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ALASKA'S LOW-SULFUR COALS HOLD LEADING EDGE IN FUTURE PACITIC-RIM AND U.S. COAL TRADE

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ABSTRACT

Alaska is endowed with more low-sulfur bituminous and subbituminous coal than any other comparable region on earth. The sulfur content of Alaskan coals on average is about half that of the lowest-sulfur coals of the contiguous United States.

The low sulfur content of Alaskan coals is one of their chief selling points. Increasing near-term usage of low-sulfur coal on the Pacific Rim should bode well for expanding the production and export of Alaska coal. Although other countries on the Pacific Rim (notably Australia and Canada) possess some reserves of low-sulfur coal, Alaska contains vast resources of very low sulfur coal that promise to make it the most important future source of low-sulfur fuel on the Pacific Rim.

The Northern fields of Alaska comprise the largest accumulations of low-sulfur bituminous and subbituminous coal in the world. The coals of the Beluga field of southcentral Alaska, which has the lowest sulfur range of any U.S. coal, are low enough to meet the Environmental Protection Agency's (EPA) standards for direct combustion. The Nenana basin, from which subbituminous coal is currently being exported to Korea, contains 8 billion tons of identified resources with total sulfur averaging 0.2 percent.

Emissions of sulfur dioxide pollution by Alaska coals is less than for eastern and western U.S. coals when burned to generate electricity. In general, all Alaskan coals containing over 8,000 Btu/lb and less than 0.5 percent total sulfur fall under EPA's 1.2 lb SO_2/MM Btu emission standard.

Although most Alaskan coals are low sulfur, all forms of pyrite can sometimes be observed in minute quantities in some coals. Typically, the organic sulfur content occurs in the highest proportion in Alaska coals. They contain very little or no pyritic and sulfate sulfur. Reduction in sulfur through the use of modern coal-cleaning technologies is effective only in those few Alaskan coals with sulfur contents over 1 percent.

INTRODUCTION

Alaska is endowed with more low-sulfur bituminous and subbituminous coal than any other comparable region on earth. The state holds perhaps as much as one-half of total U.S. coal resources, and almost all of Alaska's coal falls into the low sulfur category.

The environmental significance of low sulfur coal is great, and its importance will increase dramatically in the future. Sulfur is almost always present as an impurity in coal, and it is one of the chief parameters affecting assessments of coal quality. The total sulfur content of coal in general varies over a broad range (Tables 1 and 2), but is typically less than 5 percent in commercial coals. The sulfur content of coal may be referred to as low (less than 1 percent), medium (more than 1 percent but less than 3 percent), or high (over 3 percent; Averitt, 1973; Wood and others, 1983). Coals with extremely high sulfur contents (5 to 20 percent sulfides) are commonly referred to as carbopyrites and possess densities of 1.5 to 2.5 g/ml (Stach and others, 1982).

Schopf (1952) found that the sulfur content of coals varied with their geologic age. In general, he found that the average sulfur content of Paleozoic coal (2.3 percent) was considerably higher than Cretaceous coal (1.3 percent) and Tertiary coal (0.7 percent). He believed this general trend could indicate that anaerobic decay was considerably more important in the formation of Paleozoic than in Cretaceous or Tertiary age coal.

In general, the highest sulfur contents are found in bituminous coals which show a progressive decrease in sulfur content with increased carbon content (Schmidt, 1979). Lignites, subbituminous coals, certain bituminous coals, and anthracites show typically lower sulfur contents. For most

Table 1. Sulfur content of various substances in weight percent (modified from Meyer, 1977).

Substance	Percent
Crust of the earth	0.052
Coal	1.0-20.0
Oil	0.1-14.0
Gas	0.1-40.0
Gypsum	18.6
Soil	0.01-0.05

Table 2. Range of sulfur in coal reported by various authors.

Coals	Range (%)	Author(s)
World bituminous	0.38-5.32	Meyers, 1977
World	<1-8	Averitt, 1961
World	0.44-9.01	McClung and Geer, 1979
World (overall)	0.2-10	Attar and Hendrickson, 1982
World (most)	0.5-4	Attar and Hendrickson, 1982
World (average)	1-2	Averitt, 1973;1975
United States	0.2-7	Averitt, 1973;1975
United States	0.5-6	Wewerka and others, 1976
United States	0.3-7.7	Fieldner and others, 1942
United States (average)	1.9	Fieldner and others, 1942
Eastern United States	0.5-3.5	Attar and Hendrickson, 1982
Western United States	< 2	Attar and Hendrickson, 1982

bituminous coals, higher volatile matter contents are accompanied by larger ranges of organic sulfur contents. Organic sulfur varies widely among coals of different rank. The range of organic sulfur is greatest for coals of lower rank and least for those of higher rank.

Although most U.S. coals are low sulfur, the content of sulfur in Alaskan coals on average is about half that of the lowest-sulfur coals of the contiguous United States. Schmidt (1977) estimated that about one-third of the total U.S. potentially recoverable reserves have less than 0.7 pound sulfur per million Btu, but that nearly three-quarters of this lowest-sulfur coal occurs in Western states. Averitt (1973) estimated that the resources of low-sulfur subbituminous coal and lignite concentrated in the Rocky Mountains and Northern Great Plains represented about 54 percent of total U.S. identified resources. This low-sulfur Western coal can generally be used directly in power plants.

There has been some recent debate as to whether estimates of known and recoverable reserves of low-sulfur coal have been overstated, and whether these reserves will be adequate to satisfy projected future demands. For some purposes and for some regions, there may be no practical alternative to the use of bituminous coals of high-heating value and high sulfur content (Schmidt, 1977). However, increased usage of low-sulfur and relatively low-heating-value coals should bode well for expanding production and export of Western U.S. and especially Alaskan coals.

High sulfur coal results in difficulties in mining, coal preparation, and utilization. It may contribute to spontaneous combustion of coal in mines, in refuse piles, and in stored and stockpiled coal. Its presence in spoil banks inhibits revegetation. It produces sulfuric acid drainage that flows into streams from coal mines, spoil piles, and refuse dumps. Iron sulfides in coal create problems for desulfurization and proper material handling during coal preparation. Low sulfur coal is required for the manufacture of metallurgical coke; like phosphorous, sulfur lowers coke quality and that of resulting iron and steel products (Gluskoter and Simon, 1968; Averitt, 1973, 1975). In addition, sulfur causes deleterious effects on the throughput of blast furnaces. Boiler deposits are formed and boiler tubes are corroded resulting in reduced boiler efficiency. Air preheater equipment is particularly susceptible to sulfuric corrosion (Conwell, 1972; Averitt, 1973, 1975). Sulfur dioxide (SO_2) emissions into the atmosphere from coal-fired boilers results in significant air pollution problems.

The use of low sulfur Western U.S. coal is favored by most utilities and other coal consumers, whereas the use of high sulfur eastern coal requires the installation of expensive pollution control equipment, such as scrubbers for coal desulfurization (Averitt, 1973; 1975). The average sulfur content of coal used by electric utilities in the United States in 1977 was about 2 percent (Table 3).

Table 3. Sulfur content range of bituminous coal and lignite by consumer use in 1977 (modified from Boykins, 1977).

Use	Range	Avg. sulfur (%)
Electric utilities	0.20-4.80	2.05
Coke plants	0.55-3.45	1.00
Other industrial uses and retail dealers	0.20-3.45	1.80
All other uses	0.20-3.60	1.40
Exports	0.50-4.30	1.15
Total	0.20-4.80	1.90

The low sulfur content of Alaskan subbituminous and bituminous coals is one of their chief selling points and is a factor that should enhance future export possibilities on the Pacific Rim. For most consuming markets, sulfur in coal is looked upon as a highly undesirable constituent. Nakabayashi (1981) states that the low sulfur content of Alaskan coals is advantageous for Japanese markets. South Korea is currently importing low-sulfur Alaska coal, and Taiwan appears to be ready to purchase supplies of low-sulfur Alaska coal in the near future. For these reasons, increased future demands for Alaska coal on the Pacific Rim can be forecast.

PYRITE AND SULFUR IN COAL

The sulfur impurities of coal occur in two major forms: 1) those which are structurally or chemically bound within the coal substance, such as organic sulfur; and 2) those which can be removed from the coal substance by mechanical means, such as massive pyrites---lenses, bands, balls or nodules (Walker and Hartner, 1966). These can be divided into four morphological species of sedimentary pyrite or marcasite (FeS_2) that occur in coals and associated rocks (Figure 1). They are: 1) framboidal pyrite (less than 25 microns diameter); 2) finely disseminated euhedral grains (usually 1-10 microns diameter); 3) coarse-grained masses (larger than 25 microns diameter) replacing original plant material; and 4) coarse-grained masses occupying cleats or joints (Caruccio and others, 1977; Horne and others, 1977). Framboids and euhedra are primary pyrite varieties and the coarse-grained, massive forms are secondary.

Although most Alaskan coals are low sulfur, all forms of pyrite can occasionally be observed. It is only rarely that pyrite can be seen in hand specimens (Figure 2). During microscopic examination, scattered coarse grains of pyrite can sometimes be found even in low-sulfur coals (Figure 3). In addition, pyrite may replace or occur in close association with various coal macerals (Figure 4).

'Framboidal' pyrite refers to a unique raspberry-like

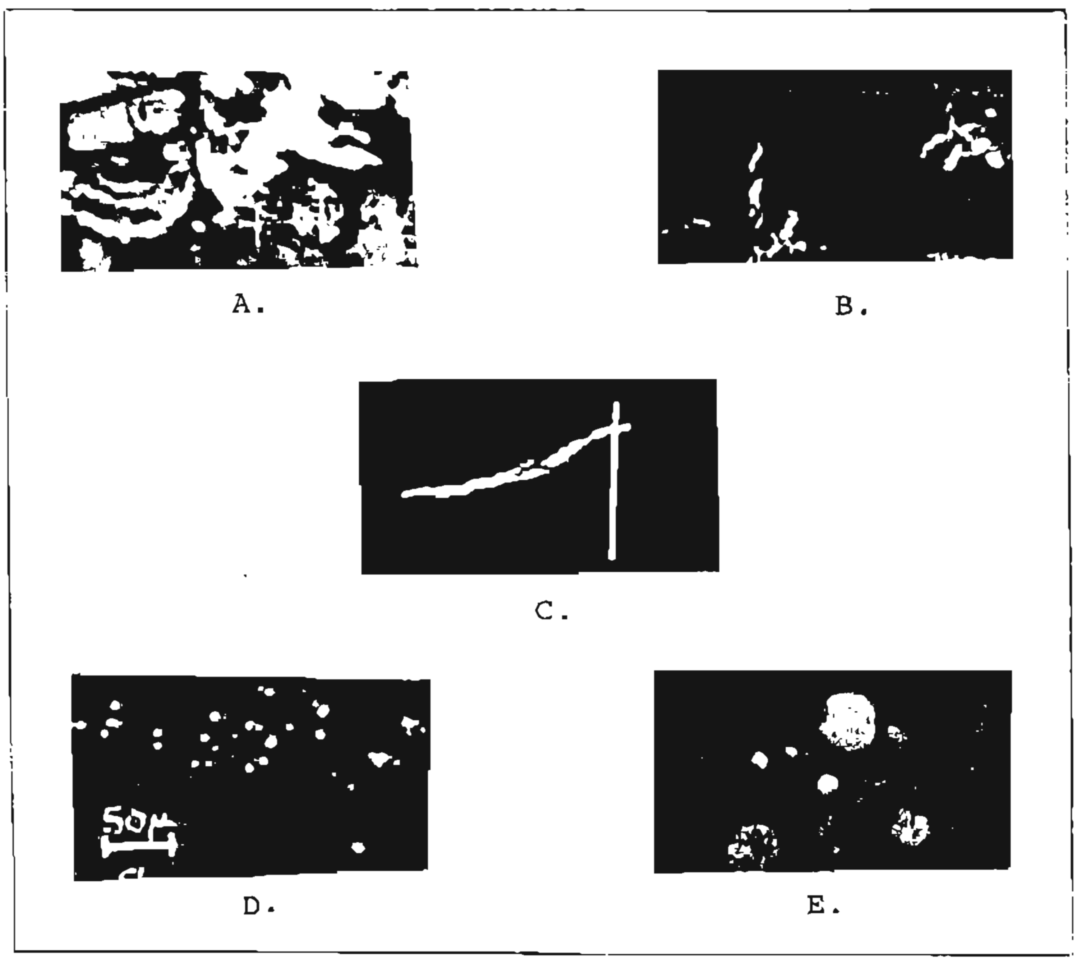

Figure 1. Forms of pyrite in coals: A,B--Secondary replacement forms; C--Cleat coats; D--Euhedra; and E--Framboidal (after Horne, 1981).

Figure 2. Coal hand-specimen from a Diamond Point, Chignik field, Alaska Peninsula seam showing abundant massive-grained pyrite, an anomaly for Alaska coals.

Figure 3. Massive, striated grain of pyrite from a Susitna lowland low-sulfur coal.

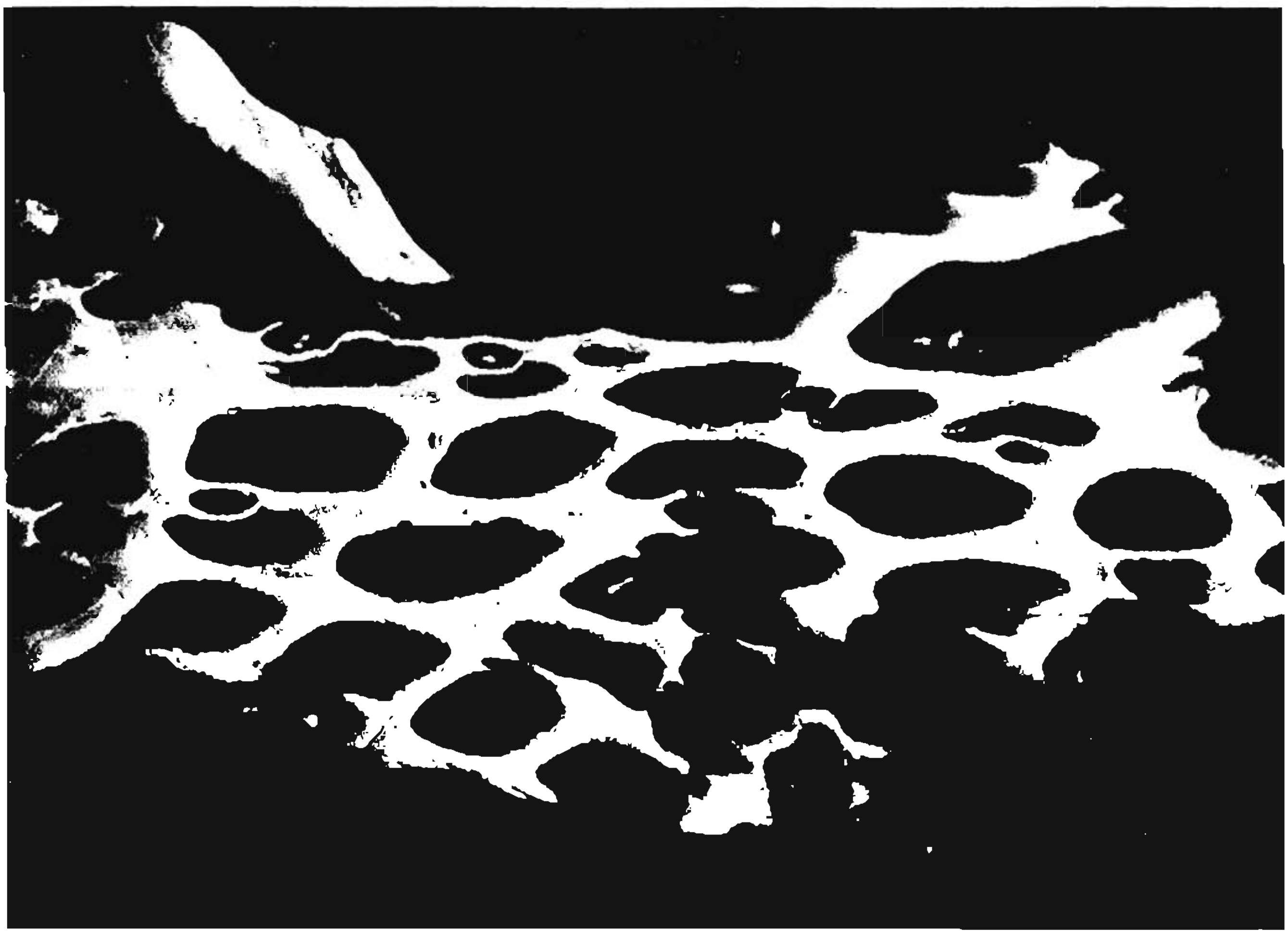

Figure 4. Pyritized fusinite maceral in a low-sulfur southcentral Alaska coal.

microtextural variety that forms clusters of spherical agglomerates of iron disulfide that are disseminated throughout coal and associated strata (Figure 5). The diameter of each microsphere ranges from 0.25 to 1 micron. These microspheres compose spherules usually less 25 microns but up to 250 microns in diameter. Groups of framboidal spheres are referred to as polyframboids (Caruccio and others, 1977). Framboidal pyrite is so disseminated throughout the coal substance that it cannot be removed in the 1.50 density sink fraction in washability tests (Horne and others, 1977). Framboidal pyrite decomposes rapidly and is the only pyrite variety that can cause severe acid mine drainage problems in coal-mining regions in the absence of carbonate (Caruccio, 1970).

Acid mine drainage is the aquatic transport mode for environmental contaminants of coals (Wewerka and others, 1976). The basic stoichiometric chemical reaction that produces acid mine drainage is the following, wherein Δ equals heat produced:

$$2\ \underline{FeS_2} + 2\ H_2O + 7\ O_2 \longrightarrow 2\ FeSO_4 + 2\ \underline{H_2SO_4} + \Delta$$

The primary sedimentary sulfides, particularly framboidal pyrites, rapidly oxidize to iron oxides and ferrous and ferric sulfates with exposure to air, but secondary massive-grained pyrites are stable and leach very slowly (Caruccio and others, 1977). Water draining regions with pyrite-bearing coal outcrops can be acidic or ferruginous in its natural or inherent state (Figure 6). With mining, the exposed surface area of these pyritiferous rocks is increased causing further oxidation, leaching, and acidic mine drainage.

The total sulfur content of a coal is usually expressed in percent, and is divided into three main forms in chemical combination---pyritic, organic, and sulfate sulfur (Walker and Hartner, 1966; Attar and Hendrickson, 1982; and Wood and others, 1983). The percentage of total sulfur and pyritic sul-

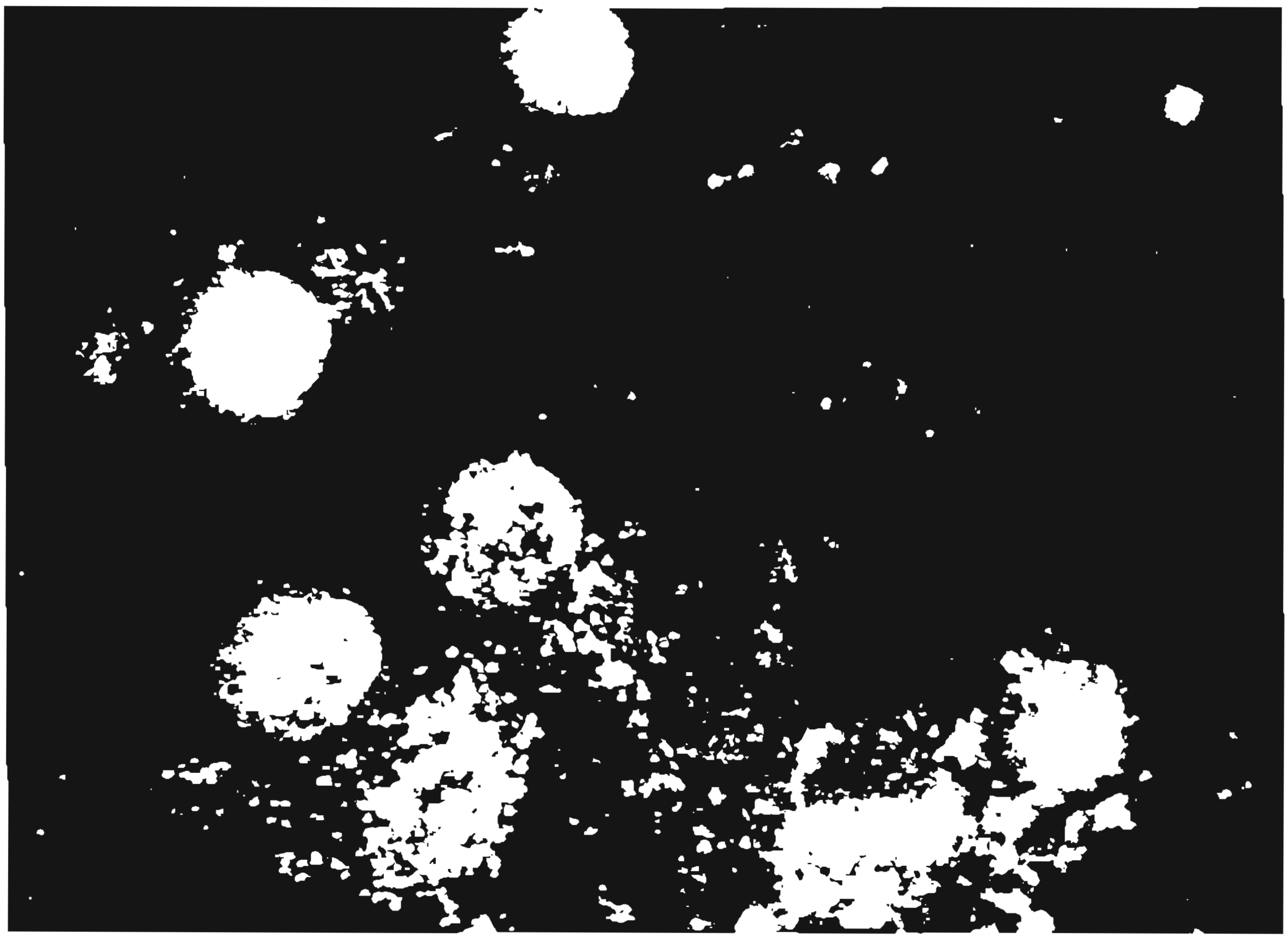

Figure 5. Framboidal pyrite in a low-sulfur south-central Alaska coal.

Figure 6. Stream on northcentral flank of Alaska Range in the Nenana basin with drainage characterized by high ferrous iron and trace element contents in its inherent state.

fur is highest in bituminous coals of Pennsylvanian age in the Appalachian and Interior coal basins, and is relatively low in subbituminous coals and lignites of the Rocky Mountain and Northern Great Plains regions (Averitt, 1973).

Inorganic sulfur occurs mostly as pyrite, but sometimes is found in marcasite and sulfates (Attar and Hendrickson, 1982). Organic sulfur occurs in combination with the coal-forming vegetal material, and is distributed throughout the coal substance as part of its molecular structure (Walker and Hartner, 1966; Averitt, 1973). Organic sulfur usually predominates in low-sulfur coals but decreases as the total sulfur content increases (Attar and Hendrickson, 1982). Organic sulfur is normally less than 3 percent in most coals (Table 4). Researchers disagree as to how organic sulfur varies laterally in a single seam. Yancey and Fraser (1921) found organic sulfur to be uniform only in limited areas of the coal seams they studied in Illinois and Kentucky. Cady (1935) found the local variation in organic sulfur rarely exceeded 1 percent, was generally less 0.5 percent, and was regionally consistent for each coal. Wandless (1959) similarly found fairly constant organic sulfur content throughout wide areas in many British coal seams (McClung and Geer, 1979).

Table 4. Range in organic sulfur contents in coals and the ratio of organic sulfur to total sulfur.

