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SURFACE MINING OF COAL A DISCUSSION OF MINING METHODS

SURFACE MINING OF COAL

A DISCUSSION OF MINING METHODS, RECLAMATION PRACTICES AND ENVIRONMENTAL REGULATIONS OF FOREIGN COUNTRIES

PREPARED FOR

THE U. S. GEOLOGICAL SURVEY

BY

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INTRODUCTION

Stated in the simplest terms, surface mining consists of nothing more than removing the topsoil, rock and other strata that lie above mineral or solid fuel deposits to recover them. In practice, however, the process is considerably more complex.

When compared with underground methods, surface mining offers distinct advantages. It makes possible the recovery of deposits which, for physical reasons, cannot be mined underground; provides safer working conditions; and, most significantly it is generally cheaper in terms of cost-per-unit of production.

Surface mining is not applicable to all situations, however, because the ratio between the thickness of the overburden that must be removed in order to recover a given amount of product places a definite economic limitation upon the operator. While this ratio may vary widely among operations and commodities owing to differences in the characteristics of the overburden, types and capacities of the equipment used, and in value of the material being mined, it is nevertheless the factor that primarily determines whether a particular mining venture can survive in a competitive market.

In the past the mining industry's primary assignment has been to provide minerals and fuels to meet the nation's need at the lowest possible cost. In a number of cases, environmental protection now is taking precedence over lowest cost as the prime objective. An added demand now is that these materials be produced with a minimum of undesirable environmental disruption. This was recently discussed by Risser*, who states:

"While some of the public realize that increased costs will be involved in this shift of emphasis, it is doubtful that the general public fully recognizes the extent of these costs or the fact that they must ultimately be borne by the consumer through increased prices if production is to continue.

As the effort toward environmental improvement progresses and the relative magnitudes of both the costs and benefits become more apparent, a greater public tendency to balance one against the other may develop. It may be decided, that beyond a certain point, the incremental benefits do not justify the added costs. Nevertheless, there is a public mood today that reflects a strong conviction that the quality of the environment must be protected from further deterioration, and the official government attitude reflects that public mood. An effort to point out the magnitude of the costs involved in complying with new regulations is unlikely to receive much sympathetic attention today. Nor will the fact that a proposed regulation or procedure appears completely impractical or infeasible necessarily mean that the legislation requiring such procedure will not be enacted.

Still another way in which some environmental effects may be reduced is through improved technology in the production and use of minerals and fuels. Such technological improvements may or may not result in increased costs. They may, in fact, bring the desired results at a reduced cost. But new technology does not just happen. Its development requires time, concerted effort, and increased investment".

It is hoped that the following discussion on mining methods, reclamation practices, and environmental regulations of foreign countries will benefit the improvement of technology in a most important area, namely surface mining of coal, and bring about a better understanding of the problem.

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* Risser, H., E., "Environmental Quality Control and Minerals", in "Focus on Environmental Geology", Ronald W. Tank, Editor, New York, Oxford University Press, London 1973, pp. 305-307.

BASIC DEFINITIONS AND TERMINOLOGY

1. Conditions Warranting Open-Cut Work

Surface mining of coal can be justified technologically and economically when the deposit lies at relatively shallow depth. To extract the coal by an open-cut method it is necessary at first to remove certain amounts of barren rocks. This operation is called stripping and the ground removed overburden or spoil. Of importance in evaluating conditions that may warrant open-cut work is not only the absolute amount of the ground subject to removal, but its relative volume per unit of coal to be extracted. It may, for example, prove impractical to strip cover-rock strata 50 feet thick from a coal seam, if the seam itself is 5 feet thick, but it might be economical if the thickness of the seam is as much as 15 feet. The ratio of the overburden volume to the amount of coal already extracted or to be extracted, expressed in volumetric or weight units, is called the stripping ratio. When the earth's surface and the coal deposit are more or less flat, the stripping ratio is fairly uniform (see Figure 1). When the surface or deposit slopes, this ratio alters along with the increase in size of the pit (see Figure 2 and 3). For conditions prevailing in each open pit there exists a maximum proportion of the amount of waste or spoil removed to a unit measurement of the coal, which it would be uneconomical to exceed. When this limit is reached and the deposit lies much deeper still, it is more profitable to change over to underground mining. This maximum proportion depends

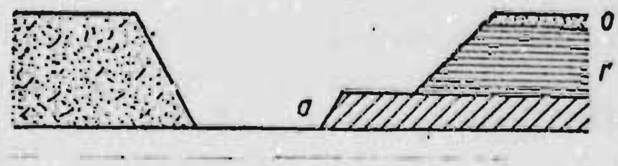

Figure 1. Open-pit layout on a flat bed with horizontal ground surface (from Shevyakov, p. 594).

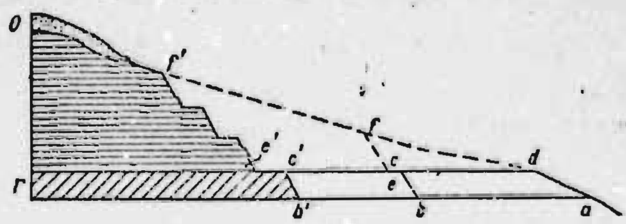

Figure 2. Open-pit layout on a flat bed with sloping ground surface (from Shevyakov, p. 594).

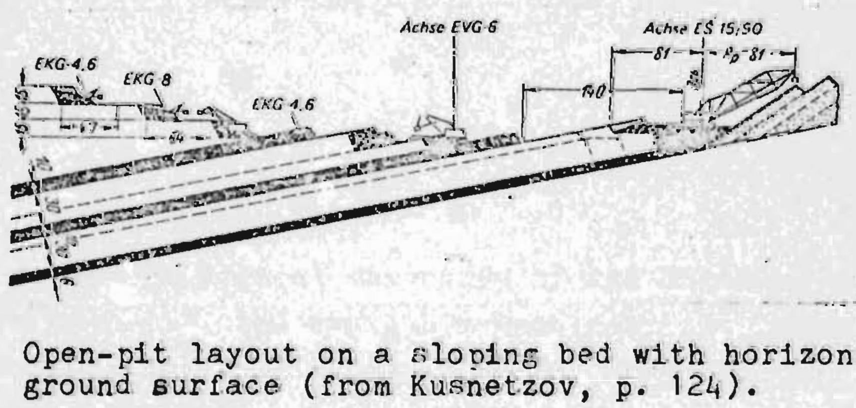

Figure 3. Open-pit layout on a sloping bed with horizontal ground surface (from Kusnetzov, p. 124).

in general on cost A charged against mining by the open-cut method of 1 cubic yard of coal, cost B of overburden stripping per 1 cubic yard and the stripping ratio. By using these symbols, we find that the total cost of mining 1 cubic yard of coal by the open-cut method, including the cost of stripping operations, will amount to

$$A + BX.$$

Conditions economically justifying the use of the open-cut method instead of underground mining will then be determined by the formula

$$A + BX < C$$

where C is the mining cost of 1 cubic yard of coal extracted by the underground method. The maximum stripping ratio X can be found from an equation expressing the cost of mining by the open-cut and underground methods

$$A + BX = C,$$

Whence

$$X = \frac{C-A}{B} .$$

Depending on the geological structure of the deposit, the size of the open-pit, the available machinery and labor, costs A, B and C may vary widely and, consequently, the differences in the value of the maximum stripping ratio are also liable to fluctuate appreciably. If, depending on the geological structure of the deposit, the stripping ratio increases as the depth of the pit increases, the maximum stripping ratio must correspond to an economical maximum depth of the pit. In Eastern Wyoming, for example, where 50 to 80 feet thick coal seams outcrop at the surface and are deposited at dips measuring only a few degrees, it is expected that area stripping using long-reach draglines equipped with 50 or 75 cubic yard buckets and 360 feet long booms, will allow open-pits to be excavated to an economical maximum depth of approximately 200 feet. Maximum stripping ratios of these pits are expected to vary between 1.4 and 2.0 cubic yards of overburden per ton of coal. The production of some surface mines in Wyoming is forecasted to reach 11 million tons of coal a year by 1980.*

Since the maximum stripping ratio may be quite different, depending on local and geological conditions and applied technology, the practice of taking "current" figures for stripping ratios as a guide for planning mining operations is to be ruled out altogether. In general, progress of mechanization in surface mining makes it possible continously to increase this ratio. In many instances, the depth of a pit is determined by a shallow occuring bottom of the deposit. In other conditions favorable for the development of open-cut mining the pits may be very deep. In the Krivoi Rog district of the U.S.S. R., for example, before it changed over to underground

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* Wyoming Coal Gas Co. & Rochelle Coal Co., "Applicants Environmental Assessment for a Proposed Coal Gasification Project - Campell and Converse Counties, Wyoming", p. III-3, (1974).

mining the pits were as much as 400 feet deep.* One brown coal pit at Korkino (Urals) is at present over 600 feet deep, and it is planned to deepen it still more. In other cases, the danger of land sliding on the slopes of a pit may require to change over to underground mining earlier than stipulated by the project. Such a situation occured at one of the open coal cuts of the Yemanzhelinka district in the Urals. And conversely, special circumstances make it emparative to continue open-cut mining at depths where underground extraction of the coal would seem more practical and economical. A typical example is the mining of thick beds of self-igniting coal.

2. Advantages and Drawbacks of Open-Cut Work as Compared to Underground Mining

Contrasted with underground mining open -cut work presents many advantages.

a. The principal advantage is that the efficiency of labor is considerably higher in open-pits, while the cost of mining is lower. In the coal industry a miner achieves 3 to 4 times as much in open-cut mining as he does underground. That is

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* Shevyakov, L., "Mining of Mineral Deposits", Foreign Languages Publishing House, Moscow, Zubovsky Blvd. 21, U.S.S.R. pp. 559 -600.

because it is possible to use highly efficient mining equipment and transport facilities, there being no limits to the overall dimensions of machines, as is the case in underground workings.

b. Large working faces and the use of highly efficient machines for the open mining of large deposits yield considerable tonnages. The same factors make it possible to increase output in a newly established open-pit much faster than in an underground mine. The reconstruction of an active open-pit enables to raise productions more quickly than is the case with an underground mine.

c. Open-pits may have a shorter service-life than underground mines, since here it is possible to transfer the costly main items of mining and transport equipment and machines to other pits for further use. Hence, pits working even limited reserves may yield larger annual tonnages.

d. Open-pits need no ground-support, filling, ventilation and artificial lighting (except at night).

e. The percentage of recovery of the coal is considerably higher in open work, amounting to 95% - almost full recovery, as compared to 50% in underground mining.

f. There is less danger of accidents. Also, added to the greater accident probabilities associated with underground mining are several industry-linked diseases by which miners are not affected working above ground. Most well known of these is the coal miners pneumoconiosis, or "Black Lung" which afflicts approximately 9 percent of all underground miners in the U.S.* However, the presence of numerous machines in the pits, the wide-flung transport network, blasting operations, and the possibility of rock slides are a constant sorce of potential accidents. Strict observance of safety rules and their enforcement, therefore, are just as imperative in the open-cut pits as underground.

The disadvantages of open-cut mining are:

a. Well developed open-cut work requires considerable tracts of land for pits and barren rocks, with the result that it is temporarely lost to agriculture, wildlife and recreation.

b. Rainfall and severe cold make work in open pits rather difficult. Large-scale operations are conducted the year round, but in severe winter conditions labor and machine efficiency drops considerably.

c. Open work at night requires large areas to be supplied with electricity for artificial lighting.

d. When larger coal beds are excavated by the open-cut

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* Lainhart, W.S., et al., "Pneumoconiosis in Appalachian Bituminous Coal Miners", U.S. Public Health Publication No. 2000, p. 137, (1969).

method, the pits at first yield lower-grade coal in the weathering zone. This decayed coal may, for one thing, be devoid of coking properties, even though normally coal in a given bed is capable of coking. These drawbacks of open-cut mining, however, are outweighed by its advantages over the underground mining method.

It was originally held that the organizational pattern of open-cut work was simpler than that of underground mining. That, however, was true only of small and primitively equipped pits. Large, modern open pits, with their heavy-duty electric and transport machinery and installations, require the elaboration of detailed mining plans, more complex than those needed for underground mining.

3. Basic Methods and Equipment Employed in Coal-Surface Mining

Open-cut methods employed to recover fuel deposits such as anthracite, bituminous and lignite are generally classified as: open-pit mining, area stripping, contour stripping and auger mining. Each has a different effect on the land.

As defined by the Department of the Interior*:

"Open-pit mining" is used to extract large, concentrated, near-surface deposits of coal and minerals. The nature of some western coal deposits is such that open-pit mining would confine the area of surface disturbance and would enhance total recovery of valuable coal.

"Area strip mining" usually is practiced on relatively flat terrain and will be the prime method of recovering coal in the Western States. A trench or "box cut", is made through the overburden to expose a portion of the deposit, which is then removed. The first cut may be extended to the limits of the pit. As each succeeding parallel cut is made, the spoil (overburden) is deposited in the cut just previously excavated (see Figure 4). The final cut leaves an open trench as deep as the thickness of the overburden plus the coal recovered, bounded on one side by the last spoil bank and on the other by the undisturbed high wall (see Figure 5). Frequently this final cut may be a mile or more from the starting point of the operation. Thus, area strip mining, unless graded or leveled usually resembles the ridges of a gigantic washboard.

"Contour strip mining" is most commonly practiced where depo-

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* "Surface Mining, Its Nature, Extent and Significance", U.S. Department of the Interior in "Focus on Environmental Geology", Ronald W. Tank, Editor, New York, Oxford University Press, London 1973. pp. 312 - 334

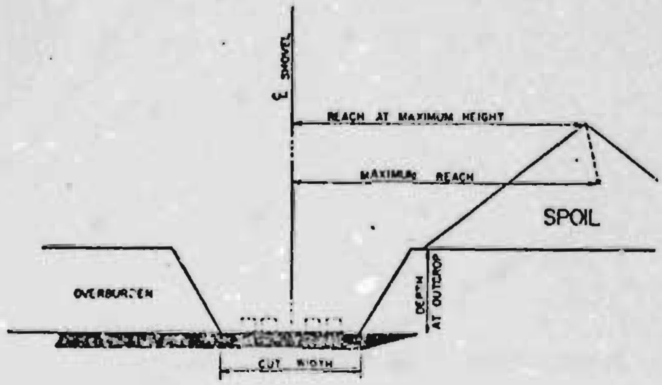

Figure 4. Cross section of the initial cut, commonly called "the box cut", by shovel operation in level terrain where the outcrop is not exposed, a common condition in level country (from Elements of Practical Coal Mining, AIME, 1973 p. 399).

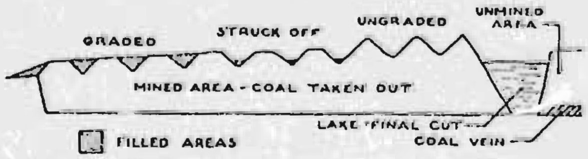

Figure 5. Typical topography resulting from complete grading, strike-off grading, no grading and the location of the final-cut lake (from SME, Mining Engineering Handbook, Vol. 2 1973, p. 17 - 146).

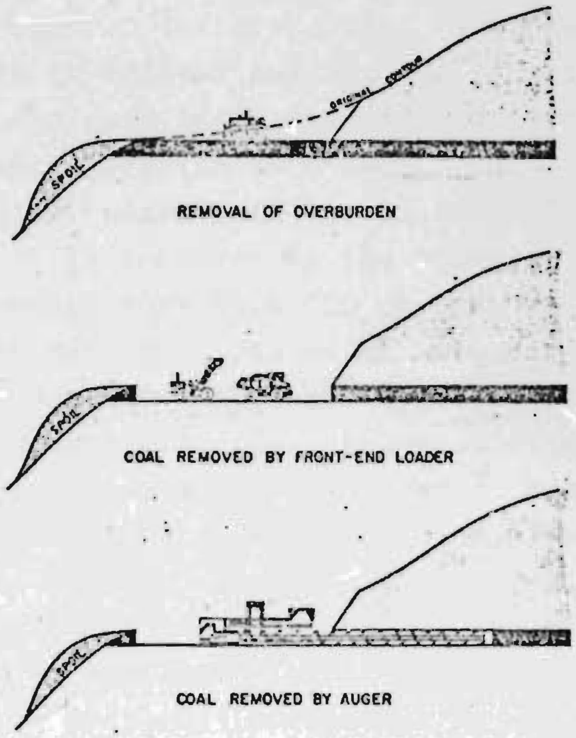

Figure 6. Sequence of development of a combined dozer-auger operation in steep terrain. Often the bulldozer merely removes enough dirt and outcrop coal to afford a face, and room, for an auger to operate. This is especially true when augering on the percipitous slopes in the Appalachians (from Elements of Practical Coal Mining, AIME, 1973, p. 406).

sits occur in rolling or mountainous country. Basically, this method consists of removing the overburden above the bed by starting at the outcrop and proceeding along the hillside. After the deposit is exposed and removed from this first cut, additional cuts are made until the ratio of overburden to product brings the operation to a halt. This type of mining creates a shelf, or "bench", on the hillside (see Figure 6). On the hillside it is bordered by the highwall, which may range from a few to perhaps more than 100 feet in height, and on the opposite or outer side by a rim below which there is frequently a precipticus downslope that has been covered by spoil material cast down the hillside. Unless controlled or stabilized, this spoil material can cause severe erosion and landsliding. Contour mining is practiced widely in the coal fields of Appalachia and western phosphate mining regions because of the generally rugged topography. "Rim-cutting" and "benching" are terms that are sometimes used locally to identify workbenches, or ledges prepared for contour or auger mining operations.

"Auger mining" is usually associated with contour strip mining. In coal fields it is most commonly practiced to recover additional tonnages after the coal-overburden ratio has become such as to render further mining uneconomical. Augers are also used to extract coal near the outcrop that could not be recovered safely by earlier underground mining efforts. As the name implies augering is a method of producing coal by boring horizontally into the seam, much like the carpenter bores a hole in wood. The coal is extracted in the same manner that shavings are produced by the carpenter's bit. Cutting heads of some coal augers are as large as seven feet in diameter. By adding sections behind the cutting head, holes may be drilled in excess of 200 feet. As augering is generally conducted after the strip-mining phase has been completed, little land disturbance can be attributed to it. However, it may, to some extent, induce surface subsidence and disrupt water channels when underground workings are intersected.

Regardless of the method used, the surface mining cycle usually consists of four steps: (1) Site preparation, clearing vegetation and other obstructions from the area to be mined, and constructing access roads and ancillary installations - including areas to be used for the disposal of spoil or waste; (2) removal and disposal of topsoil and overburden; (3) excavation and loading of coal; and (4) transportation of the coal to a concentrator, processing plant, storage area, or directly to the market.

Reclamation may not be considered by a majority as an integral component of the mining cycle. Experience here and abroad has demonstrated, that when reclamation of the land is integrated with both, the pre-planning and operational stages, it can be done more effectively and at a lower cost than as a seperate operation. This is particularly true because much of the machinery can be easily used in reducing peaks of spoil piles, segregating toxic materials and establishing controlled drainage from the site.

The rapid expansion of surface mining since World War II may be attributed primarily to the development of larger and more complex earth moving equipment. Equipment used today includes bulldozers, loaders, scrapers, trucks up to 100 ton capacity, and a miscellany of other devices. In Figures 7 and 8 a few typical illustrations of modern open pits worked by power

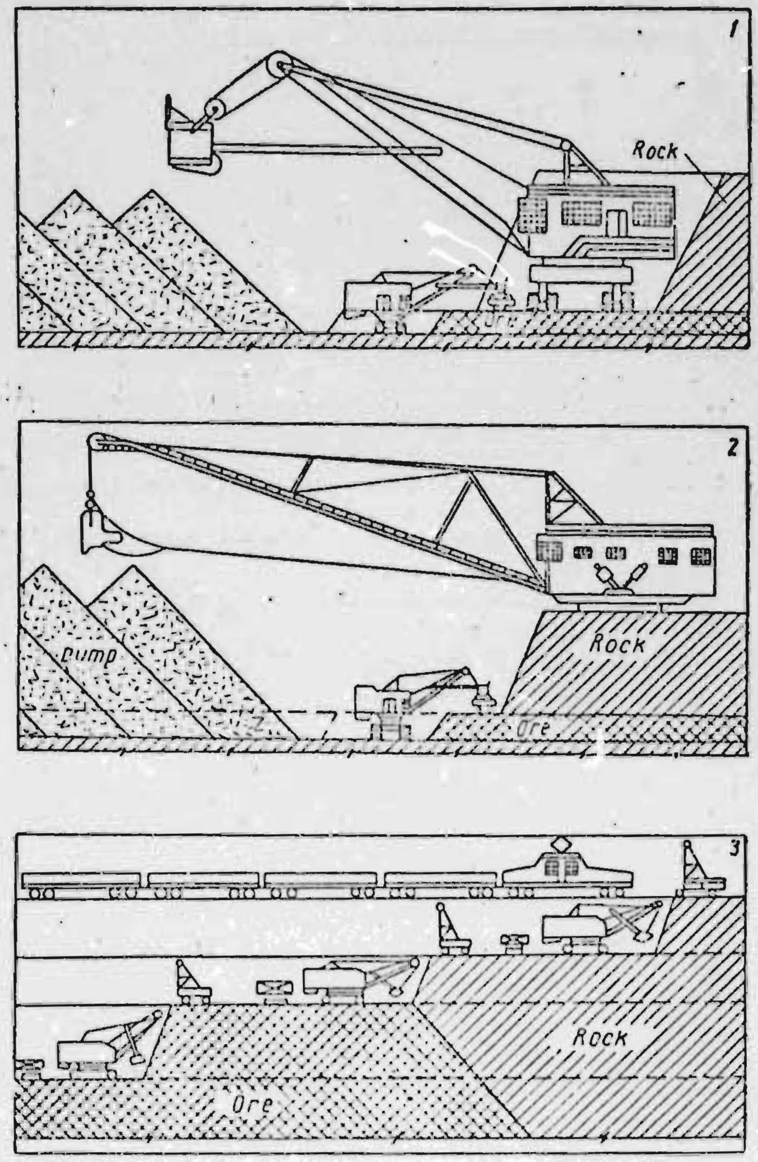

Figure 7. Basic layout patterns of mechanized open pits worked by power shovels (from Shevyakov, p. 610).

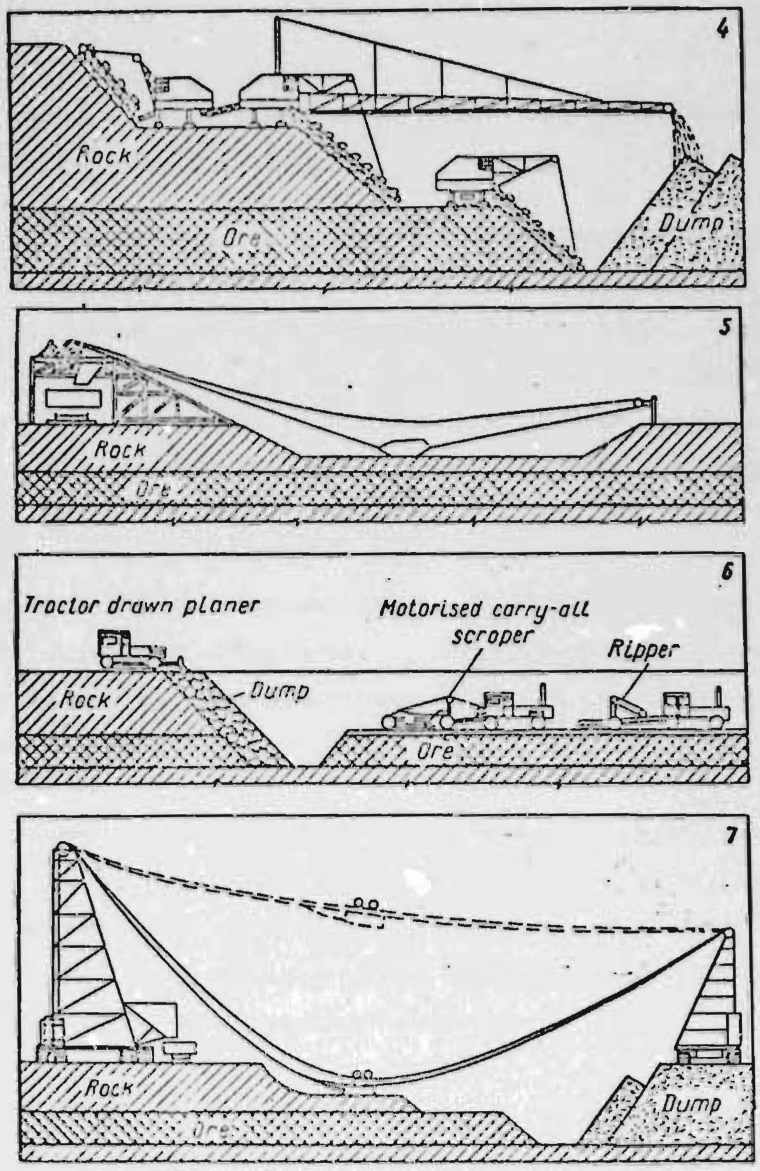

Figure 8. Basic layout pattern of mechanized open pits worked by multi-bucket excavators and scraper units (from Shevyakov, p. 611).

shovels, draglines and other equipment are presented. These may be described as follows:

1. Stripping is done by a large capacity power shovel which conveys the overburden to a waste dump. The coal is excavated by a power shovel of a smaller size, which then loads it into railway cars. (In the U.S. a shovel is now working that can handle 185 cubic yards in one "bite" with a monster having a 200 cubic yard bucket on the engineer's drawing board*).

2. The layout is the same as in 1., but overburden and coal removal are done by a dragline. (Draglines of up to 85 cubic yard bucket capacity are now operating in the U.S. and larger ones are being planned*).

3. If the material in the pit is made up of hard rock and strong coal, it is blasted. For this, blast holes are made by drilling machines. The shot overburden and coal is loaded by power shovels into railway cars which transport the material to either spoil bank or departure station.

4. The overburden covering the coal is stripped by multi-bucket excavators and is disposed of and distributed in spoil-banks by special long stacking conveyors.

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* "Surface Mining, It's Nature, Extent and Significance", U.S. Department of the Interior in "Focus on Environmental Geology", Ronald W. Tank, Editor, New York, Oxford University Press, London 1973, p. 315.

5. Mining is conducted by cable or drag scrapers.

6. Stripping of the overburden and extraction of coal is done by tractor scrapers with the use of rippers and bulldozers.

7. Overburden removal and extraction of coal involving the use of a tower or slackline cableway excavator is shown in this illustration.

4. Planning of Environmentally Acceptable Coal Surface Mining - Concurrent Planning of Mining and Reclamation

Large-scale surface mining inevitably interferes with the landscape and its natural balance. In many instances, timber is removed, wildlife habitat disrupted, agricultural land encroached upon, natural streams diverted or contaminated, and roads are built in undisturbed areas. Surface mining may also require that existing facilities such as highways, railroads, power lines, and even entire towns are relocated. To be environmentally acceptable, planning of coal surface mining must be ecologically sound. This requires that mining operations are planned concurrently with reclamation.

