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Characterization and utilization of high- and low-sodium lignite of the Beulah-Zap bed (Paleocene), Indian Head Mine, southwestern North Dakota

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CHARACTERIZATION AND UTILIZATION OF HIGH- AND LOW-SODIUM LIGNITE OF THE BEULAH-ZAP BED (PALEOCENE), INDIAN HEAD MINE, SOUTHWESTERN NORTH DAKOTA

by

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(Chairman)

This thesis meets the standards for appearance and conforms to the style and format requirements of the Graduate School of the University of North Dakota, and is hereby approved.

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Permission

Title: Characterization and Utilization of High- and Low-Sodium Lignite of the Beulah-Zap Bed (Paleocene), Indian Head Mine, Southwestern North Dakota

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ABSTRACT

A study of high- and low-sodium lignite of the Beulah-Zap bed sampled at the Indian Head Mine, Pit 11 and 12, respectively, in Mercer County, North Dakota and fly ash derived from utilization tests on the lignite, indicates the fly-ash composition and related utilization potential can be correlated to coal geochemistry.

Average lithotype abundances for each of the sampling sites were estimated to be vitrain 50%, attritus 45%, and fusain 5%. Attritus occurs more frequently in the upper part and vitrain in the middle and lower parts of the seam. Maceral groups, identified microscopically, were (in order of decreasing abundance): huminite, inertinite, and liptinite. The percentage of huminite macerals increased toward the bottom and inertinite macerals toward the top of the seam at each sampling location. Similar abundances and trends for lithotypes and maceral groups between the high- and low-sodium lignites indicate similar depositional processes.

Scanning electron microscopy and electron microprobe analysis were used to determine the abundance and distribution of major elements in the lignite. Sodium concentrations were found to be an order of magnitude higher in Pit 11 than in Pit 12. Calcium and magnesium concentrations were also higher in Pit 11 and iron, sulfur, aluminum, and silicon concentrations were higher in Pit 12. A distinct correlation between iron and sulfur abundance was noted in Pit 11, consistent with high pyrite content as determined during field descriptions and microscopic evaluation of the samples.

The differences in sodium concentrations at the two sampling locations relate to a hydrogeochemical model presented in the literature. High-sodium coal corresponds with fine-textured overburden sediments. The source of the sodium in the high-sodium coal is believed to be sodium montmorillonite clays in the overburden at Pit 11.

Combustion tests at flue-gas temperatures of 1300°C and 1500°C were made on a composite lignite sample from each of the two sampling locations. Fly-ash samples were analyzed by point-count techniques with an electron microprobe and by energy-dispersive X-ray fluorescence analyses. The chemical composition of fly-ash particles was extremely variable indicating the complexity of reaction mechanisms involved in the formation of the fly ash. Average oxide concentrations of fly ash correlate with oxide concentrations in the lignite indicating that the fly-ash composition and utilization potential can be related directly to the lignite composition. The specific mineral and amorphous phases present in the fly ash are interpreted to be determined by the elemental composition of the lignite and the temperature at which the fly-ash particles are formed.

INTRODUCTION

Purpose

The purpose of this study is to obtain an increased understanding of the petrographic and geochemical variation of high- and low-sodium lignite and to investigate how geochemical and geological properties of lignite affect utilization. The Beulah-Zap bed is a major lignite in the Sentinel Butte Formation (Paleocene) of the North Dakota part of the Fort Union Region. The lignite was studied petrographically and through chemical analysis to: 1) determine vertical variations within the lignite seam, 2) determine variations between the lignite samples collected in high- and low-sodium areas of a mine, 3) to relate fly-ash composition to high- and low-sodium lignite properties, and 4) to evaluate possible relationships between lignite properties and depositional and post-depositional processes.

Enormous quantities of low-rank coal (lignite and subbituminous coal) are present in the United States. Over 100 trillion tons of identified resources have been located and inferred (Low Rank Coal Study, 1981). Major low-rank coal deposits in the United States include lignite in the Fort Union Region and US Gulf Coast Region, and subbituminous coal in the Powder River Region, San Juan Basin, and Northern Alaska Region. These coals are distinguished from high-rank, eastern, bituminous coals by lower heating value, higher moisture content, dissimilar physical properties, generally lower sulfur content and a predominance of alkaline rather than acidic ash components. These properties of low-rank coals affect their utilization potential.

The focus of this study is the Beulah-Zap lignite bed of the Fort Union Region. The Fort Union Region has been referred to as the largest coal basin on earth (Low Rank Coal Study, 1980). Large strippable lignite deposits are found in western North Dakota and eastern Montana. The lignite is primarily used as boiler fuel at mine-mouth electric utility generating stations. Many boilers become severely fouled because of the high-sodium content of the lignite. In addition to the use of the lignite for boiler fuel, it is the feed stock for the Great Plains Gasification Plant that produces synthetic natural gas. Efficient utilization of this lignite and expansion of marketing potential requires a basic understanding of lignite properties and their affect on utilization.

Lignite is a heterogeneous, carbonaceous rock composed of megascopically observable, dominantly organic components (lithotypes). The lithotypes consist of non-crystalline constituents (macerals) and minor crystalline constituents (minerals) (Kleesattel, 1985). The purpose of this study is to investigate the interactions between megascopic, microscopic, and chemical properties, and to determine possible relationships of these properties to depositional and post-depositional processes and to final utilization of the lignite.

Study Area Location

The study area is in the Knife River drainage basin, within the Williston Basin (Figure 1) of the Fort Union Region. The Williston Basin is a broad structural and sedimentary basin containing strata from the Cambrian to Tertiary systems. The Beulah-Zap lignite occurs as a subsurface unit in Mercer and Oliver Counties of North Dakota. The study area was restricted to mining exposures at the North American Coal Corporation's Indian Head mine near the town of Zap in Mercer county (Figure 2). Samples were collected at two locations in the Indian Head mine. The high-sodium lignite samples were collected from Pit 11 in the southeast quarter of Section 16, Township 144 N., Range 88 W. The low-sodium lignite samples were collected from Pit 12 in the northeast quarter of Section 21, Township 144 N., Range 88 W.

General Geology

The following discussion on the geology of the Beulah-Zap lignite follows that of Kleesattel (1985). The Beulah-Zap lignite bed was named by Leonard et al. (1925) after the towns of Beulah and Zap where it was being mined at that time. The Beulah-Zap lignite bed is one of several laterally extensive, thick lignites occurring in the Sentinel Butte Formation (Paleocene) in North Dakota. The Sentinel Butte Formation is a nonmarine unit of the Fort Union Group

Figure 1. Location of the Williston and Knife River Basins (after Groenewold et al., 1979).