Coals	Range (%)	Percent of total sulfur	Author(s)
World	normally <3, rarely to 11	11.4-97.1	McClung and Geer, 1979
American	0.2-3	20.8-83.6, mean 51.2	McClung and Geer, 1979
		50-70	Attar and Hendrickson, 1982
Subbituminous	normally 0.3-2, rarely to 6	---	Attar and Hendrickson, 1982
Low-sulfur western U.S.	---	50-95	Averitt, 1975

Pyritic sulfur refers to either of two dimorphs of ferrous disulfide (FeS_2), that is, pyrite or marcasite. Pyrite and marcasite have the same chemical composition but differ in physical structure. Because they are difficult to distinguish from each other, they are often simply grouped as pyrites or iron pyrites (Walker and Hartner, 1966; Gluskoter and Simon, 1968). Pyritic sulfur ranges from 0.1 to 8.0 weight percent in most coals (Attar and Hendrickson, 1982). In low-sulfur western U.S. coals, all sulfur not present in the predominant organic form consists of pyrite and marcasite. In high-sulfur eastern U.S. coals, most sulfur (45 to 85 percent) occurs as pyrite and marcasite (Averitt, 1973; 1975). Although there is a tendency for pyrite (and total sulfur) to be greater in the top and/or bottom benches of a coal seam, large vertical variations in pyritic sulfur are commonly observed (Gluskoter and Simon, 1968). During mining, benches that are especially high in sulfur can be eliminated by selective mining (McClung and Geer, 1979).

Walker and Hartner (1966) noted that even though pyritic and organic sulfur forms tended to increase with increasing total sulfur, there was no direct relationship between the two. Gluskoter and Simon (1968) found a positive correlation between pyritic and organic sulfur in Illinois samples, but determined that the organic sulfur content was more uniform throughout the vertical section of a coal seam than was pyritic sulfur. McClung and Geer (1979) confirmed the latter supposition, but stated categorically that there was no relationship between organic and pyritic sulfur, and that a high sulfur content did not necessarily indicate a proportionately high organic sulfur content.

Sulfate sulfur is only significant in weathered coals where ferric and ferrous sulfates may be present (Figure 7; Gluskoter and Simon, 1968). Typical sulfates in coal include hydrous ferrous sulfates ($FeSO_4 \cdot 2H_2O$), calcium sulfates ($CaSO_4 \cdot 2H_2O$), and barium sulfates ($BaSO_4$; Averitt, 1973,

Figure 7. Weathered sulfate compounds coating surfaces and filling voids near the top of a coal seam in the Evan Jones mine area, Matanuska Valley. The coarse-grained sandstone roof rock is also observable in the upper left portion of photo.

1975; Attar and Hendrickson, 1982). Although sulfates may be present in fresh coals in small amounts, they rarely exceed 0.05 percent except in highly weathered or oxidized samples (McClung and Geer, 1979). Sulfur occurring as pyrite and marcasite is easily oxidized, especially under moist conditions, to sulfates. Because the sulfate sulfur content of commercial coals is normally low, it is not an important factor in coal utilization (Walker and Hartner, 1966).

Sulfur analysis is required for characterizing both steam and coking coals (Steele and others, 1983). Sulfate sulfur is extracted from coal with dilute hydrochloric acid. Thereafter, pyritic sulfur is extracted from the hydrochloric acid residue portion of the sample with nitric acid. The pyritic sulfur content can then be determined from the nitric acid soluble sulfur, and calculation of the pyritic iron from the nitric acid soluble iron. Organic sulfur is taken as the difference between the total sulfur and the sum of the pyritic and sulfate sulfur (Walker and Hartner, 1966).

SULFUR AND DEPOSITIONAL ENVIRONMENTS

The sulfur content of a coal can be attributed to the depositional environment in which precursor peat beds formed. In general, rapid subsidence during sedimentation favors lower sulfur contents, whereas slower subsidence during sedimentation favors higher sulfur contents (Horne and others, 1977). When splay deposits of terrigenous clastic sediment are introduced early and are of sufficient thickness, they shield the coal from sulfur-reducing bacteria and the resultant sulfur content remains low (Horne and others, 1976). Coals deposited on a stable platform where the rates of sedimentation were lower and chemical activity was higher generally exhibit higher sulfur contents. Coals generally show an increase in total sulfur (and reactive pyrite) content as they pass from upper delta plain to back-barrier environments (Horne and others, 1977).

Williams and Keith (1963) demonstrated statistically that coals with roof rocks of marine or brackish water origin contained higher sulfur than those with roof rocks of fresh water origin. Mansfield and Spackman (1965) showed petrographically that coals formed under the influence of marine water contained more sulfur than those formed in fresh water. Ferm and others (1975) established that it was sulfur present in the framboidal form of iron disulfide that was most strongly associated with roof rocks deposited in marine to brackish water environments. Bailey (1981) showed that marine-influenced coals are higher in pyrite, pyritic sulfur, and sulfate sulfur.

Coals formed in back-barrier environments are typically high in sulfur (Horne and others, 1977). Although lower-delta-plain environment coals show a highly irregular pattern of sulfur distribution, they are commonly overlain by marine to brackish sediments that contain high amounts of disseminated pyritic sulfur present in the reactive framboidal form (Horne and others, 1977). Coals of the transitional zone between lower and upper delta plain environmental facies were farther from marine influences and generally contain less framboidal pyritic sulfur, though its distribution is highly variable (Horne and others, 1977). Coals of upper delta plain to fluvial environments are rarely influenced by marine to brackish waters, and hence, coals formed in these depositional settings are typically low in pyritic and total sulfur. Most of the pyrite that is present is in the form of massive plant replacements and cleat fillings (Horne and others, 1977).

COAL CLEANING TECHNOLOGY

In addition to ash removal, separation processes are also concerned with the removal of sulfur-bearing minerals (Schmidt, 1977). Mechanical methods employing gravity concentration are used for the removal of impurities liberated from coal through grinding and size reduction. When raw coal is immersed in an appropriate dense medium, the lighter fractions (principally coal) floats and the pyrites and other impurities heavier than coal sink. The density (or specific gravity) of bituminous coal is 1.12-1.35 gm/cm^3, whereas pyrite's is 4.8-5.2 gm/cm^3 (Schmidt, 1977).

If coal processing is required to reduce the sulfur content of a coal, the form and association of sulfur are important to the success of mechanical cleaning techniques (Walker and Hartner, 1966; Rao, 1976). The physical form (size and distribution) of pyrite determines the amount that can be removed by conventional coal preparation methods. If the grains appear coarse after crushing, there is a better chance of concentrating the pyrite in the refuse. Mechanical cleaning methods can be very successful for removing pyrite occurring as cleats, joints, bands, or lenses. Reducing the sulfur content of a coal is difficult if the pyrite grains are extremely small, finely disseminated, and intergrown with the coal. Only very fine crushing and special treatment can offer any hope of separating finely disseminated pyrite from the coal substance (Walker and Hartner, 1966).

Because of its high specific gravity and occurrence as discrete particles, the pyritic sulfur content of a coal can be removed by various washing and cleaning procedures (Averitt, 1973; 1975). Mechanical cleaning processes have been designed that can remove a large fraction of the pyritic sulfur, generally the major part of the sulfur in high-sulfur coals (Office of Technology Assessment, 1979). However, very finely disseminated pyritic sulfur associated with coal macerals cannot be removed (Rao, 1976). The sulfate sulfur content of a coal, which is present in the zone of weathering and not present in fresh-mined coal, have a lower specific gravity and are less easily removed (Averitt, 1975). The organic sulfur content is associated intimately with the coal substance and cannot be removed by washing or any physical processes (Averitt, 1975; Rao, 1976).

The potentials for sulfur reduction through mechanical means have been investigated for several coals by the U.S. Bureau of Mines (Table 5; Schmidt, 1977). It was determined that less than

Table 5. Representative sulfur contents and cleaning potentials for principal coal seams (from Schmidt, 1979; original source Cavallaro and others, 1976).

Seam	Heating value	Recoverable reserves, x 10^6 tons	Sulfur content			Percent sulfur after mechanical cleaning yield				Total sulfur at 80% yield
			Pyritic	Organic	Total	90%	80%	70%	60%	
N. Appalachian:										
Lower Kittanning	13,500	2,480	2.31	0.94	3.25	0.40	0.52	0.42	0.36	1.46
Upper Freeport	13,900	1,430	1.72	0.70	2.42	0.41	0.35	0.28	0.22	1.05
Upper Kittanning	13,700	745	0.97	0.48	1.45	0.17	0.15	0.12	0.06	0.63
Pittsburgh	14,070	4,600	2.16	1.45	3.61	1.0	0.85	0.75	0.75	2.30
S. Appalachian:										
America	13,400	310	0.93	0.78	1.71	---	0.37	0.28	0.20	1.06
Clements	13,000	210	2.83	0.94	3.77	---	1.42	1.02	0.71	2.36
Midwestern										
Illinois No.6	11,000	13,650	2.11	1.66	3.77	0.75	0.80	0.60	0.50	2.46
Kentucky No. 9	12,900	5,811	2.09	1.91	4.00	0.90	0.75	0.50	0.50	2.66
Western										
Lower Cherokee	10,900	950	1.66	0.79	2.45	0.18	0.13	0.09	0.06	0.93

30 percent of the samples tested could be reduced to 1 percent or less total sulfur, although reductions of 50 percent were found in more than half the samples. Because of the organic sulfur present and pyritic sulfur that cannot be removed by mechanical cleaning, there are few coals that can be cleaned to less than 1 percent sulfur by normal preparation methods (Schmidt, 1977).

One type of fine coal sulfur reduction coal preparation plant uses dense-medium cyclones to produce a primary coal stream of less than 0.6 percent sulfur. Another plant uses a two-stage froth flotation process to reduce pyritic sulfur by up to 90 percent (Office of Technology Assessment, 1979).

Advanced washing techniques can in some cases remove a substantial amount of sulfur beyond normal mechanical cleaning methods. Among the physical and/or chemical treatments proposed for improved pyritic sulfur removal are:

1) High-gradient magnetic separation (HGMS)---separation of pyrite by exploiting its magnetic properties.
2) Magnex process---a 'pretreatment' process allowing better magnetic separation.
3) Meyers process---a chemical leaching of pyrite from the coal.
4) Otisca process---washing with a heavy liquid rather than a water suspension.
5) Chemical comminution---a 'pretreatment' process that chemically breaks down the coal to smaller sizes (Office of Technology Assessment, 1979).

In addition, there are other processes that attack organic sulfur and remove 25 to 70 percent of it from coals and substantially all pyritic sulfur. These processes are still in the laboratory stage, but projected costs are estimated to be many times those associated with physical coal cleaning. Among these processes are:

1) Ledgemont oxygen leaching process---dissolution of pyrites and some organic sulfur using a process simulating the production of acid mine water.
2) Bureau of Mines/Department of Energy oxidative desulfurization process---a higher temperature and use of air instead of oxygen; a variation of the ledgemont process.
3) Battelle hydrothermal process---leaching of pyrites and organic sulfur under high pressure.
4) KVB process---gaseous reaction of the sulfur with nitric oxide (Office of Technology Assessment, 1979).

Other advanced coal-cleaning technologies, as summarized from the Office of Technology Assessment (1979), are listed below:

1) Solvent-refined coal (SRC) involves dissolving crushed coal in a suitable solvent at moderately high temperature and pressure, treating the solution with hydrogen to remove an appreciable part of the sulfur, filtering the hot solution to remove the insoluble coal-ash minerals, and then draining off the solvent and recovering the demineralized, low-sulfur product.
2) Low-Btu gas combined cycles. Coal can be gasified to produce a low-Btu gas. Since the gas cannot economically be stored or shipped more than a few miles before combustion, it is effectively a form of direct combustion of coal. The gas is cleaned before burning so that no emission controls are required at the combustion facility. Low-Btu gas can be burned directly in a boiler to produce steam for industrial use or for the production of electricity in a conventional steam turbine. Alternatively, the gas generator can be integrated with a combined cycle plant.

3) Fluidized bed combustion (FBC) processes are used to chemically combine sulfur in the combustion chamber, and involves the feeding of crushed coal for combustion into a bed of inert ash mixed with limestone or dolomite. The bed is fluidized (held in suspension) by injection of air through the bottom of the bed at a controlled rate great enough to cause the bed to be agitated like a boiling fluid. The coal burns within the bed, and the SO_x formed during the combustion reacts with the limestone or dolomite to form a dry calcium sulfate.

4) Magnetohydrodynamics (MHD). In MHD generators, a stream of very hot gas (roughly 5,000°F), flows through a magnetic field at high velocity. Because the gas at high temperatures is an electrical conductor, an electrical current is produced through electrodes mounted on the sides of the gas duct.

5) Fuel cells consist of two electrodes immersed in a conducting electrolyte. One electrode, the anode, is flooded with hydrogen, which reacts with ions in the electrolyte, typically a solution of potassium hydroxide, to release electrons. These electrons flow through an external circuit---the electrical load---to the cathode, flooded with oxygen, where the electrons react with the electrolyte to form the ions that can react with hydrogen. Hence, the fuel cell is simply a battery, consuming chemical reactants and producing electricity. Unlike ordinary primary batteries, however, fuel cells continue to produce electrical energy as long as hydrogen and oxygen are supplied to their anodes.

AIR POLLUTION CONTROL TECHNOLOGY

The quantity of sulfur reported in ash is less than the total in coal (Averitt, 1961). This means that a portion of the total sulfur in coal is combustible and is released into the atmosphere from power plants. There are six air pollutants that have been designated by the National Ambient Air Quality Standards (NAAQS). These are: sulfur oxides (SO_x), nitrogen oxides (NO_x), particulates, carbon monoxide (CO), hydrocarbons, and petrochemical oxidants (Office of Technology Assessment, 1979).

Oxides of sulfur are the main atmospheric transport mode for environmental contaminants of coals. Sulfur impurities are released to the atmosphere as sulfur dioxide during combustion. The basic stoichiometric chemical reaction that produces sulfur dioxide emissions is the following, where Δ equals heat produced:

$$4\ \underline{FeS_2} + 11\ O_2 \longrightarrow 2\ Fe_2O_3 + 8\ \underline{SO_2} + \Delta$$ (Wewerka and others, 1976)

The release of gaseous sulfur dioxide into the atmosphere during coal utilization has led to studies designed to find ways to reduce the amounts of these byproducts emitted (Walker and Hartner, 1966).

Figure 8 is a nomograph relating sulfur content and calorific value in coals to pounds SO_2 emission per million Btu. In using the graph to compare different coals, sample analysis results for both the Btu per pound and sulfur values must be on the same basis, that is, either on as-received, moisture-free, or moisture- and ash-free basis. Cavallaro and others (1976) cite an example of a coal containing 0.8 percent sulfur and 13,100 Btu per pound as meeting the EPA SO_2 emission standard. However, they point out that a coal of the same sulfur content but containing only 10,500 Btu per pound would produce 1.5 pounds of SO_2/MM Btu and would not be in compliance.

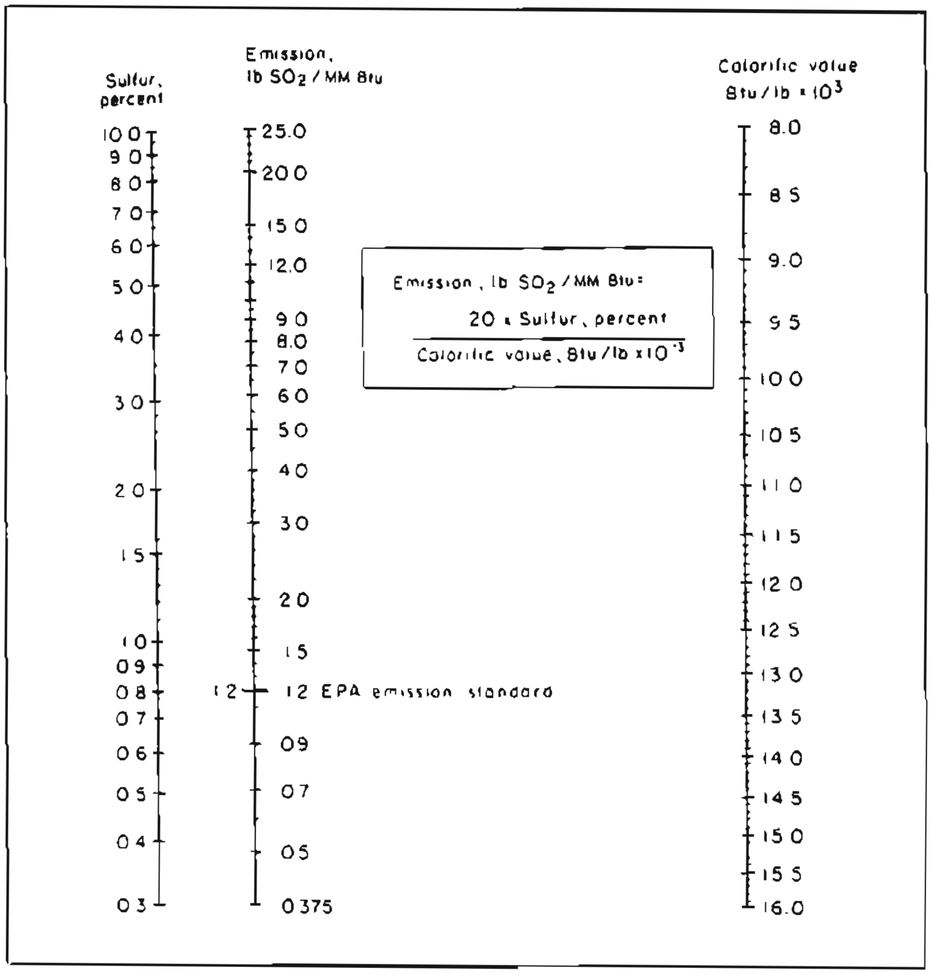

Figure 8. Nomograph relating sulfur content and calorific value in coals to pounds SO_2 emission per million Btu (from Cavallaro and others, 1976).

[The appropriate metric conversion factor is: Btu per lb x 2.326 = kJ/kg. For example, 1.2 lb SO_2 per MM Btu = 0.515 kg SO_2/million kJ.]

Emissions of sulfur dioxide pollution by Alaska coals is less than for eastern and western United States coals when burned to generate electricity. In general, all Alaskan coals containing over 8,000 Btu/lb and less than 0.5% total sulfur fall under the EPA's 1.2 lb SO_2/MM Btu emission standard (Figure 8).

The Clean Air Act of 1970, which imposed EPA's emission limits from combustion, caused the sulfur content of coal to become an increasingly important factor in coal utilization (Office of Technology Assessment, 1979). The Clean Air Amendments of 1977 established even more stringent regulations. They imposed maximum sulfur limits of 0.6 percent for coal with a heating value of 10,000 Btu/lb. For each 1,000 Btu/lb higher or lower, the permissable sulfur level changed 0.06 percent. The sulfur limit for coal with 12,000 Btu/lb is 0.72 percent, and the limit for coal with 8,000 Btu/lb is 0.48 percent. Thus, the Clean Air Amendments effectively eliminated the use of most low-sulfur U.S. coals as the sole means of compliance for new powerplants. However, many (if not most) Alaskan coals still meet these new stringent limits.

Most new plants will require the use of flue-gas desulfurization (FGD) or other new pollution control technology to reduce SO_x emissions. FGD refers to the removal of SO_x from stack gases by the use of devices commonly known as scrubbers. Scrubbers bring the SO_x-laden flue gases into contact with a liquid that selectively reacts with it (Office of Technology Assessment, 1979). A number of different types of chemical absorbents are used during FGD; these include lime, limestone, magnesium oxide, double alkali, sodium carbonate, alkali fly ash, and ammonia. FGD processes are characterized as throwaway or regenerative. The absorbent and the SO_x react to form a product (sludge or solid) of little or no market value in throwaway processes. The absorbent is recovered in a separate unit for reuse in the scrubber and a product of market value (e.g., elemental sulfur or sulfuric acid) is produced in regenerative processes (Office of Technology Assessment, 1979).

Electrostatic precipitators (ESP), which remove particulates from flue gas, are a second important type of pollution control technology widely used in large stationary combustion sources. In essence, the device charges particles in the stack gas stream and then collects them on an oppositely charged surface. ESPs that have been designed for high-sulfur fuels are adversely affected in their particulate collection efficiency by the use of low-sulfur fuels. The ash of low-sulfur coals usually has high resistivity. In these coals, the naturally formed sulfur trioxide (SO_3) is rarely sufficient to reduce the resistivity of the fly ash to a level (about 5×10^{10} ohm-cm) that permits ESPs to function normally (Office of Technology Assessment, 1979). Because high-sulfur coal has been the standard fuel for the power industry in the past, ESPs have worked well. However, with the conversion by the power industry to low-sulfur coals that comply with SO_x emission standards, redesign of ESPs and retrofitting of plants may be necessary.

SULFUR IN WORLD COALS

Table 6 summarizes sulfur forms in selected bituminous coals of the world. The total sulfur ranges from 0.38 percent to 5.32 percent. In general, most coals of the world contain significantly higher quantities of total sulfur and pyritic sulfur than do Alaskan bituminous and subbituminous coals. On the Pacific Rim, Alaska's chief trading competitors are Australia, Canada, China, and South Africa. Although these countries possess some reserves of low-sulfur coal, Alaska contains vast resources of extremely low-sulfur coal that promise to make it the most important future source of low-sulfur fuel on the Pacific Rim.

Table 6. Sulfur forms in selected bituminous coals (from Meyers, 1977; McClung and Geer, 1979).

Region and country	Location or mine	Sulfur (%) Total	Pyritic*	Organic	Ratio pyritic to organic sulfur
Asia					
U.S.S.R.	Shakhtersky	0.38	0.09	0.29	0.031
China	Taitung	1.19	0.87	0.32	2.7
India	Tipong	3.63	1.59	2.04	0.78
Japan	Miike	2.61	0.81	1.80	0.45
Malaysia	Sarawak	5.32	3.97	1.35	2.9
N. America					
U.S.	W. Virginia	1.20	0.27	0.93	0.29
Canada	Eagle No. 2	4.29	2.68	1.61	1.7
	Fernie	0.60	0.03	0.57	0.053
Europe					
Italy	Istria	9.01	1.11	7.90	0.14
Germany	---	1.78	0.92	0.76	1.2
Germany	---	3.15	0.09	3.06	0.01
Germany	---	4.77	0.20	4.57	0.03
U. Kingdom	Derbyshire	2.61	1.74	0.87	1.8
U. Kingdom	Tamworth	4.30	2.43	1.87	1.13
U. Kingdom	Parkgate	3.15	2.79	0.36	7.53
U. Kingdom	Anthracite	1.06	0.83	0.23	3.26
Poland	---	0.81	0.30	0.51	0.59
Czechoslovakia	Bohemia	0.76	0.30	0.46	0.59
Africa					
S. Africa	Natal	1.51	0.54	0.97	0.48
S. Africa	Transvaal	1.39	0.69	0.70	0.84
S. Africa	Transvaal	0.44	0.07	0.37	0.16
Australia	Lower Newcastle	0.94	0.15	0.79	0.19
S. America					
Brazil	---	2.39	1.89	0.50	3.56
Brazil	Santa Caterina	1.32	0.79	0.53	1.5

*Pyritic + sulfate reported as pyritic.

AUSTRALIAN COALS

Australia contains the fourth largest resources of coal in the world. The country contains as many as 30 coal-bearing basins. Much of the available data on Australian coals indicate that they are commonly low sulfur.

(1) Martin (1908) cited data on coal from the state of New South Wales.

Table 7. Sulfur content of New South Wales, Australia coals.

Region	No. of samples	Total sulfur (%)
Southern	21	0.46
Western	13	0.63
Northern	77	0.54

(2) Edwards and Vitnell (1978) cited data for Hunter Valley, Australia coals. Typical high quality steaming coal (low ash and high calorific value) contains 0.6 percent total sulfur on an air-dried basis. The total sulfur is comprised of 0.45 percent organic sulfur, 0.10 percent pyritic sulfur and 0.05 percent sulfate sulfur. Typical high-quality coking coal (low ash and high volatile matter) from Hunter Valley contains 0.5 percent total sulfur on an air-dried basis.

