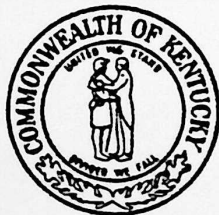
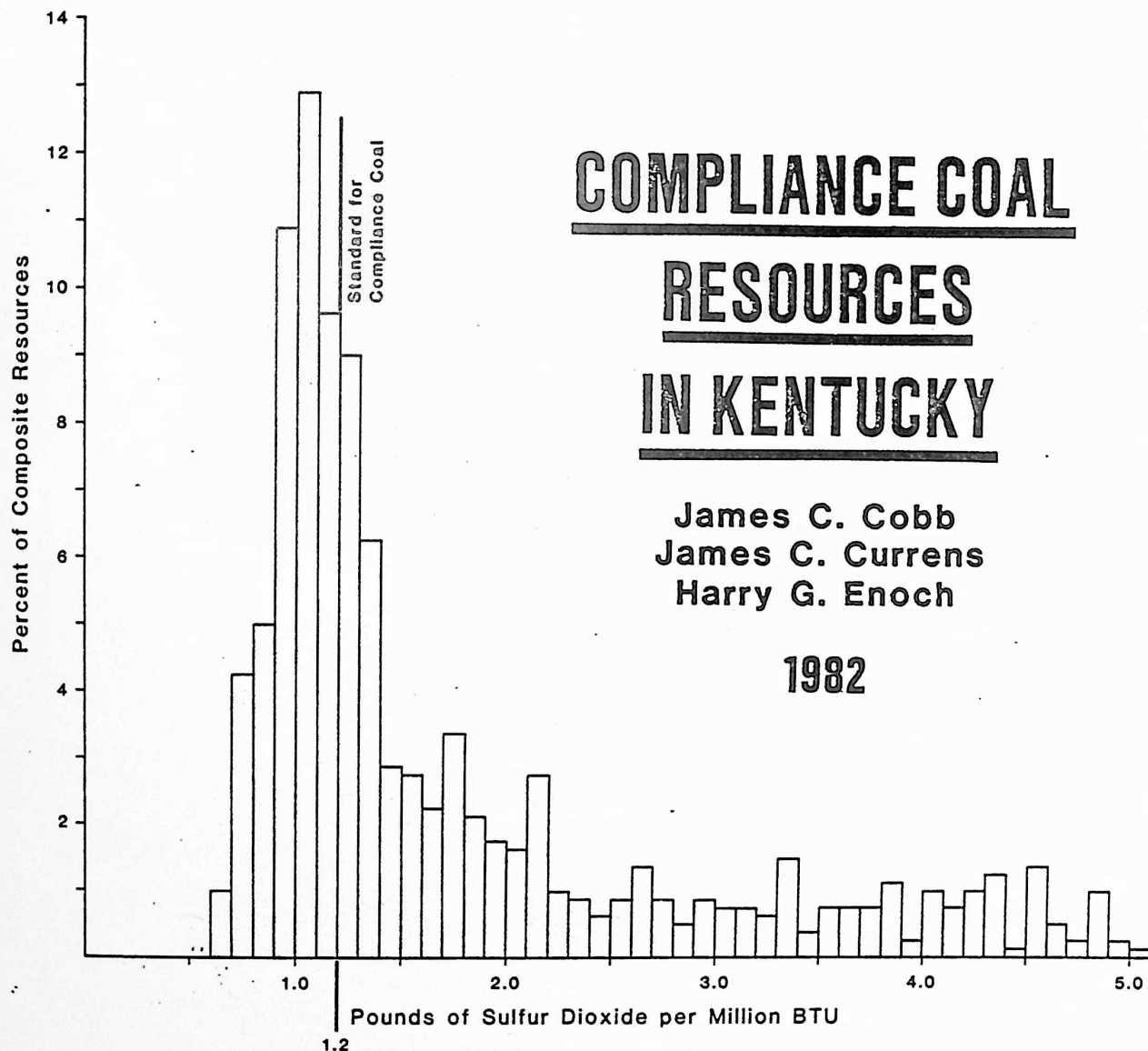


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SERIES XI



KENTUCKY GEOLOGICAL SURVEY
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COMPLIANCE COAL RESOURCES IN KENTUCKY

James C. Cobb and James C. Currans
Kentucky Geological Survey

and

Harry G. Enoch
Kentucky Department of Energy

Prepared in cooperation with the Kentucky Department of Energy
William B. Sturgill, Secretary

UNIVERSITY OF KENTUCKY

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COMPLIANCE COAL RESOURCES IN KENTUCKY

James C. Cobb^{1/}, James C. Cyrrrens^{1/},
and Harry G. Enoch^{2/}

ABSTRACT

This preliminary report describes Kentucky's coal resources in terms of the quantity of resource that could comply with various sulfur emission limits, if burned without flue-gas controls.

The selection of coal for fuel by the electricity-generating utilities, which constitutes the largest market for coal in the United States, is profoundly influenced by environmental legislation and regulation. Small changes in the Clean Air Act can determine whether new coal-fired power plants must control emissions of sulfur through the use of medium- and high-sulfur coal combined with flue-gas scrubbers or through the use of low-sulfur compliance coal.

Kentucky has two major coal fields, the Eastern Kentucky Coal Field which is characterized as low- to medium-sulfur coal and the Western Kentucky Coal Field which is predominantly high-sulfur coal. Any change in emission standards will have a profound effect on the coal industry in Kentucky, the Nation's leading coal-producing state. The decrease in compliance resources would be unexpectedly high, even if the current compliance standard were made only slightly more stringent. For example, a change in the emission standard from 1.2 lbs SO₂ per million Btu to 1.0 lb SO₂ per million Btu would exclude an additional 23 percent of eastern Kentucky resources, bringing 80 percent into noncompliance. Therefore, it is of great importance to quantify resources in terms of potential sulfur dioxide emissions in order to estimate the abundance of coal meeting specified standards.

Kentucky has about 75 billion tons of remaining coal resources (39 billion tons in western Kentucky and 36 billion tons in eastern Kentucky). At the sulfur dioxide emission standard of 1.2 lbs of SO₂ per million Btu, the percentages of compliance coal are as follows: 2.5 percent in western Kentucky, 43 percent in eastern Kentucky, and only 26 percent in the State overall.

It is important to point out that these percentages do not apply to coal as it is mined, because the data are based on ASTM channel samples. They should be considered as representative of coal that has been subjected to a moderate degree of cleaning.

One of the major findings of this study is that if the amount of allowable SO₂ were reduced slightly, the amount of resource that would qualify as compliance grade would decrease dramatically. For example, at 0.6 lb per million Btu, the percent of compliance coal is virtually zero in western Kentucky, less than 1.0 percent in eastern Kentucky, and less than 1 percent in Kentucky overall.

¹Kentucky Geological Survey, University of Kentucky, Lexington, KY

²Kentucky Department of Energy, Lexington, KY

INTRODUCTION

The Clean Air Act of 1970 required the U. S. Environmental Protection Agency (EPA) to develop stringent, technology-based standards for new industrial plants. In 1971 the EPA promulgated their New Source Performance Standards (NSPS) for steam electricity-generating plants. This standard set a limit on sulfur dioxide (SO_2) emissions from coal-fired power plants equivalent to 1.2 pounds of SO_2 per million Btu of heat input. This standard was justified on the basis of the best technology available for the control of SO_2 emissions (i.e., flue-gas-desulfurization devices, or scrubbers) which could reduce SO_2 emissions by 80 to 90 percent or to a level equivalent to or below 1.2 lbs of SO_2 per million Btu for most coals. The 1971 NSPS required that all new plants meet the 1.2 lbs of SO_2 per million Btu standard; however, they were not required to adopt scrubbers. It soon became apparent that many utilities were complying through the use of low-sulfur coal. In many cases this was at the expense of locally produced medium- to high-sulfur coals. Due, in part, to recognition of this fact, the Clean Air Act Amendments of 1977 required a sulfur reduction from all utility coals, thus eliminating the bypassing of the "best technology" through the use of compliance coal.¹ The regulations adopted under this legislation (the 1978 NSPS for steam electricity-generating plants) retained the 1.2 lbs of SO_2 per million Btu standard as an upper limit, but required a minimum of 70 percent sulfur reduction for all coals.

The Clean Air Act expires at the end of 1982, and debate is now underway in Congress on its reauthorization. One of the subjects receiving a great deal of attention is the so-called "percent-reduction" issue. The utility industry and the low-sulfur coal producers would like to see the percent-reduction requirement repealed; on the other hand, the medium- and high-sulfur producers

¹ Compliance coal may be defined as coal that meets sulfur dioxide emission standards without the use of sulfur-reduction processes such as scrubbers.

fear this would result in the loss of their markets to compliance coal. It is not at all clear which of these positions (or the many compromise positions proposed) is most favorable in terms of overall national economic and environmental consequences.

This debate has become even more complex in view of the growing concern about "acid rain," or rain of greater than "normal" acidity and having the potential for severe ecological consequences. The claim has been made that utility SO_2 emissions play a significant role in the formation of acid rain. This issue has become the driving force for a northeastern United States and Canadian movement for the reduction of U. S. SO_2 emissions. Reductions of as much as 50 percent have been proposed, and any change in the law that could result in increased SO_2 emissions will be strongly resisted. Under the present (1978) utility NSPS most new power plants must meet an emission limit of 0.6 lb of SO_2 per million Btu. If the percent-reduction requirement were repealed and the maximum emission limit remains at 1.2 lbs per million Btu, the emission standard and the potential new SO_2 emissions from utilities would, in effect, be doubled.

It may then be expected that repeal of the percent-reduction requirement would be accompanied by a significant lowering of the maximum SO_2 emission limit, perhaps to 0.6 lb per million Btu.

Before new standards are adopted it is important to assess the quality, quantity, and location of coal resources that are capable of meeting various compliance standards. This is particularly critical in Kentucky, the Nation's leading coal-producing state. Kentucky has two coal fields, broadly characterized as high-sulfur coal (Western Kentucky Coal Field) and low- to medium-sulfur coal (Eastern Kentucky Coal Field). This report was initiated by the Kentucky

Department of Energy and the Kentucky Geological Survey to provide additional coal-resource data for Kentucky. Specifically, the report estimates the maximum amount of resources present in both the Eastern and Western Kentucky Coal Fields capable of meeting various SO₂ compliance standards.

APPROACH

The purpose of this study is to estimate the abundance and distribution of coal in Kentucky meeting the EPA emissions standard of 1.2 pounds of sulfur dioxide per million Btu. This investigation concentrates on the coal resources of Kentucky which are defined as the total amount of coal in the ground. Analyses of channel samples collected under American Society for Testing and Materials (ASTM) standards were used to calculate the sulfur dioxide emissions potential for each coal bed studied.

In order to determine the abundance and distribution of compliance coal in Kentucky, coal resource data have been combined with data on the sulfur and Btu content of major coal beds. The frequency distributions for sulfur and Btu values in individual coal beds are used to apportion the coal resources by potential sulfur dioxide emissions. The data base for this study consists of nearly 600 analyses of channel samples from the Eastern Kentucky Coal Field and 125 analyses of channel samples from the Western Kentucky Coal Field. Data for comparison on sulfur and Btu contents of Kentucky coals are from the U. S. Bureau of Mines, U. S. Geological Survey, and the University of Kentucky Institute for Mining and Minerals Research.

Channel samples are used to characterize coal resources because: (1) they represent the coal in its undisturbed state; (2) they eliminate the random bias caused by different mining methods; and (3) they show the best possible

coal quality prior to mining. Channel samples are defined as samples of the entire coal bed cut vertically down a fresh coal exposure and cut uniformly so that each part of the coal is sampled in proportion to its abundance in the coal bed. Mineral partings 3/8 inch thick or more are excluded from the sample but are recorded in the geological description of the sample. Because of the exclusion of certain mineral partings from the channel sample it is also suggested that these samples may be regarded as representing partially cleaned coal.

Nearly 70 percent of the channel samples used in this study were collected at active mines where resource conditions, including coal quality, are expected to be optimum for the coal bed. In order to ensure that sample collection did not bias the results of this study, a statistical test (chi squared) was performed on data from active mines versus data from random sites. No significant difference was found to exist. Therefore, the method of collection of samples does not appear to have biased the results of this study.

The potential sulfur dioxide emission for each coal bed has been calculated using a formula by Cavallaro and others (1976) where potential sulfur dioxide emission in pounds of sulfur dioxide per million Btu equals:

$$\frac{20,000 \times \text{sulfur (percent)}}{\text{Btu per pound}}$$

The moisture- and ash-free basis for reporting coal analyses is used in this report. Readers should be aware that the results for sulfur and Btu per pound shown in this report are higher than similar data reported in the more familiar as-received basis. This is only an apparent difference due to the reporting form and not an actual difference. Of special importance to this report is the fact that as long as the same reporting form is used for sulfur

and Btu per pound the conversion of this data to pounds of sulfur dioxide per million Btu is not changed. Two examples of forms of coal analysis reporting ("as-received" and "moisture- and ash-free") and conversions to sulfur dioxide emissions are shown in Table 1. As can be seen in the table, the sulfur and Btu values are higher for the moisture- and ash-free basis, but the sulfur dioxide values are unchanged by the basis for reporting coal data.

Potential sulfur dioxide emissions were calculated for 11 eastern Kentucky coals and 3 western Kentucky coals. These coal beds represent about 75 percent of Kentucky's total coal resources. Frequency distributions of sulfur dioxide emissions were constructed for each coal bed. Coal resources estimates were combined with the emissions distributions to estimate the abundance and distribution of EPA compliance and noncompliance coal in Kentucky. The EPA emissions standard of 1.2 pounds of sulfur dioxide per million Btu is used in this report to distinguish compliance coal (1.2 pounds of sulfur dioxide per million Btu or less) from noncompliance coal (greater than 1.2 pounds of sulfur dioxide per million Btu).

Composite histograms for compliance coal, sulfur, and Btu distributions for each coal bed are given in Appendices 1 and 2 for the 14 coal beds selected.

Table 1.--Comparison of Coal Analysis Reporting Forms:
As-Received, Moisture-Free, and Moisture- and Ash-Free.

	Moisture (%)	Volatile Matter(%)	Fixed Carbon(%)	Ash (%)	Sulfur (%)	Btu (per pound)	SO ₂ (lb/10 ⁶ Btu)
<u>Coal Analysis Western Kentucky No. 9 Coal Bed</u>							
As-received	5.6	38.3	46.8	9.3	2.9	12,300	4.7
Moisture-Free	---	40.5	49.6	9.9	3.1	13,060	4.7
Moisture- and Ash-Free	---	45.0	55.0	---	3.4	14,500	4.7
<u>Coal Analysis Eastern Kentucky Lower Elkhorn Bed</u>							
As-received	1.9	29.8	51.7	16.7	0.7	11,989	1.1
Moisture-Free	---	30.3	52.7	17.0	0.7	12,214	1.1
Moisture- and Ash-Free	---	36.6	63.5	---	0.8	14,715	1.1

ESTIMATING COMPLIANCE COAL IN KENTUCKY

Kentucky's total coal resources are estimated to be approximately 75 billion tons (Kentucky Geological Survey, 1982) almost equally divided between the Eastern and Western Kentucky Coal Fields (Fig. 1). Coal resources are defined as the total amount of coal in the ground without accounting for mineability or recoverability, factors constantly changing due to technological advancements. The frequency distribution of these coal resources with respect to their potential sulfur dioxide emissions is shown in the histogram in Figure 2. The histogram is constructed from nearly 725 coal analyses from coal beds representing nearly 75 percent of Kentucky's resources. This histogram indicates that about 26 percent of Kentucky's total resources are compliance quality based on the emission standard of 1.2 lbs SO₂ per million Btu. The histogram is bimodal showing the markedly different quality of coal in the two Kentucky coal fields.

The percentages of Kentucky's coal resources at various levels of potential SO₂ emissions are plotted on the cumulative probability curve in Figure 3. The purpose of this graph is to predict the percent of resources affected by changes in the SO₂ emission standard for compliance coal. Questions about the amounts of coal resources that could meet demands at specified standards for compliance can be answered in part from the probability curve. This curve does not address the important question about the ability of coal preparation to increase the availability of compliance coal from Kentucky's resources (however, it must be kept in mind that the channel samples used to make these estimates are equivalent to a partially cleaned coal).

Table 2 gives the percentages of Kentucky resources either in compliance or noncompliance at selected standards from 2.0 lbs SO₂ per million Btu to 0.6 lb SO₂ per million Btu. These percentages are taken from the cumulative

Figure 1. Coal fields of Kentucky.

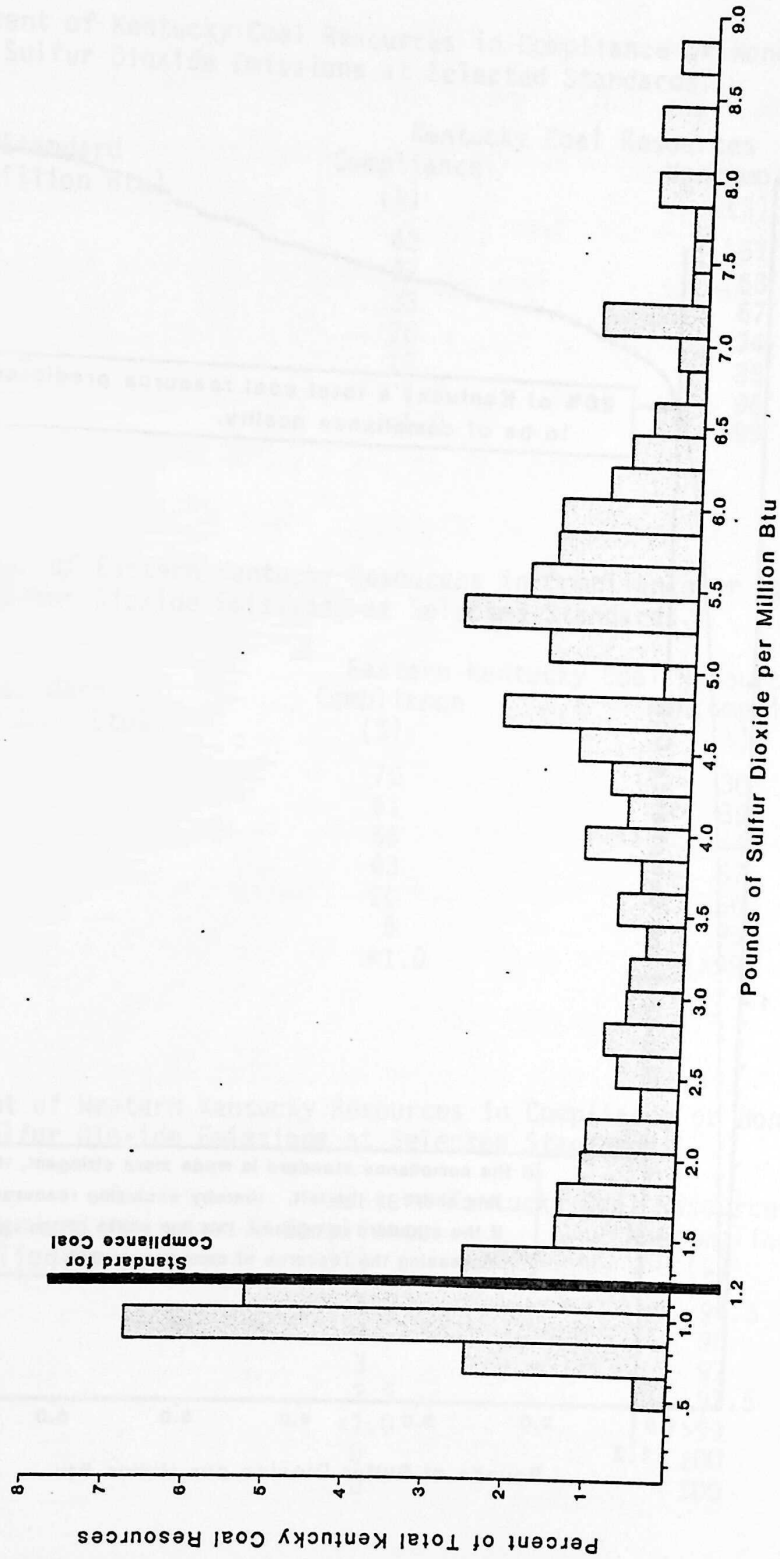


Figure 2. Distribution of total Kentucky coal resources by potential sulfur dioxide emissions.