Reclamation can restore surface-mined lands to productivity and can create diversified country sites with forests and lakes for wildlife and recreation. It can reshape spoil piles and pit slopes to a new topography to blend into the landscape pattern. In fact, a coal mining district could serve as a model for future development in which the needs of economy, agriculture, recreation, conservation of wildlife and protection of the environment are equally met. To return the land to a desirable form and productivity including a stable ecological state that does not contribute substantially to environmental deterioration and is consistent with surrounding aesthetic values, it is essential that the likely effects of mining operations are identified in advance of actual mining so that they may be dealt with in an orderly fashion. In its simplest terms, planning for reclamation requires determination of physical and biological facts before and during mining operations, i.e., a landscape analysis which is based on careful assessment of physiographic, geologic, hydrologic, and climatic conditions of the area as well as an analysis of wildlife and vegetation.

Environmentally responsible planning of surface mining includes reclamation regulated by new mining laws. Fortunately, there now are some states in the U.S. with effective legislation regulating reclamation of surface-mined lands. Before mining operations are started, these laws require registration for a permit or license. Fees are set on a flat basis with some added amount based on the number of acres to be mined. All state laws regulating reclamation require a performance bond. A comparison of state statutory requirements regarding reclamation of surface-mined lands in the Western United States can be found in Appendix B of "Rehabilitation Potential of Western Coal Lands".*

On January 1, 1970, Congress enacted Public Law 91-190, the "National Environmental Policy Act of 1969". The Act under Section 102 (2) (c) imposes the environmental impact requirement on proposals for legislation and other major federal actions significantly affecting the quality of human environment. This means that any major disdurbance proposed for public lands must be preceded by an environmental impact statement. As stated in the National Environmental Policy Act and in supplemental guidelines from the Council on

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* "Rehabilitation Potential of Western Coal Lands", Ballinger Publishing Comp., Cambridge, Mass. (1974)

Environmental Quality*, federal agencies through the use of environmental statements must openly discuss the details of a proposed action, predict the environmental impact of the action, describe and evaluate alternatives, and seek comments from other federal and state agencies and the public before approving or performing the proposed action. If the proposed action consists of a mining operation, the impact statement for both the exploration and mining phase of the project should include a careful assessment of the physiographic characteristics and geological conditions of the area including hydrology and seismicity as well as an analysis of the atmospheric, biologic, and socio-economic environments, and an assessment of archaeological, historical, and cultural values. Included too, must be a mining plan showing the location of property lines, pit limits, access roads, and support facilities as well as transportation, water supply, and power supply systems. In addition, the mining plan must provide information and data on reserve evaluation programs, employment schedules, methods and equipment to be used for topsoil , overburden, and coal removal, coal processing and waste disposal, and objectives as well as alternatives of reclamation. Major features to be discussed in a reclamation plan should include topsoil removal and redistribution, grading to final topography, refuse handling, soil nutrients, seeding mixtures, time and rate of seeding, and reclamation of mine support facilities. Alternatives to a proposed reclamation plan should be discussed under categories of grading, land use, and revegetation.

In recent years, most European countries and the United States have enacted legislation that relates to an environmental

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* 36 Federal Register 7724-27 (1971)

objective, such as clean air or water, rather to a certain type of industrial activity. National environmental statutes have been enacted only in the United States, East and West Germany, Japan, the Netherlands, Romania, and Sweden. Switzerland is currently in the process of drafting an environmental policy act. There is no single national mining law in effect for the United States and many countries abroad. A special law, the "Act for Common Planning in the Rhineland Brown-Coal District" (Gesetz fuer die Gesamtplanung im Rheinischen Braunkohlengebiet) was enacted in Germany in April of 1950 because of the relative importance of the area. The law requires that a general plan be prepared to include management of surface waters, landscape design, and nature conservation. Single national mining laws have been proposed for Germany and Austria. These laws, if enacted will regulate mining and reclamation according to new environmental legislation already incorporated in other laws. For example, the Austrian Trade Act of 1973 (Oesterreichische Gewerbeordnung 1973, BGBL 1974/50) includes legislation on water quality standards, air pollution standards, and statutes related to solid waste disposal, noise abatement, and local zoning ordinances.

The proposed national mining legislation for Austria is of special interest, since Austria's economy depends to a great deal on tourism and exploitation of mineral resources. The conditions under which minerals are extracted in the Austrian Alps are similar to those prevailing in the Rocky Mountains. The mineral and petroleum exploitation in Austria is currently controlled by the Austrian General Mining Law of 1954 (Mining) and the Mining Law Amendments of 1967 and 1969 (Petroleum). A summary of these and other mining laws of the world can be found in the U. S. Bureau of Mines Information Circular 8631.* In 1970, the Head of the Austrian Department of Commerce, Trade, and Industry ordered the Mining Authority to draft a new mining law which aside of other important changes would include provisions for states and communities to have a stronger position in regulating matters of land use planning, tourism, nature conservation and environmental protection. The same provisions are included in a proposed new forestry law. The following is a brief discussion of the most important points of the proposed new Austrian mining law as related to environmental protection:**

1. New Regulations for Completion of Mining Activities

These regulations control reclamation of surface-mined land (establishment of green belts, planting of trees, revegetation of spoil piles, etc.), and other workings to be accomplished before a mining operation can be declared completed. As in the case of granting mining permits, the procedures require that public hearings are conducted before decisions are made approving a certain reclamation or land use plan. The public has the right to take insight into all proposals and may present state and community officials with suggestions leading

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* "Summary of Mining and Petroleum Laws of the World", Part 5-Europe, U. S. Bureau of Mines Information Circular 8631 (1974)

** Mach Weber, G., "Juridical Problems of Environmental Protection in Connection with Minerals Production and Processing", BHM, 118 Jg. (1973), H. 6, pp. 176-181 to either improvement and acceptance, or rejection of a recommended plan. In addition, it is required from the operator that he includes in his statement of completion a final working plan in which is outlined how mining operations were completed. The plan is to include maps and other data which is put on file for re-examination of the lease in case damages resulting from former workings should occur to property located on reclaimed land.

2. New Regulations for Granting Mining Permits and Permits for Constructing and Operating Plants and Facilities Related to Mining Operations

The granting of these permits involves regulating matters of land use planning, nature conservation, tourism, and environmental protection. These matters are regulated by state agencies and communities which under the proposed national mining law are strengthened in their position to enforce environmental legislation already incorporated in other laws. As discussed earlier in the report, this legislation includes statutes on water quality, air pollution, solid waste disposal, noise abatement, and local zoning ordinances. In all procedures of aquiring a mining or operator permit, it must first be determined whether the environmental impact of the proposed project will not exceed certain acceptable limits. These limits depend on pollution levels which people locally are accustomed to cope with and many other factors most of which remain unknown until after the mine or plant has been in operation for a period of time. If, the environmental impact of a proposed project is difficult to predict a permit may be granted on a trial basis. In such a case, the operator is still faced with the problem of having to comply with environmental regulations and may at a later date be required to install costly pollution devices to avoid of having his operation suspended from production.

Conflicting mineral land use problems and today's energy crisis may lead to modification of proposed European mining laws before they are enacted. The demand for land to support both urban growth and mineral development (particularly sand and gravel) has created serious social and political questions in densely populated areas. In addition, when reclamation is contemplated, disagreements often occur as to the type of land use that will contribute most to society. Land planning is essential to achieve optimum use of living space, however, in enacting legislation for environmental protection it must be kept in mind that the economy and standard of living of a country depend on its mineral resources which must be available for exploitation. A group of professors of the School of Mines in Leoben warned the Austrian Government in a recent report that the implementation of new restrictive legislation, if not carefully planned (with the advise of experts) could seriously interrupt mining operations, if not lead to a still-stand of mineral exploitation in Austria. Environmental legislation and land use planning based on suggestions made by other groups that the Alps must be preserved for the recreational benefit of all European peoples in a way that would prevent Austria's economy to grow is to be ruled out altogether.*

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* Hagspiel, W., "General Technical and Economic Problems Regarding Environmental Protection from the Viewpoint of the Rock Products Industry", BHM, 118 Jg. (1973), H. 6, pp. 161-176

5. General Layouts of Open Pits

Layouts of open pits may vary widely depending on the size and geological structure of the deposit, land topography, the planned scale of mining and the availability of transport facilities and other equipment. Pit layout patterns are classified chiefly in accordance with the arrangement of waste dumps and the development of the transportation system. Characteristic from this point of view are the following typical layouts of open pits.

a. Pits with Inside Spoil Banks

The layout of an open pit is least complicated when the overburden is overcast directly to inside waste dumps as practiced in strip mining of coal. A series of such layouts are shown in Figures 7 and 8.

Down to a certain depth open pits can be worked with overcasting or course stacking of overburden even in steep deposits. The following data on open-cut mining is from a steeply pitching 20 meter-thick seam of the Kuznetsk coal fields in the U.S.S.R.* (Figure 9). After loose silt de-

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* Shevyakov, L., "Mining of Mineral Deposits", Foreign Languages Publishing House, Moscow, Zubovsky Blvd. U.S.S.R. p. 651

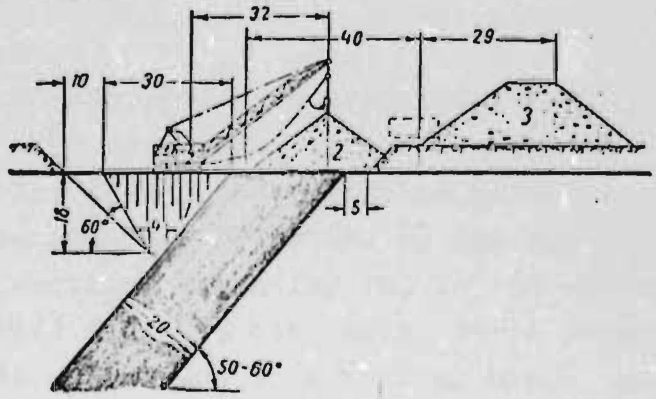


Figure 9a. Open-cut mining in the Kuznetsk coal fields using draglines for overburden removal (from Shevyakov p. 651).

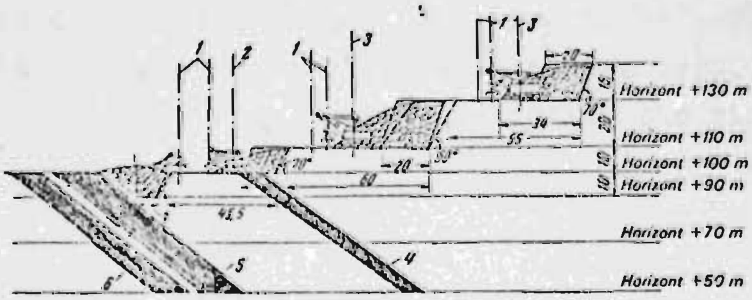


Figure 9b. Open-cut mining in the Kuznetsk coal fields using power shcvels for coal removal (from Kusnetzov 1973, p. 130).

posits have been stripped by a dragline, working trench (1) is excavated. The overburden is first overcast to a temporary waste dump (2) and later to a permanent spoil bank (3). All operations are performed by one and the same dragline over sections extending 100 to 150 meters. The coal is excavated first in one bench, 18 to 20 meters high, prepared by the excavation of a working trench, and is loaded into dump trucks. The second coal bench is worked by a shovel positioned on the first bank. The shovel dumps the the coal into piles, from which it is loaded into dump trucks. Daily output from this type of operation may be as high as 1,500 metric tons. Working faces can be prepared in 6 to 8 months. A general idea of a pit layout requiring the building of inside waste dumps with the aid of an "overburden bridge" can be obtained from Figure 10.

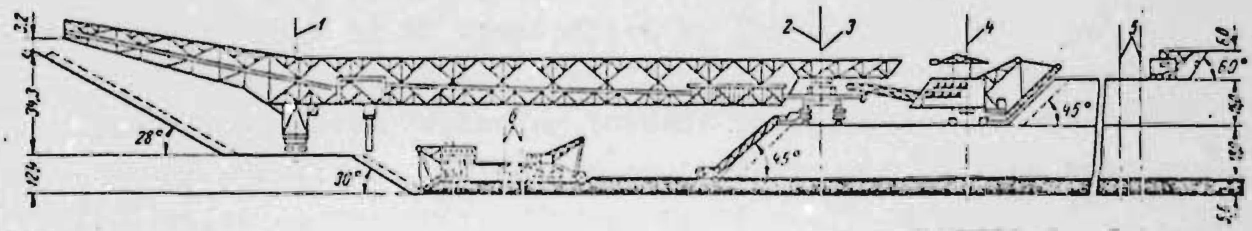
In the mining of extensive open-pit areas and flat or very gently dipping deposits, it may be desirable to transport the overburden to spoil banks in railway dump cars, although the spoil banks themselves lie inside the worked-out area.

b. Open Pits with Outside Waste Dumps

The layout and development of the railway track system, as well as of other means of transportation for open pits with outside waste dumps, may vary considerably. Some typical examples are given below.

Figures 11 and 12 are illustrative of a pit layout distinguished by the parallel disposition of stripping and pro-

Braunkohlentagebau Balachovskij



Braunkohlentagebau Morozovskij.

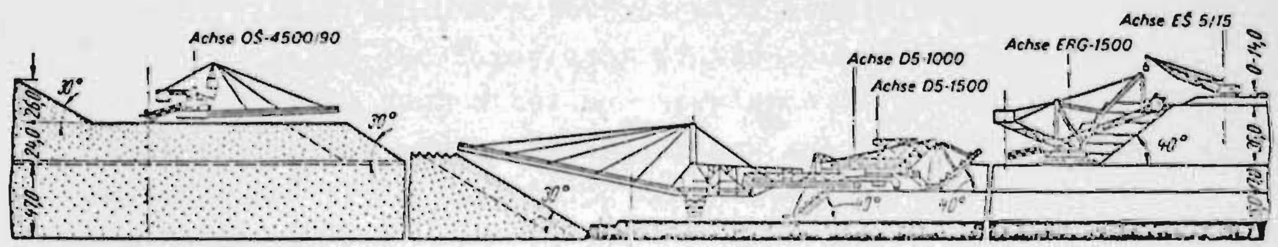


Figure 10. Open-Cast operations at the Balachovsk and Morozovsk pits of the Dnepr Lignite District, U.S.S.R. (from Kusnetzov 1973, p. 37).

duction banks and their connection with the outside road system through trenches. Figure 11 depicts stages 1-2-3 of gradual development of the pit. Stage 3 (full development of the pit) is distinguished by the fact that the spoil excavated in overburden bank h_1 is hauled to outside waste dumps via stripping trench RK, while the coal mined in bank h_2 is transported to the terminal through production trench R_1K_1. The front lines of stripping and production faces advancing towards the boundary of the pit remain parallel. The development of the pit implies the following operations: excavating of stipping trench (1), then stripping operations at large and subsequent cutting of production trench (2), and after that starting of phase (3), (actual mining of deposit). These operational stages must be coordinated in time. The location of trenches with respect to working faces, shown in Figure 11, is given approximately. Actually, the trenches may be arranged differently, although their purpose will remain unchanged. This depends on the topography of the country and the location of waste dump sites and terminals. The boundary lines of the pit may be irregular and not rectilinear, the decisive factor in this being the geological structure of the deposit.

Figure 11 depicts overburden bank h_1 and production bank h_2. If the overburden and coal deposit are of considerable thickness, there may be not one but two or many such banks. In such cases, special access ramps to individual banks are branched off from trench tracks.

The layout in Figure 11 is distinguished by the fact that stripping and production lines are laid down in separate

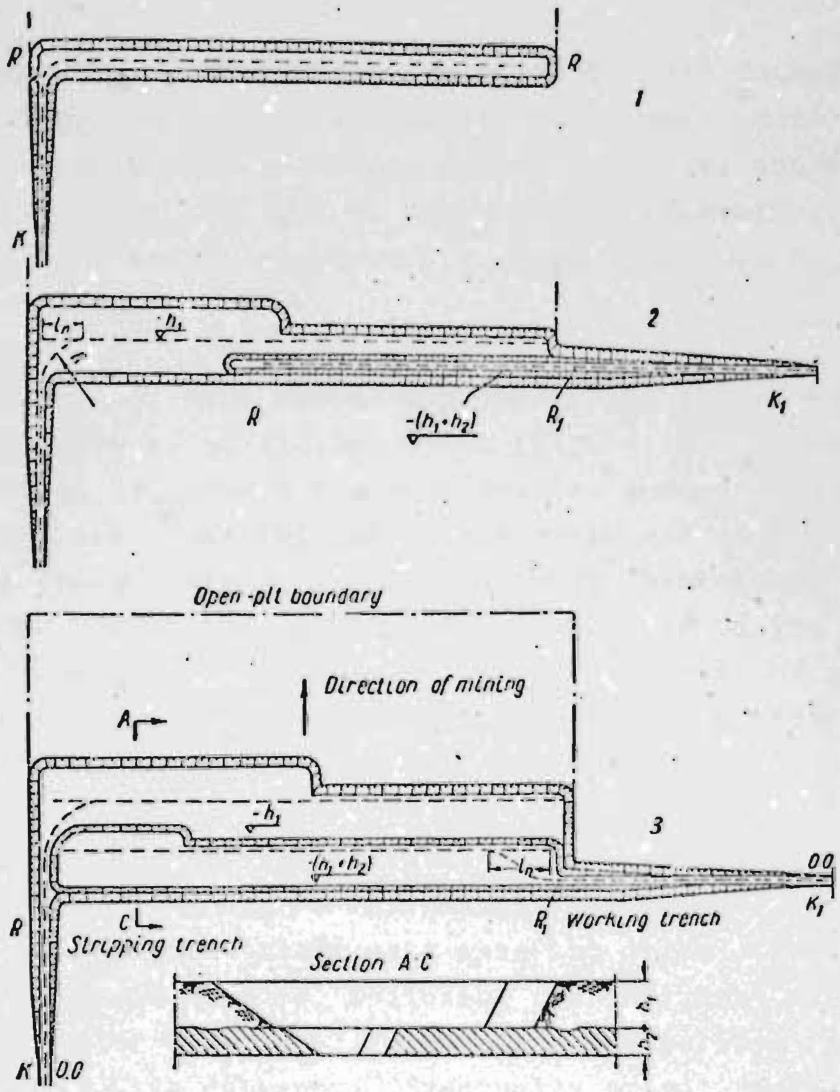


Figure 11. Layout of a pit with separate trenches (from Shevyakov p. 653).

trenches. In a pit worked at great depth this method, although very convenient because it makes independent operation of overburden and coal removal possible, would require too great a volume of earthwork in excavating trenches. In this instance, therefore, both lines can be laid in one trench.

The outgoing or exit tracks may be laid on the edge of the pit, on berms of sufficient width (Figure 12). Although this method requires a somewhat smaller amount of earthwork than the preceding one (since there are no trenches outside the pit area), it involves more development work, since the tracks have to be laid on the edge of the deeper part of the pit. Furthermore, the total length of the pit must be sufficient to allow the construction of roads with gradients conforming to the type of transportation adopted.

In deeper pits, roads (both rail and motor) may be arranged as illustrated in Figure 13. Mining of the coal bank by a series of parallel cuts starts when the spiral trench driven from the ground surface, following the periphery of the pit, reaches the working level. To open a new horizon the curvilinear trench is deepened. Eventually spiral roads encircle the entire portion of the deposit alotted for open-pit work.

6. Excavation of Trenches

In open-cut mining it is necessary to make permanent trenches (ingoing or entrance trenches and outgoing or exit trenches)

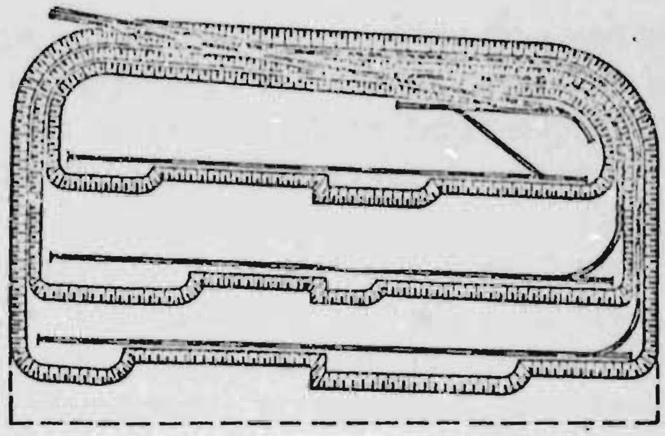


Figure 12. Layout of a pit with outgoing (ramp) roads running along the edges (from Shevyakov, p. 654).

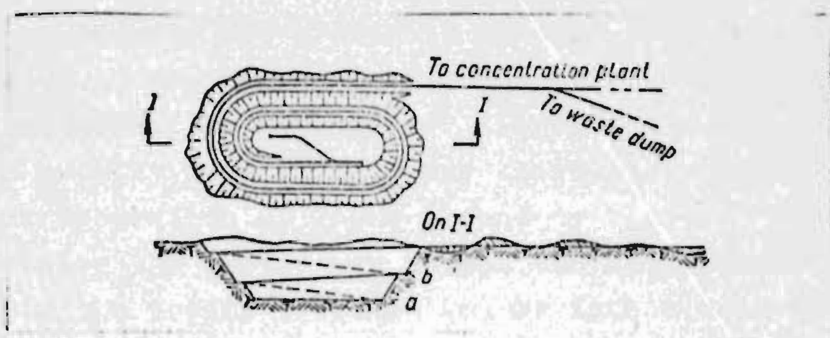


Figure 13. Spiral road layout in a pit (from Shevyakov, p. 655).

to connect the pit with the ground surface and also working trenches to develop banks for mining and other purposes. The trenches may be horizontal or inclined, with a gradient suitable for the transportation system selected.

According to Soviet recommendations (see Shevyakov, L., "Mining of Mineral Deposits", p. 657) with electromotive traction, the trench gradient should not exceed 0.030 (in extreme cases 0.040); with steam locomotives it must be not more than 0.020 (maximum 0.025) and for automotive transport not in excess of 0.080. Trenches equipped with belt conveyors must have a gradient of 16 to 18 degrees. The cross-section of trenches likewise depends on the transportation system, land topography, and the height of banks. The bottom width of entrance and exit trenches for transportation over standard-gauge railways is 7.5 to 8 meters for single tracks and 12 meters for double tracks in the U.S.S.R. As a general rule slope angles should not surpass those of repose for the ground in question. (Slope stability is discussed in section 9 of this chapter). The excavation of trenches should be mechanized. Power shovels and draglines are usually used. The power shovel is suitable for the direct excavation of loose ground or blasted rock. In both instances the shovel may unload the spoil directly at a dump near the trench (Figure 14a) or into a dump-car running either on the ground surface or on the floor of the upper bank. This is called "up-grade loading". Figure 14b illustrates how a trench is excavated in three cuts. During the first cut (1) the shovel loads the rock into cars (a) on the ground surface; in the second cut (2) the loading is done into cars standing on the floor of the first cut, and in the third cut (3) into cars positioned at the bottom of

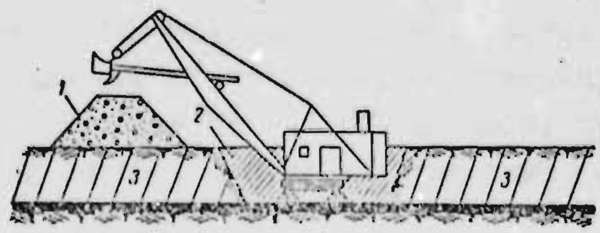


Figure 14a. Cutting a trench by a power shovel
1 - waste dump; 2 - working face; 3 - overburden
(from Shevyakov, p. 658).

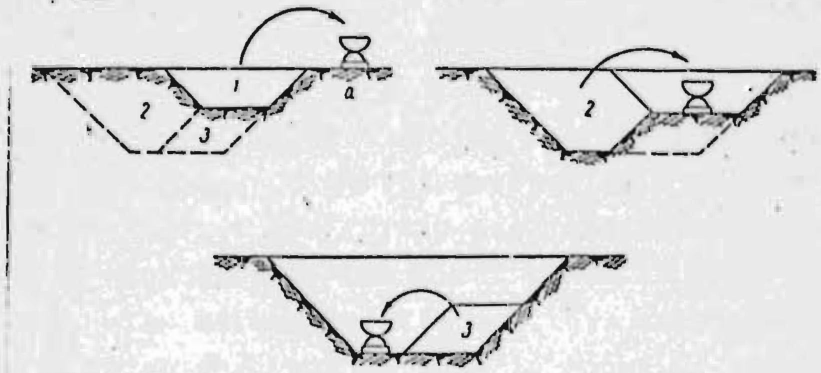


Figure 14b. Driving a trench in three cuts (from Shevyakov, p. 658).

the trench itself. Deep and wide trenches can be dug by a still greater number of cuts.

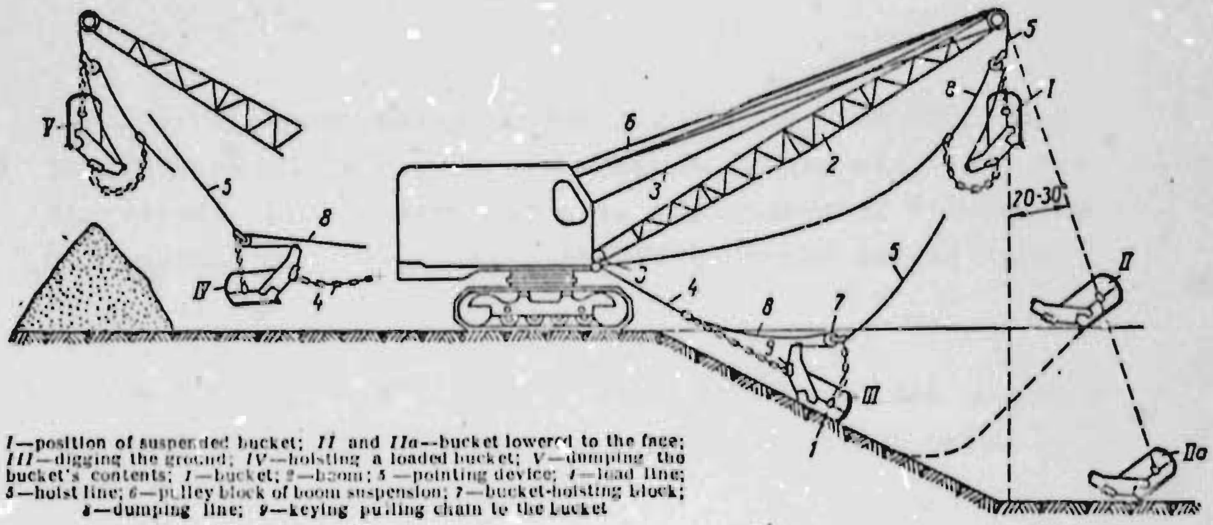
Draglines (Figure 15) are particularly useful for excavating trenches in loose ground, with course stacking along the side of the trench. Because of their long boom, they can ensure greater digging depths, larger dumping radii and discharge heights.

7. Drilling and Blasting in Open Pits

The excavation of overburden and coal in pit banks with the aid of explosives usually requires the drilling of large-diameter vertical blast holes. In certain instances, however, ordinary drill holes of smaller diameter are also used.

