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SITE SELECTION AND FINANCIAL ANALYSIS OF DEEP SURFACE MINING OF ANTHRACITE COAL

VOLUME I EXECUTIVE SUMMARY

Prepared for

U.S. Department of Energy

By

C.B. Manula
Judith Kiusalaas
C.G. Knight

The Department of Mineral Engineering
College of Earth & Mineral Sciences

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FOREWORD

This report was prepared by The Pennsylvania State University under DOE Contract No. ET-76-G-01-9006. The contract was initiated under the technical direction of the Washington Staff Office, with Mr. Lowell Gibbs acting as the technical project officer. Mr. Doyne W. Teets was the contract administrator for the Department of Energy.

This report is a summary of the work recently completed as part of this contract during the period September 30, 1976 to July 30, 1979. This report was submitted by the authors on September 1, 1979.

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16. Abstract

This report provides an introduction to the application of open pit methods for mining Pennsylvania anthracite and summarizes the results of economic feasibility studies of open pit mines at two sites: Wabash Valley in the Southern Field and Bear Valley in the Western Middle Field. These sites were selected on the basis of a previous preliminary investigation of five potential sites as providing a range of economic and mining conditions that could be anticipated in open pit mining. The aim at both sites was to determine the economic feasibility of a conventional truck/shovel mine system producing sufficient anthracite to sustain a large power plant. Primary requisites for the design were maximum extraction and environmental clean-up rather than minimized mining costs. On the basis of this analysis the Wabash Valley site appears to have the greater potential for development.

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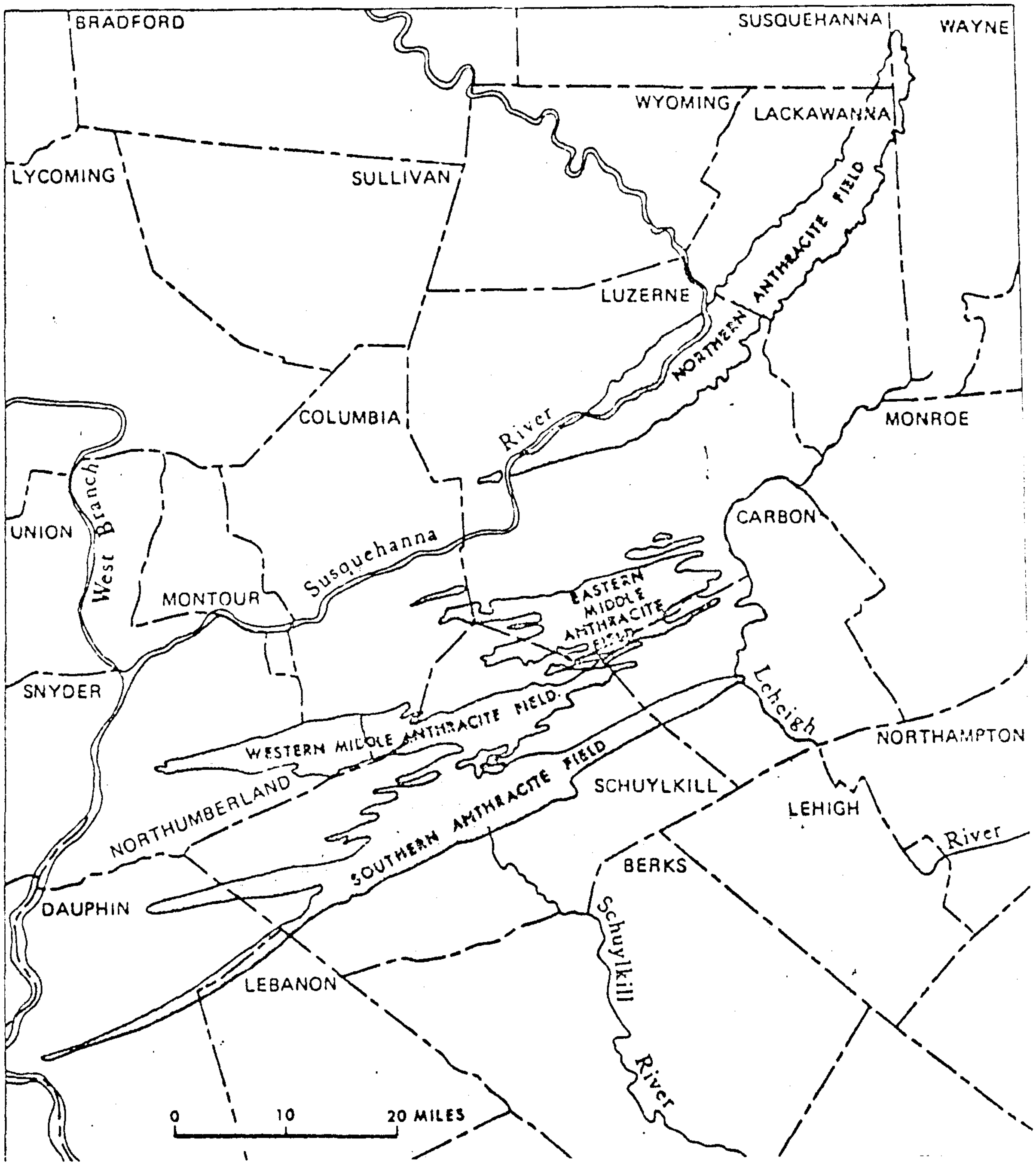
INTRODUCTION

This report examines the application of large scale, deep open pit mining methods to the anthracite coal region of eastern Pennsylvania (Figure 1) in order to determine the feasibility of using anthracite as a fuel for electric power generation. This study is part of the national reappraisal of domestic fuel reserves that has taken place in the 1970's in response to the nation's deteriorating energy situation. Concurrent developments have included the formation of the Pennsylvania Governor's Energy Council and a state Anthracite Energy Task Force, followed in 1978 by the creation of an Anthracite Office within the U.S. Department of Energy. All have the aim of revitalizing Pennsylvania's anthracite industry which has been in decline for several decades.

The decline followed almost 150 years of unrestricted mining during which coal production formed the basis of the region's economy. Throughout this period the industry was dominated by the home heating market, a market which has been lost in the past 25 years through the conversion of domestic heating to oil and electricity. As a result, the industry was left with a reduced market of some industrial and domestic use and considerable dependency on export to U.S. installations abroad. In the absence of overall policy and strong leadership, large dependable replacement markets have not been developed and anthracite has indeed become a forgotten stepchild of the U.S. coal industry. This in itself would not be so reprehensible had the decline not left in its wake a scarred and ugly landscape, polluted streams and serious social and economic problems that have defied solution in the past two decades.



(after Geol. Survey Professional Paper, 580, USGS and U.S. Bu Mines, 1968)

Figure 1. Anthracite Coal Fields

It has been estimated that within a 706 square mile area, one acre in four has been disturbed by coal mining activity. The coalfield area is characterized by a landscape of culm banks and unfilled strip pits, disturbed drainage patterns, and polluted streams. Since reclamation was not carried out at the completion or abandonment of mining, the mined areas are thinly covered by haphazard volunteer vegetation of no intrinsic value. The subsurface is honeycombed with abandoned workings which are flooded with groundwater to form extensive mine pools that provide a constant source of acid mine drainage which pollutes streams over a wide area. The pattern of mining over the years has been one of many small and medium sized mines with countless unrecorded operations that varied from small slopes and strippings to pillar and barrier robbing. The consequent proliferation of air shafts and mine entries, surface pits and subsidence, combine to make a large area unsuited to other economic use.

During the 1960's under the state's Operation Scarlift, studies were made of existing conditions but most recommendations were too costly to be implemented and the scale of the problem remains too large to be addressed. While new legislation enforces rigorous environmental standards for current stripping operations which ensures revegetation and surface cleanup, the problem of acid mine drainage caused by the underlying voids and mine pools is largely unresolved.

The abandonment of mines caused large-scale population decline, the outmigration of young people, high unemployment, low income levels and depressed retail trade and service industries in this once-flourishing region. Despite continuous efforts by county and local authorities to attract new industry and diversify the economy, the coalfields continue to exhibit the characteristics of depression. Yet, in spite of its many problems, the ethnic diversity of the social structure in the region fosters strong emotional ties in many residents and first generation outmigrants.

Large scale open pit mining has been suggested as a means to help alleviate both environmental and economic problems of the anthracite region, while providing needed fuel resources. The advantage of the open pit method is that it would remove all economically recoverable coal from a large site, eliminate the sources of acid mine drainage by digging out the voids and former workings, and then restore the area to another economic use; thus permanently breaking the cycle of mining-abandonment-remining-and-abandonment that has characterized the land use of this region for so many years. Since the proposed projects have an environmental and social value beyond the economic recovery of a fuel resource, it is imperative that the highest standards of erosion control, revegetation and maintenance are a mandatory requirement for open pit mining.

ANTHRACITE CHARACTERISTICS

Anthracite is characterized as a hard, high fixed carbon, low volatile, low sulfur coal. It contains the same three types of layers as bituminous coal: anthraxylon, attritus and fusain, but due to regional metamorphism there is less obvious lamination, the luster is brighter and more uniform, and the coal has a pronounced conchoidal fracture.

There is no uniformity in anthracite chemical characteristics within the four coalfields or even from mine to mine, but in general the highest fixed carbon, hardest, lowest volatile anthracites (approaching meta-anthracite) are found in the eastern sections of the Southern and Eastern Middle Fields, with a progressive change westward and northwards. That is, the carbonization increases toward the source of horizontal thrust to which the region was subjected. In the western extremities of the Southern and Western Middle Fields the changes are sufficiently pronounced for the coals to be classified as semi-anthracite. Typical characteristics of anthracite and semi-anthracite are shown in Tables 1 and 2[1] and details of the regional pattern of coal characteristics are shown in the maps in the Appendix of this report.[2]

Anthracite has certain advantages as a fuel source:

(i) it has a relatively high BTU content;

(ii) the high fixed carbon and low volatile percentages give long, slow combustion;

(iii) it is characterized as a "clean" fuel emitting little or no smoke;

(iv) the relatively low sulfur content ensures minimal SO_2 emission. USGS records the mean sulfur content of 6232 samples on a dry basis as 0.66%[3];

(v) its proximity to northeastern markets.

Table 1. Average Proximate Analyses and Specific Gravity of Face Samples, Anthracite Region (moisture and ash free).

Field	Number of Samples	V.M.	F.C.	Air dry Sp.Gr.	Corrected Sp.Gr. (M/A)
Northern	100	6.1	93.9	1.56	1.54
Eastern Middle	24	3.7	96.3	1.65	1.62
Western Middle (West Mahanoy dist.)	21	4.6	95.4	1.64	1.57
Western Middle (Shamokin district)	16	9.0	91.0	1.49	1.41
Southern (Panther Creek district)	13	4.2	95.8	1.65	1.61
Southern (West Schuylkill district)	10	5.3	94.7	1.64	1.57
Semi-Anthracite (Trevorton)	2	11.7	88.3	1.43	1.36

Table 2. Average of Ultimate Analyses of All Face Samples, Anthracite Region (moisture and ash free).

Field	H	C	N	O	S	Btu
Northern	2.8	92.4	1.1	2.5	1.2	15,038
Eastern Middle	2.1	94.7	0.8	1.6	0.8	14,828
Western Middle (West Mahanoy district)	2.3	94.3	0.9	1.5	1.0	14,867
Western Middle (Shamokin district)	3.6	91.2	1.5	2.6	1.1	15,258
Southern (Panther Creek district)	2.1	95.0	0.8	1.4	0.7	14,823
Southern (West Schuylkill district)	2.0	94.8	0.8	1.7	0.7	14,898
Semi-Anthracite (Trevorton)	4.1	90.8	1.6	2.5	1.0	15,440

Turner, 1930[1]

The major disadvantages of anthracite are:

(i) the high ignition temperatures, mean 925°F;

(ii) the relative difficulty of grinding anthracite which has Hardgrove Indices of 33.0 to 66.7;

(iii) the high rate of particulate emission which necessitates bag house equipment;

(iv) the dirt and inconvenience of coal storage, stoking, ash removal and disposal;

(v) current problems related to the declining industry, i.e., procurring a steady supply of good quality anthracite at a reasonable price.

Anthracite Markets

Since the inception of mining, the domestic space-heating market has been the major outlet for anthracite. It was the dominant home-heating fuel for much of the northeastern U.S. and eastern Canada until the middle of the twentieth century and was widely used for commercial and institutional space heating. However, competition from oil, natural gas and electricity proved unsurmountable and anthracite's share of the heating market has dwindled to insignificant levels. Domestic use of anthracite has continued to decline throughout the 1970's despite the national energy situation. Consumers cite the inconvenience of storage and ash disposal, the dirt produced, the vagaries of supply and quality, and the cost of anthracite as reasons for conversion to other fuels. Efficient automatic stoking equipment is available for both domestic and commercial heating purposes though it is generally more expensive to install than units for competitive fuels. Anthracite is rarely considered as an alternative for new construction. However, with the present energy outlook an increase in domestic demand can be anticipated.

The second market for anthracite is as a fuel source for electric power generation. The firing of anthracite mandates equipment with specifications very different from those used by bituminous-fired plants. The higher ignition temperatures and longer burning time necessitate much large boilers to provide the longer flame path. The boiler sizes for anthracite are roughly twice the size of the equivalent-capacity bituminous boilers. Since anthracite is much harder than bituminous coal the grinding is also more costly. While the low sulfur content is an advantage for power generation, the control of particulate emission necessitates expensive bag filter equipment. Thus, the capital expenditure for power generation is much higher than that for bituminous coal and to date the demand for electricity has not warranted development of a plant burning anthracite alone. The Sunbury Plant of P.P. & L. has the largest boilers in use, capable of producing 50,000 kw, but this plant uses coal from secondary recovery operations that does not require elaborate crushing equipment. In 1975 the electric utilities consumed 29% of anthracite production with demand holding fairly steady. This report considers the economic feasibility of providing sufficient anthracite to fire much larger power generating plants.

There are many varied industrial uses for anthracite and demand has been outstripping supply in recent years. Anthracite is used by the iron and steel industry in the sintering of iron ore fines, pelletizing beneficiated low grade domestic iron ore fines, coke production, lining pots and molds and as a substitute foundry fuel. There is also some demand for anthracite as an industrial carbon, as a filter, for use in the chemical industry in the manufacture of soda ash, and in the electronics industry. These demands and the potential for conversion are being studied by other sources in the current reappraisal.

ANTHRACITE PRODUCTION

In the years 1945-1975, anthracite's contribution to the total U.S. energy supply has declined 90%, while the total U.S. demand has increased 125%. Since 1820 when systematic records were instituted, some 5.3 billion tons of anthracite have been extracted from these coalfields, with peak production achieved in 1917 (100,445,299 net tons). The highest employment level in anthracite mining was in 1914 with 180,899 workers employed directly by the industry. Present levels of production and employment are the lowest recorded and still dropping -- in 1977, 5,060,689 net tons were produced, but only two thirds of this was mined coal, 33% was from secondary recovery operations. Employment in the anthracite industry had dropped to 3,603 workers by 1977.

Many inter-related problems have compounded to intensify the decline of anthracite mining:

1. Reliance on one major market.
2. Problems with the control of underground water resulting from the haphazard and complex pattern of mines established in the nineteenth century, compounded by indiscriminate and uncontrolled operations of independent miners.
3. The complex geology of the region with steeply-pitched folded and faulted seams which inhibits the use of modern mechanized methods of underground mining and increases reliance on labor-intensive mining thus contributing to higher mine costs.
4. The pattern of mine ownership.
5. Management policies to control the price of the commodity and limit production in the face of declining demand, which led among other things to a negative attitude toward the industry by consumers.

6. The lack of investment to modernize production and facilities.
7. Increasingly stringent federal regulations that have accelerated the rise in mining costs.

During the past century there has been a total lack of comprehensive planning or thought of stewardship of the resource, merely a concern for immediate profit.

Anthracite production is presently divided among 390 operations with 220 operators. Table 3 shows the production breakdown in 1977.

Table 3. Anthracite Production, 1977

	Deep Mines	Strip Mines	Secondary Recovery	Total
Production (tons)	499,846	2,896,979	1,663,864	5,060,689
No. of employees	706	1,412	1,485	3,603
No. of operations	109	124	157	390

(Pa. DER Annual Report, 1977)

To increase the present production to meet the sustained demand of large-scale power generation would be very difficult, perhaps impossible, with the existing fragmented pattern of mining. Large capital investment would be required by present companies and using conventional surface and deep mining methods costs would be high. Strippable reserves are limited and would be insufficient to maintain power plant requirements. As mineable reserves for current surface mines are exhausted the production demands would have to be met by deep mines. Here, problems could be anticipated in attracting, training, and motivating a work force capable of manning the deep mines, particularly in skilled and professional classifications. Ensuring safe underground working conditions in a region honeycombed with abandoned flooded workings where barrier pillars have frequently been rendered ineffective would be both difficult and costly.

For example, within the anthracite area the ratio of tons of water pumped from deep mines to tons of coal mined has risen drastically in recent years. In the years 1944 to 1948, 19 tons of water were pumped for every ton of coal produced from underground mines, by 1960 this quantity had risen to 78, and by 1970 stood at 81 tons. A small-scale operation is financially incapable of handling such volumes of water, particularly in view of present environmental requirements to treat all acid mine drainage produced by mining.

The open pit method is a viable alternative means of obtaining a sustained high production of coal for power plant use from a single source manned mainly by construction-type workers who are more readily available and easier to train than underground miners.

OPEN PIT MINING

The open pit concept was adapted to seamed deposits from the methods employed to extract ore deposits in the western U.S. Unlike the western method of extraction, separate mining systems are required for coal extraction and waste removal to provide the flexibility needed to mine the complex bedded deposits. As production and scheduling of equipment are a function of the constantly changing stripping ratios during pit development, the system is sized from the stripping ratio at the elevation of average mining conditions. Selective tipping of waste material depending on spoil characteristics must be practiced.

The open pit operation is similar to stripping operations in that heavy excavating equipment is employed to remove material, extract the resource, replace the burden, and reclaim the surface. The difference lies in the scale of the operation for here the anticipated depths would reach below sea level conditions. Figure 2 shows a typical open pit mine during development.