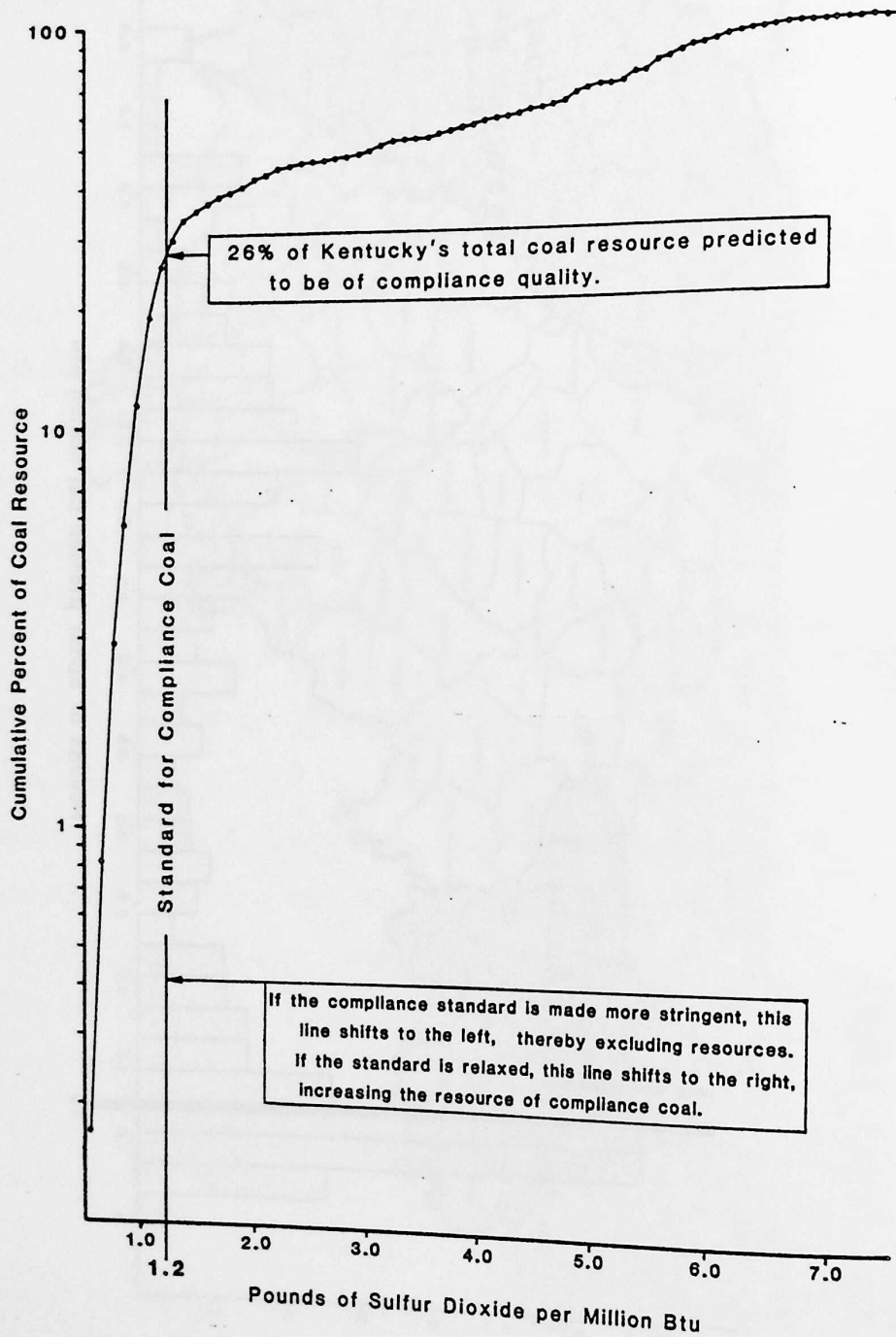


Figure 3. Cumulative probability curve for major eastern and western Kentucky coals with respect to the EPA compliance standard.

Table 2.--Percent of Kentucky Coal Resources in Compliance or Noncompliance for Sulfur Dioxide Emissions at Selected Standards.

Compliance Standard (lbs SO ₂ per Million Btu)	Kentucky Coal Resources	
	Compliance (%)	Noncompliance (%)
2.0		
1.6	43	57
1.4	37	63
1.2	33	67
1.0	26	74
0.8	15	85
0.6	4	96
	<1.0	>99

Table 3.--Percent of Eastern Kentucky Resources in Compliance or Noncompliance for Sulfur Dioxide Emissions at Selected Standards.

Compliance Standard (lbs SO ₂ per Million Btu)	Eastern Kentucky Coal Resources	
	Compliance (%)	Noncompliance (%)
2.0		
1.6	70	30
1.4	61	39
1.2	56	44
1.0	43	57
0.8	20	80
0.6	5	95
	<1.0	>99

Table 4.--Percent of Western Kentucky Resources in Compliance or Noncompliance for Sulfur Dioxide Emissions at Selected Standards.

Compliance Standard (lbs SO ₂ per Million Btu)	Western Kentucky Coal Resources	
	Compliance (%)	Noncompliance (%)
2.0		
1.6	5.2	94.8
1.4	4	96
1.2	3	97
1.0	2.5	97.5
0.8	<1.0	>99
0.6	0	100
	0	100

probability curve (Fig. 3). With a compliance standard of 0.6 lb SO₂ per million Btu, less than 1 percent of Kentucky's coal resources would be in compliance. It should be kept in mind that only a fraction of the coal resources is actually mineable because of legal, cultural, technical, and geological obstacles. Likewise, the use of data from ASTM channel samples tends to reflect coal of better quality than what is actually mined; therefore, estimates of resources in compliance at any standard would be optimistic.

ESTIMATING COMPLIANCE COAL IN THE EASTERN KENTUCKY COAL FIELD

The Eastern Kentucky Coal Field has about 36 billion tons of remaining coal resources (R. Brant, Kentucky Geological Survey, personal commun., Sept. 1982). The frequency distribution for these resources with respect to their potential sulfur dioxide emissions is given in Figure 4. Figure 4 is a composite of data for 11 coal beds: the Richardson, Broas, Peach Orchard, Hazard, Fire Clay, Amburgy, Upper Elkhorn No. 3, Upper Elkhorn No. 2, Upper Elkhorn No. 1, Lower Elkhorn, and Manchester. Histograms showing the frequency distribution for sulfur, Btu, and compliance coal for all the individual coal beds included in Figure 4 are given in Appendix 1.

The histogram in Figure 4 shows that about 43 percent of the resources in eastern Kentucky are in compliance under the EPA emission standard of 1.2 lbs SO₂ per million Btu.

The cumulative probability curve for these data is given in Figure 5. The percentage of eastern Kentucky coal meeting various levels of SO₂ emissions can be determined from the probability curve (Fig. 5) which is used to predict the percent of resources either in compliance or noncompliance given various standards for SO₂ emissions per million Btu.

Table 3 gives the percentages of eastern Kentucky resources either in compliance or noncompliance at selected standards from 2.0 lbs SO₂ per million

Coal Resources (in millions of short tons)	
Coal Bed	Resources
Bross	1088
Peach Orchard	3888
Hazard	2028
Pine Clay	8320
Amberg	3171
Upper Elkhorn #3	6661
Upper Elkhorn #2	4880
Upper Elkhorn #1	2478
Lower Elkhorn	1818
Manchester	2003
TOTAL	31,888
K.G.S. Estimate of Total - 42,888	
Eastern Kentucky Reserves (June 1982)	

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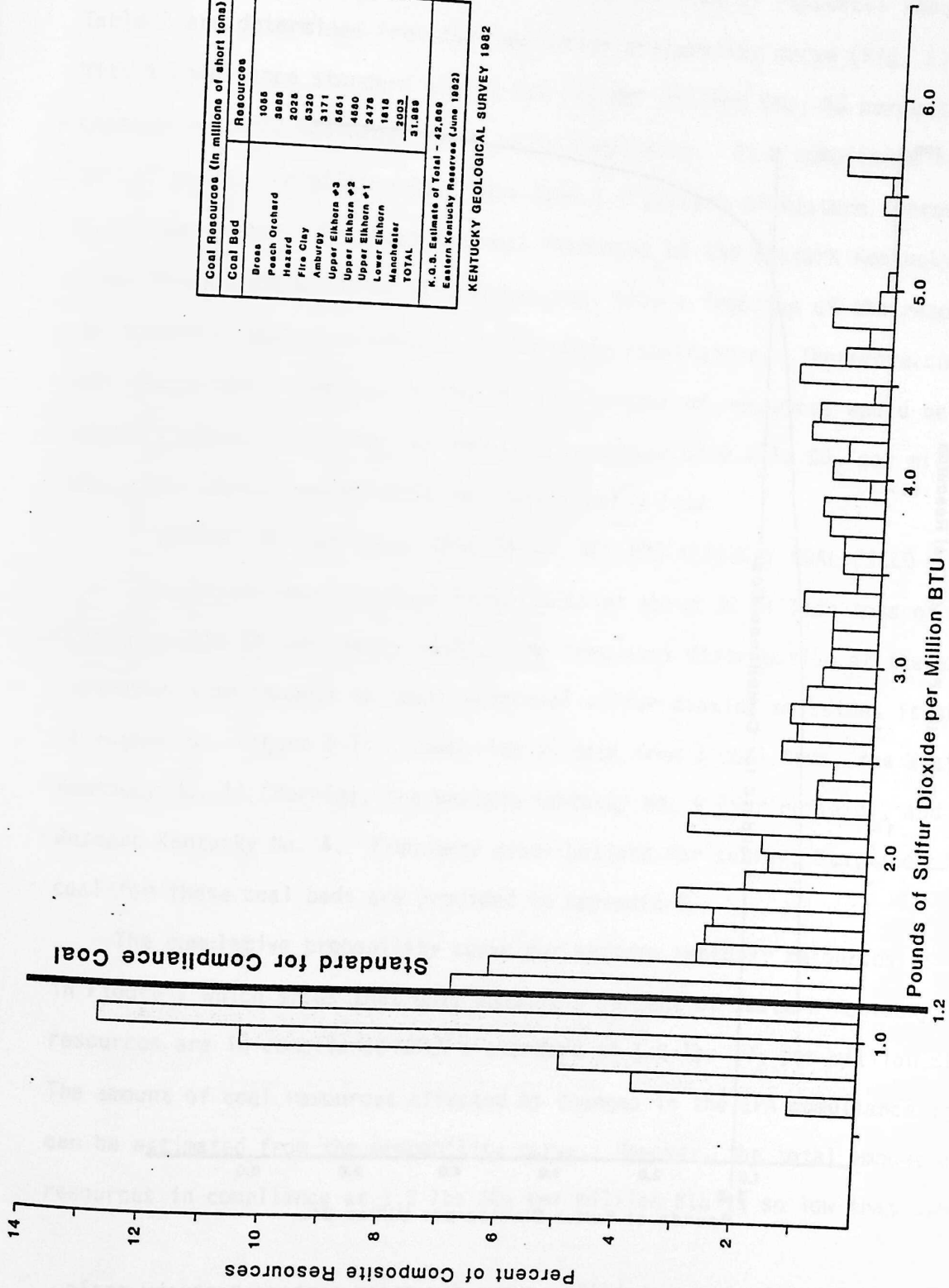


Figure 4. Distribution of major eastern Kentucky coal resources by potential sulfur dioxide emissions.

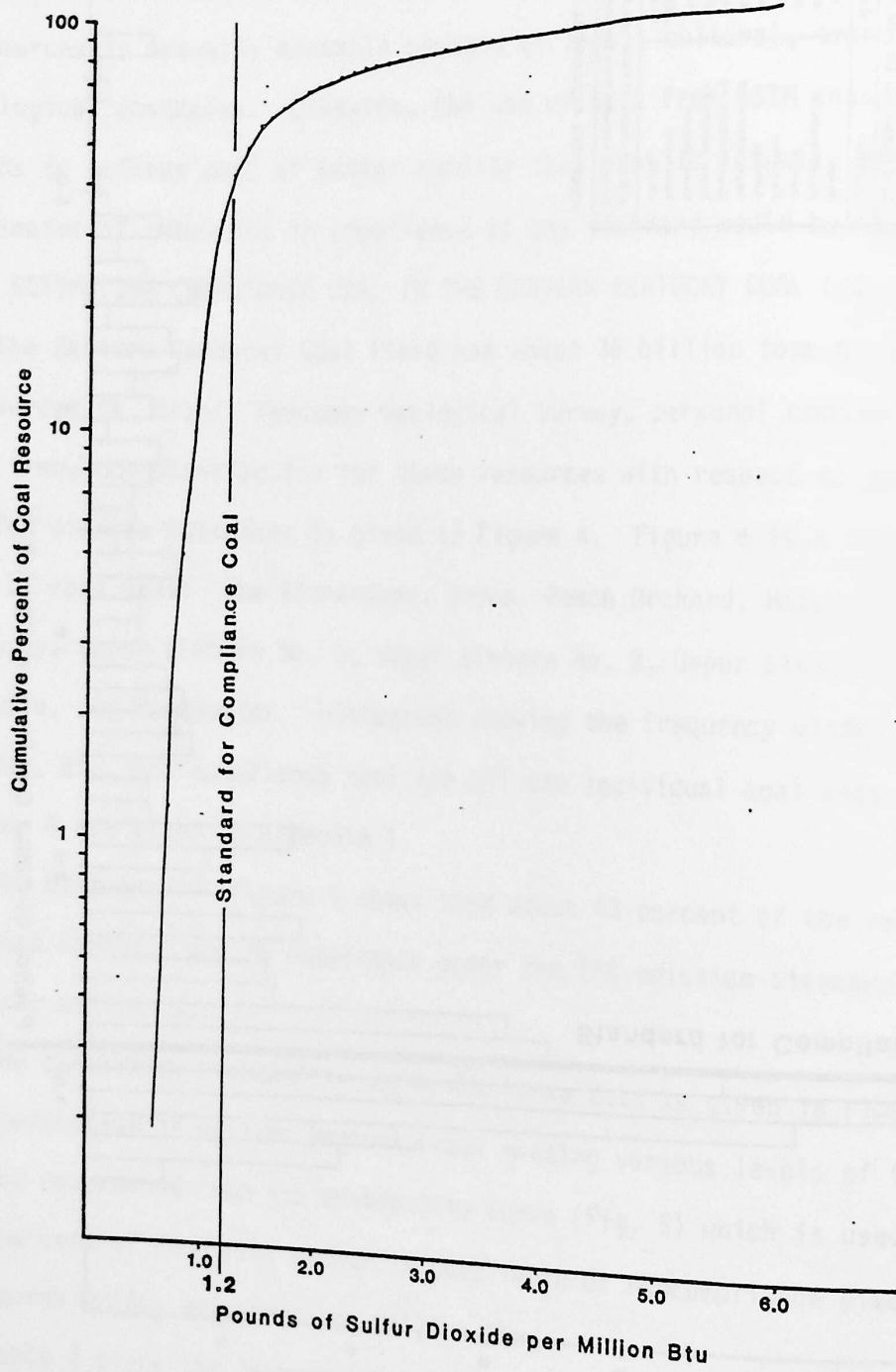


Figure 5. Cumulative probability curve for major eastern Kentucky coals with respect to the EPA compliance standard.

Btu to 0.6 lb SO_2 per million Btu. The percentages of resources shown in Table 3 are determined from the cumulative probability curve (Fig. 5). With a compliance standard of 1.2 lbs SO_2 per million Btu, 43 percent of eastern Kentucky resources would be in compliance. At a compliance standard of 0.6 lb SO_2 per million Btu, less than 1.0 percent of eastern Kentucky coal is in compliance. Although the coal resources of the Eastern Kentucky Coal Field are estimated to be 36 billion tons, only a fraction of the resources are mineable because of natural and manmade constraints. Therefore, one should not assume that 1 percent of the 36 billion tons of resources would be available compliance coal under an emissions standard of 0.6 lb SO_2 per million Btu. The actual amount would be significantly less.

ESTIMATING COMPLIANCE COAL IN THE WESTERN KENTUCKY COAL FIELD

The Western Kentucky Coal Field contains about 39 billion tons of remaining resources (Smith and Brant, 1980). The frequency distribution of these resources with respect to their potential sulfur dioxide emissions is shown in Figure 6. Figure 6 is a composite of data from 3 coal beds, the Western Kentucky No. 11 (Herrin), the Western Kentucky No. 9 (Springfield), and the Western Kentucky No. 4. Frequency distributions for sulfur, Btu, and compliance coal for these coal beds are provided in Appendix 2.