The "pin-point" method of blasting is sometimes employed in excavating trenches. With this method (Figure 16) two rows of explosive charges are fired, one immediately after the other. The rock shot by the first blast is thrown aside by the second. The method has its merits: simplicity and speed with which work can be done in rocks of any strength; but there are also disadvantages: difficulties in obtaining the desired shape of the opening, additional clean-up work with power shovels, and excavation cost are usually greater than obtained with earth digging machines.

Blasting in open pits is chiefly performed with blast holes.



I—position of suspended bucket; *II* and *IIa*—bucket lowered to the face; *III*—digging the ground; *IV*—hoisting a loaded bucket; *V*—dumping the bucket's contents; *1*—bucket; *2*—boom; *3*—pointing device; *4*—load line; *5*—hoist line; *6*—pulley block of boom suspension; *7*—bucket-hoisting block; *8*—dumping line; *9*—keying pulling chain to the bucket

Figure 15. Dragline (from Shevyakov, p. 621).

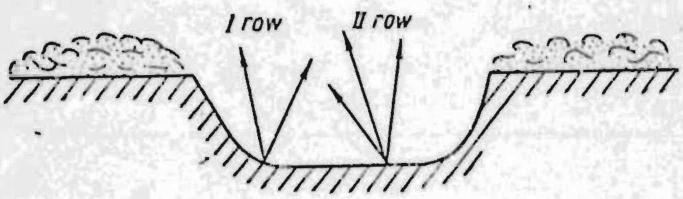


Figure 16. Driving a trench by pin-point blasting (from Shevyakov, p. 658).

Their arrangement using single and double rows in a bank is illustrated by Figure 17. In the latter case they are staggered. Blast holes may have a diameter of 150 to 300 millimeters and their depth should somewhat exceed the height of the bank.

In the U.S.S.R. the following standards have been suggested for estimating the burden and spacing of blast holes (Table 1)*.

Table 1. Bank Height versus Burden

Height of Bank H (meters)	Burden W (meters)
4.5 to 7.6	0.62H + 0.33
7.6 to 18.2	0.24H + 3.60
18.2 and above	0.10H + 6.10

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* Shevyakov, L., "Mining of Mineral Deposits", Foreign Publishing House, Moscow, Zubovsky Blvd. 2, U.S.S.R. p. 613

The burden W is the perpenticular distance from the center of the charge to the bank slope (Figure 17). The distance between the rows of blast holes may range from o.5 to 1.0 W. The spacing of individual blast-holes may have values ranging from 0.6 to 1.5 W. The charges for the blast holes and their diameter are chosen to conform with a unit standard explosive consumption determined for certain types of rock (Table 2). Explosives used are ammonium nitrate.

Table 2. Rock Characteristics versus Explosive Consumption*

Rock Characteristics	Explosive Consumption (kg/ m^3)
Sandstone and Limestone	0.4
Sandy Shale, bedded Sandstone	0.3
Hard Clay Shale, Sandstone, Gypsum	0.2
Hard Coal	0.1

The data on the consumption of explosives listed in Table 2 are

*For additional data see Shevyakov, L., Table 20, p. 613

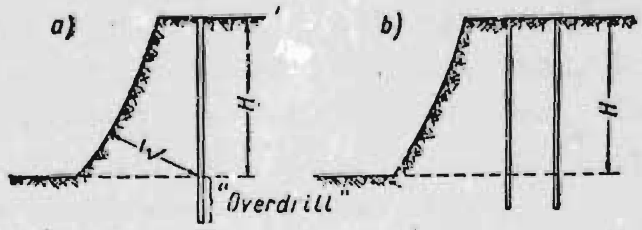

Figure 17. Location of blast-holes in a bank: a - single row; b - double row (from Shevyakov, p. 612).

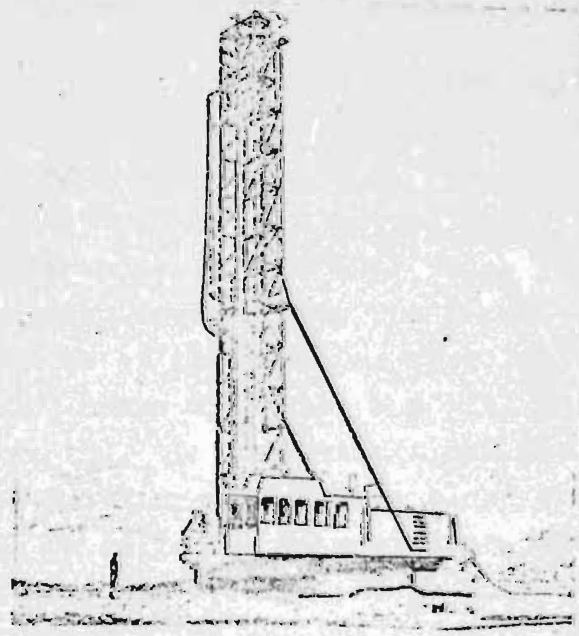

Figure 18. Large electrically powered blasthole rig BE 60R for holes up to 12¼ in. in dia (from SME Mining Engineering Handbook, Vol. 1 1973, p. 11 - 26).

rough, since they are based on testing of intact rock which does not permit to take into consideration the effects of structure, jointing, nature of bedding, etc., in determining the breakage characteristics of rock. (The effects of geological structure and blasting on pit slope stability are discussed in Section 9 of this chapter).

After the topsoil has been removed and stockpiled, the next step in implementing a mining plan is usually that of coal bank or highwall preparation. This process consists of drilling and blasting the overburden so that rock and consolidated earth material may more easily and efficiently be handled or dug by the overburden removal machines.

In modern strip mining operations in the United States, such as planned for the recovery of thick coal seams in Eastern Wyoming, bulldozers will be used to prepare benches for drilling of the overburden. Blast holes of 10-5/8 inches in diameter will be drilled on a predetermined pattern with the holes extending down to near the top of the coal seam. The drills will be of the vertical type, probably in the BE 50-R and 60-R range and size, and will be electrically powered (Figure 18). Drill cuttings and the resultant dust created by the drilling action, when blown or ejected from the hole, will be collected by a cyclone dust collection system, built into the drills. Blast hole patterns will depend on the composition and thickness of overburden. Some typical patterns for hole spacings will be 18' x 20', 20' x 25', and 18' x 30' or any combination that will give an economic ratio of pounds of powder to cubic yards of overburden, and produce a material that can be easily handled by the overburden removal or stripping machines.

These machines will be draglines with 50 to 75 cubic yard bucket capacity and up to 360 feet long booms (see Reference on page 5 of report).

With the coal seam uncovered by draglines and cleaned by bulldozers, holes of 5-7/8 inches in diameter will be drilled through the coal and charged with explosives. The blast holes for a 60 to 80 feet thick seam will be on a pattern of approximately 25' x 25' with the spacing in alternate rowns being staggered. The coal will not be blasted to the extent as may be required for the overburden, rather it will be shaken, thereby introducing many fracture planes to allow easy digging and a minimum of coal fines. The shot coal will be removed with draglines or power shovels.

8. Dewatering of Open Pits

Water inflow in open pits may be due to precipitation directly over the area of pits, or it may come from neighboring catchment basins, or underground sources.

A big danger is presented by surface water coming to the pit from adjacent catchment areas. This danger is prevented by diverting the streams through construction of dikes and ditches.

Groundwater may enter the pit from the walls, where aquifers become exposed, or in the case of water under pressure, through the pit floor. Sometimes groundwater is so abundant, that overburden strata and coal must be drained prior to making a cut.

To dispose of water in open pits discharge facilities are provided. In certain instances it is possible to convey the water from the pit to a stream in a neighboring valley. For this purpose water conveyance tunnels are constructed. In other cases the water is collected in ditches and conveyed to a low point, where a header is installed with a pumping plant. In larger open pits there may be several such plants. Most coal seams are deposited at a slight angle, requiring production to advance down dip. This very often complicates the delivery of water to pumps through ditches excavated in the floor of the pit. In such cases a vertical shaft is sunk in the vicinity of the pit in the lowest portion of the deposit, and from it, sloping slightly toward the shaft, a series of adits are driven, or holes drilled at a level somewhat below the planned depth of the pit. The purpose of these openings is to collect water and thus drain the pit. A sump pump is installed in the shaft to bring the water to the ground surface.

Some examples of diverting surface water from a pit area are furnished by the open-cut mining of gold placers. The methods amployed are analogous to those used in the drainage of placers worked by underground methods. A typical drainage system from a placer area is shown in Figure 19. The section of the mined placer (hatched in the drawing) is located in a valley. To divert the river flowing through the valley a dam is constructed at a location upstream of the placer. Further, a drainage ditch is constructed on

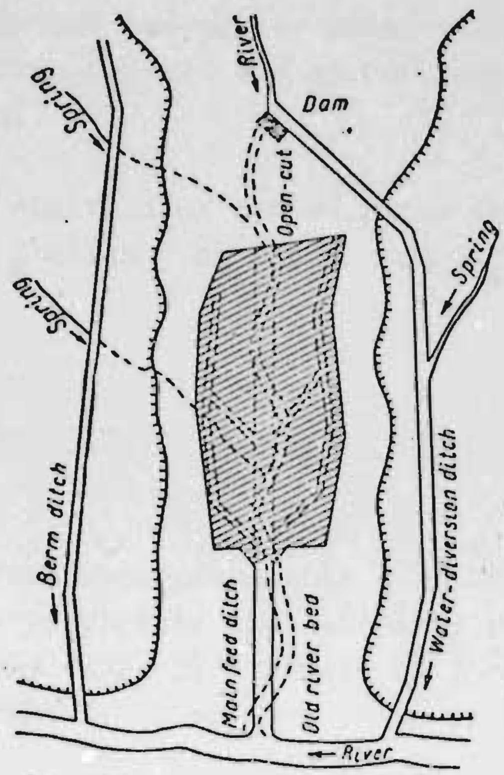

Figure 19. Diversion of water in surface mining of a placer (from Shevyakov, p. 672).

both sides of the valley. This ditch is used to convey river water around the placer area and intercept water originating from springs and storms running off the valley slopes.

Measures for controlling ground water in open pits are explained in Section 9 on slope stability.

a. Prevention of Water Pollution and Control of Turbidity

Large flows from open pits (such as 1000 gpm) may require holding ponds to provide the necessary retention period. Any required holding ponds should be located as far from streams as possible in an area clear of trees, and properly constructed to prohibit seepage from the ponds. Dikes should be constructed of impervious materials and adequately compacted and have sufficient freeboard to provide protection from accidental discharge.

Turbid wastewater resulting from mining operations, groundwater intercepted by drainholes, drainage from spoil piles and waste disposal areas, etc., should be treated by the use of acceptable methods for turbidity and pH control. Any turbidity and pH control facility installed by the operator should have the capacity to treat the maximum anticipated flow from the pit and be able to reduce the suspended solid (nonfilterable residue) concentration in the effluent to more than 25 parts per million (milligrams per liter) and be able to maintain pH of the effluent between 6.5 and 8.5.

Approved turbidity and pH control facilities should be provided with bypass equipment to discharge clear wastewater flows to the streams if such water has suspended sediment concentrations less than 25 parts per million (milligrams per liter) and a pH value between 6.5 and 8.5. The decision to bypass water treatment facilities should be subject to approval by qualified representatives of the operator.

b. Water Quality Sampling and Testing

It should be the responsibility of the operator to accomplish such water quality sampling and testing as is necessary to maintain proper control of his turbidity and pH control operations and insure compliance with the latest water quality standards issued by the State and Federal Government. Locally, these standards would be contained in the latest edition of the Water pollution and Control Commission's and Colorado Department of Health's "Standards for the Discharge of Wastes". The sampling and testing of water should be accomplished according to procedures described in the latest edition of the EPA publication "Methods for Chemical Analysis of Water and Wastes". As a minimum the program should consist of measuring the pH, turbidity and the water temperature of the effluent from the turbidity control facilities twice each working day. The location for monitoring the effluent should be specified by the operator.

As discussed earlier in the report, of equal concern in environmental quality protection related to coal-surface mining are landscape preservation, preservation of trees, abatement of air pollution, dust abatement, pesticides, and clean-up and disposal of waste materials. An excellent paper on how to design environmentally sound solid-waste disposal sites has recently been published by Gioia, M., A., et. al. (1974)*.

9. Slope Stability in Open Pit-Mining

a. Application of Rock Mechanics Principles to Pit Slope Design

The size of most surface mines is sufficiently great that the angles at which pit slopes are excavated have a major influence on the economics of the project. Up until only a few years ago expenditure of more than a few thousand dollars on slope stability studies was criticized by many mining engineers. However, as a result of many pit failures the economics of stability have recently been the subject of intense scrutiny. A vigorous effort is presently under way around the world to place the design of rock slopes on a

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* Gioia, M., A., et. al., "Environmentally Acceptable Coal-Ash Disposal Site", in Civil Engineering, ASCE (December 1974), pp. 64 - 67

rational basis. Therefore, a knowledge of stress distributions in and under slopes is a fundamental requirement for any mechanistic understanding of rock slope behaviour. An accurate evaluation of stresses and displacements around excavations in rock is a difficult task, particularly for the geometries of rock slopes, if the rock mass in which the slope is to be cut is not homogeneous, isotropic and elastic.

In Canada*, for example, rock slope research arises primarily from the need for more information on the stability of the walls in large open-pit mines. During the last decade the mineral production from open-pit mines in Canada has significantly increased, so that now this method accounts for approximately 60% of the total ore mined. In turn this had led to a great increase in the volume of waste excavations. At present the selection of pit slope angles is, however, still largely a matter of experience and engineering judgement. Thus, much thought is being given to the considerable economic benefit which would result if pit slope angles could be made steeper by even two or three degrees. As re-

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* Herget, G., "Recent Research on Rock Slope Stability by the Mining Research Centre" (Canada) in Proceedings of the Second International Conference on Stability in Open Pit Mining, The American Institute of Mining and Metallurgical and Petroleum Engineers, Inc., New York (1972) pp. 47 - 66

ported by C. O. Brawner* many pits in Canada now range between 800 and 2,500 feet in depth. In these, savings of as much as 5 to 12 million dollars can be achieved for each degree the slope can be steepened. This potential saving has emphasized the benefit of the application of rock mechanics principles to open-pit mining.

It is generally recognized that slope stability depends primarily, on how the rock behaves under a stress system caused by the excavations. In general the design of an open-pit mine should be such that the slopes are steep enough to result in economical mining and flat enough to ensure safety of the crew and the equipment in the pit. Research work is still required to provide the necessary scientific information and to show its method of application to the design of optimum pits.

1) Factors to be considered in Stability Assessment and Design

Recent laboratory and field research has emphasized the importance of geology, rock strength, groundwater and

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* Brawner, C., O., "Rock Mechanics in Open Pit Mining" in Proceedings of the Third Congress of the International Society for Rock Mechanics, Vol. 1, Part A, Printing and Publishing Office National Academy of Sciences 2101 Constitution Avenue, N.W. Washington, D.C. 20418 (1974) pp. 755 - 773

blasting on pit slope stability. Since these factors will vary throughout the pit, slopes with variable angles should be the rule rather than the exception.

a) Geology and Rock Strength: Because of stresses acting on rock slopes and foundations are generally low, fracture of intact rock is seldom involved in the failure of these structures; their mechanical behaviour being governed by shear movement or discontinuities, such as faults, bedding planes and joints. Consequently, determination of the shear strength of these discontinuities is a question of fundamental importance.

In coal pits surfaces of seperation frequently consist of stratigraphic layers, such as bedding planes and geologically induced fractures, such as faults and joints. These structural features have a tensile strength which is for all practical purposes zero, and a shear strength which depends on wall roughness, the filling material, and the amount of imbrication (arrangement of individual blocks). The most dangerous for stability are obviously the surfaces that are planer, smooth, filled with soft materials of large areas and not interlocked. Where clay infilled faults or shear zones dip out of the slopes, slopes as flat as 15° to 20° may be required. On the other hand slopes in excess of 70° have been stable in hard, massive, igneous or limestone rock.

It is a widespread error to believe that benches invariably increase the stability of rock slopes. They only do so in certain cases; in general the stability of a rock cut is dependent on the mean inclination of the slope*. By artificial reinforcement (anchorage, tying, etc.), the stability of rock slopes can often be considerably increased. Not rarely, immediate success is achieved by only small means. In other cases the prospective results do not warrant the effort. It invariably depends on the geomechanical properties of the rock structure whether such reinforcement is an economic proposition or not. In each individual case, the decision rests with comparative computations.

Frequently, borehole information is all that is available for structural studies. Plans should be made to obtain maximum data from the borehole program. The core should be photographed, logged structurally and where possible, oriented. The structural data should be evaluated statistically, using polar plots**.

Where the geology program locates discontinuities which dip

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* Mueller, L., "The European Approach to Slope Stability Problems in Open-Pit Mines" in Quarterly of the Colorado School of Mines, Vol. 54, Number 3 (July 1959) pp. 114 - 133

** Hoek, E., and Bray, W., J., "Rock Slope Engineering" The Institution of Mining and Metallurgy, London (1974), pp. 37 - 55 out of the slope the effective angle of shear resistance 'Ø' must be determined. The direction of tests should coincide with the potential direction of failure in the field and the stress range should coincide with field stress conditions. If gouge exists in the joints, tests are required for rock on rock, rock on gouge, and in the gouge, to determine the lowest value.

Shear tests must be performed to determine the lowest or residual angle of shear resistance as well as the peak value. This has practical significance if a slide has developed. If stabilization is attempted before the strain at which peak strength is developed; much less effort and cost will be recognized to stabilize the movement, than if the strain has been sufficient for the angle of shear resistance to be reduced below the peak value. Procedures for rock testing are described in the above referenced literature by O. C. Brawner and E. Hoek et. al. (1974).

b) Groundwater: The existance of groundwater also has a major influence on stability. The drainage of wet slopes frequently will allow steepening of slopes by 3 to 10 degrees while maintaining the same safety factor.

Water pressure in discontinuities reduces the shear strength of rock by reducing the normal forces which develop shear resistance. Water which flows through the rock creates seepage pressures and water which fills tension cracks creates additional horizontal forces against the slide mass. Where freezing temperatures exist, special attention must be paid to water pressure during winter periods. The face of the slope may freeze and inhibit seepage which results in increased water pressures and reduced stability in slopes. Considerable past literature has attributed failure of a slope due to the lubrication action of water. Water is not a lubricant but reduces stability by reducing the effective pressure which mobilizes shear resistance or reduces shear strength by softening.

In determining the permeability of the rock mass, consideration should be given to both coal and overburden. From permeability tests estimates can be prepared of the amount of seepage to expect and subsequent 'in-pit' pumping requirements. Permeability should be determined from pumping tests or borehole permeability tests. Since it is the water in the discontinuity that influences stability, laboratory permeability tests on rock core are generally meaningless and misleading.

If drainage of pit slopes will improve stability or allow steeper slopes to be used several methods are available. Horizontal drains 2 to 4 inches in diameter, spaced 20 to 50 feet apart, drilled on a plus 5 percent gradient into the slope for a distance equal to about 2/3 of the slope hight, with a maximum length of 400 feet have been found very effective on over 30 mining projects around the world (Brawner 1974, p. 758). In some instances slope drainage can be effectively developed using drainage adits supplimented with percussion drain holes fanned out from the adit (Hoeck, et. al., 1974, pp. 240 - 243). Where heavy seepage is encountered pumping from deep wells may be successful (Figure 20). Piezometers should always be installed to monitor water pressures and to determine the benefit of drainage. It must be recognized that the amount

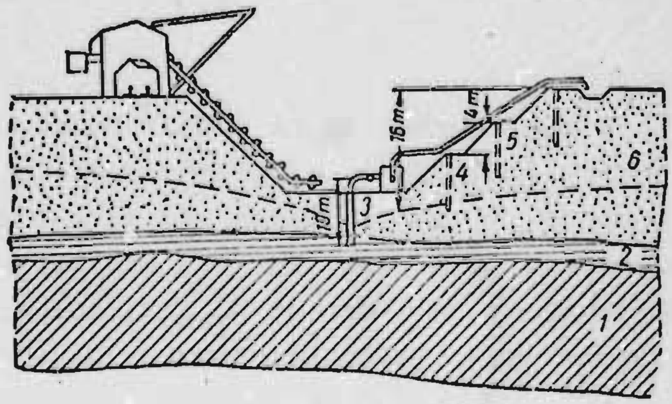

Figure 20a. Drainage of an open pit through suction filters
1 - coal; 2 - clay; 3, 4, 5 - banks; 6 - sand
(from Shevyakov, p. 674).

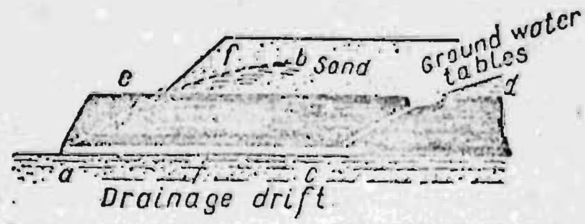

Figure 20b. Dewatering of a coal seam through drainage workings (from Shevyakov, p. 673).

of water intercepted is not an accurate measure of the effectiveness of drainage. The significant factor is the reduction obtained in the water pressure. Frequently rock faces which appear dry are inferred to be drained. If the rate of evaporation exceeds the rate of seepage, the face will appear dry and may mask high water pressure in the slope.

c) Blasting: As discussed in Section 7 of the report, blasting in open-cut mining is frequently required for excavating trenches and removal of overburden and coal. If this is not performed carefully the shear strength of the rock in the final slope can be significantly reduced. Shear stress in the rock is increased by seismic acceleration forces, discontinuities are opened, new cracks are developed, ground water enters cracks in the slopes, and the potential of landsliding and rock falls is increased.

Up until recently dynamic forces were approximated by superimposing an acceleration force as a static force in the slide zone. Dynamic stress analysis using finite element methods (Seed, 1967 * and Prater, 1973 **) now offers more accurate assessment.

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* Seed, H., B., "Slope Stability during Earthquakes", Journal of Soil Mechanics and Foundation Division, A.S.C.E. Paper 5319 (1967).

** Prater, E., G., "Die Stabilitaet von erdbebenbeanspruchten Boeschungen", Schweizerische Bauzeitung 91. Jahrgang, Heft 47, (22. November 1973) pp. 1157 - 1162.

Blast sizes per hole on mining projects usually range from 500 to 2000 pounds. Frequently many holes are detonated at one time (per delay) which causes very high acceleration forces and tension stresses in the rock. If the rock is jointed, high air pressures frequently develop in the joints, and if the jointed rock mass is saturated, hydrodynamic shock forces develop for considerable distance away from the blast location.

To minimize the damage to rock slopes by blasting the amount of explosive per delay should be as low as practical, angle drilling of 70 to 75 degrees can be used at the final face, and line drilling incorporating pre-shear or cushion blasting, used successfully on many civil engineering projects, should be considered.

Other factors to be considered in stability assessment and design of pit slopes are loads induced by equipment and earthquakes.

d) Equipment: In most strip-mining operations after the overburden has been lifted, a dragline will position itself on the shot material and begin the digging of the prepared overburden. The working weight of a walking dragline such as manufactured by the firm Bucyrus-Erie (Model 1570-W with 70 cubic yard bucket and 320' boom), for example, is 6,480,000 pounds. If unfavorable geological conditions prevail in a pit slope and equipment of such weight is operated to close to the edge of a bank, failure of the bank may occur directly under the dragline causing it to slide into the pit. A slope failure of this type could result in thousands of dollars of equipment damage, loss of production, and even loss of life. It is thus important that equipment loads are taken into consideration in slope stability analyses to determine safe operating positions for draglines, power shovels, bulldozers, and other heavy equipment working in the pit.

e) Earthquakes: Of equal concern in pit slope stability are dynamic loads induced by earthquakes. Consequently a careful assessment of the seismic activity of the area in which the project is located (preferably within a 300 mile radius of the project) providing information on epicenter location, magnitude, intensity, focal depth and reoccurance of earthquakes, as well as their relation to geological structure, is of fundamental importance in planning and design of any mining project.

The effects of an earthquake are known to be greatest where seismic waves approach soft or unconsolidated subsoil deposits, underlain by firm ground. As reported by M. Wohnlich, 1973*, the greatest amplifications in ground acceleration occur when the soil deposits are 20 to 30 meters thick. Among the structures most affected by earthquakes in open-cut mining would be spoil banks or waste tips, tailings dams, dikes for water diversion, and any structures erected on reclaimed land.

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*Wohnlich, M.,"Erdbebenprognosis und Seismisches Risiko" Schweizerische Bauzeitung 91. Jahrgang, Heft 46 (15. November 1973) pp. 1139 - 1148.

According to S. Ocamota, 1973* earthquake damage on reclaimed land may be considerable. The behaviour of such land can be considered to correspond to that of the softest alluvial soil posing many problems in regard to earthquake resistance. Therefore individual investigations are necessary as to the behaviour of reclaimed land at the time of an earthquake. Investigated damage from earthquakes in Tokyo and Osaka has shown that the districts in which houses were destroyed and great numbers of people have been killed were almost all reclaimed land. Tokyo and Osaka are examples where the ground under the reclaimed fill is extremely soft. Therefore reclaimed land, if used for residential or industrial purposes, should be investigated together with the underlying ground in estimating earthquake resistance.

To evaluate te effects which local and distant earthquakes of various magnitudes might impart to structures, artificial embankments, slopes, etc., maximum bedrock accelerations a, velocities v, displacements d, and durations s, of these events may be computed and plotted in form of attenuation curves as illustrated in Figures 21 through 24 (Ueblacker, H., 1974)**.

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* Ocamota, S., "Earthquake Damage on Reclaimed Land", in "Introduction to Earthquake Engineering", John Wiley & Sons, New York (1973) pp. 108 - 109.

** Ueblacker, H., "Earthquake Analysis for a Proposed Wyoming Coal Development Project", unpublished report (1974).

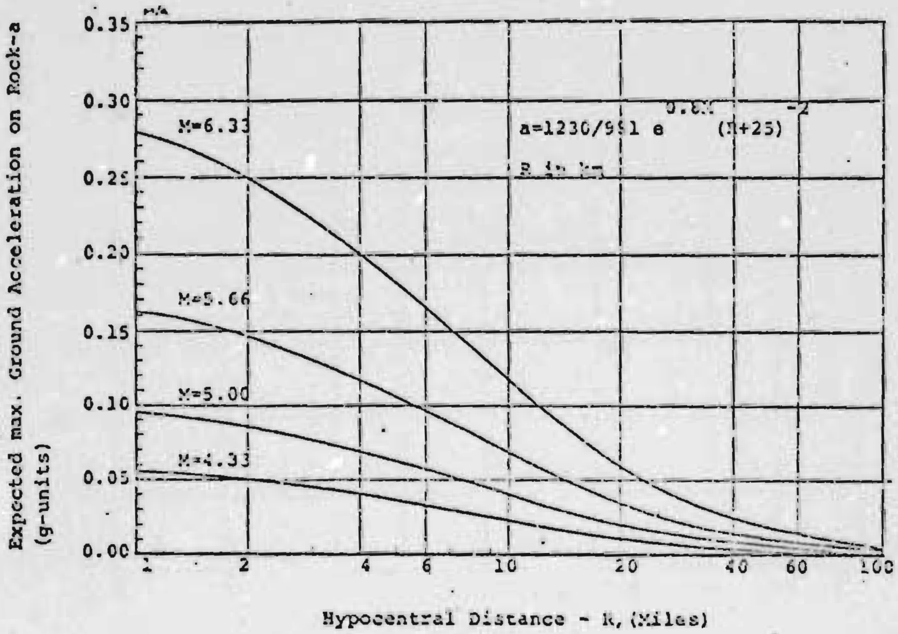

Figure 21.

