer, and discharge points and occurs due to spillage or windage. A conveyor belt is shown in Figure 3.7. The total weight loss in transit is certainly greater than the fugitive dust emissions from this operation since much of the spillage is deposited along the conveyor and some of the windblown material is in the settleable size range.

Excessive moisture in the material or air currents can create discharge problems on belt conveyors. Therefore, most are enclosed, and in some cases the transfer points may be hooded and vented to a dust collector. Both the enclosure and the hooding greatly reduce fugitive dust emissions from this operation.

Emission Estimate

Conveying is one of the most variable mining operations with respect to fugitive dust emission rates. In many

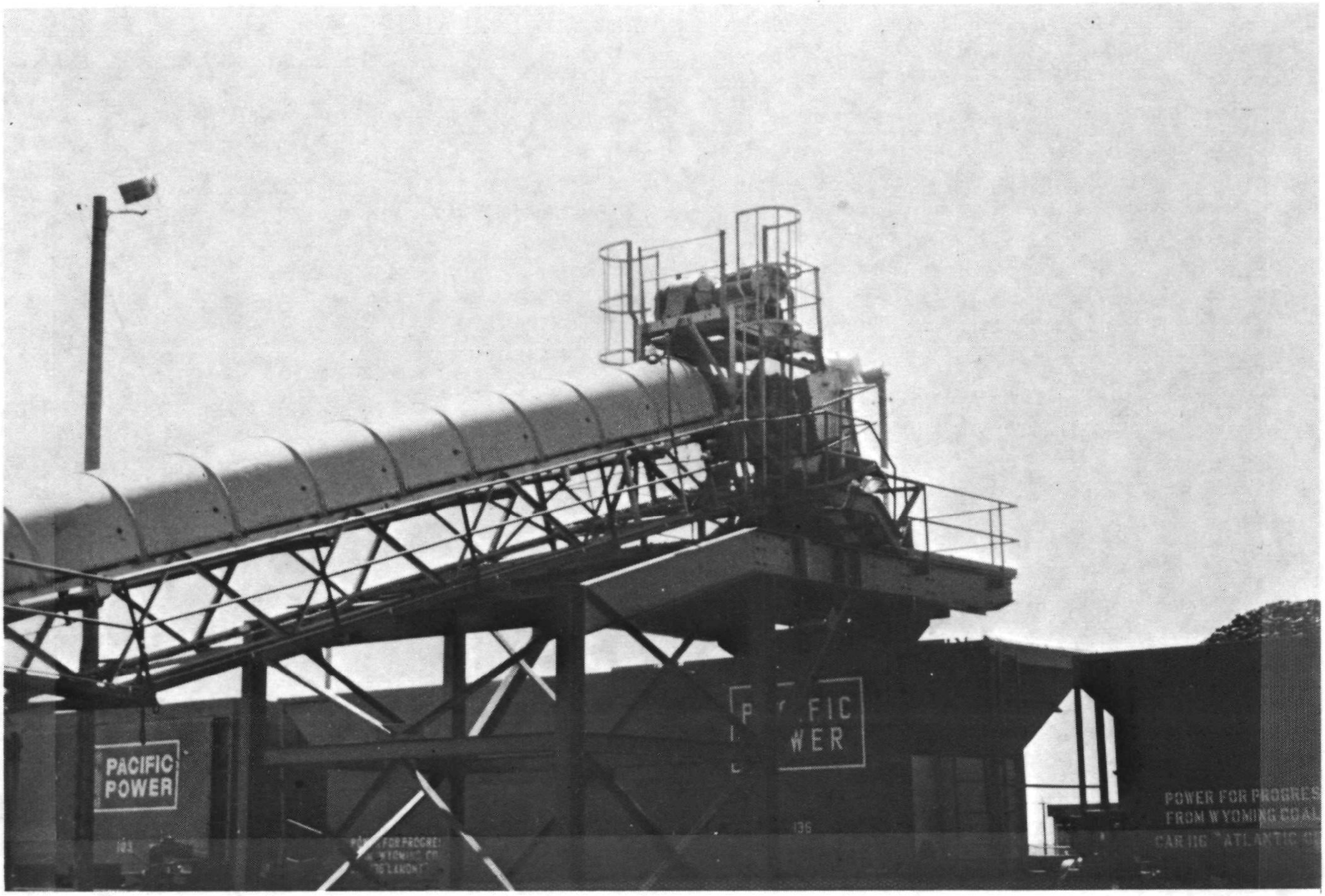

Figure 3.7. Transfer and conveying.

mines, there are no belt conveyors or similar transfer processes; the material is moved by truck to the tipple and loaded directly onto trains. At other mines, extensive networks of unenclosed conveyors are used, such as with bucket wheel excavators. Also, the emissions from conveying different materials vary greatly, depending in part on size distribution and moisture content.