The cumulative probability curve for western Kentucky resources is given in Figure 7 which shows that only about 2.5 percent of western Kentucky resources are in compliance with a standard of 1.2 lbs SO_2 per million Btu. The amount of coal resources affected by changes in the EPA compliance standard can be estimated from the probability curve. However, the total amount of resources in compliance at 1.2 lbs SO_2 per million Btu is so low that almost

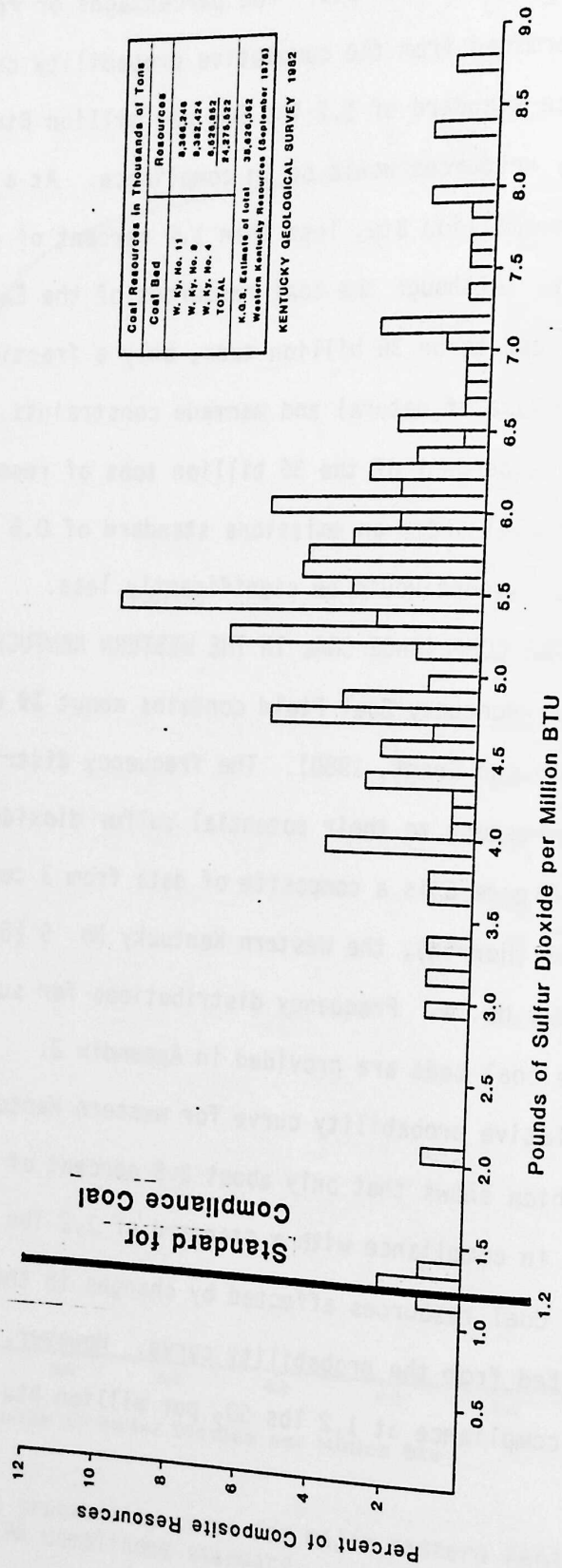


Figure 6. Distribution of major western Kentucky coal resources by potential sulfur dioxide emissions.

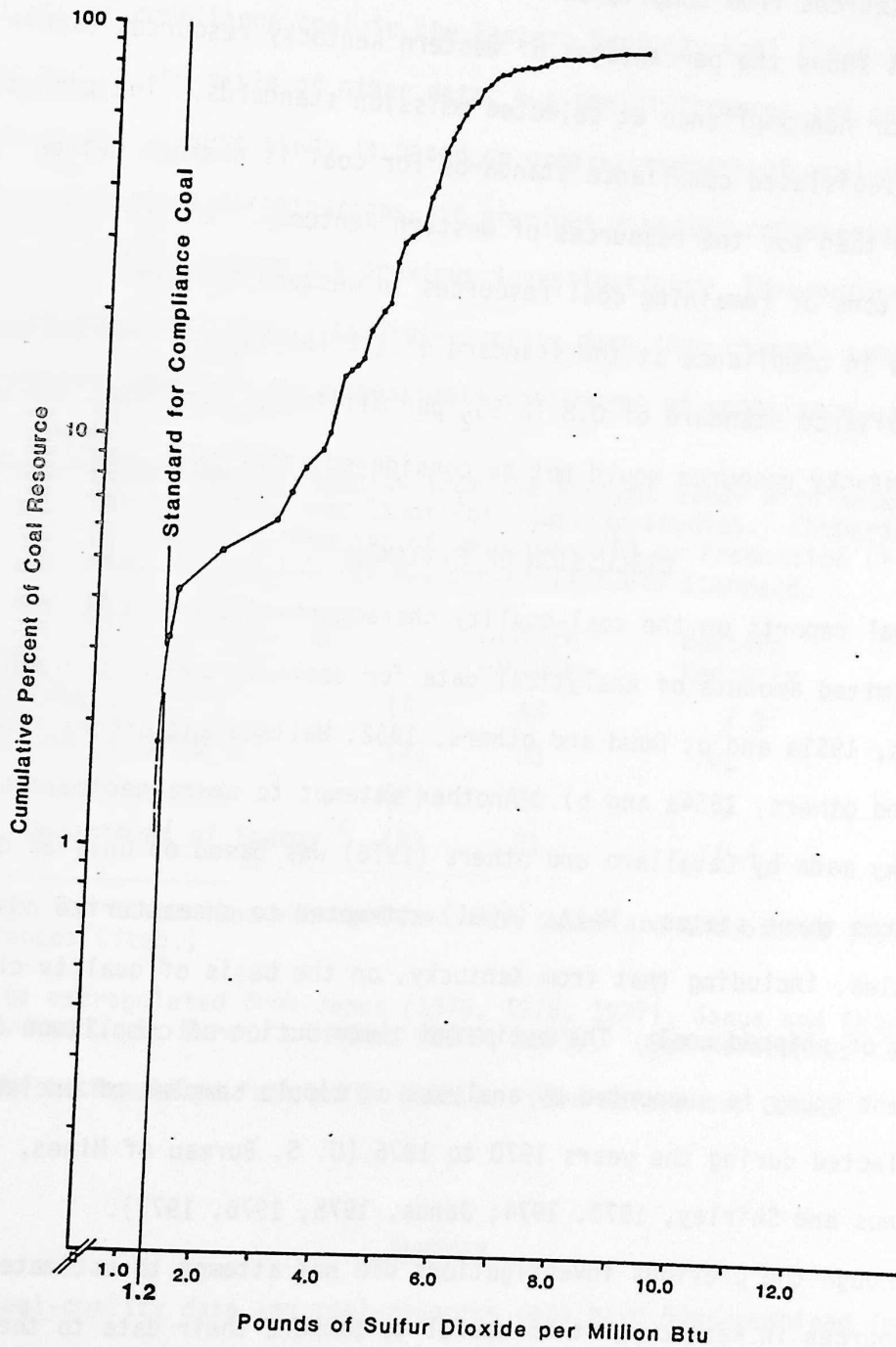


Figure 7. Cumulative probability curve for major western Kentucky coals with respect to the EPA compliance standard.

any decrease in the amount of allowable SO_2 would eliminate all western Kentucky resources from compliance.

Table 4 shows the percentages of western Kentucky resources either in compliance or noncompliance at selected emission standards. The potential effects of legislated compliance standards for coal is nowhere better illustrated than for the resources of western Kentucky. Of the approximately 39 billion tons of remaining coal resources in western Kentucky, only 2.5 percent are in compliance at the standard of 1.2 lbs SO_2 per million Btu. With a compliance standard of 0.8 lb SO_2 per million Btu or less, the entire western Kentucky resource would not be considered compliance coal.

DISCUSSION OF FINDINGS

Several reports on the coal-quality characteristics of coals in Kentucky contain limited amounts of analytical data for coals in specific areas (Dowd and others, 1951a and b; Dowd and others, 1952; Wallace and others, 1953; Wallace and others, 1954a and b). Another attempt to characterize coal resources in Kentucky made by Cavallaro and others (1976) was based on only 35 coal-bed samples from three states. Watts (1981) attempted to characterize coal used by utilities, including that from Kentucky, on the basis of quality characteristics of shipped coal. The estimated distribution of compliance coal in the present study is supported by analyses of tipple samples of uncleaned coal collected during the years 1970 to 1976 (U. S. Bureau of Mines, 1971, 1972; Janus and Shirley, 1973, 1974; Janus, 1975, 1976, 1977).

Although the previous investigations did not attempt to estimate compliance coal resources in Kentucky, it is useful to compare their data to the results of the present study. Certain assumptions and interpretations have been applied

to the data from these sources in order to make this comparison. Table 5 gives the results of the comparison. The present study predicts greater amounts of compliance coal in the Eastern Kentucky Coal Field than would be expected on the basis of other data, but the differences are not great. Because the present study is based on greater numbers of analyses with wider and more uniform distributions, it provides a better representation of the coals in Kentucky than the previous investigations. The sources of data in the present and previous studies--quality data from channel samples and coal deliveries--may tend to overestimate the amount of compliance coal.

Table 5.--Comparison of Results from the Present Study with Results Extrapolated from Other Coal-Quality Studies. Comparisons are Based on Percent of Resources (R) or Production (P) Meeting the 1.2 lbs SO₂ per million Btu standard.

Source		Eastern Kentucky	Western Kentucky	Entire State
Present Study	(R)	43	2.5	26
Cavallaro and Others ^a	(R)	35	<1	--
U. S. Bureau of Mines ^b	(P)	34	0	--
U. S. Department of Energy ^c	(P)	33	0.4	24

^a Data for comparison extrapolated from Cavallaro and others (1976). (See References Cited.)

^b Data extrapolated from Janus (1975, 1976, 1977), Janus and Shirley (1973, 1974), and U. S. Bureau of Mines (1971, 1972). (See References Cited.)

^c Data extrapolated from Watts (1981). (See References Cited.)

SUMMARY

Coal-quality data and coal-resource data have been combined in this report to estimate the maximum resources of compliance coal for selected sulfur dioxide emission standards. At the EPA standard of 1.2 lbs SO₂ per million Btu, the percentages of coal resources in compliance in Kentucky are:

43 percent for the Eastern Kentucky Coal Field, 2.5 percent for the Western Kentucky Coal Field, and 26 percent for Kentucky overall. If the compliance standard is reduced to 0.6 lb SO₂ per million Btu, the percentage of compliance resources in Kentucky will drop significantly to less than 1 percent for the Eastern Kentucky Coal Field and zero for the Western Kentucky Coal Field.

One of the most important findings of this study is the recognition that any reduction in the amount of allowable sulfur dioxide from 1.2 lbs SO₂ per million Btu would eliminate a large percentage of Kentucky's coal resources from compliance. The curves of the cumulative probability plots for Kentucky's combined resources and for the Eastern Kentucky Coal Field (Figs. 3 and 5) are such that the current standard of 1.2 lbs SO₂ per million Btu is at the points of maximum change in slope. Therefore, even a small decrease in the emission standard impacts a large percentage of coal resources in Kentucky.

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The coal resources data were provided by Russell A. Brant, Principal Investigator for the Eastern Kentucky Coal Resources Project.

Special mention goes to Paul Reeves who compiled the histograms and performed the statistical work. He also drafted the illustrations. Mr. Kim Blackburn assisted in compiling the analytical data.

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APPENDIX 1

HISTOGRAMS SHOWING DISTRIBUTION OF COAL RESOURCES IN RELATION
TO POTENTIAL SULFUR DIOXIDE EMISSIONS AND SULFUR AND Btu
CONTENT FOR ELEVEN PRINCIPAL EASTERN KENTUCKY COALS

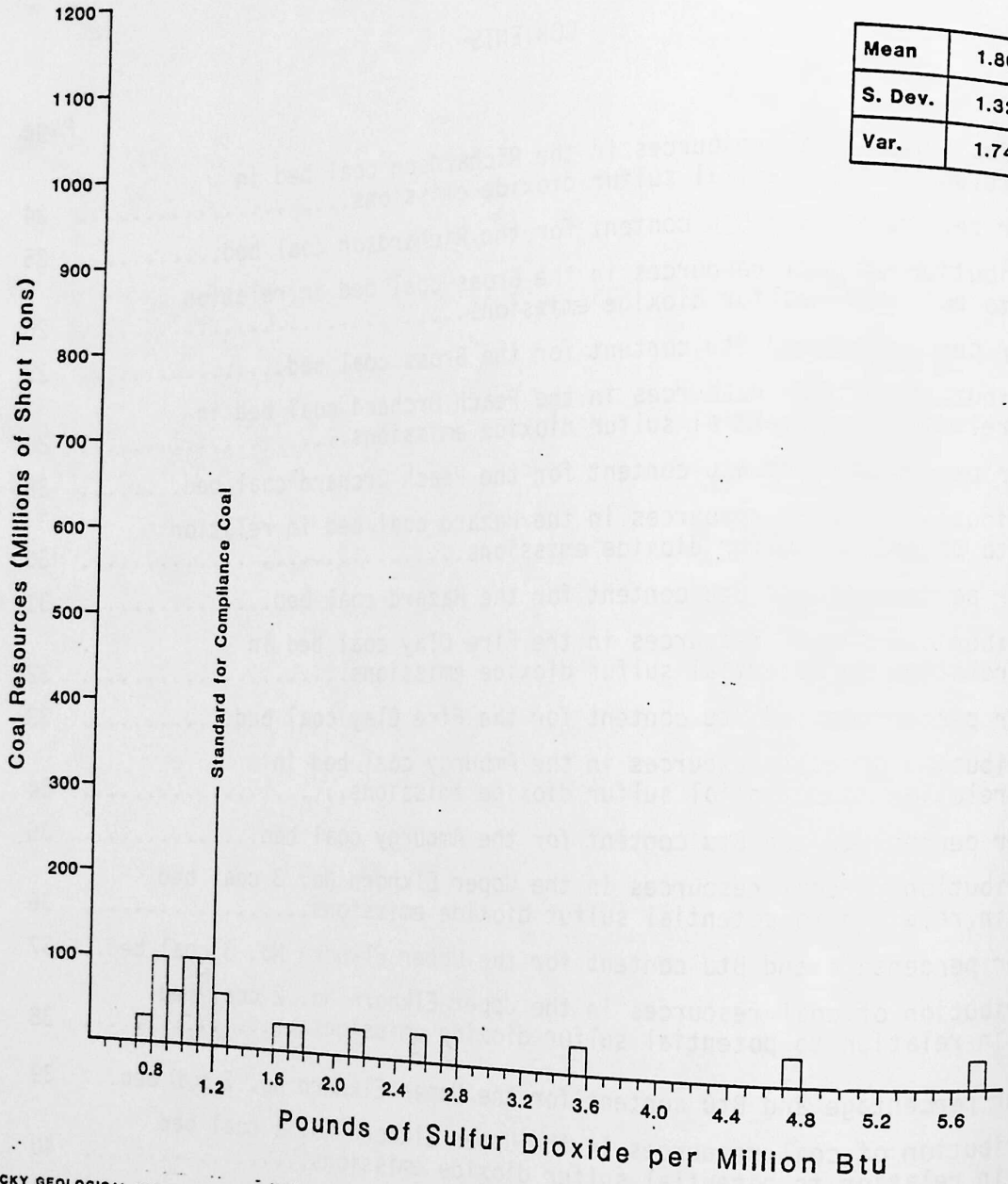
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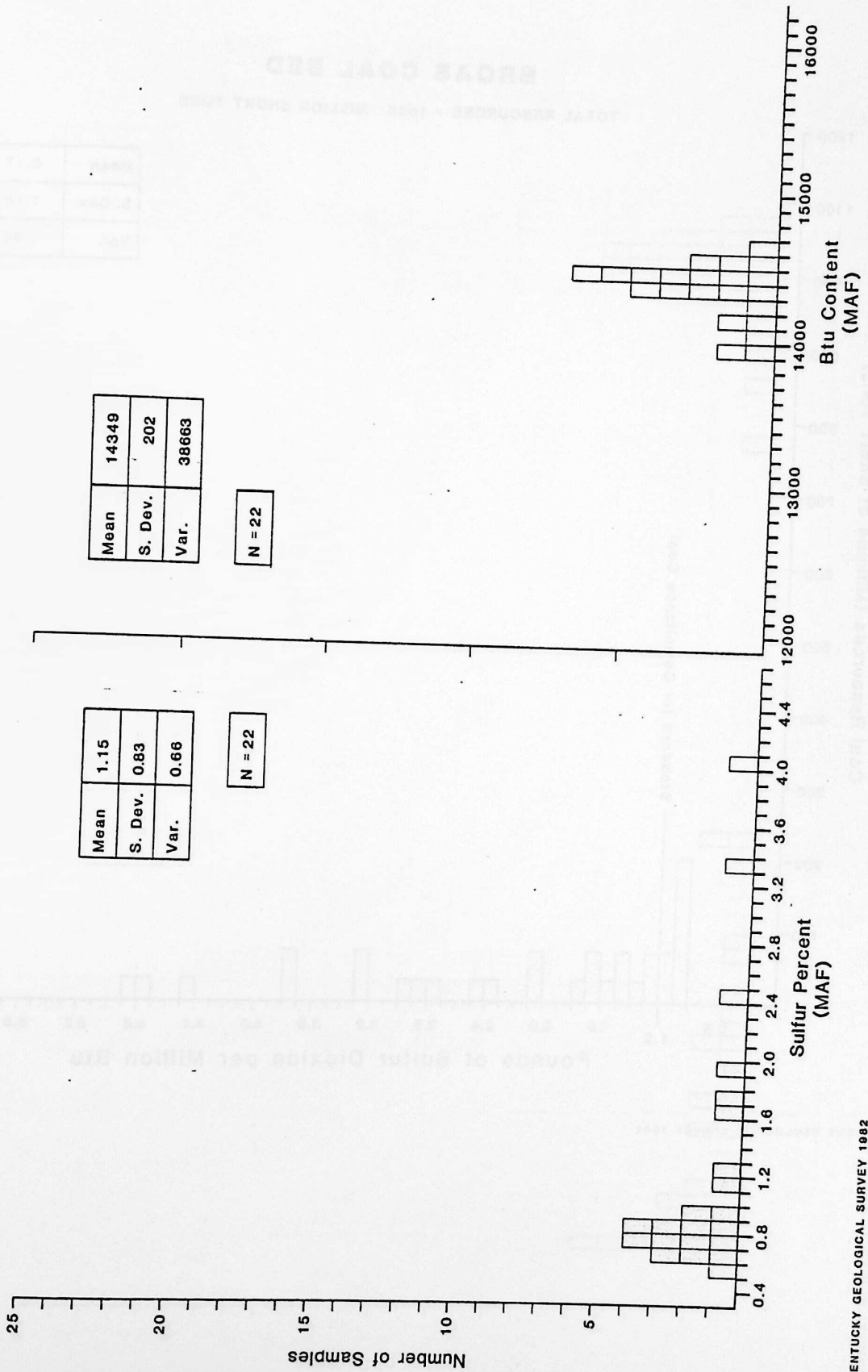
RICHARDSON COAL BED