The operation has three main phases: 1. A developmental phase during which the coal deposit is proved, delineated, and sampled, the surface facilities are constructed, and the dewatering of underground mine pools is begun. During this phase the site is prepared, top soil removed and stockpiled. With the commencement of mining the equipment is phased-in gradually until full production can be met. 2. During this phase, a Mode 1 operation, the initial pit is developed to its full extent. Waste material is removed from the pit and placed on adjacent spoil piles. For the waste removal operation the haulroads develop their maximum grades and greatest extent and the truck fleets

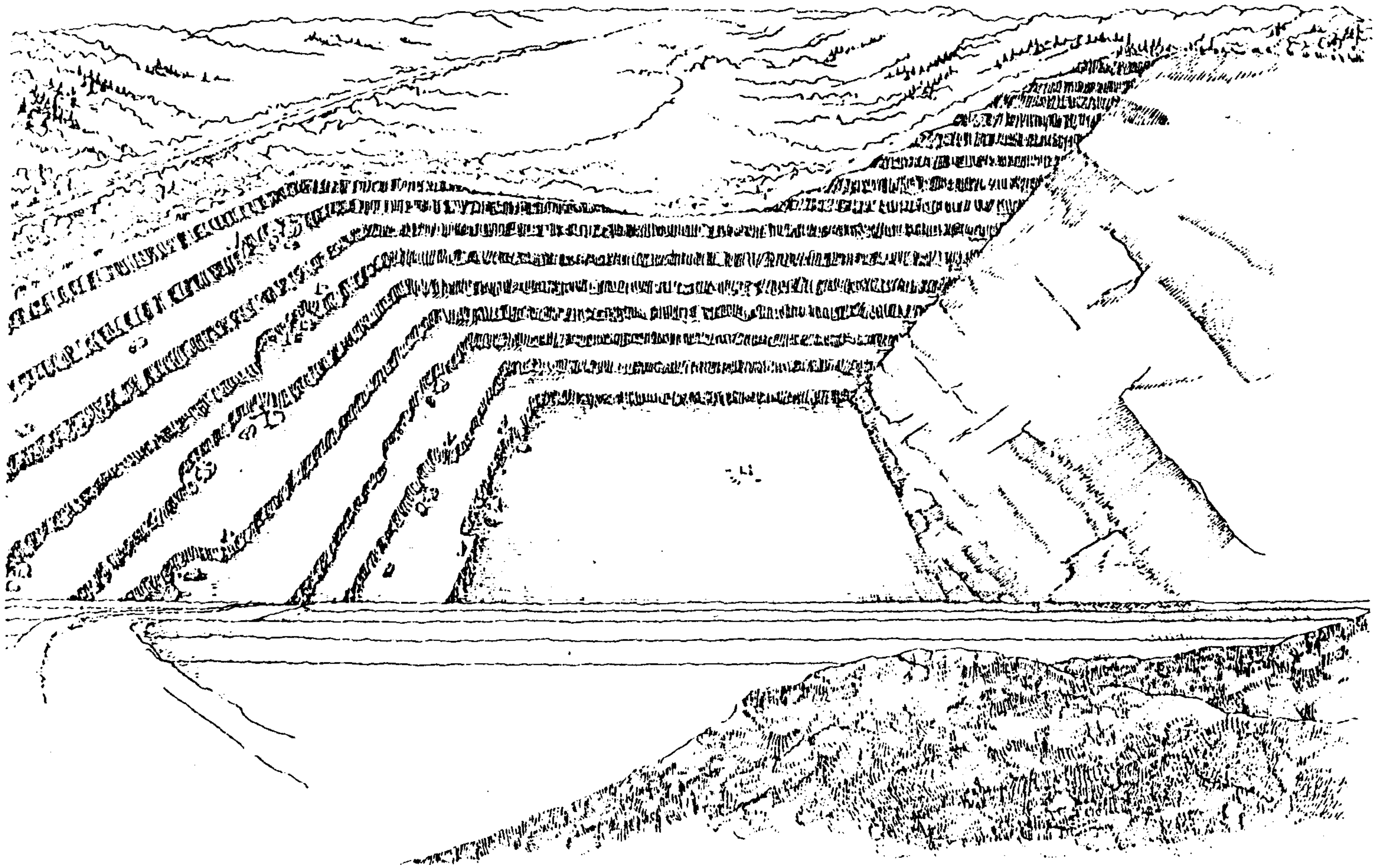


Figure 2 An Open Pit Mine

must be maintained at their maximum level. The initial pit would be excavated at one end of the mine site to keep haulage distances as short as possible. The pit would be developed to the full width of the site and to the full mineable depth. The depth of mining would to some extent be determined by the width of the valley since critical widths must be maintained at the pit floor. 3. Following full development of the initial pit, the outer wall of the pit would be expanded gradually to the limits of the mine property and a dragline operation would be commenced to maximize extraction at the pit floor. This is the Mode 2 operation, which would be in operation for most of the mine life. Spoiling would be carried out within the pit with material replaced as closely as possible to the elevation in which it was extracted. Since the haulroad distances would be reduced the truck fleets for the waste removal system can be decreased during this phase. Although the internal pit configuration would be in constant flux during the 40-year operation, the working benches on the pit walls would be designed to maintain an overall slope of 45°.

In examining sites for the open pit operation, the basic parameters were taken to be:

i) a reserve of at least 120 million tons clean coal with favorable stripping ratios;

ii) reserves lying within a pit configuration that provides safe working conditions at the floor;

iii) adequate spoiling area for the vast quantities of waste material produced by the initial pit;

iv) practical and economic control of underground water;

v) a favorable environmental impact i.e., the improvement to area watersheds must be permanent and total reclamation included in the design; and

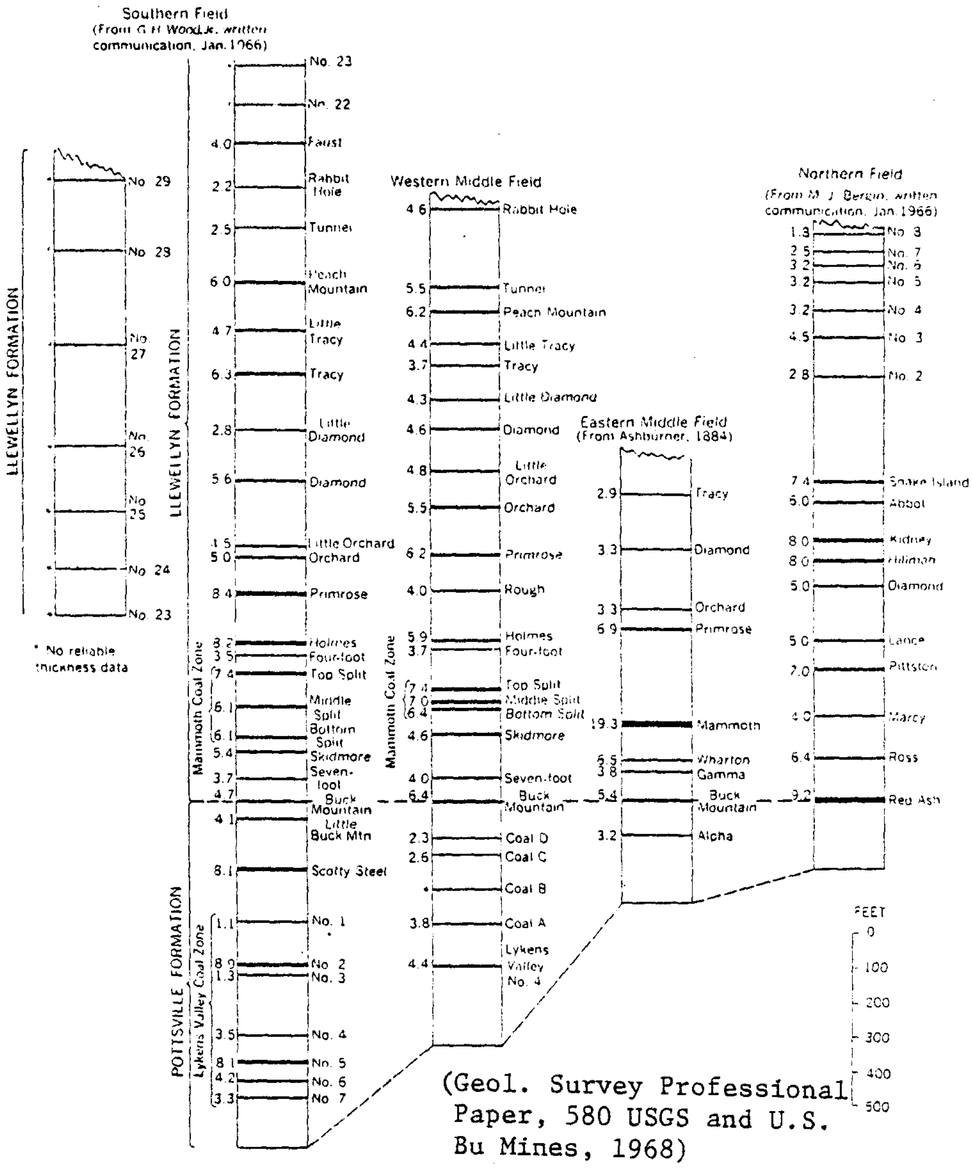
vi) a positive social impact, i.e., the economic benefits accruing to the local area should exceed the disruption caused by the relocation of existing structures.

SITE SELECTION

The open pit method is by no means applicable to the entire anthracite region. Coal measures underlie a surface area of about 484 square miles. Unlike the bituminous coalfields of western Pennsylvania, the anthracite region is an area of complex, sinuous, assymetric folding in which thrust faulting is common. The structural complexity increases southward, so that in the north the folds are more open and symmetrical, while in the south high-angle faulting with considerable strata displacement and tight folding is typical. The anthracite region is separated into four distinct coalfields; the Northern Field with an area of about 176 square miles; the Eastern Middle Field with an area of 33 square miles; the Western Middle Field of 94 square miles; and the Southern Field with 181 square miles (Figure 1). The general stratigraphy of coal seams is shown in Figure 3.

The Northern Field

The Northern Field is a crescent-shaped trough about 60 miles long and up to five miles wide, At Wilkes-Barre the coal measures are 2,000 feet deep with 18 workable beds. The field is divided into two main basins: the Lackawanna in the east which is shallower and less complex, with seams lying almost horizontal in the center of the basin and outcropping steeply at the margins; and the deeper Wyoming Basin which increases in structural complexity westward where there are numerous deep sub-basins. Deep mining was carried out extensively in this field despite difficult mining conditions. Between Scranton and Nanticoke the



(Geol. Survey Professional Paper, 580 USGS and U.S. Bu Mines, 1968)

Figure 3 Generalized columnar sections of the Pennsylvania anthracite fields.

coal seams lie below a glacial outflow channel in which water flows at depth through a boulder-filled course covered by gravel and quicksand deposits up to 320 feet deep.

Deep mine reserves were virtually exhaused in the Lackawanna Basin after World War II, and the abandonment of the mines led to inundation by groundwater. This water crossed the saddle between the two major basins causing the abandonment of underground mines in the Wyoming Basin. At present the subsurface of this entire area is underlain by a series of interconnected pools containing an estimated 261.8 billion gallons of water[4]. This precludes any consideration of open pit mining in the Northern Field at the present time.

Eastern Middle Field

The Eastern Middle Field occupies the crest of an anticlinorium in which coal occurs in a series of small canoe-shaped basins where the dip may vary from almost horizontal to 90 degrees. The field, which centers around Hazleton, has been extensively mined and stripped. Since many of the coal basins lie above the drainage horizon of surrounding areas, it has been possible to dewater the higher workings by means of gravity flow drainage channels and the 31 pools that occupy abandoned workings in this field are relatively small and lie below the drainage channel elevation. Berger Associates[4] estimated the total anthracite resource in this field at 275 million tons, including 11.5 million in refuse piles and 43 million tons in strippable surface workings (within 150 feet of the surface). Specific examination of the suitability of this field to open pit mining was not made at this time, due in part to a lack of suitable data, but it is anticipated that the basins here have insufficient reserves to sustain the required production.

Western Middle Field

This coalfield is about 42 miles long and from two to five miles wide. It consists of six major basins separated by anticlines and faults. Berger[4] estimated the total resources in this field at over three billion tons, but recovery is complicated by water conditions. The entire field has been deep mined with some workings extending well below sea level, but almost all the deep mines are now abandoned due to the cost and difficulty of handling mine water. In the early 1950's Ash[5], for example, reported operations pumping six to eight mines in order to maintain hydrostatic pressures against mine barriers at safe levels. At present there are within this area 67 pools containing an estimated 61 billion gallons of water. One section of the Western Midddle Field was studied to determine the feasibility of open pit recovery and appears in this report as Bear Valley site evaluation. While other areas of this field are not considered prime sites, the economic feasibility of mining this coalfield by open pit methods should be reconsidered when experience has been gained from mining other areas.

Southern Field

The Southern Field lies mostly in Schuylkill County and is 70 miles in length and more than six miles across at its widest point (near Pottsville). To the west of Pottsville the coal measures extend

4,000 feet deep from the surface. This field has both the largest reserves, due to the depth of the coal seams, and the most difficult mining conditions as a result of complex folding and thrust faulting with considerable disruption of strata. The total estimated reserve of this field is 12,151,000,000 tons [4] but much of this is not economically recoverable with today's methods. However, in some places the former mines worked only the limbs so mine pools are at fairly high elevations. It is these areas that hold the greatest promise for open pit mining. One such site, near Tamaqua, is examined in this report. There are currently 46 separate mine pools in the Southern Field containing an estimate 38 billion gallons of water.

Site Evaluation

Five areas were selected by Gordon Wood, USGS, as having the basic reserve requirements for open pit mining. These areas are all in the Southern and Western Middle Fields where detailed recent work had been carried out by the U.S. Geological Survey. The general location of the sites is shown in Figure 4.

A screening methodology was applied to these sites by Penn State and subsites were selected for more detailed analysis. The subsites were ranked on the basis of reserves, the cost of relocating structures, an estimate of mining costs, and an evaluation of the social and environmental effects of mining. It should be stressed that all five sites have mining potential and are considered capable of the production needed for large scale power generation, provided that the need for fuel justifies the costs involved. Consequently, a decision to mine the five sites is essentially political and economic. A detailed

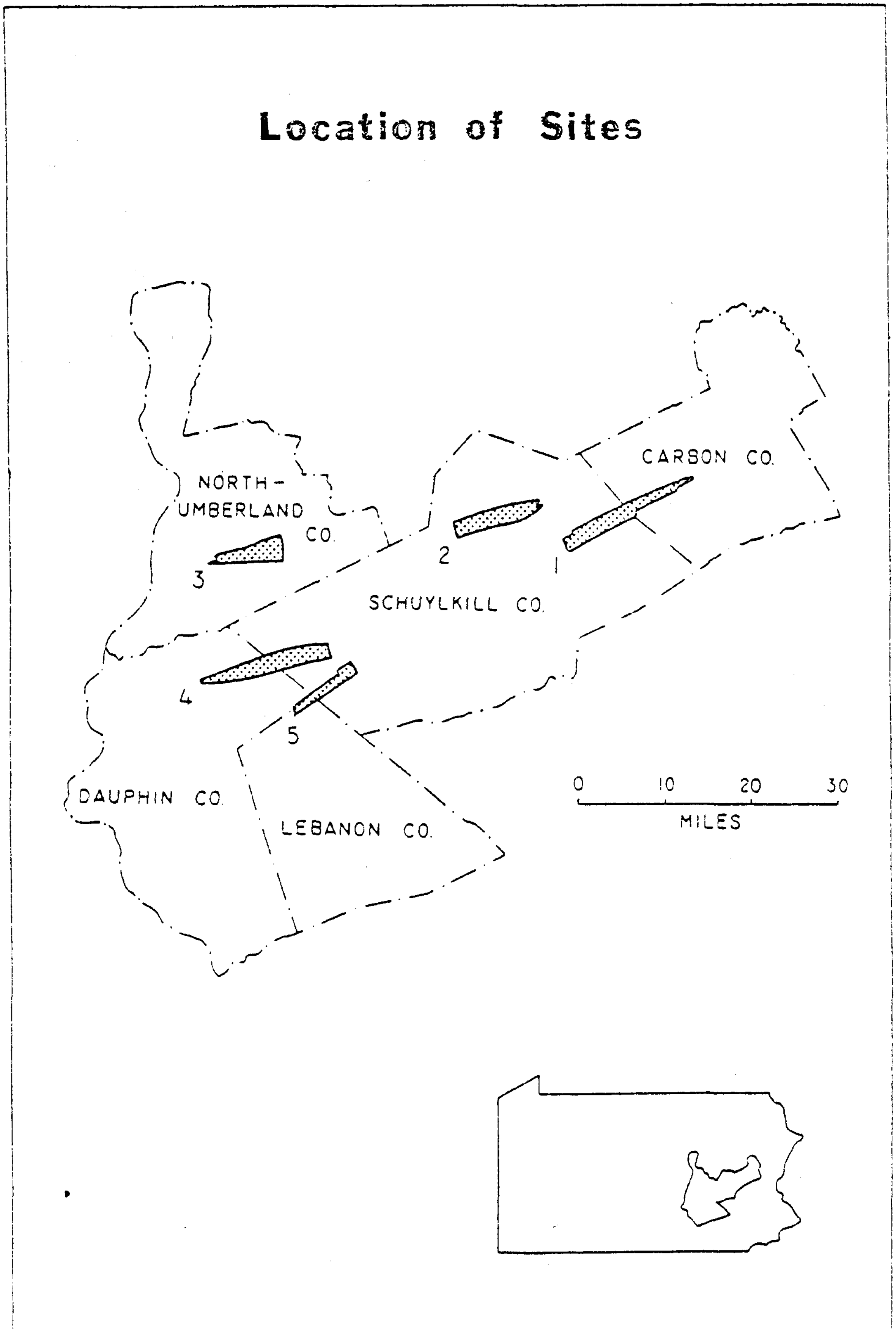


Figure 4 Location of Sites

evaluation, such as those carried out here for Wabash Valley and Bear Valley provides a basis on which to build contingency plans for future energy needs against the background of changing social priorities. For example, one area with high potential for mining overlaps state lands used for hiking and as a game reserve. This site was rejected for initial study largely on the basis of anticipated opposition by environmental groups. But the site should still be included in state contingency plans since at some future date the need for fuel could outweigh the need to keep this area "unspoiled", bearing in mind that this "natural wilderness" has been previously timbered and partially mined.

Two potential sites have been examined to date to provide a sample range of costs that might be anticipated in developing open pit mining in the anthracite region. During the course of this investigation a viable method of analysis was developed and refined. The underlying aims for the work were to design an open pit that would give maximum economic recovery of the resource and maximum environmental cleanup; no serious attempt was made at this stage to minimize mining costs. In order to scale the operation an arbitrary required production of three million tons of clean coal per year was selected as adequate to fire a 1200 mw power plant, together with a mine life of 40 years.

Method of Analysis

The general information flow of the analysis is shown in Figure 5. The initial phase consisted of a compilation of site data. Since no drilling program was funded and a specific request was made by state authorities to avoid contact with area residents in order to prevent

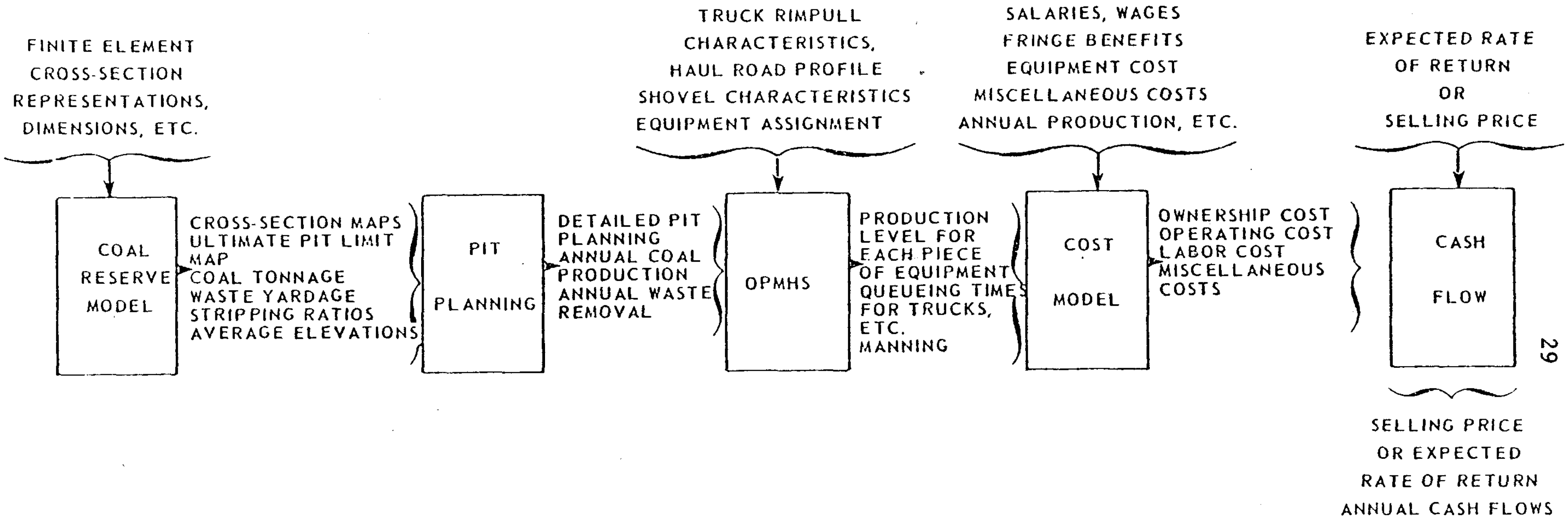


Figure 5 General Information Flows

speculation, this data was restricted to published sources and statistics in the public domain. A detailed survey was made of local geology, drainage, land use, land use regulation and social and economic characteristics. A general analysis of problems of pit slope stability was based on local data provided by Bethlehem Mines Corporation. Results of research on revegetating anthracite spoil were compiled from many sources including an invaluable thesis documentation carried out by Susan Cornwell in Panther Valley.[6] Assistance was obtained from the USDA Forest Service, the U.S. Soil Conservation Service, and the Departments of Forestry and Agriculture at Penn State.