ERT proposed a single emission factor for the combined processing sources at coal mines in northwestern Colorado--0.44 lb/ton (0.044 percent of material processed with half of these emissions fugitive dust). The processing sources at these mines were identified as transfer and conveying, crushing, and storage. Since other emission estimates are available specifically for the crushing and storage operations at coal mines, a value for conveying can be determined by subtraction from the overall ERT emission factor. Using the higher of alternative emission estimates for crushing and storage of 0.18 lb/ton and 0.054 lb/ton, respectively, the indicated emission rate for conveying would be 0.20 lb/ton. This seems to be excessive in comparison with estimates for conveying other material, and may be an indication that other unidentified particulate sources are also included in the ERT emission factor for the processing area. The value of 0.20 lb/ton does not account for the relatively high control efficiencies, usually at least 90 percent, associated with enclosed transfer and conveying systems.

The Hittman report stated that coal conveyor systems "are either covered or operated at such a speed that dusting does not occur to any great extent." Also, it was pointed out that only a small proportion of coal transport is done by this method. However, the same report used a value of 0.04 percent, or 0.8 lb/ton, loss through spillage at conveyor transfer points. Even if only a few percent of the spillage losses are in the form of dust, emissions from coal conveying would be comparable to those from coal storage piles.

Monsanto Research sampled conveying operations at a granite quarry and determined that fugitive dust emissions from conveying crushed granite are also negligible.[14] The report did not mention whether the conveyor was enclosed.

Monsanto Research also sampled storage and handling operations for phosphate rock and derived an emission factor of 0.35 lb/ton for the combined operations.[23] With a stated emission factor of 0.20 lb/ton for storage, the indicated emission rate for handling (conveying and loading onto railroad cars after drying) is 0.15 lb/ton. It is assumed that all the handling following drying is in enclosed, controlled systems.

PEDCo developed an emission factor for transfer and loading of dry phosphate rock which agrees well with Monsanto Research's factor. The PEDCo emission estimate of 1.5 lb/ton uncontrolled, with average control efficiencies of 90 to 95 percent, was developed from source test data and company estimates provided by six phosphate industry plants in Flordia.

3.8 CLEANING

Description

Cleaning or beneficiation of the ore improves the quality of the mined material by separating undesired components at the mine site. This operation greatly reduces the amount of material which must be shipped to the processing plant and also decreases solids handling and disposal problems in all subsequent refining steps (or the combustion process in the case of coal).

By far the most common method of beneficiation is froth flotation, where a slurry of the crushed ore is subjected to aeration in the presence of reagents which selectively separate the mineral being mined from other material in the deposit. In order for the flotation process to work properly, the ore must be crushed or ground small enough to liberate the mineral being extracted. Metallic ores are generally ground finer than 48 mesh and coal and most non-metallic ores should be 20 mesh or finer.

In flotation machines, the ore is suspended in water at a loading of 15 to 35 percent solids by means of air or mechanical agitation. Surfaces of the mineral particles are treated with chemicals called promoters or collectors which make the particles aerotropic and hydrophobic. With continued aeration or agitation and the addition of a frother, a layer of foam forms at the water surface. The treated mineral particles become attached to air bubbles, rise to the surface, and are skimmed off. Untreated components collect in the bottom area and are drained off as underflow. The valuable concentrate from froth flotation may be either the froth product or the underflow product. Metallic sulfides of copper, lead, zinc, nickel, mercury, and molybdenum collect in the froth.

The initial low-grade concentrate may be processed through a second "cleaner" flotation cell to remove additional extraneous material. The tailings from the cleaner cells are recirculated through the system or concentrated separately in additional cells. Regrinding of these middlings is necessary in many ores. The tailings or waste material from the flotation machine are discarded in slurry form for easier transport. The final concentrate is dewatered in thickeners and filters prior to shipment.

Well over 90 percent of non-ferrous metallic ores are concentrated by froth flotation prior to smelting.[24] Most of the phosphate rock fines in Florida are recovered by flotation. About 70 percent of the coal from underground mines and 30 percent from surface mines are subjected to some type of mechanical cleaning--by jigs, concentrating tables, dense media, or flotation. Of the coal that is cleaned, about 20 percent is thermally dried.[9]

Emission Estimate

Much of the cleaning operation is performed in water, and even after the concentrate or cleaned material is dewatered it is still wet and non-dusting. Only if an unusual cleaning process such as magnetic separation, dry tabling, mechanical classification, or air blowing is used does this operation have any potential for fugitive dust generation.