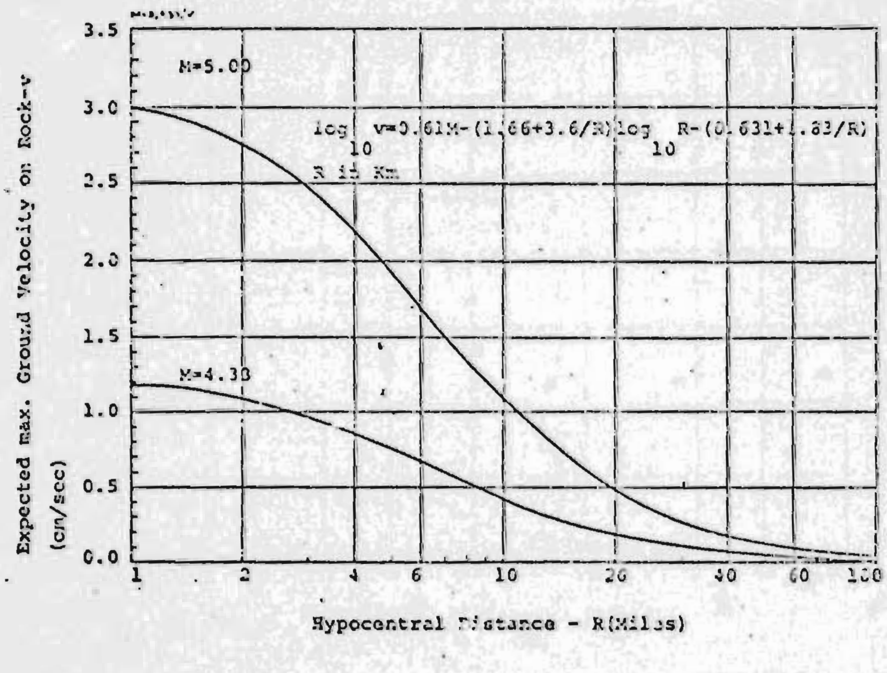

Figure 22.

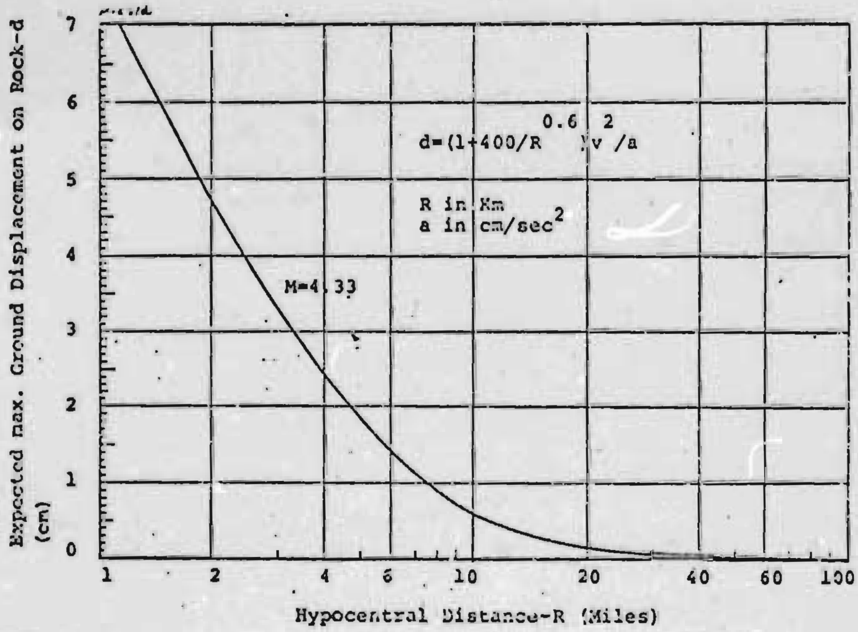

Figure 23a.

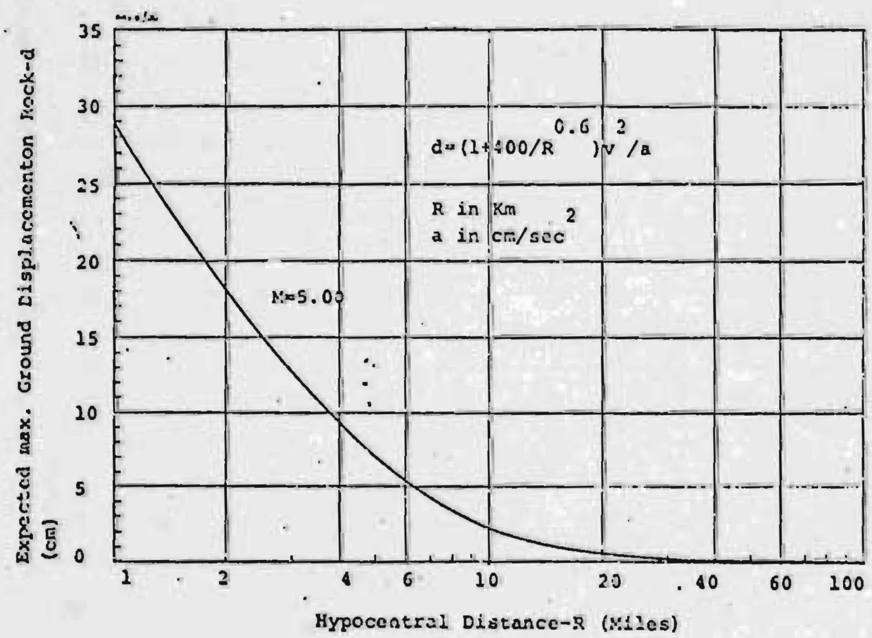

Figure 23b.

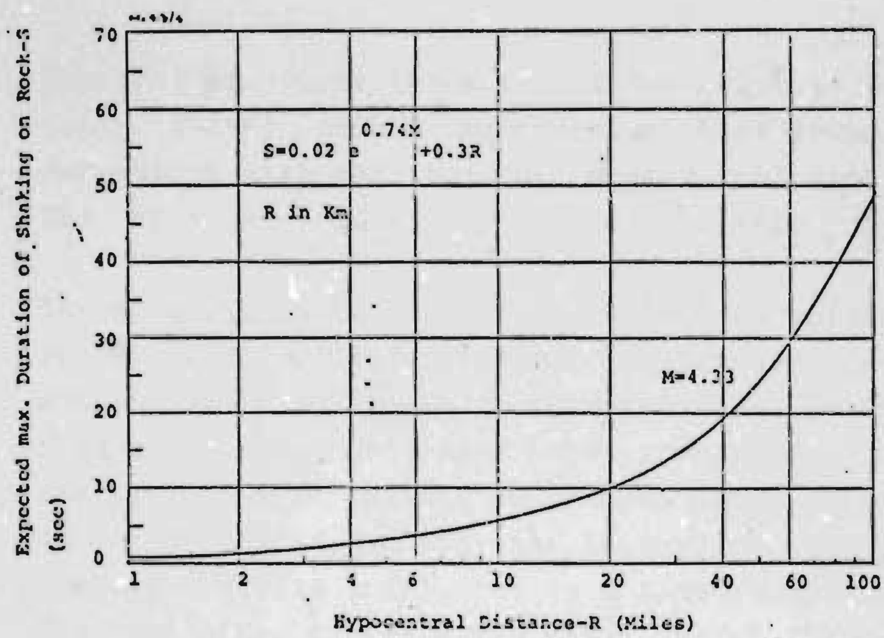

Figure 24a.

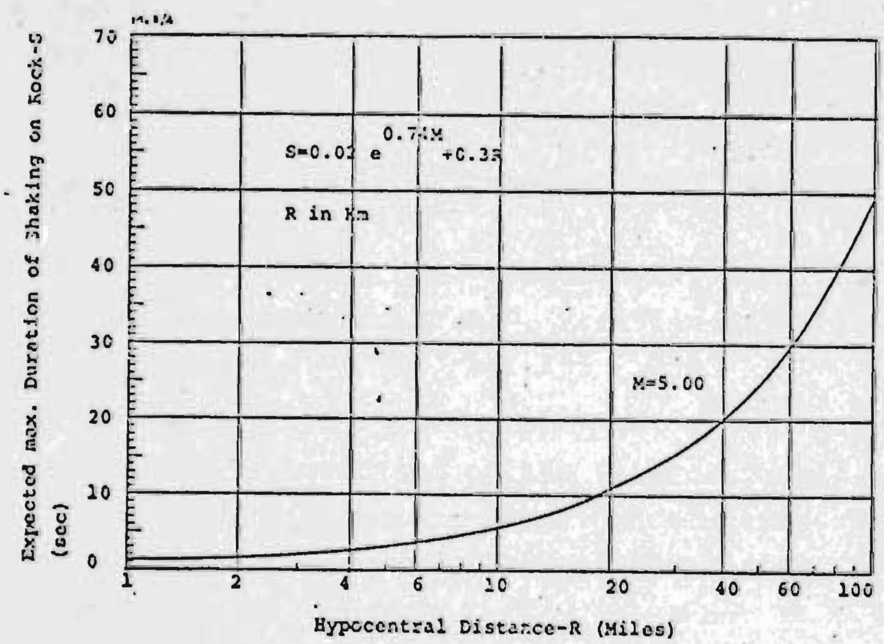

Figure 24b.

Empirial equations (Newmark and Rosenblueth, 1971* and Kanai, 1972**) permitting correlation of ground motion parameters with magnitude and hypocentral distance (Figures 25, 26) of an earthquake may be used for this purpose.

These quations imply that an earthquake originates at one focus and do not recognize more complicated generating mechanisms. In particular the structural geology of a region which is not always known in detail, is important for the study of seismic epicentral zones, since in reality, an earthquake is not only the liberation of energy at a certain specific point, but in a zone along one or several faulting lines of the earth crust, where the triggering action takes place. In addition, it is obvious that the intensity of motion at the ground surface will be a function of the mechanical, stratigraphical and hydraulic properties of the subsoil which overlies the rock formations at a specific site. Considerable dispersion should therefore be anticipated, if the above referenced equations, or en-

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* Newmark, N., M., and Rosenblueth, E., "Fundamentals of Earthquake Engineering", Prentice-Hall, Inc., Englewood Clifts, N.J. (1971) pp. 233 - 236

** Kanai, "Proceedings of the International Conference on Microzonation for Safer Construction, Research and Application", University of Washington, Seattle Washington (1972) Vol 1, p. 177

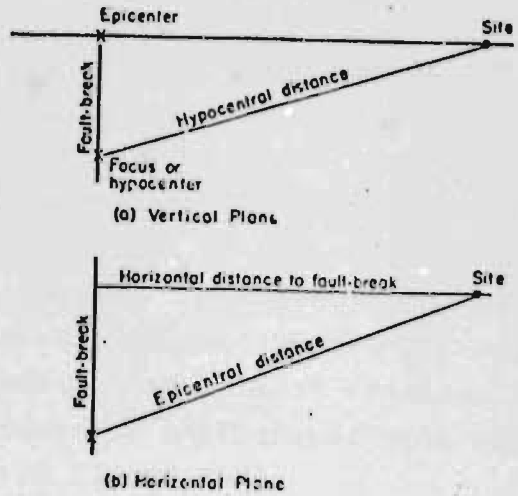

Figure 25. Relative positions of site and fault (from Schnabel and Seed, 1973, p. 587).

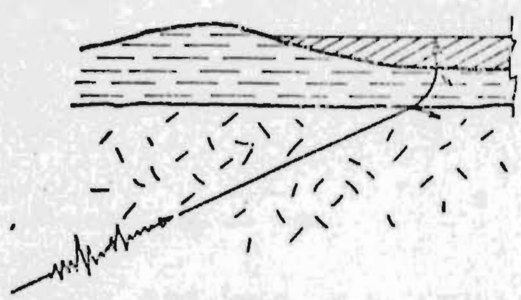

Figure 26. Propagation path (from Schnabel and Seed, 1973, p. 507).

closed attenuation curves are used to estimate the effects of shallow earthquakes. They are probably adequate for estimating the effects which earthquakes of moderate and long focal distances may impart to structures on firm ground, although the dispersion is expected to be high even in this range. Nevertheless, the attenuation curves computed for maximum rock accelerations (Figure 21) appear to be in reasonable agreement with those obtained for recorded rock motions, at least for earthquakes with magnitudes up to M = 5.0 (Figures 27 and 28*).

More reliable data on ground motion parameters for estimating the effects of earthquake can be obtained through installation of seismic monitoring devices at a site (preferably during the planning stage of the project) and detailed geological studies of seismic epicentral zones of a region.

On firm ground, given an estimate of the maximum base acceleration,velocity and displacement, and a measure of the duration of ground motion, the expectations of the responses of a wide variety of ideal structures can be computed following the

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* Schnabel, P.B., and Seed, B.H., "Accelerations in Rock for Earthquakes in the Western United States." Bulletin of the Seismological Society of America, Vol. 63, No. 2, (April 1973), p. 506

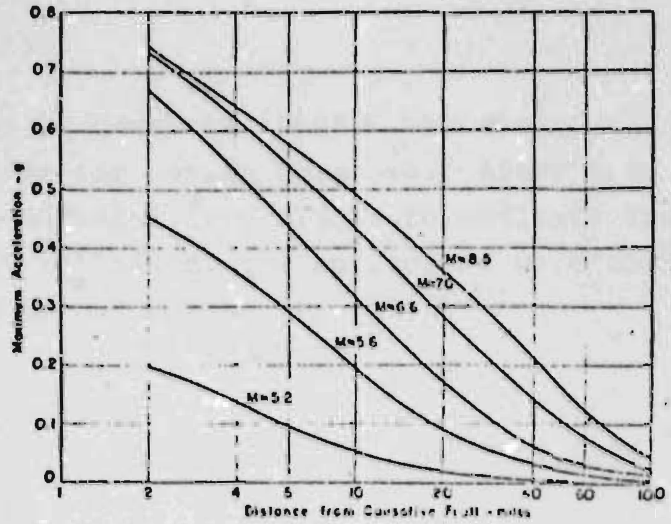

Figure 27. Average values of maximum accelerations in rock (from Schnabel and Seed, 1973, p. 506).

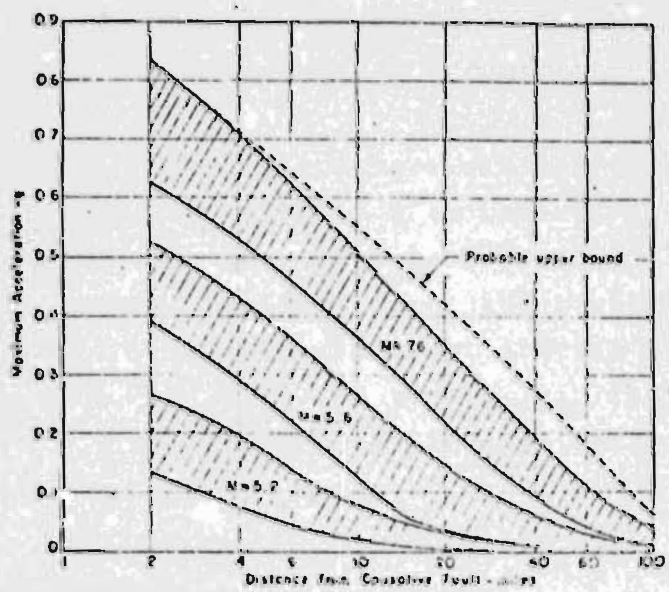

Figure 28. Ranges of maximum acceleration in rock (from Schnabel and Seed, 1973, p. 506).

suggestions of Newmark, 1968*. These expectations practically suffice for design purposes. After this has been done, an additional step allows to estimate the design spectra for motions at the surface of soft soil through which firm ground motion may filter.

b. Stability of Tailings Dams and Waste Tips

The waste Material from both coal and metal mines falls into two size ranges: large sized rock or low grade mineral from developments, variously known as rock, spoil (coal mines) or mullock (metal mines); and finely ground material from the metallurgical plant or from the coal washery. From a metal mine mill the fines are usually known as tailings and go to a tailings pond. Waste rock in coal mines can be overburden or spoil (in the U.S.) and go to a spoil bank or waste dump, or can be chitter (as in Australia) and go to a tip or bing. For convenience the terms waste and tip will be used.

Open-pit coal and metal mines have similar problems; they have to find space in which to dump the waste and must dump it safely. Although there have been frequent slides of waste tips and failures of tailings dams, the problems were emotionally highlighted by the pit heap slide at Aberfan in South Wales, on October 21, 1966, in which 144 people lost their lives. Most of the victims were children at the local school which was

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* Newmark, N. M., "Earthquake Resistant Building Design", in Structural Engineering Handbook, Gaylord and Gaylord, Editors, Mc Graw-Hill Book Comp., New York (1968) Section 3

4413 UEBLACKER H
SURFACE MINING OF COAL A DISCUSSION OF MINING METHODS

over-run by the slide of mud and fine coal. Previous slides of this type around the world had disrupted communications and blocked highways, but had rarely trapped a group of victims in this way.

There was an immediate examination of mine waste disposal techniques in most countries and both Britain and the U.S.A. have published the results of investigations. [1, 2, 3] The National Coal Board investigations have been endorsed in Britain by governmental legislation, and most States and Countries now have legislation controlling mine waste disposal. The main field of activity concerns liquification of fines or of argillaceous (clayey) waste, with consequent dam failure or tip slides.

1) Site Investigations

Before either a dam or a waste heap is built, the site should be thoroughly investigated. Case studies are given

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1) National Coal Board N.C.B., "Technical Handbook on Spoil Heaps and Lagoons", London (1970)

2) Towsenhend - Rose, F.H.E., and Thomson, G. M., "Security of Tips - Statutory and Technical Requirements", The Mining Engineer, No. 125, p. 293 (Feb. 1971)

3) Kealy, C. D., and Soderberg, R. L., "Design of Dams for Mill Tailings", U.S. Bureau of Mines, Information Circular I.C. 8410, (1969)

in recent publications by the American Institute of Mining, Metallurgical and Petroleum Engineers, Inc. [1, 2, 3] and by Toland, 1971*, but the following recommendations are based on the National Coal Board publications, referenced above. The steps to be taken are:

1. Make a preliminary investigation: look at the local geology, make your own maps if necessary. Decide on possible future mining subsidence which can cause instability. Look for evidence of surface instability and chart the local hydrology, particularly of seasonal springs or streams.

2. Carry out tests: sink trial pits and boreholes and collect samples. Classify the surface soil by type and

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1) Hartman, H. L., Editor, "Case Studies of Surface Mining", (1969) 322 p.

2) Brawner, C. O., and Milligan, V., Editors, "Stability in Open-Pit Mining", (1971) 242 p.

3) Brawner, C. O., and Milligan, V., Editors, "Geotechnical Practice for Stability in Open-Pit Mining", (1972) 274 p.

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* Toland, G. C., "About Tailings Dams - Construction, Sealing and Stabilization", Mining Engineering, p. 51, Dec. 1971

measure the shear strength and permeability of the surface soil, subsoil and underlying rock.

3. Calculate the foundation stability taking into consideration the tip material and its likely water table and make sure it has an appropriate factor of safety. A tip near a built-up area needs more security than one several miles from habitation. Remember that (a) mining subsidence may open up fissures, creating paths for preferential water flow (b) seepage pressures will exist in tips and foundations (c) clay can give an unstable foundation, particularly if saturated (d) if there is a natural slope to the ground then it must be drained and stabilized (e) extending an existing tip can be dangerous if its previous history is unknown.

4. For a waste tip the final site chosen must be large enough to have space of at least 30 feet clear around the base of the tip for access and safety. The clearance should be increased for tips on sloping ground, high tips, or tips with a low factor of safety.

2) Factors of Safety

A design factor of safety depends on the consequence of failure with respect to persons and property, the reliability of the design input data, and the reliability of the design assumptions over the life of the tip. National Coal Board recommendations (Great Britain) were, that for new spoil tips on flat ground where there may be a risk to people and property the factor of safety should be 1.5, in other cases it may be 1.25. On sloping sites or in areas where earthquakes can occur a safety factor of 1.75 or greater may be required.

As in stability assessment and design of pit slopes, safe construction of spoil banks or waste tips, tailings dams and dikes for water diversion, etc., depends on various parameters governing the strength of the soil and on the stresses which develop within slopes and foundations. Mine waste material must be assessed for size distribution, specific gravity, plasticity, moisture content and density. The shear strength, consolidation and permeability must be determined. It is also necessary to assess a change in characteristics with respect to time, such as a breakdown of shales, liability to spontaneous combustion of carbonaceous materials or sulphides, or cementation of some deposits.

In conclusion of this section on slope stability the following recommendations are made. To achieve optimum safety and economy in pit slope, waste tip and tailings dam design, a number of possible situations should be studied by varying the angle and drainage of slopes using a representative mathematical model. Important parameters affecting the stability of excavated slopes and artificial embankments are the stress conditions that develop within these structures and their foundations; the state of stress that pervails in overburden formations and coal prior to mining, i.e., the initial state of stress in the rock mass or soil; adversely oriented structural features of the rock mass; groundwater conditions, mechanical and hydraulic properties of soil and rock; seismic loads induced by blasting and earthquakes; and equipment loads. The more carefully and accurately these parameters are determined and taken into consideration in stability analyses, the more confidently can pit slopes, waste embankments and dams be designed and constructed, i.e., essentially the more safely and economically can a coal surface mine be operated.

CASE STUDIES

1. Australia

Australia has in the last few years become a notable producer of minerals. As reported by L. J. Thomas, 1973*, this continent contains what are probably the world's two largest iron ore mines, both located in the Pilbara region of Western Australia (Figure 29). Hamersley Iron produces about 37.5 million tons of ore yearly and the Newman Consortium about 35 million tons. Present mining is of high grade haematite with about 64 percent iron.

The aluminium industry has reserves of more than 2000 million tons of bauxite in the Weipa area of Northern Queensland alone, and more than 3,700 million tons available in Australia to provide for its expansion. The Gladstone Alumina plant (Queensland) had a rated capacity of 2,000,000 tons annualy in 1972, making it the biggest in the world, and should by now operate at a capacity of 2,400,000 tons.

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* Thomas, J. L., "An Introduction to Mining", (Exploration, Feasibility, Extraction, Rock Mechanics) Halsted Press, a Division of John Wiley & Sons, Inc., 605 Third Avenue, New York, N.Y. 10016 (1973) 436 p.

Figure 29. Western Austria (from National Geographic Feb. 1975, p. 160).

There are enormous reserves of coal for that rapidly growing industry (Figure 30). The world's second largest dragline with a $100m^3$ bucket being capable of removing 6,500 tons of overburden or coal per hour is operating at Moura Mines in Queensland*. In some underground mines coal production outputs of 900 to 1000 tons per shift from a continuous miner are obtained regularly and several mines are producing 1 million to 1-1/4 million tons per year with a working force of 100 to 300 men. Only about four percent of coal from New South Wales is at present won by longwall methods, but by using equipment specially strengthened to support the hard sandstone roofs, high productivity is now obtained.

For heavy mineral sands (rutile, ilmenite and zircon) Australia is the world's largest producer and has pioneered some dry-mining techniques. Australia is also the third largest producer of lead, exceeded only narrowly by the United States and the Soviet Union. In 1969 the lead content of Australia ore production was 445,000 tons. Mount Isa Holdings produced about one third of this total from its mine at Mount Isa in Queensland. This mine also produces quantities of copper and zinc and is probably the largest underground metal mine in the world. Nickel production in Australia is rising rapidly, excellent deposits of uranium have been found in the Northern Territories.

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* Bossman, M., "Die Abbautechnik im australischen Steinkohlenbergbau", Glueckauf 110 (1974) Nr. 17, p. 690

Figure 30. Map of Australia showing coal measures, a, b = bituminous coal, c = brown coal (from Bossmann, 1974, p. 687).

Almost every commercial metallic ore is mined in some part of Australia. In 1970 more than $170 million were spent on mineral and petroleum exploration. Private capital investment totaled $1,750 million, and another $860 million were spent on extraction, refining and foundry plants. Currently another $1,600 million are committed to expansion of existing projects, or to new ventures, such as the $14 million asbestos project in New South Wales.

The Australian population is concentrated mainly along short stretches of the coastal fringe, and the interior of the continent is virtually without water. Many mining developments have to establish their own communities. Most homes are air-conditioned and are constructed at a cost of approximately $40,000 per unit. The companies may have to provide their own roads, electricity, water supplies, and railways to the coast and even their own ports.

Construction materials and equipment may have to be freighted 3000 km across the continent and food may have to be air-freighted in to a remote mine. Consequently, the mines must be planned to produce a large output from a small working force, especially if the ores are low grade. This has caused a rapid improvement in mining technology.

To cope with the expansion of mining in Australia many overseas engineers have been brought in. Overseas technology has been adapted to local conditions for new minerals, an engineers, from necessity, produced innovations and increased productivity.

a. Coal Fields

The principal known coal deposits of Australia are shown on the map in Figure 30. Most of these deposits are located near the continent's eastern coast. According to Thomas, 1973, p. 220, domestic electricity utilities take about one third of Australia's coal production. The trend is to build the generating station adjacent to the mine. The New South Wales Electricity Commission operates underground coal mines as well as power stations. The coal is won mechanically, conveyed to the surface, cleaned, and conveyed to the power station boilers without being touched by human hands. Munmorah Colliery, for example, produces and conveys 6000 tons of coal daily from its underground mine to an adjacent power station with a working force of only 250 men.

As reported by W. A. Weimar, 1969*, southeast of Melbourne enormous brown coal deposits ranging from 200 to 750 feet in thickness with 50 feet or less of sandy overburden are being mined by surface methods. The coal is of low grade having a calorific value of 3000 BTU per lb. and a moisture content of 50 to 70%. The coal is produced for mine-mouth power generating plants of the State of Victoria Electricity Commission. The Commission estimates that the Latrobe Valley here has 17 billion tons of coal. The coal is extracted by several chain

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* Weimar, W. A., "Australia - Recent Developments in Surface Mining" in 'Case Studies of Surface Mining', Proceedings of the Second International Surface Mining Conference, The American Institute of Mining, Metalurgical and Petroleum Engineers, Inc., New York (1969) pp. 3 - 11

bucket excavators and bucket wheel excavators, the wheel digging above the base and the chain buckets digging below the bench base.

Most impressive coal mining developments are located in Central Queensland. They are the Utah Development Pty. Ltd. at Blackwater which began in 1967 and the Thiess-Peabody Mitsui Coal Pty. Ltd. at Moura which began in 1963. Utah has a walking dragline with a 30-cubic-yard bucket in a 285-ft. boom. In contrast to Utah and other developments (see Thomas 1973, p. 130), Thiess Peabody Mitsui employes the second largest dragline in the world with a 130-cubic-yard bucket on a 275-ft. boom.