(3) Svenson (1979) listed total sulfur specifications for various Australian coking coals.

Table 8. Australian coking-coal sulfur specifications.

Coal	Total sulfur (%)
Gregory	0.80
Norwich Park	0.65
German Creek	0.80
Hail Creek	0.40
South Blackwater	0.50
Moura	0.45
Bulli Seam, Burragorang, NSW	0.45
Oaky Creek	0.85
Curragh	0.57

(4) The U.S. Department of Energy (1980) listed sulfur contents for several Australian coal basins.

Table 9. Range in total sulfur for Australian coal basins.

State	Basin	Total sulfur(%)
New South Wales	Sydney	0.4-0.7
Queensland	Bowen	0.3-0.8
	Clarence-Moreton	0.4-0.7
	Galilee	0.6

(5) Hunt and Hobday (1984) compared the sulfur contents of coals of two Australian basins.

Table 10. Sulfur content of coals of Permian Sydney and Gunnedah basins, eastern Australia.

Basin and age	Coal measures	Sulfur content (%daf)
Sydney Basin (Late Permian)	Newcastle Coal Measures	Low (<0.55) to medium (1.0)
	Tomago Coal Measures	Medium to high (0.55 to >1.0)
Gunnedah Basin (Early Permian)	Maules Creek Formation	Low (<0.55)

CANADIAN COALS

Canada contains the fifth largest resources of coal in the world. The main coal-bearing region occupies a belt across southern Saskatchewan, Alberta, and British Columbia. The sulfur content of Canadian coals appears variable but typically low.

(1) Martin (1908) cited the sulfur content of some British Columbian coals.

Table 11. Average total sulfur of British Columbia, Canada coals.

Location	No. of samples	Total sulfur(%)
Crows Nest Pass	10	0.37
Comox	9	1.54
Nanaimo	6	0.64

(2) Williams and Ross (1979) cited an as-received total sulfur content of 0.63 percent for bulk and drill-core samples of the upper coal, Tulameen coal field, south-central British Columbia, Canada.

(3) The U.S. Department of Energy (1980) listed general total sulfur contents of British Columbia and Alberta coals.

Table 12. Average total sulfur of coals of various regions of British Columbia and Alberta, Canada.

State	Region	Sulfur(%)
British Columbia	Southeast	0.5
	Northeast	0.5
Alberta	Inner Foothills	0.6
	Outer Foothills	0.5
	Plains	0.5

(4) Nurkowski (1984) listed the range and average total sulfur content of Albertan coals.

Table 13. Sulfur contents of Upper Cretaceous and Tertiary Plains coals, Alberta, Canada.

Rock unit	No. of samples	Sulfur (%), dry basis		
		Minimum	Maximum	Mean
Scollard Member	199	0.15	1.79	0.39
Horseshoe Canyon Fm.	358	0.03	2.80	0.47
Belly River Group	41	0.33	1.19	0.66
Wapiti Formation	49	0.11	0.95	0.32

COALS OF PEOPLE'S REPUBLIC OF CHINA

The People's Republic of China contains the third largest resources of coal in the world, only surpassed by the resources of the United States and U.S.S.R. Available data on Chinese coals is sparse, but Aughenbaugh and others (1982) state that Carboniferous-age coals are high sulfur, while Permian and Jurassic coals are typically low sulfur. Argall (1983) gives the sulfur content of coals in several districts (Table 14).

Table 14. Sulfur contents of certain coals of the People's Republic of China.

Mining district	Province	Sulfur(%)
Panxie	Huainan, Anhui	<1.0
Huatong	Gansu	0.56
Xiangaing (No. 10)	Shanxi	4.0-6.0
Shenmu	Shanxi	0.27-0.88

SOUTH AFRICAN COALS

South Africa has been an important coal-producing and coal-exporting country of the world. The sulfur contents of South African coals is variable but typically medium sulfur (U.S. Department of Energy, 1980).

Table 15. Total sulfur content of South African coals (from U.S. Department of Energy, 1980).

State	Sulfur(%)
Transvaal	1.0-2.0
Natal	0.5-3.0
Orange Free	1.0-2.0

SULFUR IN U.S. COALS

The United States holds about 30 percent of world coal resources, with perhaps as much as half of this amount concentrated in the state of Alaska alone. Western U.S. coal is generally low sulfur, whereas Eastern and Midwestern coals are typically high sulfur. Alaska contains the lowest-sulfur coals of the U.S. and the world. Tables 16-24 summarize total sulfur and sulfur forms of U.S. coals excluding Alaska.

Table 16. Sulfur content of U.S. coals by rank (from the U.S. Bureau of Mines, 1954).

Rank Class	Rank Group	State	County	Sulfur(%)
I. Anthracitic	1. Meta-anthracite	Pa.	Schuylkill	0.77
	2. Anthracite	Pa.	Lackawanna	0.60
	3. Semianthracite	Va.	Montgomery	0.62
II. Bituminous	1. Low volatile bituminous	W.V.	McDowell	0.74
		Pa.	Cambria	1.68
	2. Medium volatile bituminous	Pa.	Somerset	1.68
		Pa.	Indiana	2.20
	3. High volatile A bituminous	Pa.	Westmoreland	1.82
		Ky.	Pike	0.70
		Ohio	Belmont	4.00
	4. High volatile B bituminous	Ill.	Williamson	2.70
		Utah	Emery	0.90
	5. High volatile C bituminous	Ill.	Vermilion	3.20
III. Subbituminous	1. Subbituminous A	Mont.	Musselshell	0.43
	2. Subbituminous B	Wyo.	Sheridan	0.30
	3. Subbituminous C	Wyo.	Campbell	0.55
IV. Lignitic	1. Lignite A	N.D.	Mercer	0.40

Table 17. Sulfur content of U.S. coals by rank and on different bases (from Slatjck, 1980).

Classification by rank	State	County	Coal bed	Total sulfur(%) 1	2	3
Meta-anthracite	R.I.	Newport	Middle	0.3	0.3	0.4
Anthracite	Pa.	Lackawanna	Clark	0.8	0.8	0.9
Semianthracite	Ark.	Johnson	L. Hartshorne	1.7	1.8	1.9
Low-volatile bituminous coal	W.V.	Wyoming	Pocahontas No. 3	0.8	0.8	0.8
Medium volatile bituminous coal	Pa.	Clearfield	Upper Kittanning	1.0	1.1	1.1
High-volatile A bituminous coal	W.V.	Marion	Pittsburgh	0.8	0.8	0.8
High-volatile B bituminous coal	Ky. (west)	Muhlenburg	No. 9	2.8	3.0	3.4
High-volatile C bituminous coal	Ill.	Sangamon	No. 5	3.8	4.4	5.0
Subbituminous A coal	Wyo.	Sweetwater	No. 3	1.4	1.7	1.8
Subbituminous B coal	Wyo.	Sheridan	Monarch	0.5	0.6	0.6
Subbituminous C coal	Colo.	El Paso	Fox Hill	0.3	0.4	0.5
Lignite	N.D.	McLean	Unnamed	0.9	1.4	1.6

Basis: 1-As received; 2-Moisture free; 3-Moisture and ash free.

Table 18. Total sulfur content of various U.S. coals compiled from the data sources listed.

Deposit/bed	Total sulfur,% (as received)	Data source
Wasatch Plateau	0.56	Vaninetti, 1979
San Miguel lignite	1.47	Snedden and Kersey,1981
Wilcox-East	0.81	do.
Wilcox-Central	1.00	do.
Itman	0.80	Svenson, 1979
Pittston	0.68	do.
Tono, Washington/Tono	0.42	Evans, 1916
Mendota, Washington/Mendota	1.28	do.
Sheridan, Wyoming/Monarch	0.31	do.
Miles City, Montana/Mt. Kircher	0.68	do.
Miles City, Montana/Mt. Weaver	0.55	do.
Glendive, Montana/Snyder Mine	1.33	do.
Rosebud, Montana/Rosebud	0.41	do.
Pennsylvania anthracites (average 9)	0.59	Martin, 1908
Loyalsock, Pennsylvania semianthracite (avg. 4)	0.86	do.
Pocahontas, W.V. 'semibituminous'(avg. 38)	0.62	do.
Georges Creek, Maryland 'semibituminous'(avg. 53)	1.01	do.
Connellsville, Pennsylvania bituminous (avg. 3)	0.81	do.
Fairmont, W.V. bituminous (average 63)	2.30	do.
Washington		
Wilkeson (avg. 7)	1.42	do.
Cokedale (avg. 3)	0.34	do.
Blue Canyon (avg. 3)	0.53	do.
Carbonado (avg. 15)	0.94	do.
Roslyn (avg. 9)	0.24	do.
Franklin (avg. 5)	0.15	do.
Renton (avg. 10)	0.61	do.
Newcastle (avg. 5)	0.48	do.
Black Diamond (avg. 4)	0.44	do.
Oregon Coos Bay (avg. 4)	1.02	do.

Table 19. Total sulfur (%, dry basis) of Rocky Mountain region coal samples (from Eliot, 1978).

Category	Rank	State	No. of analyses	Avg. % wt. dry
I.	Bituminous	Arizona	13	0.79
		Colorado	561	0.78
		Montana	110	2.16
		N. Mexico	89	0.97
		Utah	231	0.83
		Wyoming	206	0.71
II.	Subbituminous	Arizona	8	1.32
		Colorado	171	0.49
		Montana	136	1.19
		N. Mexico	14	0.78
		Utah	12	1.90
		Wyoming	185	0.70
III.	Lignite	Montana	65	0.94
		N. Dakota	144	0.98

Table 20. Total sulfur (%, as-received basis) in Appalachian coal fields (from Steele and others, 1983).

Coal fields	Total sulfur range
Pittsburgh-Huntington	1.5-4.0
Pocahontas	0.4-1.5
Central Appalachian	0.5-2.0
Chattanooga Plateau	1.5-3.5
Black Warrior Basin	0.9-2.5
Anthracite Basins	0.5-1.5

Table 21. Typical total sulfur content of Gulf Coast U.S. lignites by group and location (modified from Luppens, 1979).

Group	State	Region	Sulfur,% (as-received)
Wilcox	Texas	Northeast	0.59
		Central	0.93
	Louisiana	---	0.71
	Arkansas	Southwest	0.53
		Northeast	0.60
	Mississippi	Northern	0.54
		Southern	1.17
	Alabama	Western	2.65
		Central	2.08
Claiborne	Arkansas	Southwest	0.98
	Tennessee	---	0.59
	Mississippi	---	0.54
Claiborne/ Jackson	Texas	Central	1.20
Wilcox/ Claiborne/ Jackson	Texas	Southwest	1.67

Table 22. Comparison of the sulfur content of Gulf Coast and North Dakota lignites (from Luppens, 1979).

Group	Location	Sulfur (%, prox. analysis, as-rec.)	Sulfur (%, ult. analysis, dry)
Wilcox	Central Texas	0.93	1.36
Claiborne	Mississippi	0.54	0.92
Lignites	North Dakota	0.48	0.80

Table 23. Forms of sulfur in various U.S. coals (from McClung and Geer, 1979).

Location of mine	Coal seam	%, Moisture-free basis Total sulfur	Pyritic sulfur	Organic sulfur	Org. sulfur as % of total sulf.
Washington Co., Pennsylvania	Pittsburgh	1.13	0.35	0.78	69.0
Clearfield Co., Pennsylvania	Upper Freeport	3.56	2.82	0.74	20.8
Allegheny Co., Pennsylvania	Thick Freeport	0.92	0.46	0.45	48.9
Somerset Co., Pennsylvania	B	0.78	0.19	0.57	73.1
Somerset Co., Pennsylvania	C prime	2.00	1.43	0.54	27.0
Clearfield Co., Pennsylvania	B	1.90	1.12	0.75	39.5
Cambria Co., Pennsylvania	Miller	1.25	0.56	0.65	52.0
Franklin Co., Illinois	No. 6	2.52	1.50	1.02	40.5
Franklin Co., Illinois	No. 6	1.50	0.81	0.69	46.0
Montgomery Co., Illinois	No. 6	4.97	2.53	2.40	48.3
Williamson Co., Illinois	No. 6	4.01	2.17	1.80	44.9
Union Co., Kentucky	No. 9	3.28	1.05	2.23	68.0
Union Co., Kentucky	No. 9	3.46	1.65	1.81	52.3
Webster Co., Kentucky	No. 12	1.48	0.70	0.78	52.7
Pike Co., Kentucky	Freeburn	0.46	0.13	0.33	71.7
Letcher Co., Kentucky	Elkhorn	0.68	0.13	0.51	75.0
McDowell Co., West Virginia	Pocahontas No. 3	0.55	0.08	0.46	83.6
Boone Co., West Virginia	Eagle	2.48	1.47	1.01	40.7
Walker Co., Alabama	Pratt	1.62	0.81	0.81	50.0
Jefferson Co., Alabama	Pratt	1.72	0.97	0.72	41.9
Jefferson Co., Alabama	Mary Lee	1.05	0.33	0.69	65.7
Clay Co., Indiana	No. 3	3.92	2.13	1.79	45.7
Cumnock, N. Carolina	Deep River	2.32	1.52	0.80	34.5

Table 23 (con.)

Location of mine	Coal seam	%, Moisture-free basis Total sulfur	Pyritic sulfur	Organic sulfur	Org. sulfur as % of total sulf.
Cumnock, N. Carolina	Deep River	2.08	1.53	0.55	26.4
Allegheny Co., Maryland	Big Vein	0.86	0.18	0.67	77.9
Meigs Co., Ohio	8-A	2.51	1.61	0.86	34.3

Table 24. Forms of sulfur for Rocky Mountain region coals (modified from Eliot, 1978).

Rank	Average values sulfur, wt. % dry basis Total	Pyritic	Organic
Bituminous	0.92 (1210)	0.29 (261)	0.60 (261)
Subbituminous	0.80 (527)	0.22 (168)	0.53 (168)
Lignite	0.96 (221)	0.15 (28)	0.58 (28)

( )= No. of analyses

SULFUR IN ALASKA COALS

Compared to other United States coals, Alaska coals are characterized by relatively low sulfur (Affolter and others, 1981). Indeed, the chief attraction of Alaskan coals is their extremely low sulfur, which is generally less than 0.5 percent or about half the sulfur content of Powder River Basin coals (Sanders, 1983). Analyses of Alaskan coals indicate that they nearly all fall into the low-sulfur category. Typically, in an unweathered sample of most Alaskan coals, the organic sulfur content occurs in the highest proportion. Alaskan coals contain very little or no pyritic sulfur.

Cleaning of Alaska coals for sulfur is generally not required. The organically combined variety of sulfur present in Alaska coals is difficult to remove. Reduction in sulfur is significant only in those few coals with sulfur contents over 1 percent, such as the medium sulfur coal from the Jarvis Creek field (Rao and Wolff, 1979a). In these coals, a percentage of the coarse-grained massive pyrite can be removed using standard specific gravity techniques.

Figure 9 compares the total sulfur contents of typical low sulfur Alaskan coals to other coals of the conterminous United States. Table 25 summarizes the total sulfur content of selected Alaskan coals of different rank.

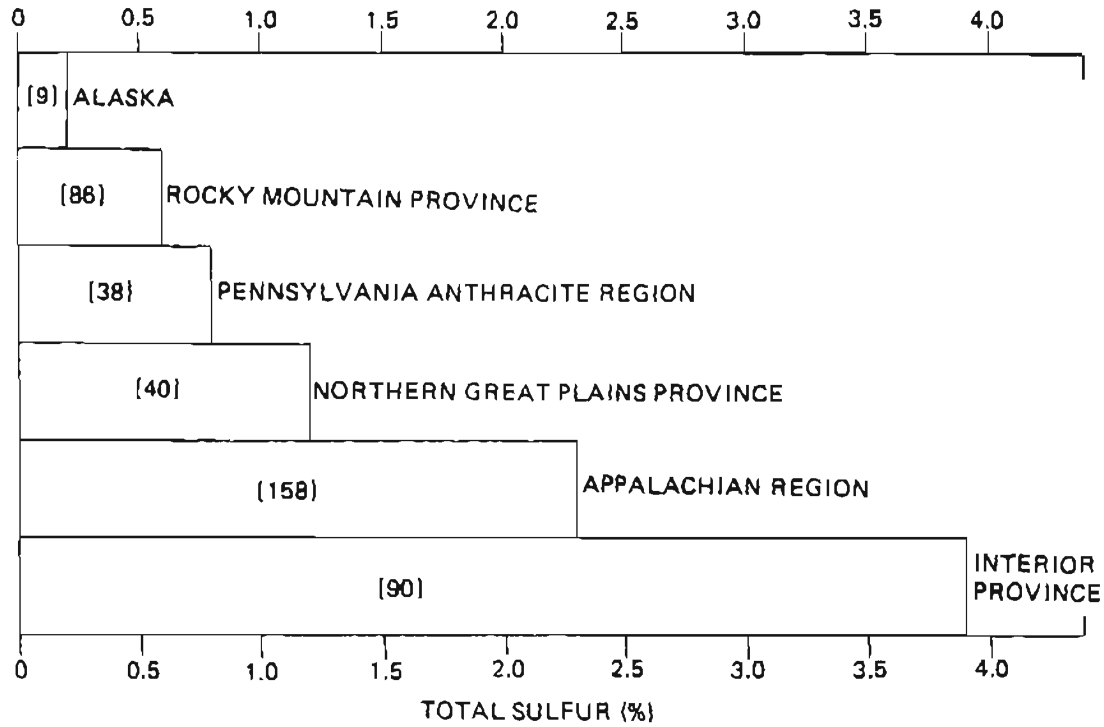

Figure 9. Comparison of total sulfur of typical low-sulfur Alaskan coal with other coals of the conterminous United States (from data in Swanson and others, 1975).

Table 25. Sulfur content of various Alaskan coals by rank (as received basis).

Coal rank: Class	Coal rank: Group	Region/ Coal field	Total sulfur(%)
I. Anthracitic	1. Meta-anthracite	Anthracite Ridge/ Matanuska	0.30
	2. Anthracite	Bering River	1.30
	3. Semianthracite	Anthracite Ridge/ Matanuska	0.60
II. Bituminous	1. Low-volatile bituminous	a. Bering River	0.78
		b. Chickaloon, Matanuska	0.70
	2. Medium-volatile bituminous	a. Coal Creek, Matanuska	0.43
		b. Lisburne	0.95
	3. High-volatile A bituminous	a. Castle Mtn., Matanuska	0.46
		b. Nulato	0.50
		c. Chignik	1.30
	4. High volatile B bituminous	a. Kukpowruk	0.28
		b. Tramway Bar	0.15
	5. High-volatile C bituminous	Wishbone Hill, Matanuska	0.50
III. Subbituminous	1. Subbituminous A	Herendeen Bay	0.60
	2. Subbituminous B	Wainwright, Northern Alaska	0.28
	3. Subbituminous C	Beluga	0.20
IV. Lignite	1. Lignite A	Unga Island	0.50

NORTHERN ALASKA PROVINCE

Northern Alaska Fields

The coal resources of the Northern Alaska fields, which are among the largest in the world, occur in the Nanushuk and Colville Groups. The coals formed in prograding deltaic depositional systems in swampy coastal lowlands. The coal-bearing strata are flat-lying to gently dipping. Coals of the Foothill's subprovince are typically high volatile C bituminous, 10,000-13,500 Btu/lb, 4-15 percent ash, and 0.1-0.3 percent sulfur. Coals of the Coastal Plains' subprovince are typically subbituminous B, 7,700-10,700 Btu/lb, 3-20 percent ash, and 0.2-0.8 percent sulfur. Seams less than 5-ft thick are characteristic, but beds 15- to 40-ft thick are not uncommon. Identified resources are 150 billion short tons and hypothetical resources are 4 trillion short tons. Much of the coal is located in the National Petroleum Reserve of Alaska (NPRA) but major deposits exist both east and west of NPRA.

Detailed sulfur data on coals of the Northern fields are summarized below:

(1) Martin (1908); Crane (1913)

Table 26. Sulfur content of Northern Alaska coals.

Location	Rank	Total sulfur(%)
Anaktuvuk River	Subbituminous	0.54
Wainwright	Lignite	0.62
Colville River	Lignite	0.50

(2) Cooper and others (1946)

Table 27. Average total sulfur of Northern Alaska coals on different bases.

Basis*	No. of samples	Avg. total sulfur(%)
1	16	0.4
2	16	0.5
3	9	0.6

*1-As received; 2-Dried at 105°C; 3-Moisture and ash free.

(3) Boley (1965)

Table 28A. Sulfur content of composite samples of Kokolik, Alaska coals.

Coal	Composite Blend No.	Total sulfur(%)	
		As received basis	Maf basis
Kokolik	1	0.4	0.4
	2	0.4	0.4
	3	0.3	0.4
	4	0.3	0.3
	5	0.3	0.3
	6	0.3	0.3

Table 28B. Sulfur content of composite samples of Kokolik, Alaska coals carbonized at 900°C-925°C (as carbonized).

Coal	Composite Blend No.	Total sulfur(%)
Kokolik	1	0.3
	2	0.4
	3	0.4

(4) Barnes (1967a)

Table 29. Sulfur content of Northern Alaska coals by rank.

Location	Rank	Total sulfur(%)
Kukpowruk River	Bituminous	0.2-0.3
Kokolik and Utukok Rivers	Bituminous	0.2-0.6
Kuk and Kugrua Rivers	Subbituminous	0.2-0.3
Meade and Ikpikpuk Rivers	Subbituminous	0.2-0.8
Meade and Ikpikpuk Rivers	Bituminous	0.7
Colville River	Subbituminous and bituminous	0.3-0.7

(5) Barnes (1967b)

Table 30. Sulfur content of Northern Alaska coals by geologic formation.

Location	Formation	No. of samples	Rank	Total sulfur(%)
Kukpowruk Rr.	Corwin	4	Bituminous	0.3
Kokolik Rr.	do.	3	do.	0.2
Utukok Rr.	do.	3	Bit.-subb.	0.3
Elusive Ck.	do.	1	Bituminous	0.3
Ketik Rr.	do.	1	Bit.-subb.	0.3
Kuk Rr.	Chandler(?)	2	Subbituminous	0.2
Kugrua Rr.	do.	1	do.	0.3
Meade Rr.	Chandler	2	Bit.-subb.	0.6
Kigalik Rr.	do.	2	Subbituminous	0.2
Ikpikpuk Rr.	do.	1	Bit.-subb.	0.8
Colville Rr.	do.	3	Bituminous	0.4
Kurupa Rr.	do.	2	do.	0.4
Oolamnagavik Rr.	do.	1	do.	0.4
Killik Rr.	do.	1	Subbituminous	0.3
Chandler Rr.	Prince Ck.	1	Bituminous	0.3
Anaktuvuk Rr.	do.	1	Bit.-subb.	0.7

(6) Rao (1976) cited a range of total sulfur of 0.14-0.46 percent and an average total sulfur of 0.28 percent for 12 Kukpowruk River high-volatile B bituminous coal samples.

(7) The Alaska Division of Energy and Power Development (1977) cited a range in total sulfur of 0.3-0.7 percent for the Cretaceous-age bituminous coals of the Foothills' subprovince and 0.2-0.7 percent for subbituminous coals of the Coastal Plains' subprovince.

(8) McFarland (1978) cited a range in total sulfur of 0.2-0.7 percent for the subbituminous and bituminous coals of the Northern Alaska fields.

(9) Martin and Callahan (1978) found that NPRA coals were low sulfur, with as-received samples showing values of less than 1.0 percent and the majority of the samples showing less than 0.5 percent sulfur.

Table 31. Summary of total sulfur data for NPRA coals.