Thermal dryers at coal cleaning plants are significant particulate air pollution sources, but they would not be categorized as fugitive dust sources. Emission estimates for the common types of coal dryers are presented in EPA's Compilation of Air Pollutant Emission Factors, along with estimated efficiencies of various control devices:

Type dryer	Uncontrolled emissions, lb/ton
Fluidized bed	20
Flash	16
Multilouvered	25

Cleaning has been included as a mining operation with potential for fugitive dust emissions mainly for completeness. At most mines, there are no emissions associated with this operation. No emission factors were found in the literature for sources other than the thermal coal dryers.

3.9 STORAGE

Description

This operation involves any open storage pile of the mined material that is located at the mine site, either prior to or after some initial processing. The storage piles may be short-term with a high turnover to accommodate irregular daily or weekly throughput rates for different sequential processes, or may provide a long-term reserve for emergency supplies or to meet cyclical seasonal demands. Frequently, however, there is no stockpiling of material at the mine site because of the extra handling required.

The material is usually placed on the storage pile by means of a tipple arrangement or a conveyor, as shown in Figure 3.8. Equipment such as bulldozers, front-end loaders, and small shovels may be used to move material within the storage area or position it for loading out of storage.

The emission estimates presented in this section are, with the exception of dry phosphate rock, for unenclosed storage piles. In cold or wet climates, the material may be placed in storage silos from which it can be loaded directly into unit trains. Silos vary in diameter, height, and number depending on mine production and train scheduling. For coal, silos about 150 ft high and 70 ft in diameter with a capacity of approximately 11,000 tons are typical. The only fugitive dust losses associated with silos or other enclosed storage facilities are from transfer and conveying, which are considered as a separate operation (see Section 3.7).

Also, the storage operation as defined herein does not include topsoil or waste material storage. These are also parts of other operations, reclamation and waste disposal.

Figure 3.8. Storage.

Emission Estimate

Fugitive dust emissions from the storage area occur as a result of several activities. According to sampling data compiled and evaluated by Midwest Research Institute,[12] the four major emission-producing activities and their approximate relative contributions for crushed rock storage are:

Loading onto piles	12%
Equipment and vehicle movement in storage area	40%
Wind erosion	33%
Loadout from piles	15%

Although the percentage contributions from these activities may vary for storage of different materials or for specific storage area configurations, the same activities are probably the major dust sources for all types of open storage.

The MRI study produced emission factors applicable to a wide range of aggregate storage operations, possibly including crushed ore storage. These values are summarized in Table 3.2. MRI also developed a climatic factor to correct the emission estimates shown in Table 3.2 for different geographic areas: $(100/PE)^2$, where PE is the annual precipitation-evaporation index.[a] EPA has adopted the MRI emission factor based on tonnage throughput for storage piles with a normal mix of activity for publication in the latest supplement to their Compilation of Air Pollutant Emission Factors: $0.33/(PE/100)^2$ lb/ton.

The Hittman report contained emission estimates for aboveground coal storage for only two coal mining areas, the

[a] A national map showing PE values for all parts of the country can be found on p. 99 of EPA's Compilation of Air Pollutant Emission Factors, Supplement No. 5.

Table 3.2. EMISSION FACTORS FOR CRUSHED ROCK STORAGE PILES

Activity rating	Emission factor lb/acre of storage/day	 lb/ton placed in storage
Active[a]	13.2	0.42
Inactive (wind erosion only)	3.5	0.11
Normal mix[b]	10.4	0.33

[a] Eight to 12 hours of activity per 24-hr period.

[b] Five active days per week.

Source: Development of Emission Factors for Fugitive Dust Sources, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, Publication Number EPA 450/3-74-037, June 1974.

Northwest (Powder River Basin) and the Southwest (Four Corners area). In the Northwest, emissions were assumed to be "minimal" because of the rapid turnover of coal in storage. The emission factor for coal storage in the Southwest was 0.0235 lb/ton, based on the average wind erosion rate for arid portions of the Great Plains, 428 lb/acre/yr. The coal at the single mine for which this estimate is applicable is stored in piles 90 ft wide, 800 ft long, and 30 ft high, containing about 30,000 tons of blended coal.

A coal storage pile was sampled for dust losses by Monsanto Research. On two separate runs, the coal pile produced emissions at rates of 0.009 and 0.016 lb/ton in the pile (static rate); these were converted to an annual emission rate of 0.054 lb/ton placed in storage by use of additional information on the storage throughput rate.[23] It was indicated that no loading or unloading took place in the storage area during either of the sampling periods.