A computer model[7] was applied to interpolate geological data provided by USGS and calculate the estimated coal and waste tonnages and strip ratios. Data digitized from geological cross-sections provided the reserve information on which the pit design was based. Several assumptions were made:

i) data from each cross section was applied to the intervening area within its distance of influence;

ii) only coal seams with an average thickness greater than 24 inches (based on USGS averages) were digitized;

iii) the first 100 feet from the surface was assumed to contain no coal; and

iv) in previously mined seams 50 percent of the coal was assumed to remain in place due to the methods employed during the period of mining.

Repeated simulations were made of varying pit configurations to locate the initial pit in order to obtain a balance between production and the available volume of spoiling area. Specifications for the selected pit were compiled and required haulroad profiles, distances, and coordinates determined.

Primary equipment was selected and the manufacturer's specifications together with haulroad data, selected mining schedules, and reserve information were used as input to a materials handling simulator[8] to obtain the performance characteristics and productivity rates needed to size the mine system. The information flows in this program are shown in Figure 6.

The required support equipment, surface facilities, and manning were determined and the capital costs and operating and maintenance costs calculated. These were used as input to a discounted cash flow model to determine ranges of return on investment with selected selling prices and a sensitivity analysis was performed to reflect changes in production and costs. A predicting equation for the relationship between ROR and selling price was obtained for each site.

The reclamation of the site was planned with consideration of alternative revegetation schemes and methods of erosion control.

A brief analysis was made of the possible impact of the operation on the local area.

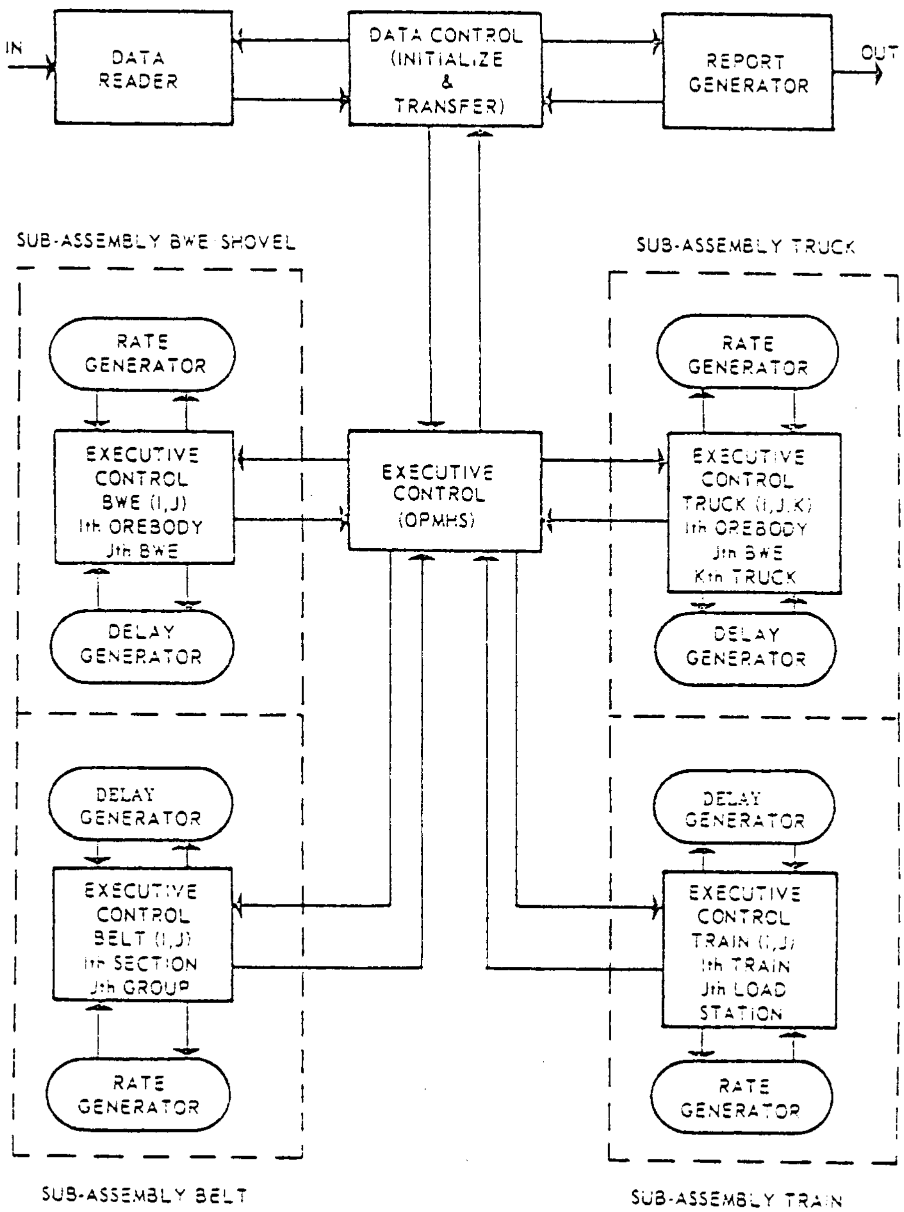


Figure 6 Generalized Flow Model, OPMHS

SUMMARY OF THE WABASH VALLEY SITE

This site is located in the Southern Anthracite Field in a narrow valley between Tamaqua and Tuscarora, Figure 7. The valley is approximately four miles in length and has a valley floor around 950 feet above sea level. The ridges have a maximum elevation of 1600 feet above sea level. A low watershed crosses the valley about a mile east of Tuscarora separating headstreams of the Schuylkill River from the east-flowing Wabash Creek that flows into the Little Schuylkill River at Tamaqua. Mining this site would require the relocation of a four-mile section of U.S. 209 and the resettlement of approximately 26 families from the villages of Newkirk and Reevesdale.

Reserve

Wabash Valley is completely underlain by coal measures which are folded and very extensively disturbed by high-angle thrust faults. The vertical displacement of seams by faulting precludes mechanized underground mining in this area. A typical cross section is shown in Figure 8. The site has been previously deep mined and stripped, but the abandoned workings extended only to depths of 600 feet above sea level leaving a resource of about 1,000 feet of coal-bearing strata. The former workings are flooded by groundwater to form two main mine pools containing an estimated 1,112 million gallons of acid water. The pools extend between the unmined barriers that underlie Tamaqua in the east and Tuscarora in the west.

The open pit mine detailed in Volume II of this report would mine the Llewellyn Series (post-Pottsville). The site would have an estimated

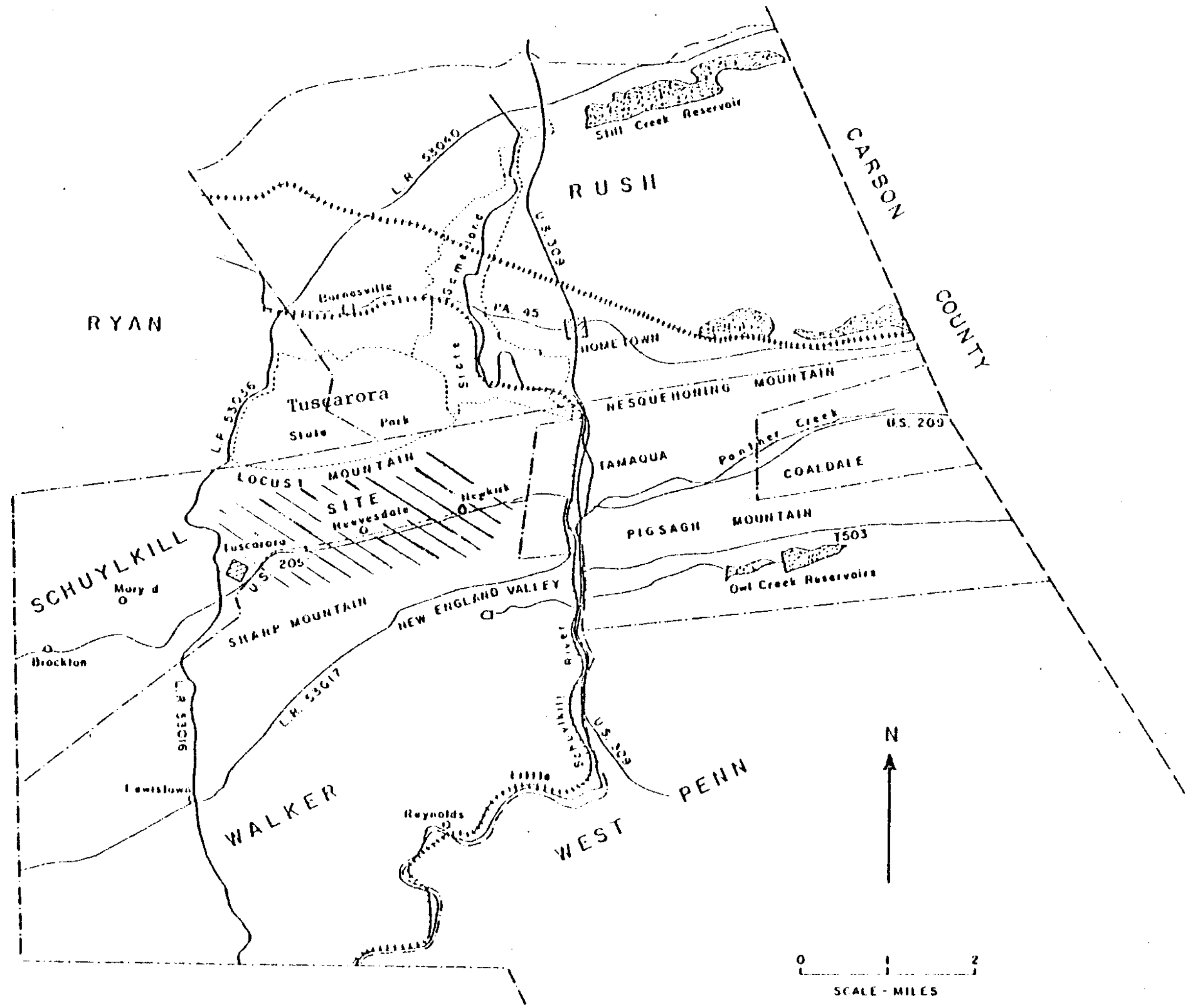
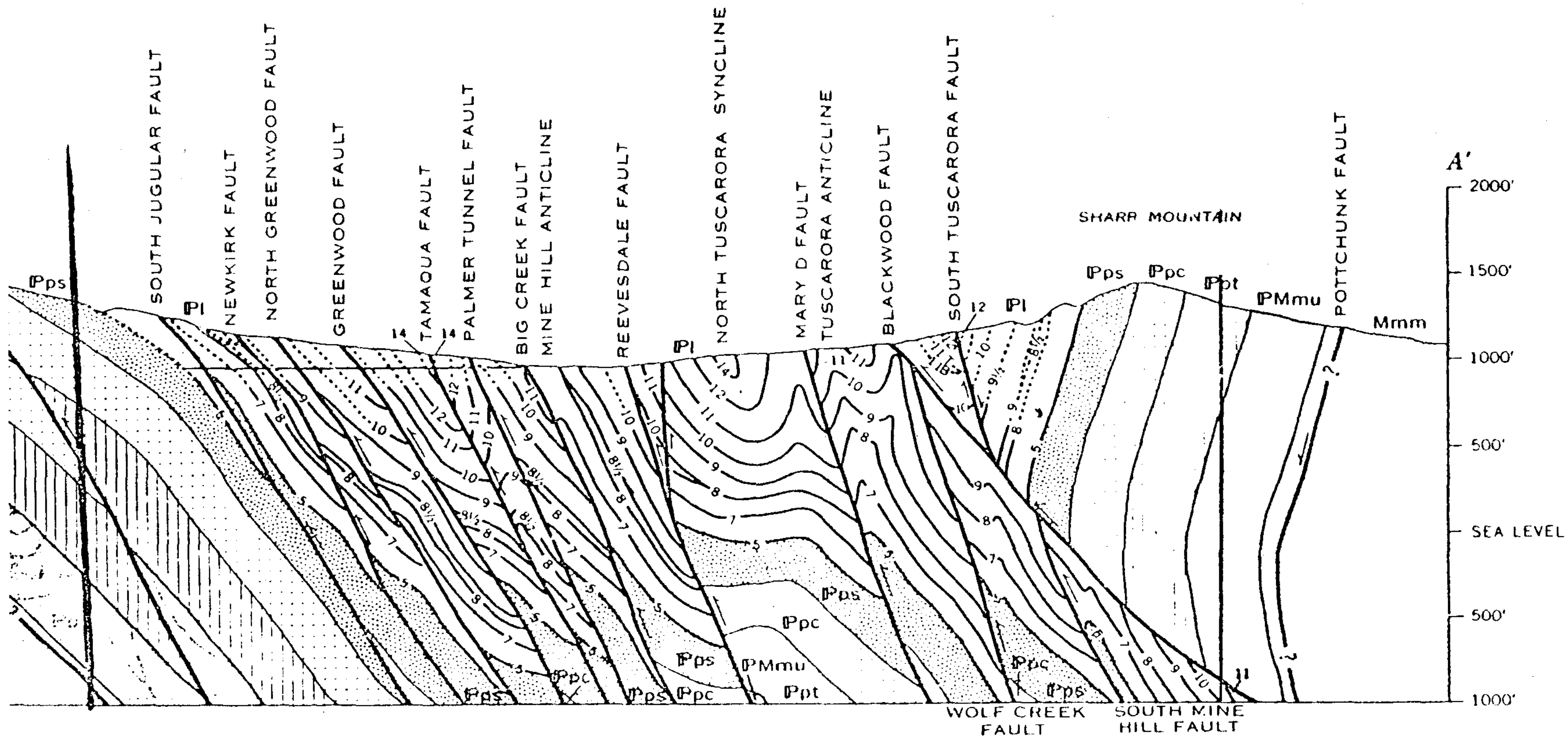


Figure 7 Location of Wabash Valley Mine Site



(USGS, GQ 1054. G. H. Wood Jr. & H. H. Arndt, 1973)

Figure 8. Geological Cross Section of Wabash Valley

total production of 126,543,488 tons of clean coal, i.e., a mine life of about 40 years with a production level greater than three million tons per year. The overall stripping ratio for the site is estimated at 10.82 and the average stripping ratio is 16.12.

The Mine Design

The aim was to locate the initial pit as close to Tamaqua as possible, given the need to minimize disturbance to local residents and the requirement to spoil an estimated 287 million bcy of waste material. The location of the initial pit was thus largely determined by the area needed for spoiling while the maximum depth of mining was influenced by the narrow width of the valley. The east-west dimension was a function of both the safety requirements at the floor and the need to minimize the quantities of waste to be removed from the initial pit. The mine plan is shown in Figure 9.

The designed initial pit has an east-west dimension of 3,500 feet and the north-south dimension averages 5,000 feet. The eastern pit rim is located about 6,400 feet from the Tamaqua boundary. The northern footwall would be formed by the bedding plane below the Buck Mountain seam (#5). This is composed of the highest member of the Pottsville rocks and is a structurally competent conglomerate believed to be intact. The exact location of the southern wall would be dependent on decisions made regarding the relocation of Route 209, i.e., if the highway is removed from the valley the south wall would be the bedding plane below the Buck Mountain seam; but if the highway were to be relocated higher on the slopes of Sharp Mountain, the pit wall is suggested at the 1200 foot contour (the latter was used in reserve calculations for the

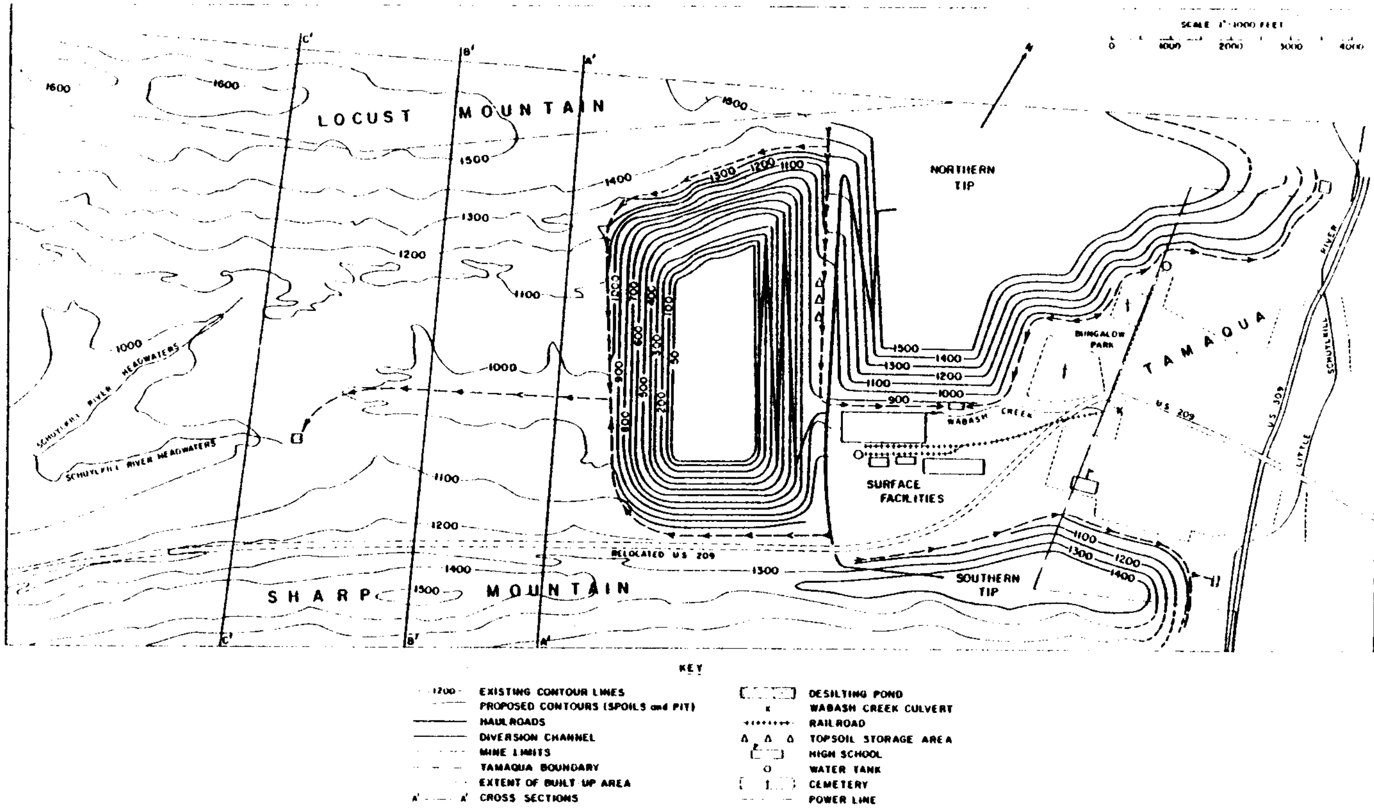


Figure 9 The Wabash Valley Mine Site

operation). The pit would be mined to a depth of 15 feet below sea level, where the floor would have dimensions of 946 feet by 2,650 feet. Working benches would be created every 50 feet with a bench outslope of 68 degrees, to give an overall pit slope of 45 degrees. In the absence of site data, a general discussion of pit slope stability based on data from Bethlehem Mines Greenwood operation to the east of Tamaqua is given in Volume II.