Rank of samples	No. of samples	Average total sulfur(%)		
		1	2	3
Bituminous	13	0.3	0.3	0.4
Subbituminous	17	0.3	0.3	0.4
Lignite	1	0.7	1.0	1.3

Basis: 1-As received; 2-Moisture free; 3-Moisture and ash free.

(10) The Committee on Alaskan Coal Mining and Reclamation (COACMAR, 1980) stated that Arctic coastal plain coals were low-sulfur bituminous, and that Brooks Range foothills' coals averaged 0.6 percent total sulfur.

(11) Rao (1980) gave an average total sulfur of 0.22 percent (bed moisture basis) and 0.30 percent (dry, ash-free basis) for 47 Cape Beaufort region samples.

(12) U.S. Department of Energy (1980)

Table 32. Sulfur content of western Arctic Alaska coals.

Location	Total sulfur(%)
Kukpowruk River	0.2-0.3
Utukok River	0.2-0.6
Kuk River	0.2-0.3

(13) Rao and Wolff (1980); Rao and Wolff (1981)

Table 33. Pyritic and total sulfur contents of Northern Alaska coals.

Seam	Rank	Pyritic sulfur(%)			Total sulfur(%)		
		1	2	3	1	2	3
Wainwright	subB	0.08	0.10	0.10	0.28	0.35	0.35
Meade River	subB	0.06	0.07	0.08	0.43	0.53	0.55
Sagwon Bluffs	hvCb	0.04	0.05	0.14	0.06	0.07	0.20

Basis: 1-Equilibrium bed moisture; 2-Moisture free; 3-Moisture and ash free.

(14) Knutson (1981) cited a total sulfur content of 0.25 percent for Kukpowruk River bituminous coal.

(15) Sanders (1981)

Table 34. Range in total sulfur of several Northern Alaska coals.

Location	Total sulfur(%)
Kukpowruk River	0.2-0.3
Kuk River	0.2-0.3
Meade River	0.2-0.8

(16) Affolter and others (1981a,b) found that Utukok River quadrangle coals of subbituminous C to high-volatile A bituminous rank were significantly lower in total sulfur contents than Powder River region coals.

Table 35A. Average total sulfur for 24 Utukok River quadrangle coals (from Affolter and others, 1981a).

Basis*	Total sulfur(%)
1	0.3
2	0.3
3	0.3

*1-As received; 2-Moisture free; and 3-Moisture and ash free.

Table 35B. Statistical comparison of total sulfur in Utukok River quadrangle coals with Powder River region coals (from Affolter and others, 1981b).

Statistic	Total sulfur(%)
Arithmetic mean	0.3
Observed range:	
Minimum	0.2
Maximum	0.5
Geometric mean	0.3
Geometric deviation	1.3
Powder River region geometric mean	0.5

(17) Callahan and Martin (1981) stated that the low sulfur content of most Corwin Formation coals suggested that they were isolated from marine and brackish water influences as might be expected in an upper delta plain or flood plain environment. They found that Corwin Formation coals in the Wainwright area were overall low in sulfur, but that the sulfur content of coals lower in the stratigraphic sequence had somewhat higher sulfur values (0.4 to 1.4 percent in the lower 1000 ft) compared to coals higher in the formation (0.2 to 0.9 percent in the upper 1300 ft).

Table 36. Analysis of total sulfur in core samples of Northern Alaska.

Location	Drill hole	Coal bed	No. of samples	Average total sulfur(%) 1	2	3
Cape Beaufort	72-3C	7	8	0.2	0.2	0.3
	72-7C	7	5	0.2	0.3	0.3
	72-10C	7	6	0.2	0.2	0.3
	72-8C	8	6	0.3	0.3	0.4
Lookout Ridge,	---	3	17	0.2	0.3	0.3
Oxbow Syncline	---	5	22	0.2	0.2	0.2

Basis: 1-As received; 2-Moisture free; and 3-Moisture and ash free.

(18) Rao and Wolff (1982) gave sulfur data for the Cape Beaufort No. 7 seam of high-volatile C bituminous rank.

Table 37. Total and pyritic sulfur of Cape Beaufort No. 7 seam.

Basis*	Pyritic sulfur(%)	Total sulfur(%)
1	0.02	0.25
2	0.02	0.28
3	0.03	0.37

*1-Equilibrium bed moisture; 2-Moisture free; and 3-Moisture and ash free.

(19) Sanders (1983) listed an average total sulfur of Arctic coastal plain, North Slope, coal of 0.5 percent.

(20) Rao and Smith (1983)

Table 38. Summary of the total sulfur content of various Northern Alaska coals.

Location	No. of samples	Average total sulfur(%) 1	2
Corwin Bluff	24	0.3	0.4
Cape Beaufort	13	0.2	0.3
Kukpowruk River	11	0.3	0.3
West Utukok River	13	0.4	0.4
Kokolik River	13	0.4	0.4
Archimedes Ridge	3	0.5	0.7
Elusive Creek	13	0.3	0.3
Central Utukok River	13	0.4	0.4
East Utukok River	5	0.2	0.3
Lookout Ridge	8	0.3	0.4
Tunalik Test Well	8	0.4	0.5
Kuk River	1	0.3	0.5
Peard Bay Test Well	4	0.7	1.0

Basis: 1-Equilibrium bed moisture; 2-Dry, ash-free.

(21) Affolter and Stricker (1985) stated that the sulfur values of coals of the Cretaceous Corwin and Chandler Formations, NPRA, were extremely low (0.1%).

(22) Arctic Slope Consulting Engineers (1986) cited a range in total sulfur contents of 0.1 to 0.3 percent for Western Arctic Alaska coals. This included coal from Deadfall Syncline which contained about 0.03 percent pyritic sulfur.

Lisburne Field

The Lisburne field contains coals in the Mississippian-aged Kapaloak Formation of the Lisburne Group. The geologic structure of the field is fairly complex with most coal beds deformed and broken by faults. Coals are predominantly of low-volatile bituminous to semianthracite in rank, 11,500-14,750 Btu/lb, 2-18 percent ash, and 0.4-0.8 percent sulfur. Seams are typically less than 6-ft thick.

Detailed sulfur data on coals of the Lisburne field are summarized below:

(1) Brooks (1902) cited a total sulfur value for bituminous coals of 0.36 percent.

(2) Martin (1908) cited an average total sulfur for 3 'semibituminous' coals of 0.96 percent and 0.35 percent for 11 subbituminous coals.

(3) Crane (1913) quoted the data from Martin (1908).

(4) Coffin (1919) cited only the average total sulfur of 0.96 for 3 'semibituminous' samples from Martin (1908).

(5) Tailleur (1965) listed averaged total sulfur values of 7 samples as 0.7 percent (as-received basis), 0.7 percent (moisture-free basis), and 0.8 percent (moisture and ash free basis).

(6) Warfield (1967) quoted total sulfur of 0.96 percent from Martin (1908).

(7) Conwell and Triplehorn (1976) reported the total sulfur of two beds on as-received basis as: Kukpuk River bed---0.2 percent and Cape Thompson bed of 1.2 percent.

COOK INLET-SUSITNA PROVINCE

The Cook Inlet-Susitna province includes the Matanuska, Kenai, Beluga, Yentna, Little Susitna, and Broad Pass fields. This coal province contains the second largest resource of coal in Alaska. Coals of this region are all characterized by very low sulfur.

Matanuska Field

Coals of the Matanuska field occur in the Chickaloon Formation (Paleocene-early Eocene) of the Matanuska Valley in southcentral Alaska. Coal-bearing strata are moderately to complexly folded and faulted; beds range in dip from 7° to overturned but usually are 20° to 65°. Coal rank increases eastward in Matanuska Valley throughout the three main coal districts. Wishbone Hill district coal is high volatile B bituminous, 10,400 to 13,200 Btu/lb, 4-22 percent ash, and 0.2-1.0 percent sulfur. Chickaloon district coal is low-volatile bituminous, 11,960-14,400 Btu/lb, 5-20 percent ash, and 0.4-0.7 percent sulfur. Anthracite Ridge district coal is semianthracite, 10,720-14,000 Btu/lb, 7-20 percent ash, and 0.2-0.7 percent sulfur. Seams range from 2 to 38 ft thick. Identified resources are 150 million short tons and hypothetical resources are 500 million short tons. Past production was 7.5 million tons.

Detailed sulfur data on coals of the Matanuska field are summarized below:

(1) Stone (1905) cited total sulfur for a Matanuska River sample at 0.89 percent.

(2) Griffith (1906)

Table 39. Sulfur content of various Matanuska field coals (as-received basis).

Location	Total sulfur(%)
Moose Creek	0.251
Eska Creek	0.430
N. side of Matanuska River, 3 mi. west of Hicks Creek(2)	0.510 0.439

Table 39 (con.)

Location	Total sulfur(%)
Kings River	0.517
Chickaloon, No. 1 bed	0.549
Chickaloon, No. 2 bed	0.801
Chickaloon, No. 3 bed	0.588
Chickaloon, No. 4 bed	0.526
Equal portions of beds Nos. 2 and 3 after washing	0.689
Matanuska River, south bank	0.341
Coal Creek, lower bed	0.437
Coal Creek, upper bed	0.457

(3) Martin (1906)

Table 40. Total sulfur of selected Matanuska Valley samples.

Location	Sulfur(%)
Between Boulder and Hicks Creeks (anthracite)	0.57
Chickaloon River (avg. 5)	0.67
Coal Creek (avg. 6)	0.42
Kings River (avg. 3)	0.67
Young Creek	0.58
Eska Creek	0.42
Tsadaka Creek	0.32

(4) Martin (1908)

Table 41. Average total sulfur of Matanuska Valley coals by rank.

Rank	No. of samples	Average total sulfur(%)
Anthracite	1	0.57
'Semibituminous'	16	0.57
Subbituminous	4	0.37

(5) Crane (1913a,b) quoted data from Martin (1906) and Martin (1908).

(6) Coffin (1919) quoted data from Martin (1908).

(7) Chapin (1920) reported results of U.S. Navy tests on Matanuska Valley coal. In 1914, 586 tons of coal from Chickaloon was tested aboard the U.S.S. Maryland and found suitable for naval use. General analysis of the coal showed 0.49 percent total sulfur. Chickaloon coal was also used in coking tests; the resulting coke showed 0.57 percent total sulfur.

Table 42. Total sulfur(%) of Eska Creek coals.

Bed	Basis* 1	2	3	4
Eska	0.37	0.38	0.39	0.48
Emery	0.33	0.34	0.35	0.39
Maitland	0.39	0.41	0.42	0.54
Maitland (lower bench)	0.44	0.65	0.46	0.50
Kelly (upper bench)	0.40	0.41	0.42	0.46
Kelly (lower bench)	0.54	0.55	0.55	0.61
David	0.52	0.53	0.35	0.85

*1-As received; 2-Air dried; 3-Moisture free; 4-Moisture and ash free.

(8) Evans (1925) compared the total sulfur content of Matanuska Valley and Pennsylvania anthracite. He listed average total sulfur of Matanuska anthracite at 0.57 percent and of Pennsylvania anthracite at 0.59 percent.

Table 43. Range and average total sulfur of Matanuska Valley coals by area.

Area	No. of samples	Range total sulfur(%)	Average total sulfur(%)
Chickaloon River	5	0.46-0.90	0.67
Matanuska River	2	0.34-0.37	0.36

Table 43 (con.)

Area	No. of samples	Range total sulfur(%)	Average total sulfur(%)
Coal Creek	4	0.44-0.50	0.46
Kings River	3	0.52-0.89	0.67
Young Creek/ Red Mountain	2	0.23-0.58	0.40
Eska Creek	2	0.41-0.42	0.42
Moose Creek	2	0.25-0.38	0.32

(9) Richards and Waring (1933)

Table 44. Comparison of total sulfur in Matanuska Valley coals by rank.

Rank	No. of samples	Average total sulfur(%)
Semianthracite	12	0.5
'Semibituminous'	3	0.7
Bituminous	6	0.6

(10) Waring (1934)

Table 45. Sulfur contents of coal from Jonesville and Moose Creek areas, Wishbone Hill district, Matanuska Valley.

Source of sample	Total sulfur(%)		
	1	2	3
Evan Jones mine	0.2	0.2	0.2
Premier mine	0.2	0.2	0.2
Moose Creek area:			
Drill hole 1 (depth 57 ft; coal veinlets)	0.3	0.3	0.4
Drill hole 2 (depth 320 ft; coal lense)	0.2	0.2	0.2
Drill hole 2 (depth 1,010 ft; coal lense)	0.4	0.4	0.5

Basis: 1-As received; 2-Moisture free; 3-Moisture and ash free.

(11) Waring (1936)

Table 46. Average total sulfur of 30 Anthracite Ridge district samples.

Basis*	Sulfur(%)
1	0.5
2	0.5
3	0.6

*1-As received; 2-Moisture free; 3-Moisture and ash free.

(12) Capps (1940)

Table 47. Sulfur content of Matanuska Valley coals on different bases.

Location	Total sulfur(%)			
	1	2	3	4
Evan Jones mine	0.3	0.3	0.3	0.4
Eska Creek	0.32	---	0.34	0.45
Chickaloon		0.78		
Coal Creek		0.54		
Anthracite Ridge		0.45		

Basis: 1-As received; 2-Air dried; 3-Moisture free; 4-Moisture and ash free.

(13) Selvig and others (1944)

Table 48. Sulfur content of Eska and Jonesville coals, Matanuska Valley.

Mine	Bed	Rank	Total sulfur(%)		
			1	2	3
Eska	Upper Shaw	hvAb	0.5	0.5	0.6
Jonesville	No. 8	hvBb	0.3	0.3	0.4

Basis: 1-As received; 2-Moisture free; 3-Moisture and ash free.

(14) U.S. Bureau of Mines (1944)

Table 49. Average total sulfur of 12 samples from Buffalo Coal Co. mine, Moose Creek, Alaska.

Basis*	Total sulfur(%)
1	0.3
2	0.3
3	0.4

*1-As received; 2-Moisture free; 3-Moisture and ash free.

(15) Barnes and Byers (1945)

Table 50. Total sulfur of Evan Jones and Eska coals, Matanuska Valley, on different bases.

Coal bed	Location	Sulfur (%) 1	2	3	4
4	Evan Jones mine, south-limb workings	0.3	0.3	0.3	0.3
3	Evan Jones mine, south-limb workings	0.3	0.3	0.3	---
5	Evan Jones mine, north-limb workings	0.2	0.3	0.3	0.3
6	Evan Jones mine, north-limb workings	0.3	0.3	0.3	0.3
8	Evan Jones mine, north-limb workings	0.3	0.3	---	0.4
Upper Shaw	Eska mine, south-limb workings	0.5	0.5	---	0.6

Basis: 1-As received; 2-Air dried; 3-Moisture free; 4-Moisture and ash free.

(16) Bain (1946)

Table 51. As-received total sulfur of Wishbone Hill district coals.

Coal bed	Location	Sulfur (%)
4	South limb, Evan Jones mine	0.27
3	do.	0.30
2	North limb, Evan Jones mine	0.20
2	do.	0.30
8	do.	0.30
Upper Shaw	South limb, Eska mine	0.50

(17) Kurtz (1946) cited an as-received total sulfur content of coal from Evan Jones mine of 0.4 percent.

Table 52. Sulfur content of Evan Jones lump-nut coal, beds nos. 5 and 8.

Basis*	Sulfur (%)
1	0.4
2	0.4
3	0.4
4	0.5

*1-As received; 2-Air dried; 3-Moisture free; 4-Moisture and ash free.

(18) Cooper and others (1946)

Table 53. Average total sulfur contents of 116 Matanuska Valley coal samples.

Basis*	No. of samples	Average total sulfur(%)
1	116	0.5
2	116	0.5
3	72	0.5

*1-As reveived; 2-Dried at 105°C; 3-Moisture and ash free.

(19) Barnes and Payne (1956)

Table 54. Sulfur content of coals from different mines of Wishbone Hill district, Matanuska coal field.

Mine	Total sulfur(%)		
	1	2	3
Matanuska Center	0.5	0.5	0.7
Rawson (New Black Diamond)	0.4	0.5	0.5
Buffalo	0.3	0.3	0.4
Baxter	0.3	0.3	0.3
Premier	0.4	0.4	0.4
Doherty	0.5	0.5	0.7
Evan Jones	0.4	0.4	0.5
Eska	0.4	0.4	0.5
Knob Creek	0.4	0.5	0.5

Basis: 1-As received; 2-Air dried; 3-Moisture free; 4-Moisture and ash free.

(20) May and Warfield (1957)

Table 55. Sulfur content of face samples from section 1,200 ft northeast of old Evan Jones slope.

Sample	Sulfur(%)			
	1	2	3	4
A	0.4	0.5	0.5	0.6
B	0.4	0.5	0.5	0.6

Basis: 1-As received; 2-Air dried; 3-Moisture free; 4-Moisture and ash free.

(21) Barnes (1962)

Table 56. Average total sulfur of coals from the three main districts of Matanuska coal field.

District	Rank	Sulfur(%)
Wishbone Hill	hvBb	0.4
Chickaloon	lvb	0.6
Anthracite Ridge	an	0.6

(22) Geer and Fennessy (1962)

Table 57. Sulfur in Evan Jones mine coal beds.

Coal bed (bench)	Sulfur(%)
5	0.3
6	0.3
7 (upper)	0.3
7 (lower)	0.3
7A	0.3
7B (upper)	0.3
7B (lower)	0.3
7C	0.4

(23) Boley (1965) reported a total sulfur content of Castle Mountain mine coal of 0.6 percent (maf basis).

Table 58. Sulfur content of Castle Mountain mine sample carbonized at 900°C-925°C (as carbonized).

Blend	Total sulfur(%)
1	0.6
2	0.7
3	0.6

(24) Warfield and others (1966)

Table 59. Sulfur in drill cuttings and reduced ash samples of Castle Mountain mine coal.

Sample	Total sulfur(%)	
	1	2
Drill cuttings	0.5	0.6
Reduced-ash	0.6	0.6

Basis: 1-As received; 2-Moisture and ash free.

(25) Barnes (1967)

Table 60. Range in total sulfur of coals from three main districts of Matanuska field.

Coal district	Coal rank	Total sulfur(%)
Wishbone Hill	Bituminous	0.2-1.0
Chickaloon	Bituminous	0.4-0.7
Anthracite Ridge	Semianthracite	0.5-0.7

(26) Rao (1976)

Table 61. Average and range in total sulfur for Evan Jones, Castle Mountain, and Premier mines.

Mine	No. of samples	Rank	Range total sulfur(%)	Average total sulfur(%)
Evan Jones	14	hvB	0.26-0.43	0.33
Castle Mountain	2	mvB	0.39-0.53	0.46
Premier	6	hvB	0.29-0.78	0.46

(27) Alaska Division of Energy and Power Development (1977)

Table 62. Range in total sulfur for Matanuska Valley bituminous and semianthracite-anthracite coals.

Coals	Total sulfur(%)
Bituminous	0.2-1.0
Semianthracite-anthracite	0.2-0.7

(28) McFarland (1978) cited a range in total sulfur of 0.2-1.0 for bituminous and anthracitic coals of Matanuska field.

(29) Rao and Wolff (1979); Rao and Wolff (1981)

Table 63. Sulfur contents of Lower and Big seams, Castle Mountain and Premier mines, Matanuska coal field.

Seam	Rank	Basis*	Pyritic sulfur(%)	Total sulfur(%)
Lower seam, Castle Mountain mine	hvAb	1	0.09	0.46
		2	0.09	0.46
		3	0.09	0.47
		4	0.11	0.57

Table 63 (con.)

Seam	Rank	Basis*	Pyritic sulfur(%)	Total sulfur(%)
Big seam,	hvBb	1	0.04	0.35
Premier		2	0.04	0.36
mine		3	0.04	0.37
		4	0.05	0.43

*1-As received; 2-Equilibrium bed moisture; 3-Moisture free; 4-Moisture and ash free.

(30) The U.S. Department of Energy (1980) cited a total sulfur range of 0.2-1.0 percent for Matanuska Valley coals.

(31) Patsch (1981) stated that Evan Jones mine coal sold under washed specifications of 0.4-0.5 percent sulfur.

(32) Sanders (1981) quoted the sulfur data from Barnes (1967) for Matanuska field coals, except that Anthracite Ridge coals varied from 0.2-0.7 percent total sulfur.

(33) Rao and Wolff (1982)

Table 64. Pyritic and total sulfur contents of Evan Jones mine seams on different bases.

Seam	Rank	Pyritic sulfur(%)			Total sulfur(%)		
		1	2	3	1	2	3
7A	hvBb	0.02	0.02	0.02	0.40	0.42	0.52
7 (lower)	hvBb	0.04	0.04	0.05	0.43	0.45	0.55
7 (upper)	hvBb	0.01	0.01	0.01	0.43	0.45	0.54
6 (lower)	hvBb	0.02	0.02	0.02	0.35	0.37	0.47
6 (upper)	hvBb	0.02	0.02	0.03	0.35	0.37	0.54
5	hvBb	0.05	0.05	0.08	0.24	0.26	0.40

Basis: 1-Equilibrium bed moisture; 2-Moisture free; 3-Moisture and ash free.

(34) Sanders (1983) cited average total sulfur of 0.5 percent for Wishbone Hill, Matanuska Valley coal.

(35) Hawley and others (1984) reported that product coal from the western Wishbone Hill district would have about 0.4 percent total sulfur. They also stated that all the coaly material tested was low sulfur, and almost all sulfur was in the organic form.

(36) Merritt and Belowich (1984) quoted the total sulfur ranges for Matanuska Valley coals from Barnes (1967) and Sanders (1981).

(37) Merritt (1985b) found that the total sulfur content of Matanuska Valley coals was low in all samples analyzed. Organic sulfur proved to be the most abundant form in Matanuska Valley coals as it is in most Alaskan coals. Evan weathered samples of Matanuska Valley coals have very low sulfate sulfur contents. Locally sulfates can be observed on coal seam surfaces though (Figure 7).

Merritt (1985b) found that total sulfur ranged from 0.2-0.8 percent and averaged 0.45 percent in 58 samples analyzed (Figure 10). The mean and maximum total sulfur contents in Matanuska Valley coals on a moisture and ash free basis are respectively 0.7 and 1.3 percent (Figure 11). The isopach map (Figure 12) indicates that the total sulfur content in coals decreases toward the margins of the Matanuska basin. It tends to be relatively lower in the Wishbone Hill district of the western Matanuska Valley and to be relatively higher in the Chickaloon and Anthracite Ridge districts. This trend is expected due to the introduction of sulfide minerals during diastrophic carbonization.

Coals of the Anthracite Ridge district are of anthracitic and semianthracitic rank. Merritt (1985b) compared the sulfur content of the anthracitic coals of this district with those of the Bering River field, Alaska and of Pennsylvania.