Monsanto Research performed a similar sampling study for a phosphate rock storage pile and developed an average emission factor of 0.20 lb/ton of "wet" rock in open storage. The phosphate rock may be shipped wet to the chemical processing plant or it may be dried at the mine site. Because of the difficulty in handling the material after it has been dried, the trend is toward locating the driers and grinders at the chemical processing plant rather than at the mine. However, if the phosphate rock is dried on-site, then subsequent storage prior to shipment is a major fugitive dust source even though the dry phosphate rock must be stored in an enclosure. EPA's published emission factor for transfer and storage of dry rock is 2.0 lb/ton uncontrolled.[20] Source test data and company estimates of material loss collected by PEDCo for nine phosphate industry plants and mines in Florida indicated exactly the same average uncontrolled emission rate as the EPA value--2.0

lb/ton. Overall control efficiencies for storage buildings of 90 to 95 percent can be obtained by use of baghouses or scrubbers on vents and at transfer points within the building.

3.10 WASTE DISPOSAL

Description

In the mining and beneficiation of minerals and ores, large amounts of waste material are often generated. Examples of this waste material are low grade ore, slack coal, extraneous unmarketable rock of relatively large size, tailings, coal slurry, and mud slime. The waste may have the same handling characteristics as the raw material being mined and be disposed of in a fill such as shown in Figure 3.9 (e.g., a waste dump, leach pad, or gob pile), or the waste may be a slurry resulting from a cleaning or separation process which requires ponding.

The waste disposal operation is distinguished from overburden disposal because in most cases the area used for wastes is not reclaimed. The wastes are segregated and saved for future reprocessing, for byproduct recovery, or because they contain higher concentrations of toxic materials than the overburden. If the waste contains no potentially recoverable material and its toxic components do not create a leaching problem, it can be buried in the spoils for disposal.

Some of the activities associated with waste disposal are the same as for the mining of the ore, i.e., truck loading and dumping, haul road traffic, scraper operation, and grader operation. For purposes of estimating emissions by unit operation at the mine, movement of waste material should not be considered a distinct operation from the

Figure 3.9. Waste disposal.

Source: Environmental Protection in Surface Mining of Coal, U.S. Environmental Protection Agency, EPA 670/2-74-093, 1974, p 66.

primary activity (e.g., shovel/truck loading) unless it employs different equipment or occurs at a separate location such as the dump site.

The other aspect of waste disposal is the disposal site itself. If berms or dikes are constructed to contain a slurry waste, this activity is part of the waste disposal operation. Also, dried or inactive ponds of fine waste material, particularly copper tailings, are subject to severe wind erosion if they are not stabilized.

Waste disposal at coal mines creates another potential particulate air pollution source--spontaneous combustion of coal refuse piles and gob piles. However, burning coal waste piles are not fugitive dust sources, so they are not included within the scope of this report.

Emission Estimate

Excluding the disposal site, most of the fugitive dust-producing processes associated with waste disposal utilize the same equipment and activities as used in other mining operations. Therefore, their emissions can be estimated by comparison with these operations and application of appropriate emission factors.

The equipment activity which occurs at the disposal site, such as berm construction or grading of a leach pad, can generally be categorized as heavy earthwork construction. It may be appropriate to apply the emission factor for heavy construction from Supplement 5 of EPA's Compilation of Air Pollutant Emission Factors--1.2 ton per acre of active construction per month. However, this value is applicable only in arid Western areas in which the sampling to develop the emission factor was done.[12]

Emission estimates for dried tailings have been developed by PEDCo with use of the U.S. Department of Agriculture's wind erosion equation.[25] These estimates are a function of regional climatic conditions and assume no surface crusting:[17]

Climatic factor[a]	Emissions, ton/acre/yr
0.1	1.3
0.2	2.6
0.3	4.0
0.4	5.3
0.5	6.6
0.6	8.0
0.7	9.3
0.8	10.6
0.9	12.0
1.0	13.3
1.2	16.0

If complete crusting of the fine tailings material does occur, emissions are reduced by about 80 percent. Approximately the same emission reductions can be achieved by either chemical or vegetative stabilization of the tailings.

For most waste dumps and gob piles, there are emissions when the material is dumped onto the pile but probably no additional emissions from wind erosion due to a lack of small particles on the surface.

No other references were found which identified waste disposal operations as significant fugitive dust sources. With the exception of tailings pile erosion at certain types of mines, waste disposal is generally a very minor dust-producing operation.

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[a] See Figure 3.11 for climatic factors for all parts of the country.

3.11 LAND RECLAMATION

Description

All surface mining causes considerable alteration of the land on which it occurs and a certain amount of the surrounding area as well. Experience has shown that the most successful land reclamation results where programs are preplanned by the mine operators and become a concurrent part of the daily operation of the mine.[16] Segregation of the various strata in overburden removal is critical so that inferior spoil can be buried under clean fill, with topsoil returned to the surface to ensure successful revegetation.