To maximize recovery from the pit, a 100-foot dragline operation is suggested at the commencement of the western expansion and pit backfilling. The estimated 197,570 tons of clean coal per year from this contract dragline operation was included in the production estimate. Development of the initial pit would be complete in seven to eight years at the projected production rate.

The initial pit would create an estimated 287,301,120 bcy of waste material, which with a swell of 0.67 and compaction factor of 15% would require a spoiling area that would accept 364,486,495 cu. yd. Spoiling is designed for two waste tips that would be constructed up the slopes of Locust and Sharp Mountains in 100-foot terraces, beyond the western boundaries of Tamaqua. An attempt was made to avoid spoiling above ridge crest and an additional bench above the ridge line would only be required if the swell and compaction factors varied from those estimated here. Should the mine plan become a reality, detailed work on the spoil area is required since several options are available. If, for example, local residents do not object to operations closer to the town; it may be possible to move the initial pit further east, and thus recover more coal. On the other hand, if ridge top spoiling were to be prohibited a further westward movement of the initial pit might be necessary and recovery would drop from the estimates given here. Additional spoiling area would be available if Rte 209 was removed from the valley. A further alternative would be to backfill additional spoil in the initial pit during final steps of its development.

It is felt that the suggested mine design is a reasonable compromise in view of the fact that mine operations and unreclaimed spoil tips have existed in close proximity to the town for many years. Since complete reclamation of the waste tips is an integral part of the mine operation, the waste tips would be fenced, a forested barrier between residences and work areas has been specified, and spoiling adjacent to the borough would be completed within eight years, there may be room for negotiation.

As backfilling of the initial pit is completed and the working pit is expanded westward, the original floor of the valley would be restored and present drainage placed in lined channels. Excess material would be placed in contoured terraces on the ridge slopes with the valley floor kept as wide as possible.

Surface facilities for the mine would be located at the eastern margin of the mine property between the northern and southern waste tips as shown in Figure 9. The coal preparation plant would be served by a reconstructed railroad spur connected with the main line that runs through Tamaqua. One unit train per day would be required to move the coarse-cleaned coal to the power plant and one service train per week to provide supplies. These should be scheduled to minimize disturbance to traffic in the borough.

Mine Schedule

The most efficient mining plan is seen to have three phases of operation:

1. Developmental Phase - lasting 3 years. During this phase the equipment would be phased in and production would be insufficient to meet the required demand. It was assumed that coal produced during this period (approximately 1.3 million tons) would be sold to another market. Waste removal would commence with one rock shovel and a fleet of nine trucks and a further shovel/truck system would be added every quarter until the end of the third year when the full fleet of 12 shovels and 108 trucks would be in operation.
2. Mode 1 Operation - This phase extends through the development of the initial pit when truck haulage distances would be at a maximum. For this mode a total fleet of 147 100-ton trucks (117 in service) is anticipated. Production of three million tons clean coal could be met from the commencement of this phase.
3. Mode 2 Operation - This phase begins with the completion of the initial pit i.e. during the 8th year. Here, backfilling in-pit would reduce the truck haulage distances for the waste removal system and the truck fleet could be reduced to 72 with an attendant decrease in manning and support.

Mine Equipment and Personnel

The basic equipment for the designed operation would consist of:

12 - 15-cubic yard rock shovels
3 - 15-cubic yard front-end loaders
147 - 100-ton rear-dump trucks

A blasting operation with 12 9-7/8" rotary drills using 30,000 tons of ANFO per year.
A pumping system designed to handle 8,000 gpm.
A water treatment facility designed to treat 14.4 mgd.
A power system designed to handle 23.7 MVA connected load.
A coarse-cleaning coal preparation plant with an ROM capacity of 1,424 tons per hour.

A full capital equipment list is provided in Volume II, Table 4.17.

The mine personnel consists of 69 salaried employees including a geologist and an environmental engineer in charge of the reclamation operation, and 898 wage payroll employees of which 450 would be truck drivers. During the Mode 2 operation, the number of truck drivers would be reduced to 210 and the total wage payroll reduced to 611. The manning charts are provided in Volume II, Tables 4.15 and 4.16.

Mine Costs

All costs in the report were based on early 1977 prices. Estimated costs for the mine system were determined and applied to a discounted cash flow analysis to determine internal rates of return at a range of selling prices. A sensitivity analysis was performed on the results to reflect changes in production and costs, and a predicting equation for the relationship between ROR and selling prices was obtained.

Capital Costs. The estimated total capital investment for the project including deferred capital is $248,748,139 with a salvage (book) value of $22,510,000. The initial investment is estimated at $141.2 million. This includes direct costs (TDC) of $115.7 million and indirect costs of $25.5 million.

The direct costs were taken to include all plant and equipment for the designed mine system. Land costs (surface only) were estimated at $500 per acre or $1,375,00. Relocation costs were estimated at $3.5 million and site preparation at $104 thousand. Land acquisition, relocation and site preparation were taken to be expensed items retrieved during the final year of operation. Exploration costs, $1.7 million, and the indirect costs were not recovered but handled as cash outflow at the start of the project. Indirect costs include: field indirect @ 2% TDC; engineering @ 2% TDC; administration and overhead @ 5% TDC; fees @ 2% TDC; contingency @10% TDC and interest during construction.

Operating and Maintenance Costs. These costs are summarized in Table 4.

Table 4. Operating and Maintenance Cost Summary

Item	Mode 1		Mode 2	
	Annual Cost ($)	$/ton clean coal	Annual Cost ($)	$/ton clean coal
wage labor	18,935,039.42	6.3117	12,751,954.93	4.2507
salaried labor	1,663,670.73	0.5546	1,663,670.73	0.5546
trucks	22,367,081.00	7.4557	10,094,045.00	3.3647
shovels	2,881,440.00	0.9605	2,881,440.00	0.9605
loaders	331,760.00	0.1106	331,760.00	0.1106
blasting	6,979,200.00	2.3264	6,979,200.00	2.3264
drilling	1,140,303.70	0.3801	1,140,303.70	0.3801
pumping	260,706.00	0.0869	260,706.00	0.0869
water treatment	309,030.00	0.1030	309,030.00	0.1030
coal prep.	1,680,000.00	0.5600	1,680,000.00	0.5600
secondary equip.	1,129,007.00	0.3763	848,918.00	0.3763
maintenance	1,410,400.00	0.4701	1,410,400.00	0.4701
reclam. supplies*	1,022,656.25	0.0085	1,022,656.25	0.0085
miscellaneous	7,307,501.00	2.4625	7,397,501.00	2.4625
TOTAL		22.1669		15.9216

*total

Miscellaneous charges in this table include bonding and licensing; royalties @ $1.00/ton clean coal; UMWA Health and Welfare @ $1.20/ton clean coal; local taxes (74 mills on surface facilities) and insurance.

Discounted Cash Flow Analysis. In the cash flow program the project life was taken to be 20 years. The capital investment schedule is included in the Volume II report. The results of the analysis appear as the base case in Table 5 together with the results of the sensitivity analysis.

Table 5. Discounted Cash Flow Summary

Selling Price \ ROI	Base Case	Production +10%	Production -10%	Costs +10%	Costs -10%
$30	0.0983	0.1062	0.0887	0.0892	0.1237
$35	0.1373	0.1461	0.1267	0.1330	0.1607
$40	0.1698	0.1797	0.1579	0.1672	0.1935
$45	0.1990	0.2099	0.1860	0.1980	0.2232

The predicting equation for the relationship between rate of return on investment and selling price for this site is:

$$Y = 15.0 + 149x$$

so that for a rate of return of 15% the selling price would be $37.35 at 1977 prices.

Impact of the Mine

It is believed that the mine would have a positive environmental impact. The site is presently scarred by unreclaimed strip pits and refuse piles and is for the most part unused. The species used in the revegetation program would have a higher aesthetic and economic value than the existing vegetation that it would replace. In the present drainage pattern runoff infiltrates the strip pits that line the valley and flows into the underlying mine pools which discharge acid water into area streams. It has been estimated that Wabash Creek, for example, discharges the equivalent of 4,860 lb acid, 272 lb iron, and 8,190 lb sulfates per day into the Little Schuylkill River[9]. These pollutants would be removed by water treatment at the site and all water leaving the mine property would be desilted and meet state water quality standards. Since the mine pools and mine voids would be removed during the course of mining there would be a permanent improvement to water quality in the area. Special consideration was given to minimizing runoff into the Tamaqua storm sewer system.

While the operation meets known local, state, and county regulations with the exception of a Walker Township ordinance that limits mining hours, there would be unavoidable problems particularly during the early phases of the operation. These would center around the construction of the railroad spur, the highway relocation, the resettlement of families and the visual impact of the waste tips. However, in this economically depressed area where unemployment rates are high, the economic benefits far outweigh individual inconvenience.

The mine would have a positive impact on this area which has experienced population decline and economic depression for several decades. In 1970 the population of Tamaqua and three neighboring townships was 14,618. The population decline in Tamaqua in the decade 1950-1960 was 11.6%, from 1960-1970 a further 9.1%, including a large outmigration of young people. In 1970 the total area workforce was 5,867 with unemployment rates consistently higher than the state average. Operatives in manufacturing industries dominate the work force. The garment industry, employing female labor almost exclusively, is the most widespread industry. In 1975 Tamaqua had 15 industrial establishments employing 709 workers and has insufficient jobs for its residents, resulting in considerable economic commuting. Many residents are employed by manufacturing industries located in an industrial park in Hometown, adjacent to Tamaqua and by Atlas Powder Company, the area's largest employer. Income levels are generally low with the median income well below state and U.S. medians.

SUMMARY OF BEAR VALLEY SITE

This site is located at the western extremity of the Western Middle Field in Northumberland County, Figure 10. Bear Valley extends almost eight miles westward from Shamokin and is completely enclosed by mountain ridges, except for one water gap on the northern ridge where a branch of Zerbe Run cuts through Big Mountain at Trevorton. Mining is the only economic function in the valley. The only settlement consists of scattered dwellings close to Shamokin which would not be affected by the proposed operation. A secondary road that traverses the western valley through the Trevorton water gap would be eliminated by the mine.

The eastern half of the valley drains to Shamokin Creek, and the western half is part of the Mahanoy Creek drainage system via Zerbe Run. The watershed between the two lies at about 1,100 feet above sea level. The surface of the valley is severely disturbed by strippings and waste piles, and much of the natural drainage pattern has been eliminated by mine workings.

Coal-bearing rocks underlie the entire valley and both the Llewellyn Series and the deeper Lykens Valley seams of the Pottsville have been mined, the latter at outcrop on both slopes of the ridges. The cross-section that bisects the initial pit is shown in Figure 11.

Siting the Mine

The site selected for this open pit operation was not the one originally anticipated and does have certain inherent disadvantages: the operation would be mining only semi-anthracite; large sections of

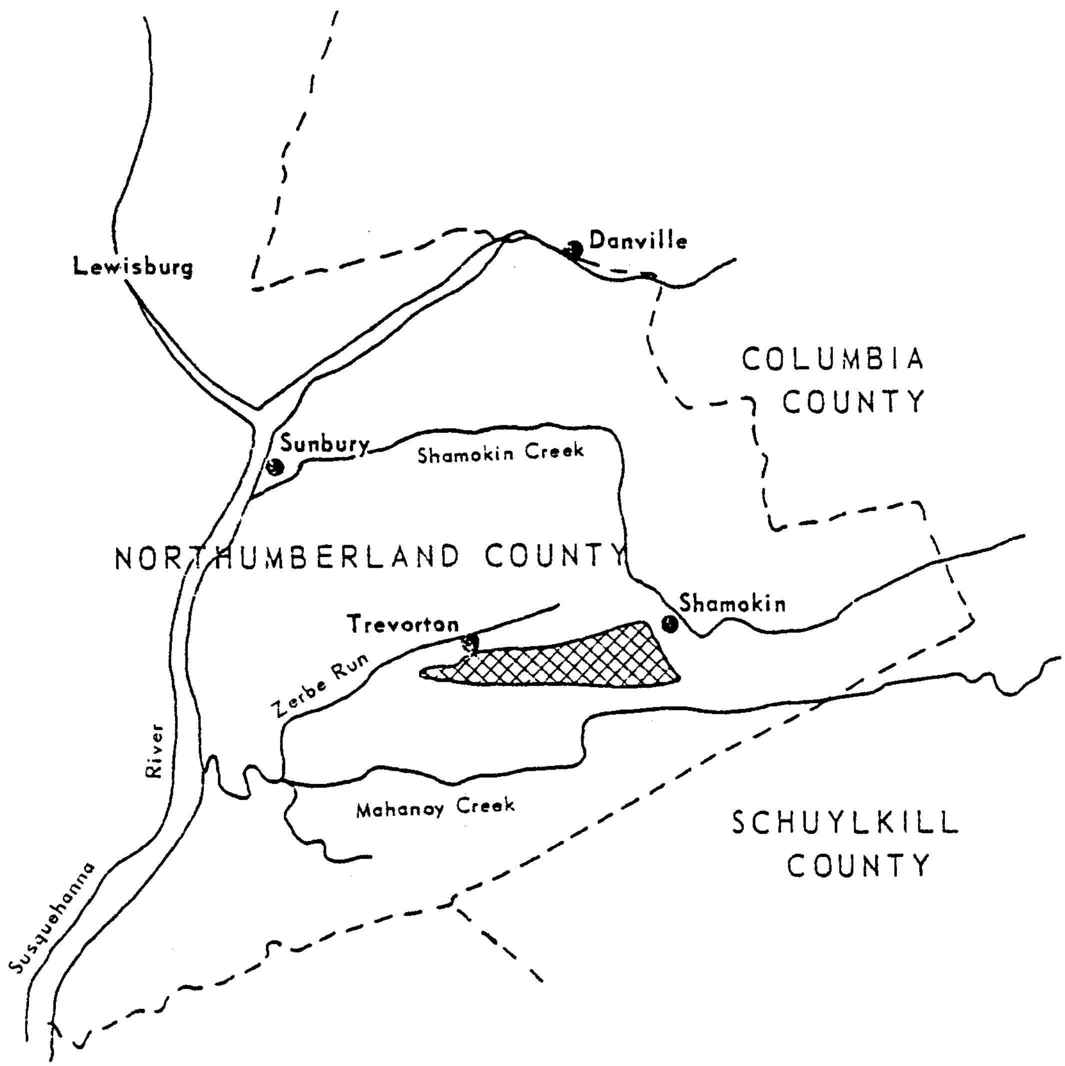
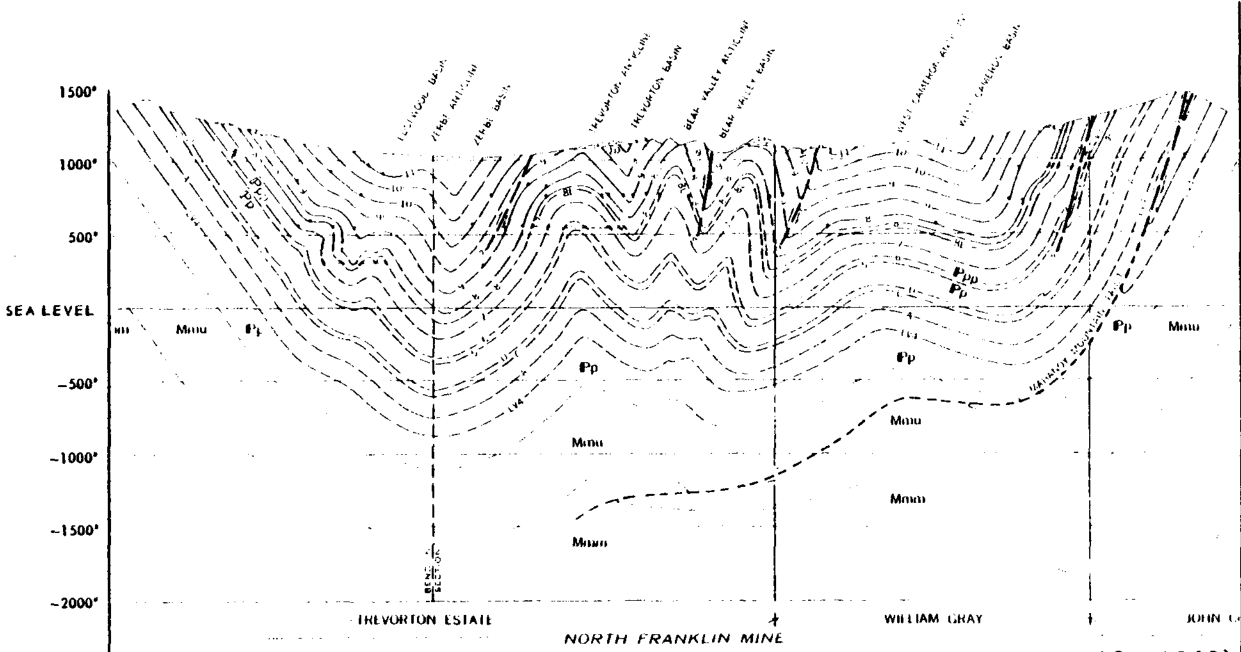


Figure 10 Location of Bear Valley



(USGS Coal Inv. Map C-48, 1963)

Figure 11 Typical Cross Section of Bear Valley the better seams have been previously mined; and a large area of potentially productive seams must be covered by spoil. On the other hand, at the conclusion of mining this site an entire sub-watershed area would be fully reclaimed and the water quality of Zerbe Run, the receiving stream, would be permanently improved.

Two factors were crucial in determining the location of this operation: the control of underground water and the quantities of spoil produced by the initial pit. The Western Middle Field has been extensively deep mined and is almost entirely underlain by mine pools. Due to pillar robbing and subsidence, many of the mine barriers that separate the pools are ineffective and the flow of underground water is complex and imperfectly understood. Underground pools in Bear Valley are shown in Figure 12.[10] Any mine in the eastern half of the valley could anticipate drawing underground water from a wide area, and further, the costly pumping and treatment of water would have an insignificant permanent effect on water quality in Shamokin Creek, the receiving stream.

An operation designed to mine the entire valley would have to handle and treat water from three separate underground systems during the life of the mine. An open pit designed to avoid disturbing barriers around the recently abandoned Glen Burn mine would have reduced underground water volumes but safe dimensions for the pit floor could not be achieved when mining only the southern limb. And further, backfilling schemes are infeasible with the expansion of the pit to full valley width as it migrates westward. Bear Valley broadens toward Shamokin where it is 2.5 miles wide so that the volumes of waste material produced by the initial pit are very great. Any spoiling operation at

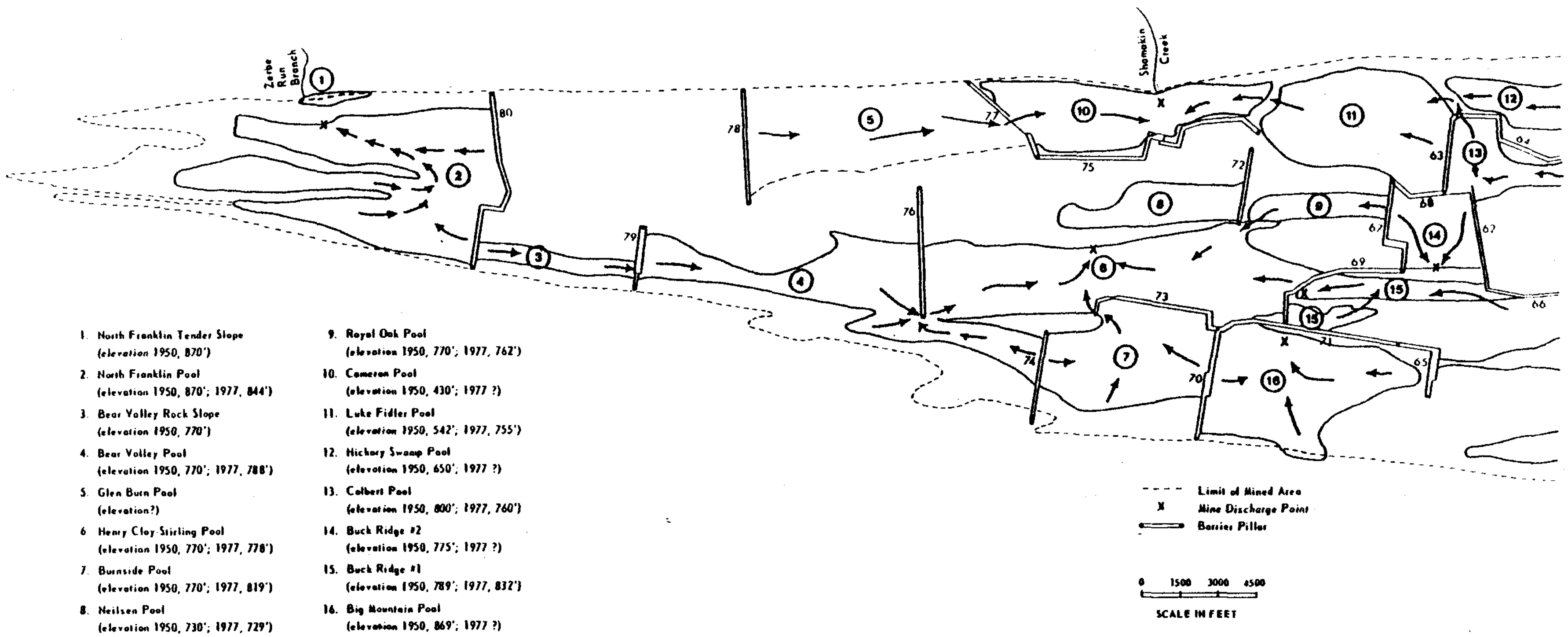


Figure 12 Mine Pools in Bear Valley[10]

this end of the valley is constrained by housing and particularly by a pipeline that crosses the valley to the west of Ferndale. Active stripping permits are also in effect for sections of the eastern valley.