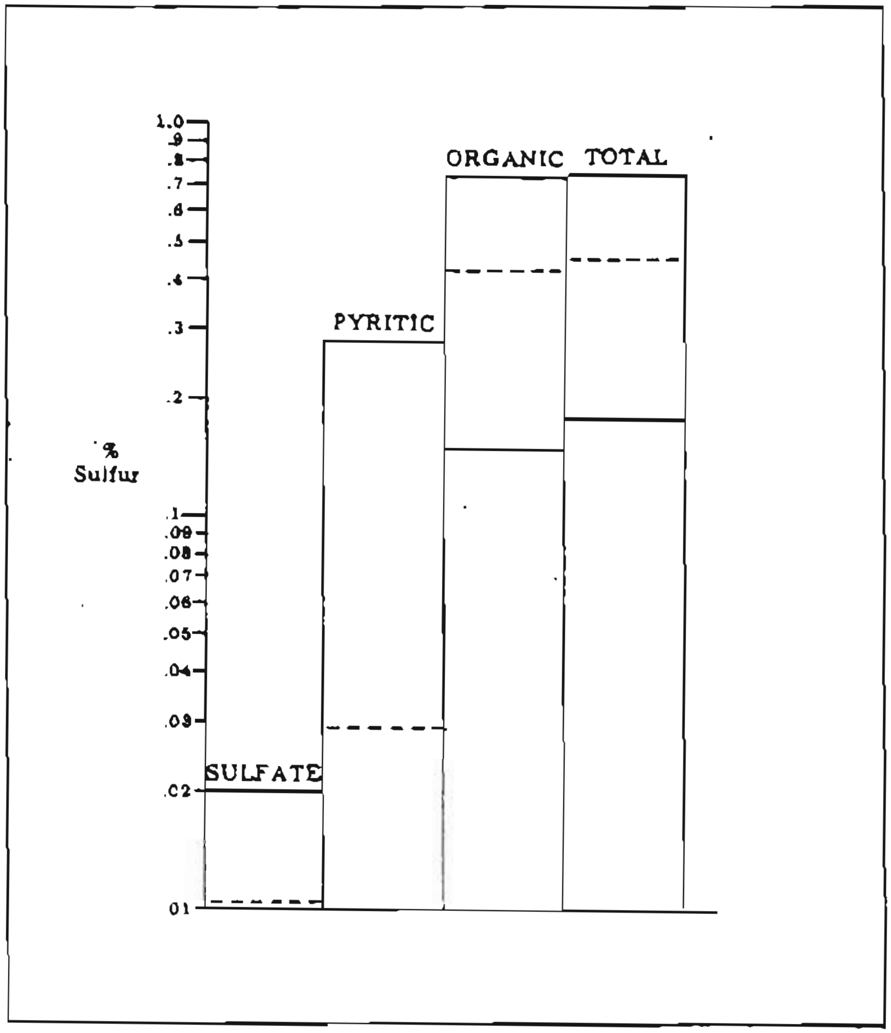

Figure 10. Bar graph showing the maximum and arithmetic mean values for the percent total sulfur and sulfur forms of 58 analyzed Matanuska Valley coal samples (as-received basis).

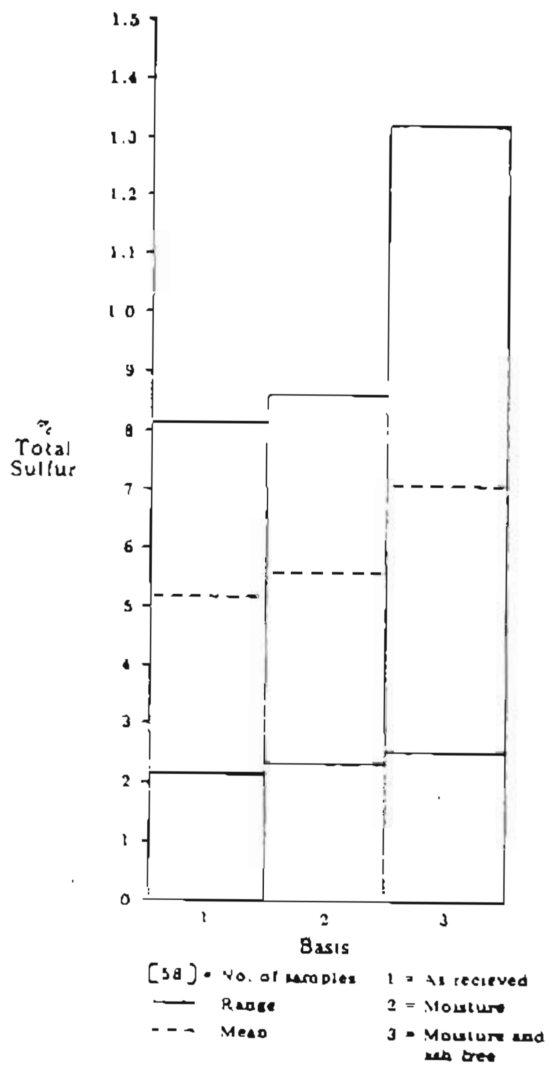

Figure 11. Bar graph showing the range and arithmetic mean values for the percent total sulfur of analyzed Matanuska Valley raw coal samples (different bases).

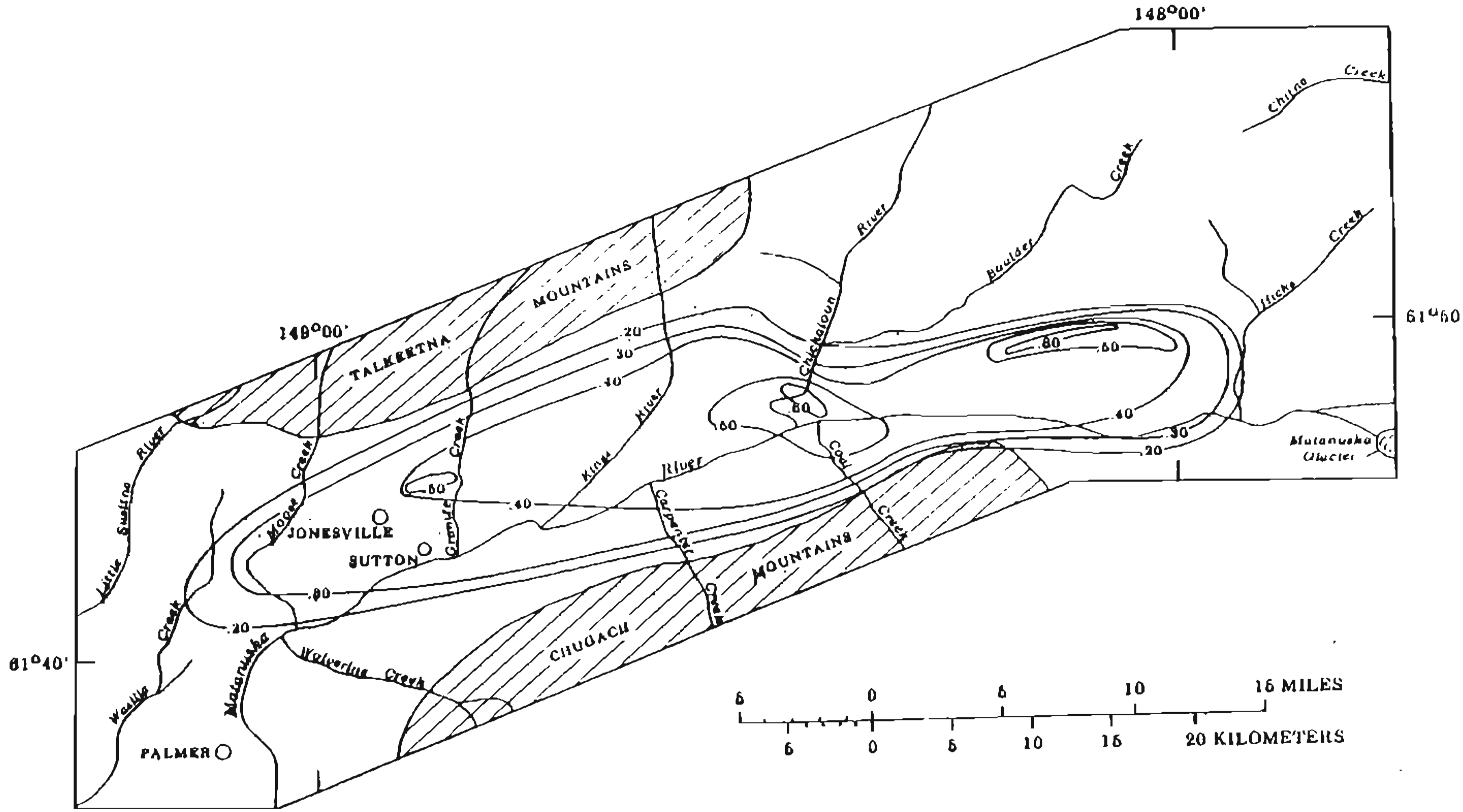

Figure 12. Highly generalized isopach map of total sulfur distribution in coal samples (as-received basis) of the Matanuska Valley.

Table 65. Comparison of the total sulfur content of Matanuska, Bering River, and Pennsylvania anthracites.

Coal field	Sulfur(%)
Matanuska[1]	0.5
Bering River[2]	1.2
Pennsylvania[3]	0.7

[1]Mean of 11 samples analyzed by Merritt (1985b).

[2]U.S. Bureau of Mines, 1946, p. 62-67; mean of 10 samples.

[3]Average of three samples from Slatjck, 1980; Cady, 1978; and Babcock and Wilcox, 1972.

Kenai Field

Coals of the Kenai field occur in the Beluga and Sterling Formations (Miocene-Pliocene) of the Kenai Group. The Oligocene-early Miocene Tyonek Formation coal-bearing strata are found at depth in oil wells. The beds are predominantly flat-lying to gently dipping. Coals are typically of subbituminous C rank, 6,500-8,500 Btu/lb, 3-25 percent ash, and 0.2-0.4 percent sulfur. Seams vary from 2.5 to 20 ft thick. Identified resources (onshore only) are 320 million short tons, and hypothetical resources (onshore only) are 35 billion short tons. Past production has been less than 100,000 tons.

Detailed sulfur data on coals of the Kenai field are summarized below:

(1) Dall (1896)

Table 66. Sulfur content of Kenai Peninsula seams.

Seam	Total sulfur(%)
Bradley	0.49
Eastland Canyon (avg. 3)	0.26
Curtis	0.46
Port Graham	1.20

(2) Brooks (1902) stated that subbituminous coals of the Kenai Peninsula ranged from 0.17 to 0.49 percent in total sulfur and averaged 0.35 percent. He quoted Dall's figure of 1.20 percent total sulfur for Port Graham coals.

(3) Stone (1905)

Table 67. Total sulfur of Kachemak Bay and Port Graham coals.

Location	Seam	Sulfur(%)
Kachemak Bay	Mine Camp (avg. 3)	0.35
	Curtis	0.46
	McNeil Canyon	0.34
	Eastland Canyon	0.27
Port Graham	---	0.39

(4) Martin (1908) quoted the sulfur data of Stone (1905).

(5) Crane (1913) quoted the sulfur data of Stone (1905).

(6) Coffin (1919) quoted the sulfur data of Dall (1896) and Stone (1905).

(7) Kurtz (1946) cited a sulfur content of coal from Homer area of 0.2 percent (as-received and air-dried bases).

(8) Cooper and others (1946)

Table 68. Average total sulfur of Kenai Peninsula coals on different bases.

Basis*	No. of samples	Average total sulfur(%)
1	10	0.4
2	10	0.5
3	6	0.6

*1-As received; 2-Dried at 105°C; and 3-Moisture and ash free.

(9) Toenges and Jolley (1949) cited total sulfur contents of 0.3 percent and 0.4 percent for Bidarki Creek and Cooper Bed (respectively) of the Homer Coal Corporation mine, Homer district.

(10) Barnes and Cobb (1959)

Table 69. Average total sulfur content of 16 coal samples from Homer district, Kenai coal field, Alaska.

Basis*	Total sulfur(%)
1	0.2
2	0.3
3	0.3
4	0.4

*1-As received; 2-Air dried; 3-Moisture free; 4-Moisture and ash free.

(11) Barnes (1962)

Table 70. Sulfur content of coal samples from Ninilchik outcrop and Kenai oil well, Kenai coal field.

Sample	Locality	Depth(ft)	Rank	Total sulfur(%)
1	Ninilchik outcrop	Surface	lig	0.2
2	do.	Surface	subC	0.3
3	Kenai oil well	5,500	subB	0.8
4	do.	10,200	hvCb	0.3
5	do.	10,230	hvCb	0.3
6	do.	10,680	hvCb	0.4
7	do.	10,720	hvBb	0.5
8	do.	11,110	hvBb	0.3
9	do.	11,360	hvCb	0.2

(12) Barnes (1967a) reported a range of 0.1 to 0.4 percent in total sulfur for the subbituminous and lignite coals of the Homer district.

(13) Conwell (1977)

Table 71A. Range and average total sulfur of Deep Creek, Ninilchik, and Clam Gulch area coals, Kenai field.

Area	No. of samples	Range total sulfur(%) 1	2	3	4	Avg. total sulfur(%) 1	2	3	4
Deep Creek	3	0.3-1.3	0.3-1.6	0.3-1.7	0.3-1.9	0.7	0.8	0.8	1.0
Ninilchik	5	0.2-0.3	0.3	0.3-0.4	0.4-0.5	0.3	0.3	0.3	0.4
Clam Gulch	2	0.3	0.3-0.4	0.3-0.4	0.5-0.6	0.3	0.4	0.4	0.6

Basis: 1-As received; 2-Air dried; 3-Moisture free; 4-Moisture and ash free.

Table 71B. Forms of sulfur of Deep Creek, Ninilchik, and Clam Gulch area coals, Kenai field.

Area	No. of samples	Sulfate sulfur(%) 1	2	3	Pyritic sulf.(%) 1	2	3	Organic sulf.(%) 1	2	3
Deep Creek	3	0.02	0.03	0.04	0.04	0.05	0.07	0.58	0.75	0.85
Ninilchik	5	0.02	0.02	0.03	0.06	0.08	0.08	0.19	0.25	0.30
Clam Gulch	2	0.02	0.02	0.03	0.06	0.07	0.10	0.23	0.30	0.42

Basis: 1-As received; 2-Moisture free; 3-Moisture and ash free.

(14) The Alaska Division of Energy and Power Development (1977) quoted the range in total sulfur in Homer district coals reported by Barnes (1967).

(15) McFarland (1978) quoted the sulfur data of Barnes (1967).

(16) The U.S. Department of Energy (1980) quoted the sulfur data of Barnes (1967).

(17) Rao and Wolff (1980); Rao and Wolff (1981)

Table 72. Pyritic and total sulfur data for the subbituminous C Cabin bed, Kenai field.

Basis*	Pyritic sulfur(%)	Total sulfur(%)
1	0.01	0.23
2	0.01	0.30
3	0.01	0.34

*1-Equilibrium bed moisture; 2-Moisture free; 3-Moisture and ash free.

(18) Sanders (1981) reported a range in total sulfur for Kenai field coals of 0.2-0.4 percent.

(19) Affolter and others (1981a,b) found that Kenai quadrangle coals were significantly lower in total sulfur and pyritic sulfur contents than Powder River region coals, but organic sulfur contents were not significantly different. They found that Seldovia quadrangle coals were significantly lower in total sulfur, sulfate, and pyritic sulfur contents than Powder River region coals.

Table 73A. Average total sulfur content of 10 Kenai quadrangle coals (from Affolter and others, 1981a).

Basis*	Total sulfur(%)
1	0.4
2	0.5
3	0.6

*1-As received; 2-Moisture free; 3-Moisture and ash free.

Table 73B. Statistical summary for total sulfur of 10 Kenai quadrangle coals (from Affolter and others, 1981b).

Statistic	Total sulfur(%)
Arithmetic mean	0.4
Observed range:	
Minimum	0.2
Maximum	1.3
Geometric mean	0.3
Geometric deviation	1.7
Powder River region geometric mean	0.8

Table 74A. Average total sulfate, pyritic, and organic sulfur contents of 10 Kenai quadrangle coals (from Affolter and others, 1981a).

Basis*	Forms of sulfur(%)		
	Sulfate	Pyritic	Organic
1	0.02	0.06	0.32
2	0.03	0.07	0.41
3	0.04	0.09	0.50

*1-As received; 2-Moisture free; 3-Moisture and ash free.

Table 74B. Statistical summary for forms of sulfur in 10 Kenai quadrangle coals (from Affolter and others, 1981b).

Statistic	Forms of sulfur(%)		
	Sulfate	Pyritic	Organic
Arithmetic mean	0.02	0.06	0.29
Observed range:			
Minimum	0.02	0.01	0.16
Maximum	0.03	0.12	1.29
Geometric mean	0.02	0.04	0.24
Geometric deviation	1.1	2.7	1.8
Powder River region geometric mean	0.02	0.29	0.3

Table 75A. Average total sulfur content of 6 Seldovia quadrangle coals (from Affolter and others, 1981a).

Basis*	Total sulfur(%)
1	0.4
2	0.4
3	0.5

*1-As received; 2-Moisture free; 3-Moisture and ash free.

Table 75B. Statistical summary for total sulfur of 6 Seldovia quadrangle coals (from Affolter and others, 1981b).

Statistic	Total sulfur(%)
Arithmetic mean	0.4
Observed range:	
Minimum	0.3
Maximum	0.4
Geometric mean	0.3
Geometric deviation	1.2
Powder River region geometric mean	0.8

Table 76A. Average total sulfate, pyritic, and organic sulfur contents of 6 Seldovia quadrangle coals (from Affolter and others, 1981a).

	Forms of sulfur(%)		
Basis*	Sulfate	Pyritic	Organic
1	0.01	0.02	0.3
2	0.01	0.02	0.4
3	0.01	0.02	0.5

*1-As received; 2-Moisture free; 3-Moisture and ash free.

Table 76B. Statistical summary for forms of sulfur of 6 Seldovia quadrangle coals (from Affolter and others, 1981b).

	Forms of sulfur(%)		
Statistic	Sulfate	Pyritic	Organic
Arithmetic mean	0.01	0.02	0.33
Observed range			
Minimum	0.01	0.01	0.22
Maximum	0.01	0.04	0.42
Geometric mean	0.01	0.02	0.31
Geometric deviation	1.0	1.9	1.3
Powder River region geometric mean	0.02	0.29	0.31

Susitna Lowland (Beluga and Yentna Fields)

Coals of the Susitna lowland occur in the Beluga, Tyonek, and Sterling Formations of the Kenai Group. They are found in two main fields---Beluga and Yentna. The coals are of Oligocene to Pliocene age and are found in relatively flat-lying strata that have broad gentle folds and minor faults locally. The coals are typically subbituminous C, 6,200-9,500 Btu/lb, 3-30 percent ash, and 0.1-0.7 percent sulfur. Seams range from 5 to 50 ft thick. Identified resources are 10 billion short tons and hypothetical resources are 30 billion short tons.

Detailed sulfur data on coals of the Beluga and Yentna fields of the Susitna lowland are summarized below:

(1) Martin (1908) cited average total sulfur of 0.38 percent for 4 Tyonek area lignites.

(2) Crane (1913) quoted the data from Martin (1908).

(3) Coffin (1919) gave an average total sulfur content of 0.57 percent for 5 Tyonek and Beluga River area lignite samples.

(4) Capps (1940) cited total sulfur values of 0.22 percent (as-received basis) and 0.24 percent (air-dried basis) for a Beluga River coal sample.

(5) Cooper and others (1946)

Table 77. Average total sulfur of 5 Tyonek area coals.

Basis*	Total sulfur(%)
1	0.3
2	0.4
3	0.4

*1-As received; 2-Dried at 105°C; and 3-Moisture and ash free.

(6) Barnes and Ford (1952)

Table 78. Analysis of sulfur content of coal from Willow Creek, Susitna lowland.

Basis*	Total sulfur(%)
1	0.2
2	0.2
3	0.3
4	0.3

*1-As received; 2-Air dried; 3-Moisture free; 4-Moisture and ash free.

(7) Holdsworth (1956)

Table 79. Average sulfur of Beluga River field coals.

Basis*	Total sulfur(%)
1	0.1
2	0.2
3	0.2

*1-As received; 2-Moisture-free; 3-Moisture and ash free.

(8) Barnes (1962) gave a total sulfur content of 0.1 percent for Chuitna area, Beluga field lignite.

(9) Geer and Fenessy (1962) reported as-received and moisture-free total sulfur contents of 0.2 percent for Drill Creek, Beluga River coal.

(10) Barnes (1966)

Table 80A. Range in total sulfur in percent for 16 coal samples from the Beluga-Yentna region.

Basis*	Total sulfur(%)
1	0.1-0.4
2	0.1-0.6
3	0.1-0.6

*1-As received; 2-Moisture free; 3-Moisture and ash free.

Table 80B. Sulfur content of coals from the Beluga-Yentna region by rank.

		Sulfur(%)		
Location	Rank	1	2	3
Sunflower Creek	lig	0.1	0.1	0.1
Johnson Creek	subC	0.2	0.2	0.3
Contact Creek	subC	0.1	0.2	0.2
Saturday Creek	subC	0.2	0.3	0.3
Wolverine Creek	subB	0.4	0.6	0.6
Drill Creek	subC	0.2	0.2	---
Capps Creek	subC	0.2	0.2	0.2
Beluga River	subB	0.2	0.2	0.3
Chuitna River	subC	0.2	0.3	0.3

(11) Barnes (1967a) reported a range in total sulfur of 0.1 to 0.4 percent for the subbituminous and lignitic coals of the Beluga-Yentna region.

(12) McGee (1973) reported that total sulfur for Chuitna-Beluga-Capps coals was low, generally 0.2 to 0.3 percent, in 47 samples.

(13) McGee and O'Connor (1975) quoted the sulfur data from McGee (1973).

(14) Patsch (1976) reported that coals of the Beluga field were very low in sulfur, low enough to meet U.S. government standards for sulfur content for direct burning. In addition, he stated that because of the low sulfur in the coal and the clean overburden sediments, no acid mine drainage problems would be encountered. He cited an average total sulfur content of Beluga coals of 0.15 percent (as-received basis) and 0.20 percent (dry basis).

(15) Rao and Wolff (1976) reported an average total sulfur content of 0.2 percent for coals of the Chuitna River district, Beluga field.

(16) Conwell (1977)

Table 81A. Average total sulfur of Chuitna area coals.

Basis*	Total sulfur(%)
1	0.1
2	0.2
3	0.2
4	0.2

*1-As received; 2-Air dried; 3-Moisture free; 4-Moisture and ash free.

Table 81B. Sulfur form data for Chuitna area coals.

Basis*	Sulfur (%)		
	Sulfate	Pyritic	Organic
1	0.02	0.00	0.10
2	0.02	0.00	0.13
3	0.04	0.00	0.15

*1-As received; 2-Moisture free; 3-Moisture and ash free.

(17) The Alaska Division of Energy and Power Development (1977) cited a total sulfur content of 0.2 percent for subbituminous to lignitic coals of the Beluga and Yentna region.

(18) Anderson (1978) quoted sulfur data from Patsch (1976).

(19) McFarland (1978) quoted sulfur data of the Alaska Division of Energy and Power Development (1977).

(20) The U.S. Department of Energy (1980) quoted sulfur data from Barnes (1967a) and the Alaska Division of Energy and Power Development (1977).

(21) Rao and Wolff (1980); Rao and Wolff (1981)

Table 82. Pyritic and total sulfur contents of Waterfall and Sunflower Creek seams, Beluga-Yentna region.

Coal field	Seam	Rank	1	2	3	1	2	3
Beluga	Waterfall	subC	0.01	0.01	0.01	0.14	0.18	0.21
Yentna	Sunflower Creek (avg. of 2)	lig	0.01	0.01	0.01	0.08	0.11	0.12

Basis: 1-Equilibrium bed moisture; 2-Moisture free; 3-Moisture and ash free.

(22) Blumer (1981) cited a range in total sulfur content of 0.1-0.2 percent for Johnson Creek and Canyon Creek coals, Yentna field.

(23) Ramsey (1981)

Table 83. Total sulfur content of Chuitna River district coals, Beluga field.

Seam	Total sulfur(%)
Brown	0.33
Yellow	0.28
Green	0.23
Blue	0.16
Orange	0.20
Red	0.17

(24) Sanders (1981) cited a range in total sulfur of 0.1-0.3 percent for coals of the Beluga-Yentna region.

(25) Ruby and Huettenhain (1981)

Table 84. Comparison of typical total sulfur contents of Chuitna River subbituminous coal with other coals.

Region/coal rank	Sulfur(%)
Chuitna River subbituminous	0.1-0.2
North Dakota lignite	0.5-2.5
Texas lignite	1.0-1.5
Montana subbituminous	0.4-1.7
Wyoming subbituminous	0.5-1.0
Illinois bituminous	2.0-6.0

(26) Merritt (1982) reported sulfur contents generally less 0.2 percent for coals of the Kenai Group, south-central Alaska. He also reported the occurrence of framboidal pyrites in these coals.