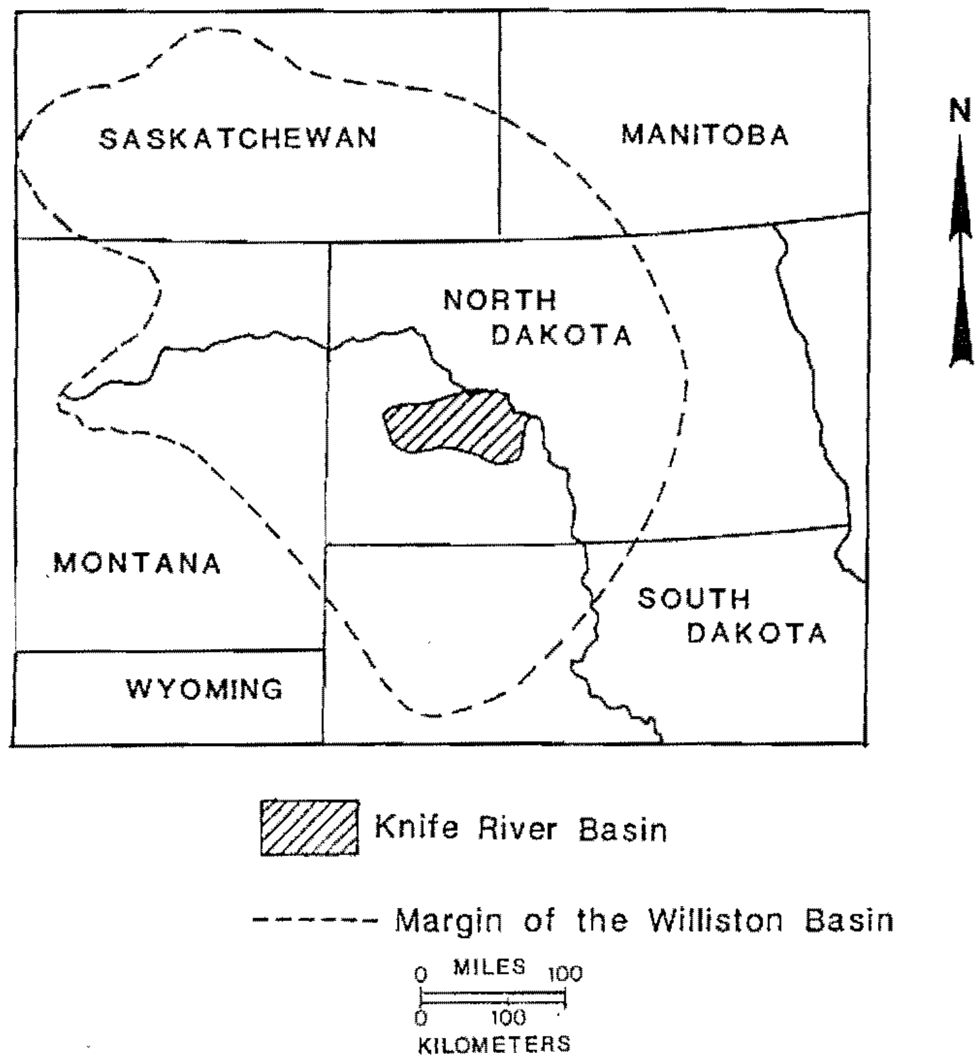
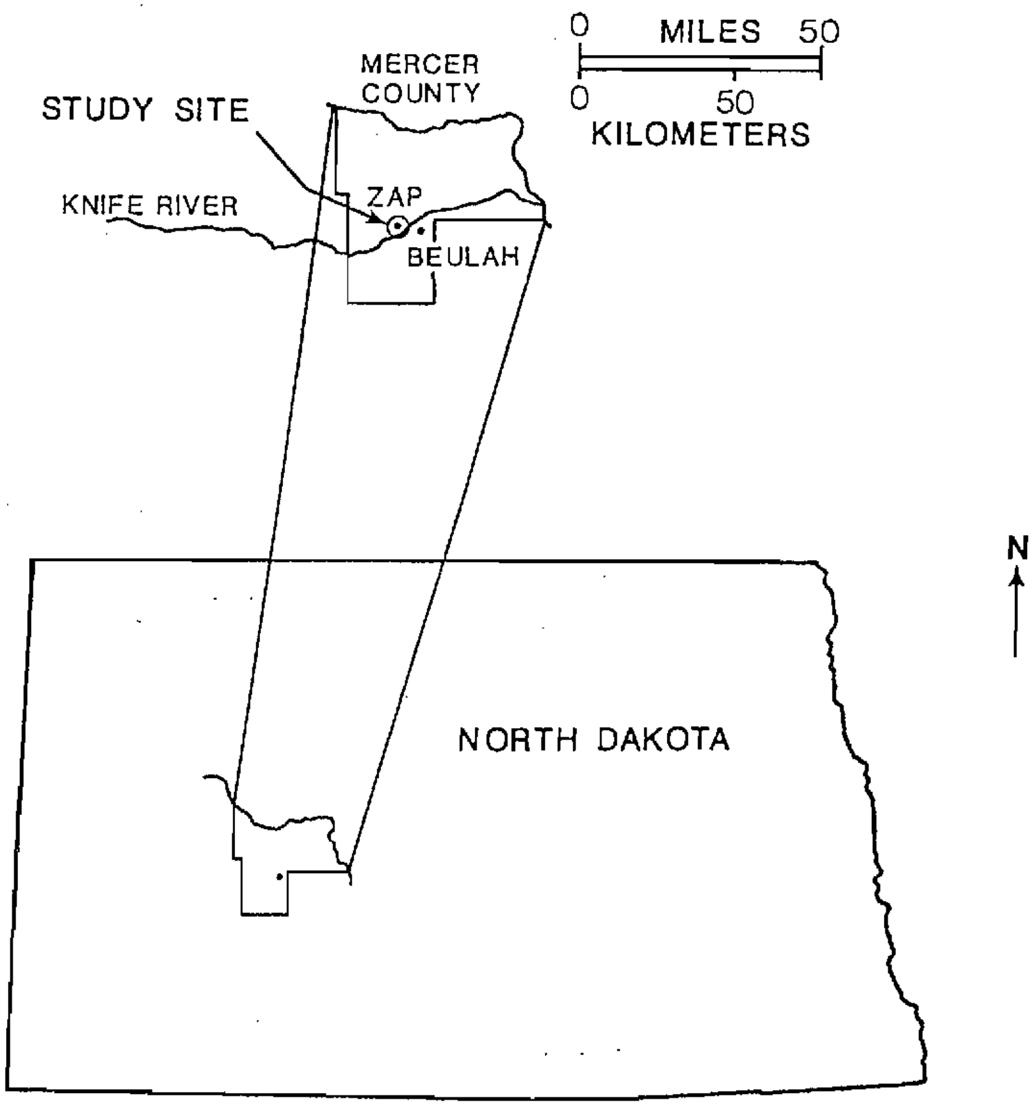

SASKATCHEWAN
MANITOBA
NORTH DAKOTA
MONTANA
WYOMING
SOUTH DAKOTA
N
Knife River Basin
Margin of the Williston Basin
0 MILES 100
0 100
KILOMETERS

Figure 2. Generalized map of study area location.


0 MILES 50
0 50 KILOMETERS
MERCER COUNTY
STUDY SITE
KNIFE RIVER
ZAP
BEULAH
N
NORTH DAKOTA

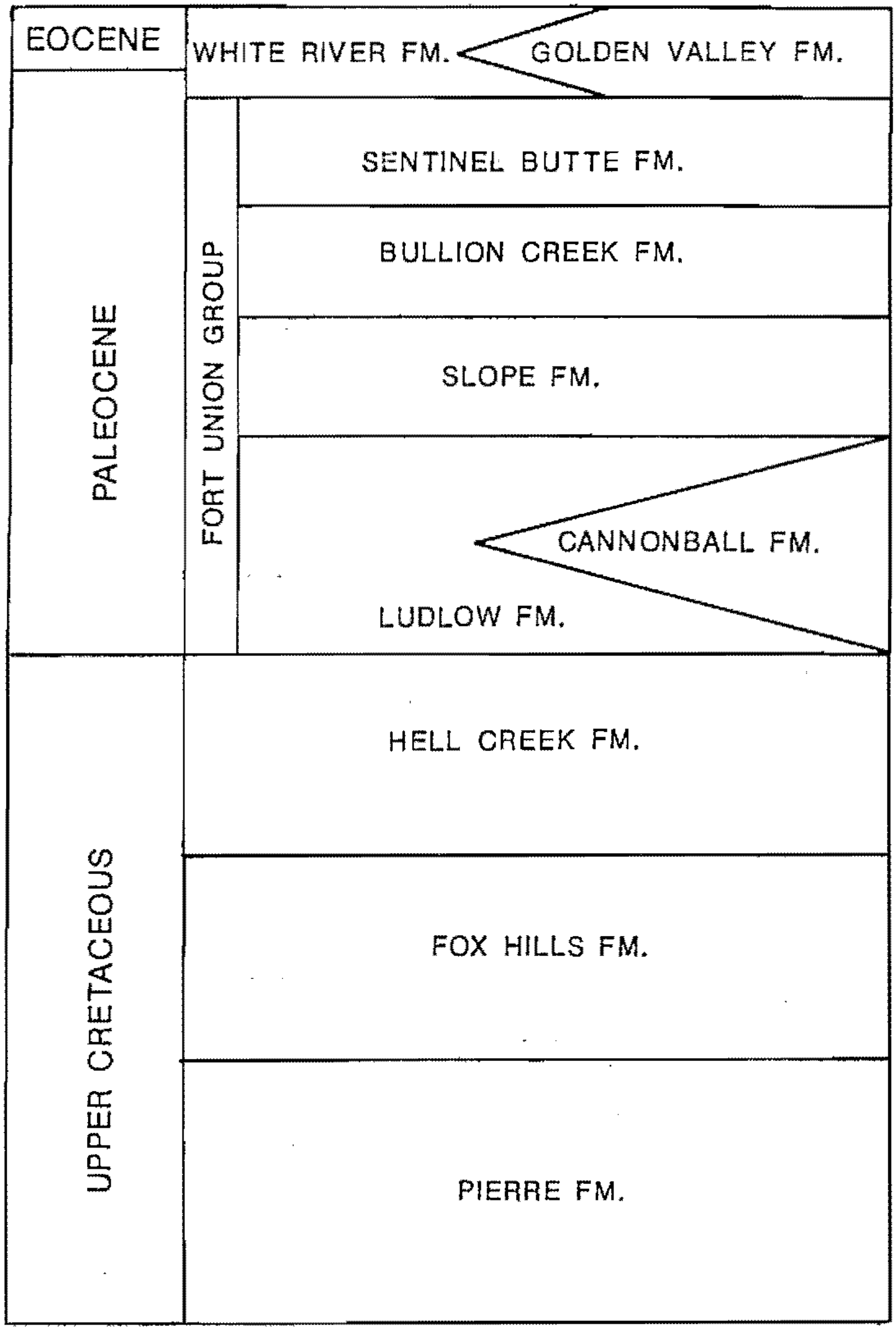
consisting of alternating beds of clay, silt, sand, and lignite which is in general gray and brown (Jacob, 1976). Nine major lignite beds are recognized in the Sentinel Butte Formation, two of which are presently mined on a commercial scale, the Beulah-Zap and the Hagel beds (Groenewold et al., 1979).

The topography of the study area is of gently rolling, grassy uplands. Spring Creek, the principal tributary of the Knife River, flows eastward through the study area. A thin glacially-deposited veneer of sediments covers areas not eroded by stream activity (Groenewold et al., 1979).

The Golden Valley Formation, Paleocene-Eocene in age, conformably overlies the Sentinel Butte Formation (Figure 3) but occurs only in a few scattered locations as erosional remnants in the Knife River Basin (Hickey, 1972). The Sentinel Butte Formation (Paleocene) conformably overlies the Bullion Creek (Paleocene) Formation (Clayton et al., 1977).