TOTAL RESOURCES - 672 MILLION SHORT TONS

Mean	1.80
S. Dev.	1.32
Var.	1.74



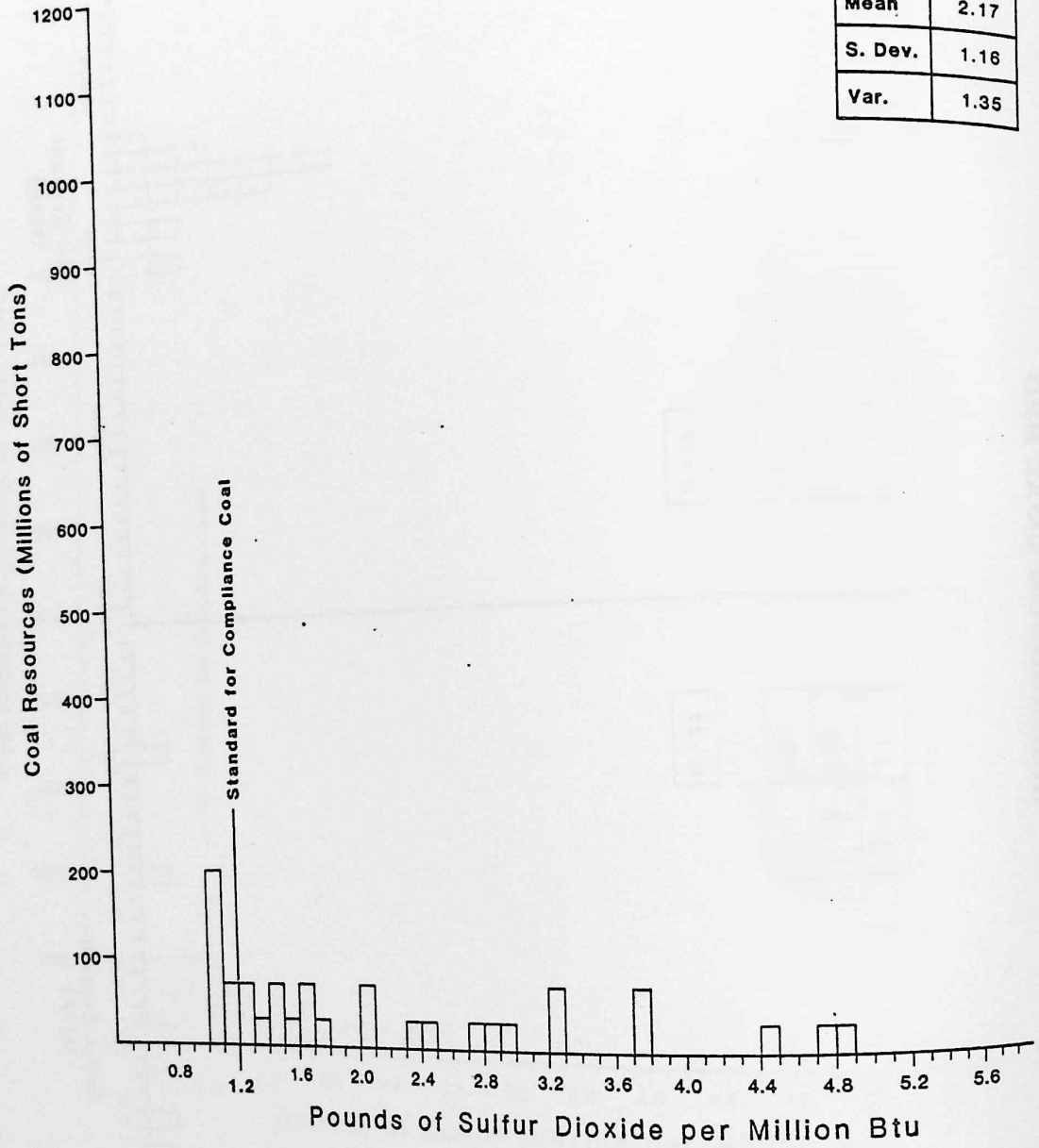
RICHARDSON COAL BED



BROAS COAL BED

TOTAL RESOURCES - 1055 MILLION SHORT TONS

Mean	2.17
S. Dev.	1.16
Var.	1.35



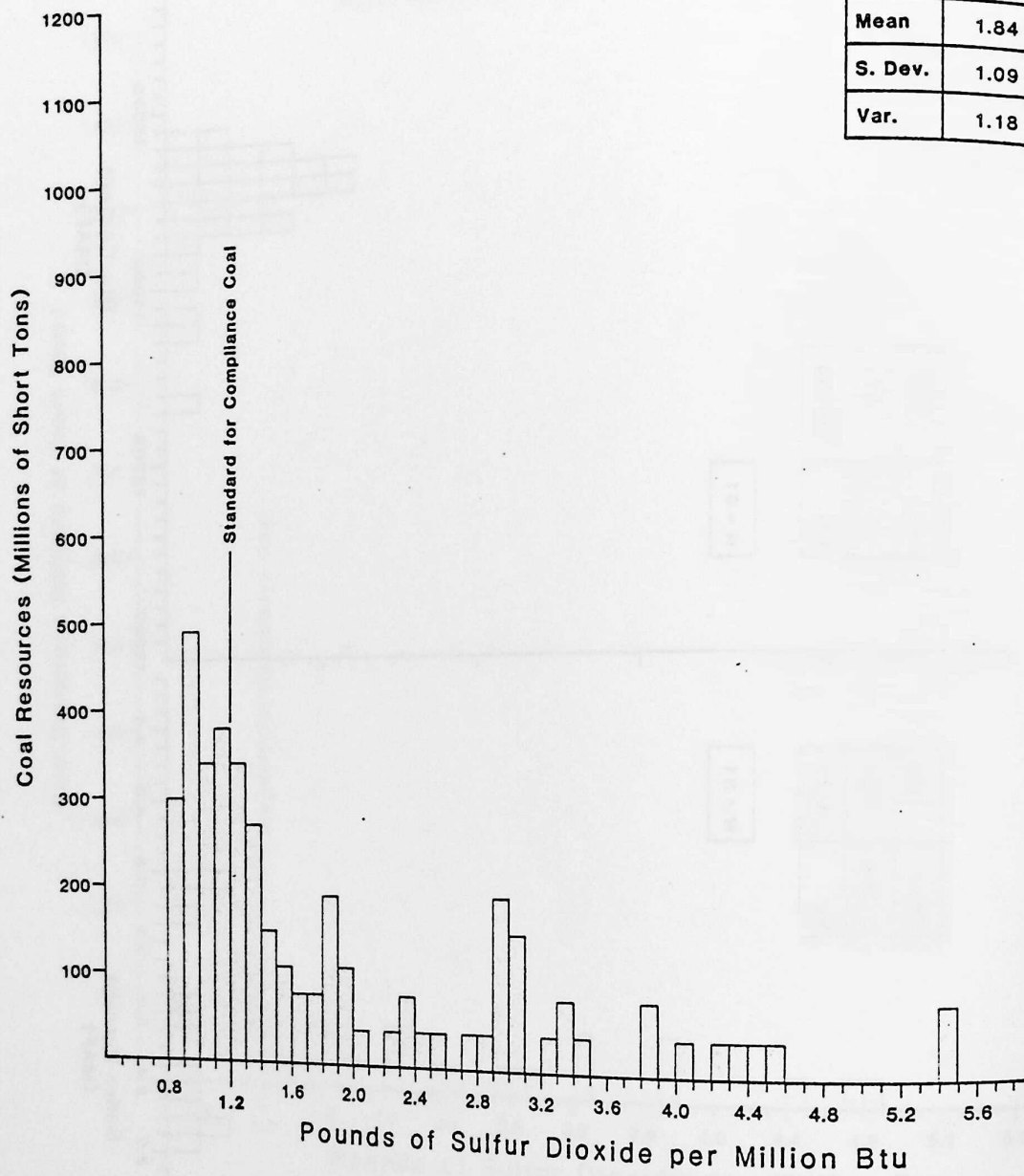
BROAS COAL BED



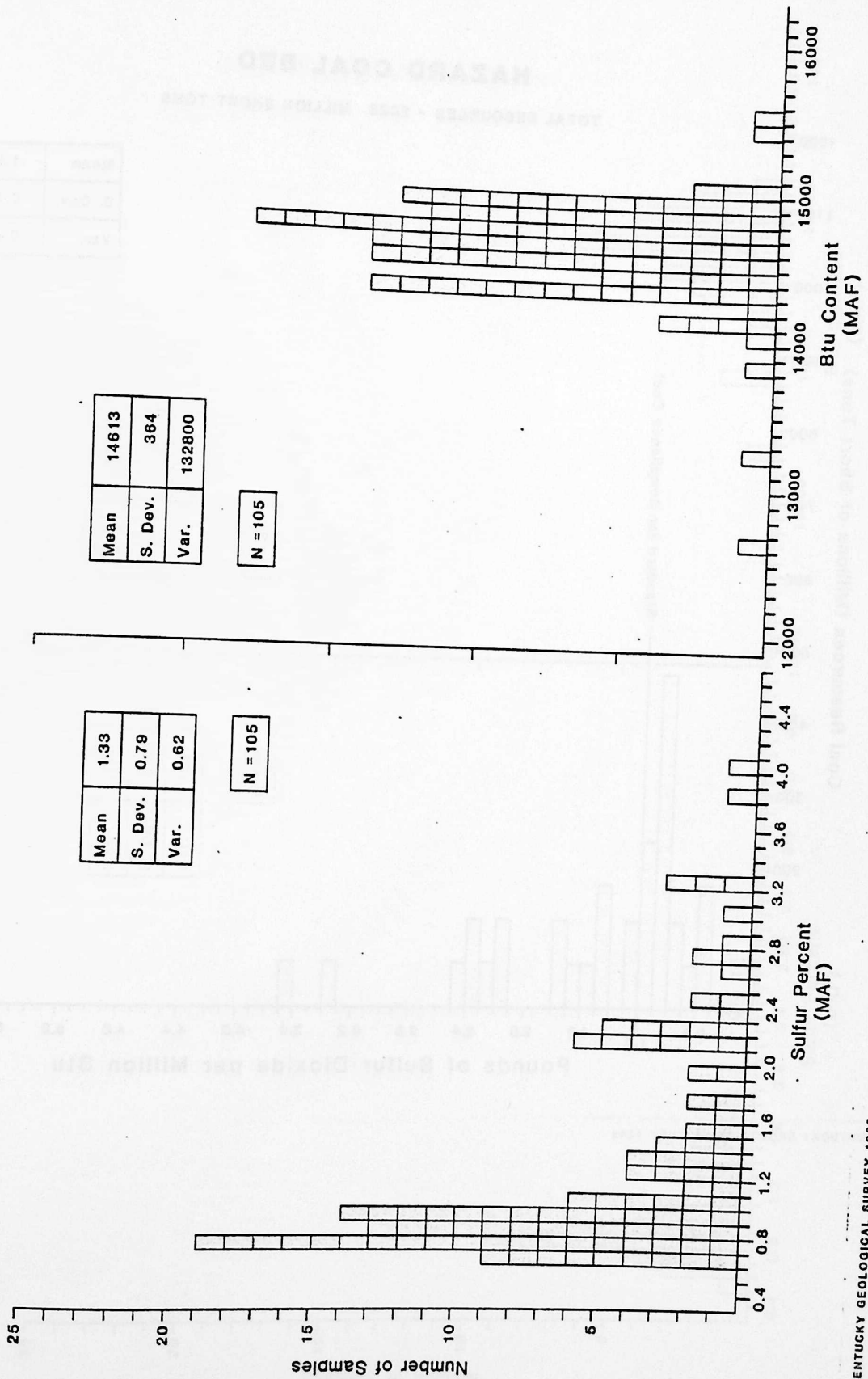
PEACH ORCHARD COAL BED

TOTAL RESOURCES - 3985 MILLION SHORT TONS

Mean	1.84
S. Dev.	1.09
Var.	1.18

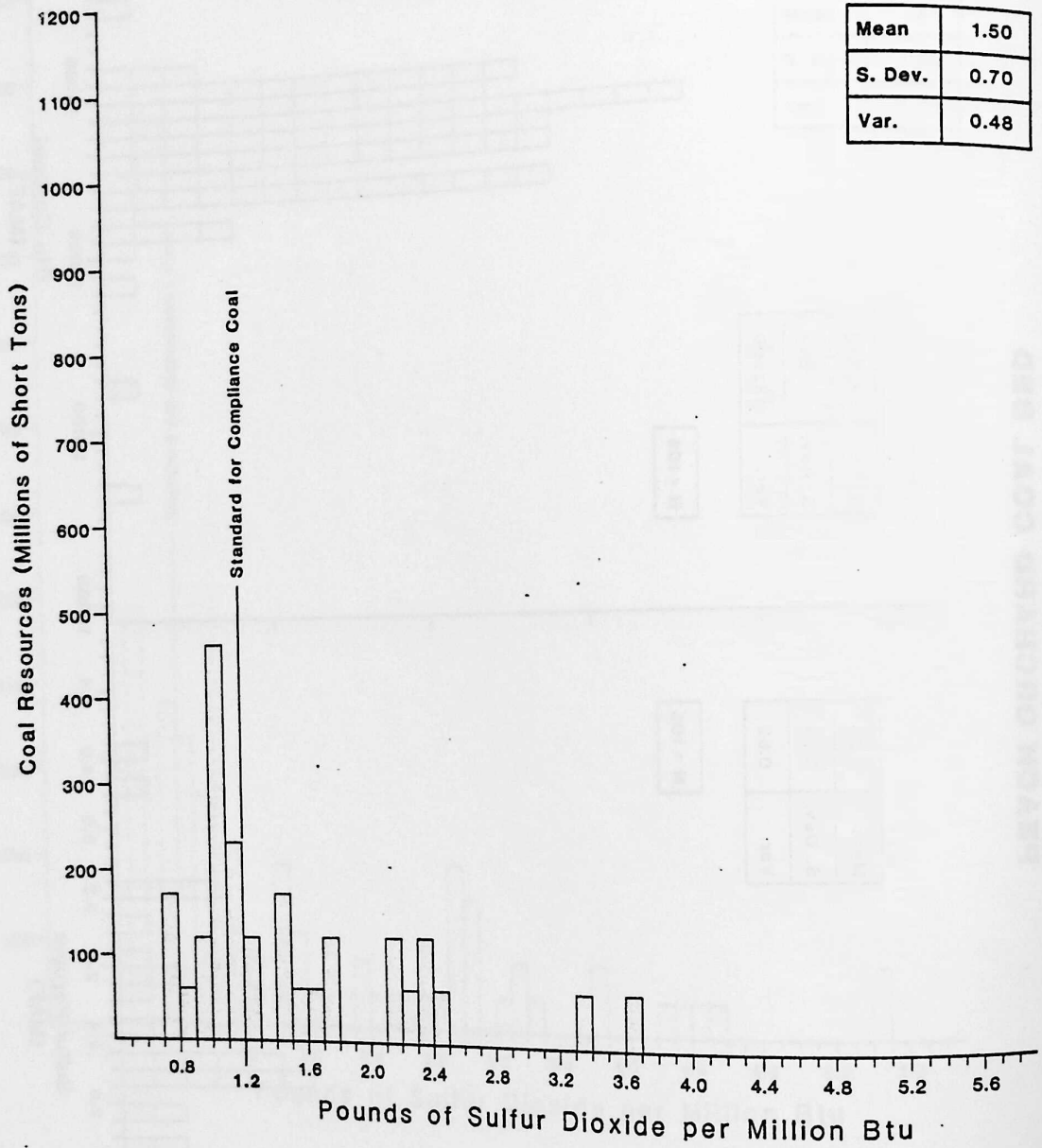


PEACH ORCHARD COAL BED

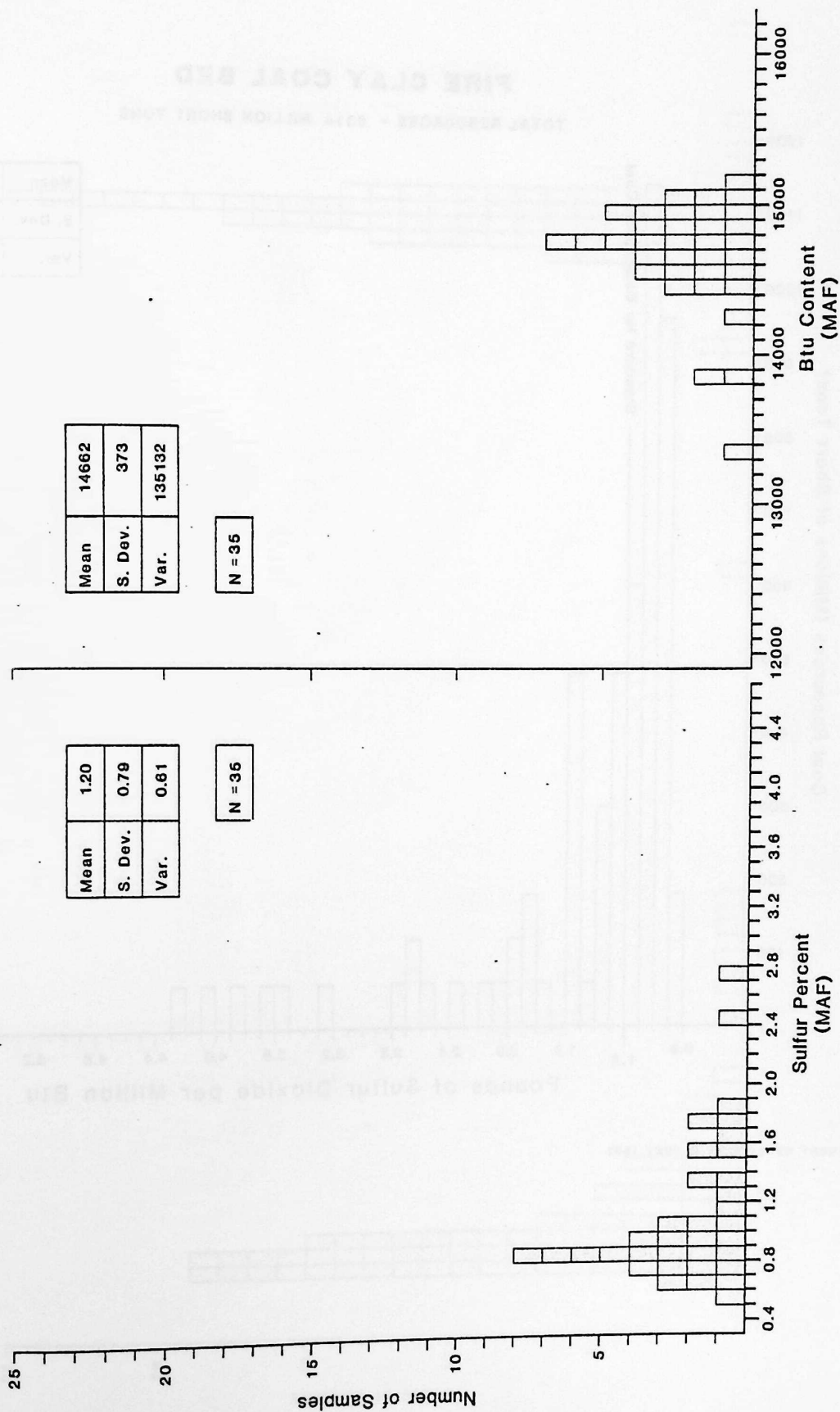


HAZARD COAL BED

TOTAL RESOURCES - 2023 MILLION SHORT TONS