Successive simulations were made moving the initial pit westward until the following conditions could be met:

i. the pit could be maintained at full valley width;
ii. the total tonnages were adequate for a 40 year mine life;
iii. spoil volumes were balanced with available spoiling space;
iv. stripping ratios were favorable;
v. water conditions could be handled with reasonable confidence.

Reserves

The designed operation shown in Figure 13 would mine only the Llewellyn Series i.e. seams above the Buck Mountain #5 Seam, due mainly to the increased blasting costs to remove burden in the Pottsville Seams where the conglommerates are highly resistant. However it is recommended that the economic feasibility of extracting the Lykens Valley, A, B, C, and D seams be reexamined if a decision is made to employ open pit methods in this area.

The mine property of 4,610 acres is estimated to contain a recoverable reserve of 120,804,400 tons of clean coal in the Llewellyn Series. Some 41,845,840 tons of this reserve lies within the initial pit. The overall stripping ratio for the entire operation is 12.56. The entire property lies within Zerbe township with the eastern boundary approximately following the Zerbe/Coal township line and extending westward ridge crest to ridge crest to the valley head.

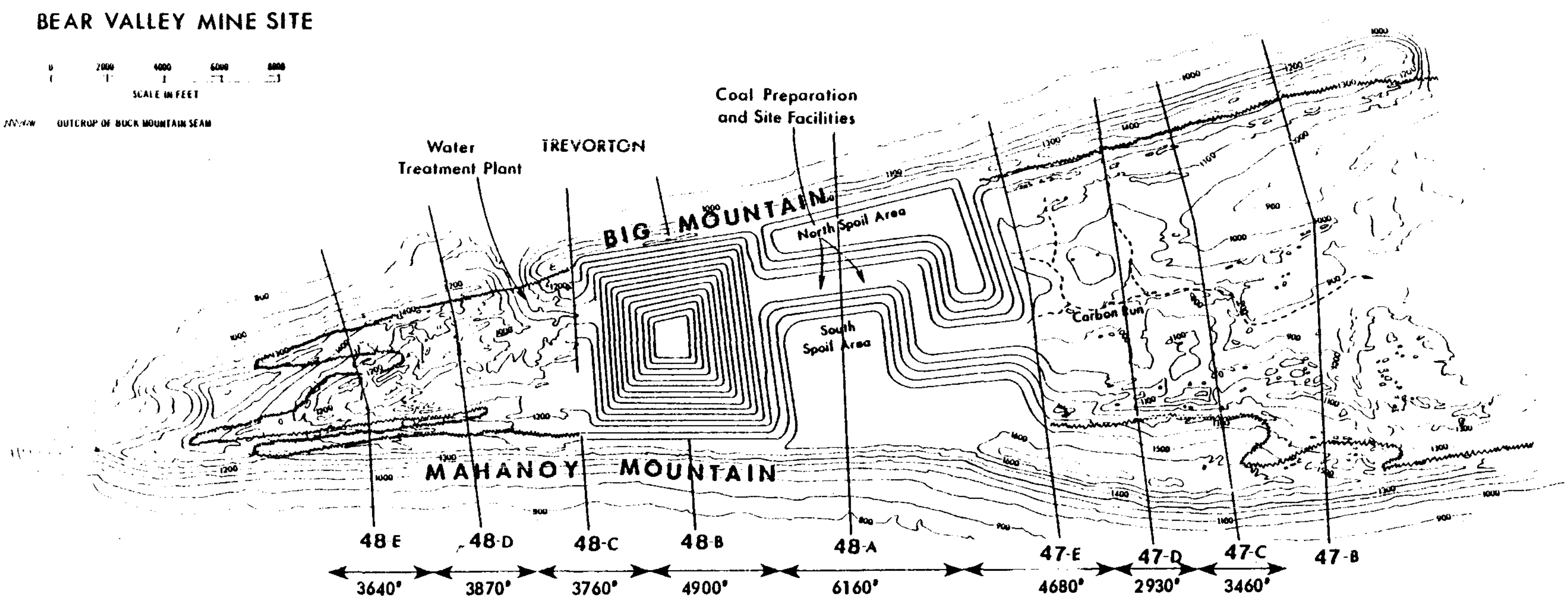


Figure 13 Bear Valley Mine Site

The Mine Design

The initial pit has dimensions of 6,000 feet east-west and 7,000 feet north-south. The northern pit limit is the bedding plane below the Buck Mountain seam at approximately the 1300 foot contour; the southern pit limit is the Buck Seam following about the 1400 foot contour. The eastern pit wall would lie close to the mine barrier of the former North Franklin mine, which is at least 120 feet wide and considered to be intact and effective with the exception of one gangway connection at 874 feet in the north limb of the Mammoth and one encroachment at 554 feet that reduces the width to 80 feet. The North Franklin mine pool abutts this barrier to about 870 feet in the west and Bear Valley Rock Slope pool adjoins it on the southern limb to elevations around 770 feet. The maximum depth of the floor of the initial pit would be at an elevation of 139 feet below sea level, that is 1100 feet below the present valley floor. At this elevation the dimensions of the pit floor would be 1,000 by 1,200 feet. A contract dragline operation is anticipated for the pit floor to remove an additional 100 feet of coal on the northern and southern limbs and add 17,758 tons clean coal per year (this was included in the reserve estimate).

The initial pit will produce 553,278,200 bcy of waste material which with a swell factor of 0.67 and compaction of 15% becomes approximately 702 million cubic yards of spoil. This material would be placed in two terraced waste tips between the initial pit and the Zerbe/Coal township line, as shown in Figure 13.

The corridor between the waste tips follows the configuration of the valley floor and would be used for the surface facilities. These would be connected with Shamokin by an extended railroad spur. The water treatment plant would be located at the Trevorton water gap at the site of the former pump house of the North Franklin mine, which is the main discharge point of water from the North Franklin pool. The discharge rate from the two outflow points located here averages 8.02 million gallons per day.[11]

Mining Schedule

1. Development Phase. During this phase of operation equipment would be added each quarter until the full system is in operation. For the waste removal system, 1 shovel with a fleet of 9 trucks was added each three months to obtain the costing data. During this approximately three-year phase the full production could not be attained and coal produced would be sold to another market.

2. Mode I Operation. This mode would be in effect until the initial pit is fully developed, estimated to be during the 13th year. There would be a fleet of 147 100-ton trucks in operation in this phase.

3. Mode II Operations. With the westward migration of the pit the truck fleet can be reduced in response to the easier haulroad conditions. For the waste removal system the fleet size per shovel would be decreased from 9 to 4 and the total number of 100-ton trucks can be reduced to 72, with an attendent decrease in manning and support services.

Mining Equipment and Personnel

The basic equipment for this operation is:

12 - 15 cubic yard rock shovels
3 - 15 cubic yard front-end loaders
147 - 100-ton rear-dump trucks

A blasting system using 13 45-R overburden drills and 32,400 tons ANFO per year.
A dewatering system designed to handle 10,000 gpm.
A water treatment facility designed to handle 14.4 mgd.
A coarse-cleaning coal preparation plant with ROM capacity of 1,424 tph.
A power system designed to handle a 23.7 MVA connected load.

The required mine personnel were calculated to be 69 salaried employees and 907 wage payroll employees, of which 450 would be truck operators. During the Mode II operation this could be reduced to 620 with a reduction of truck drivers to 210.

Mine Costs

All costs in the report were based on early 1977 prices. Estimated costs for the mine system were determined and applied to a discounted cash flow analysis to obtain internal rates of return at a range of selling prices. A sensitivity analysis was perfromed on the results to reflect changes in production and costs, and a predicting equation for the relationship between ROR and selling prices was obtained.

Capital Costs. The estimated total capital investment including deferred capital is $257,110,016 with a salvage value (book) of $22,784,704. The initial investment is $148.9 million, which includes direct costs (TDC) of about $122 million and indirect costs of approximately $27 million.

The direct costs were taken to include all plant and equipment for the designed mine system. Land costs (surface only) were estimated at $500 per acre or $2,304,875 and site preparation at $173,972. Land acquisition and site preparation were handled as expensed items retrieved during the final year of operation. Exploration costs were estimated at \$2,564,250 and were handled as cash outflow at the start of the project. Indirect costs were also handled as cash outflow. The indirect costs include: field indirect @ 2% TDC; engineering @ 2% TDC; fees @ 2% TDC; administration and overhead @ 5% TDC; contingency @ 10% TDC and interest charges during construction.

Operating and Maintenance Costs. These annual costs are summarized in Table 6.

Table 6. Operating and Maintenance Cost Summary

Item	Mode 1		Mode 2	
	Annual Cost (\$)	\$/ton clean coal	Annual Cost (\$)	\$/ton clean coal
wage labor	19,098,027.82	6.3660	12,939,790.60	4.3133
salaried labor	1,663,670.73	0.5546	1,663,670.73	0.5546
trucks	22,338,229.00	7.4461	9,925,371.00	3.3085
shovels	2,881,440.00	0.9605	2,881,440.00	0.9605
loaders	331,760.00	0.1106	331,760.00	0.1106
blasting	7,528,800.00	2.5096	7,528,800.00	2.5096
drilling	1,233,793.00	0.4113	1,233,793.00	0.4113
pumping	477,128.00	0.1590	443,204.00	0.1477
water treatment	293,930.00	0.0980	293,930.00	0.0980
coal prep.	1,680,000.00	0.5600	1,680,000.00	0.5600
secondary equip.	1,129,007.00	0.3763	848,918.00	0.2830
maintenance	1,410,400.00	0.4701	1,410,400.00	0.4701
reclam. supplies*	1,714,264.38	0.0142	1,714,264.38	0.0142
miscellaneous	7,448,833.00	2.4829	7,448,833.00	2.4829
TOTAL		22.5192		16.2243

*total

Miscellaneous annual costs include an 88 mill local tax assessment on surface facilities; \$1.20/ton clean coal for UMWA Health and Welfare; royalties @ \$1.00/ton clean coal; insurance, bonding and licensing.

Discounted Cash Flow Analysis. In the cash flow program the project life was assumed to be 20 years. The capital investment schedule is given in the Volume III report. The results of the discounted cash flow analysis are shown as the base case in Table 7 together with the results of the sensitivity analysis.

Table 7. Discounted Cash Flow Summary

ROI / Selling Price	Base Case	Production +10%	Production -10%	Costs +10%	Costs -10%
$30	0.0429	0.0496	0.0348	0.0282	0.0714
$35	0.0850	0.0923	0.0760	0.0771	0.1089
$40	0.1176	0.1260	0.1074	0.1121	0.1415
$45	0.1466	0.1560	0.1354	0.1428	0.1707

The predicting equation for the relationship between rate of return on investment and selling price for this site is:

$$Y = 23.3 + 144X$$

so that for a rate of return of 15% the selling price would be $46.04 at 1977 prices.

Impact of the Mine

An advantage of the proposed operation is that it would clean-up a major contributor to the pollution of Mahanoy Creek and restore surface drainage to an area in which the drainage pattern is presently totally disrupted. The site was ranked first in priority for reclamation in the Mahanoy Creek study of Operation Scarlift[11]. Since the site is concealed from the view of residents in neighboring valleys and is relatively isolated, negative impacts are minimized.

There is potential for the site to be designed as parkland at the completion of mining since this region is deficient in public open space. Such a large scale operation would serve to improve the economy of this area which is characterized by declining population, low income levels, high unemployment and insufficient local job opportunities for the labor force.

SITE RECLAMATION

The reclamation of the open pit is considered to be a continuous process throughout the mine life rather than a concluding phase. Reclamation is an integral part of the operation, such that the required personnel and equipment is included in the costing of the mine. With a projected mine life of 40 years continuous maintenance of the seeded and planted areas will be possible and should be mandated to ensure reclamation standards of the highest order.

The aim adopted here is reforestation of the disturbed areas with mixed tree and bush species on the initial waste tips and the possibility of softwood plantations for the remainder of the mine property. In view of the location of the proposed mines use of the disturbed land for agriculture, housing or industry was felt to be an unlikely alternative. Use of the Bear Valley site as public open space was however considered to be viable in view of the scarcity of parkland in this region.

It must be recognized that the volumes of loose waste material produced by the open pit method are too great to restore the areas to the original contour but that a system of terraces modifying the valley slopes throughout the mine property would be required. These terraces would not be as steep as those needed in the initial spoil areas when spoil is being removed from the first pit excavation, but particularly in the case of the narrow Wabash Valley would be visually apparent. For the initial waste tips a system of selective spoiling with acid-producing material deposited at depth and the better spoil types closer to the surface is recommended. The terraces produced in the remainder of the valley would be composed only of the surface and immediate sub-surface layers since in the backfilling of the pit the material would be replaced at the approximate elevation in which it was mined and revegetation should be a simpler procedure. It is recommended that full use be made of federal, state and university expertise so that this project may achieve its potential as an example of the correct method for reclaiming anthracite mined lands. Discussion of the spoil types found in the area and methods of reclamation are given in detail in the appendices of Volume II together with a summary of all research carried out to date on the revegetation of anthracite mined land.

Reclamation of disturbed land is at best an imprecise science in which a range of procedures must be adopted to counter the vagaries of weather and the variable chemical and physical characteristics of the spoil. Time is a crucial factor in reclamation. There is both a need to revegetate the land as fast as possible to stabilize the eroding surface and the need for extremely flexible scheduling so that as much as possible can be accomplished during favorable weather. Close monitoring of the area is required and swift action is needed to counter problems as they occur to prevent costly remedial work.

The initial erosion control problems are the greatest, caused by the porosity of the spoil and the steep slopes. The aim is always to prevent rapid runoff and retard infiltration in order to hold sufficient rainwater at the surface to provide suitable growing conditions for seedling trees and herbaceous cover. Suggested erosion prevention methods include:

i) terracing of slopes with contour benches sloping slightly toward the toe to prevent runoff from eroding the bench lip;

ii) a system of slope drainage with drainways along the toe and staggered downdrains to control the movement of water down the slopes;

iii) culverts connecting the toe drainways with the downdrains to prevent erosion of the outer bench rim;

iv) contour furrowing or scarification of the terrace slopes to check sheet erosion;

v) placement of top soil in a manner to encourage horizontal movement of run-off; and

vi) selection of species developed for their erosion control properties and fast growth.

The reclamation procedure for a typical bench section is shown in Figure 14.

The development of a dense vegetative cover is the best means of overcoming problems of porosity and erosion. Once the surface is held by plant roots, successive seasons increase the buildup of natural mulch and improve conditions for seed germination and growth. It is therefore essential to provide the best conditions possible for plant growth. The following recommendations were made:

i) all possible top soil be placed on the disturbed land augmented by the oxidized subsurface deposits;

ii) application of 2.5 tons per acre high-calcium lime;

iii) scarification of the slopes to incorporate the lime as deeply as possible and provide contour furrows;

iv) application of fertilizer (100 lb N, 200 lb P_2O_5, 100 lb K_2 per acre with 50% nitrogen slow-release);

v) hydroseeding of grass mixtures;

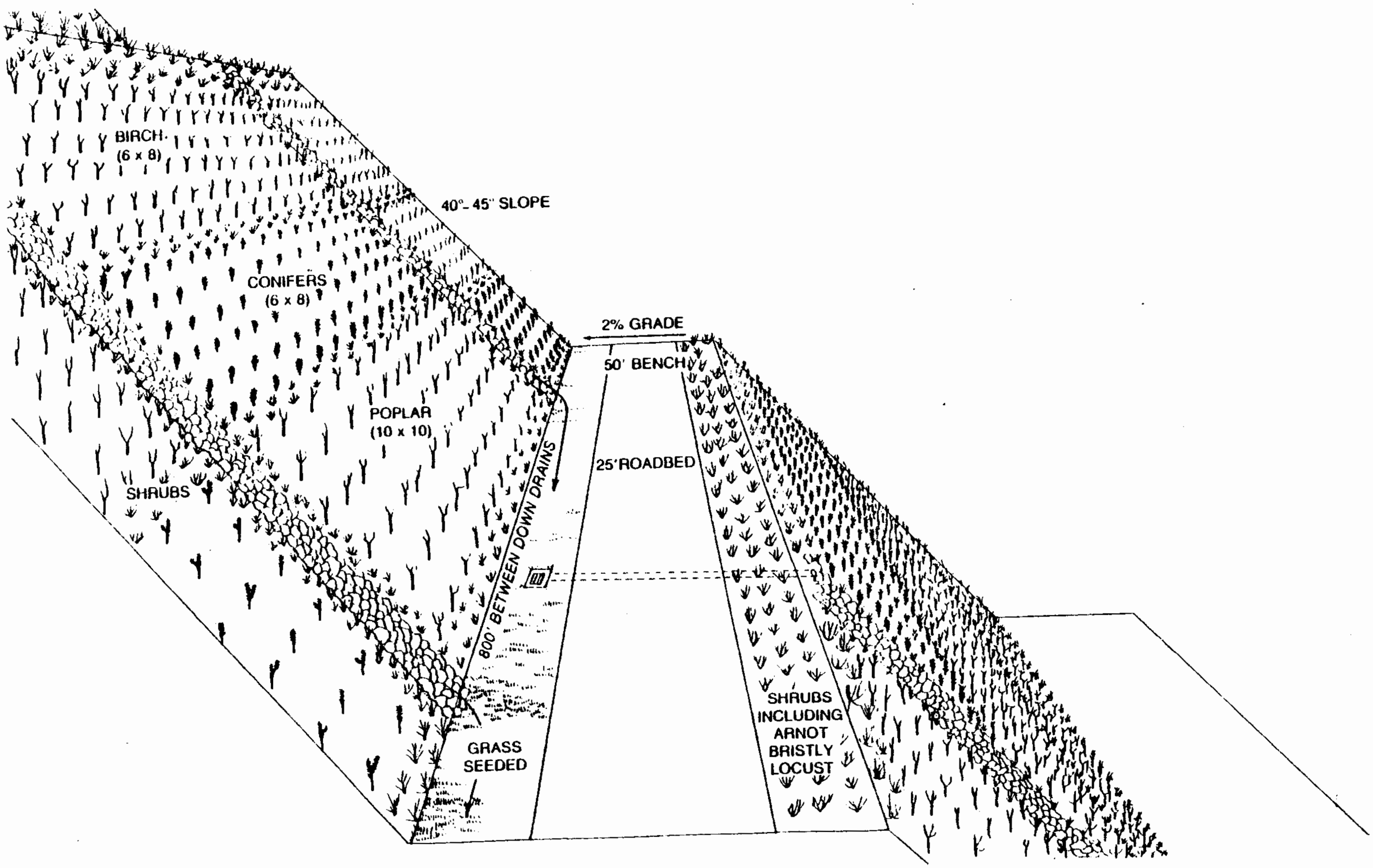


Figure 14 Reclamation of a Typical Bench Section

vi) application of hydromulch separately (on adverse sites v and vi should be separate operations to ensure that seed comes into close contact with the soil, otherwise it will wither following germination); and

vii) application of tacked straw to provide shade and protection for new seedlings.