The Beulah-Zap bed is black to brownish-black coal; it is locally continuous with as many as five lignite and carbonaceous clay seams separated by clay, silt, or sand (Groenewold et al., 1979). At the Indian Head mine, two seams are present. The upper seam, called the "Main Beulah", is the focus of this study and is the most economically important seam in the Indian Head mine. The lower seam is separated from the "Main Beulah" by a clay parting. The thickness of the "Main Beulah" is 3.2 to 3.6 metres at the study site. The lower seam, commonly high in inorganic content and saturated with water, was not completely exposed at either sampling location and could not be measured. The thickness of the clay parting between the

Figure 3. Stratigraphic nomenclature of upper Cretaceous, Paleocene, and lower Eocene strata in western North Dakota (from Steadman, 1985).


EOCENE
WHITE RIVER FM.
GOLDEN VALLEY FM.
PALEOCENE
FORT UNION GROUP
SENTINEL BUTTE FM.
BULLION CREEK FM.
SLOPE FM.
CANNONBALL FM.
LUDLOW FM.
UPPER CRETACEOUS
HELL CREEK FM.
FOX HILLS FM.
PIERRE FM.

two seams is 0.5 to 0.9 metres. The thickness of the overburden at sampling sites in Pit 11 and Pit 12 is approximately 20 metres and 15 metres, respectively.

Previous Work

Previous studies on geochemical variation of lignite characteristics in the Fort Union Region have been summarized in the literature (Low-rank Coal Study, 1980). Variability of specific geochemical constituents within and between mines has been reported by Sondreal et al. (1968). Data presented in these reports focus on average compositions (proximate, ultimate, and heating value data) for the coals from the different mines and the range of variability for each coal.

Previous work on the vertical and horizontal distribution of elements within a lignite seam is limited. Karner et al. (1983) investigated the distribution of a number of major, minor, and trace elements in the Kinneman Creek Bed, which is also in the Sentinel Butte Formation. It was determined in that study that patterns of element distribution include 1) concentration in the margins of the seams, 2) concentration in the lower part of the seam, 3) even distribution throughout the seam, and 4) for some elements, indefinite or irregular patterns.

In a later study of the Kinneman Creek and Beulah-Zap lignites, Karner et al. (1984) reported on the patterns of distribution of inorganic elements and related occurrence to geochemical properties and depositional and post-depositional processes.

Schobert et al. (1984) summarized the distribution of 40 elements, including sodium, in the Beulah-Zap lignite seam. Six categories of inorganic distributions were used which included concentration at the top of the coal seam, at the center, at the base, or at both margins; an even or uniform distribution; and an apparently random distribution. They relate the distribution of inorganic elements within the seam to inorganic and organic affinities and ionic potential. Sodium is found to have a strong organic affinity. Factors controlling the occurrence and distribution of the inorganic constituents include depositional processes, post-depositional processes, and the type of original vegetation.

Karner et al. (1985) investigated the distribution and occurrence of inorganic constituents in samples of high- and low-sodium Beulah-Zap lignite. Results indicate relationships between some inorganic constituents and the sodium content and also indicate an organic affinity for sodium.

Miller et al. (1986, 1987) and Given et al. (1987) reported on a comprehensive study of major, minor, and trace elements within lignites. They found that the distribution of minerals and major, minor, and trace elements within the lignite seams different from those in the enclosing sediments and partings. They developed a model for the incorporation of inorganic components in peat which they consider to be the major source of mineral matter in the lignite.

Ting (1972) found a strong correlation between the sodium content and the rock type of the immediate overburden of the lignite. The sodium content of the lignite was usually low when the immediate overburden was sandstone and high when the immediate overburden was shale. In a later study, Ting (1987) found the sodium cations in lignite to be inversely proportional to calcium cations. The presence and concentration of the calcium cations in the lignite relate to the concentration of the calcium cations and permeability of the immediate roof rocks.

Groenewold et al. (1981) related depositional settings to groundwater quality in coal-bearing sediments in western North Dakota. They interpreted the deposition of sediments to have occurred in various settings in alluvial flood plain environments. Coal beds result from deposition of organic materials in reducing environments in swamps of broad flood plains that flank stream channels. Sand and coarse silt are deposited in largely oxidizing environments on point bars in channel areas; coarse to fine silt is deposited under generally oxidizing conditions in natural levee settings adjacent to channels; and clayey, fine-grained sediments are deposited farthest from channels in largely reducing environments in flood basins. Clay minerals, particularly sodium montmorillonites, are much more abundant in the flood basin deposits than in the sediments of channel or natural levee origin. Carbonate minerals, particularly dolomite and calcite, are more abundant in point bar and natural levee deposits. The critical hydrogeochemical processes include pyrite oxidation, carbonate mineral dissolution, gypsum precipitation and dissolution, cation exchange, and sulfate reduction.

Groenewold et al. (1983) summarized and further refined this hydrogeochemical model and presented additional evidence supporting the concept that hydrogeochemical processes operate almost exclusively in the zone above the water table. They also demonstrated the regional applicability of the hydrogeochemical model. Alternate wetting and drying of the upper portion of the landscape is the key mechanism in the chemical evolution of the subsurface water in this region and controls the quality of water in shallow (< 150 metres) aquifers.

Zimmer-Dauphinee (1983) analyzed samples from the Hagel, Beulah-Zap, and Lehigh Beds (Sentinel Butte Formation) and the Harmon Bed (Bullion Creek Formation) for 24 major, minor, and trace elements including sodium. She relates high concentrations of sodium at the top of seams to deposition by groundwater.

Fulton (1987) related the sodium content in lignite to hydrogeologic controls including the texture, lithologic composition, and thickness of the overburden and the position of the water table. In general, sodium-rich coals are associated with low hydraulic conductivity in both overburden and coal and with clayey overburden rich in exchangeable sodium. Low concentrations of sodium are associated with thin or coarse-textured overburden.

In addition to studies on the chemical characteristics of lignite, several investigations have been made on the physical characteristics. Lithotype is a term used for classifying coal on the basis of recognizable physical characteristics. Schobert et al. (1984) and Kleesattel (1984) reported on the concentrations of lithotypes in the Beulah-Zap lignite. Schobert reported average concentrations for vitrain, fusain, and attritus of 35-40, 5, and 40-60 percent, respectively, and Kleessattel reported average concentrations of 35, 5, and 60 percent, respectively. Kleessattel (1985) reported on the vertical distribution patterns of the different lithotypes in the Beulah-Zap lignite. He found that fusain occurs more frequently at the top of the lignite seams, vitrain occurs most frequently in the middle and at the very bottom of the seams, and attritus occurs more frequently in the lower one-third and at the top of the lignite.

Kleesattel (1985) also investigated the macerals in the Beulah-Zap lignite and related the maceral groups to the lithotypes present. He reported that the maceral groups, in decreasing order of abundance, were huminite, inertinite, and liptinite. Associations between the maceral groups and the lithotypes includes the following patterns: 1) vitrain is composed of mainly huminite group macerals, 2) fusain is predominately inertinite group macerals, and 3) attritus is composed of detrital macerals of all three groups, but predominately huminite. Data obtained in his study were also used to interpret the depositional environment of the Beulah-Zap lignites.

One of the problems associated with the combustion of low-rank coals is the build-up of ash fouling deposits on convective pass heat exchange surfaces. The University of North Dakota Energy and Mineral Research Center (formerly the Grand Forks Energy Technology Center) has studied the mechanisms involved in the ash fouling process for more than 30 years. The most important factors in determining the fouling potential of a lignite is the ash content of the coal, the sodium content of the ash, and to a lesser extent the silicon and calcium contents in the ash. Sondreal et al. (1977) reviewed these relationships in the ash fouling process. They also relate the fouling process to the formation of alkali and alkaline earth aluminosilicates.

Silicates present in the fly ash of most western low-rank coals are amorphous or glass-like (Benson, 1987). Stevenson et al. (1988) used general trends of the individual ash grain composition as revealed on ternary $CaO-SiO_2-Al_2O_3$ and $CaO-Na_2O-MgO$ plots to evaluate lignite fly ash.

METHODS

Study Site Selection

The study site selection was based on two major criteria. The first of these criteria was the sodium content of the lignite. The availability of both high- and low-sodium lignite was desired. Data on the sodium content of the lignite at different locations within the study area was required for selection of the sampling sites. The second criterion required correlation of the seam at the sampling locations.

The Beulah-Zap bed lignite at the Indian Head mine was selected. The Beulah-Zap is a laterally extensive, thick lignite unit consisting of two seams easily correlated between different locations at the mine site. Mining operations are closely controlled by analytical results on sodium in the lignite. Based on mine data, samples could be collected from two locations providing the maximum range of sodium content available at the time.

In addition, a large data base is available for the Beulah-Zap lignite. The University of North Dakota Energy and Mineral Research Center (EMRC) has done considerable work on this coal and established a large data base, including chemical characteristics, and megascopic and microscopic properties.