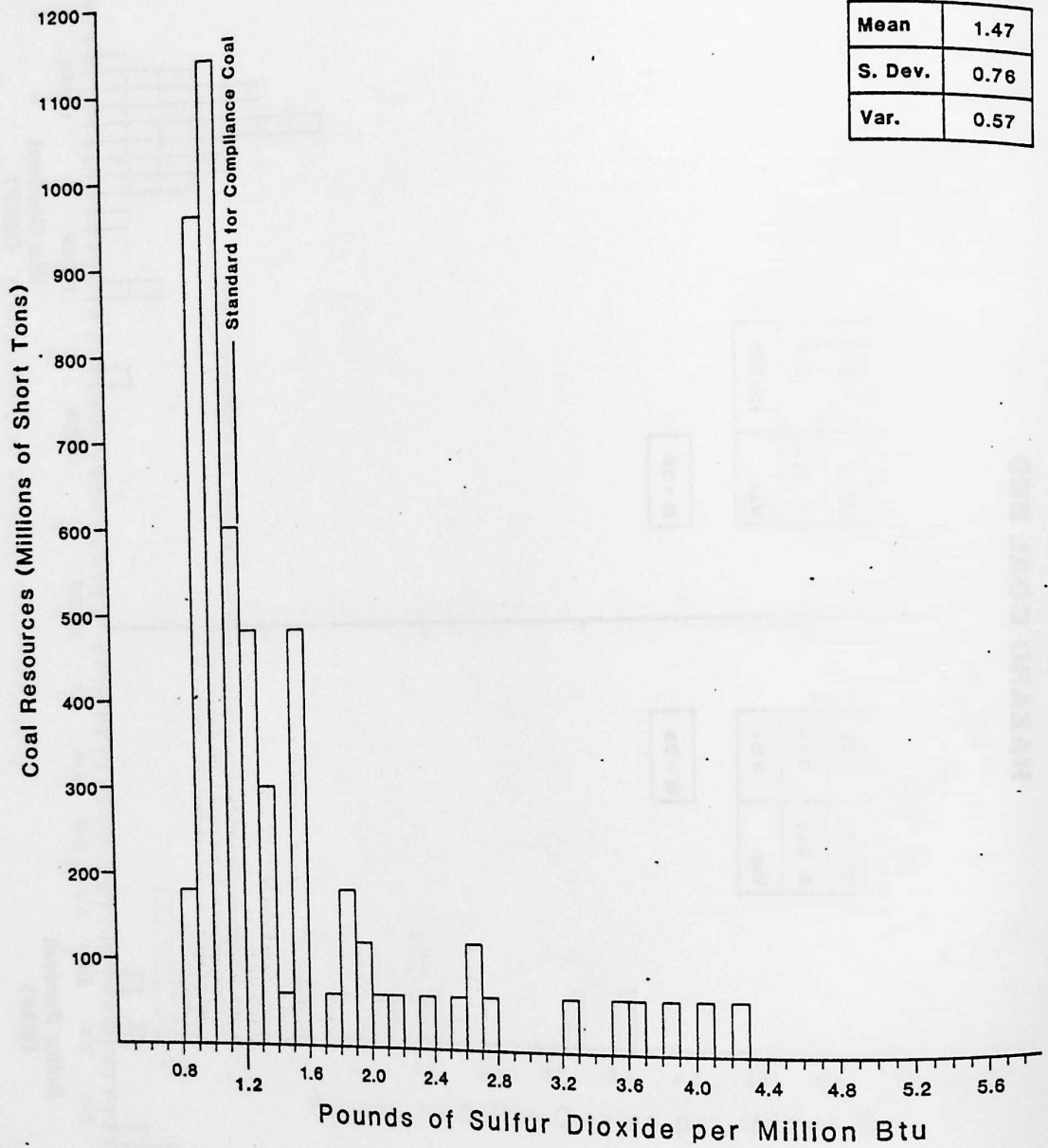


HAZARD COAL BED

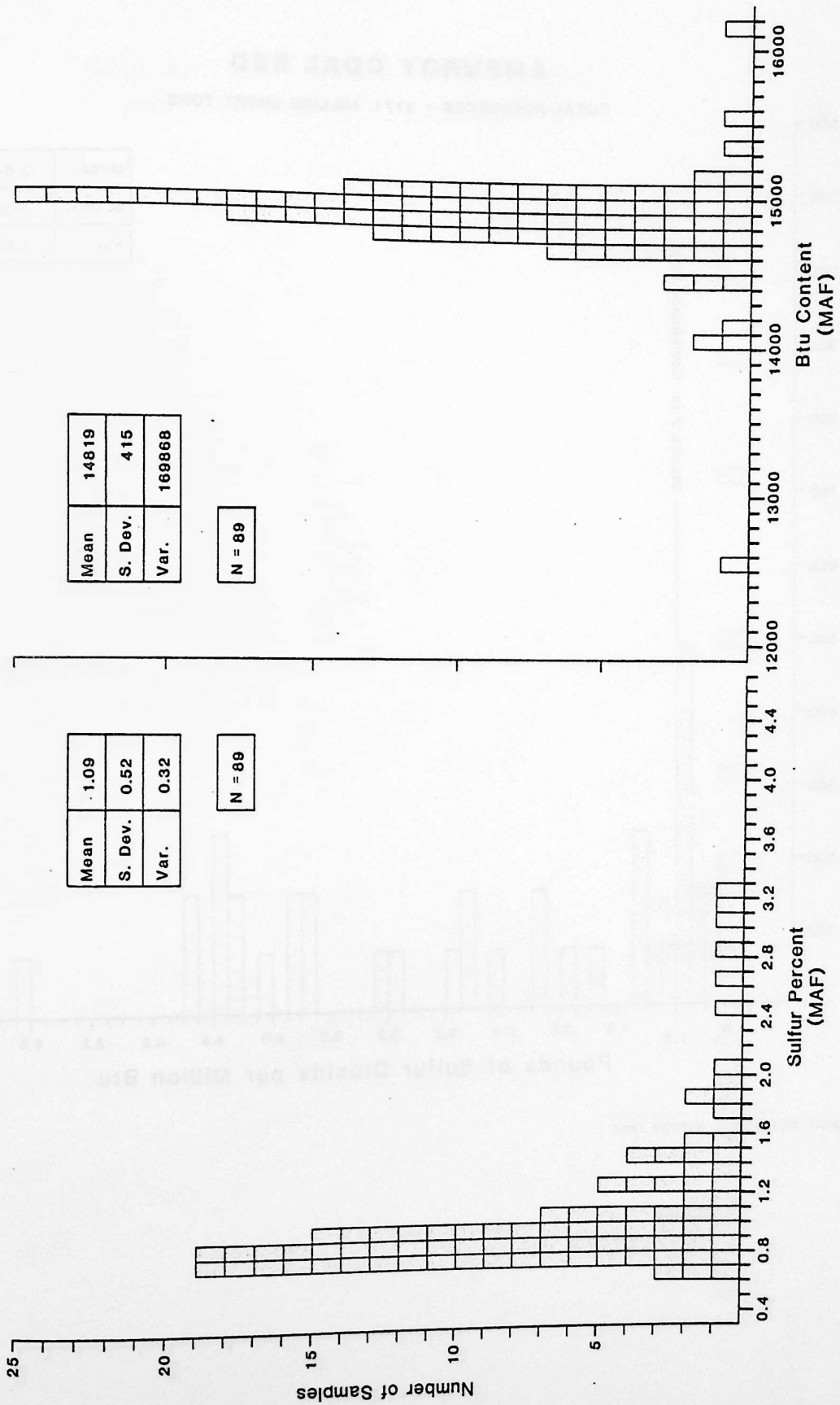


FIRE CLAY COAL BED

TOTAL RESOURCES - 5314 MILLION SHORT TONS



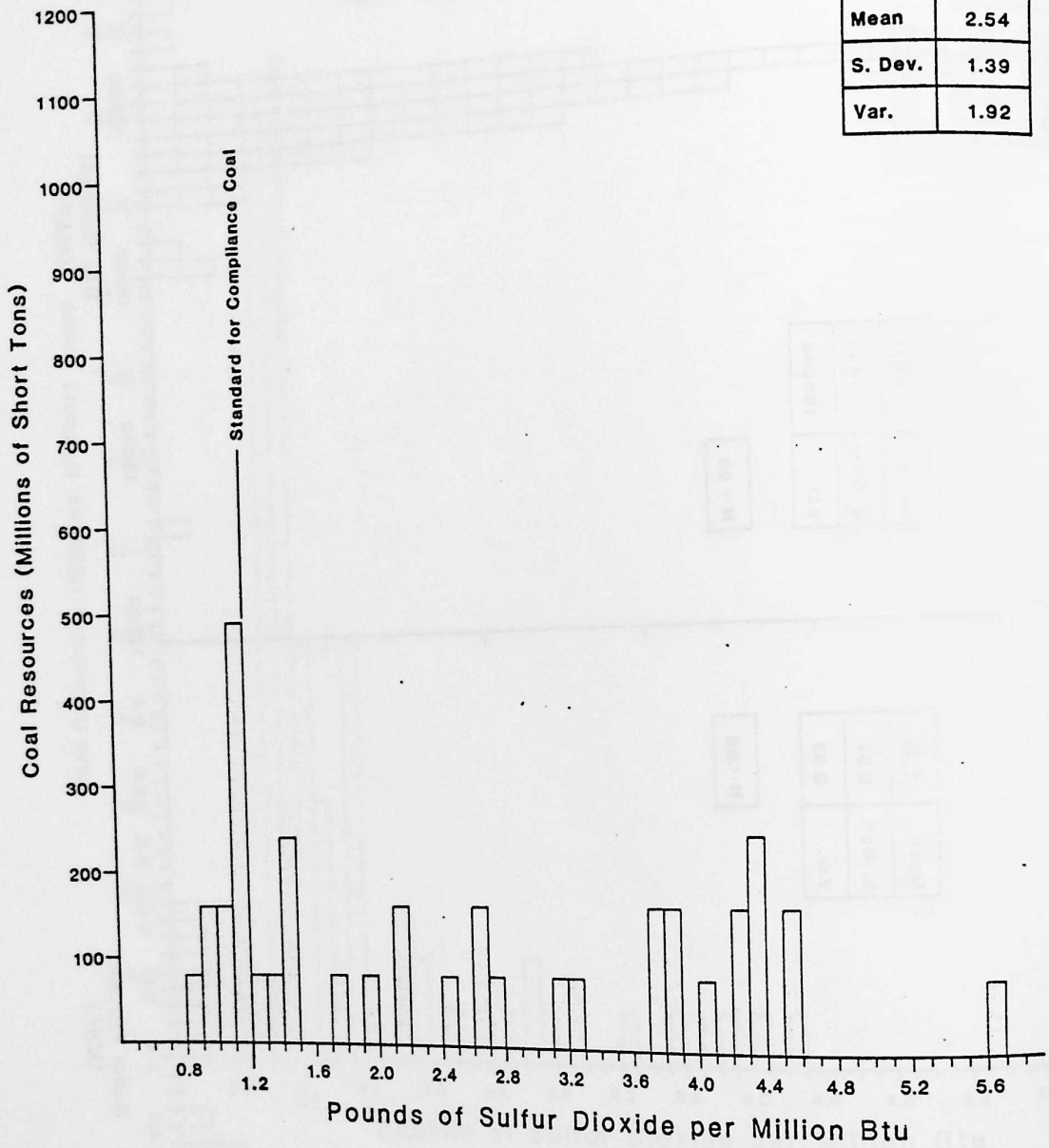
FIRE CLAY COAL BED



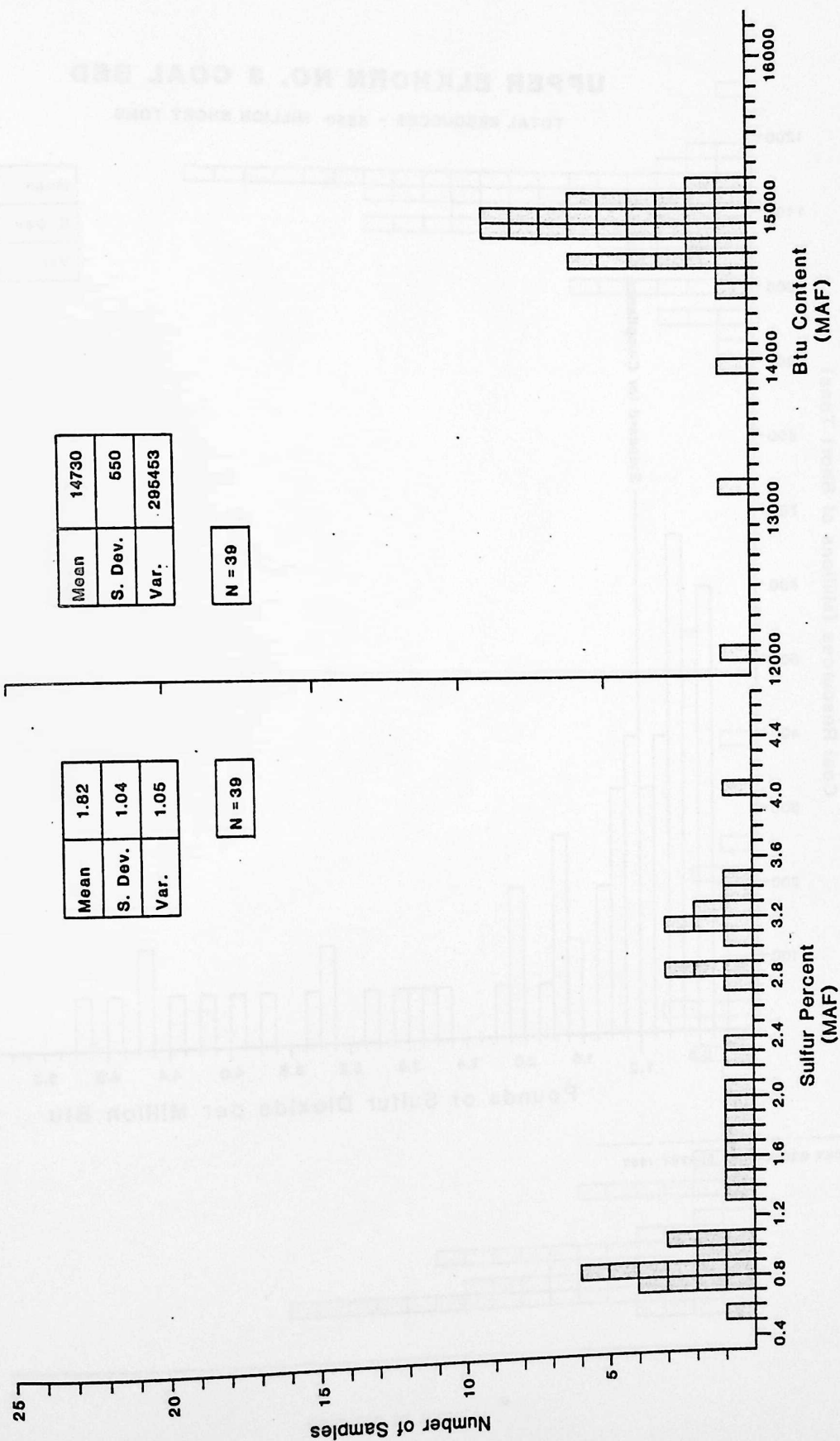
AMBURGY COAL BED

TOTAL RESOURCES - 3171 MILLION SHORT TONS

Mean	2.54
S. Dev.	1.39
Var.	1.92



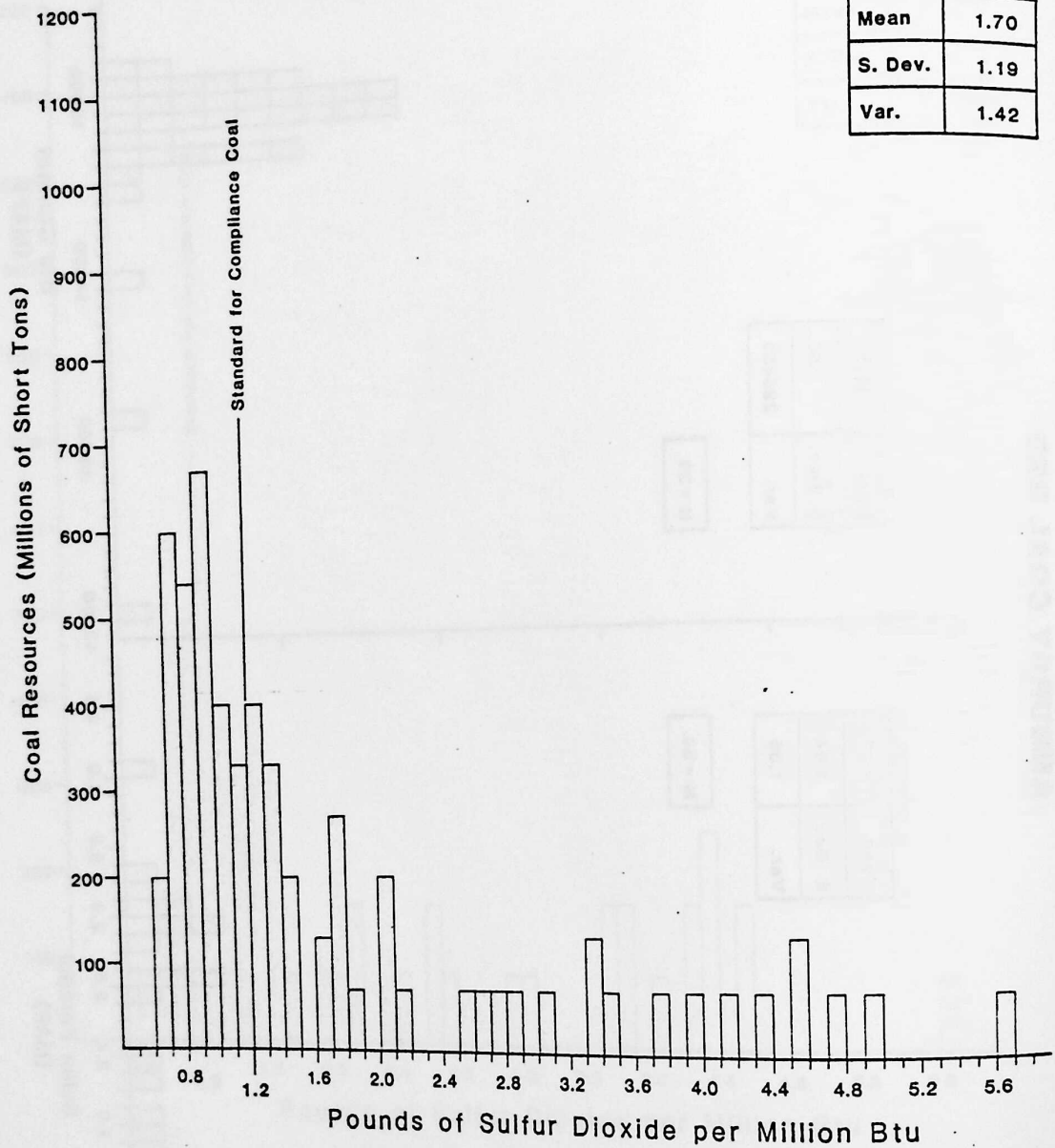
AMBURGY COAL BED



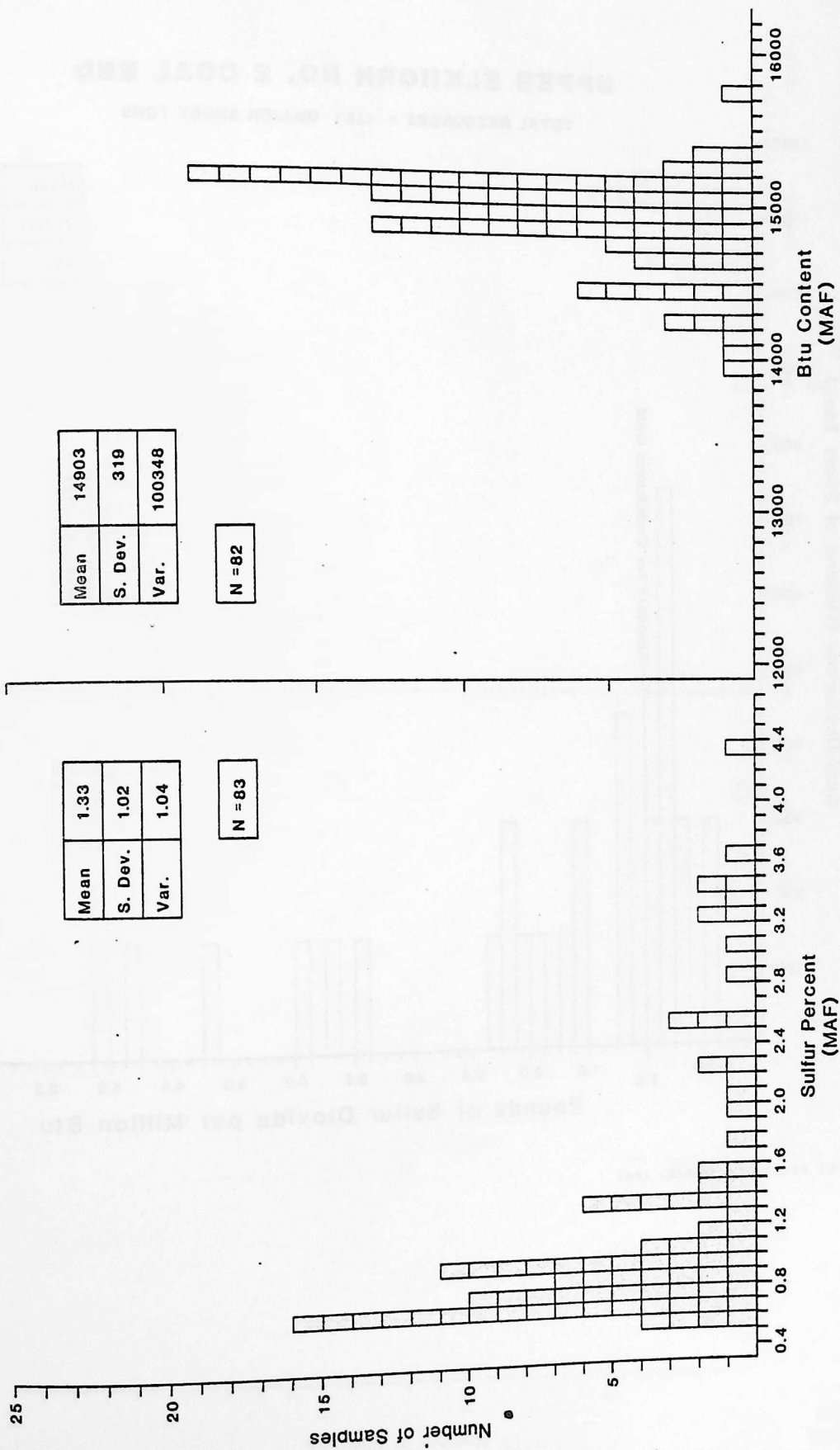
UPPER ELKHORN NO. 3 COAL BED

TOTAL RESOURCES - 5550 MILLION SHORT TONS

Mean	1.70
S. Dev.	1.19
Var.	1.42



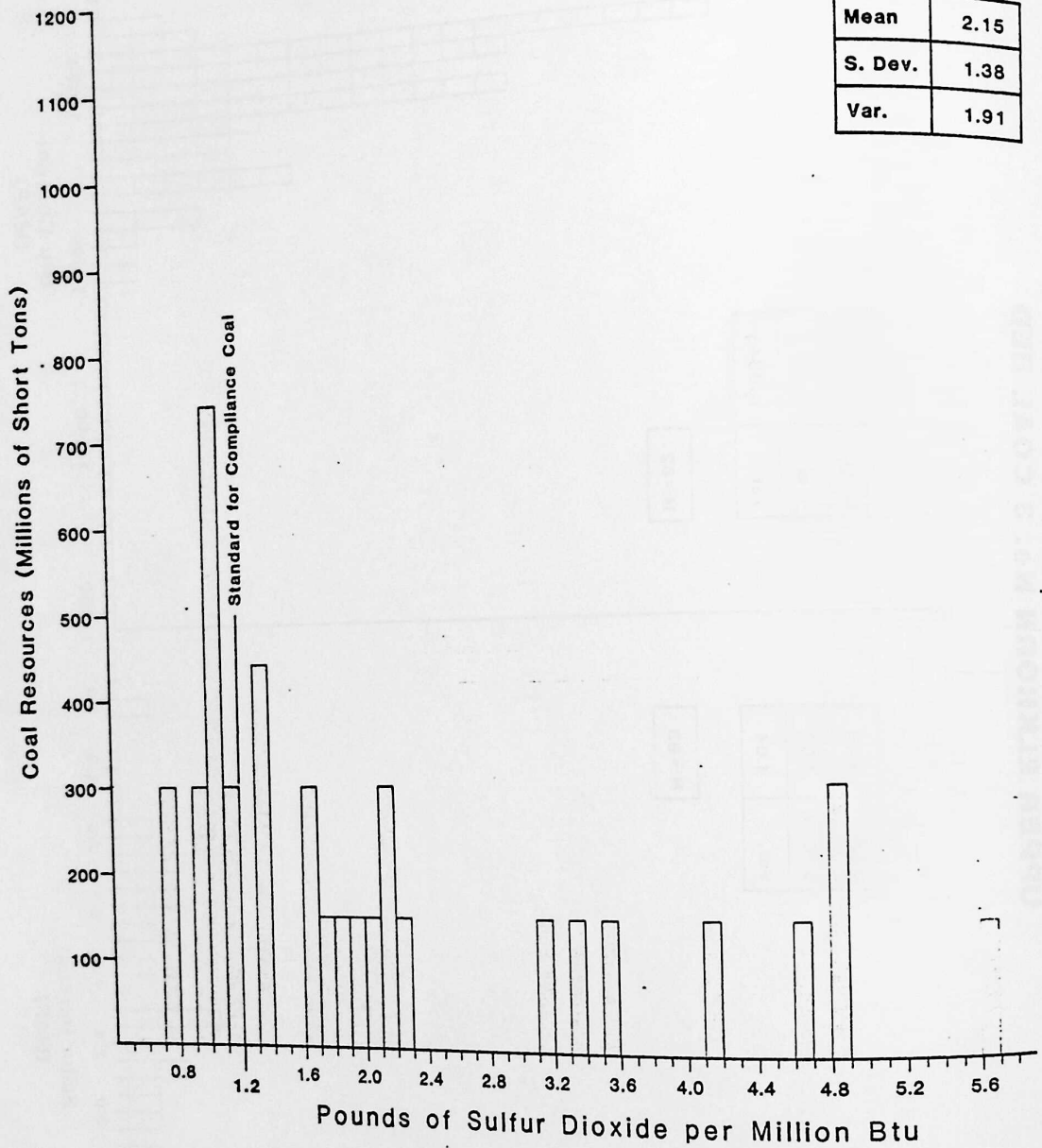