1) Open-Cast Workings at Moura

According to Thomas, 1973, p. 131, open-cast workings at Moura produce about 3,100,000 tons of coal annually and another 600,000 tons are produced by underground methods. Open-cast reserves are about 35,000,000 tons and total reserves are more than 75,000,000 tons in an area of 470 km^2.

The overburden consists of shales and sandstones which are stripped down to 48m depth as a cut-off limit. The equipment includes:

Draglines	One Marion 8900 100 m^3 electric with 84 m boom. One Marion 7900 30.1 m^3 electric with 84 m boom. One BE 480W with a 9.2 m^3 bucket.
Shovels	Two Marion 151M with 10.7 m^3 coal loading buckets as main production units.

Front-end loaders	Two Cat 992 with 10.7 m^3 buckets for coal loading. The mine also has two Hough 400 units for stock-pile duties and a Cat 988 unit for loading and clean-up duties.
Trucks	14 Euclid bottom dump trucks, mainly 100 ton units with some 50 ton units. These are only used for coal; no overburden is moved with trucks.
Drills	Two rotary blast hole drills on crawlers for overburden drilling; both BE61R using 0.38 m bits.

The coal also has to be drilled and fired before loading out on two 10 hr shifts per day. Maximum haul distances are nearly 13 km to the dump where the coal is then fed through a rotary breaker. Coarse sizes are washed in a magnetite dense medium bath, small sizes are cleaned in a dense medium cyclone and the fines are cleaned by froth flotation. All coal is crushed to minus 32 mm and stockpiled for loadout. Transport is by 3000 ton unit trains to the port at Gladstone 177 km away. There are five seams to be mined but because of their general dip and vertical interval they are not mineable together. Each seam worked is started with its own box cut, the deepest can be mined first. Overburden stripping is performed 24 hours a day, 7 days a week. The overburden is drilled with holes inclined at about 18° from the vertical to give a sloping highwall for stability. About 300 holes are put into an area 450 m x 55 m (on a 9 m x 9 m grid). ANFO explosives are used at about 0.7 kg/ton.

The walking dragline is the optimum tool for the open-cut mining of seams that dip 6 to 18.5 degrees. A crawler mounted machine would have difficulties working on such slopes. Figure 31 shows a cross-section and plan view for open-cast mining using the dragline bench method as employed at Moura Mines. The 275-ft. boom machine is used to uncover a split seam of coal 190 feet wide in 100 feet of cover. It is not necessary for the dragline to move laterally but to advance lengthwise of the pit to uncover coal at this depth. As the depth increases, the machine can be stepped sidewise to maintain the pit width and increase the digging depth. This is one of the many advantages of a walking dragline. Figure 32 outlines portions of the dig sown in Figure 31.

The triangle of bench under the centerline of the machine represents the maximum amount of spoilwhich must be rehandled (about 20% of the loose measure of the solid bank in this particular cross-section). The bench can be raised or lowered to fit the reaches of the machine. Lowering the bench reduces the rehandle.

In contrast to other mining methods using draglines, the method just described is less expensive. With this method, the length of the boom is shorter to reach from the bottom of the cut to and beyond the crest of the spoil, thus the machine is maintained at an advantageous plane above the coal. Since the use of a shorter boom enables the machine to carry a bucket of greater capacity and permits greater acceleration and deceleration of swinging movements, larger and more frequent loads can be accomodated. The utilization of the machine-supporting bench and the portion of the triangular bench enables the dragline to be moved laterally to a position close to a spoil or close to a digging bank, thus giving the boom a greater effective length; this permits mining to a greater depth of overburden.

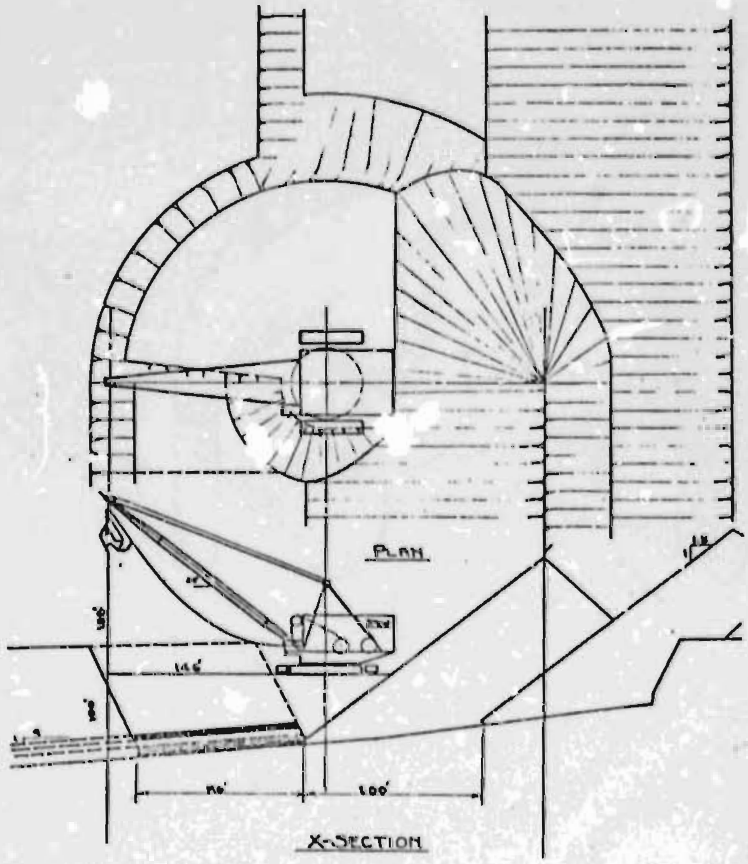

Figure 31. Cross-section and plan for open-cast mining, using the dragline bench method (from Weimar, 1969, p. 9).

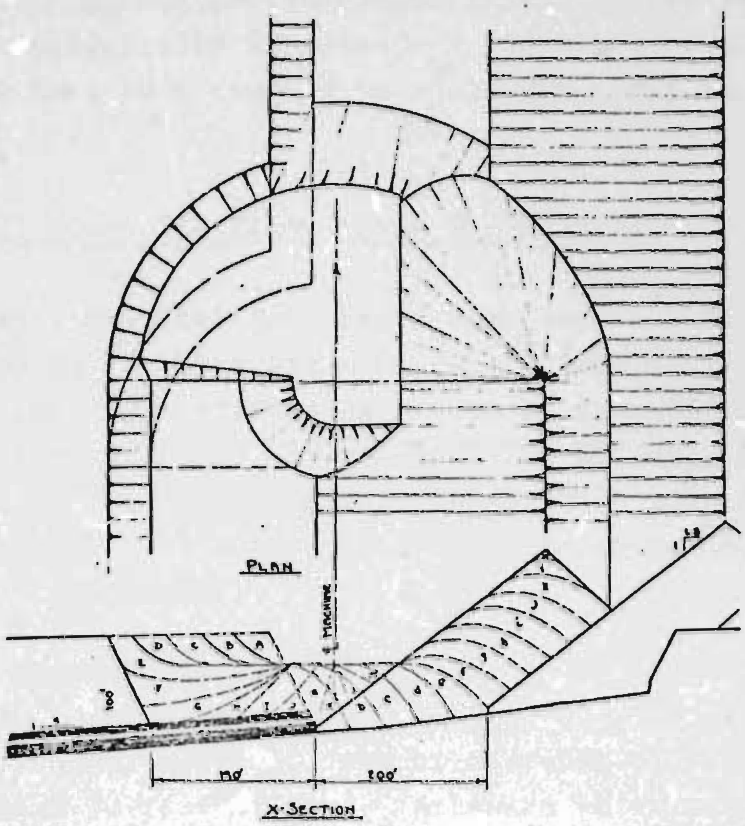

Figure 32. Direction of movement of overburden in open-cast mining shown by plan and in detail in the cross section (from Weimar, 1969, p. 10).

According to W. A. Weimar, 1969, who lists a number of other advantages, this method was developed primarily for deeper stripping but undoubtedly was ahead of its time, as the past three decades have been devoted to shallower strip mining.

2) Open-Pit Coal Mining in Victoria

As already mentioned, the soft brown coal deposits of the Latrobe Valley in Victoria are used as a source of fuel for power generation. The coal is extracted by open-pit mining. According to case studies reported by O. C. Brawner, 1974*, a typical open pit is approximately 1-1/4 miles long, 1 mile wide and up to 500 feet deep. Production is approximately 14 million tons annually.

The brown coal occurs in two thick seams. The upper coal seam, which is being mined, is 270 to 540 feet thick. This seam is underlain by about 30 feet of over-consolidated clay resting on about 30 feet of sand. Artesian water conditions exist within this sand stratum which is referred to as the upper aquifer. The lower coal seam is 150 to 200 feet thick and is underlain by a thick sequence of clay and sand strata,

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* Brawner, O. C., "Rock Mechanics in Open-Pit Mining", Proceedings of the Third Congress of the International Society for Rock Mechanics, Vol. 1, Part A, Printing and Publishing Office National Academy of Sciences 2101 Constitution Ave., N.W. Washington, D.C., 20418 (1974) pp. 761 - 765

referred to as the lower aquifer zone. Artesian water pressures greatly in excess of those in the upper aquifer exist within the lower aquifer.

Large-scale ground movements have occured as a result of the mining operations. By 1970 movements of the following magnitudes had occured: vertical heave of the pit floor in excess of 12 feet; horizontal movements of the pit slopes of 8 to 10 feet; and vertical settlement of up to 3 feet within a town which is located adjacent to the pit. An extensive investigation was undertaken to determine the cause of these movements and their implication with respect to the future operation of the mine and influence on the town.

a) Groundwater: An important factor influencing the ground movements is the groundwater regime. The unit weight of the coal averages only 71 lb./cu. ft. The difference between the unit weights of the coal and of water averages only 8.5 lb/cu. ft. For most rocks this difference is about 100 lb./cu. ft.

b) Floor Heave: With expansion of the pilot opening from the 300 feet level to the 350 feet level, the pit floor heaved up to 12 feet. This was accompanied by the development of cracks in the pit floor from which water flowed at the rate of about 1,500 gal./min. The investigation established that the heave was caused by the artesian water pressures in the lower aquifer. Although approximately 250 feet of strata seperated the pit floor from the lower aquifer, the uplift water pressures in the aquifer was about 5,000 lb./sq. ft. greater than the pressures due to the weight of the overlying strata. Complete 'blow-up' of the pit floor was prevented by the vertical shear resistance between the 250 feet of strata underlying the pit floor and the strata underlying the pit walls (Figure 33).

Prior to the investigation, the existence of the lower aquifer was unknown and it had been thought that the heave was caused by water pressures in the upper aquifer which was being dewatered. As heaving of the base of the pit continued the existence of the lower aquifer was postulated. This was subsequently confirmed with piezometers and multiple-borehole extensometers. Dewatering of the lower aquifer was undertaken, and further heave has been controlled.

c) Slope Stability: Inward slope movements 8 to 10 feet, opening of cracks on the slope faces, and the heaving and cracking of the pit floor raised questions concerning slope stability. A detailed shear strength and geologic mapping program indicated the strength and jointing characteristics of the coal precluded a major pit slope failure within the coal. However, the average residual angle of shear resistance 'Ør' of the clay stratum at the base of the upper coal seam was found to be only 12°. Any major slope failure would therefore occur as a block failure bounded by the weak nearly horizontal clay stratum and the vertical joints in the coal.

The stabilizing shear force in the clay stratum is proportional to the weight of material above the clay less the uplift force of the water pressure in the clay. Because of the coal's low unit weight, this stabilizing force is relatively small and the motivating force is almost entirely due to hydrostatic pressure within the vertical joints. As this force is proportional to the square of the height of water in the cracks, the elevation of the water table within the coal controls the

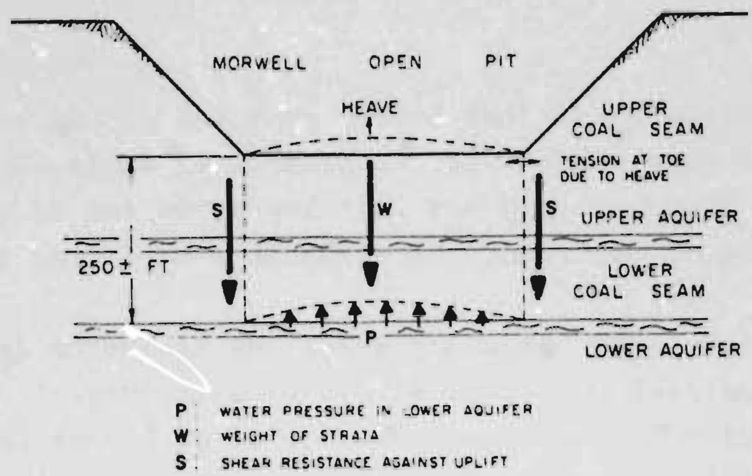

Figure 33. Pit floor heave mechanism (from Brawner, 1974, p. 764).

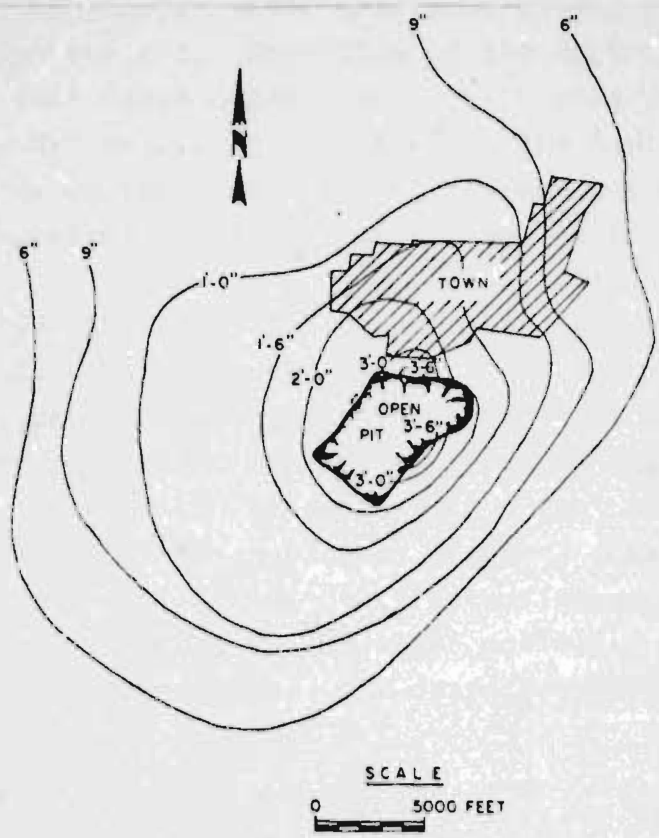

Figure 34. Observed vertical settlements (from Brawner, 1974, p. 765).

slope stability. Analyses showed that the stability of the toe of the slope is essential. If the toe were to become unstable, it was estimated that the failure could progress back into the slope a distance of 2,000 feet or more.

Horizontal movements and water pressures were monitored and measurements were made to depths up to 700 feet successfully. Horizontal drains up to 800 feet long are being installed in the toes of the pit slopes to lower the water table, and thereby improve stability.

d) Settlement of Town: The aquifer dewatering in the pit area, required to prevent blow-up of the pit floor, has reduced the aquifer water pressures within a radius of several miles from the pit. Reduction of the fluid pressures in an aquifer will cause consolidation of a compressible stratum which is hydraulically connected to the aquifer. The extensive dewatering of the thick coal strata has resulted in large-scale regional ground settlement about the pit (Figure 34).

By Mid-1971 the settlements under the town varied from in excess of 3-1/2 feet near the mine to about 6 inches on the far side of town. Analysis indicated that the dewatering necessary for future mine development to mid-1980 would cause ultimate settlements ranging up to 9 feet adjacent to the pit. An assessment of the influence of these settlements indicates they are not expected to cause extensive damage to buildings. However, some damage to the sewer and water lines, and disruption of the hydraulic flow characteristics of the sewer system are anticipated.

If the magnitude of the settlement begins to cause damage it has been proposed that deep de-watering wells be drilled on the far side of the town to lower the water pressures in that area. This will increase the settlement away from the pit and reduce the differential settlement across the town.

b. Mining Laws and Environmental Legislation

Throughout Australia practically all minerals are the property of the government, and their exploration and exploitation are administered by the State Department of Mines. Surface owners do not control the minerals. Their mining codes protect the prospectors. If a prospector obtains a permit, "miners right", it entitles him to search for minerals any place within the state, only holding him responsible for damages he may incur in his exploration. If he finds something of interest, he may then apply for an authority to prospect, which gives greater latitude and protection in his work to develop the find. However, he will be obligated to spend a minimum specified amount to exclusively hold an area. He will be required to furnish maps, analyses, and geological data to the Mines Department. Presuming that he has located something economically valuable for mining, he may then apply for a mining lease or be granted a franchise to produce a specific material. It will contain a quantity clause so that the area cannot be held indiscriminately without production of the mineral (Weimar, W. A., 1969, p. 3).

The problem of living down a bad past also applies to Australia. Approaches for a mining lease may be greeted with objections to possible blasting vibrations, dust, noise atmospheric pollution, water pollution and increased traffic density. It is not always realized that vibrations, dust noise and pollution can be greatly limited by modern mining methods. Indeed legislation now exists in Australia to confine mining to approved methods. As mentioned earlier, land restored after mining can be more fertile farmland or new recreational areas, or be returned to original within very few years. Some Australian mineral sands companies are spending $1250-2500 per hectare ($500 to $1000 an acre) to restore land worth less than $12.50 per hectare ($5 per acre). An increased traffic density may even be an advantage because the mining company will have to widen, strenthen and resurface the roads which benefit local traffic. Most governments require a financial bond to be deposited before mining can start to cover the anticipated cost of making good after mining.

It is unlikely that a mine would be forced to work underground instead of open-cut methods to avoid public nuisance but it is perhaps fortunate that most large open-cut mines are remote from all but their own workforce and tourists, who seem to enjoy the guided visits that enlightened companies provide. Some mines have a noticeable operational budget item in public relations booklets and free samples which, with staff wages, can reach tens of thousands of dollars per year.

1) Government Aids and Controls

Apart from environmental control, which is often administered by non-mining government departments, there is usually a rigid control of mining by a state or federal Mines Department with its inspectors. There is also a tax man, who in the early years of a project can give as well as take away.

In the field of environment mounting public agitation has caused most countries or states to enact legislation to control the effects of mining. Great Britain, for example, passed its

Town and Country Planning Act many years ago and this controls the general use of any land for any purpose, including mining. All surface works have to be suitably screened or of aesthetic appearance. Heights of waste tips and of building structures are restricted. Pollution in Britain may be controlled by several acts at once so that a succession of inspectors may call on a mine and care must be taken to consult local government authorities as well as national bodies.

In Australia there may be an overlap between Federal and State laws. It is too soon to be certain but air and water pollution may well be controlled by Federal laws whereas mining is governed by State acts. In New South Wales the Mining Act No. 49, 1906, which governs general mining activities, was amended in July 1971 to provide a new Regulation, 59A, which prohibits uncontrolled drainage, or pollution of water, and states that all open-cut mines must be left in a safe condition. It also lays down that the land must be revegetated to prevent erosion if the Minister (for mines) so directs. Previously to this mining pollution was controlled in that applications for mining leases would only be granted subject to controls on methods of working, and land restoration if necessary.

Some aspects of damage to public property are controlled by other acts. New South Wales has a Mine Subsidence Compensation Act 1961-1967 which regulates that aspect of working mines of coal and shale. It is difficult to summarize an act in a few words but, roughly, if mine workings damage property already built, then compensation must be paid to the owner of that property. If however anyone builds on land already proclaimed as a mining area, then that person will not be compensated for subsequent damage. Common law rights may also exist in relation to some operations.

In addition to meeting the costs of environmental controls a mining company also has to conform with legislation which controls working practices. Similar legislation exists throughout Australia. The state Mining Acts usually control prospecting and granting of leases, and then there will be an Act, or Regulations, to control the actual working practice at mines. Thus in New South Wales, in addition to the Mining Act 1906, there is the Mines Inspection Act 1901-1968 which deals with working all mines except those of coal and shale, and the Coal Mines Regulation Act, No. 37, 1912 which covers coal and shale workings. As if this were not enough there is a Scaffolding and Lifts Act, 1912-1960. If an engineer is engaged in tunneling work other than mining, or in deepening his harbour, then the Regulations of this Act will control his work under the most inappropriate title. The practizing mining engineer should know his local mining laws by heart and these may include Explosives Acts, Mines Rescue Acts, Workers Compensation Acts, and so on.

Mining acts and their administration need money. Consequently every ton of mineral mined is likely to have royalties and levies imposed on it. However some royalties and taxes can be semi-returnable. Governments make initial prospecting and marketing surveys. They may also pay prospecting subsidies or offset all exploration money against tax. For small miners New South Wales hires out exploration equipment at low rates, and will make current interest loans to enable small companies to buy essential equipment to start up a mine. In some types of mining there may be initial tax offset advantages for development of prescribed minerals. The tax laws have to be studied carefully and can have advantages as well as disadvantages. (Thomas, J. L., 1973 pp. 66-68).

2) Legislation and Restoration of Pits

When an open-cast coal mine is abandoned there is a risk that the seam will catch on fire, because of spontaneous combustion. Consequently mining legislation may lay down what is good practice in any case. The outcrop of the seam must be sealed off with a thick bank of earth and rock. The pit floor may be bulldozed up against the seam but a more efficient method is to drill and blast the crest of the highwall so that it is thrown down into the pit. This both seals the seam outcrop and reduces the highwall slope to an angle at which it can be safely abandoned. Many underground fires (particularly in the United States) might never have started if this procedure had been observed. Once a fire starts to creep along underground it can be expensive and almost impossible to extinguish.

The following paragraph is taken from the Eighth Schedule of the Coal Mines Regulation Act, No. 37, 1912, of New South Wales. It is typical of most acts.

"The owner, agent, contractor or manager of any open-cut working shall, unless otherwise directed by the Minister, cause to be removed separately for replacement as far as may be practicable, the top soil on such part of the area as may be disturbed, and such owner, agent, contractor or manager shall, as work progresses, cause the strata removed for the purpose of extracting a seam of coal or shale and all other residues, to be returned to the excavations made, or deposited on such sites, in such manner as the Minister may in writing direct. Such work shall be completed within six months of the giving of such direction. In all worked areas, the exposed coal seam shall be effectually covered with inert material to prevent fire hazards and the side of the cut shall be battered to a safe low angle and graded to slopes and contours consistent with the surrounding land, the top soil previously removed shall be replaced and all depressions effectually drained unless such depressions are, with the consent of the Minister, to be used for the purpose of ponding water or depositing other materials; such fillings, battering, grading and drainage shall be carried out to the satisfaction of the Minister".

The Mining Act, No. 49, 1906 of New South Wales, which governs metalliferous mines, makes a similar statement and in addition may require the area to be replanted with shrubs and trees. It also requires proper drainage to prevent erosion and treatment of drainage water to prevent pollution.

This brings out a basic difference between the two types of deposits. With a bedded deposit the excavation can be filled in and contoured as the open cut progresses. With direct back casting the operation is simple. When the last cut is taken the material from the box cut is restored in its proper order and the surface is made good. The swell of the broken ground over solid (bank) volume will usually compensate for the coal that has been removed.

A mined area can be used as pasture or farmland for a few years before it is used for building or other operations requiring stabilized ground. With fertilization and contour drainage the restored surface can be used to grow crops immediately and full fertility is restored within 2 or 3 years. Depressions may be left deliberately for reservoirs, stock ponds or recreational lakes. Shrub or tree planting may be adopted for reserves and amenity areas.

A large open-cut mine may have to remain as a hole in the ground, but some mines in Australia have produced ambitious restoration plans. A natural terraced amphitheater can be easily constructed by restoring the subsoil and topsoil which should have been saved. The bottom of the pit can be a lake withpicnic areas on the banks. The minimum requirement of safe slopes and fencing, if adopted close to an urban area, might well produce refusals for futher mining leases.

c. Reclamation Practices

Restoration of mined areas is also an essential part of mineral sands mining in Australia, and the companies have to post a financial bond to cover restoration before the State will grant a mining lease. Costs of restoration can vary from about $200 per hectare ($500 an acre) to $400 per hectare for bad areas that may need double treatment. Figure 35 shows the restoration plan.

The general treatment of the mining area is similar for all types of surface mining. Topsoil should be removed and stored for later replacement before any mining takes place. This is essential because it contains the humus and a reserve of seeds needed to regenerate the area.

Revegetation of sand dunes is difficult because the light topsoil is particularly susceptible to wind erosion. The first area to be mined has its vegetation removed and the topsoil bulldozed to one side. After mining has progressed the tailings are contoured and the topsoil spread evenly across the area ready for revegetation. The area should be reseeded as soon as possible although the time interval between stripping and seeding is around 6 months because the sand must be allowed to settle before the topsoil is replaced and cereals sown. This necessitates an area of about 150 m by 450 m being open for mining and tailings consolidation.

When the area is ready for restoration it is divided into three zones. The frontal dune area (not always present) is exposed to wind and salt spray and spreads about 40 to 50 m up the beach. It must be stabilized with a brush mat which

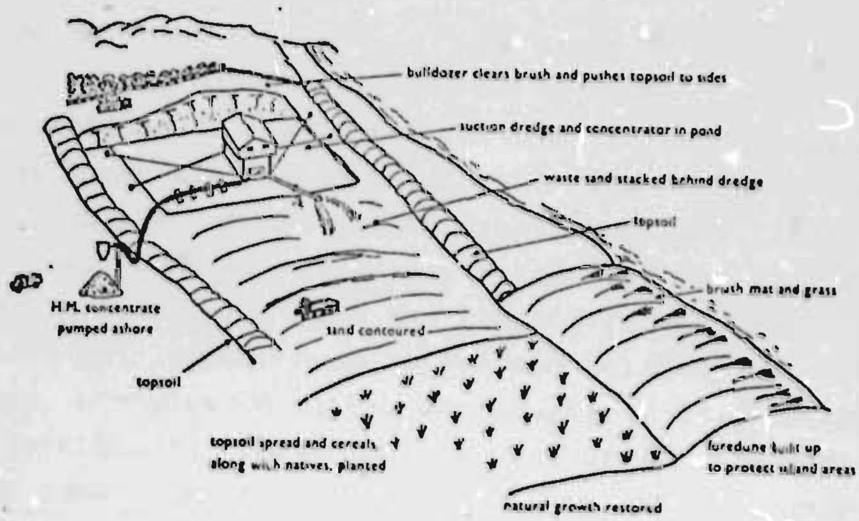

Figure 35. Restoration of mineral sands mining area (from Thomas, 1973, p. 95).

gives a wind cover to newly planted spinifex or marram grass. These grasses throw out runners which bind the sand together. With fertilizers and a proper rainy season the grass will bind the soil before the mat decays. The brush is obtained mainly from scrub cut from the area to be mined.

The second zone is the hind dune immediately behind the frontal crest. It is slightly protected but may occasionally have to be treated as frontal dune. However it is usually possible to sow with cereals and to brush mat. The brush mat drops seed pods, and the company plants other seeds and shrubs. Horse-tail oaks, coastal wattle and bitou bush are planted for permanent growth. Pig face and flannel flowers may be added. Cereals and legumes such as rye and sorghum, and West Australian lupins, are planted either in advance of or with the natives, and fertilized. These provide shelter for the young natives and extra humus when they rot down. They are not harvested.