Careful scheduling of these steps will minimize erosion and maximize seed germination and survival. Immediate seeding with a mixture of a fast-growing grass species with spreading root systems (Eragrostis curvulata) and the slower developing perennial grass that will be the eventual dominant species (K-31 fescue) is recommended, together with hedgerow planting of leguminous Robinia fertilis in contour bands at intervals on the slopes and along the bench lip. The robinia is an excellent erosion control species, attractive and fast growing. The quantities of grass seed (about 30 lb per acre) are designed to give adequate cover but not provide excessive competition with the seedling trees and bushes that will be subsequently spring-planted. Recommended tree species are rooted cuttings of hybrid poplar (Populus maximowiczii X.P. trichocarpa, clone NE-388), paper birch (Betula papyrifera Marsh. N.E.) and mixed conifers. Recommended species for hedgerow plantings Robinia fertilis are autumn olive (Elaeagnus umbellata), forsythia (Forsythia spp.) honeysuckle (Lonicera Amur L.Maackii) and arrowood viburnum (Viburnum dentatum). The aim is to provide vegetated slopes such as those shown in Figure 15.

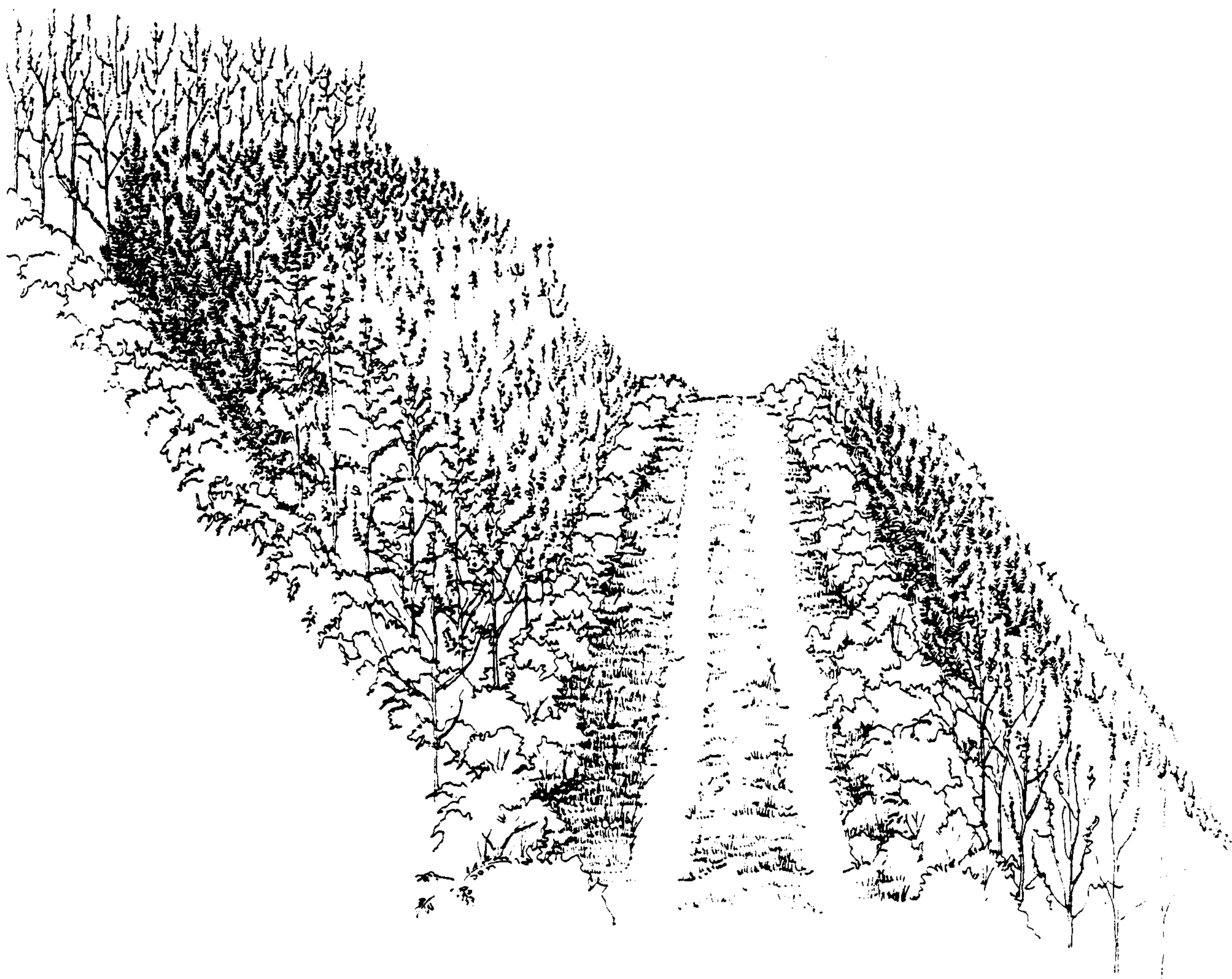


Figure 15 A Revegetated Bench Section

CONCLUSIONS

The mine plan outlined in this report uses shovels, front-end loaders and 100-ton trucks for the primary coal and waste removal systems. This is by no means the only feasible method for open pit mining, but was selected because it is a conventional approach for which data is readily available. The aim here was not to minimize mine costs but to determine the economic feasibility of a system that achieves maximum recovery and maximum environmental clean-up of a previously-mined area. This is a truck-intensive system and the costs for equipment and truck operators are high. To reduce these costs a two-mode operation was adopted in which maximum equipment and manning is required during the early years of operation when the initial pit is being developed, and lower equipment and manning levels are maintained during the remainder of the mine life. Without this 2-mode plan, the mine costs would have been higher and the economic feasibility reduced.

It follows that the shorter the period in Mode 1, i.e. the smaller the initial pit, the lower the mine costs. However, there are two variables that must be balanced in the design of the pit: costs and recovery. As the size of the initial pit is decreased the mining costs are lowered, but at the same time the pit becomes shallower, since the pit walls are designed for a 45° overall slope and critical pit floor dimensions must be maintained. As the pit depth is reduced the resource recovery drops and the mine life is decreased. Other major factors that influence the economic feasibility of the mine design are: the stripping ratios; the average mining locations, which influence the sizing of the mine system; and the nature of the available spoiling space, since the waste tip configuration affects haulroad distances and profile, both of which are directly reflected in the fleet sizes and hence mine costs.

The length of time required to develop the initial pit -- 7-8 years in Wabash Valley and 13 years in Bear Valley -- is reflected in the selling prices calculated for the anthracite with a 15% ROR -- $37.35 for Wabash Valley and $46.04 for Bear Valley. This difference is primarily due to the width of the valley at the two sites, since the stripping ratios and average waste removal locations were comparable.

The sites outlined in this report typify conditions in the anthracite coalfields and both have potential for open pit mining, although the Wabash Valley has a definite cost advantage over the Bear Valley site. On the basis of the costs outlined for the open pit operation, the cost of the Wabash Valley anthracite (1977 prices) would be $1.46/million BTU, and the Bear Valley anthracite $1.74/million BTU. These costs appear to be within the competitive range of other power-generating fuels when the scrubbing exemption is applied. The prices paid by local power plants for fuel during 1976 are shown below:

coal (without sulfur restrictions)	$0.96-$1.26/million BTU
coal (low sulfur)	$0.98-$1.67/million BTU
#2 oil (low sulfur)	$2.51-$2.99/million BTU

REFERENCES

1. Turner, H. G. Anthracites and Semianthracite of Pennsylvania. Trans AIME Coal Div., 1934.

2. Deasy, G. R. and P. R. Griess. Atlas of Pennsylvania Coal and Coal Mining. Part II Anthracite. Bulletin of The Mineral Industries Experiment Station, No. 80, The Pennsylvania State University, 1963.

3. Blair, J. F. et al. An Analysis of the Impacts of the EPA's Proposed NSPS SO_2 Regulations on the Anthracite Industry in Northeastern Pennsylvania. Franklin Research Center, 1978.

4. Berger Associates. Evaluation of Mining Constraints to the Revitalization of Pennsylvania Anthracite. BuMines, 1975.

5. Ash, S. H. et al. Water Pools in Pennsylvania Anthracite Mines. BuMines T. P. 727, 1949.

6. Cornwell, S. M. Anthracite Mining Spoils as Media for Plant Growth. Cornell University, Ph.D., 1966. University Microfilms Inc., Ann Arbor, Mich.

7. Manula, C. B., F. A. Camilli and J. Kiusalaas. An Ore Body Model for Steeply Pitching, Multi-Seam Deposits. Computer Methods for the 80's, AIME, 1979.

8. Manula, C. B., E. K. Albert and R. V. Ramani. Application of a Total System Surface Mine Simulator to Coal Strippings. Vol. 2: Users Manual. USDI, Washington, D.C. NTIS PB294 628/AS, 1976.

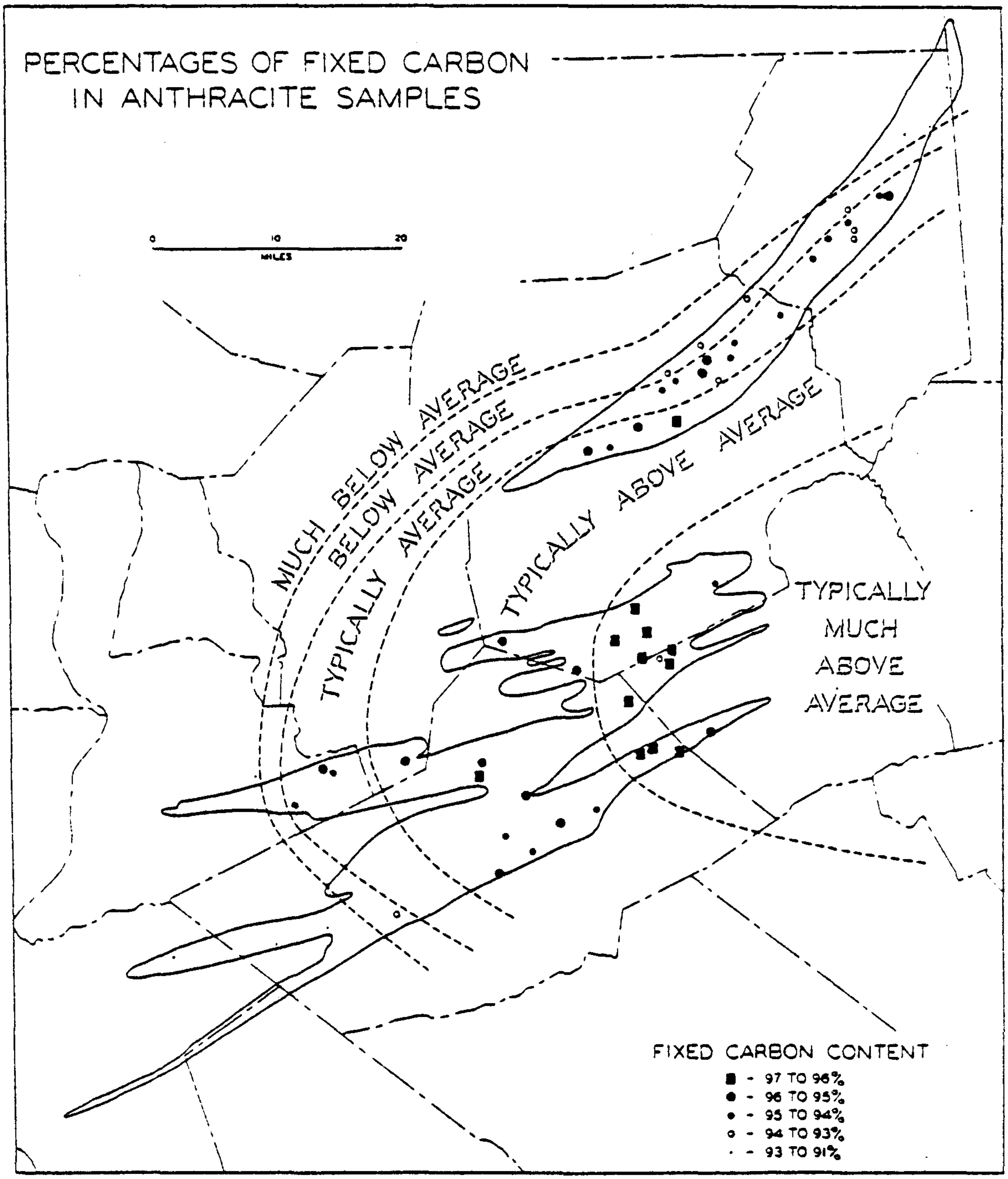
9. A. W. Martin Associates. Little Schuylkill River Basin. Operation Scarlift, PA. DER, 1973.

10. Ash, S. H. et al. Barrier Pillars in the Western Middle Field. BuMines Bulletin 521, 1953.

11. Sanders and Thomas Inc. Mahanoy Creek. Operation Scarlift, PA. DER, project SL197, 1974.

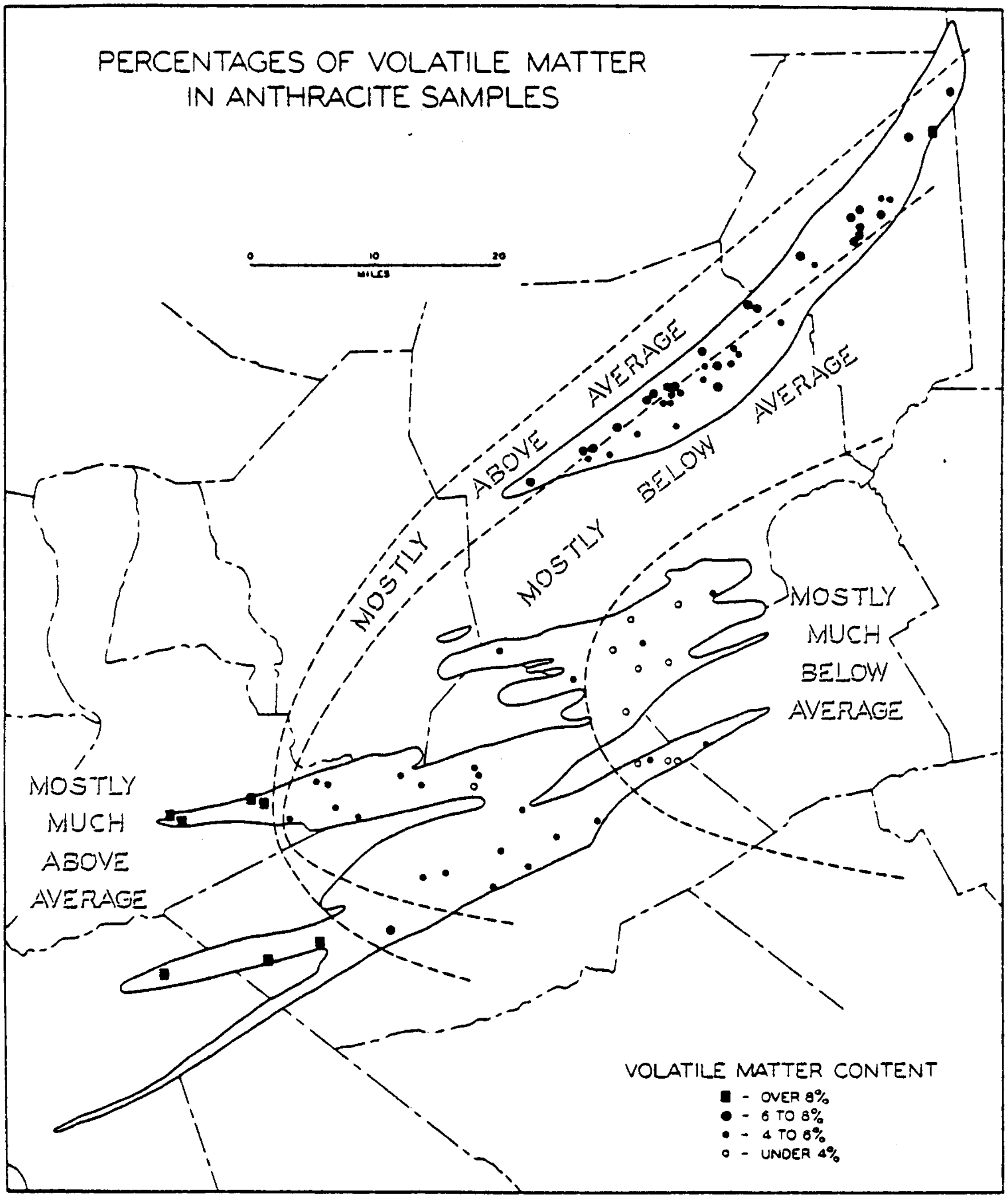
APPENDIX

Characteristics of Anthracite



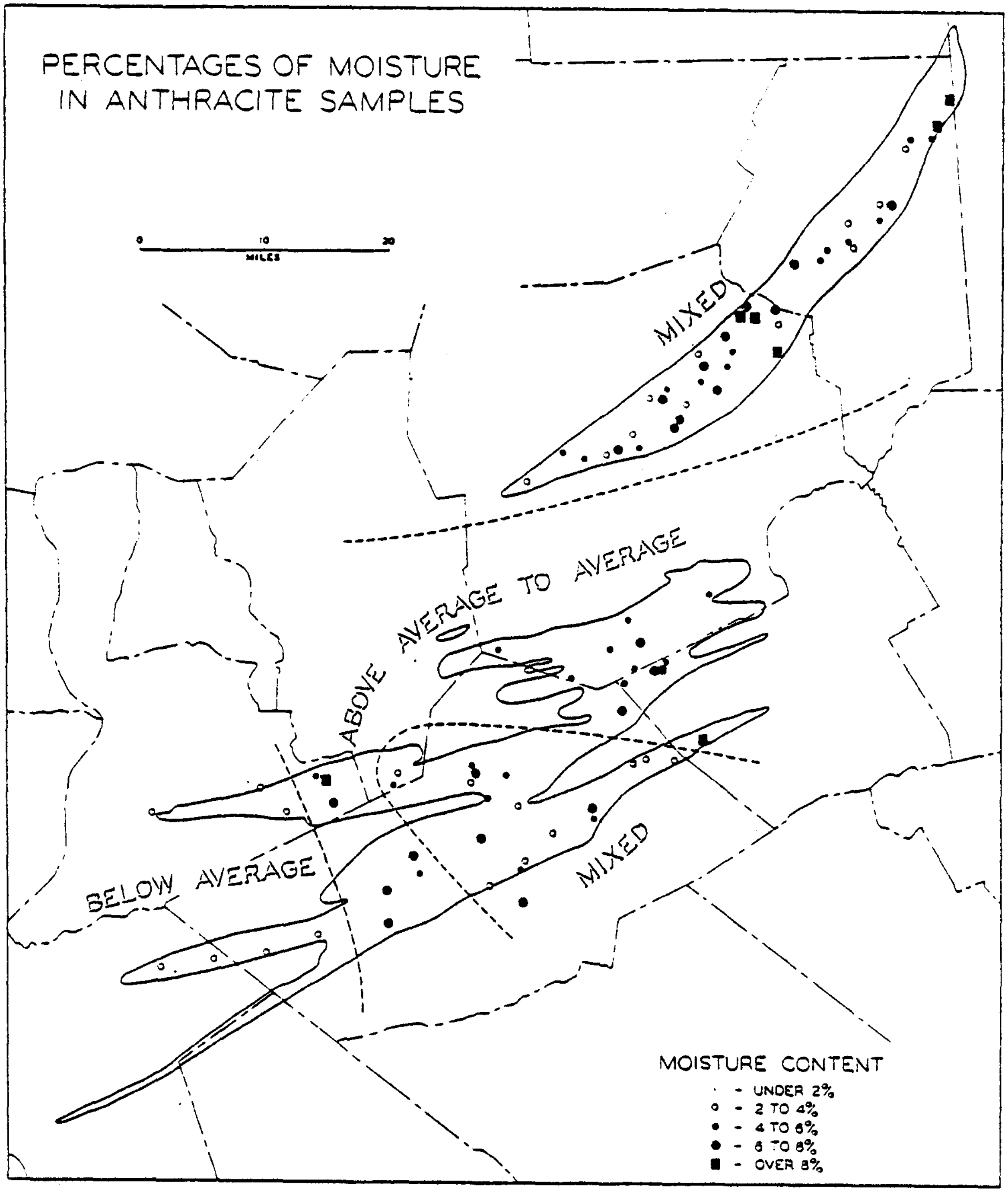
(Deasy and Griess, 1963 [2])