(27) Rao and Wolff (1982)

Table 85. Pyritic and total sulfur contents of coals of Beluga and Yentna fields on different bases.

Table 85 (con.)

Coal field	Seam	Rank	Pyritic sulfur(%) 1	2	3	Total sulfur(%) 1	2	3
Beluga	Green	subC	0.01	0.01	0.01	0.12	0.16	0.18
Beluga	Waterfall	subC	0.02	0.02	0.03	0.20	0.26	0.36
Yentna	Johnson Ck.	subC	0.01	0.01	0.02	0.18	0.24	0.28
Yentna	Canyon Ck.	subC	0.01	0.01	0.02	0.14	0.17	0.21

Basis: 1-Equilibrium bed moisture; 2-Moisture free; 3-Moisture and ash free.

(28) Merritt (1983a) reported average total sulfur of 0.26 percent for 66 Susitna lowland coal samples and a range from 0.1 to 0.7 percent (Figure 13). Organic sulfur, sulfate sulfur, and pyritic sulfur averaged 0.2, 0.04, and 0.01 % respectively (Figure 14).

Table 86. Range and mean total sulfur content of 66 raw coal samples from the Susitna lowland.

Statistic	Basis*	Sulfur(%)
Range	1	0.01-0.73
	2	0.01-0.91
	3	0.01-1.03
Mean	1	0.26
	2	0.31
	3	0.39

*1-As received; 2-Moisture free; 3-Moisture and ash free.

(29) Sanders (1983) reported the following sulfur contents for Beluga and Yentna coals: Beluga generally less 0.2 percent total sulfur, Chuitna less 0.2 percent, Capps 0.17 percent, and Yentna (Canyon Creek) from 0.1 -0.2 percent.

(30) Affolter and Stricker (1984) reported that six coal beds of the Tyonek Formation (lower Oligocene to middle Miocene),

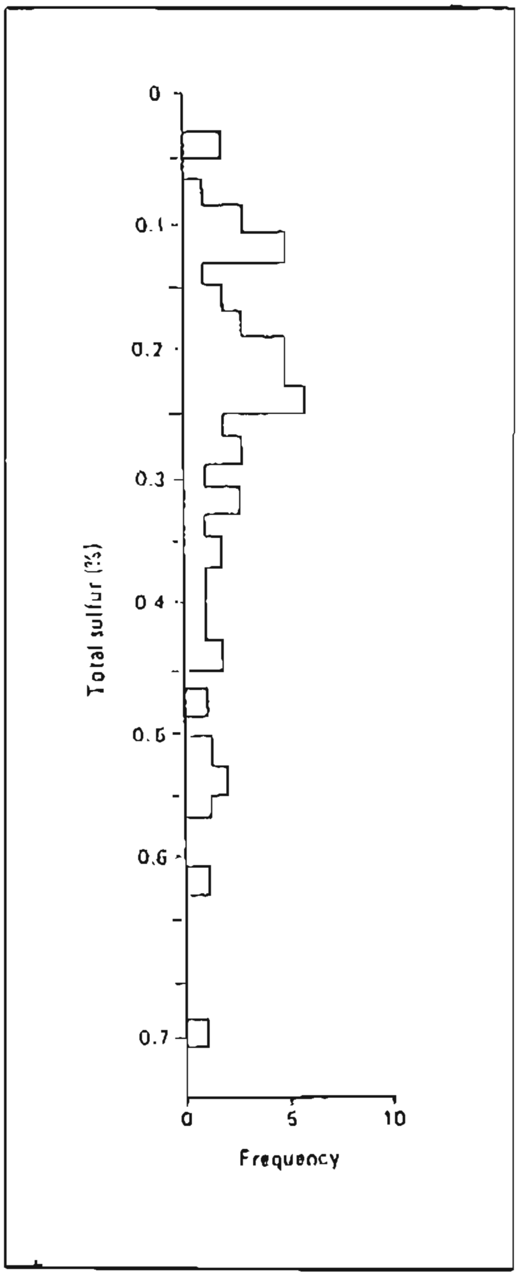

Figure 13. Total sulfur histogram for Susitna lowland coal samples.

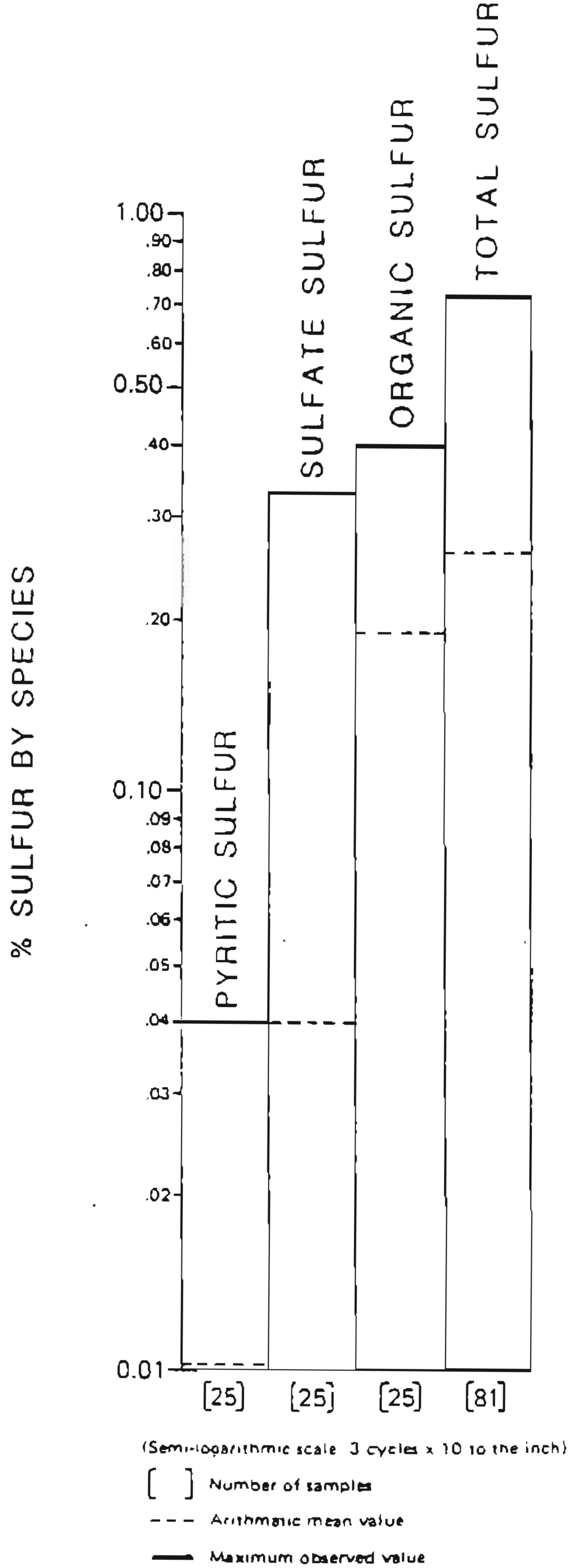

Figure 14. Bar graph showing range and mean values of total sulfur and sulfur forms in Susitna lowland coal samples (as received basis).

Beluga field showed one of the lowest sulfur ranges for any United States coal---0.08-0.33 percent. The average values for forms-of-sulfur of the six coal beds was reported as: 0.13 percent organic sulfur, 0.02 percent sulfate sulfur, and only 0.01 percent pyritic sulfur.

Little Susitna Field

Coals of the Little Susitna field occur in the Tyonek Formation (late Oligocene-Miocene) of the Kenai Group. The coal-bearing strata is moderately (30°-35°) to gently (4°-15°) dipping, and is modified by slight folding. Coals are typically subbituminous B, 8,400-9,300 Btu/lb, 9-25 percent ash, and 0.3-0.6 percent sulfur. Most beds are too thin (less 2-ft) to be considered minable, but a few seams range from 2.5- to 10-ft thick at less than 1,000-ft depth. Hypothetical resources are 10 million short tons. Past production has been less than 100,000 tons.

Detailed sulfur data on coals of the Little Susitna field are summarized below:

(1) Cooper and others (1946) cited an average total sulfur of 9 Houston area coal samples on as received and dried (at 105°C) bases.

(2) Barnes and Ford (1952)

Table 87. Analysis of the sulfur content of coal from the Houston strip mine, Little Susitna field.

Sample	Basis*	Sulfur(%)
A	1	0.4
	2	0.5
	3	0.5
	4	0.6
B	1	0.4
	2	0.5
	3	0.5
	4	0.6

*1-As received; 2-Air dried; 3-Moisture free; 4-Moisture and ash free.

(3) May and Warfield (1957)

Table 88. Sulfur content of diamond-drill core samples from Houston coal-drilling project.

Sample	Total sulfur(%)			
	1	2	3	4
A	0.3	0.4	0.4	0.5
B	0.3	0.3	0.3	0.4
C	0.2	---	0.3	0.3

Basis: 1-As received; 2-Air dried; 3-Moisture free; 4-Moisture and ash free.

(4) Barnes and Sokol (1959)

Table 89. Average total sulfur (3 samples) of Little Susitna district coals.

Basis*	Total sulfur(%)
1	0.4
2	0.5
3	0.6

*1-As received; 2-Moisture free; 3-Moisture and ash free.

(5) Barnes (1962) found average total sulfur of 0.4 percent for 10 subbituminous B-ranked coals of the Houston strip mine, Little Susitna field.

(6) Barnes (1967a) cited average total sulfur of 0.4 percent for Little Susitna field coals.

Broad Pass Field

Coals of the Broad Pass field occur in two main districts---the Broad Pass or Graben district and the Costello Creek district. Coal beds are found in gently dipping (less 10°) strata and are generally 5- to 10-ft thick. Broad Pass coal is lignitic, 5,500 to 7,100 Btu/lb, 10-20 percent ash, and 0.2-0.4 percent sulfur. Costello Creek coal is subbituminous A, 8,000-10,200 Btu/lb, 7-21 percent ash, and 0.3-0.6 percent sulfur. Identified resources are 50 million short tons and hypothetical resources are 500 million short tons. Past production has been less than 100,000 tons.

Detailed sulfur data on coals of the Broad Pass field are summarized below:

(1) Capps (1940) cited a total sulfur content of 0.41 percent (air dried basis) for coal of Costello Creek basin.

(2) Selvig and others (1944)

Table 90. Average total sulfur of Dunkle-Camp Creek bed No. 8 of subbituminous B rank.

Basis*	Total sulfur(%)
1	0.6
2	0.7
3	0.7

*1-As received; 2-Moisture free; 3-Moisture and ash free.

(3) Wahrhaftig (1944)

Table 91. Total sulfur analysis of Costello Creek and Dunkle mine coals.

	Total sulfur(%)			
Samples	1	2	3	4
Costello Creek	0.5	0.5	0.5	0.6
(No. of samples)	(23)	(15)	(24)	(24)
Dunkle mine	0.5	0.6	0.6	0.6
(No. of samples)	(4)	(4)	(4)	(4)

(4) Cooper and others (1946)

Table 92. Average total sulfur of Broad Pass and Costello Creek coals.

Coals	Basis*	No. of samples	Average total sulfur(%)
Broad Pass	1	5	0.2
	2	5	0.3
	3	5	0.4
Costello Creek	1	5	0.5
	2	5	0.7
	3	4	0.7

*1-As received; 2-Dried at 105°C; 3-Moisture and ash free.

(5) Barnes (1967a) listed an average total sulfur for Broad Pass district lignite of 0.2-0.3 percent, and for Costello Creek district subbituminous coal of 0.3-0.6 percent.

(6) The Alaska Division of Energy and Power Development (1977) cited an average total sulfur content of Broad Pass Tertiary subbituminous coals of 0.3-1.4 percent.

(7) The U.S. Department of Energy (1980) quoted Barnes (1967a) average total sulfur of 0.2-0.3 percent for Broad Pass lignite.

(8) Rao and Wolff (1980); Rao and Wolff (1981)

Table 93. Pyritic and total sulfur content of Coal Creek, Broad Pass district lignite.

Basis*	Pyritic sulfur(%)	Total sulfur(%)
1	0.03	0.15
2	0.04	0.21
3	0.05	0.26

*1-Equilibrium bed moisture; 2-Moisture free; 3-Moisture and ash free.

(9) Sanders (1981) quoted Barnes' (1967a) figure for total sulfur of Broad Pass lignite.

NENANA PROVINCE

Nenana Basin

The Nenana basin is comprised of at least 10 separate coal fields. The coal-bearing Suntrana, Healy Creek, and Lignite Creek Formations are part of the Tertiary Usibelli Group. The coal-bearing strata are typically in moderately dipping (30°-45°) fault blocks and gentle folds. The coals are subbituminous C, 6,200-9,800 Btu/lb, 3-30 percent ash, and 0.2-1.2 percent sulfur. Seams range up to 60-ft thick. Identified resources are 8 billion short tons and hypothetical resources are 20 billion short tons. Past production has been about 25 million tons, more than any other region in Alaska.

Detailed sulfur data on coals of the Nenana basin are summarized below:

(1) Prindle (1907) listed a total sulfur value of 0.16 percent for Healy Creek coal.

(2) Martin (1908) quoted Prindle (1907).

(3) Evans (1916)

Table 94. Total sulfur of Bed Nos. 1 and 5, Healy Creek.

Sample	Total sulfur (%)	
	As received basis	Dry basis
Bed No. 1	0.24	0.33
Bed No. 5	0.48	0.68

(4) Coffin (1919) quoted Prindle (1907).

(5) Capps (1940) listed total sulfur of 0.1 percent (on all bases) for Healy Creek coal.

(6) U.S. Bureau of Mines (1943; 1944)

Table 95. Average total sulfur of Roth Property coals (13 samples), south side of Healy Creek.

Basis*	Sulfur(%)
1	0.2
2	0.2
3	0.3
4	0.3

*1-As received; 2-Air dried; 3-Moisture free; 4-Moisture and ash free.

(7) Selvig and others (1944)

Table 96. Sulfur content of coals of Old and New Suntrana mines.

Mine	Bed	Rank	Total sulfur(%)		
			1	2	3
Old Suntrana	No. 3	subC	0.2	0.2	0.2
	No. 4 (avg.3)	subC	0.2	0.2	0.3
	No. 6	subC	0.1	0.1	0.1
New Suntrana	B	subB	0.2	0.3	0.3
	C	subB	0.2	0.3	0.3
	D	subB	0.3	0.4	0.5
	E	subB	0.4	0.5	0.6
	F	subB	0.2	0.3	0.3

Basis: 1-As received; 2-Moisture free; 3-Moisture and ash free.

(8) Kurtz (1946)

Table 97A. Sulfur content of coal from Healy Creek field mines (as-received basis).

Mine	Total sulfur(%)
Suntrana	0.2
Diamond	0.2
Usibelli	0.2

Table 97B. Sulfur content of coal from Suntrana mine, Healy Creek.

Coal type	Total sulfur(%) 1	2	3	4
Run-of-mine	0.2	0.2	0.2	0.2
Lump-nut	0.2	0.2	0.2	0.2

Basis: 1-As received; 2-Air dried; 3-Moisture free; 4-Moisture and ash free.

Table 97C. Sulfur content of mine-run coal from Diamond Pit, Healy Creek.

Basis*	Total sulfur(%)
1	0.2
2	0.2
3	0.2
4	0.2

*1-As received; 2-Air dried; 3-Moisture free; 4-Moisture and ash free.

Table 97D. Sulfur content of run-of-mine coal from Usibelli Strip Pit, Healy Creek.

Basis*	Total sulfur(%)
1	0.2
2	0.2
3	0.2
4	0.2

*1-As received; 2-Air dried; 3-Moisture free; 4-Moisture and ash free.

Table 97E. Sulfur content of Roth Property coals (dry basis), Healy Creek.

Sample	Total sulfur(%)
Basal bed (avg. 2)	0.4
Mammoth bed	0.1
Moose bed	0.2
Car (avg. 3)	0.2

(9) Cooper and others (1946)

Table 98. Average total sulfur of Nenana field coals.

Basis*	No. of samples	Total sulfur(%)
1	54	0.2
2	54	0.3
3	38	0.3

*1-As received; 2-Dried at 105°C; 3-Moisture and ash free.

(10) Toenges and Jolley (1949)

Table 99A. Sulfur content of Savage River coals (as-received basis), north boundary of Mt. McKinley Park.

Sample	Total sulfur(%)
1	0.4
2	0.1
3	0.4
4	0.3
5	0.3
6	0.2

Table 99B. Sulfur content of Sanctuary River coals (as-received basis), north boundary of Mt. McKinley Park.

Sample	Total sulfur(%)
1	0.3
2	0.3

Table 99C. Sulfur content of Teklanika River coals (as-received basis), north boundary of Mt. McKinley Park.

Sample	Total sulfur(%)
1	0.2
2	0.3

Table 99D. Sulfur content of Sushana River coal (as-received basis), north boundary of Mt. McKinley Park.

Sample	Total sulfur(%)
1	0.2

(11) Wahrhaftig (1951)

Table 100. Range and average total sulfur of Western Nenana field coals.

Basis*	Range total sulfur(%)	Average total sulfur(%)
1	0.1-0.4	0.3
2	0.2-0.5	0.3
3	0.2-0.6	0.4
4	0.2-0.7	0.4

*1-As received; 2-Air dried; 3-Moisture free; 4-Moisture and ash free.

(12) Wahrhaftig and others (1951)

Table 101. Average total sulfur content of Healy Creek (24 samples) and Lignite Creek (10 samples) coals.

	Sulfur(%)	
Basis*	Healy Creek	Lignite Creek
1	0.2	0.20
2	0.2	0.23
3	0.2	0.26
4	0.3	0.29

*1-As received; 2-Air dried; 3-Moisture free; 4-Moisture and ash free.

(13) Wahrhaftig and Birman (1954)

Table 102. Average total sulfur content of 8 coal samples of lower Lignite Creek.

Basis*	Sulfur(%)
1	0.2
2	0.3
3	0.3

*1-As received; 2-Moisture free; 3-Moisture and ash free.

(14) Barnes (1967a) estimated the total sulfur range of Nenana field subbituminous coals at 0.1-0.3 percent.

(15) Hatch (1976)

Table 103A. Average total sulfur of 4 core samples of coal from Usibelli, Alaska.

Basis*	Sulfur(%)
1	0.2
2	0.3
3	0.3
4	0.4

*1-As received; 2-Air dried; 3-Moisture free; and 4-Moisture and ash free.

Table 103B. Sulfur form data for 4 coal core samples from Usibelli, Alaska.

	Sulfur(%)			
Basis*	Sulfate	Pyritic	Organic	Total
1	0.02	0.07	0.14	0.23
2	0.02	0.09	0.19	0.30
3	0.03	0.10	0.22	0.35

*1-As received; 2-Moisture free; 3-Moisture and ash free.

(16) Rao and Wolff (1976) cited an average total sulfur of 0.2 percent for Nenana field coals.

(17) The Alaska Division of Energy and Power Development quoted total sulfur data from Barnes (1967a).

(18) McFarland (1978) quoted total sulfur data from Barnes (1967a).

(19) Rao and Wolff (1979)

Table 104. Sulfur data for Lignite Creek field coals.

Seam	Rank	Pyritic sulfur(%)				Total sulfur(%)			
		1	2	3	4	1	2	3	4
No. 6 (top)	subC	0.01	0.01	0.01	0.01	0.17	0.20	0.22	0.28
No. 6 (middle)	subC	0.01	0.01	0.01	0.01	0.12	0.14	0.16	0.18
No. 6 (lower)	subC	0.01	0.01	0.01	0.01	0.13	0.15	0.17	0.20
No. 2	subC	0.02	0.02	0.02	0.03	0.17	0.19	0.23	0.25
Moose	subC	0.01	0.01	0.01	0.01	0.15	0.16	0.15	0.21
Caribou	subC	0.02	0.02	0.02	0.03	0.13	0.15	0.17	0.20

Basis: 1-As received; 2-Equilibrium moisture; 3-Moisture free; 4-Moisture and ash free.

(20) The Committee on Alaska Coal Mining and Reclamation cited an average total sulfur of 0.20 percent for the Nenana basin coals of interior Alaska.

(21) The U.S. Department of Energy quoted total sulfur data from Barnes (1967a).

(22) Rao and Wolff (1980); Rao and Wolff (1981)

Table 105. Pyritic and total sulfur contents of seam nos. 4 and 6, Lignite Creek field.

Seam	Rank	Pyritic sulfur(%)			Total sulfur(%)		
		1	2	3	1	2	3
No. 4	subC	0.02	0.02	0.03	0.33	0.44	0.51
No. 6	subC	0.01	0.01	0.01	0.14	0.18	0.22

Basis: 1-As received; 2-Moisture free; 3-Moisture and ash free.

(23) Denton (1981) cited average total sulfur contents of 0.2 percent for seam nos. 3, 4, and 6.

(24) Sanders (1981) quoted total sulfur data from Barnes (1967a).

(25) Affolter and others (1981a,b) found that Healy quadrangle coals are significantly lower in total sulfur, sulfate, pyritic, and organic sulfur contents than Powder River region coals.

Table 106A. Average total sulfur of 12 Healy quadrangle coals (from Affolter and others, 1981a).

Basis*	Sulfur(%)
1	0.2
2	0.3
3	0.4

*1-As received; 2-Moisture free; 3-Moisture and ash free.

Table 106B. Statistical summary for total sulfur of 12 Healy quadrangle coals (from Affolter and others, 1981b).

Statistic	Sulfur(%)
Arithmetic mean	0.2
Observed range:	
Minimum	0.1
Maximum	0.7
Geometric mean	0.2
Geometric deviation	1.6
Powder River region geometric mean	0.8

Table 107A. Average total sulfate, pyritic, and organic sulfur contents of 12 Healy quadrangle coals (from Affolter and others, 1981a).

Basis*	Forms of sulfur(%)		
	Sulfate	Pyritic	Organic
1	0.02	0.08	0.16
2	0.02	0.10	0.22
3	0.02	0.12	0.25

*1-As received; 2-Moisture free; 3-Moisture and ash free.

Table 107B. Statistical summary for forms of sulfur in 12 Healy quadrangle coals (from Affolter and others, 1981b).

Statistic	Forms of sulfur(%)		
	Sulfate	Pyritic	Organic
Arithmetic mean	0.01	0.08	0.16
Observed range:			
Minimum	0.01	0.01	0.07
Maximum	0.04	0.12	0.51
Geometric mean	0.01	0.07	0.14
Geometric deviation	1.7	1.9	1.7
Powder River region geometric mean	0.02	0.29	0.31

(26) Rao and Wolff (1982)

Table 108. Sulfur content of selected seams from the Nenana coal field.

Seam	Rank	Pyritic sulfur(%)			Total sulfur(%)		
		1	2	3	1	2	3
No. 1	subC	0.01	0.01	0.02	0.16	0.21	0.25
No. 3	subC	0.01	0.01	0.01	0.16	0.22	0.25
Bed A (Arctic Mine)	subC	0.02	0.02	0.03	0.29	0.38	0.48
Lignite Creek	lig	0.01	0.01	0.01	0.24	0.33	0.38

Basis: 1-Equilibrium bed moisture; 2-Moisture free; 3-Moisture and ash free.

(27) Sanders (1983) quoted sulfur data from Rao and Wolff (1976).