The third zone is the heath area which is wind and salt free. When its own topsoil is replaced and fertilized the native generation is usually satisfactory. The area can be developed as pasture, or quick growing native seedlings may be added to speed restoration.

Extra expense is caused when dry periods hold up restoration, or kill off partly restored areas and necessitate replanting. It may also be necessary to fence areas and leave proper tracks to the beach to prevent indiscriminate leisure use from damaging young-shooted areas. It is perhaps worth nothing that tracks on sand dunes, whether for mining access or post mining leisure, should run along the crest of dunes. The wind then keeps them clear instead of drifting sand onto them. Plastic netting pegged out as windbreaks can help slow down drifting sand.

Governmental concern is now such that advice from agronomists is easily available for any mining restoration and the large mineral sands mining companies also employ their own specialist staff. Companies such as Associated Minerals have research facilities for revegetation and maintain their own nurseries. The latest AMA innovation is to use an elevating bowl scraper to remove topsoil and transfer it directly to the area to be restored. This preserves the essential bacterial life and native seeds to accelerate restoration (Thomas, J. L., 1973 pp. 95 - 96).

2. Western Europe

a. General Remarks on Energy

The rates of current and projected consumption of the world's energy sources are of equal concern to Western Europe. As in the United States, they have led to considerable discussion about the adequacy of coal, oil and natural gas for future industries and domestic use, and the possibilities of substitution, especially with nuclear fuel. Distribution of coal is relatively well known because of the accuracy with which coal deposits can be mapped (Table 3)*. Agreed estimates on

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* Simmons, I. G., "The Ecology of Natural Resources", John Wiley and Sons, New York (1974) p. 253

reserves of other fuels are uncommon, and most depend on assumption about economics, technology and politics that may undergo alteration during the periods about which prognoses are made.

Table 3. Minable Coal and Lignite (Metric Tons x 10^9)

Region	Estimated Resources	Established by Mapping
USSR including European part	4,310	2,950
USA	1,486	710
Asia outside the USSR	681	225
North America outside the USA	610	70
Europe	377	280
Africa	109	35
Oceania	59	25
South and Central America	14	10
Total	$7.6 x 10^{12}$	$4.3 x 10^{12}$

Bradley (1975) in his recent report on Germany states that

* Bradley, J. W., "Germany, Coal and the Community", Mining Congress Journal, (Feb. 1975) pp. 60 - 65

among even the most dedicated backers of coal, it would be going a bit far to call the 1973 oil embargo and price boosts blessings in disguise. But as long as cheap and abundant oil and gas were available at the turn of a tap, there was little incentive to invest large sums of money in coal R&D and in mine improvements. Accordingly, from the mid-50's on, the European mines that were not closed down had to put up with inadequate investment in maintenance and new equipment, even though those that continued to operate made vast improvements in mechanization and output per man-shift. But social considerations often had as much to do with keeping a mine open as did economics. Behind each decision there was always the question, "What will we do with the miners if we close the mines?" It was in the background of the carefully worked out German Energy Policy of 1973. Promulaged only a month before the Arabs imposed the oil embargo, it called for increased reliance on oil, gas and nuclear energy over the next ten years while cutting coal production back gradually from 97 million tons that year to 83 million in 1978. And this level could be maintained only with the help of substantial subsidies. In other European countries the trend was the same, while the cost in subsidies for maintaining whatever production was to be maintained was even higher.

In Great Britain, where coal mining comes closer to making a profit than on the Continent, there was less of a headlong rush away from coal to other forms of energy. Even so, production there fell from 147 million tons in 1971 to 130 million in 1973; and if in the accounting year ending in March the record shows 120 million tons mined, the mining community will be vastly gratified. The National Coal Board is running an aggressive sales campaign to encourage domestic and industrial use of coal, pursues research and development vigorously and has an active exploration program which was responsible a few years back for the discovery of the Selby field, with a potential output of 10 million tons a year by 1985. According to Bradley (1975), labor rather than faulty government policy or mining difficulties has been the greatest obstacle to the maintenance of a high rate of coal production in Great Britain. The 1973 strike brought on the three-day work week, an officially proclaimed national emergency and the fall of the Conservative Government. In 1974 the Communist wing of the Miners Union Executive Committee was responsible for the union's rejection of a productivity and bonus scheme proposed by the National Coal Board, much to the shock of its more conservative members and the bitter disappointment of the Coal Board's management. The union will shortly lay out its demands for what it calls a substantial increase in basic pay amounting to almost 86%. With this, all hopes for profits will probably be gone and with them the chances of modernizing and expanding the industry. To be sure, Britain still has North Sea oil reserves to fall back on, with the promise of eventually making it independent of imported oil. But that happy day is at least ten years off; and meanwhile government policies that are widely criticized by oil men, plus threats of confiscatory taxes, are cooling the ador of prospectors and drillers for that sector of the North Sea. Obviously, the higher prices that oil and gas are now fetching have influenced the policies and aims of both the board and the union. It is recognized that oil and natural gas are premium fuels which should be used where coal can not do the job. As a result of the National Coal Board's and others' campaigning in this direction, coal is the primary energy for 66% of Great Britain's electric power production, compared to 32% in Germany, with lignite contributing an additional 33%.

The effect of the oil embargo and subsequent price rise in Germany was to force the Economics Ministry to overhaul radically the Energy Policy it had promulgated only a month before; and it was painfully slow about that. The 1974 Energy Policy, designed to deal with the oil crisis, was made public on October 1974, just a year and five days after the start of the embargo. The actual changes in projected energy demand and the shares to be met from different sources as set out in the two programs were not great. Starting from the base of 387 million tons of coal equivalent in total energy demand in 1973, the program of that year projected a demand of 510 million tons by 1980. Of this, oil would provide 270 million tons and coal 97 million. The 1974 policy reduces the total demand in 1980 to 475 million tons of coal equivalent, with oil covering 221 million tons and coal 117 million. Nuclear energy, which now meets 4.5% of the country's total energy requirements (i.e. 11,763 mw of electric power) would, under the 1973 policy, have been expanded to 18,000 mw in 1980 and 40,000 in 1985. The 1974 policy raises the targets to 20,000 mw in 1980 and to between 45,000 and 50,000 mw by 1985. Natural gas now supplies 10.2% of total energy requirement. The 1974 policy gives gas an 18% share by 1980 (87 million tons of coal equivalent) and the same share in 1985, but equal to 101 million tons of coal equivalent. Holland, Russia, Norway and Iran will be the principal suppliers, and expenditures for domestic gas exploration would be stepped up, with over DM40 million help from the federal government. Between 1974 and 1985 lignite production is to be expanded modestly from 33.1 million tons of coal equivalent to 38 million, which will lower its share of the total energy input from 9 to 7%. More important than these quantitative changes is the government's acknowledgement that is must rely more than it has in the past on indigenous resources. This has reassured the coal industry that it is not to be treated as a stepchild in the national economy which, it is hoped, will encourage new investment, stimmulate research and development and contribute to the build-up of a stable labor force. Further, it provides the means of stabilizing production by making funds available to finance the stockpiling of 10 million tons of coal.

In France and Belgium, with or without the higher oil prices, coal production will have to be curtailed, since several of the main mining areas in both countries are either close to exhaustion or the mines in them are far more costly to work than German or British mines. Thus, France will go ahead with plans to cut its current output of 25.6 million tons to around 15 million tons by 1985; and Belgium, with 8.8 million in 1973 will be down to 7 million in 1985. These decreases could be tempered slightly by new investments to raise productivity in the mines that are to be kept going. Holland's last mines were closed in November 1974. England now has no surplus coal for export nor will it in foreseeable future. This leaves Germany as the single West European country with an exportable surplus to meet the needs of its coal-short neighbors: about 23 million tons with production at 94 million tons a year. This is based on a demand of 25 million tons for the iron and steel industry, 35 million for electric power generation and 11 million for domestic heating and miscellaneous small users. The German mine operators would like to have long term contracts from the EEC countries guaranteeing their purchase of this surplus; but as matters stand now they are selling it on a spot basis. Without an assured outlet for around 20 million tons, that much capacity could conceivably be shut down.

Whatever the outcome of that problem will be, German mine owners are now investing substantial sums in mine improvements. Since 1968, when Ruhrkohle AG was founded to consolidate operations of the better mines in the Ruhr area and closed the less efficient ones, investments have been running at about DM1 billion a year. There was a lot of catching up of deferred maintenance and general improvement to be done during that period, not to mention the joint operation of a number of neighboring mines. In the last few years the federal government and the governments of the states of North Rhine Westphalia and the Saarland have been contributing about DM120 million a year to this work. Under the 1974 policy, they will contribute DM210 million a year initially, and may go higher later. Much of this money has gone into mechanization, which is now about 96% complete. As a result, the output of German mines averages 4.068 tons per man-shift, compared to 3.91 tons in Great Britain and between 2 and 3 tons in France and Belgium, although the French Lorraine fields, with an output of over 10 million tons a year, have the best record in Europe with 4.496 per man-shift. Consequently, further mechanization will yield marginal improvements in productivity, so whatever gains are to be made from here on will depend on more efficient cutting machines, improved roof supports, better transportation systems in the mines and safer and healthier working conditions for the miners. Much of the research and development work under way at the industry's Coal Research Center at Essen-Kray (Bergbauforschung GmbH) is devoted to these ends. It has an annual operating budget of DM90 million from industry sources which is supplemented by the federal government and the state of North Rhine Westphalia.

Within the period of time covered by the 1974 Energy Policy, i.e. up to 1985, no provision is made for any substantial expansion of coal production. In an emergency, output could be boosted by about 10 million tons a year by expanding the work force in the mines now in production, but it would take five to eight years to open new mines. Geology rules out surface mining of coal, though all lignite is mined by that method, and its course, including the development of the biggest pit ever, is set for the next 50 years. Whether or not production will be expanded depends on the outcome of the Coal Research Center's current research and development work. Among the projects being studied there that could lead to an increased demand for coal are coal gasification through improvements in the Lurgi process, with a DM30 million budget between 1973 and 1976; pressurized gasification of coal dust, employing oxygen or enriched air, DM 45 million between 1973 and 1979; and coal liquefaction by the SRC progress, DM 115 million between 1974 and 1979. The objectives of these projects by the dates shown are pilot plants, after which production plants would have to be designed and built. Thus, assuming success all along the line, it would be at least 1985 before they could have any effect on the total demand for coal.

Basically, the European coal problem settles down to the clash between winning independence from foreign energy supplies and the high cost of mining the coal that is available in Europe in great abundance. If the price alone were chief consideration, Polish, Russian and, eventually South African imports could take care of a major share of the Community's needs. But that would leave it in the same hazardous position regarding coal as it already is regarding oil. High mining costs make subsidy payments necessary in all European countries. They range from about $0.80 a ton in Germany, and probably a bit less than in England, to about $12 a ton in the poorer fields of Belgium and France. Fortunately, coal from the good fields of Germany, Great Britain and France, which accounts for about 235 million tons a year, can in many cases be sold at a profit with the average price at $50 a ton. By contrast, production costs in the poorer fields, which now have an output of 36 million tons a year, are roughly twice as high.

b. Open-Cast Mining of German Brown Coal

In spite of its relatively low calorific value of 1600 to 2900 Kcal per kg, brown coal is the cheapest form of primary energy in the Federal Republic of Germany because of its shallow surface cover enabling it to be worked predominantly by large-scale opencast mining using high-capacity equipment for optimum production. To satisfy the high consumption of coal at the brown coal power plants, output has reached more than 100 million tons per annum and this output requires the removal of more than 267 million yd^3 of overburden which can only be achieved by complete mechanization of both the winning and conveying operations. In addition to the carboniferous coal seams of the Ruhr deep mining coalfield, Germany has vast Tertiary brown coal deposits, most of them near the surface. The total reserves of German brown coal average some 100,000 million metric tons and of this some 60,000 million tons are within the Federal Republic. About 9000 million tons of this can be won by the present open-cast mining techniques, 85% of it from the Lower Rhine region in which lie the main deposits, others being near Helmstedt in Lower Saxony, at Regensburg in Bavaria, near the zone boundaries and in Hesse near Frankfurt.

The deposits of brown coal in the Lower Rhine area (Figure 36) are the most important in the Federal Republic of Germany and make up the largest brown-coal mining area of Europe. They cover an area of 2500 km^2 and have been duscussed in detail by a number of authors. [1, 2, 3]

In contrast to deep-mined 'black coal' German brown coal is mainly overlain by loose material such as sand, gravel, clay or loam. Miocene brown coal from the Lower Rhine has a calorific value of 7000 Btu per kg (3182 Btu per lb) with a moisture content of 60 to 62% and ash from 2 to 8%. Bulges in the

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1) Tilman, W., "Brown Coal Mining in Western Germany" in 'Surface Mining' The American Institute of Mining, Metallurgical and Petroleum Engineers, Inc., New York (1968) pp. 955 - 968

2) Gartner, E., "Garsdorf Lignite Strip Mine - Operations to unusual Depths", in 'Case studies of Surface Mining' (publisher as above) (1969) pp. 12 - 35

3) Kausch, P., "Der rheinische Braunkohlenbergbau und seine Moeglichkeiten zur land- und forstwirtschaftlichen Rekultivierung sowie zur Landschaftsgestaltung" BHM, 118 Jg. (1973) H. 6, pp. 199 - 204 (see Bibliography of Foreign Language Literature in back of report, page 3).

Figure 36. Location of the Rheinish lignite area in northern Europe (from Gartner, 1969, p. 13).

underlying rock have caused faults running south-east to north-west and have split seams originally horizontal and from 32.5 ft to 195 ft thick, averaging 130 ft. (Figures 37 and 38). The open-cast workings are, however, getting deeper and will reach a depth of over 800 ft which, to enable work to proceed, will entail the complete de-watering of the area by deep filter wells 6.5 ft. diameter with submersible pumps of 1300 hp with eleven stages raising 3300 gallons per minute against a head of 1000 ft.

Some 550 wells are in operation in the Lower Rhine district to keep the water table 500 ft below the deepest point of the opencast, the total annual pumping load in the Rhine district being 400,000 million gallons, the water to coal ratio being 15 to 1.

In the districts where open-cast mining commenced the overburden to coal ratio is 0.35 to 1 but in new fields it will be 3-1/2 to 1 rising to 6 to 1.

The type of overburden and the relative softness of the coal has enabled continuously operating excavators to be used and these were at first bucket chain dredges mounted on rails or caterpillars with a cutting depth of 130 ft and still in use. They weigh up to 1400 tons with bucket capacities of 3 yd^3 and outputs of up to 70,000 yd^3 per day and consist of a bucket ladder carrying a bucket chain with a bucket every fourth link, which is suspended from a boom by wire ropes controlled by winches.

In the newly opened deposits in less favourable conditions the bucket-wheel excavator without travelling boom has become the dominant type. Transport to the surface is by belt conveyors the buckets doing the digging only. Bucket-wheel ex-

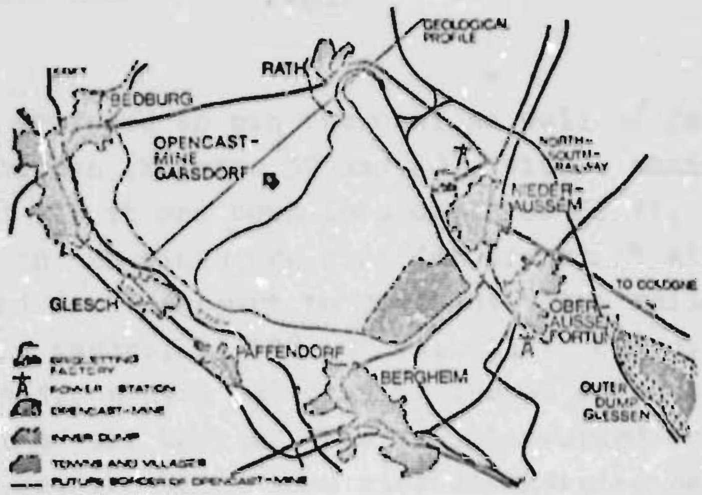

Figure 37. Location of the Garsdorf lignite open pit (from Gartner, 1969, p. 15).

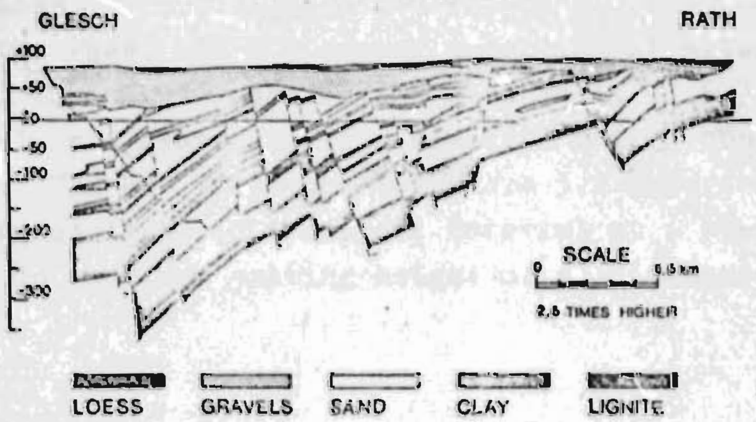

Figure 38. Geological profile of the Garsdorf lignite seam (from Gartner, 1969, p. 15).

cavators are used to win the coal as well as for removing the overburden (Figures 39 and 40), with a maximum cutting height of 163 ft and down to a depth of 82 ft. Conveyor belts up to 86 in in width are used for transport at 780 ft per minute and for transport to power stations rail haulage is used with large wagons, of 128 yd^3 capacity. The overburden consisting of sand, gravel and clay is dumped on outside dumps or close behind the working face or into worked-out pits, overburden spreaders being used with discharging belt conveyor boom up to 325 ft in length. Transport to the dumping site is by conveyor or rail.

According to a recent paper by Georgen et. al. (1974)*, a bucket-wheel excavator currently under design and scheduled for operation at the Gasdorf lignite mine in 1976 will have a capacity of 200,000-cubic meters per day. Assemblage of the machine was started in August 1973. This excavator is 220 meters long, 84 meters high and weighs about 13,000 metric tons. The wheel has a diameter measuring 21 meters and consists of 18 buckets each having a capacity of 6.3 cubic-meters. The wheel is operated by four electric motors consuming a total of 2520 kw. Conveyor belts are 3.2 meters wide and have been designed to transport material at a speed of 3.8 m/sec. The maximum cutting height of the machine is 51 meters.

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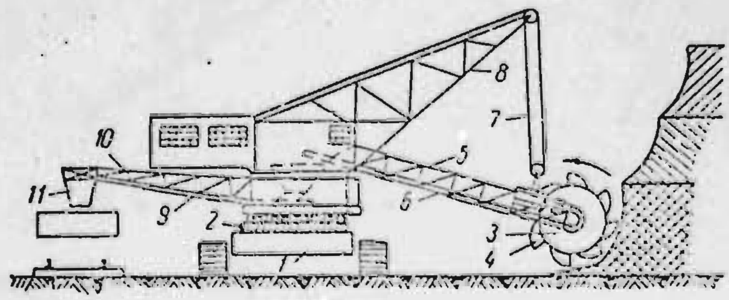
* Georgen, H., et. al., "Die Tagebautechnik in der Bundesrepublik Deutschland", Glueckauf (3. October 1974) pp. 763 - 767



The body of the bucket-wheel excavator rests on underframe *1*, fitted with crawler bogies or caterpillar wheels. The body of the machine is made to turn around its vertical axis by swinging mechanisms *2*. Operating wheel *3* of the excavator has eight or six curved blades (buckets) *4*. The wheel itself is set up at the end of frame (jib) *5*, shaped like a girder truss or beam. The jib carries belt conveyer *6*, which transfers mined ground to the loading, tail part of the machine, made in the shape of a swinging cantilever or arm *10*. This cantilever is furnished with belt conveyer *9*. Rocks are dumped into a railway car.

Figure 39. Bucket-wheel excavator (from Shevyakov, p. 627).

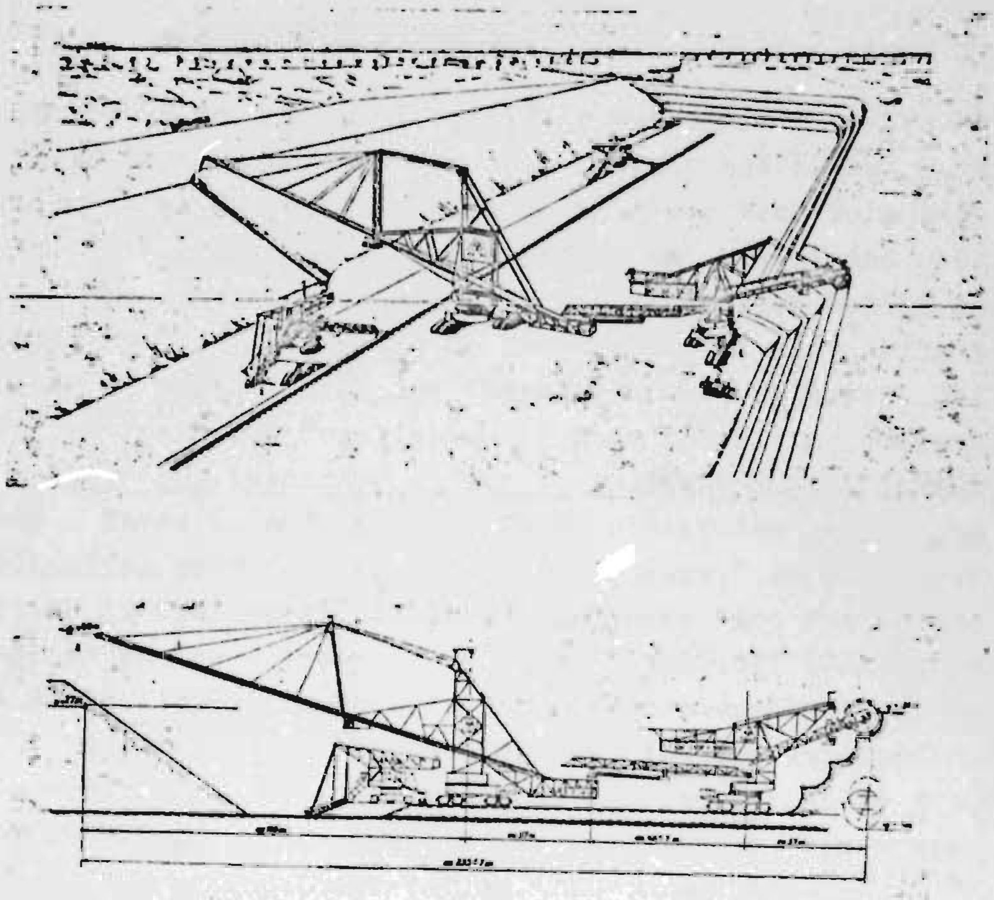


Figure 40. Plan view and cross-section of mining operation at Arjuzaux, France, using a bucket-wheel excavator manufactured by the firm KRUPP, Germany (from Woodruff, "Methods of Working Coal and Metal Mines, Vol. 3, p. 430, Pergamon Press, New York 1966).

1) Land Reclamation

In the brown coal area of the Lower Rhine district some 130 km^2 have been taken over for open-casting and 60 km^2 have been restored and of this area 34 km^2 have been forested, 16 km^2 returned to agriculture and 10 km^2 have found other uses. The landscape undergoes great alteration during open-casting on the 70 km^2 area in use for mining, involving the removal of agricultural and forestry areas, villages, rail-ways and roads but regulations require the mining companies to restore the landscape as far as possible to its former state. There is no single national mining law regulating reclamation practices in effect in Germany. As mentioned earlier in the report, a special law, the "Act for Common Planning in the Rhineland Brown-Coal District" (Gesetz fuer die Gesamtplanung im Rheinischen Braunkohlengebiet) of April 25, 1950, was enacted because of the size and importance of this area. This act requires that a general plan be pre-pared to include management of surface waters, landscape design, and nature conservation.