This practice of continuous reclamation has already been introduced in Section 3.1 where the earth moving aspects of overburden removal were considered. In area strip mining, draglines fill mined strips with overburden removed from succeeding strips and topsoil is placed on top to prevent rehandling. In contour mining, the reclamation follows a pattern of grading and backfilling the bench between the highwall and the downslope. In this type of surface mining, the topsoil can be stockpiled for a limited time and replaced after the mining and grading have been completed. In contour mining by the block cut method, topsoil is removed and placed on graded areas in a single operation.

Success in reclaiming mined land is determined to a large extent by geographic location and climatic conditions. Each location has its own inherent problems to be dealt with if an area is to be returned to the original topography. In contour mining operations in the East, careful practices of grading and backfilling can return natural drainage patterns and contour to the land. Use of trees alone to revegetate these areas was found to be unsatisfactory, due to the length of time required for the trees to establish themselves and the loss of soil by erosion in the interim. Presently, herbaceous species are preferred to stabilize the land rapidly and plant covers suitable to the area are selected to control erosion, siltation, dust, and acid formation. In addition, seeding is no longer limited to the spring. Selecting species appropriate to the season when planting is needed and following with a perennial species in spring or fall provides optimum conditions for revegetation. In these Eastern states, as well as those Central states where contour mining is used, a period of two to three years is required to reach this condition.[9]

In Florida, area mining is practiced where phosphate rock is mined. Draglines strip overburden and fill the previous strip with this material in a single operation. The overburden is approximately 20 ft deep, with phosphate deposits of some 16 ft lying below. Land reclamation generally results in an area being filled and then graded to a level somewhat less than the original topography. Since the water table is comparatively close to the surface, this depression usually creates lakes but the process is completed and the area stabilized in one to two years.[26]

Area mine reclamation in Midwestern states poses the fewest reclamation problems. These lands can be returned to their original topography by spoil segregation, backfilling, and grading as deposits are removed. Compaction of the soil can be controlled with conventional equipment, and this ground preparation for revegetation is aided by a climate that provides sufficient annual precipitation.

Reclamation in the West is another matter. Here the seam thickness of deposits mined is much greater and the original elevation cannot be restored. If a pattern of continuous reclamation is used at these mines, the overburden is deposited by draglines parallel to the strip being mined; smaller draglines or bulldozers then level these deposits to reduce slopes. This returns the area to a topography that will meet proper conditions for land stability, drainage control, and maintenance of vegetation. A recently regraded area is shown in Figure 3.10. The process of reestablishment is estimated to require a minimum of five years. Due to the arid or semiarid climate, successful reclamation to native climax vegetation is questionable. The extreme climatic conditions, with a seasonal variation of -60 to 120° F and an annual precipitation for 75 percent of the area of less than 20 inches, create a soil of highly saline condition that contributes to a lack of adequate topsoil. Wind also erodes this unprotected soil, adding to the problems of reestablishment. It is possible to regrade this disturbed land but knowledge for successful seeding and procedures for revegetating the area are not yet adequate. In certain areas, such as the rimrock country in eastern Montana, it has been recommended that no mining be permitted in certain deposits. Here it would be impossible to restore the original drainage patterns and slopes.

The amount of soil loss due to wind erosion of the barren land prior to revegetation is a function of the surface soil type, roughness of the surface, windspeed, average surface moisture content, and unsheltered distance across the regraded area. Obviously, the total wind erosion losses from a reclaimed area are directly proportional to the length of time to establish protective vegetation on the surface. While these wind erosion losses are low level except during wind storms, they occur fairly continuously over the entire reclamation area and therefore may produce more fugitive dust than the mining and processing operations in some high wind erosion areas of the country.