Lignite Sampling Procedures

Each of the two sets of samples to be collected was from a different mining pit at the Indian Head mine. Based on mine chemical data, low-sodium lignite was collected from Pit 12 and the high-sodium lignite was collected from Pit 11. Selection of sampling areas for the measured sections in each of the pits was based on several factors. First and most important was safety. Unstable highwalls in strip mines are a serious problem. Slides due to unconsolidated overburden are common and several locations within each pit to be sampled had areas where slides had occurred. In addition, significant rainfall had preceded the sampling trip, requiring extra caution in selecting the areas for sampling. Each of the sampling areas was selected well away from overhangs or areas where previous slides had occurred. As an added safety precaution, mine personnel back-sloped the overburden above the sampling site in Pit 12.

The second factor for selection of a sampling site within each pit was accessibility. Both pits were actively being mined and considerable coal transportation activities were underway. Large areas of both pits contained water which excluded access to them. Water from the recent rains and drainage from the lignite beds obscured contacts that would have made sampling difficult. Also, water would have resulted in unsafe conditions for ladder placement or footing.

The third factor in sample collection was based on the freshness of the exposed section. Both pits were actively mined with exposures in Pit 11 less than one week old and exposures in Pit 12 less than one day old. Collection of samples from fresh exposures avoided excessive loss of moisture and oxidation of the lignite.

After selection of the specific areas for sample collection within each of the mine pits, a channel was prepared to expose a fresh non-weathered surface free from extraneous matter due to mining operations and material that may have fallen from the overburden. The channel, which was approximately 20 to 30 centimetres wide and 8 to 10 centimetres deep, was prepared with the use of rock pick, hammer, and chisel. The channel was then cleaned by use of a broom to remove loose material.

The seam was measured and samples were collected at approximately 15-centimetre intervals throughout the seam. A megascopic description was made of each sample collected. Adjacent underclays and overburden were collected separately and described.

Samples were collected beginning at the base of the seam and working upwards to avoid contamination of the channel. Approximately two kilograms of lignite were collected from each sampling interval and placed in double plastic bags.

Sample Preparation and Characterization Techniques

Characterization of samples included field descriptions, microscopic analyses, and chemical analyses for the lignite, overburden, and underclay samples and chemical analyses of the ash derived from the utilization portion of this study.

Chemical characterization of the lignite included electron microprobe analysis at the University of North Dakota Department of Geology and Geological Engineering and reflected light and fluorescence microscopy, proximate analysis, ultimate analysis, heating value determinations, and energy-dispersive X-ray fluorescence spectrometry at the University of North Dakota Energy and Mineral Research Center.

Ash characterization was done by electron microprobe analysis at the Energy and Mineral Research Center.

Field Descriptions

Two sets of channel samples were taken from the "Main Beulah" seam at the Indian Head mine: one set from Pit 11, which contained high-sodium lignite, and the other from Pit 12, which contained low-sodium lignite. The cleared channels were first measured and then megascopic descriptions were made of the freshly exposed coal face.

Twenty one channel samples were collected from the "Main Beulah" seam in Pit 11 at 5.5- to 6.5-inch (14.0- to 16.5-centimetre) intervals. Twenty were collected from the "Main Beulah" seam in Pit 12 at 7.0- to 8.0-inch (17.8- to 20.3-centimetre) intervals. Since the main purpose in collecting these samples was to determine the vertical distribution of elements within the seam at each location, it was decided that the samples should be taken at regular intervals. A secondary objective was to separate the samples based on lithologic characteristics which accounts for the minor variance in sampling intervals presented above.

Megascopic properties used in describing the lignite samples included luster, color, fracture patterns, hardness, mineral occurrences, and lithotypes. A background into the development of lithotype terminology is given by Kleesattel (1985). Lithotype terminology is based on the megascopic components of the coal, however, a lithotype nomenclature system for low-rank coals has not yet been agreed upon internationally. As a result, the terminology used in this study is based on the system used by Kleesattel (1985). Kleesattel used three terms to describe the megascopic components of coal, those being vitrain, fusain, and attritus. In addition, clay and/or silt partings within the seam can also be referred to as a lithotype. A description of each of the three lithotypes is given below.

Vitrain. Vitrain can be identified on the basis of four main characteristics being 1) a bright luster, 2) smooth surfaces, 3) fractures which are at a 90 degree angle to the bedding planes, and 4) extreme brittleness. Vitrain is commonly found as discontinuous lenses, from 5 to 30 millimetres thick, within the dull granular matrix of the coal (Kleesattel, 1985). Due to its fracture pattern and brittle property, it forms blocky fragments which can easily be separated from surrounding material. Vitrain is also clean to the touch and can be distinguished from fusain which "dirties" the hand.

Vitrain forms in areas of steady, rapid subsidence. Material deposited is buried rapidly under anaerobic conditions which inhibits physical and biological degradation.

Fusain. Fusain is composed of fragmental chips and fibers, occurring as fine lenses less than 2 centimetres in thickness on bedding plane surfaces (Kleesattel, 1985). It is extremely friable and is responsible for producing more fine particulates than other lithotypes. Fusain's characteristic friability is responsible for many horizontal partings found in the seam.

Fusain forms in the driest of swamp environments in areas of slow subsidence or low groundwater levels. Subaerial exposure is assumed as a contributing factor in its formation (Kleesattel, 1985).

Attritus. Attritus is the term used for the dull to moderately bright, granular, finely laminated portions of the seam. It's granular texture distinguishes it from other lithotypes. Attritus also has the characteristic of being resistant to physical weathering which can result in visual distinction on the highwall face.

Attritus forms in relatively deep, stagnant water where subsidence and burial rates are low. The original plant material is more characteristic of a deep water environment and the plant material has undergone extreme degradation.

Macerals Group Analysis

Stopes (1935) suggested using the term 'macerals' for the microscopically discernible constituents of coal. Nomenclature introduced by Stopes later became the basis for an international classification of the megascopic and microscopic components of coal.

This classification, referred to as the Stopes-Heerlen System, was established by the Congress on Coal Nomenclature and is currently the most widely accepted system (Kleesattel, 1985).

The three major maceral groups found in lignites are 1) huminite, 2) liptinite, and 3) inertinite (Ting, 1981). Each of these groups can be distinquished on the basis of characteristic ranges of reflectance and fluorescence. The reflectance and fluorescence characteristics of each maceral group are due to the chemical composition of the macerals (carbon and hydrogen content). Specific macerals in each group are identified on the basis of morphology and reflect the type of original plant material. For the purposes of this study, only the different maceral groups were determined to aid in the interpretation of depositional and post-depositional processes affecting lignite formation.

Huminite Maceral Group. The huminite maceral group is microscopically medium-grey under reflected light and very dark brown to black under fluorescent light. Huminite macerals form in moderately deep water under weakly oxidative conditions (Stach et al., 1982). This group is indicative of depositional conditions in which the plant material is highly degraded by physical and chemical processes.

Liptinite Maceral Group. The liptinite maceral group is microscopically reddish-brown to dark-grey to black under reflected light and yellow to orange under fluorescent light. Macerals of this group show little diagenetic alteration through the lignite stage.

Inertinite Maceral Group. The inertinite maceral group is microscopically light-grey to white under reflected light and black under fluorescent light. Inertinite macerals are typically formed in shallow water to subaerially exposed conditions (Klessattel, 1985).

For maceral group analysis the samples were first vacuum dried to reduce the moisture content and to make crushing easier. Approximately four grams per sample was used in the drying process, which took 24 to 48 hours at a pressure of 10 to 15 microns of mercury. The process of vacuum drying, although not commonly used for the preparation of most biological specimens, does not seem to alter the maceral morphology (Kleesattel, 1985). After drying, the lignite samples were crushed by hand with a mortar and pestle and passed through a 20-mesh screen. This particle size allows complete impregnation in the epoxy-embedding mixture without excessive reduction of the particle size.

Pellets were formed by mixing approximately two grams of sample with a premixed epoxy and hardner. The amount of epoxy used was limited to that needed to impregnate the lignite. The epoxy and coal mixture was then placed in a 2.5-centimetre inner diameter mold. Additional epoxy was poured over the epoxy and coal mixture to form a pellet approximately 2.0 centimetres thick. The pellets were allowed to cure for a period of 8 to 12 hours before being removed from the molds.

The coal/epoxy pellets were polished using a lapidary wheel and various size polishing compounds. Initial grinding was done with a 400 grit sand paper disk with water lubrication. The pellets were further polished with nine, six, three, and finally one micron diameter diamond paste. After each polishing step, the samples were cleaned in an ultrasonic bath for approximately five minutes. After final polishing, the pellets were placed in protective plastic caps to minimize moisture absorbance by the lignite from the air.

Maceral group identifications were by standard reflected light and fluorescence microscopy techniques (Stach et al., 1982). A Nikon Labophot microscope with a 40x oil immersion objective was used for quantitative point-count analysis. The point-count method for maceral identification used here was developed by Stach et al. (1982), and consisted of 500 counts on each of the samples. The epoxy component of the pellets was not considered in the point counts.

Chemical Characterization

Lignite. Chemical characterization of the lignite was accomplished by electron microprobe analysis. Samples were ground by hand with a mortar and pestle to a fine powder and passed through a 60-mesh screen. The ground lignite was then vacuum dried for 24 to 48 hours at 10 to 15 microns of mercury. Approximately two grams of dried sample was then placed in a mold and compressed under 20 tons pressure to form a pellet 3.0 centimetres in diameter and approximately 0.3 centimetres thick. The pellets were carbon-coated for electron microprobe analysis.