(28) Merritt (1985a) found that sulfur contents in 70 Nenana coals ranged from 0.2 to 0.7 percent and averaged 0.3 percent (table 109; Figures 15 and 16). A few Nenana coals have sulfur contents over 0.5 percent, and one sample had over 1.2 percent (Figure 15). The latter sample was from Newman Creek of the West Delta field. Samples in which fram-

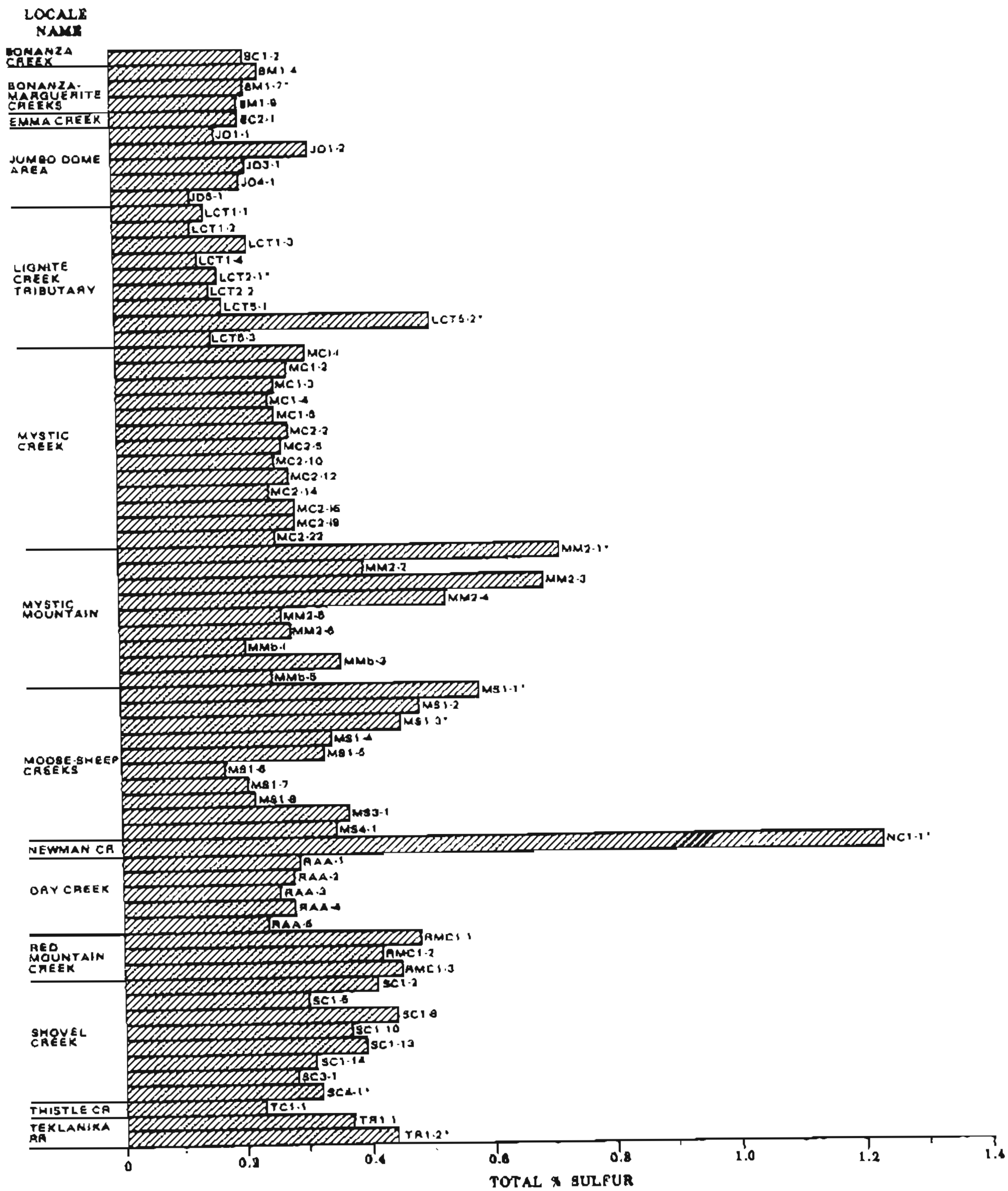

Figure 15. Total sulfur bar graph for Nenana basain coal samples. Individual samples are indicated by the code after each bar. An asterisk indicates a sample in which framboidal pyrite was identified.

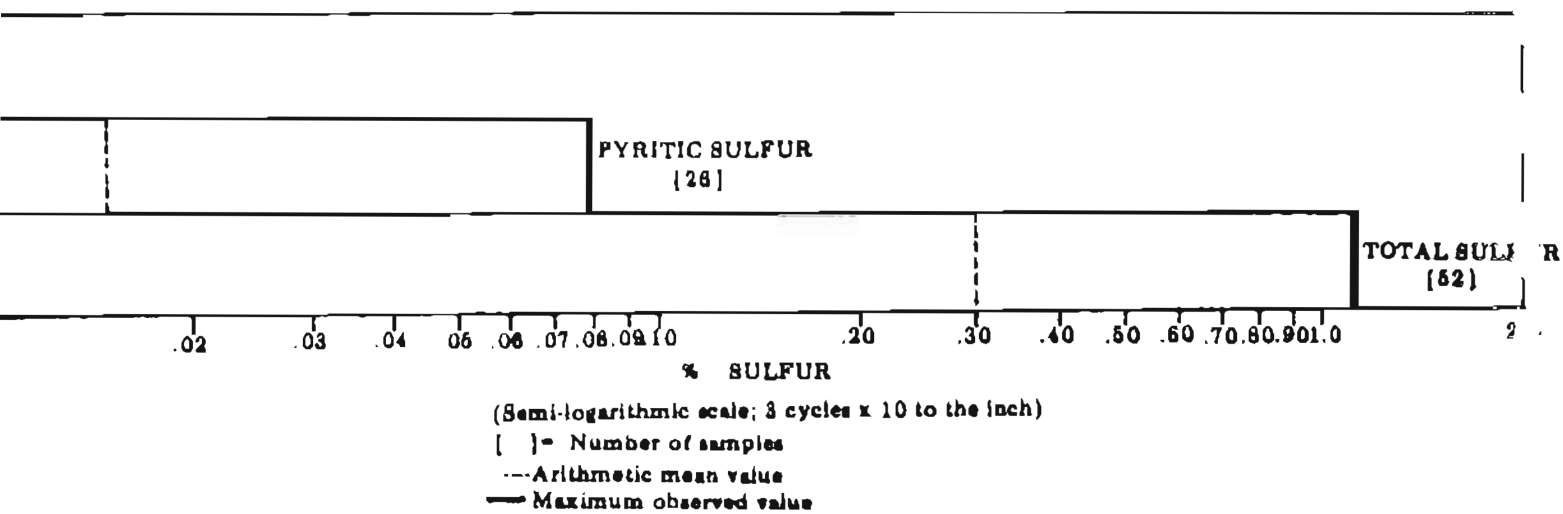

Figure 16. Bar graph showing the maximum and arithmetic mean values for the percent pyritic and total sulfur of analyzed coal samples from the Nenana basin (as received basis).

boidal pyrite was identified is indicated by an asterisk after each bar. Figure 16 shows that the pyritic sulfur content of these samples is very low. The mean pyritic sulfur content for the Nenana coal samples analyzed is less than 0.02 percent.

Table 109. Range and mean statistical summary data for total sulfur in Nenana coals.

Statistic	Basis*	Sulfur(%)
Range	1	0.2-0.7
	2	0.2-0.7
	3	0.2-0.9
	4	0.2-1.0
Mean	1	0.3
	2	0.3
	3	0.4
	4	0.4

*1-As received; 2-Equilibrium moisture; 3-Moisture free; and 4-Moisture and ash free.

Jarvis Creek Field

Jarvis Creek is the easternmost coal field of the Nenana basin. It contains coals of the Usibelli Group, in part the Healy Creek Formation. The coal-bearing strata dip gently (less 10°) around the rim of this relatively isolated structural basin. Coals are subbituminous C, 7,800-9,500 Btu/lb, 5-15 percent ash, and 0.3-1.5 percent sulfur. There is a single 10-ft bed and several thinner beds. Identified resources are 75 million short tons and hypothetical resources are 175 million short tons.

Detailed sulfur data on coals of the Jarvis Creek field are summarized below:

(1) unpublished correspondence (mid-1940's)

Table 110. Total sulfur content of Ruby Creek mine coals.

Name	Location	Sample	Rank	Sulfur(%) 1	2	3	4
Donelly, Alaska	5 mi. from Richardson Highway	14-ft thick bed; sampled 3-ft fresh coal	subb	0.2	0.2	0.2	0.3
Head of Little Gold Creek (A)	6 mi. se Donnelly, Richardson Highway	5-ft top seam	lig	2.2	2.5	2.9	3.3
Head of Little Gold Creek (B)	6 mi. se Donnelly, Richardson Highway	8-ft lower seam	lig	0.8	0.9	1.1	1.2

Basis: 1-As received; 2-Air dried; 3-Moisture free; 4-Moisture and ash free.

(2) Toenges and Jolley (1949)

Table 111. Sulfur content of Little Gold Creek coals (as-received basis).

Sample	Total sulfur(%)
1	1.4
2	0.4
3	0.4

(3) Wahrhaftig and Hickcox (1955)

Table 112. Average total sulfur in 4 coal samples from Jarvis Creek field.

Basis*	Sulfur(%)
1	0.6
2	0.7
3	0.8
4	1.0

*1-As received; 2-Air dried; 3-Moisture free; 4-Moisture and ash free.

(4) Barnes (1967a) cited a total sulfur range of 0.3-1.4 percent for Jarvis Creek field coals.

(5) Unpublished analyses, U.S. Bureau of Mines (1970)

Table 113. Average total sulfur content of 23 coal samples of Jarvis Creek field.

Basis*	Sulfur(%)
1	1.0
2	1.3
3	1.6

*1-As received; 2-Moisture free; 3-Moisture and ash free.

(6) Warfield (1973)

Table 114. Analyses of drill hole coal samples, Jarvis Creek field.

Drill Hole No.	Depth (ft)	Total sulfur(%) 1	Total sulfur(%) 2
2	71-74	0.6	1.1
3	62-65	0.8	1.4
3	65-70	0.8	1.1
3	70-73.5	1.3	2.0
3	80-81.5	1.3	2.1
5	34.6-37.5	0.6	1.0
5	37.5-41	1.1	1.6
5	41-43.8	1.5	2.3
6	49.5-52	1.4	2.4
6	69.5-74.5	0.7	1.4
6	74.5-78	1.0	2.2
6	80.5-83.5	0.9	1.8
7	20-29.5	0.9	1.5
7	32-35	0.9	1.7
8	25-26	0.8	1.2
10	66-67	0.1	---

Basis: 1-As received; 2-Moisture and ash free.

(7) The Alaska Division of Energy and Power Development (1977) quoted Barnes' (1967a) total sulfur data.

(8) McFarland (1978) quoted the total sulfur data from Barnes (1967a).

(9) Rao and Wolff (1979) found that the main Jarvis Creek field seam was unusually high in sulfur for an Alaskan coal, i.e., 1.20 percent. About a third of this sulfur is pyritic sulfur.

Table 115. Pyritic and total sulfur content of the No. 1 seam (subC), Jarvis Creek field.

Basis*	Pyritic sulfur(%)	Total sulfur(%)
1	0.31	1.05
2	0.34	1.15
3	0.39	1.32
4	0.44	1.49

*1-As received; 2-Equilibrium moisture; 3-Moisture free; 4-Moisture and ash free.

(10) The U.S. Department of Energy (1980) quoted total sulfur data from Barnes (1967a).

(11) Sanders (1981) quoted total sulfur data from Barnes (1967a).

McKinley Park Region

There are numerous scattered coal occurrences throughout the McKinley Park region along the northern flank of the Alaska Range.

Detailed sulfur data on these coal occurrences are summarized below:

(1) Capps (1940)

Table 116. Sulfur content of coal from the East Fork of Toklat River, Mt. McKinley National Park.

Basis*	Total sulfur(%)
1	0.5
2	0.5
3	0.6
4	0.6

*1-As received; 2-Air dried; 3-Moisture free; 4-Moisture and ash free.

(2) Cooper and others (1946)

Table 117. Average sulfur content of coal from McKinley Park region.

Basis*	No. of samples	Total sulfur(%)
1	7	0.4
2	7	0.5
3	3	0.5

*1-As received; 2-Dried at 105°C; 3-Moisture and ash free.

(3) Toenges and Jolley (1949)

Table 118. Sulfur content of coal along McKinley Park Highway.

Location	Sample	Total sulfur(%)
Mile post 39	1	0.3
Mile post 42	2	0.4

Table 119. Sulfur content of coal of Mt. McKinley Bituminous Mine.

Sample (as received)	Total sulfur(%)
1	0.7
2	0.4
3	0.4
Composite 1-3	0.4

(4) Rao and Wolff (1982)

Table 120. Sulfur content of Yanert Mine coal of high volatile B bituminous rank.

Basis*	Pyritic sulfur(%)	Total sulfur(%)
1	0.07	0.18
2	0.07	0.19
3	0.16	0.41

*1-Equilibrium bed moisture; 2-Moisture free; 3-Moisture and ash free.

(5) Crane (1913) cited a total sulfur content of 0.16 percent for a Cantwell River lignite sample.

(6) Pilgrim (1930) reported a total sulfur content of 3.8 percent for a 30-ft thick lignite seam on Coal Creek, a tributary of Stony Creek about 5 mi north of Copper Mountain in Kantishna district.

Little Tonzona Field and Associated Districts

Coal beds of the Little Tonzona field occur in high-angle (55° to 70°) fault blocks with minor folds. The main seam has an aggregate thickness over 100-ft but is possibly fault-repeated. It is subbituminous C, 7,600-8,500 Btu/lb, 5-11 percent ash, and 1.0-1.5 percent sulfur. Total estimated identified resources are 1.5 billion tons. The field has had no significant past production.

Coals also occur at Windy-Middle Forks, Deepbank Creek, and Cheeneetnuk River. Seams at Deepbank Creek range from 5- to 20-ft thick. Coal on Cheeneetnuk River is marginal bituminous.

Detailed sulfur data on coals of the Little Tonzona field and associated districts are summarized below:

(1) Player (1976)

Table 121. Sulfur content of Little Tonzona River coal samples.

Sample	Total sulfur (%) 1	2	3
1	1.4	1.7	1.9
2	1.1	1.3	1.4
3	1.2	1.5	1.6
4	1.2	1.6	1.7

Basis: 1-As received; 2-Moisture free; 3-Moisture and ash free.

(2) Rao and Wolff (1980); Rao and Wolff (1981) found that sulfur in the Little Tonzona coal bed is high and that very little of it is in the pyritic form. Although washing reduced the ash, it did not reduce sulfur in the product.

Table 122. Sulfur content of the main seam, Little Tonzona field.

Basis*	Pyritic sulfur(%)	Total sulfur(%)
1	0.06	1.11
2	0.08	1.40
3	0.09	1.63

*1-Equilibrium bed moisture; 2-Moisture free; 3-Moisture and ash free.

(3) C.C. Hawley and Associates, Inc. (1981)

Table 123. Sulfur content of coals at Little Tonzona River and vicinity.

Location	Total sulfur(%), as-received basis
Little Tonzona River	1.1-1.7
Deepbank Creek	0.3-1.0
Windy Fork	0.1-0.4

(4) Sloan and others (1981) found that the sulfur content varied considerably from bed to bed in the Little Tonzona field and associated districts. The Little Tonzona main seam contains about three times the percentage of sulfur as coal from the Nenana basin. However, the sulfur content of Deepbank Creek coals is lower than for coals from Little Tonzona and roughly the same or slightly higher than for Nenana basin coal.

Table 124. Average total sulfur of coals of the Little Tonzona field and associated districts.

Location	No. of samples	Sulfur(%)		
		1	2	3
Little Tonzona	10	1.1	1.4	1.6
Deepbank Creek	2	0.4	0.6	0.6
Windy Fork	9	0.2	0.2	0.4

Basis: 1-As received; 2-Moisture free; 3-Moisture and ash free.

(5) Solie and Dickey (1982)

Table 125. Pyritic and total sulfur contents of McGrath quadrangle coals.

Location	Pyritic sulfur (%)			Total sulfur (%)		
	1	2	3	1	2	3
1 Sheep Creek(1)	---	---	---	0.55	---	---
2 Windy Fork(5)	0.12	0.13	0.15	0.54	0.60	0.70
3 McGrath B-3 Quad(1)	0.06	0.09	0.10	0.33	0.45	0.52

Basis: 1-Equilibrium moisture; 2-Moisture free; 3-Moisture and ash free.

Table 126A. Pyritic and total sulfur content of Cheeneetnuk River coal.

Basis*	Pyritic sulfur(%)	Total sulfur(%)
1	1.15	2.18
2	1.28	2.45
3	1.50	2.84

*1-Equilibrium moisture; 2-Moisture free; 3-Moisture and ash free.

Table 126B. Total sulfur content of Cheeneetnuk River subbituminous and bituminous coals. Samples were collected by U.S. Geological Survey and analyzed by U.S. Department of Energy.

Sample	Rank	Sulfur(%)		
		1	2	3
1	hvCb or subA	1.3	1.6	1.7
2	subC	0.7	0.9	1.1
3	subC	0.7	0.9	1.0
4	subB	0.7	0.9	1.0

Basis: 1-As received; 2-Moisture free; 3-Moisture and ash free.

(6) Sanders (1983) cited a total sulfur range of 0.7-1.7 percent for Little Tonzona field coals.

ALASKA PENINSULA PROVINCE

Cretaceous and Tertiary bituminous and subbituminous coal and lignite are widespread on the Alaska Peninsula. Coals occur in three main fields---Chignik, Herendeen Bay, and Unga Island fields---and in several other districts and occurrences.

Detailed sulfur data on Alaska Peninsula coals are summarized below:

(1) Dall (1896) cited a total sulfur content of 0.75 percent for Amalik Harbor bituminous coal.

(2) Brooks (1902) and Stone (1905) quoted Dall (1896).

(3) Martin (1908) cited an average total sulfur of 5 Alaska Peninsula subbituminous coal samples of 1.07 percent.

(4) Crane (1913) quoted Martin (1908).

(5) McFarland (1978) cited a total sulfur range of 0.3-0.6 percent for the bituminous and subbituminous coals of Herendeen Bay, Chignik, and Unga Isle fields.

(6) Merritt and others (1986)

Table 127. Distribution of sulfur content by rank in Alaska Peninsula coal samples.

Coal rank		No. of	Average total
Class	Group	samples	sulfur(%)
Bituminous	High-volatile A bit.	1	0.49
	High-volatile B bit.	5	0.45
	High-volatile C bit.	34	0.76
Subbituminous	Subbituminous A	40	1.26
	Subbituminous B	1	1.79
	Subbituminous C	2	0.46
Lignite	Lignite A	11	1.27

Chignik Field

Coals of the Chignik field occur in the Late Cretaceous Chignik Formation, which consists of cyclic nearshore marine and nonmarine strata. The coal-bearing strata are moderately folded and faulted. Chignik Formation coal is high-volatile B bituminous, 10,000-11,800 Btu/lb, 7-30 percent ash, and 0.3-2.8 percent sulfur. Seams are less than 8-ft thick. Total identified resources are 230 million short tons, and hypothetical resources are 1.5 billion short tons.

(1) Dall (1896) cited a total sulfur value of Chignik Bay, Alaska Peninsula bituminous coal of 1.71 percent.

(2) Brooks (1902) quoted Dall (1896).

(3) Stone (1905) gave a total sulfur content of 2.15 percent for a Chignik River coal.

(4) Atwood (1909; 1911)

Table 128. Range and average total sulfur content of 4 Chignik Bay coals.

Basis*	Range total sulfur(%)	Avg. total sulfur(%)
1	0.70-2.26	1.50
2	0.75-2.35	1.56

*1-As received; 2-Air dried.

(5) Crane (1915) cited a total sulfur content of 1.25 percent for Chignik Bay coals.

(6) Coffin (1919) gave an average total sulfur of 1.50 percent for 4 Chignik Bay subbituminous coals.

(7) Knappen (1929)

Table 129. Total sulfur content of Chignik field coal occurrences.

Location	Sulfur(%) 1	Sulfur(%) 2
Hook Bay	2.26	2.35
Thompson Valley	0.70	0.75
Whalers Creek	1.75	1.79
Chignik River	1.30	1.37

Basis: 1-As received; 2-Air dried.

(8) Cooper and others (1946)

Table 130. Average total sulfur of 4 Chignik Bay coal samples.

Basis*	Sulfur(%)
1	1.5
2	1.6
3	2.0

*1-As received; 2-Dried at 105°C; 3-Moisture and ash free.

(9) Barnes (1967a) cited a total sulfur range of 0.7-2.3 percent for bituminous coals of Chignik field.

(10) Conwell and Triplehorn (1978)

Table 131A. Total sulfur of Chignik River mine coal.

Location	Sulfur(%) 1	2	3
Chignik River Mine	1.1	1.1	1.6
Chignik River Mine (composite sample)	1.3	1.4	1.8

Basis: 1-As received; 2-Moisture free; 3-Moisture and ash free.

Table 131B. Sulfur forms of Chignik River mine coal.

Location	Basis*	Sulfur(%) Sulfate	Pyritic	Organic
Chignik River Mine	1	0.02	0.57	0.49
	2	0.02	0.58	0.50
	3	0.03	0.83	0.71
Chignik River Mine (composite sample)	1	0.2	0.57	0.76
	2	0.2	0.58	0.78
	3	0.3	0.76	1.01

*1-As received; 2-Moisture free; 3-Moisture and ash free.

Table 132. Total sulfur contents of samples from coal benches in a tunnel near the Chignik River mine.

Sample	Sulfur(%)
1	2.75
2	1.37
3	0.31
4	0.50
5	0.58

Table 133. Total sulfur contents of Thompson Valley coal samples.

Sample	Sulfur(%)
1	0.55
2	0.27
3	0.34
4	1.38
5	1.12

(11) McGee (1979) listed an as-received total sulfur range of 0.70-2.20 percent and an average total sulfur of 1.53 percent for the Chignik Bay coal field.

(12) The U.S. Department of Energy (1980) gave a total sulfur range of 0.7-2.3 percent for Chignik field coals.

(13) Vorobik and others (1981) stated that sparse detrital disseminated pyrite and angular to subrounded sand grains in the Chignik Formation indicated local rapid deposition possibly in a reducing environment. In the Coal Valley Member, they found that marcasite and pyrite had both locally replaced carbonaceous material and were present as thin detrital beds (1-2 in) proxi-

mal to the coal horizons. The sulfur content was moderately high in the two areas where they computed coal reserves: 1. Thompson-McKinsey Valley and 2. Diamond Point.

Table 134. Weighted total sulfur range and average percentages at equilibrium moisture for McKinsey Ridge minable lower zone and Diamond Point trenches.

Location	No. of samples	Range sulfur(%)	Average sulfur(%)
McKinsey Ridge	11	0.38-2.77	1.08
Diamond Point	3	0.13-0.21	0.17

(14) Rao and Wolff (1982) found 1.12 percent sulfur in Chignik Bay Mine coal on a moisture-free basis. After washing the 1-½ in x 100 mesh coal at 1.60 specific gravity, the product contained 1.9 percent sulfur with 50.2 percent yield. Although half of the total sulfur was in the pyritic form, reduction in sulfur by washing at a finer size was only moderate.

Table 135. Pyritic and total sulfur in Chignik Bay Mine coal of high-volatile C bituminous rank.

Basis*	Pyritic sulfur(%)	Total sulfur(%)
1	1.05	1.64
2	1.12	1.76
3	1.76	2.76

*1-Equilibrium bed moisture; 2-Moisture free; 3-Moisture and ash free.

Herendeen Bay Field

Coals of the Herendeen Bay field occur both in the Late Cretaceous Chignik Formation and Unga Conglomerate Member of the Miocene Bear Lake Formation. The Chignik Formation consists of cyclic nearshore marine and nonmarine strata, and the Bear Lake Formation consists of transitional marine and nonmarine strata. Chignik Formation coals are typically high-volatile B bituminous, 10,000-11,800 Btu/lb, 7-30 percent ash, and 0.3-2.8 percent sulfur. Bear Lake Formation coals are typically lignitic, 5,800-7,000 Btu/lb, 7-35 percent ash, and 0.5-2.2 percent sulfur. Seams are less than 8-ft thick. Total identified resources of the Herendeen Bay field are 130 million short tons, and hypothetical resources are 1.5 billion short tons.