UPPER ELKHORN No. 3 COAL BED



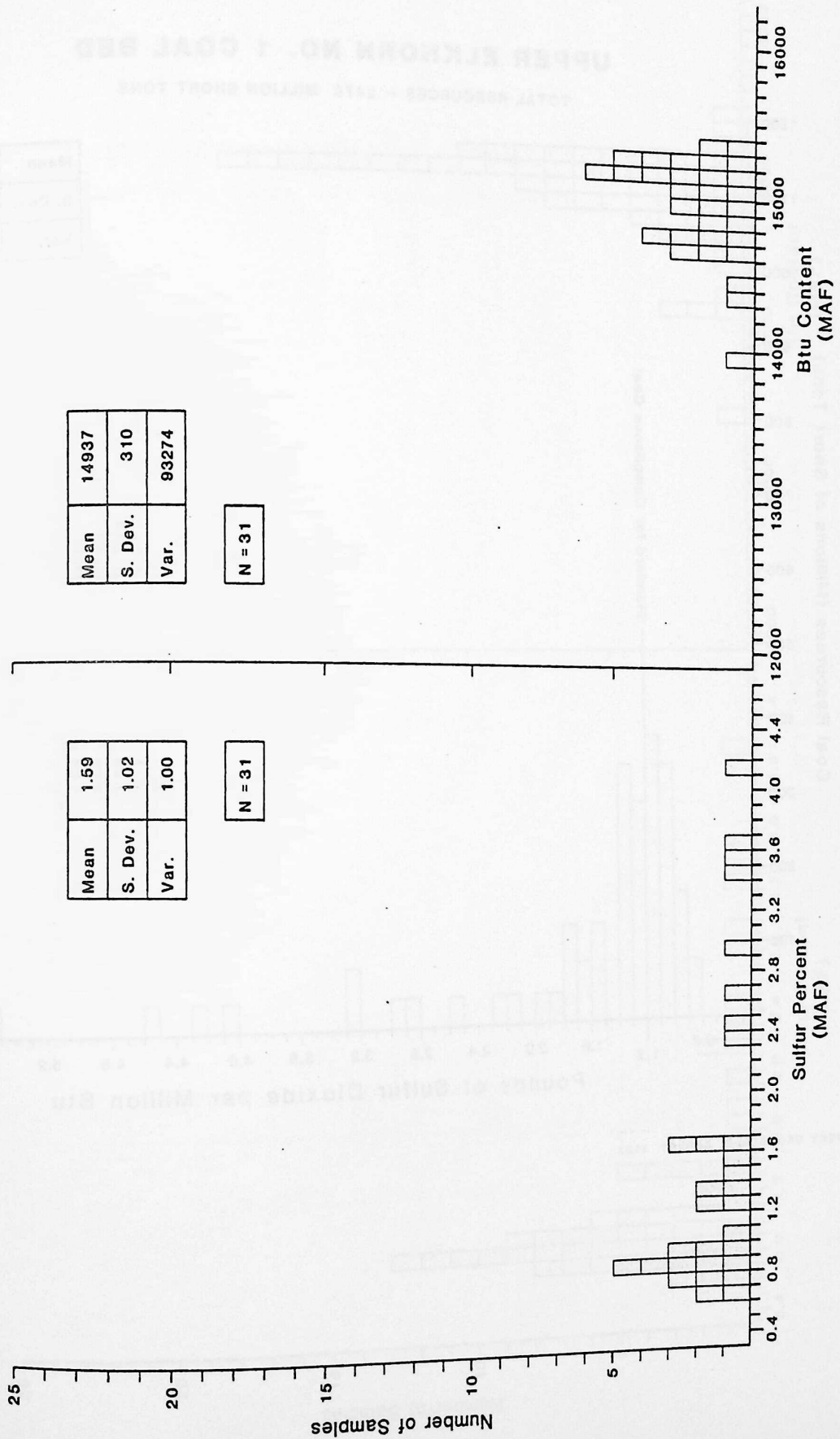
UPPER ELKHORN NO. 2 COAL BED

TOTAL RESOURCES - 4581 MILLION SHORT TONS

Mean	2.15
S. Dev.	1.38
Var.	1.91

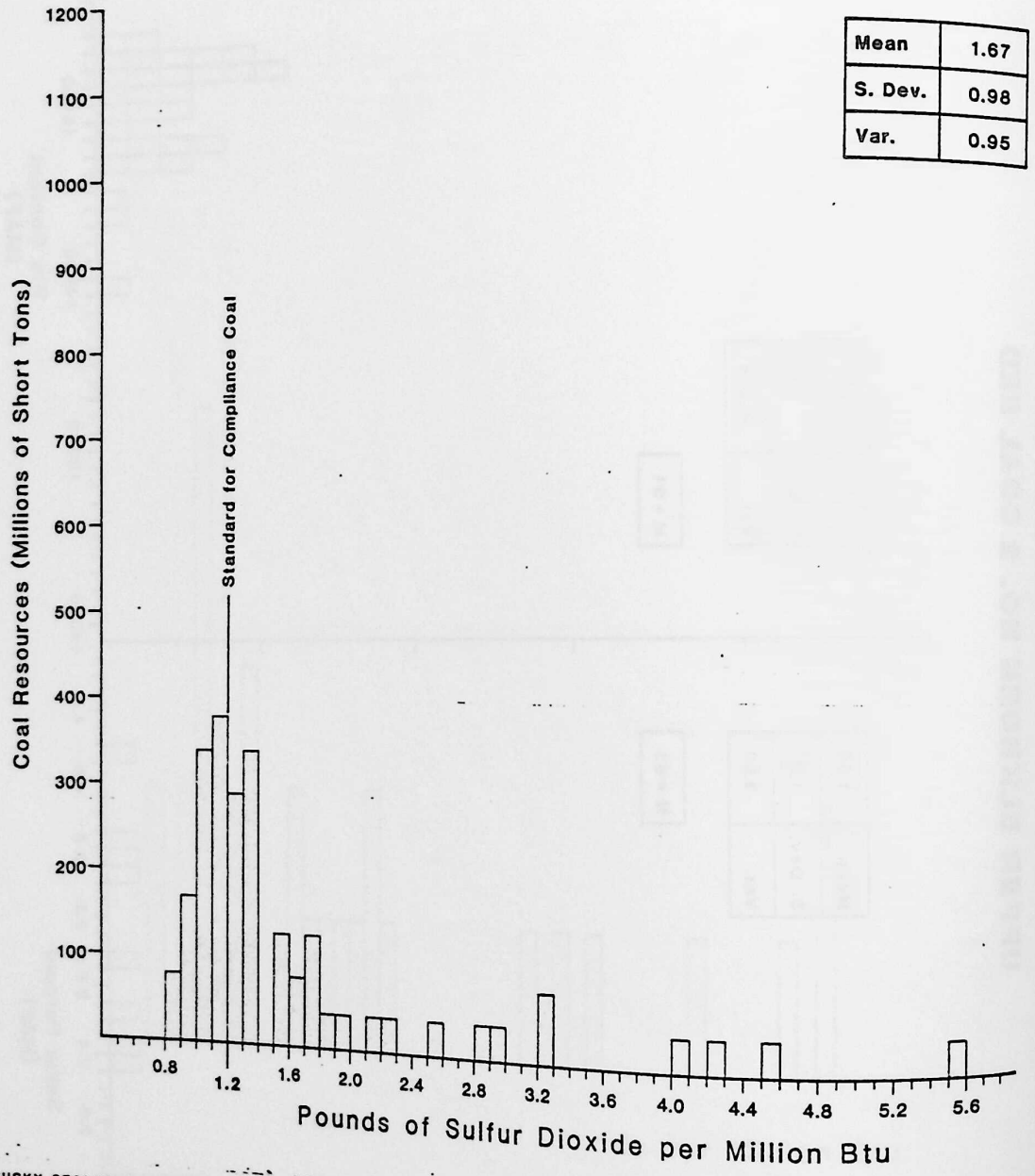


UPPER ELKHORN NO. 2 COAL BED



UPPER ELKHORN NO. 1 COAL BED

TOTAL RESOURCES - 2478 MILLION SHORT TONS

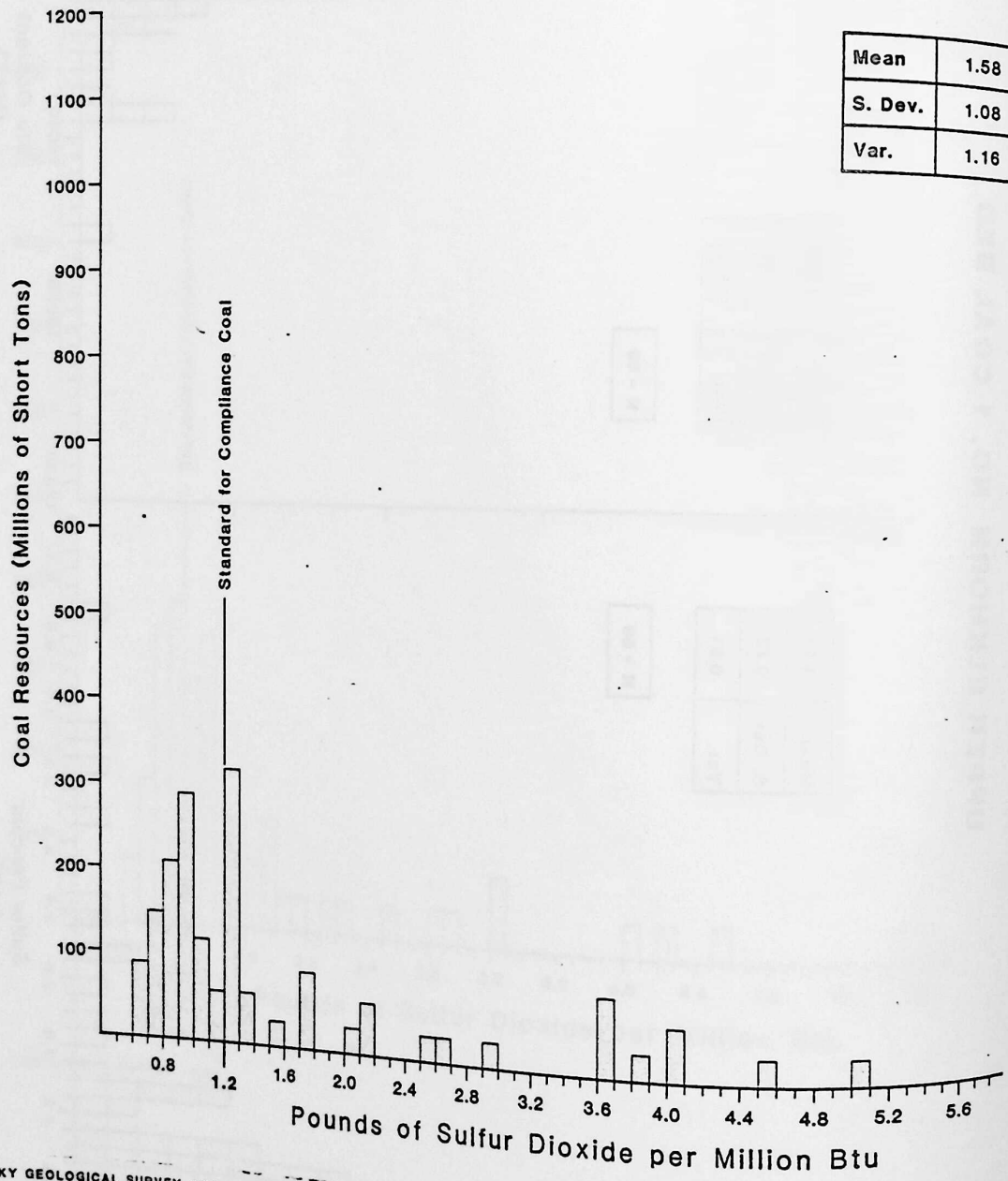


UPPER ELKHORN NO. 1 COAL BED

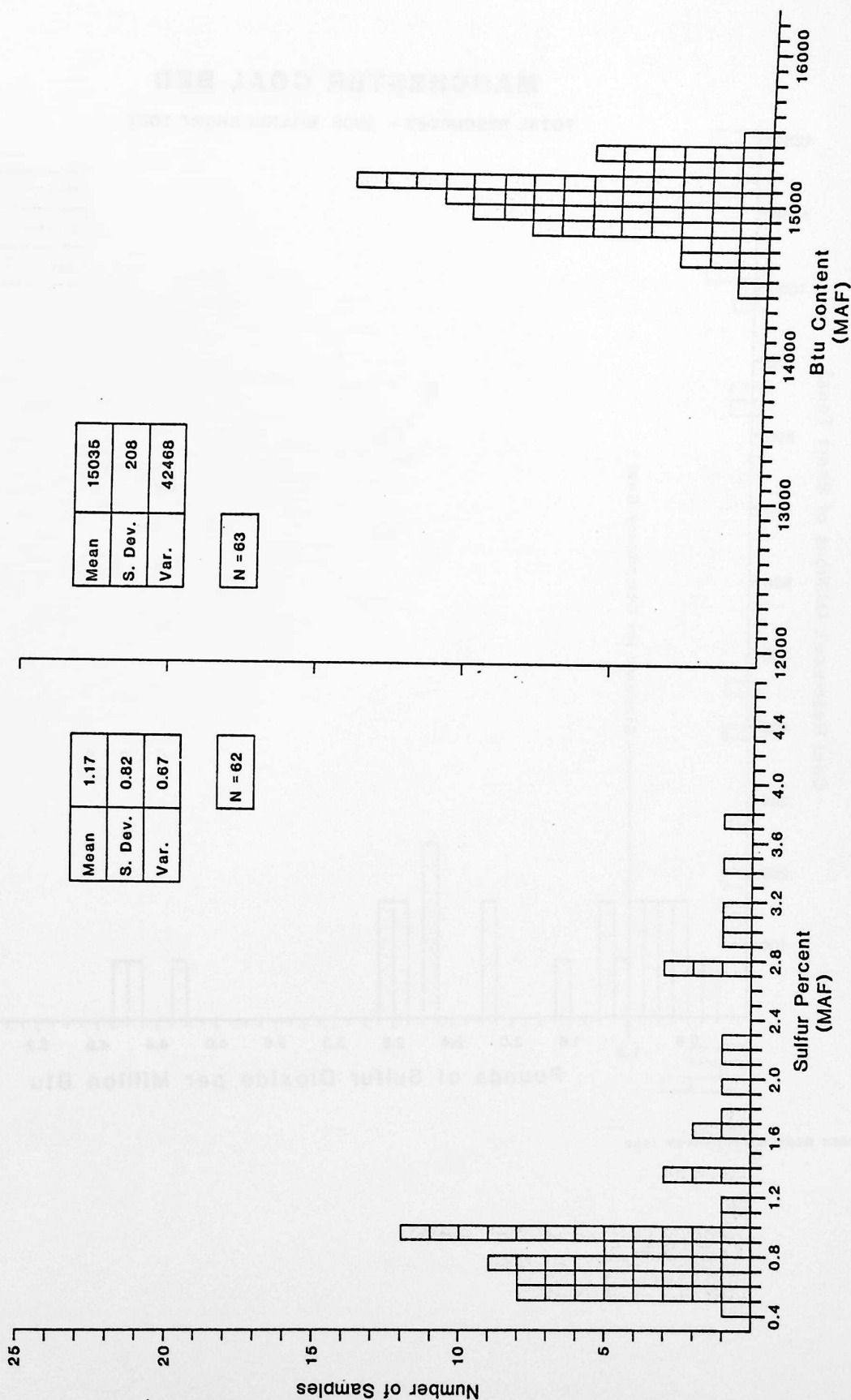


LOWER ELKHORN COAL BED

TOTAL RESOURCES - 1820 MILLION SHORT TONS



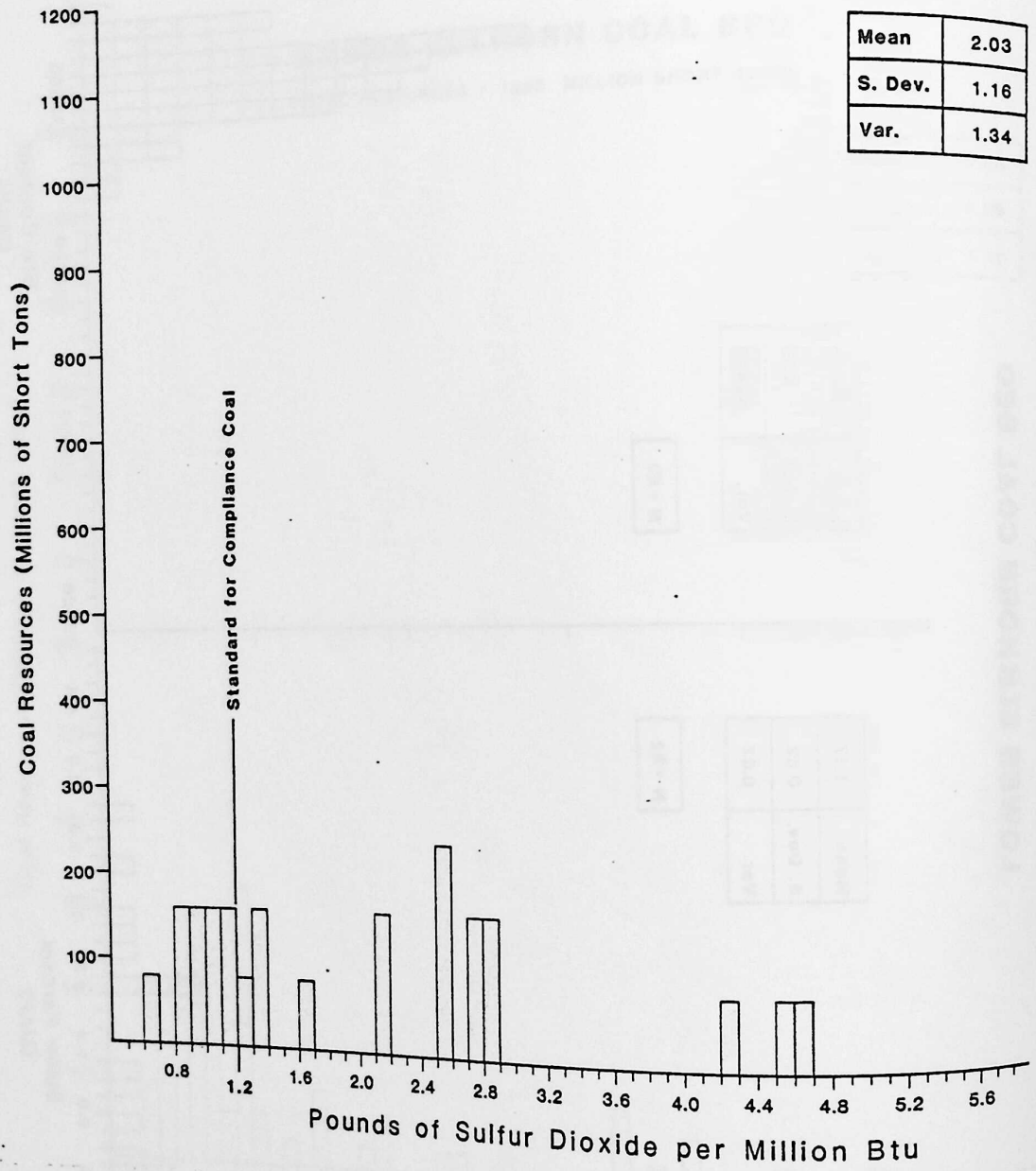
LOWER ELKHORN COAL BED