A JEOL JSM-35C scanning electron microscope/electron probe microanalyzer was used to examine the Beulah-Zap lignite samples to determine concentrations of inorganic elements. The procedure used was that developed by Karner et al. (1986). An energy-dispersive system was used for quantitative elemental analysis. Operating conditions included: 1) a beam current at 15 kev, 2) a sample current of approximately 1000 picoamps, and 3) an analysis time of 200 seconds. All data collected were stored by a Tracor Northern 2000 data reduction system. A ZAF program (Z = atomic number factor, A = absorption factor, and F = characteristic fluorescence factor) was used to correct for effects such as 1) differences between specimen and standard for electron scattering and retardation, 2) absorption of X-rays within the specimen, and 3) fluorescence effects (Goldstein et al., 1984). Elements determined by this procedure were sodium, magnesium, aluminum, silicon, phosphorous, chloride, potassium, calcium, titanium, manganese, and iron. Carbon, hydrogen, nitrogen, and oxygen contents were combined into one value and determined by difference. Between two and four analyses were made per sample and the data averaged.

A composite lignite sample from each pit was used in the utilization portion of this study. Each of the two composite samples were dried and crushed to pass through a 60-mesh sieve. Ultimate, proximate, and heating value analyses were done on each sample. The proximate analysis determines the moisture, ash, volatile matter, and fixed carbon content. Ultimate analysis determines the total carbon, hydrogen, sulfur, nitrogen, ash, and oxygen contents. A Fisher Coal Analyzer was used for the proximate analysis (ASTM, 1983a) and a Perkin Elmer 240 Elemental Microanalyzer was used for the ultimate analysis (ASTM, 1983b). The heating value, which is reported in British Thermal Units (BTU), was determined in an adiabatic oxygen bomb calorimeter (ASTM, 1980).

The two composite lignite samples were also examined by energy-dispersive X-ray fluorescence spectrometry to determine the oxide weight percents for sodium, magnesium, aluminum, silicon, phosphorous, potassium, calcium, titanium, and iron. The energy-dispersive X-ray fluorescence analysis was done according to Benson et. al. (1980).

Utilization Products. Each composite sample was tested at two combustion temperatures resulting in four ash samples being generated during the test program. The ash samples were collected on glass fiber filters. A description of the combustion test equipment and sample collection system are provided in the utilization experiments section of this report.

The ash samples were transferred from the glass fiber filters to carbon-based-polymer double-stick tape and then carbon-coated. A JEOL JSM-35 scanning electron microscope/electron probe microanalyzer was used for elemental analysis. The procedure used was that developed by Kalmanovitch et al. (1987). An energy-dispersive system was used with a point-counting technique to obtain quantitative analysis. Operating conditions included: 1) a beam current at 15 kev, 2) a sample current of approximately 350 picoamps, and 3) an analysis time of 50 seconds. The sample stage was automated and controlled by a dedicated Tracor Northern 5500 computer system. The stage was programmed to move over a raster pattern, stopping at predefined intervals in order to collect and analyze X-rays produced from the sample. The data for each mineral point were processed by the computer using ZAF procedures.

Utilization Experiments

Test Equipment

A drop-tube furnace was used for combustion of the Beulah-Zap composite lignite samples. The drop-tube furnace is a bench-scale, laminar-flow tube furnace that can be used to simulate a commercial utility boiler. Combustion parameters such as initial hot-zone temperature, residence time, and gas-cooling rate can be closely controlled and monitored (Benson, 1987).

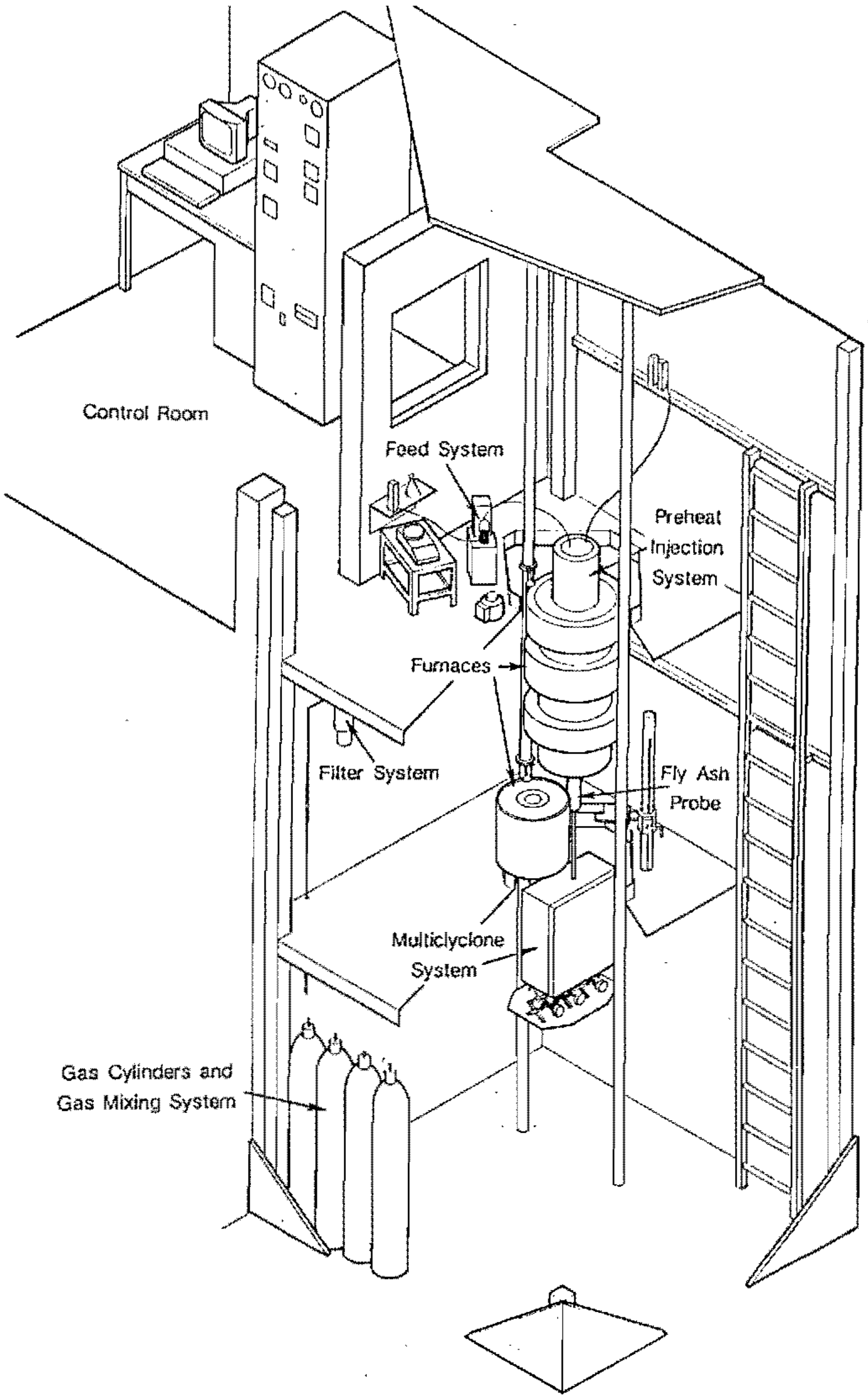
A diagram of the drop-tube furnace facility is presented in Figure 4. Coal, primary air, and secondary air are introduced into the furnace by means of an injector. Coal and primary air enter the furnace at ambient temperature through a water-cooled probe. Secondary air is preheated to approximately 1000^{o}C before entering the furnace. The coal and preheated secondary air travel down the length of the furnace tube in a laminar-flow regime where the coal is combusted.

The fly ash produced from the combustion of the lignite samples is cooled by means of a fly-ash quenching probe and collected on a glass-fiber filter system.

Experimental Design

Composites of the lignite samples from each pit were made for the utilization portion of this study. The two composite samples were dried and crushed to pass through a 60-mesh sieve. Ultimate, proximate, and heating value analyses were done on each sample. The remaining portions of each of the two samples were further crushed to

Figure 4. Schematic of drop-tube furnace system (from Benson, 1987).



Control Room
Feed System
Preheat
Injection
System
Furnaces
Filter System
Fly Ash
Probe
Multiclyclone
System
Gas Cylinders and
Gas Mixing System

pass through a 200-mesh sieve. This coal particle size, commonly referred to as utility blend, was used for the utilization tests.

Each of the composite Beulah-Zap lignite samples was burned at two combustion temperatures, 1300°C and 1500°C (temperature of the flue gas). These temperatures were selected because they bracket the range found in commercial utility boiler operations. Secondary air was maintained at 1000°C for both furnace conditions and added at a rate designed to provide 30 percent excess air in order to provide realistic combustion conditions. Residence time of the particles of coal in the combustion tube was 1-2 seconds.

RESULTS

Field Descriptions

General

The thickness of the "Main Beulah" seam in Pit 11 was 3.17 metres and the thickness of the "Main Beulah" seam in Pit 12 was 3.66 metres. Overburden thickness at the sampling site in Pit 11 was approximately 20 to 25 metres and at the sampling site in Pit 12 was approximately 15 metres. The Schoolhouse bed, approximately 0.5 metres thick, occurred about 15 metres above the "Main Beulah" seam in Pit 11.

Observations

Megascopic descriptions of the samples from the "Main Beulah" seam lignite, overburden, and underclay for each sampling location in the Indian Head mine are included in Appendix A.