(1) Dall (1896) cited a total sulfur content of 0.44 percent for Herendeen Bay bituminous coal from Alaska Commercial Co. tunnel.

(2) Brooks (1902) quoted Dall (1896).

(3) Stone (1905) quoted Dall (1896).

(4) Paige (1906) quoted Dall (1896).

(5) Atwood (1909; 1911)

Table 136. Range and average total sulfur of 2 Herendeen Bay coals.

Basis*	Range sulfur(%)	Average sulfur(%)
1	0.31-0.41	0.36
2	0.32-0.43	0.38

*1-As received; 2-Air dried.

(6) Coffin (1919) quoted Atwood (1909; 1911).

(7) Gates (1944)

Table 137. Average total sulfur of 2 Mine Creek, Herendeen Bay coal samples.

Basis*	Sulfur(%)
1	0.5
2	0.5
3	0.5
4	0.6

*1-As received; 2-Air dried; 3-Moisture free; 4-Moisture and ash free.

(8) Cooper and others (1946)

Table 138. Average total sulfur of Herendeen Bay coals.

Basis*	No. of samples	Sulfur(%)
1	13	0.4
2	13	0.4
3	2	0.4

*1-As received; 2-Dried at 105°C; 3-Moisture and ash free.

(9) Barnes (1967a) cited a total sulfur range of 0.3-0.6 percent for Herendeen Bay field bituminous coals.

(10) The Alaska Division of Energy and Power Development quoted the total sulfur data from Barnes (1967a).

(11) Conwell and Triplehorn (1978)

Table 139. Total sulfur contents of coal samples from Mine Harbor, Herendeen Bay.

Sample	Sulfur(%)
1	0.40
2	0.39
3	0.33
4	0.34
5	0.27

Table 140A. Total sulfur contents of Lawrence Valley and Coal Bluff coals from Herendeen Bay field.

Location	Sulfur(%) 1	Sulfur(%) 2	Sulfur(%) 3
Lawrence Valley	0.3	0.3	0.4
Coal Bluff	0.6	0.6	1.2

Basis: 1-As received; 2-Moisture free; 3-Moisture and ash free.

Table 140B. Sulfur forms of Lawrence Valley and Coal Bluff coals from Herendeen Bay field.

Location	Basis*	Sulfur(%) Sulfate	Pyritic	Organic
Lawrence Valley	1	0.2	0.05	0.23
	2	0.3	0.05	0.24
	3	0.3	0.06	0.29
Coal Bluff	1	0.2	0.42	0.16
	2	0.2	0.43	0.16
	3	0.4	0.86	0.33

*1-As received; 2-Moisture free; 3-Moisture and ash free.

(12) The U.S. Department of Energy (1980) quoted total sulfur data from Barnes (1967a).

(13) Sanders (1981) gave a range in total sulfur of 0.3-0.4 percent for Herendeen Bay field bituminous coals.

(14) Rao and Wolff (1982)

Table 141. Pyritic and total sulfur contents of Coal Point, Herendeen Bay field high-volatile B bituminous coal.

Basis*	Pyritic sulfur(%)	Total sulfur(%)
1	0.87	1.81
2	0.89	1.91
3	1.58	3.39

*1-Equilibrium bed moisture; 2-Moisture free; 3-Moisture and ash free.

Unga Island Field

Coals of the Unga Island field occur in the Unga Conglomerate Member of the Miocene Bear Lake Formation. The coals, which underlie the northwest peninsula of Unga Island, are lignitic, 5,800-7,000 Btu/lb, 7-35 percent ash, and 0.5-2.2 percent sulfur. Seams are less than 3-ft thick. Total hypothetical resources are 150 million short tons.

(1) Dall (1896) gave total sulfur contents of 2 Unga Island lignite seams---upper seam 2.17 percent and lower seam 0.56 percent.

(2) Brooks (1902) and Stone (1905) quoted Dall (1896).

(3) Martin (1908) gave an average sulfur content of 1.36 percent for 2 seams listed by Dall (1896).

(4) Atwood (1909; 1911) cited as-received total sulfur of 0.53 percent and air-dried total sulfur of 0.60 percent for Unga Island coal.

(5) Crane (1913) quoted Martin (1908) and Dall (1896).

(6) Cooper and others (1946)

Table 142. Total sulfur content of Unga Island coal.

Basis*	Sulfur(%)
1	0.5
2	0.7
3	1.1

*1-As received; 2-Dried at 105°C; 3-Moisture and ash free.

(7) Barnes (1967a) cited a total sulfur value of 0.5 percent for Unga Island coal.

(8) Naske and Triplehorn (1980) stated that W.H. Dall tested the Unga Island coal in the ship's galley of the U.S.S. Humboldt in 1872 and found it unsatisfactory due to its high sulfur and ash content.

(9) The U.S. Department of Energy (1980) quoted total sulfur data from Barnes (1967a).

GULF OF ALASKA PROVINCE

Bering River Field

Coals of the Bering River field occur in the Eocene-early Miocene Kushtaka Formation. Geologic structure is complex with coals in tightly folded, locally deformed and overturned beds and lenses cut by many faults. Coal increases in rank toward the east from medium- and low-volatile bituminous to anthracite. The low-volatile bituminous coal contains 11,000-15,000 Btu/lb, 2-30 percent ash, and 0.1-1.0 percent sulfur. Beds and lenses range from 6- to 30-ft thick. Identified resources are 110 million short tons and hypothetical resources are 3.5 billion short tons.

Detailed sulfur data on coals of the Bering River field are summarized below:

(1) Martin (1906) stated that one coal in a tunnel on the creek 1 mile north of Bering Lake contained 3.36 percent total sulfur, and that a coal on Kushtaka Ridge, 710 ft above the lake contained 5.27 percent total sulfur.

Table 143. Average and range in total sulfur contents of Bering River field coals.

Samples	Average sulfur(%)	Range in sulfur(%)
1-7	1.30	0.82-2.90
8-9	0.65	0.51-0.79
10-20	1.51	0.61-5.27

(2) Martin (1908)

Table 144. Average total sulfur of Bering River field coal samples collected 1903-1906.

Rank	No. of samples	Sulfur(%)
Anthracite	7	1.30
Semianthracite	12	1.08
'Semibituminous'	28	1.73

Table 145. Average and range in total sulfur of Bering River field coal samples collected 1905-1906.

Rank	No. of samples	Average sulfur(%)		Range in sulfur(%)
		1	2	
Anthracite	5	0.98	1.05	0.86-1.18
Semianthracite	10	0.99	1.04	0.52-2.63
'Semibituminous'	17	1.89	1.96	0.64-6.65

Basis: 1-As received; 2-Air dried.

(3) Crane (1913) cited average total sulfur contents of 1.30 percent for 7 Bering River anthracite samples and 1.51 percent for 11 Bering River semianthracite samples.

(4) Fisher and Calvert (1914) gave a total sulfur range in 39 Bering River coal samples of none or trace to 1.56 percent, and an average total sulfur of 0.62 percent in 35 samples.

(5) Coffin (1919) quoted Martin (1908).

(6) Hill (1921)

Table 146. Total sulfur content of Bed No. 16, Bering River field.

Sample series	Sample 1	Sample 2	Composite
1919	0.86	0.92	---
1920	0.68	0.69	0.68

(7) Evans (1925) quoted sulfur data from Martin (1908).

(8) Cooper and others (1946)

Table 147. Average total sulfur of Bering River field coal samples.

Basis*	No. of samples	Sulfur(%)
1	63	1.2
2	62	1.3
3	43	1.6

*1-As received; 2-Dried at 105°C; 3-Moisture and ash free.

(9) Barnes (1951) stated that beds from the west fork of Barrett Creek contained 'sulfur kidneys.'

(10) Barnes (1967a)

Table 148. Sulfur content of Bering River coals by rank.

Rank	Range total sulfur(%)
Bituminous	0.7-1.4
Semianthracite	0.5-4.9
Anthracite	0.6-2.9

(11) Rao (1969)

Table 149. Sulfur content of Leeper Creek coals.

	Total sulfur(%)		
Seam	1	2	3
Leeper Creek No. 1	1.22	1.24	1.32
Leeper Creek No. 2	0.78	0.79	0.82

Basis: 1-Equilibrium bed moisture; 2-Dry; 3-Moisture and ash free.

(12) Rao (1976) cited a range in total sulfur of 0.60-1.00 percent and average sulfur of 0.78 percent in 5 Bering River low-volatile bituminous coal samples.

(13) Sanders (1976) found the coals of the Carbon Creek area of the Bering River field were low sulfur.

(14) The Alaska Division of Energy and Power Development (1977) cited a total sulfur range of 0.3-5.2 percent for the Tertiary bituminous and anthracite coals of the Bering River field.

(15) McFarland (1978) quoted sulfur data from the Alaska Division of Energy and Power Development (1977).

(16) The U.S. Department of Energy (1980) cited a total sulfur range of 0.5-1.4 percent for Bering River field coals.

(17) Sanders (1981) quoted total sulfur data from Rao (1976).

YUKON-KOYUKUK PROVINCE

Detailed sulfur data on coals of this province are summarized below:

(1) Cooper and others (1946)

Table 150. Average total sulfur of Unalakleet coals.

Basis*	No. of samples	Sulfur(%)
1	2	0.4
2	2	0.5
3	1	0.6

*1-As received; 2-Dried at 105°C; 3-Moisture and ash free.

(2) Rao and Wolff (1982)

Table 151. Pyritic and toal sulfur content of Coal Creek, Unalakleet subbituminous C-ranked coal.

Basis*	Pyritic sulfur(%)	Total sulfur(%)
1	0.01	0.44
2	0.01	0.54
3	0.01	0.61

*1-Equilibrium bed moisture; 2-Moisture free; 3-Moisture and ash free.

(3) Martin (1908) gave an average total sulfur of 0.48 percent for 11 lower Yukon River bituminous coals.

(4) Crane (1913) quoted the sulfur data of Martin (1908).

(5) Coffin (1919) quoted the sulfur data of Martin (1908).

(6) Holzheimer (1926)

Table 152. Total sulfur content of lower Yukon River coals.

Sample	Bed thickness (ft)	Location	Sulfur(%) 1	2	3
1	4	8 mi below Kaltag	0.4	0.5	0.5
2	4	8 mi below Kaltag	0.4	0.4	0.6
3	3	25 mi below Kaltag	0.5	0.6	0.7
4	1	5 mi above Kaltag	0.7	0.7	0.8

Basis: 1-As received; 2-Moisture free; 3-Moisture and ash free.

(7) Cooper and others (1946)

Table 153. Average total sulfur of lower Yukon River coal samples.

Basis*	No. of samples	Sulfur(%)
1	6	0.6
2	6	0.6
3	2	0.8

*1-As received; 2-Dried at 105°C; 3-Moisture and ash free.

(8) Chapman (1963)

Table 154. Sulfur content of coal from deposits along the Yukon River between Ruby and Anvik, Alaska.

Location	Sulfur(%) air-dried basis
Nahoclatilton(2)	0.5
Pickart mine(2)	0.6
Bush mine	0.4
Blatchford mine(2)	0.7
Adolph Muller prospect	0.5
Williams mine(2)	0.5
Coal mine no. 1	0.3

(9) Barnes (1967a) cited a range in total sulfur of 0.2-0.6 percent for bituminous coals of the Ruby-Anvik district.

(10) Warfield (1967)

Table 155. Sulfur content of lower Yukon River coal mine samples.

Location	Sulfur(%)
Pickart coal mine	0.60
Williams mine (upper bench)	0.40
Williams mine (lower bench)	0.53

(11) C.C. Hawley and Associates (1981) cited a total sulfur content of 0.6 percent for coal occurrences on the Yukon River between Blackburn and Nulato.

Nulato Field

Coals of the Nulato field occur in the Late Cretaceous Kaltag Formation. The geologic structure is generally simple but locally complex with folding and faulting. Coals are high-volatile C bituminous, 9,100-9,750 Btu/lb, 3-22 percent ash, and 0.2-0.6 percent sulfur. Seams are generally less than 4-ft thick. Hypothetical resources are 50 million short tons.

(1) Cooper and others (1946) listed total sulfur values of 0.9 percent on as-received and dried (at 105°C) bases for Nulato field coals.

(2) Sanders (1981) cited a total sulfur range of 0.2-0.6 percent for Nulato field coals.

(3) Rao and Wolff (1982)

Table 156. Pyritic and total sulfur contents of high-volatile A bituminous coals of the Nulato field.

Sample	Basis*	Pyritic sulfur(%)	Total sulfur(%)
1	1	0.16	0.36
	2	0.16	0.38
	3	0.47	1.08
2 (1.60 specific gravity float)	1	0.08	1.04
	2	0.08	1.07
	3	0.09	1.19

*1-Equilibrium bed moisture; 2-Moisture free; 3-Moisture and ash free.

Kobuk Fields

Coals of the East and West Kobuk fields occur in the upper member of the middle Cretaceous Bergman Group. The coal-bearing strata is characterized by generally shallow dips (less 30°) defining broad open folds, locally steeply dipping near high-angle faults. Coals are high-volatile C bituminous, 9,200 to 10,500

Btu/lb, 7-35 percent ash, and 0.4-1.1 percent sulfur. Seams are typically less 3-ft in thickness.

The only sulfur data reported for Kobuk River bituminous coal was a 0.4 percent total sulfur value from Barnes (1967a).

Hockley Hills

(1) Burand (1959) reported on coal near Selawik, Alaska in the Hockley Hills, at the southwest edge of Waring Mountains, in a bluff on the right side of the Singauruk River, Noatak-Kobuk precinct. He gave an average total sulfur of 0.5 percent for 2 samples on both as-received and moisture free bases.

(2) Clough and others (1983b)

Table 157. Pyritic and total sulfur contents of Hockley Hills, Singauruk River area coals.

Sample	Basis*	Sulfur (%)	
		Pyritic	Total
1	1	---	0.25
2	1	---	0.24
3	1	---	0.35
4	1	---	0.28
5	1	0.14	0.46
	2	0.17	0.53
	3	0.19	0.61
6	1	0.01	0.26
	2	0.02	0.28
	3	0.04	0.68

*1-Equilibrium bed moisture; 2-Moisture free; 3-Moisture and ash free.

Kallarichuk River

Clough and others (1983a) reported on Kallarichuk River area coals.

Table 158. Pyritic and total sulfur contents of Kallarichuk River coals.

Sample	Basis*	Pyritic sulfur(%)	Total sulfur(%)
1	1	0.41	1.05
	2	0.47	1.22
	3	0.55	1.43
2	1	---	0.38

*1-Equilibrium bed moisture; 2-Moisture free; 3-Moisture and ash free.

Tramway Bar Field

The Tramway Bar field contains the thickest coals of the Yukon-Koyukuk province. The field is an eastern extension of coal-bearing rocks in the Kobuk fields (Barnes, 1967a). Rao and Wolff (1980) sampled and analyzed the thickest of three seams in the main outcrop. The coal seams dip at about 56°. The coals are high-volatile B bituminous rank.

Table 159. Pyritic and total sulfur contents of the main seam coal, Tramway Bar field (from Rao and Wolff, 1980).

Basis*	Pyritic sulfur(%)	Total sulfur(%)
1	0.04	0.14
2	0.04	0.15
3	0.07	0.25

*1-Equilibrium bed moisture; 2-Moisture free; 3-Moisture and ash free.

UPPER YUKON PROVINCE

Barker (1981) reported on coals of the Upper Yukon Cenozoic basin. He found the sulfur contents of Ray River coal samples (0.74 percent and 1.17 percent at bed equilibrium moisture) were unusually high for typical Alaskan coal. He also found the coal of the Tozitna River Valley to be slightly high (0.66 percent at bed equilibrium moisture) for Alaskan coal.

Table 160. Sulfur contents of coals of Yukon Flats Cenozoic basin.

Location	No. of samples	Rank	Total sulfur(%)		
			1	2	3
Coal Creek (Dall River)	3	ligA-subC	0.16	0.23	0.28
Hodzana River	2	ligA-subC	0.59	0.78	0.84
Ray River	2	ligA-subC	0.96	1.32	1.56
Tozitna River (Ray Mtns.)	1	ligA	0.66	0.97	1.14

Rampart Field

The Rampart field contains Early Tertiary coal-bearing strata that dip steeply (over 45°). Coals are subbituminous A to high-volatile C bituminous, 9,500-11,000 Btu/lb, 8-15 percent ash, and 0.2-0.5 percent sulfur. Seams are typically less than 5-ft thick. Hypothetical resources are 50 million short tons.

(1) Martin (1908) listed an average total sulfur of 6 Rampart field coals of 0.33 percent.

(2) Crane (1913) quoted the sulfur data from Martin (1908).

Circle District

Martin (1908) gave an average total sulfur value of 1.30 percent for the subbituminous to lignitic coals of the Circle district. Crane (1913) quoted Martin's (1908) sulfur data for these Upper Yukon coals.

Eagle Field

The Eagle field contains Late Cretaceous to Tertiary coal-bearing strata in broad open folds with dips less 45°. Coals are typically of subbituminous rank and occur in seams less 5-ft thick. Identified resources are 10 million short tons and hypothetical resources are 100 million short tons.

(1) Martin (1908) cited an average total sulfur of 1.26 percent for 13 lignitic coals of the Eagle field.

(2) Crane (1913) quoted the sulfur data from Martin (1908).

(3) Cooper and others (1946) gave an average total sulfur of 0.4 percent for Eagle field coals on both as-received and dried (at 105°C) bases.

(4) Barnes (1967a) cited a total sulfur content of 0.2-0.3 percent for Washington Creek, Eagle field coals.

(5) Sanders (1981) cited a range in total sulfur of 0.2-0.6 percent for Eagle field coals.

Nation River

The Nation River coal occurrence occupies a separate deposit near the Eagle field. It is found in Paleozoic or Mesozoic(?) coal-bearing strata on the Nation River near its junction with the Yukon River. The coals are medium-volatile bituminous, 10,900-11,500 Btu/lb, and 2-22 percent ash. Less than 2,000 tons of coal has been mined from this deposit.

(1) Martin (1908) cited a total sulfur value for Nation River coal of 2.98 percent.
(2) Crane (1913) quoted sulfur data from Martin (1908).
(3) Barnes (1967a) cited a total sulfur content of 3.0 percent for Nation River bituminous coal.
(4) The U.S. Department of Energy (1980) quoted Barnes (1967a).

Fortymile Prospect

Selvig and others (1944) listed coal quality data for Fortymile Prospect.

Table 161. Total sulfur of subbituminous C coal of the Fortymile Prospect.

Basis*	Sulfur(%)
1	1.3
2	1.8
3	2.0

*1-As received; 2-Moisture free; 3-Moisture and ash free.

Chicken District

Cooper and others (1946) reported average total sulfur for 2 Chicken district coals of 0.5 percent (as-received basis) and 0.6 percent (dried---at 105°C---basis).

Rao and Wolff (1982) found the sulfur content of a Chicken coal sample to be high. Much of the sulfur was organic and no significant reduction in sulfur was possible by cleaning.

SEWARD PENINSULA PROVINCE

Lignitic coals are widely distributed over the Seward Peninsula.

(1) Martin (1908) cited a total sulfur value of 0.68 percent for a Seward Peninsula lignite.

(2) Crane (1913) quoted Martin (1908)

(3) Cooper and others (1946)

Table 162. Average total sulfur of 10 Seward Peninsula coal samples.

Basis*	Sulfur(%)
1	0.9
2	1.3
3	1.5

*1-As received; 2-Dried at 105°C; 3-Moisture and ash free.

Chicago Creek Field

Coals of the Chicago Creek (Kugruk River) field occur in Late Cretaceous to Paleocene strata. Seams are found in a narrow (1,000-ft wide) graben and dip from 45° to 70°. Coals are lignitic, 6,500-7,700 Btu/lb, 4-10.5 percent ash, and 0.5-1.1 percent sulfur. One seam is 80-ft thick. Identified resources are 3.5 million short tons and hypothetical resources are 10 million short tons. Past production has been over 110,000 tons.

(1) C.C. Hawley and Associates, Inc. (1981) cited a total sulfur content of 0.9 percent.

(2) Rao and Wolff (1982)

Table 163. Pyritic and total sulfur content of the main seam, Chicago Creek field, coal of subbituminous C rank.

Basis*	Pyritic sulfur(%)	Total sulfur(%)
1	0.04	0.60
2	0.06	0.84
3	0.07	0.98

*1-Equilibrium bed moisture; 2-Moisture free; 3-Moisture and ash free.

St. Lawrence Island

St. Lawrence Island has minor occurrences of lignitic coals.

Table 164. Total sulfur content of St. Lawrence Island lignites (from Snodgrass, 1936).

Sample	Sulfur(%) 1	2	3	4
Lignite 1	0.7	0.7	0.8	1.1
Lignite 2	2.3	2.5	2.7	3.0

Basis: 1-As received; 2-Air dried; 3-Moisture free; 4-Moisture and ash free.

SOUTHEAST ALASKA

There are several localized coal occurrences in southeast Alaska.

(1) Martin (1908) cited an average total sulfur of 0.57 percent for 5 lignites.

(2) Crane (1913) and Coffin (1919) quoted Martin (1908).

(3) Cooper and others (1946)

Table 165. Average total sulfur of Admiralty Island, southeast Alaska coals.

Basis*	No. of samples	Sulfur(%)
1	3	0.8
2	3	0.9
3	2	1.5

*1-As received; 2-Dried at 105°C; 3-Moisture and ash free.

(4) Sanders (1981) cited a total sulfur range of 0.9-1.3 percent for Admiralty Island coals.

Kootznahoo Inlet Field

Coals of the Kootznahoo Inlet field are of Tertiary age, and occur in strata that is moderately deformed and faulted but locally only gently folded and nearly horizontal. The coals are typically of high volatile B bituminous rank, 9,900-10,700 Btu/lb, 10-30 percent ash, and 0.8-1.5 percent sulfur. Seams are less than 3-ft thick.

(1) Dall (1896)

Table 166. Sulfur content of Kootznahoo Inlet field seams.

Seam	Total sulfur(%)
Sepphagen	0.32
Point Sullivan	0.51
Mitchell	0.47
Brightman and DeGroff	0.89
McCluskey	0.67

(2) Brooks (1902) quoted Dall (1896) in stating a total sulfur range of 0.32 to 0.89 percent and an average total sulfur of 0.57 percent for Kootznahoo Inlet, Admiralty Island bituminous coals.

(3) Barnes (1967a) listed a total sulfur range of 0.9-1.3 percent for Admiralty Island bituminous coals.

(4) The U.S. Department of Energy (1980) quoted Barnes (1967a).

SOUTHWEST ALASKA

Southwest Alaska contains several scattered coal occurrences. Sulfur data will only be cited here for the Nelson Island district.

Table 167. Sulfur content of 5 Nelson Island coals (from Cooper and others, 1946).

Basis*	Total sulfur(%)
1	0.5
2	0.5
3	0.6

*1-As received; 2-Dried at 105°C; 3-Moisture and ash free.

KODIAK AND SITKINAK ISLANDS

Kodiak Island

Dall (1896) reported a total sulfur content of 0.17 percent for a Red River, Kodiak Island lignite. Brooks (1902), Stone (1905), Martin (1908), and Crane (1913) quoted Dall (1896).

Sitkinak Island

(1) Jasper (1959)

Table 168A. Sulfur content of Sitkinak Island coal.

Basis*	Total sulfur(%)
1	0.4
2	0.5
3	0.5

*1-As received; 2-Dry; 3-Moisture and ash free.

(2) Warfield (1962)

Table 168B. Sulfur content of Sitkinak Island coal.

Basis*	Total sulfur(%)
1	0.1
2	0.1
3	0.2

*1-As received; 2-Dry; 3-Moisture and ash free.

(3) Anderson (1969) cited an average total sulfur of 0.4 percent for 3 Sitkinak Island subbituminous coal samples.

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