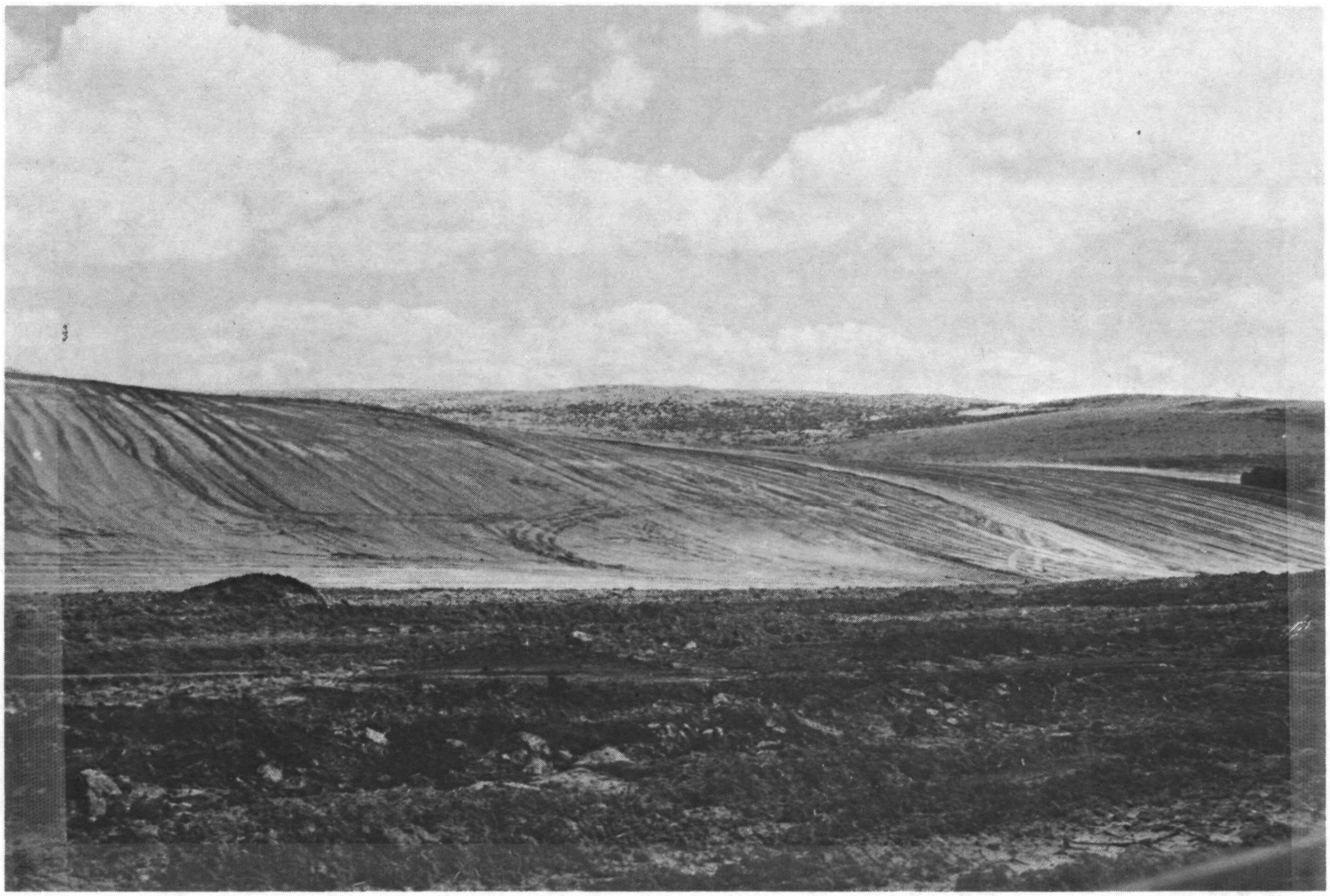

Figure 3.10. Reclamation.

Emission Estimate

For continuous reclamation, the earth moving by the dragline and scrapers produces a large amount of fugitive dust, but these emissions are already included as part of the overburden removal operation. If the topsoil is stored and later redistributed or if a smaller dragline or bulldozer is used to grade the spoils area before applying the topsoil layer, emissions from these activities can be estimated with the same emission factors as for overburden removal.

All other emissions associated with the reclamation operation are due to wind erosion over the unreclaimed or partially reclaimed land. Emissions from wind erosion across cleared or unprotected soil surfaces have been estimated by use of the U.S. Department of Agriculture's wind erosion equation in several recent studies. The wind erosion equation was originally developed to estimate soil losses from cropland, but has been adapted[12] to predict the suspended particulate fraction of total soil losses and has been applied to evaluate exposed soil surfaces other than cropland.

The modified wind erosion equation is as follows:

$$E = a\ I\ K\ C\ L'\ V' \qquad \text{(eq.2)}$$

where E = emission factor, ton/acre/yr

a = portion of total wind erosion losses that would be measured as suspended particulate

I = soil erodibility, ton/acre/yr

K = surface roughness factor

C = climatic factor

L' = unsheltered field width factor

V' = vegetative cover factor

In this equation, K, C, L', and V' are all dimensionless.

Some recent work[27] has indicated that the variable "a," as well as I, is related to soil type. Values for "a" and I which might be appropriate to surface mined areas during or following regrading are summarized below:

Surface soil type	a	I, ton/acre/yr
Rocky, gravelly	0.025	38
Sandy	0.010	134
Fine	0.041	52
Clay loam	0.025	47

Values for K can vary between 0.5 and 1.0, with 0.5 denoting a surface with deep furrows and ridges, which protect against wind erosion, and 1.0 denoting a smooth erodible surface. Unless the surface of a regraded spoil area has been plowed or roughened, a K factor of 1.0 should be used in the wind erosion equation.

Climatic factors (C) for use in the equation have been determined for most parts of the country by USDA, as shown in Figure 3.11 (the values in the figure should be multiplied by 0.01). For exposed areas greater than about 2000 ft wide, the field width (L) no longer affects the emission rate and L' = 1.0. For smaller reclamation areas in irregular terrain where the field width is only about 1000 ft, the L' value is approximately 0.7. Since there is little or no vegetation on the recently regraded surfaces, V' in the equation is almost always 1.0.