In Pit 11, the location of the high-sodium lignite, the overburden consisted of clay grading downward into interbedded shale and clay. The lowest layer of overburden collected consisted of a banded layer of shale, clay and lignite. The lignite contained numerous shale clasts. Between the "Main Beulah" and the overburden, a sandy band rich in quartz was noted.

In Pit 12, the location of the low-sodium lignite, the overburden consisted of sand grading downward into silty clay. Much of the sand showed cross-bedding and the silty clay was finely laminated. Between the overburden and the "Main Beulah", a layer rich in pyrite was noted.

The underclay in Pit 11 consisted of a silty clay rich in pyrite. The underclay in Pit 12 consisted of a finely laminated carbonaceous clay.

The approximate average percentages of the three lithotypes in both pits were the same with attritus being 45, vitrain 50, and fusain 5. Vertical distribution patterns at both sampling sites showed that attritus was more abundant in the upper part of the seam and vitrain in the middle and lower parts of the seam. Preserved plant structures were observed in much of vitreous coal. In Pit 11, clay lenses were observed in five of the lignite samples and pyrite nodules were observed in sixteen of the lignite samples. In Pit 12, a cherty concretion layer was found in the upper part of the seam and pyrite nodules were observed in two of the lignite samples.

Macerals

General

Appendix B presents the percent occurrence of the maceral groups and the minerals, if present, in each of the samples studied. Minerals identified in some of the samples were clay, quartz, and pyrite. Figures 5 and 6 depict the maceral group vertical

Figure 5. Distribution pattern for maceral groups identified in Pit 11 Beulah-Zap lignite samples. Compiled from Appendix A.

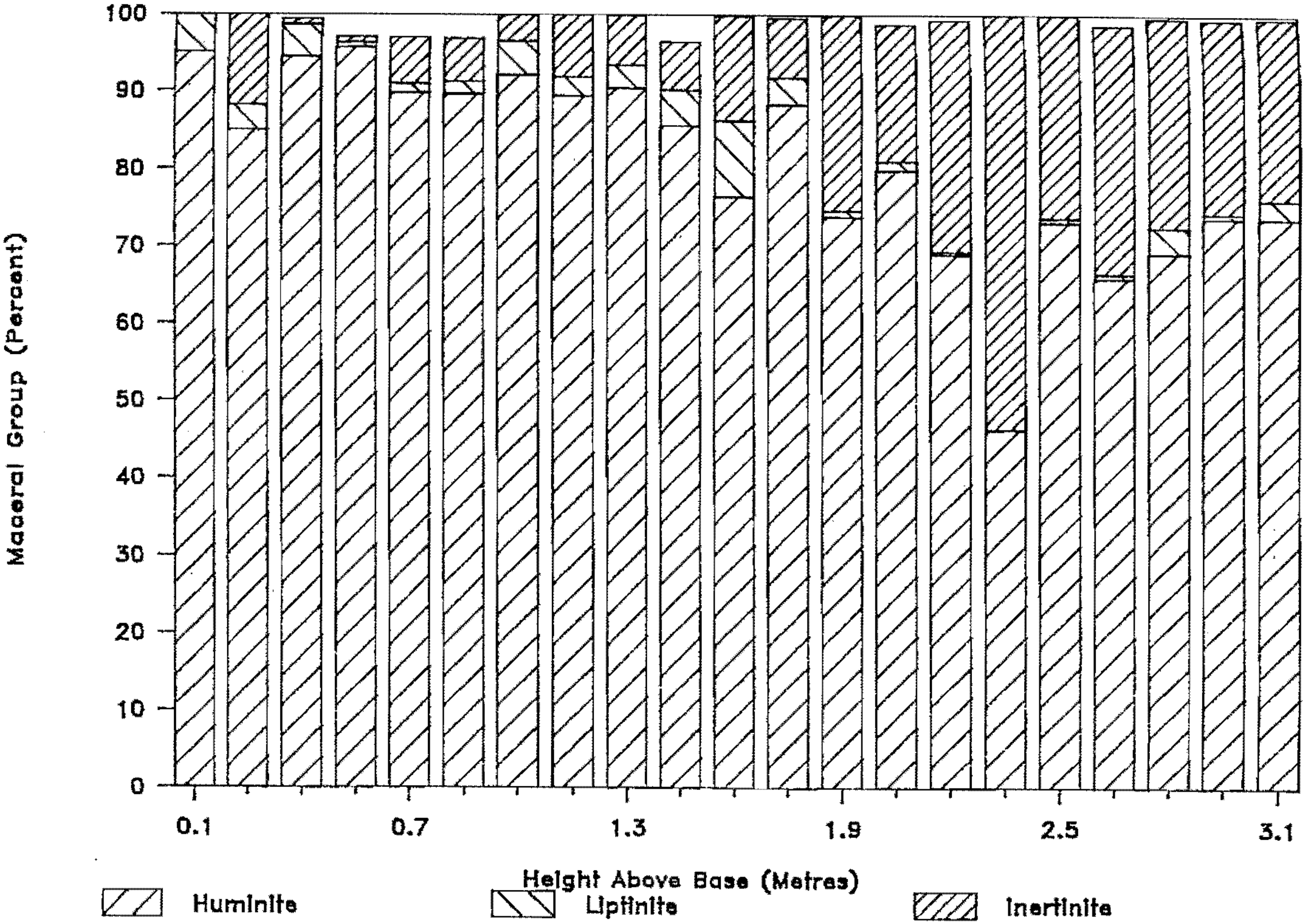
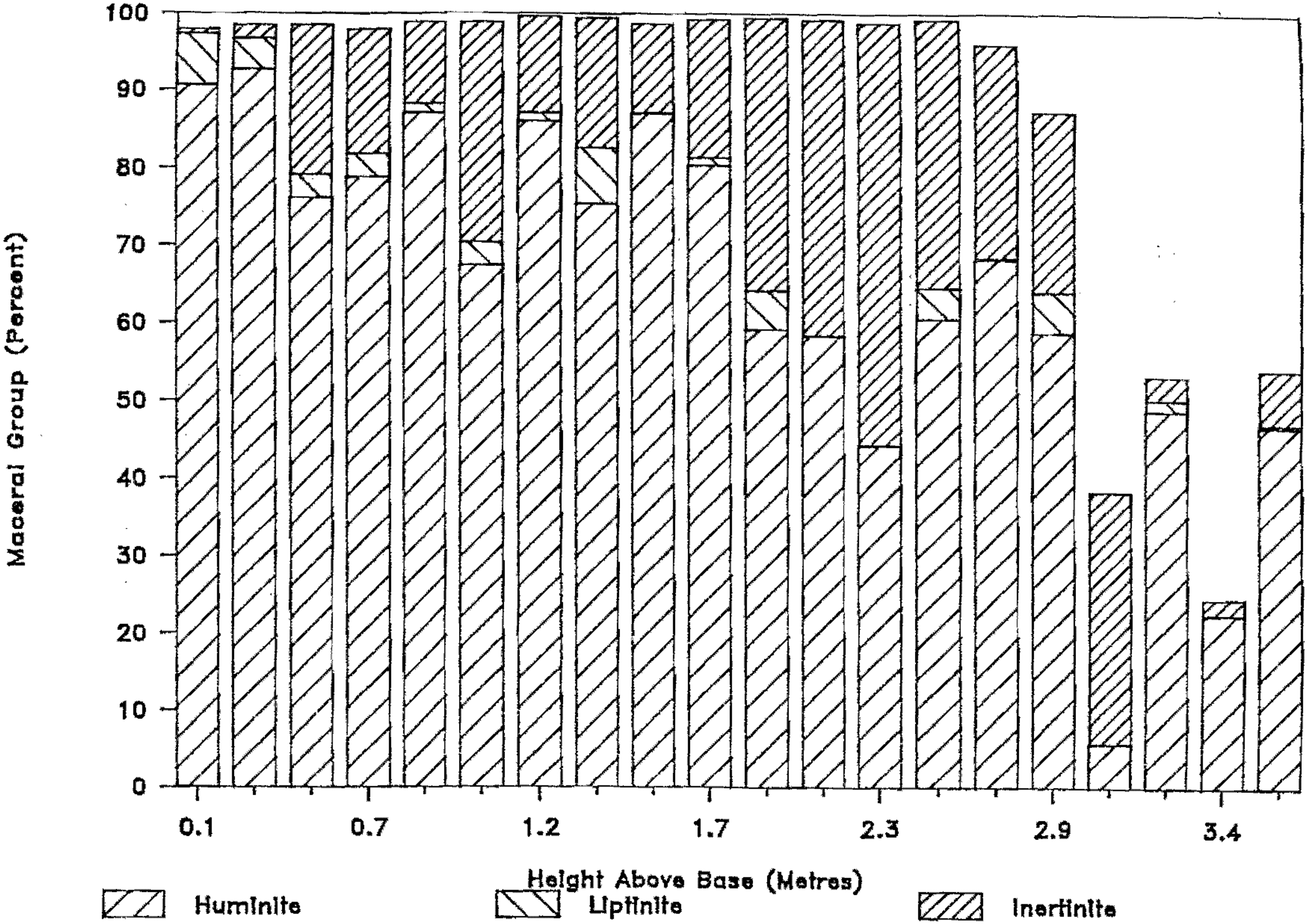

Maceral Group (Percent)
100
90
80
70
60
50
40
30
20
10
0
0.1
0.7
1.3
1.9
2.5
3.1
Height Above Base (Metres)
Huminite
Liptinite
Inertinite

Figure 6. Distribution patterns for maceral groups identified in Pit 12 Beulah-Zap lignite samples. Compiled from Appendix A.