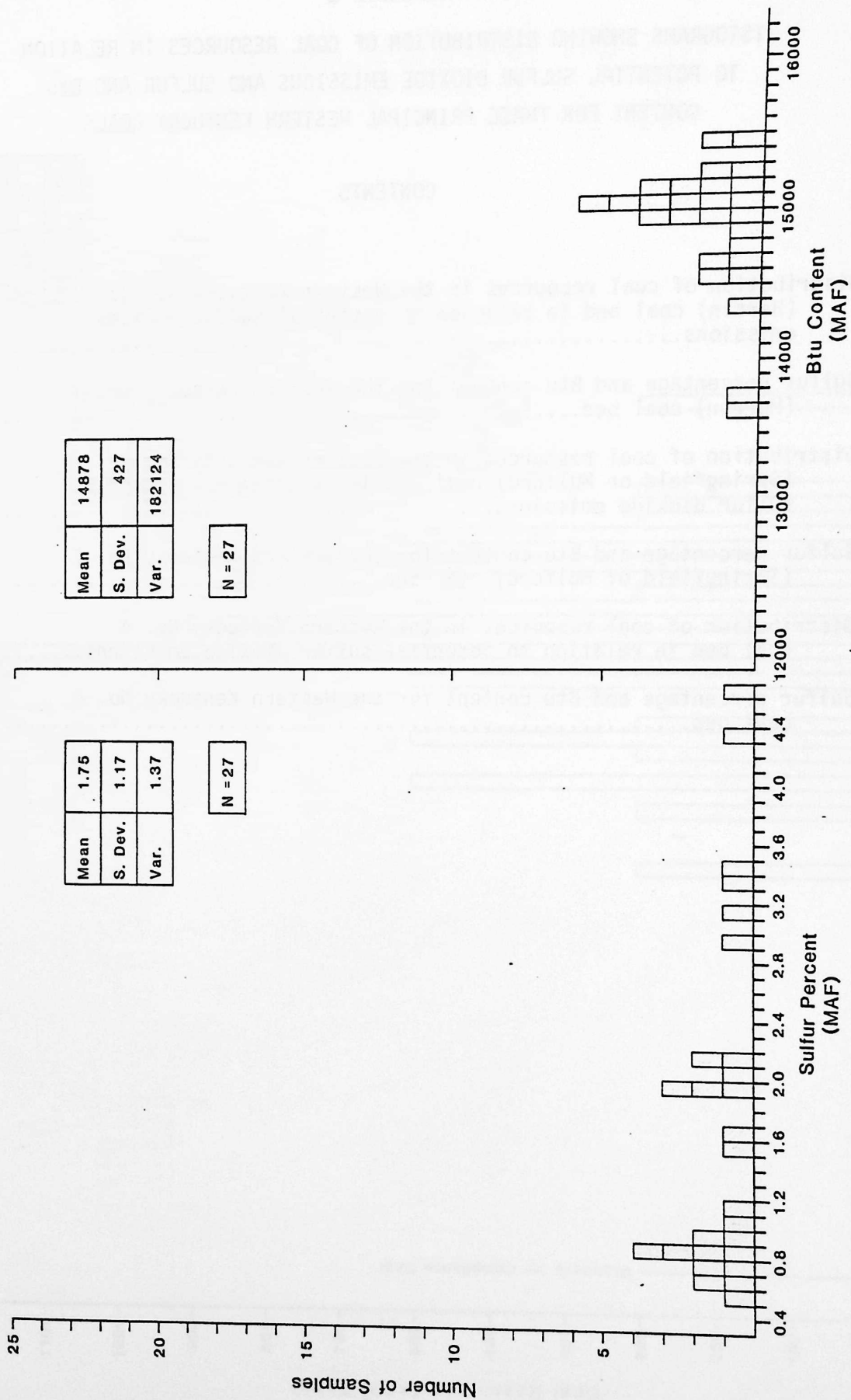
MANCHESTER COAL BED

TOTAL RESOURCES - 2005 MILLION SHORT TONS

Mean	2.03
S. Dev.	1.16
Var.	1.34



MANCHESTER COAL BED



APPENDIX 2

HISTOGRAMS SHOWING DISTRIBUTION OF COAL RESOURCES IN RELATION
TO POTENTIAL SULFUR DIOXIDE EMISSIONS AND SULFUR AND Btu
CONTENT FOR THREE PRINCIPAL WESTERN KENTUCKY COALS

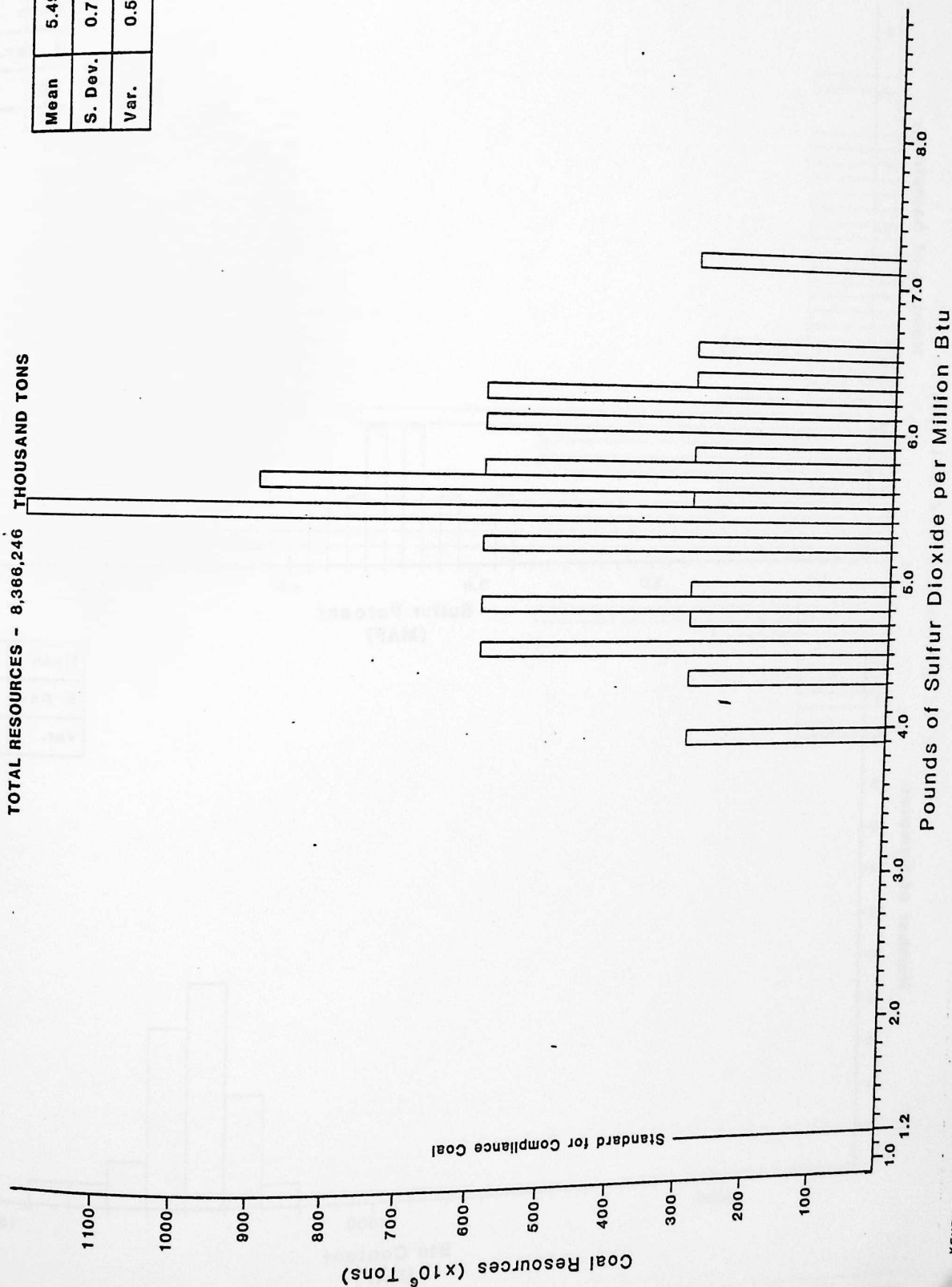
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WESTERN KENTUCKY NO. 11 (HERRIN)

TOTAL RESOURCES - 8,386,246 THOUSAND TONS

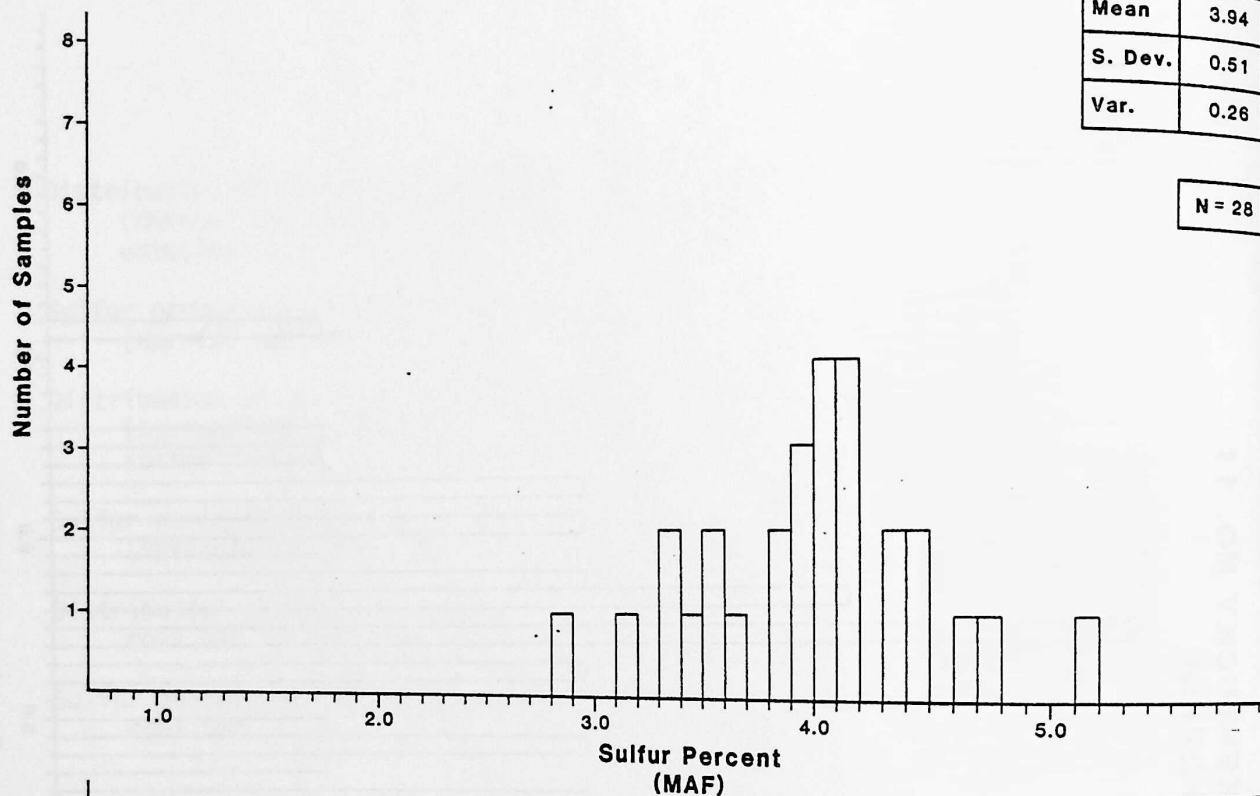
Mean	5.49
S. Dev.	0.71
Var.	0.50



WESTERN KENTUCKY NO. 11 (HERRIN)