By substituting the appropriate data into the wind erosion equation, the annual emission rate for any specific situation can be calculated. This estimated emission rate (E) is then multiplied by the number of barren acres at the mine during a particular year to determine total fugitive dust due to wind erosion. For a more detailed explanation

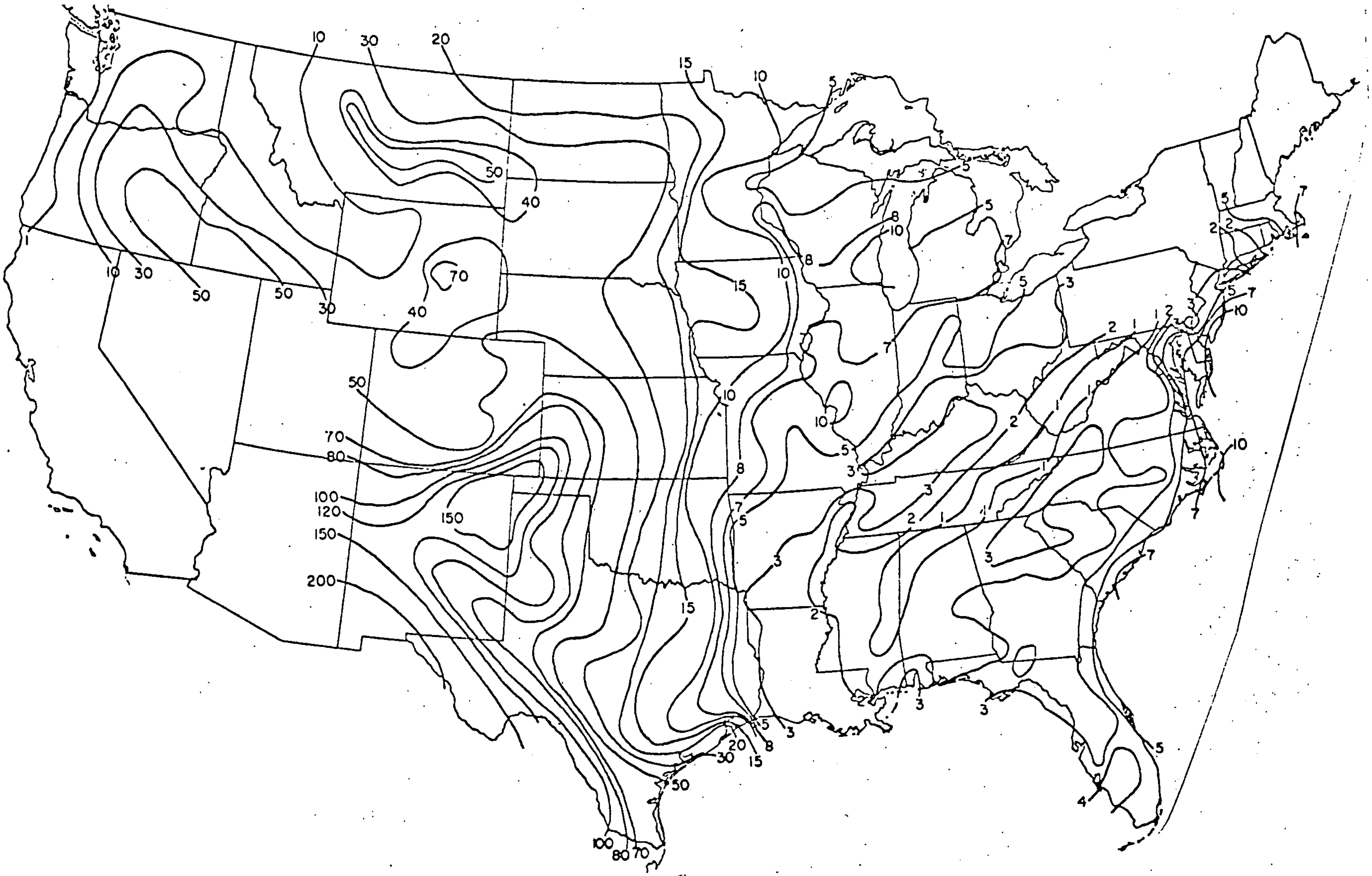

Figure 3.11. Climatic factors for use in the wind erosion equation.

Source: Armbrust, D. V. and N. P. Woodruff, 1968.

of the modified wind erosion equation, see Appendix A of Development of Emission Factors for Fugitive Dust Sources.[12]

While this method of estimating wind erosion emissions is acknowledged to have limited accuracy, no other method has been proposed. All efforts to quantify wind erosion emissions which were found in the literature used some published USDA data on annual soil losses per acre as their basis. Because the emission rates per unit time from wind erosion are very low and highly variable, it is not possible to check the accuracy of the estimates by comparison with source sampling results.