FIXED CARBON



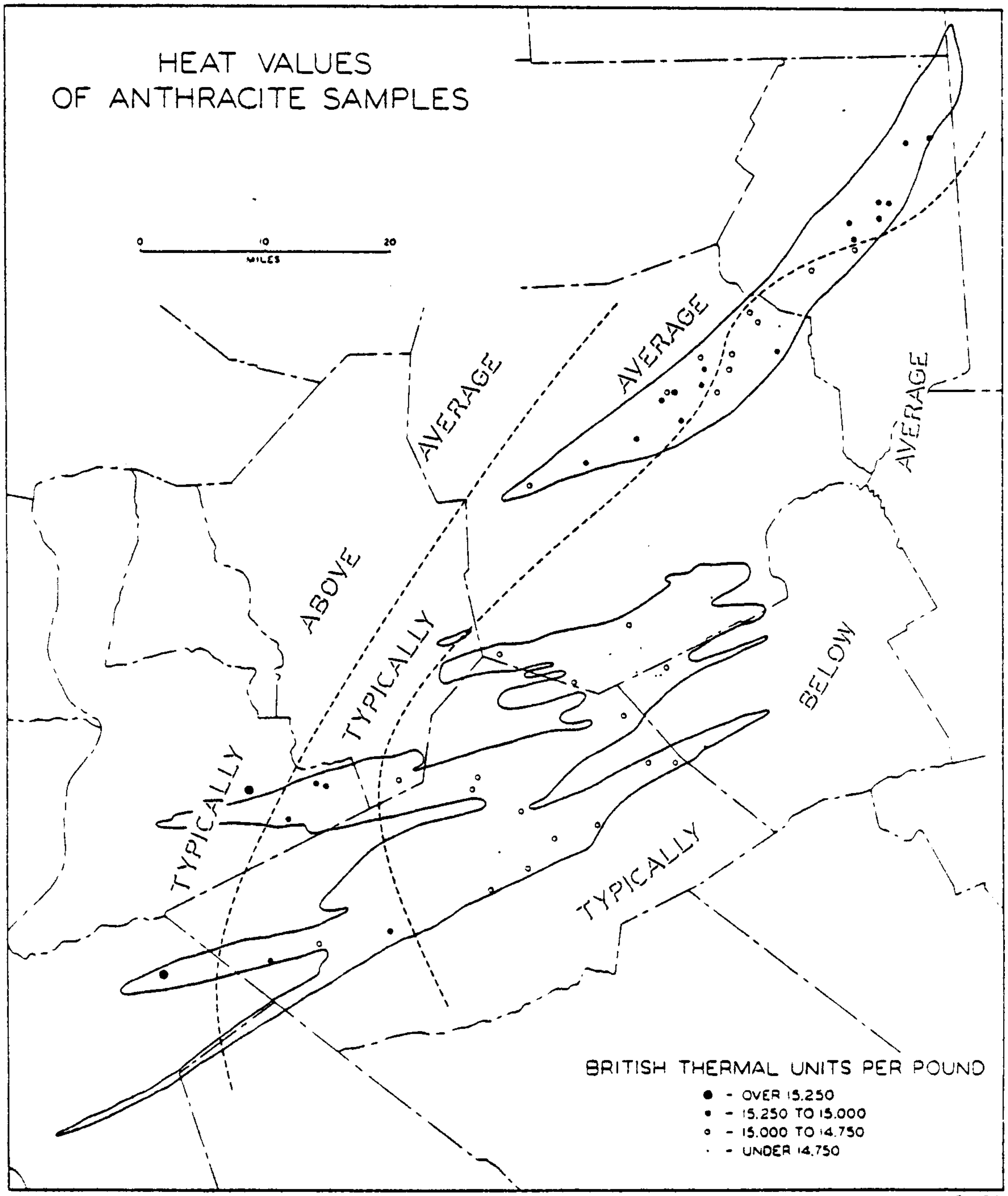
(Deasy and Griess, 1963 [2])

VOLATILE MATTER



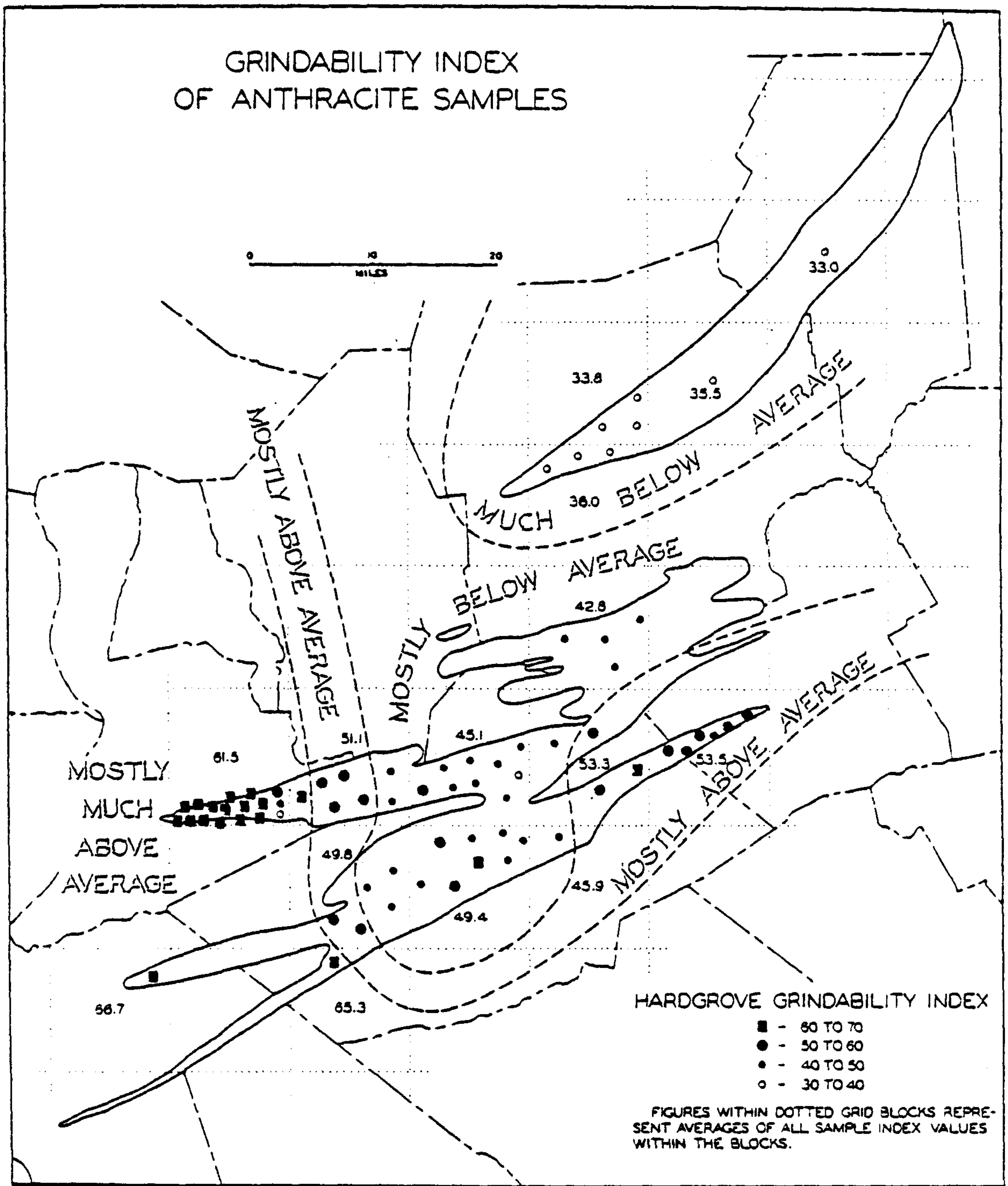
(Deasy and Griess, 1963 [2])

MOISTURE



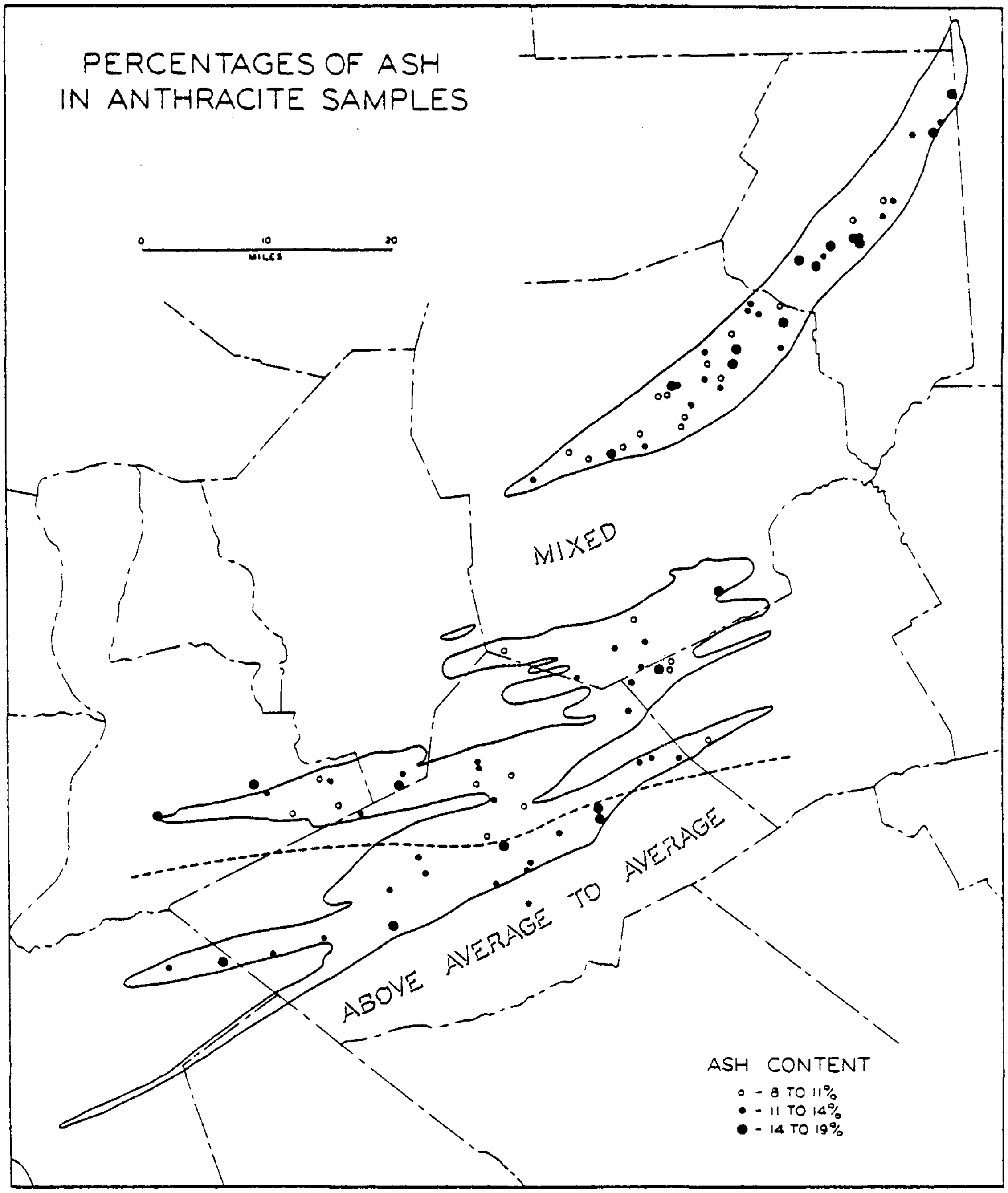
(Deasy and Griess, 1963 [2])

HEAT VALUES



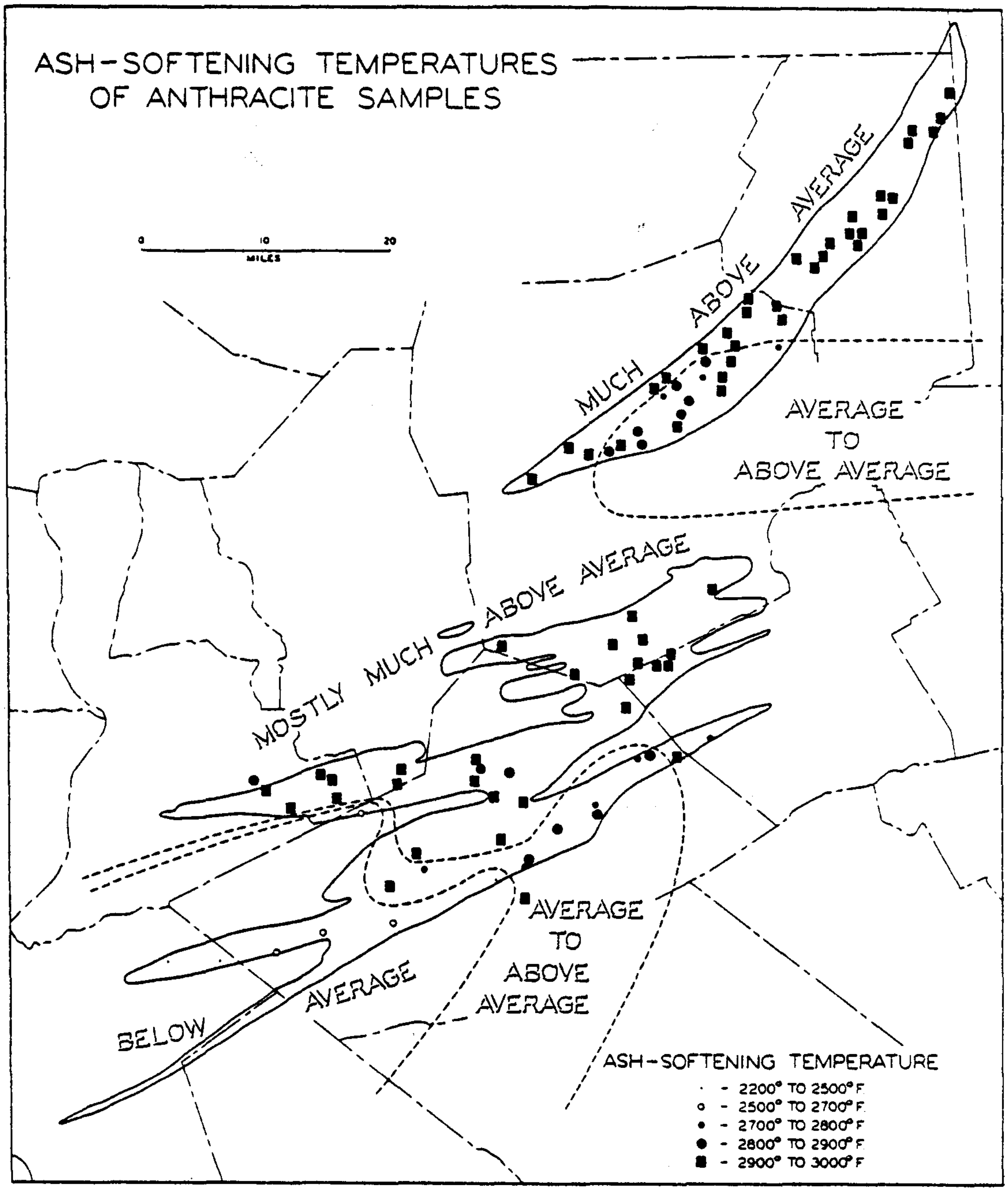
(Deasy and Griess, 1963 [2])

GRINDABILITY INDEX



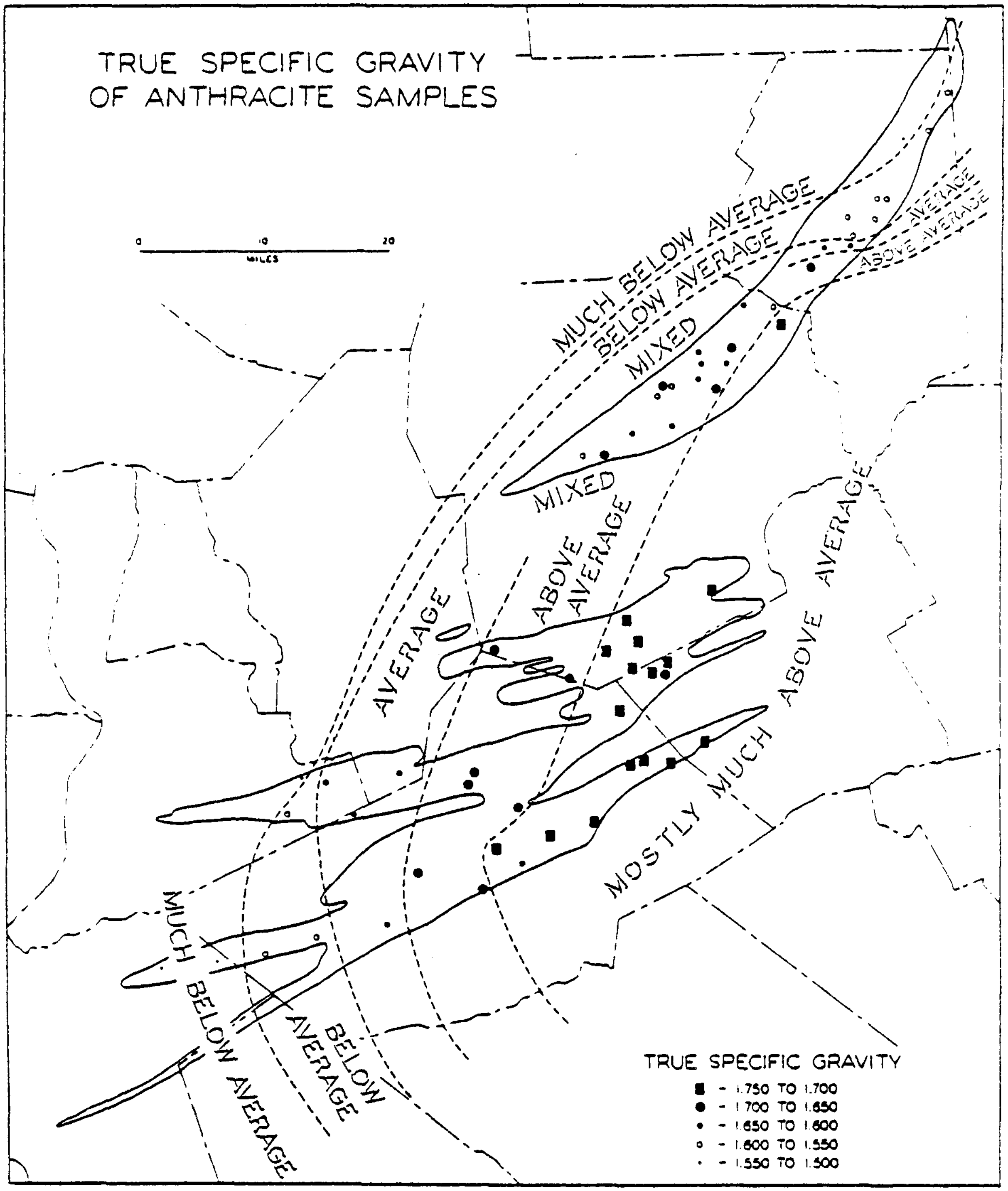
(Deasy and Griess, 1963 [2])