As reported by Gartner (1969) there are about 1,300 people per square mile in the Nordrhein-Westphalia province. Lig-nite mining by underground caving methods would have caused serious surface damage without the possibility of economically restoring the land to its original condition. Even if costly stowage techniques were applied, irregular subsidence of the surface would have occured. Only with surface mining, en-tailing the removal of overburden was it possible to restore the landscape. In addition to the density of population, the Rhineland has another unusual aspect: besides the lignite deposits there is another valuable natural resource on which is based extensive agriculture, i.e., a very fertile loess topsoil, which was deposited by aeolian action. In order to conserve the valuable loess, it is carefully scraped away and then spread on the surface of the overburden fill. To lower the cost of recultivation, a technique has been developed whereby loess is sluiced with water in a 1 : 1 ratio into evaporation ponds set up on the surface of the overburden dumps. After evaporation of the surface water, the loess-filled ponds are grouped together and are cultivated for 5 to 7 years by the mining company; thereafter, the loess thus prepared can be given to farmers who were relocated because of the mining operation. Another contribution to the welfare of the population is the reforestation, for recreation purposes, of the land reclaimed by fill. Although the inhabitants of villages at first adopted a critical attitude towards resettlement, yet, after the move was completed, they could note a substantial improvement in their standard of living. The new houses are larger and equipped with modern facilities; environmental conditions are substantially improved. Villages, once plagued by the dust and noise of through-traffic have been replaced by quiet, well planned localities with green space, set up away from relocated highways, railroads or streams, and yet easily accessible. By a well planned blending of access to transportation with the landscape, mistakes of the past were avoided. By 1968, 18 years from the date of the decision to exploit the Garsdorf field by surface rather than underground mining, the decision was fully justified. The company has succeded in reaching a depth of 660 ft, mining lignite without sustantial loss of substance at a low cost, and transporting it separately as briquets and steam coal to the principal customers. The company has used waste to create an attractive new landscape and, by so doing, has set an example of how to solve the problems encountered in surface mining of coal. (For illustration see Civil Engineering - ASCE, December 1974, p. 58).

a) Methods of Restoration: The methods of agricultural reclamation which are undertaken depend on the thickness of the loess deposits, which range up to 20 m in the western and northern parts of the area. It is a relatively young loess with high contents of lime and sand and only small amounts of clay. The high proportion of lime and the great permeability of the undisturbed loess provide a favorable air and water balance that are important for agricultural use. However, if the loess is excavated and then deposited in another area, it will soon develop a poor water balance and will become very vulnerable to erosion caused by overland flow. Due to this vulnerability to erosion, newly created arable lands should have a slope of less than 1 to 1.5%. This is especially necessary when shaping the dumps for agricultural purposes. Depending upon the distance from the origin of the loss material, the new areas destined for agricultural use are covered with loess layers of 1 to 2 m. A loess covering of 2 m results in optimum yields. Of the different methods of placing loess on the restored lands, two types have proved to be most effective: (1) spreading with a big machine, and (2) flooding with loess slurry. As already mentioned, in the so-called "wet procedure", loess and water are mixed in a 1 to 1 ratio, and the mixture is poured on the dump area into previously established evaporation ponds of 2 to 3 ha. Studies have shown that one year after cultivation the loess placed on the lands by this method has a higher pore volume than loess remaining on its natural sites. Original loess areas cultivated in the normal manner show a pore volume of about 46%; loess layers put on the reclaimed lands by the dry procedure show values between 43 to 45%; but loess layers put on the lands by the wet procedure reach a pore volume of 48 to 50% after 12 months of cultivation. This is due to the desiccation of the loess following the swelling of the soil particles when they were in contact with water. By this desiccation, hollow spaces which will fill up with air are created. Over a long period considerable experience has been gained concerning reforestation of reclaimed areas. The older plantations in the southern parts of the mining area were established about 30 years ago when reforestation was initiated using coniferous trees, primarily pines and larches. Since World War II, deciduous trees have been used more and more. To prepare the area for afforestation, they are covered by a so-called "forest-soil" consisting of a mixture of diluvial gravel with alluvial constituents and some loess-loam; the large proportion of very fine soil material helps to achieve satisfactory tree growth. This forest-soil was better than a layer of very fine soil and topsoil, as no soil horizons develop to hinder the roots from growing quite deep. If it becomes necessary to plant the trees in soil low in clay and nutrients and only a very small amount of fine soil or topsoil is available, one must carefully mix this valuable soil with the subsurface soil. With these procedures, afforestation will be speeded up and certain seral stages can be skipped. It is possible to grow more demanding plants of higher seral stages as well as the pioneer species on sites improved in this manner. An admixture of topsoil proved to be advantageous in all seeding trials. According to Olschowy (1973)* two aspects of afforestation on

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* Olschowy, G., "Landscape Planning on an Ecological Basis", in 'Ecology and Reclamation of Devastated Land', Vol. 1, Gordon and Breach, New York, (1973) p. 481

new lands are given the greatest consideration: ( ) agricultural areas should generally be separated from and p..tected against settlement or industrial areas by broad forest belts; (2) the extended edges of waste banks must be afforested with plants of naturally adapted forest communities in order to blend the banks into the surrounding landscape. Waste banks or dumps actually provide a number of severe problems for good landscape designing, but they can be used for creating quite a dynamic and varied scenery. Molding of the dump edges proves to be most important for blending waste banks into the surrounding landscape. The shape of the dump must be designed so that there will be no abrupt changes in topography and wind currents will be led upward without causing undesirable effects. To achieve these two aims, the slope of the edges must not be steeper than 1 to 3. Broad steps or terraces must be constructed to prevent erosion, and afforestation should be the principal method of revegetation. As enough material to fill all of the excavations is not available, ground water runs into the depressions and turns them into artificial lakes. There are many such lakes in the older southern portions of the mining area; these cover a total area of about 400 ha. Their value for recreation or as an ecological asset must be judged by how well the lakeshores have been designed and constructed. They should be kept nearly flat, with an inclination not steeper than 1 to 3 and without any sharp incisions at the foot or the upper edge of the slope, so that the transition to adjacent levels is smooth. Lakesides to be used for bathing must be levelled to a slope of 1 in 10. Waters to be used for fishing must have some steep banks to serve as shelter for the fish; also, flatter portions should be set aside for spawning. Lakesides not used for bathing are designed as habitats for wildlife, especially birds, by encouraging growth of a suitable community of reeds and other plants. Permanent protection of the lakeshore has to be achieved, and biological self-purification of the water must be promoted. When it is desirable to prevent the reeds (Phragmites communis) from reaching too far into the open water of the lake, terraces are built around the shores; these terraces are 50 cm below the water surfaces and the reeds are planted upon them. The oldest of these lakes in the southern part of the area are so magnificently fitted into the surrounding landscape, mainly through their masterly designed lakeshores, that plant and animal life is hardly any different from natural waters. A very rich bird life especially can be observed as the reeds offer them favorable habitats. Because of the large water area of 400 ha, the southern part of the mining area offers good recreation facilities for the inhabitants of the city of Cologne and the Ruhr Industrial District. We can find here a beautiful and impressive scenery of lakes, forests, hand hills; this is partially protected as a so-called "landscape reserve" (Landschaftsschutzgebiet) by a special Landscape Protection Ordinance. The lakes in the Rhineland browncoal district total 39. To provide for recreation more green spaces covered with forests, hedges, and shelter belts are needed. The forests, lakes and even the agricultural areas will be opened up for recreational use by properly designed roads and scenic routes. The landscape plan is divided into a basic part and a development part. Ecological and analytical research with respect to the landscape belongs to the basic part. Proposals and measures for modeling and development of the landscape founded on this basic research are dealt with in the development part. Thus the landscape plan can provide a reliable basis for regional planning, town planning, and other special planning projects, and it must, as far as possible become an integral part of authoritative planning.

In the Rhineland brown-coal district, a new landscape has been created in which the requirements of agriculture, economics, recreation and nature conservation are equally met, even though one would expect some controversial results from this confrontation of different interests within the same area. All of these interests must be kept within the limitations set by the natural balance of the landscape. Thus ecological research provides the basic plattform for all planning and design. The Rhineland brown-coal district has demonstrated that technology, economics, and nature need not to conflict, but that arrangements and compromises can be achieved in a reasonable way.

3. Russia and Poland

a. General Remarks on Energy

In contrast to West Europe's troubles in finding a balance between supply and demand of energy sources, Russia and Poland are doing extremely well in their respective spheres. While the Arabs are getting most of the headlines and public abuse for boosting oil prices, the Russians are taking their share of the gravy with very little attention and even less criticism.

Even before the 1973 blow-up, oil was Russia's biggest foreign exchange earner. Now, with oil prices four times higher than they were, its earnings from oil are expected to swell to nearly $3 billion a year - roughly half of the value of all exports to non-Communist countries. In addition the Soviet Union has contracts with Ruhrgas AG of Essen, Germany, for the delivery of 10 billion cubic meters of gas a year by 1980.

Poland is expanding its coal production steadily through the development of new mines, which will be highly mechanized, the mechanization of the older ones and the treatment of coal miners as privileged citizens in matters of pay, social benefits and national prestige. Production in 1974 probably exceeded 160 million tons, compared to 100 million in 1960, to put Poland in fourth place among the world's coal producers, after Russia, the United States and China. Particular attention is being paid to coking coal, of which 24 million tons were mined in 1974, a threefold increase since 1960. Mine safety, reported to be as low as 0.7 injuring accidents per million tons of coal mined, is said to be the best in the world. Average output per man-shift is now three tons and is improving steadily. As with oil and gas in Russia, coal is helping Poland's foreign exchange balance. In 1973 it exported 37.5 million tons. Thirteen million of this went to western Europe, up two million from 1972. This is a major annoyance to the German coal industry, as well as to potential exporters from other non-Communist countries, since the Polish price is consistently below the world prices.*

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* Bradley, J. W., "Germany, Coal and the Community", Mining Congress Journal (Feb. 1975) pp. 60 - 65

b. Open-Cast Lignite Mining in the USSR

According to recent figures published by Kusnetzov (1974)*, the Soviet Union disposes over 6,000 x 10^9 tons of mineable coal which is more than 50% of the world's resources. The main portion of this vast reserve, amounting to 5,600 x 10^9 tons, is located in the provinces east of the Ural Mountains. The main bituminous coal producing areas are the Donets Basin in the Ukraine, the Kuznetsk Basin in Siberia, the Karaganda Basin in Kasakhstan and the Petschova Basin of Northern Russia. The dynamic development of these basins is reflected by their increased output in recent years. (Table 4).

Table 4. Annual Output of the Main Coal Producing Provinces in the USSR (Million tons)

Basin	1965	1970	1972
Donets	205	216	217
Kuznetsk	94	110	119
Karaganda	31	38	42
Petschova	18	22	23

Source: Kusnetzov, K.K., Glueckauf 110 Nr. 2(Jan. 24,1974) p. 55

* Kusnetzov, K.K.,(Moscow) "New Developments in the Field of Mining Engineering in the Soviet Coal Mining Industry" (in German) Glueckauf 110 (1974) Nr. 2, pp. 55-60

In 1972, the USSR produced a total of 655 million tons of coal of which 156 million tons were lignite. Projections for 1975 (Figure 41) indicate that Soviet coal output will reach 695 million tons. To satisfy fuel requirements of the national economy coal production must be increased two fold by 1990. This increase is expected to be obtained by wide advances in coal mining technology, through improvement of existing surface and underground mines, and the development of new mines. Very large open-cast coal operations, with potential annual outputs of up to 100 million tons, are currently under development in the eastern regions of the Soviet Union. These operations are designed to provide the growing industry of West and East Siberia and Kaskhstan with low-cost fuel. For example, brown coal from open-cast mines in the Kansk-Achinsk Basin of Siberia and Ekibastuz Basin of Kasakhstan is planned to be primarily used for generating electricity. A huge energy complex consisting of mine-mouth operated power plants with a capacity of 34,000 MW will be installed in the western section of the Kansk-Achinsk basin within the next 10 to 15 years.

1) The Kansk-Achinsk Brown Coal Basin

The Kansk-Achinsk Basin is of special interest since it is the largest fuel source of the Soviet Union*. It is located in the province of Krasnoyarsk and extends partially into the district of Kemerovo and Irkutsk (Figure 42).

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* Kusnetzov, K. K., "Die Stein- und Braunkohlentagebaue der Sovietunion" (The Bituminous and Brown Coal Surface Mines of the Soviet Union) Rohstoffwirtschaft International Bd. 2, Verlag Glueckauf GmbH, Essen Germany (1973) pp. 168 - 187

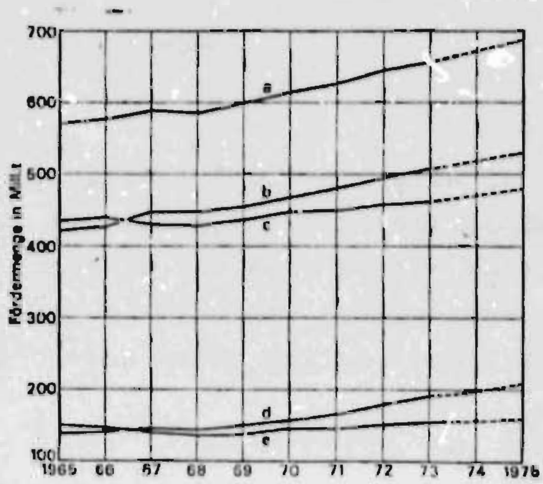

Figure 41. Development of Soviet Coal Production
a = Total, b = Bituminous Coal, c = Underground
d = Open-Cast, e = Lignite (from Kusnetzov, Glueckauf 24. Jan. 1974, Nr. 2, p. 56).

Figure 42. Mining and Manufacturing in the Soviet Union (from Encyclopedia International, Grolier, Inc. New York, 1968, E/I p. 342).

The physiography of this 45,000 km^2 area is characterized by rolling plains with changes in elevation between 250 and 400 meters. Drainage to the west of the basin is controlled by the river Chulym, a tributary to the river Ob. Water from the eastern part of the basin drains into the river Kan and Birjusa.

The climate of the region is strictly continental with a long cold winter and short summer. The mean annual air temperature is +0.5° C. Absolute maximum and minimum temperatures are at +45°C and -50°C. Annual precipitation averages 354 mm and snowfall does not exceed 50 cm. Frost penetration is 1.5 to 2.5 meters.

The Kansk-Achinsk Basin contains a number of deep depressions and flat folds in which the coal is deposited. These depressions and folds occured during the Jurassic period approximately 190 million years ago. The basin contains an estimated 670,000 million tons of lignite of which 140,400 million tons are suitable for open-cast mining. Most of the coal is deposited in gently dipping seams (2 to 9°) which range from 6 to 15 meters and 60 to 96 meters in thickness. The geological exploration program is 40% completed. Todate a total of 24 deposits have been located within the basin, the most important ones being the Itatsk, Berezovsk, and Bogotolsk deposits. Their geological cross-sections are shown in Figure 43. The overburden material consists of Jurassic sand and clay deposits covered with Quaternary loam. Where coal deposits are flat cover-rock strata is 80 to 90 meters thick. Where gently dipping deposits are present overburden increasing in thickness from 200 to 400 feet will have to be removed.

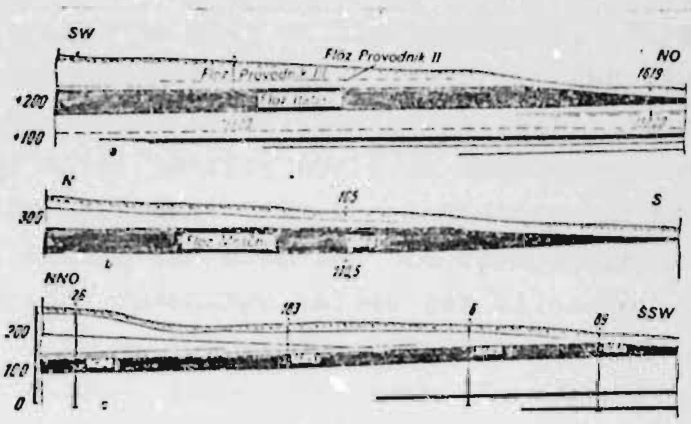

Figure 43. Geological cross-section through Itatsk (a) Berezovsk (b) and Bogotolsk (c) deposits of the Kansk-Achinsk Basin, USSR (Kusnetzov, 1973, p. 177).

Quaternary deposits may reach 25 to 30 meters in thickness (Bogotolsk), but generally are only 10 to 15 meters thick. The overburden to coal or stripping ratio of most investigated deposits is 1 to 2 m^3/ton and does not exceed 3.5 m^3/ton. The rock below the coal consists of sandstone interbedded with layers of argillaceous shale. Most formations are loosely cemented with calcerous clay as bonding agent. Physical properties of cover-rock are given in Table 5. The prevailing hydrological conditions in the basin are fairly complicated. A total of four water bearing horizons have been discovered in the Quaternary sediments, in the sandstone formations above the coal seam, within the seam and the rock formations below the coal. Computed discharge values per kilometer of pit length amount to 1000, 1000-1200, 500, 150 and 200 m^3/h for the Itatsk, Berezovsk, Nazarovsk, Irsha-Borodinsk and Abansk deposits respectively. The "Mosčnij" coal seam of the Berezovsk deposit (Figure 43) contains the largest aquifer.

The coal of the Kansk-Achinsk Basin is predominantly lignite containing 21 to 44% water, 7 to 13% ash and 0.3 to 0.7% sulfur. Its calcrific value varies between 3040 and 4440 kcal/kg. As already mentioned the brown coal from the Kansk-Achinsk Basin will mainly be used for generating electricity. Trying of the coal and converting it into dust, prior to burning it in the power plant boilers, will raise the coal's calorific value to 4900 and 5000 kcal/kg.

At present there are only the Nazarovsk and Irsha-Borodinsk deposits mined by open-cut methods. Their combined annual output is 14 to 15 million tons. However, production of these mines will be considerably increased in future years as mechanization of the pits using more efficient mining machinery

Table 5. Physical Properties of Cover Rock from the Berezovsk Deposit of the Kansk- Achinsk Brown Coal Basin

Rock	Density (t/m^3)	Water Content (%)	Pore Vol. (%)	Friction Angle (Degrees)	Cohesion (kg/cm^2)	Compressive Strength (kg/cm^2)
Loam	1.8-2.1	20.1-33.6	36-47	22	0.40	9.7
Argillite	1.9-2.3	10.4-22.4	23-41	21	0.45	51.0
Aleurolite	1.8-2.3	4.8-21.8	21-38	31	0.72	15.0
Sandstone	1.7-2.1	2.4-20.1	20-41	31	0.56	63.0

Source: Xusnetzov, K. K., "Die Stein- und Braunkohlentagebaue der Soviet Union" Rohstoff-Wirtschaft International Bd. 2, Verlag Glueckauf GmbH, Essen Germany (1973) p. 171

progresses, and is expected to reach 50 million tons per annum by 1990. The equipment presently in use for overburden and coal removal consists of Type SE-3, EKG-4 and EKG-8 power shovels. In addition to the three shovels used at each mine the Nazarovsk pit employes a walking dragline of the type ES-15.90 which is used for back casting of overburden into mined-out areas of the pit. This dragline (Figure 44) is equipped with a 15 m^3 bucket and a 90 m boom. The ES-15.90 weighs 1613 tons. The shovel EKG-8, for example, is available with bucket capacities of 6, 8, and 10 m^3 and has a boom length of 13.35 meters. The EKG-8 (Figure 45) weighs 363 tons. Transportation of overburden and coal is by rail using steam locomotives. Future operations at the Nazarovsk pit, where coal seams are 15 to 20 m thick, will employ draglines of the type ES-80.100 and bucket-wheel excavators of the type ER-1250. The overburden will be deposited in the pit as illustrated in Figure 46. Thus rail transport of overburden to outside waste dumps will be eliminated. The walking dragline ES-80.100 is equipped with a 100 m boom and has a bucket capacity of 80 m^3, it weighs 8400 tons. The ER-1250 bucket-wheel excavator is capable of transporting 1800 tons of overburden or coal per hour. It's maximum cutting height is 18 meters. (For more details on Soviet mining machinery see Kusnetzov, K., "Die Stein- und Braunkohlentagebaue der Sovietunion", 1973, pp. 298-323).

In mining the Itatsk, Berezovsk and other deposits, where seam thickness vary between 60 and 100 meters, it is necessary to continue overburden removal with power shovels. The cover-rock stratum contains hard lenses of sandstone which prevent bucket-wheel excavators of current design to be used at these locations. Overburden and coal is being transported

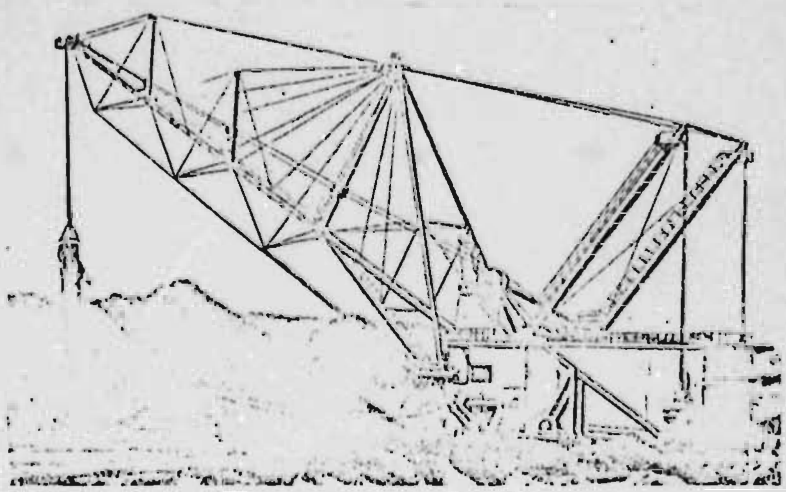

Figure 44. Soviet Dragline ES-15.90 (from Kusnetzov, 1973, p. 303).

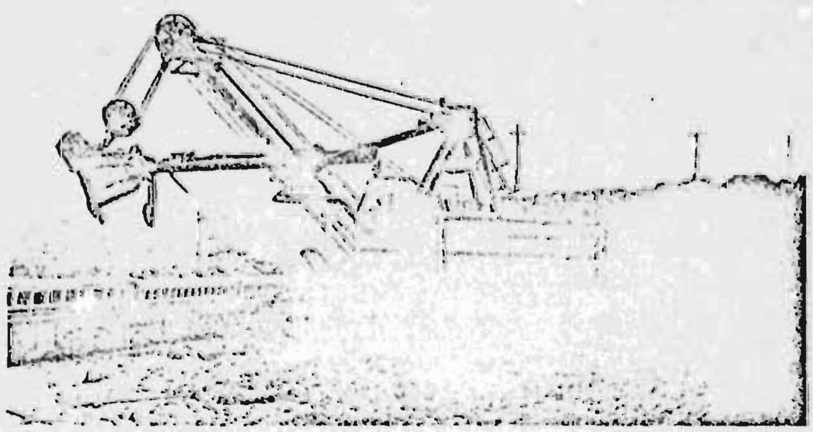

Figure 45. Soviet Power Shovel EKG-8 (from Kusnetzov, 1973, p. 299).

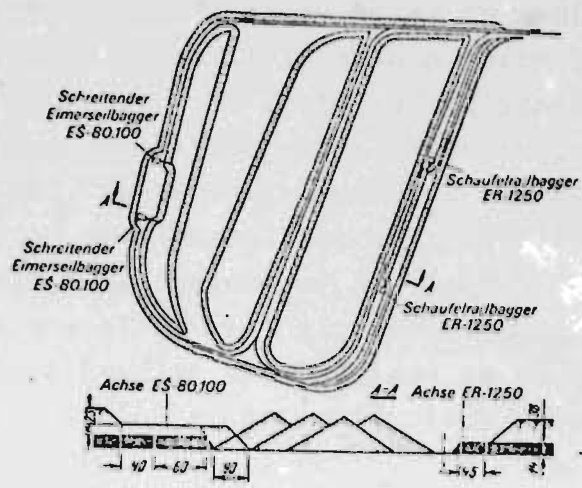

Figure 46. Overburden removal at the Nazarovsk Open-pit Nr. 2 (from Kusnetzov, 1973, p. 176).

by rail to dumps and storage facilities located outside the pit. Electric locomotives with 360Mp pull running on 10KV AC power are used for rail transport.

The main consideration in planning new open-cast mines in the Soviet Union is the use of fully automated, highly productive stripping equipment which when employed in minimum numbers, will produce at a high unit rate with a corresponding increase in output per man-hour. The choice of equipment depends on the mining geology so that at sites where the seam is flat and comparatively thin, up to 65 ft thick, a dragline system of working is adopted using draglines with bucket capacities of 30 to 120 yd^3 and boom lengths of 310 to 375 ft. The normal methods adopted are strip mining or cut-and-fill when overburden material is handled by draglines on to spoil banks in mined-out areas. If there is insufficient room to place the waste rock in the spoil banks, rehandling is adopted and for this purpose draglines are stationed on the spoil banks. Shovels are used to load the coal into road or rail transport, roads made or rails being laid on the bottom of a bench, one, two or more benches being used for loading. If the general dip of the strata does not equal 10^o and the thickness of overburden is considerable combined methods of mining are adopted. For example, at the Vakhrushev open pit in the Urals, in mining a seam 97.5 ft. thick, the upper benches of the rock overburden are excavated and transported to spoil banks by road or rail while the lower bench is excavated by the cut-and-fill method. In this case the overburden waste is dumped on to spoil banks in a mined-out area. In order to meet the requirements of the chief consumers of open-cast coal, the electric power stations, the work routine at most large open-cast sites provides for a continuous working year of 360 to 365 days.

Complete mechanization of auxiliary process is a necessity for efficient working at large open-cast sites in the USSR. Work is in progress on automatic operational control of equipment and transportation through automatic monitoring.[1,2,3]

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1) Kusnetzov, K. K., "Planning Large Opencast and Underground Coal Mines for High Productivity", Mining Magazine, December 1966, Vol. 115, No. 6, p. 452

2) Sobitsky, V., "Open-Cast Coal Mining in the USSR: Methods and Technology" in 'Case Studies of Surface Mining', Proceedings of the Second International Surface Mining Conference, The American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, 1969. pp. 57 - 64

3) Kusnetzov, K. K., et. al. "Die Hauptentwicklungsrichtung bei der Vervollkommnung der Technik und der Technologie der Kohlegewinnung in den Tagebauen der UdSSR", Neue Bergbautechnik, 3. Jg., Heft 10, Oktober 1973, pp. 732 - 736

c. Open-Cast Brown Coal Mining in Poland

Although relatively small in area and population (120,664 square miles and 33 million people), Poland (Figure 47) ranks fourth among the nations of the world in coal production since 1972. Compared to the USA, the USSR and China which produced 535, 500 and 400 million tons of bituminous coal respectively in 1972, Poland's output was 150.69 million tons. Bituminous coal production in 1974 probably exceeded 160 million tons (Bradley, 1975) and output for 1975 is projected to consist of 167.2 million tons of bituminous coal and 36.5 million tons of lignite (Table 6). According to figures published in 1974*, Poland disposes of 60,903 million tons of bituminous coal and 11,500 million tons of lignite.

Almost all of the bituminous coal is in the Upper Silesian Basin (Figure 48), which extends over more than 6000 km^2, has thick seams (3.5 m) and lies at an average depth of 300 m beneath the surface (Strzyszcz, Z., et. al., 1974)**.

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* Sajkiewicz, S., "Der Stand und die Entwicklung des polnischen Bergbaues", Neue Bergbautechnik, 4. Jg. Heft 8 (August 1974) p. 557

** Strzyszcz, Z., et. al., "Reclamation of Coal-Mined Land in Poland" in 'Second Research and Applied Technology Symposium on Mineral Land Reclamation, National Coal Association, The Coal Bldg. 1130 7th Street, N. W., Washington, D.C. 20036 (1974) pp. 242 - 252

AREA: 120,664 square miles POPULATION: 33,000,000 CAPITAL: Warsaw, population 1,300,000 GOVERNMENT: Actual power in the Polish People's Republic resides with the Politburo of the Polish United Workers' (Communist) Party; the elected 460-seat Sejm holds legislative authority. ECONOMY: Dominated by industry—steel, coal and copper mining. RELIGION: Predominantly Roman Catholic. CURRENCY: One zloty (100 groszy) equals 5 cents U. S. at the official rate, and half that much at the tourist rate.

Figure 47. Poland (from National Geographic April 1972, p. 468).

Figure 48. Major Coal Producing areas of Poland (from Strzyszcz, 1974, p. 243).

Table 6. Coal Production of Poland since 1938 with Projections to 1990

	1938	1945	1950	1955	1960	1965	1970	1975	1980	1985	1990
Bituminous Coal (in mill. metric tons)	13.8	27.4	78.0	94.5	104.4	118.8	140.1	167.2	190.0	205.0	225.0
Brown Coal (in mill. metric tons)	0.01	-	4.8	5.9	9.3	22.6	32.8	36.5	38.7	85.6	120.2

Source: Sajkiewicz, J., Neue Bergbautechnik, 4. Jg. Heft 8 (August 1974) p. 556

Because of these rich coal deposits, the Upper Silesian Region has become the most highly industrialized region in Poland, and ranks near the top among the industrialized regions in the world. About two million people live in this metropolitan area. However, instead of a single large city dominating the area, there are many smaller ones; Katowice, the largest has a population of less than 300,000. The concentration of coal mines within this highly populated and highly industrialized region has two important consequences: (1) a large number of people are affected significantly by mining and subsequent reclamation; and (2) high levels of air pollution impose constraints on reclamation programs.

Mining of brown coal, which is used primarily for generating electricity is centered in the Turoszow area, which produces about 55% of the total, the Zary area, 2%, both of which are in southwestern Poland, and the Konin-Turek area, 43%, in central Poland. The brown coal is currently mined by the open-cast method to a depth of about 100 m; in the future, the depth will likely exceed 200 m.