4. SUMMARY

Eleven different mining operations were evaluated for their potential as fugitive dust sources. Although these operations do not have the same emission rates at all mines or in all mining industries, the intent of this report was to identify operations that may be major dust sources at mines.

Emission estimates for the mining operations are summarized in Table 4.1. These estimates should be used only after reviewing the descriptions in Chapter 3 relevant to their development and applicability. From these emission estimates and typical production rates, it can be determined that the approximate ranking of operations in order of decreasing emission rates is:

1. Overburden removal
2. Haul roads
3. Reclamation
4. Storage
5. Shovels/Truck loading
6. Transfer and conveying
7. Truck dumping
8. Blasting
9. Crushing
10. Waste disposal
11. Cleaning

Overburden removal is much more of a dust problem at surface coal mines and phosphate rock mines than at copper

Table 4.1. SUMMARY OF EMISSION ESTIMATES FOR MINING OPERATIONS

Operation	No. of emission estimates	Range	Units	Emission factors by industry				More data needed
				Coal	Copper	Rock	P_2O_5 rock	
Overburden removal	5	0.0008-0.45 0.048-0.10	lb/ton of ore lb/ton of overburden	0.05	0.0008			x
Blasting	2	0.001-0.16	lb/ton of ore					x
Shovels/Truck loading	5	neg-0.10	lb/ton of ore	0.05	0.05	0.05	NA	
Haul roads	4	0.8-2.2	lb/VMT	depends on speeds & controls				x
Truck dumping	3	0.00034-0.04	lb/ton of ore	0.02	0.02	0.04	NA	
Crushing	4	neg-0.7	lb/ton of ore	neg		0.044		x
Transfer & conveying	5	neg-0.2	lb/ton of ore				0.15	x
Cleaning	0	usually negligible			neg		neg	
Storage	5	0.0235-0.42 3.5-13.2	lb/ton of ore lb/acre/day	0.054	0.33	0.33 10.4	0.20	
Waste disposal	1	neg-14.4	ton/acre/yr					
Reclamation	1	use wind erosion equation	ton/acre/yr	depends on climate & soil				x

NA = not applicable

mines and rock quarries because of the greater amounts of overburden material handled in the former mines. Fugitive dust from reclamation is also associated primarily with coal mining and phosphate rock mining, and results from regrading of the spoils and wind erosion across the regraded surfaces. Haul roads are a major dust source at almost all mines, even though they are normally kept watered. The remaining operations generate dust through the handling or processing of the material being mined. Because of this, emission rates for most of them are highly dependent on the characteristics of the material as mined, i.e., moisture content, amount of fines, hardness.

Some of the operations create dust only in a few instances, such as copper tailings as a waste disposal source or air blowing as a cleaning process for coal. Waste disposal and cleaning operations generally are not significant fugitive dust sources at mines.

In order to estimate the fugitive dust emissions that stay suspended, an attempt has been made to express the emission factors in terms of the fraction less than 30 microns diameter wherever possible. Since data were not available to do this in all cases, some of the reported emission estimates may overstate the impact of those operations on a regional scale.

Table 4.1 also notes those operations for which more sampling or emission data are needed before reliable emission factors can be developed. More than half the operations, including those indicated to be the three largest sources at mines, are on this list. Many of these operations have not been sampled previously because of extreme difficulties in defining a representative process for sampling or because of special technical problems such as those encountered with measuring blasting or wind erosion emissions.

The air quality impact of fugitive dust from a specific mining industry is a function of the number of mines and the population exposed to their emissions. There are a relatively large number of coal mines. The dusty Western surface mines are in remote locations, but the Midwest surface mines, although less dusty, are often in areas of moderate population density. There are relatively few copper mines and these are in isolated locations except for the mines near Tucson, Salt Lake City, and Butte. In all three of these cities, fugitive dust from mining is shown to cause increased urban particulate concentrations. Stone quarries account for the most mining sites and they are often located near urban areas to reduce transportation costs. Phosphate rock is produced from relatively few mines, mainly in a limited area of west central Florida. With the exception of the cities of Lakeland and Winter Haven, population exposure to these mining emissions is low.

The air quality impact of mining emissions is attenuated by two additional factors. At many of the larger mines, the dust-producing activities occur in a pit that is considerably below surrounding ground level. Emissions from a depressed level have a lesser impact on ambient concentrations than the same emissions would have at ground level or from an elevated source. At other large mines, the property extends for many miles from the points of emission origin so that concentrations may be negligible by the time the dust plume reaches a property line.

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