100
90
80
70
60
50
40
30
20
10
0
Maceral Group (Percent)
0.1
0.7
1.2
1.7
2.3
2.9
3.4
Height Above Base (Metres)
Huminite
Liptinite
Inertinite

distributions in Pits 11 and 12. The tables and appendices present the data and graphs are used only to illustrate data points.

Maceral Distribution and Occurrence

The huminite and inertinite maceral groups have characteristic vertical distribution patterns. Inertinite percentages tend to increase upwards within the seam and the huminite percentages tend to increase downwards within the seam. A decrease in the the percentage of huminite accompanied by an increase in inertinite was found at approximately 2.4 metres above base at each of the sampling locations.

The huminite group is the dominant maceral group in both sampling locations. A higher overall average huminite maceral group percentage was found in Pit 11 than in Pit 12 (approximately 80 percent versus 65 percent). The vertical huminite maceral group percentage for samples was more variable in Pit 12 than in Pit 11.

A higher average inertinite maceral group percentage was found in Pit 12 than in Pit 11 (approximately 20 percent versus 16 percent). The vertical inertinite maceral group percentage for samples was also more variable in Pit 12 than in Pit 11.

The liptinite maceral group had the lowest concentrations of the three groups at both sampling locations. A higher variability in the percentage and a slightly lower overall liptinite concentration was noted in Pit 12.

Chemical Characterization

Lignite and Overburden

Electron microprobe analysis data from the overburden samples from Pit 11 and Pit 12 are presented in Table 1. The results are shown as average oxide weight percents and Appendix C provides the raw data. The oxide percentages do not total 100 percent because the organic portion of the samples remains unaccounted for in the microprobe analysis. Therefore, water, carbon dioxide, carbon, nitrogen, oxygen, and probably other minor constituents do not appear in the chemical profile.

Sodium is found in slightly higher concentrations in the Pit 11 overburden. Sodium content decreases in the overburden samples at both sampling locations toward the contact with the lignite. Sulfur concentrations increase dramatically at the interface with the lignite. Higher concentrations of magnesium, calcium, and iron are found in the overburden samples at Pit 12.

Averaged chemical data for the Beulah-Zap lignite samples from electron microprobe analysis are presented in Tables 2 and 3 and the raw data are presented in Appendix C.

Sodium concentrations are higher in Pit 11 than in Pit 12. Figure 7 shows the vertical distribution of sodium in Pit 11 and Figure 8 shows the vertical distribution of sodium in Pit 12. In Pit 11, the high-sodium lignite, there is an overall increase in sodium toward the top of the seam. No specific trend can be seen in the low-sodium lignite vertical profile. Figures 9 and 10 show the vertical distribution of calcium in Pits 11 and 12, respectively.

Table 1. Average chemical oxide weight percentages for overburden sediments from electron microprobe analysis (top to bottom vertical sequence for samples).

Sample	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClO	K_2O	CaO	TiO_2	MnO	FeO	Total
PIT 11													
2	0.9	2.8	17.3	55.2	0.4	0.2	0.0	3.0	1.2	0.9	0.3	8.0	90.0
3	0.8	1.2	14.6	18.3	0.2	0.8	0.0	2.0	0.8	0.8	0.0	1.8	41.3
7	0.5	1.4	16.1	65.5	0.2	0.1	0.0	2.4	0.4	1.1	0.1	1.7	89.5
8	0.4	1.0	14.0	59.2	0.2	0.4	0.0	2.2	0.5	1.1	0.1	1.3	80.5
11	0.4	1.1	16.7	67.1	0.2	0.2	0.0	2.5	0.3	1.0	0.1	2.0	91.4
12	0.7	1.2	14.9	52.3	0.1	0.4	0.0	1.9	0.8	0.9	0.0	2.1	75.3
13	0.3	0.2	13.4	65.5	1.6	2.2	0.0	0.7	0.8	2.2	0.0	1.7	88.7
PIT 12													
1	0.5	3.5	15.5	57.2	0.4	0.1	0.0	2.3	3.4	0.8	0.2	6.4	90.2
2	0.8	3.5	16.9	57.5	0.4	0.5	0.0	2.8	2.1	0.9	0.2	6.7	92.2
3	0.6	3.0	17.9	56.6	0.5	0.3	0.0	2.9	1.1	0.8	0.2	6.6	90.4
4	0.4	3.0	18.7	58.5	0.4	0.5	0.0	3.1	0.8	0.9	0.0	9.7	95.9
5	0.5	1.3	13.0	53.7	0.2	1.3	0.0	1.7	1.3	0.7	0.1	3.1	76.9

Table 2. Averaged chemical data for Beulah-Zap lignite samples from electron microprobe analysis at Pit 11 (top to bottom vertical sequence for samples).

SAMPLE	NA	MG	AL	SI	P	S	CL	K	CA	TI	MN	FE	O
42	0.8	0.4	1.3	2.0	0.1	0.4	0.0	0.1	1.3	0.1	0.0	0.2	93.4
41	0.8	0.4	0.8	1.1	0.1	0.3	0.0	0.1	1.0	0.0	0.0	0.2	95.3
40	1.1	0.5	0.6	0.9	0.0	0.3	0.2	0.1	1.1	0.1	0.1	0.2	95.0
39	0.8	0.4	0.5	0.4	0.1	0.3	0.0	0.0	1.3	0.1	0.0	0.2	95.9
38	0.8	0.4	0.3	0.3	0.0	0.8	0.0	0.1	0.8	0.0	0.0	0.4	96.3
37	0.8	0.4	0.5	0.4	0.1	0.3	0.0	0.0	1.3	0.1	0.0	0.2	95.9
36	0.7	0.3	0.3	0.3	0.0	0.3	0.0	0.0	1.7	0.0	0.0	0.2	96.3
35	0.6	0.3	0.2	0.2	0.0	0.2	0.0	0.0	0.4	0.0	0.0	0.0	89.1
34	0.7	0.4	0.2	0.1	0.0	0.2	0.0	0.0	0.7	0.0	0.0	0.1	97.6
33	0.7	0.3	0.3	0.1	0.0	0.3	0.0	0.0	0.7	0.0	0.0	0.1	97.6
32	0.6	0.3	0.3	0.1	0.0	0.5	0.0	0.0	0.5	0.0	0.0	0.2	97.4
31	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	99.6
30	0.8	0.4	0.4	0.3	0.0	1.3	0.0	0.0	1.8	0.0	0.0	0.8	94.3
29	0.7	0.3	0.6	1.0	0.0	0.4	0.0	0.0	1.2	0.0	0.0	0.2	95.3
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
27	0.8	0.4	0.6	0.6	0.0	1.7	0.0	0.0	1.2	0.1	0.0	1.2	93.4
26	0.1	0.9	8.8	23.2	0.0	0.2	0.0	2.3	0.6	0.4	0.0	2.3	61.3
25	0.0	0.4	0.5	0.7	0.0	0.7	0.0	0.0	1.6	0.0	0.0	0.4	95.6
24	0.4	0.4	0.4	0.4	0.0	0.6	0.0	0.0	1.2	0.0	0.0	0.3	96.4
23	0.4	0.4	0.4	0.2	0.0	0.2	0.0	0.0	1.3	0.0	0.0	0.2	97.2
22	0.0	0.7	0.8	0.7	0.0	0.3	0.0	0.0	2.7	0.0	0.1	0.9	93.8

Table 3. Averaged chemical data for Beulah-Zap lignite samples from electron microprobe analysis at Pit 12 (top to bottom vertical sequence for samples).

SAMPLE	NA	MG	AL	SI	P	S	CL	K	CA	TI	MN	FE	O
6	0.0	0.7	6.0	16.2	0.0	0.7	0.0	0.9	1.0	0.4	0.0	1.2	72.9
7	0.0	0.7	7.4	19.7	0.0	0.3	0.0	1.2	1.1	0.4	0.1	1.0	68.0
8	0.1	0.7	5.7	12.6	0.0	0.5	0.0	0.8	1.6	0.4	0.0	1.0	76.8
9	0.0	0.6	6.3	21.6	0.0	0.2	0.0	0.7	1.3	0.6	0.1	1.5	67.1
10	0.0	0.7	2.4	4.7	0.0	0.5	0.0	0.1	2.4	0.1	0.0	1.1	88.1
11	0.0	0.7	0.8	0.9	0.0	0.5	0.0	0.1	2.3	0.0	0.0	1.6	93.3
12	0.0	0.8	1.0	1.8	0.0	0.4	0.0	0.1	2.7	0.1	0.1	0.8	92.3
13	0.0	0.5	0.3	0.2	0.0	1.1	0.0	0.0	2.1	0.0	0.1	0.2	95.4
14	0.1	0.6	0.4	0.2	0.0	1.8	0.0	0.0	3.3	0.1	0.0	0.7	92.9
15	0.0	0.6	0.3	0.3	0.0	0.6	0.0	0.0	2.3	0.0	0.0	2.3	93.6
16	0.1	0.7	0.4	0.3	0.0	0.4	0.0	0.0	2.6	0.0	0.0	0.8	94.7
17	0.0	0.5	0.2	0.1	0.0	0.6	0.0	0.0	1.3	0.0	0.0	0.3	96.8
18	0.1	0.8	0.7	0.5	0.0	0.5	0.0	0.0	3.6	0.1	0.1	3.7	90.1
19	0.0	0.7	0.5	0.6	0.0	0.4	0.0	0.0	3.0	0.1	0.0	0.9	93.7
20	0.1	0.7	0.7	1.1	0.0	0.4	0.0	0.0	2.9	0.1	0.0	1.0	93.2
21	0.1	0.8	0.8	0.6	0.0	0.5	0.0	0.0	3.6	0.0	0.1	1.6	92.0
22	0.0	0.8	1.0	1.0	0.0	0.3	0.0	0.0	3.6	0.1	0.1	1.3	91.8
23	0.1	0.7	0.7	0.5	0.0	0.3	0.0	0.0	2.9	0.0	0.0	0.9	94.0
24	0.0	0.4	0.4	0.3	0.0	0.4	0.0	0.0	1.4	0.0	0.0	0.3	96.8
25	0.1	0.5	0.7	0.7	0.0	0.7	0.0	0.1	1.7	0.0	0.0	0.5	95.2