1) Mining Operations

The brown-coal mining operations are highly mechanized. The coal is removed from vast open-pit mines and transported to electric generating stations by a system of conveyor belts and railroads. The overburden is removed by huge bucket-wheel excavators, transported by a conveyor-belt system, sometimes for miles, and piled in several layers, one above the other. Conveyor belt installation in Polish lignite pits exceeded 100 km in 1974 and will reach 350 km by 1990. Initially, the overburden is piled outside the mined areas, i. e. in external dumps; later, it is piled in areas from which the brown coal has been removed, i.e. in internal dumps. During the operations, water is pumped from deep wells in order to depress the water table below the mining level. In 1970 water inflows of as much as 120 m^3/min. were recorded at the Datnow open-pit. The final phase of the operation in any one area thus will result in the formation of a depression which will probably fill with water. The most serious problemstherefore are the hydrologic problems associated with the mining and final reclamation.

2) Reclamation of Surface-Mined Land

Because the properties of the overburden material differs among the three areas, different methods of reclamation are used. The Turoszow deposits lie to the south of the town of Zgorzelec in the so-called Zytawa Basin, which is a depression structure of tectonic origin. The lithological composition of the overburden is 80 to 90 percent Tertiary clays and marls and 10 to 20 percent sands and gravels. Despite wide lithological variations, all formations represented in the overburden have an acid reaction.

The coal deposits in the Zary region occur in the Tertiary strata; in the overburden are Quaternary formations represented by marls, morainic clays, and sandstones. The lithological composition of the series overlying the coal measures is 75 percent arenaceous formations, 18 percent argillaceous and marly formations, 7 percent interlayers of lignites. Except for the surface layers, the reaction of the overburden ranges from acid to very acid.

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SURFACE MINING OF COAL A DISCUSSION OF MINING METHODS

In the Konin-Turek region, there are in principle two deposits, both very similar in geological structure. The overburden, composed of both Tertiary and Quaternary formations, consists of 17 to 20 percent sands and gravels, 40 to 55 percent marls, and 20 to 27 percent clays of various kinds. Virtually all the formations have a basic or neutral reaction.

The area occupied by all these surface mines is currently about 800 ha (1900 acres) of which about 400 ha (950 acres) are in pits and internal dumps, about 300 ha (740 acres) in external dumps, and the remainder is occupied by buildings and other structures. Research and experiments conducted for more than a dozen years provided the basis for the elaboration, during the period 1961 to 1968, of a reclamation system for land disturbed by open-cast mining of brown coal. The reclamation, scheduled to be accomplished over a four-year period, has the following stages:

(1) reshaping the topography to suit the requirements of the given reclamation method;
(2) regulation of the hydrogeological regime;
(3) construction of essential access roads;
(4) creation of suitable soil conditions for plant life; and
(5) introduction of trees and other plants and the stabilization of slopes through engineering and vegetative methods.

Soil properties are recreated by adding suitable fertilizers and neutralizing toxic formations. Agricultural lime is generally used for neutralization, but sometimes magnesium-oxide lime, a waste product in zinc metallurgy, is used. This latter compound has proven to be particularly active as a neutralizing agent and is applied to the severely toxic dumps in the Zary region (pH in KCL 2.0 to 2.5) at the rate of 30 mt/ha (13 tons/acre). Following liming and fertilizing, trees of either pioneer or production species are planted. Several different combinations of species, planting patterns, and methods of mixing the seedlings have been developed. The one recommended for a specific site depends upon the properties of that site and the reclamation objective. Among the pioneer species used for improving conditions for future plant life, best results have been achieved with European and grey alder and aspen. Of the production species, the best growth and development has been made by European larch, sycamore maple and various species and hybrids of populus. Stabilizing the slopes is accomplished by planting different species in strips along contour. The number and width of the strips depend on the height and gradient of the slopes. Such biological stabilization becomes an extraordinarily complex undertaking in cases such as the dump at Turoszow whose eventual height will be 250 m. The species forming tha major part of the tree complex for stabilizing the slopes are black locust, grey alder, hybrid poplar, willows, and sea buckthorn. By the time exploitation of these brown-coal fields has been completed, more than 14,000 ha (35,000 acres) will be reclaimed or scheduled for reclamation, 7,000 ha (17,000 acres) of which will be forest recultivation and 4,600 ha (11,000 acres) agricultural. Most of the rest will be in water storage.

3) Current and Future Reclamation Research

As reported by Strzyszcz, Z. et.al., (1974) there are two main groups of Polish scientists actively engaged in research in the reclamation of industrial wastelands, the

Institute of Environmental Protection of Industrial Regions of the Polish Academy of Science at Zabrze and the Institute of Shaping and Protection of the Environment of the Academy of Mining and Metallurgy in Cracow. They cooperate closely with industry, which is charged with carrying out the reclamation, and with the government agencies responsible for drawing up the regulations concerning reclamation. Industry relies heavily on the institutes for advice in their reclamation projects, and the institutes often incorporate large-scale studies into these projects. As a result, most of the research is of an applied nature. Nevertheless, some basic studies are currently underway or have recently been completed. These include:

(1) determination of the rate of weathering of shales and sandstones;
(2) lysimeter studies on the rate of leaching of mineral salts from coal-mine wastes and their effect on tree seedlings;
(3) influences of grass cover on the process of salt uptake and release, especially in regard to the role transpiration plays in preventing water from percolating through the spoil to the groundwater;
(4) research on the development of microorganism populations on the reclaimed wastes;
(5) influence of various forms of nitrogen on a number of species planted on the wastes;
(6) relative tolerance of various tree species to high soil temperatures; and
(7) rooting characteristics of various tree species planted on a variety of waste materials.

Scientists at these two institutes have published many papers describing the results of their research. The most important publications are listed below. [1,2,3]

An important unsolved problem in Poland is that of hydrological disturbances caused by mining. Some areas become excessively wet; others, excessively dry. Since the mining industry itself can do little to lessen this type of adverse effect, other departments must develop and undertake long-term preventive measures to reduce the degradation of the surface which inevitably follows such hydrological disturbances. A perculiarly difficult problem is that of counteracting the effects of excessive drainage and a declining groundwater level in sandy soils, especially under conditions of high atmospheric pollution. Both theoretical investigations and field experiments are being conducted on this problem. Work is being done on the reclamation of other types of

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1) Paluch, J., "Problems of Reclamation of Post-Industial Lands" in 'Matenaly Symozjalne, Part B', ZBN GOP-DAN Bull. No. (1965)

2) Hutnik, R. J., et.al., "Ecology and Reclamation of Devasted Land", Gordon and Breach Sci. Publ. New York, Vol. 1, 538 p.

3) Greszta, J., "The recultivation of Post-Industrial Territories", in 'Protection of Man's Natural Environment', Polish Sci. Publ. Warsaw, p. 396 - 417 (1973).

industrial wasteland. Among these, the most serious unsolved problems are associated with: (1) land deformed in the extraction of sulfur by underground-leaching method in areas having a high water table, which leads to servee chemical and hydrochemical pollution; and (2) land degraded due to winning of rock materials (slow-weathering granites, dolomites, and limestones) where topography and poor soil-forming properties of the rock material hinder effective reclamation (Skawina, Kamieniecki, and Strzyszcz, 1973)*.

Polish scientists are convinced that preventive action, in its widest interpretation, must necessarily form an integral part of all reclamation plans.

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* Skawina T., Kamieniecki F., and Strzyszcz Z., Urowen i perspektiwi rekultywacji w Polsze. V Mezunarodnyj Sympozjum "Razrabotka sposobow rekultywacji landszafta naruszonego promyszlennoj dejatelnostiu". Burgas (1973)

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Ruesberg, K. H., "The Planning of Planning Work", Glueckauf 110 (1974) Nr. 13, pp. 525 - 529.

Dach G., "The Coal Mining Industry 1973 in Countries of the European Community", Glueckauf 110 (1974) Nr. 13, pp. 535 - 540.

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Fricken, U., v., "The Polnish Coal Mining Industry. Developments and Prospects", Glueckauf 110 (1974), Nr. 6, pp. 214 - 218.

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BHM, 118 Jg. (1973) H. 6, pp. 199 - 204.

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Hawner, K.H.., "Progress in the German Coal Mining Industry - Balance of Success and Prospects in Mining Engineering and Coal Refining". Glueckauf 110 (1974) Nr. 2, pp. 47 - 50.

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Kusnetzov, K., K., "New Developments in the Field of Mining and Engineering in the Soviet Coal Mining Industry". Glueckauf 110 (1974) Nr. 2, pp. 55 - 60.

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Neue Bergbautechnik, 4, (1974) Nr. 6, pp. 425 - 429.
The present status of using the technique of simulation in the lignite mining of the G.D.R. is analysed. Important differences in the technique are briefly characterized by means of general cases of application. An improvement of this useful method is determined by practical requirements.

Busse, H., G., Mueller, D., "Effects of Unevenness of the Subgrade on Technical Processes in Open-Cast Mines".
Neue Bergbautechnik 4, (1974) Nr. 6, pp. 429 - 434.
By means of a subgrade model effects are described, which are exerted by the unevenness of a subgrade on: the accuracy of computing quantities, the calculation of movements of quanitties necessary for increasing the evenness of the subgrade, the calculation of necessary depths of ditches, the inclination of slopes, the division of cuts in open-cast mines, and on the gradient of bench sections and travelling resistance. Measures to be taken for increasing the evenness of the subgrade are suggested.

Foerster, W., Zwingmann, A., Walde, M., "Geohydraulic Problems of Dams constructed to block Water-Bearing Roads in Open-Cast Lignite Mines".
Neue Bergbautechnik, 4, (1974) Nr. 6, pp. 435 - 438.
A system of roads is to be blocked against water inflow with a maximum hyrdrostatic pressure of 5 kp/cm^2. The hydraulic criteria presenting themselves essentially influence the execution of the blocking structures if a longterm stability must be designed. The flowing-about must be encountered in two ways, either by excluding the danger of erosion for a long term or by adapting the technology of constructing the dam according to the existing conditions.

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Baier, H., "Technical-Economic Advantages of Using Thyristor Controls instead of Leonard Converters for Travelling Gears of Open-Cast Mine Equipment".
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Folkens, K., "Some Remarks on Operating Problems of Filter Wells for Draining Open-Cast Lignite Mines".
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Matschak, H., Schaef, H.-J., "Deformation of Cohesionless Soils in the Floor of Lignite Deposits Due to the Flow of Perculating Water. Part 2: Liquification of Lower Lusatian Floor Sediments and the Effect of Cut-off Walls".
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For basic failures due to erosion in open-cast mines the critical hydraulic gradients and a high geometrical risk of Liquification of the floor sediments are determined, which should be considered when erecting cut-off walls because they cannot fail to increase the hydraulic gradient. By suitably designing the retaining height base failures due to erosion will be supressed.

Brandl, A., Friedrich, K., "Low-Loss Speed Control of Direct-Current Industrial Locomotives in Open-Cast Lignite Mines.
Neue Bergbautechnik 4 (1974) Nr. 3, pp. 191 - 194.
A description is given of the conversion of direct-current industrial locomotives to direct-current pulse control by means of power thyristors, showing both in difficulties recognizable at present in the technical realization as well as remarkable economic advantages and technical improvements of the fleet of tractive units available.

Miertschink, R., "Maintenance Problems to Be Solved when Preparing the Operation of New Open-Cast Mine Equipment".
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Early experiences and further ideas are described with a view to solving maintenance problems when preparing the operation of new major mining equipment.

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Neue Bergbautechnik 3 (1973) Nr. 12 pp. 910 - 915.

Schuhmann, H., "Measures Taken in the Zone in Front of the Open-Cast Mine and along Excavator Slopes with a View to Improving Winter Work in Open Cast Lignite Mines".
Neue Bergbautechnik 3 (1973) Nr. 11, pp. 801 - 807.
A description is given of results of investigations and preventive measures to improve working in open-cast lignite mines in winter time. Methods tried with success are suggested for protecting the zone in front of the open-cast mine, the excavator slopes and planes of separation against freezing.

Graf, W., "Fitting Rear Rippers into DET or T 100 M Bulldozers for Intermediate Working Planes and Tilting Trenches". Neue Bergbautechnik 3 (1973) Nr. 11, pp. 807 - 808.

Rothe, D., "Methods for Preventing the Freezing of Overburden and Raw Brown Coal at the Wall of Coal Cars in Lignite Mines during Winter Time".
Neue Bergbautechnik 3 (1973) Nr. 11, pp. 809 - 815.
An absolute prerequisite for continuously operating lignite mines also in the winter months is an undisturbed overburden transportation and coal production. This is the reason why a detailed account is given for the technology and economy of frostproof brines made by the potash industry of the G.D.R., whose corrosive properties are outlined. As from the energetic point of view electric coal car heating is very expensive for preventing the freezing of raw brown coal onto the walls, attempts are described for attaining the same effect by coating the wall with PE panels as well as by using other methods. Suitable suggestions are presented for practical operation.

Unger, S., "Use of Blasting in Open-Cast Lignite Mines for Controlling Definite Winter Problems".
Neue Bergbautechnik 3 (1973) Nr. 11, pp. 816 - 821.
From analyses of the winter 1962/63 and 1963/64 the limit presently justified for using blasting is considered, with the particular emphasis on developing a standard rotary drilling equipment in lignite mining. Final remarks deal with details of the blasting technique and submit an experimental program for discussion.

Scheibe, U., "Experiences with the Use of Jet Engines for Controlling Difficulties Encountered in Open-Cast Lignite Mines in Winter Time".
Neue Bergbautechnik 3 (1973) Nr. 11, pp. 821 - 825.
A description is given of experiences attained with jet engines for keeping free points and travelling lines, for cleaning coal and overburden cars, as well as for removing snow and cleaning belts in order to be able to control difficulties encountered in winter in open-cast lignite mines, and in particular in mass transportation. The construction of an operation of such installations are described.

Strzodka, K., Piske, G., "Tasks and Problems of Brown-Coal Mining in the G. D. R.".
Neue Bergbautechnik 3 (1973) Nr. 10, pp. 725 - 731.
Till past 1990 the brown coal will remain the most important source of primary energy in the G.D.R., and will keep its importance as a fuel and carbon carrier far into the 21st century. The future picture of brown-coal mining will be

changed by new developents, such as fully mechanized and partially automated overburden conveyor bridges with a digging capacity of 60 m. Where such conveyor bridges can not be operated, new high- efficiency bucket wheel excavators, belt conveyors and overburden spreaders will be used for outputs of about 15,000 m^3/h. A prominent part will be played by drainage and recultivation.

Kusnezow, K. K., Scharkow, A. M., "The Main Development Trends in the Perfection of the Technique and Technology of Coal Mining in Open-Cast Mines of the U.S.S.R.". Neue Bergbautechnik 3 (1973) Nr. 10 pp. 732 - 736.

Zajac, Z., Kozlowski, Z., "Optimization of the Coal Quality from Multiple-Step Brown-Coal Open-Cast Mines, Illustrated by the Projected Open-Cast Mine of Belachów (Poland)". Neue Bergbautechnik 3 (1973) Nr. 10, pp. 737 - 740.

Tschernegow, Y. A., "Planning and Control of the Scientific-Technical Progress in the Mining Industry of the U.S.S.R.". Neue Bergbautechnik 3 (1973) pp. 740 - 745.
The organization for controlling the scientific-technical progress in the national economy of the U.S.S.R. (in general as well as in particualr in the mining industry) is particularly improved by widely using an optimum planning which, for its part, assumes a comprehensive operation of electronic computers. A description is given of the optimum planning as applied to the solution of two problems of planning the scientific-technical progress in the mining indurstry.

Simonovic, M., Kun, J., "The Brown-Coal Mining in the Power Producing Industry of the Socialistic Federative Republic of Yugoslavia".
Neue Bergbautechnik 3 (1973) Nr. 10, pp. 745 - 751.
The brown coal will continue to occupy an important place in the power producing industry of Yugoslavia, in particular with regard to satisfying the needs of large thermal power stations, that is to say with regard to the production of electricity. The difficult problem that faces the Yugoslav brown coal industry is to maintain the cost of production by an increased productivity, even if the conditions of mining are somewhat unfavourable. The answers are found in a choice of optimum mining methods for individual phases of production with great emphasis placed on a proper choice and better utilization of the types of equipment available.

Popa, A., Fodor, D., "The Brown-Coal Mining Indurstry of Rumania".
Neue Bergbautechnik 3 (1973) Nr. 10, pp. 752 - 755

Milde, G., Milde-Darmer, K., "Practical Conclusions to Be Drawn from Influences Exerted by the Drainage of Mines on Landscaping"
Neue Bergbautechnik 3 (1973) Nr. 10, pp. 755 - 761.
On the basis of possible principal influence of measures taken for the drainage of mines on landscaping (surface subsidences, lowering of water table, qualitive influence on the out fall ditch by drainage water), a discussion is presented of problems connected with the effect of lowering the water table and of water inlets.

Mitrega, J., "The Fuel and Energy Basis of The People Republic of Poland, Today and in the Year 2000".
Neue Bergbautechnik 3 (1973) Nr. 9, pp. 637 - 641.

Bocsanczy, J., Bruzsa, F., Gozon J., "Technical and Technological Studies of Production in the Visonta Brown-Coal Open-Cast Mine. (Hungary)
Neue Bergbautechnik 3 (1973) Nr. 8 pp. 573 - 578.

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Neue Bergbautechnik 3 (1973) Nr. 8, pp. 578 - 583.

Draganow, L., "The Electrochemical Consolidation - a Method for Increasing the Carrying Capacity of Clays in the Sub-Structure of Stationary Tracks in Open-Cast Mines".
Neue Bergbautechnik 3 (1973) Nr. 8, pp. 584 - 588.

Schmidt, M., Arnold, E., "Experience gained from an Installation for Monitoring the Utilization of Belt Conveyors in Open-Cast Mines".
Neue Bergbautechnik 3 (1973) Nr. 8, pp. 594 - 597.

Brandl, A., Goetze W., Friedrich K., "Control of the Load of Conveyance in Brown-Coal Open-Cast Mines by Means of Over-dumping Control Units".
Neue Bergbautechnik 3 (1973) Nr. 8, pp. 597 - 599.

Festner, M., Foerster, K.-H., Noack, A., "The Maintenance of Overburden Conveyor Bridges".
Neue Bergbautechnik 3 (1973) Nr. 8, pp. 599 - 602.

Almasan, B., "The Mining Industry of Rumania".
Neue Bergbautechnik 3 (1973) Nr. 6, pp. 409 - 412.

Mueller, D., "Use of Electronic Data Processing in the Brown-Coal Industry".
Neue Bergbautechnik 3 (1973) Nr. 6, pp. 415 - 418.

Nobis, K., H., "Use of Large Computers in the Brown-Coal Industry for the Point of View of AUTEVO".
Neue Bergbautechnik 3 (1973) Nr. 6, pp. 419 - 423.
Many technical-economical and technological boundary conditions must be observed when planning highly expensive brown-coal open-cast mines. By means of large computers a great number of variants can be calculated with a view to making an optimum decision. The present and future utilization of programmed computers is explained.

Kaden, St., Luckner, L., Quast, J., "Practical Examples Illustrating the Solving of Problems of Groundwater Flow by the Method of Finite Elements with Digital Computers".
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Foerster, W., Walde, M., Zwingmann, A., "Geomechanical Problems of Designing Dams for Sealing off Water-Bearing Layers in Brown-Coal Open-Cast Mines".
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Graeber, P., W., "Method for a Time-Discrete Electric Simulation and Numerical Calculation of the Equation for the Horizontal-Plane Groundwater Flow."
Neue Bergbautechnik 3 (1973) Nr. 3, pp. 183 - 184.

Bilz, P., "Longterm Movements in a Slope System Consisting of Filled Cohesive Mixed Soils Due to the Rise of Ground Water".
Neue Bergbautechnik 3 (1973) Nr. 3, pp. 185 - 195.

Piatkowiak, N., "A Model for Planning and Scheduling the Operation of Machinery and Equipment".
Neue Bergbautechnik 3 (1973) 1, pp. 33 - 35.

Suess, M., Sonntag, E., "New Geological and Petrological Knowledge on the Problem of Xylite Contained in Lusatian Brown Coals.
Neue Bergbautechnik 2 (1972) Nr. 12 pp. 898 - 907.
It is shown by analyses based on statistics that the content of xylite of defined groups of coalfields presents significant differences. As far as coal refining is concerned, the maximum limit permitted for xylite contents is often exceded, parti-

cularly in the base deposits of VEB Gaskombinat Schwarze Pumpe and VEB Kraftwerk Boxberg.

Doerschel, D., Dutschke, L., Langheinrich, G., "Use of the Zielbaum Method for the Exact Definition of Problems in Open-Cast Mining Techniques".
Neue Bergbautechnik 2, (1972) Nr. 12, pp. 907 - 910.
A description is given for defining problems of research in the field of open-cast mining techniques, using the "Zielbaum Method".

Wiehe, J., "Problems and Open Questions on Measuring and Evaluating Noise".
Neue Bergbautechnik 2 (1972) Nr. 12, pp. 930 - 934.
Open questions and problems on measuring and evaluating noise are discussed. As the noise level does not permit to evaluate correctly the spectrum, errors occur when evaluating the noxiousness of noise. In case of doubt the limit curve method is still justified. More attention must be devoted to the parameter 'q' dependent on the load when determining the 'L_{eq}' level. For noise containing pulses the peak value must be used for the purpose of evaluation.

Krause, H., Bartke, J., "The Surveying of Tracks Reviewed from the Point of View of Brown-Coal Mining".
Neue Bergbautechnik 2 (1972) Nr. 12, pp. 936 - 938.

Siebold, K., "The Development of the Brown-Coal Industry in the German Democratic Republic".
Neue Bergbautechnik 2 (1972) Nr. 11, pp. 837 - 840.

Franke, H., Goetschke, W., Schulze, H., Strzodka, K., "Regulations in the Exploitation of Mineral Deposits". (Congress Lecture).
Neue Bergbautechnik 2 (1972) Nr. 11 pp. 854 - 859.

Peukert, D., Reichenberger, H., "Contribution to the Effect of Residual and Surface Waters in Brown-Coal Open- Cast Mines".
Neue Bergbautechnik 2 (1972) Nr. 10, pp. 762 - 767.
A description is given of the effects produced by residual and surface waters on the stability of pit slopes and spoil banks. Problems of surface drainage and dewatering of the pit are discussed.

Strzodka, K., "Theoretical Studies of the Efficiency of Cut-off Walls. Part 3: Mathematical Consideration of Rotation Symmetrical Flow through Complete Cut-Off Walls in the Homo-

genous and Isotropic Aquifers with and without Partial Percolation".
Neue Bergbautechnik 2 (1972) Nr. 10, pp. 768 - 770.

Siebold, K., "The Present State of Safety of Opencast Mines in the Brown Coal Industry and Problems Derived from it".
Neue Bergbautechnik 2 (1972) Nr. 9, pp. 641 - 646.

Reinisch, E., "Role of the Safety Working Group in Open-Cast Mines as a Control Instrument of the Works Manager".
Neue Bergbautechnik 2 (1972) Nr. 9, pp. 648 - 649.

Nowotnick, G., "Operation of Overburden Conveyor Bridges under Difficult Geological and Hyrological Conditions in the Lohsa Open-Cast Mine".
Neue Bergbautechnik 2 (1972) Nr. 9, pp. 650 - 653.

Reisner, H., "Development Trends in Draining Open-Cast Mines".
Neue Bergbautechnik 2 (1972) Nr. 9, pp. 657 - 660.

Bothe, H., Caldonazzi, O., Mielke M., "Increasing the Availability of Drainage Works by Remote Supervision and Control with Respect to the Safety of Open-Cast Mines".
Neue Bergbautechnik 2 (1972) Nr. 9, pp. 660 - 661.

Rechenberger, H., Peukert, D., "Transferring Results of Research Work to the Field of Open-Cast Mine Drainage".
Neue Bergbautechnik 2 (1972) Nr. 9, pp. 661 - 663.

Tomczak, H., J., "Protection of Environment of Brown Coal Mines".
Neue Bergbautechnik 2 (1972) Nr. 8, pp. 565 - 567.
Comprehensive precautions must be taken by the brown-coal industry in order that the socialistic landscape treatment might be realized. The passing of the German standard Specification TGL 24,663 entitled "Maximum Concentration of Emission for the Discharge of Dust" made it possible to show technical and organizational solutions conceived for priority objectives still to be solved. They include effects produced by the brown coal on the water resources of the G.D.R., with emphasis placed on the multiple utilization of water. A particular attention is devoted to the restoration to agriculture and forestry of mining districts, as well as to their further uses as local recreation centers.

Eckart, D., "Types and Causes of Damages from Completed Mine Workings".
Neue Bergbautechnik 2 (1972) Nr. 8, pp. 619 - 625.

Fischer, M., Hackeschmidt, M., "On Determining the Level of Residual Water when Draining Brown-Coal Opencast Mines by the Singularity Method and Electric Analogy".
Neue Bergbautechnik 2 (1972) Nr. 6, pp. 433 - 436.
Residual water levels affecting the stability of overburden slopes and tips present themselves when draining the covering beds of brown-coal open-cast mines. Proceeding from the equation for determining the level of residual water in the case of single bars (limiting bars), an equation is developed for its determination in the case of double bars, which is based on the singularity method.

Busse, H., G., Mueller, D., "The Subgrade in Open-Cast Mines - Its Characteristics and Importance to Surface Drainage".
Neue Bergbautechnik 2 (1972) Nr. 6, pp. 441 - 445.
A high effect of discharge is necessary in order to reduce the influence exerted by rainfall on the subgrade. From theoretical considerations and comprehensive surveys general statistical regularities are developed and a relatively simple mathematical model is developed for a subgrade, which can be used to determine depths of ditches and to serve as a basis for calculating the effect of discharge.

Junghans, R., "The New Legislation on Noise Abatement in the G.D.R., with Special Reference to Working Places in Open-Cast and Underground Mines".
Neue Bergbautechnik 2 (1972) Nr. 5 pp. 322 - 324.
As a result of the law of socialist landscape treatment comprehensive and very concrete regulations were published in 1970 in execution of this law as far as the noise abatement is concerned. Results of new measurements show for many working places below and above ground continuous equivalent sound levels which in part are considerably above the limiting values. Noise abatement measures are suggested.

Krummsdorf, A., "Third International Conference on Phyto-amelioration (Growing of Field Woods) in the Peoples Republic of Poland".
Neue Bergbautechnik 2 (1972) Nr. 1 pp. 79 - 80.

Sajkiewicz, J., "The Present Status and Development of the Polish Mining Industry".
Neue Bergbautechnik 4 (1974) Nr. 8, pp. 556 - 566.
The Peoples Republic of Poland disposes of comprehensive deposits of mineral and raw materials. In this article a description is given of the present status and planned development of coal and lignite mining, of the production of natural stones and aggregates, of lead and zinc mining, as

well as of copper ore mining. The technical development of these branches of mining is discussed together with associated problems.

Rudolf, H., "Causes of Earth Movements in the Geisel Valley and Occurance of Damages Due to Mining".
Neue Bergbautechnik 4 (1974) Nr. 8, pp. 567 - 573.
The individual causes of earth movements are described and explained, with examples characterizing them quantitatively on the basis of mine surveying observations. Their different effects on the environment of open-cast mines are also shown. Furthermore, a description is given of relations that may exist between the individual causes and the occurence of damages due to mining, dealing in particular with the lowering of the water table to be considered in this respect.

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