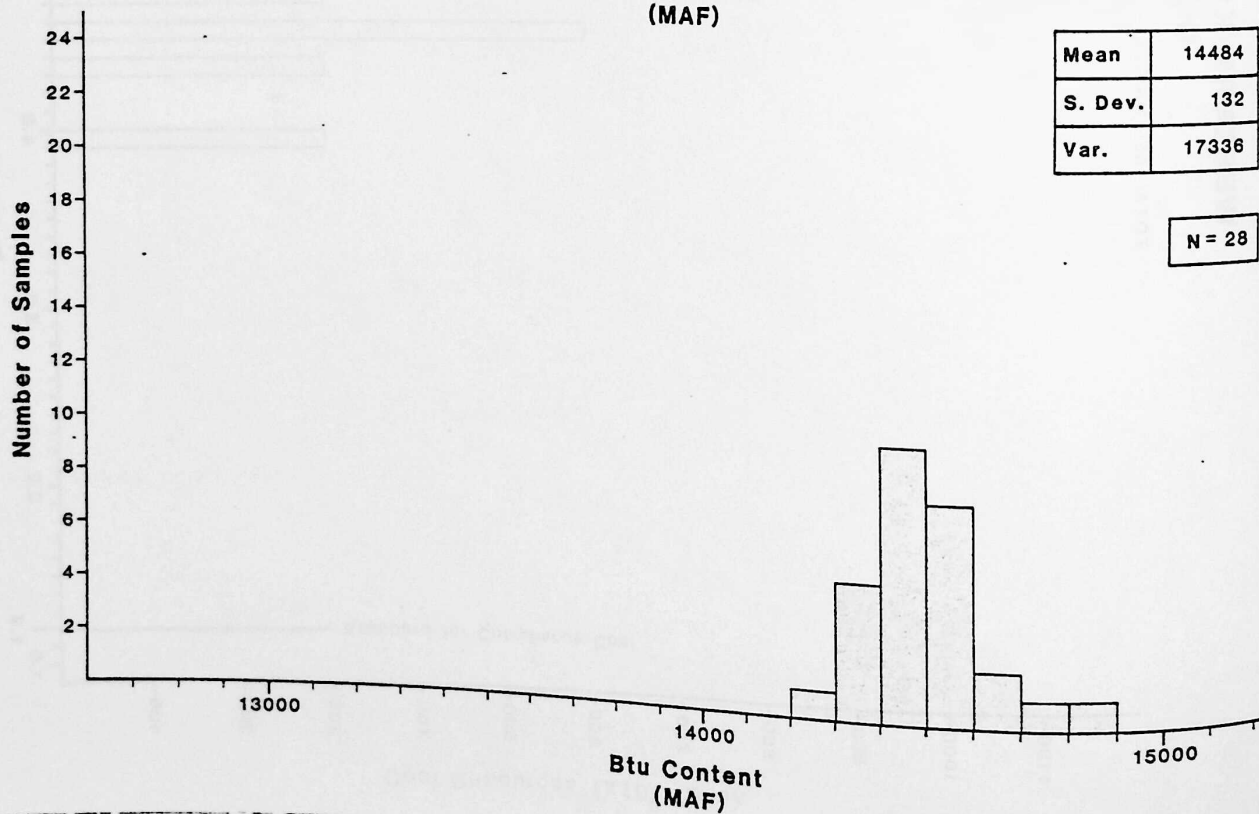
Mean	3.94
S. Dev.	0.51
Var.	0.26

N = 28



Mean	14484
S. Dev.	132
Var.	17336

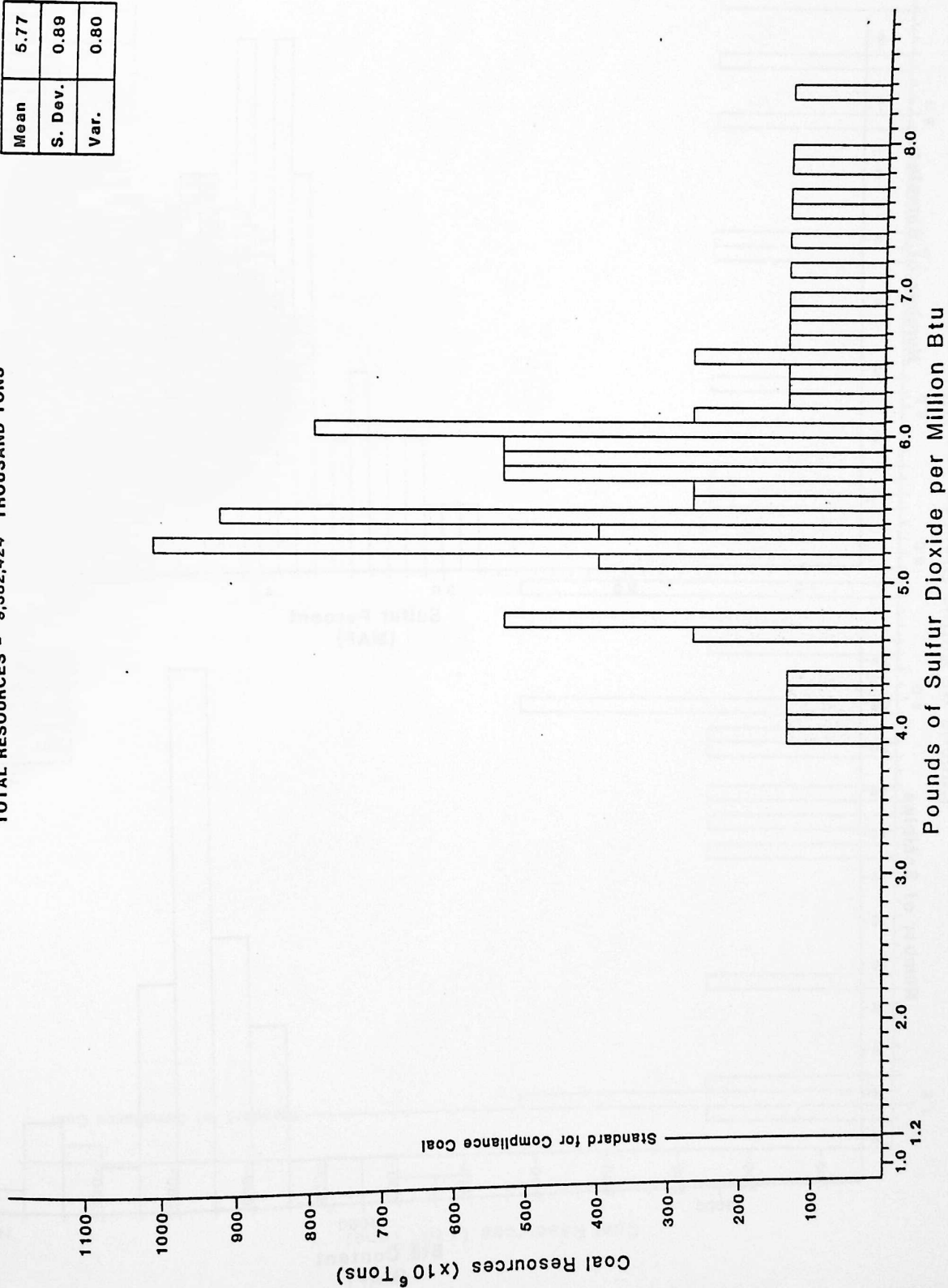
N = 28



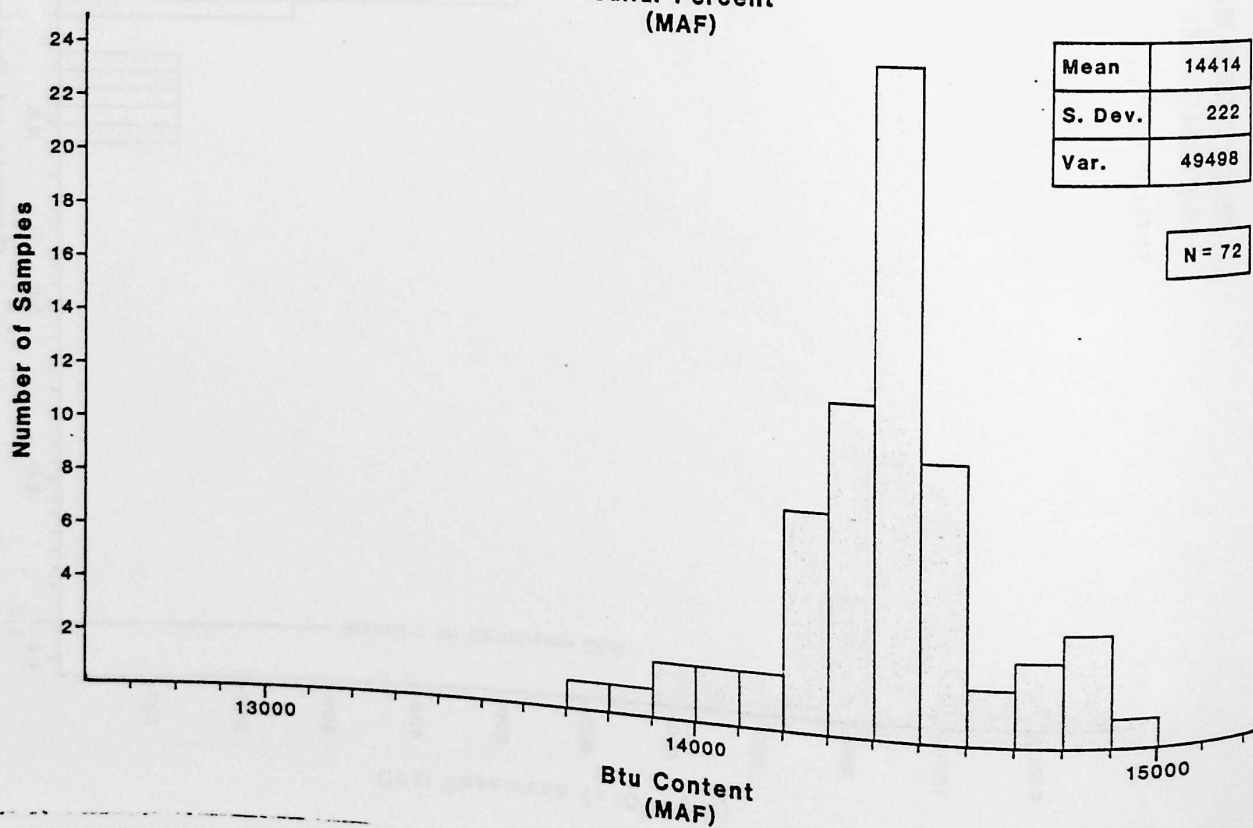
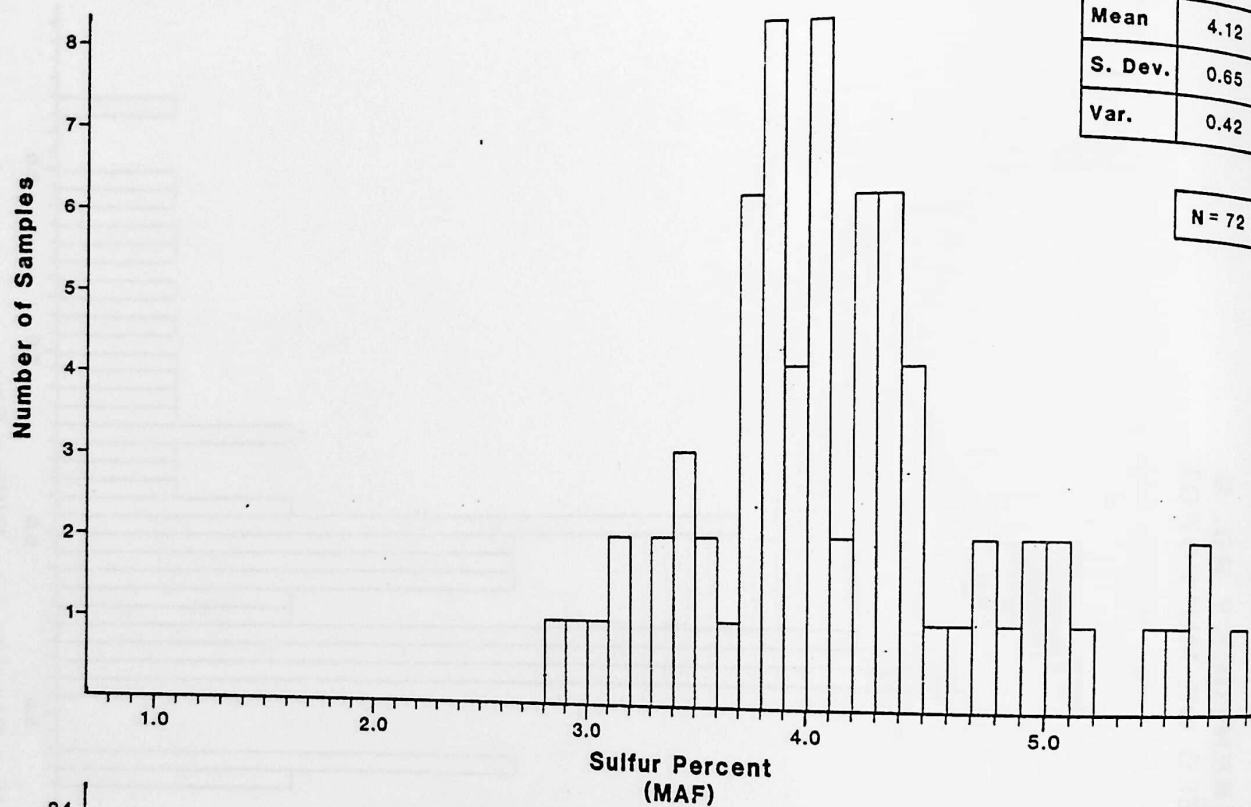
WESTERN KENTUCKY NO. 9 (SPRINGFIELD OR MULFORD)

TOTAL RESOURCES - 9,382,424 THOUSAND TONS

Mean	5.77
S. Dev.	0.89
Var.	0.80

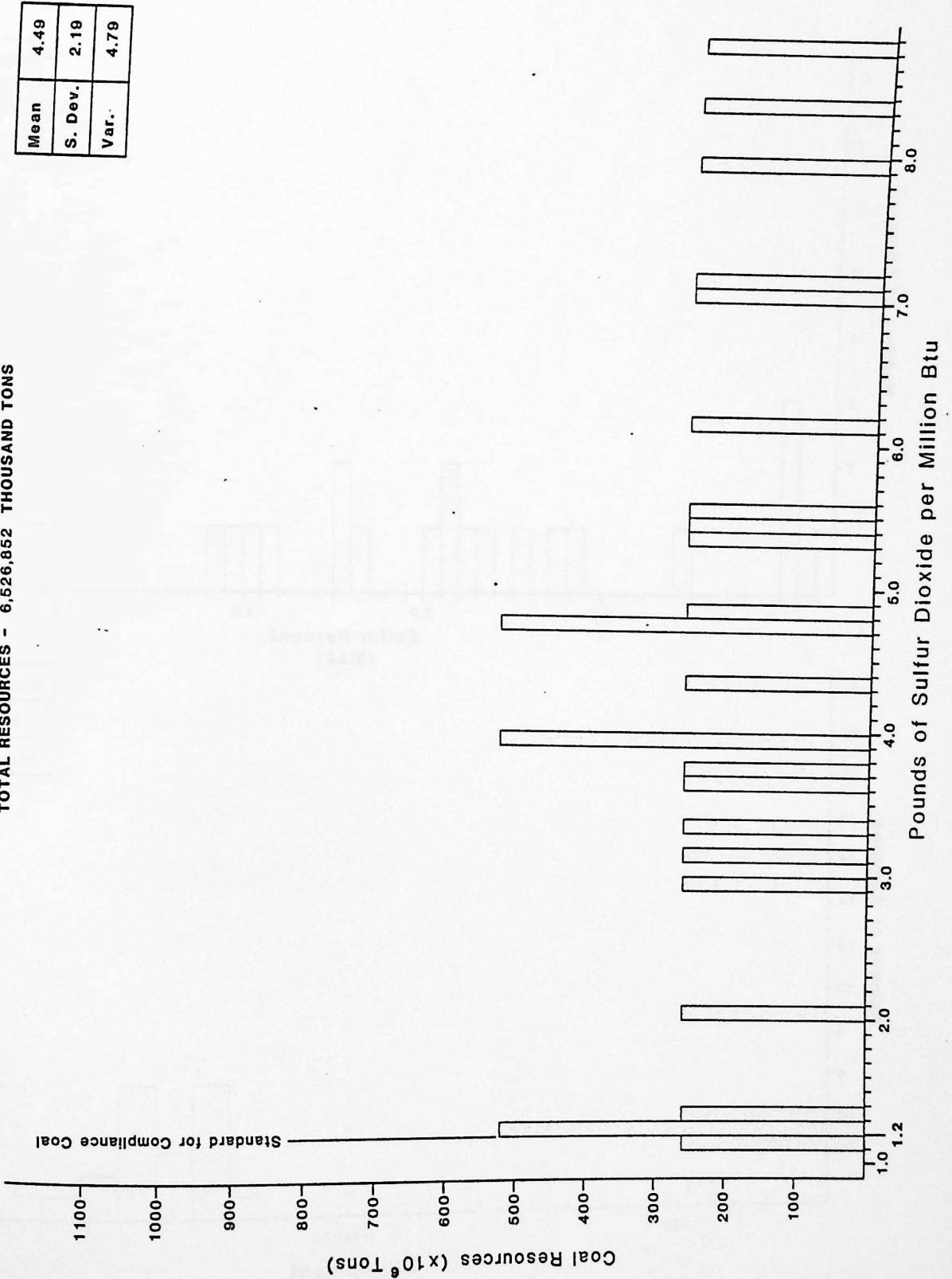


WESTERN KENTUCKY NO. 9 (SPRINGFIELD OR MULFORD)



WESTERN KENTUCKY NO. 4

TOTAL RESOURCES - 6,526,852 THOUSAND TONS



WESTERN KENTUCKY NO. 4