ASH



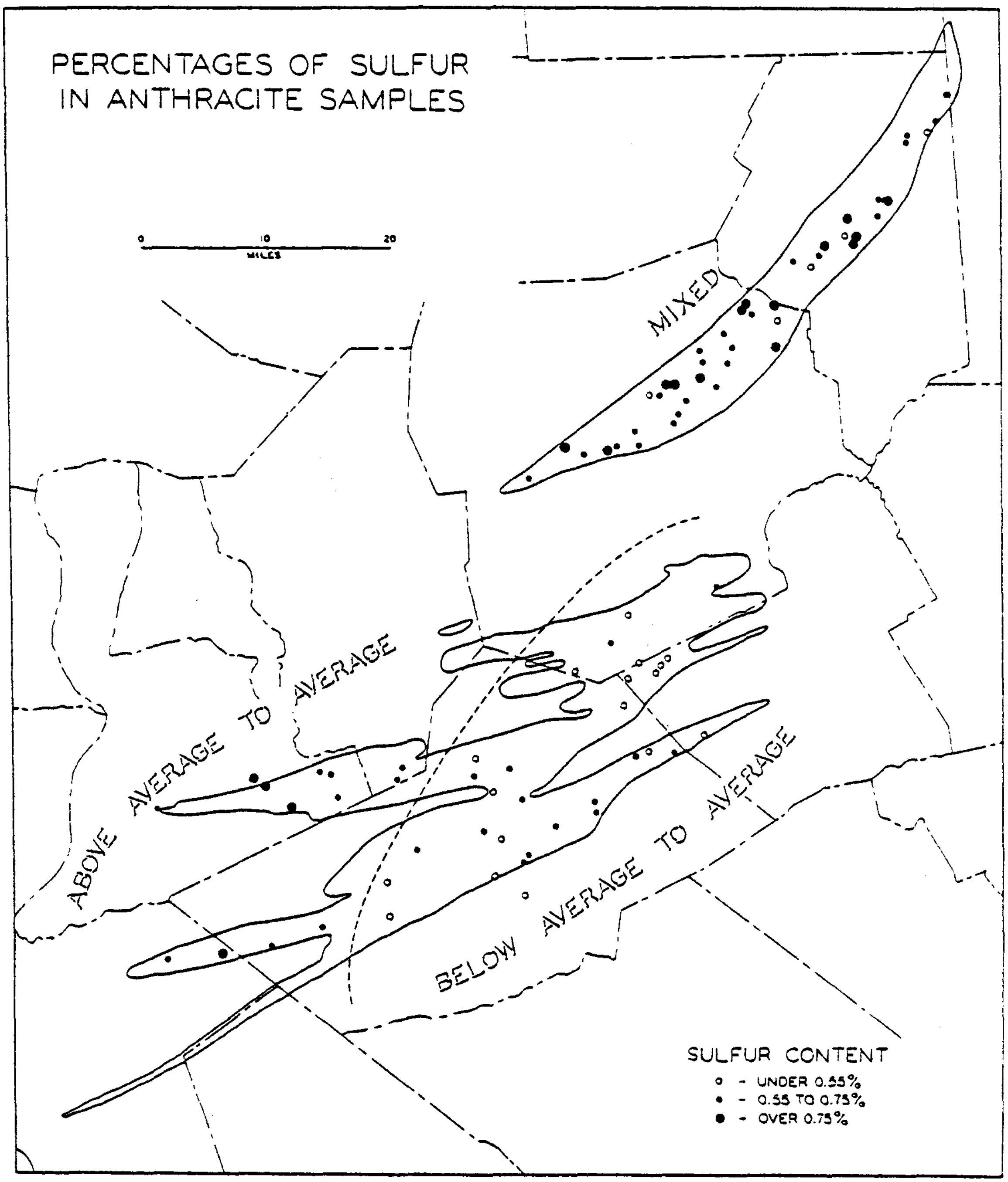
(Deasy and Griess, 1963 [2])

ASH-SOFTENING TEMPERATURES



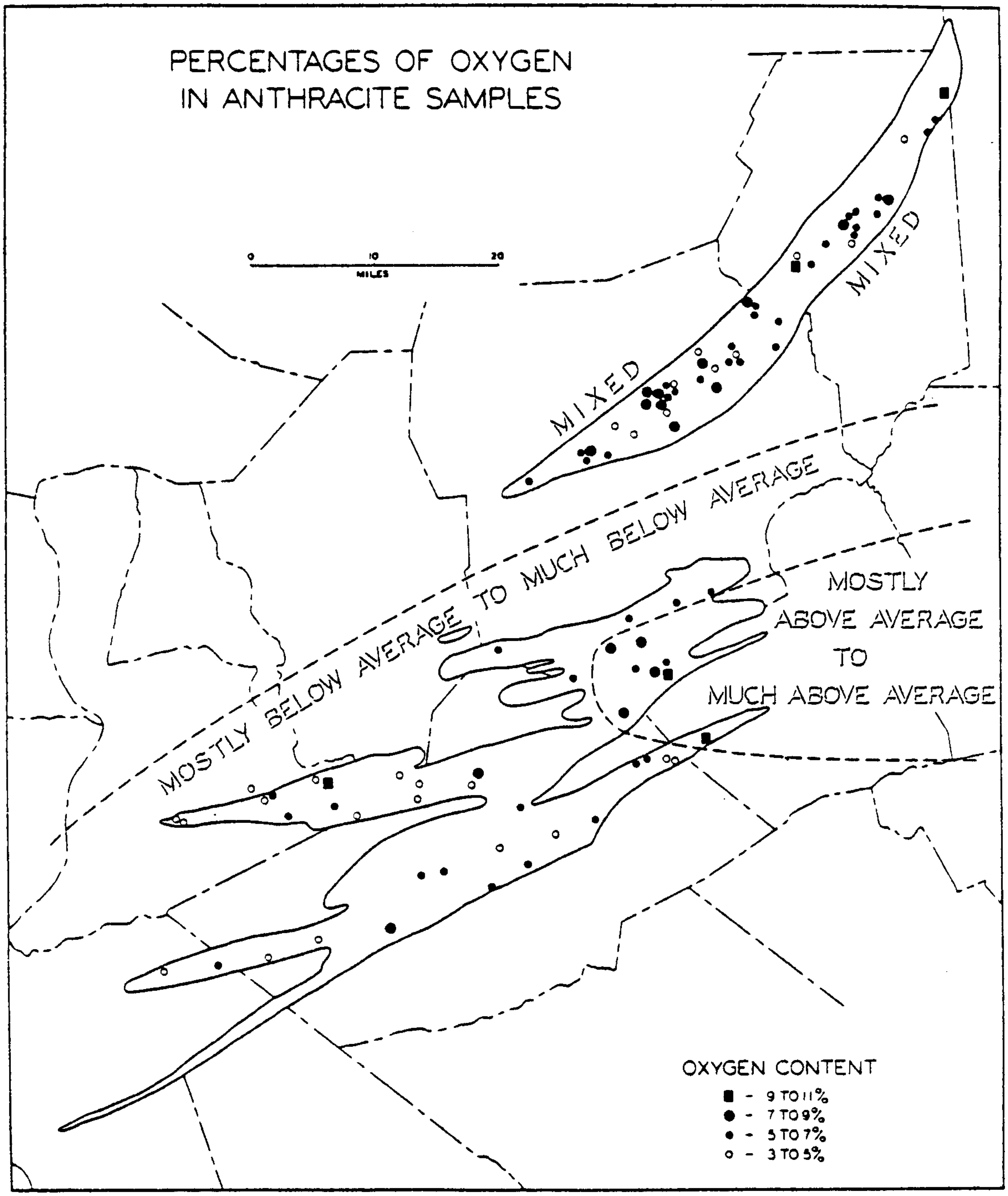
(Deasy and Griess, 1963 [2])

TRUE SPECIFIC GRAVITY



(Deasy and Griess, 1963 [2])

SULFUR



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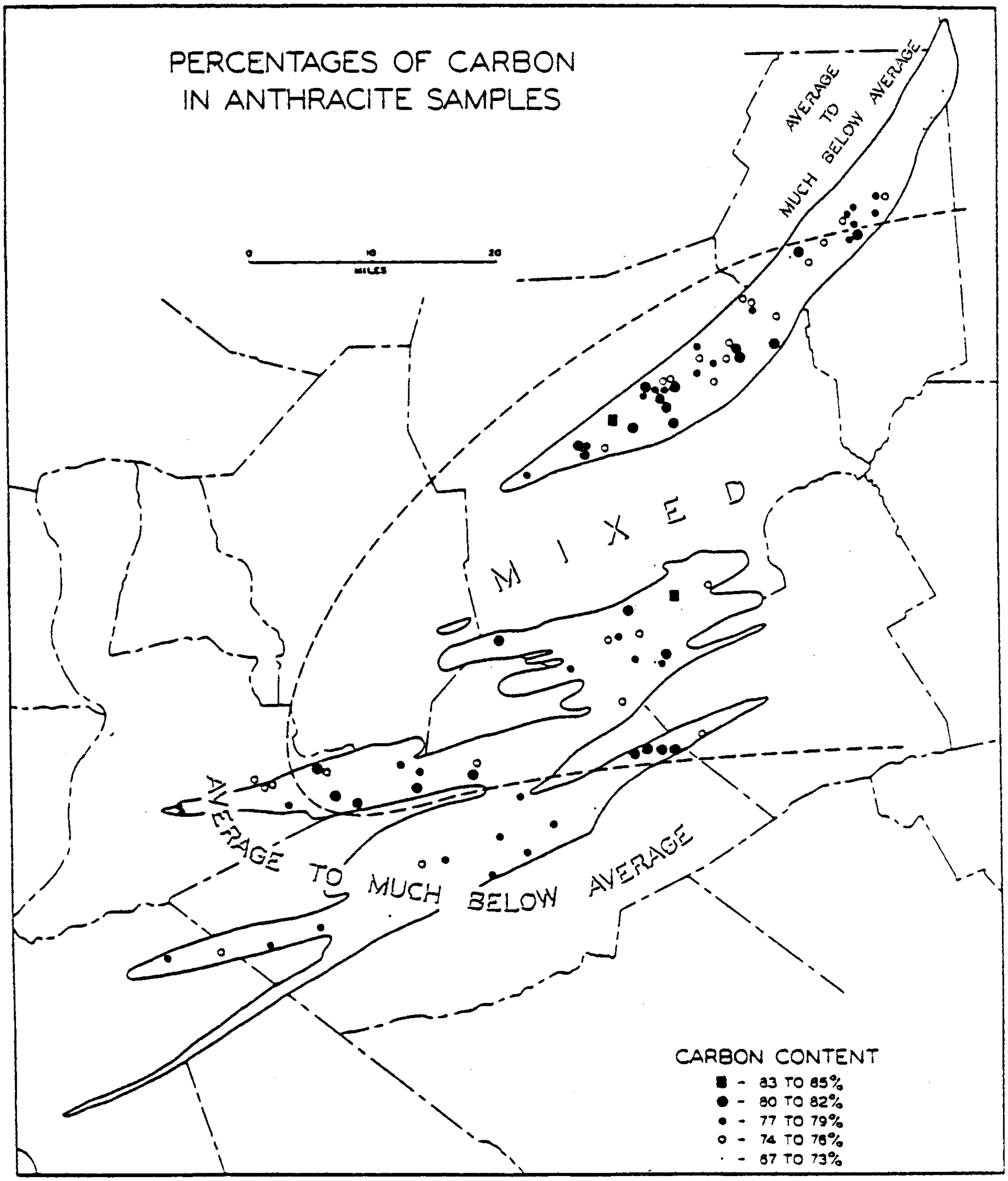
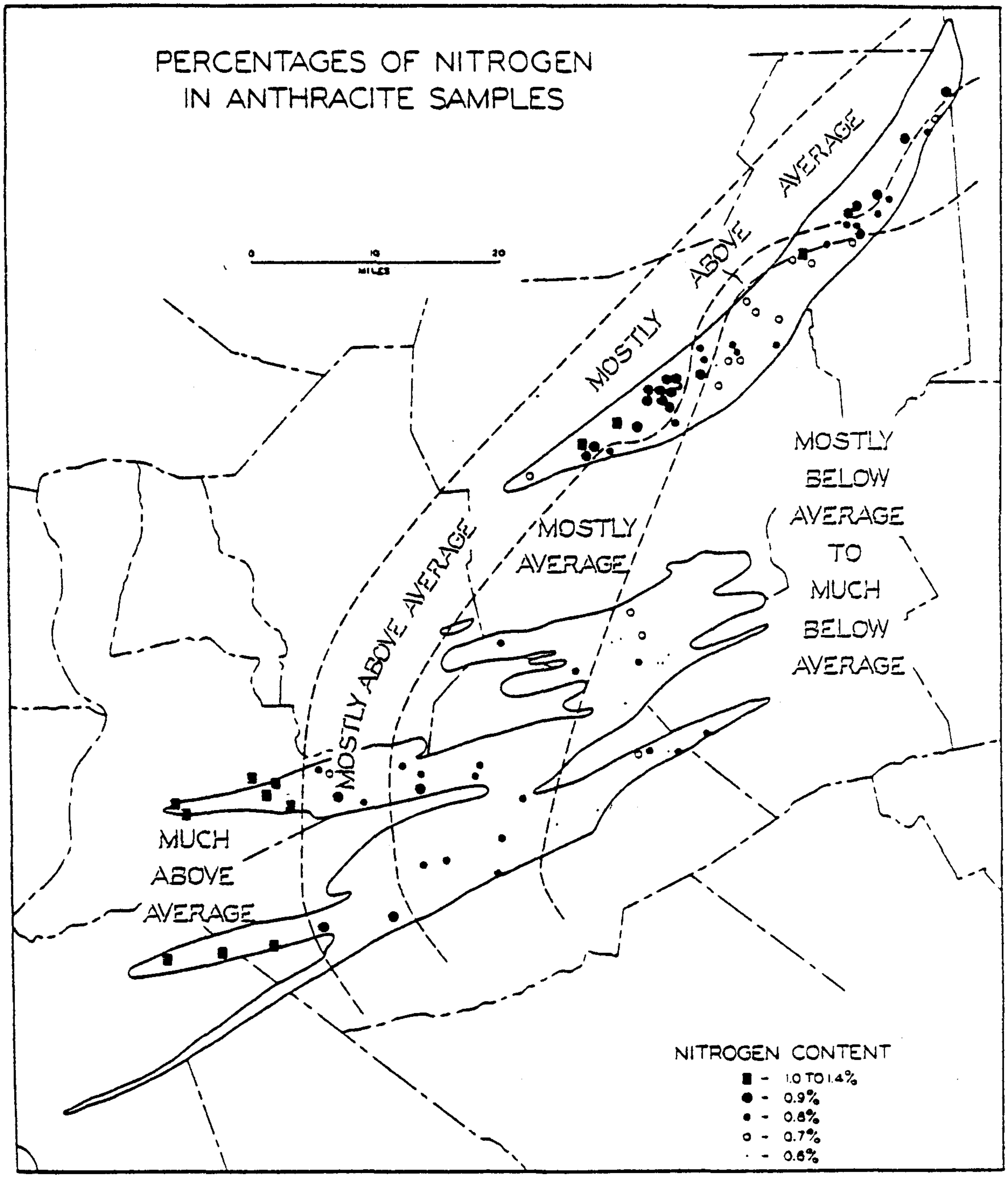
OXYGEN



(Deasy and Griess, 1963 [2])

CARBON



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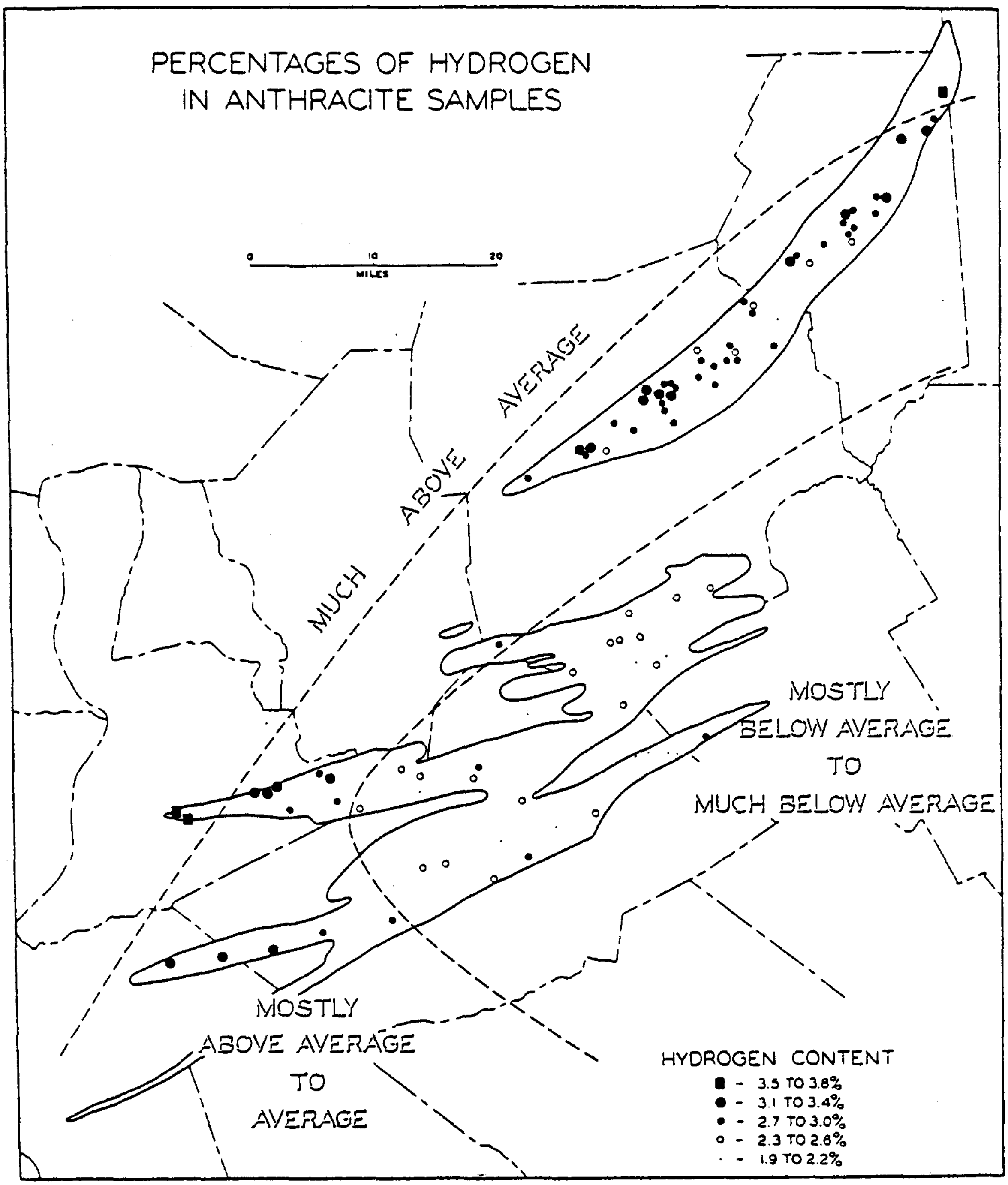
NITROGEN



(Deasy and Griess, 1963 [2])

HYDROGEN