Figure 7. Vertical distribution of sodium content for Beulah-Zap lignite samples from Pit 11. Compiled from Table 2.

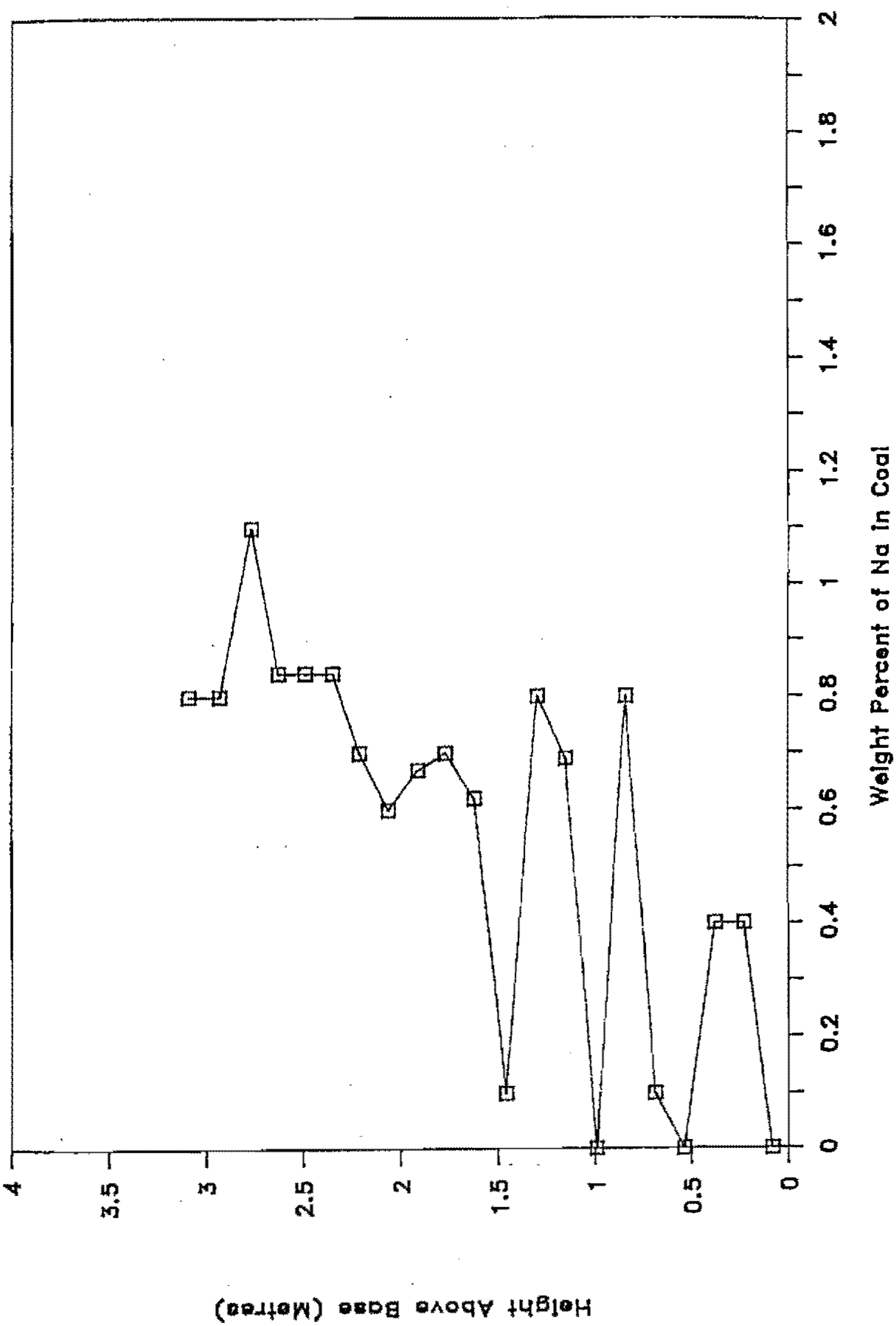

Weight Percent of Na In Coal
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Height Above Base (Metres)
0
0.5
1
1.5
2
2.5
3
3.5
4

Figure 8. Vertical distribution of sodium content for Beulah-Zap lignite samples from Pit 12. Compiled from Table 3.

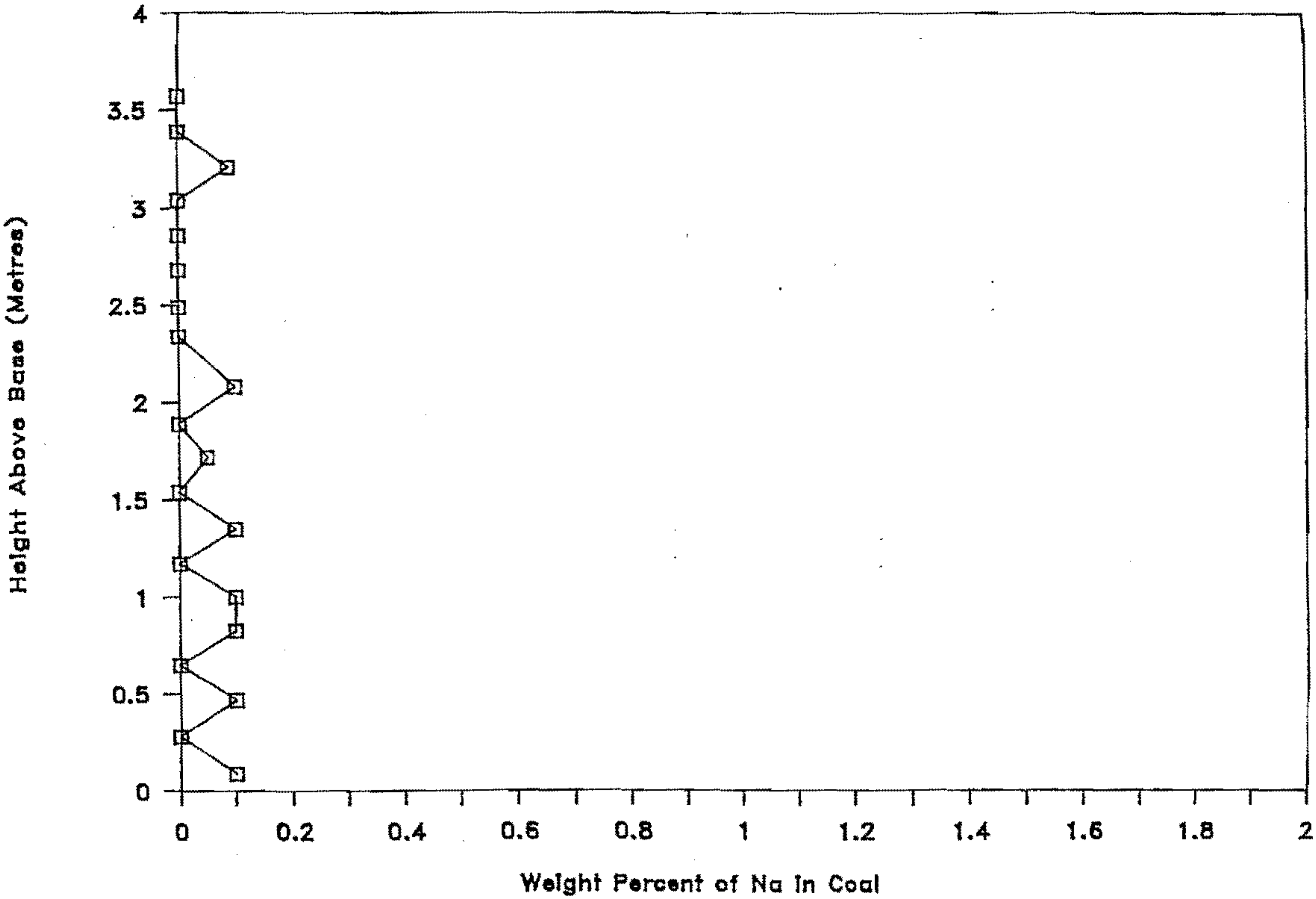
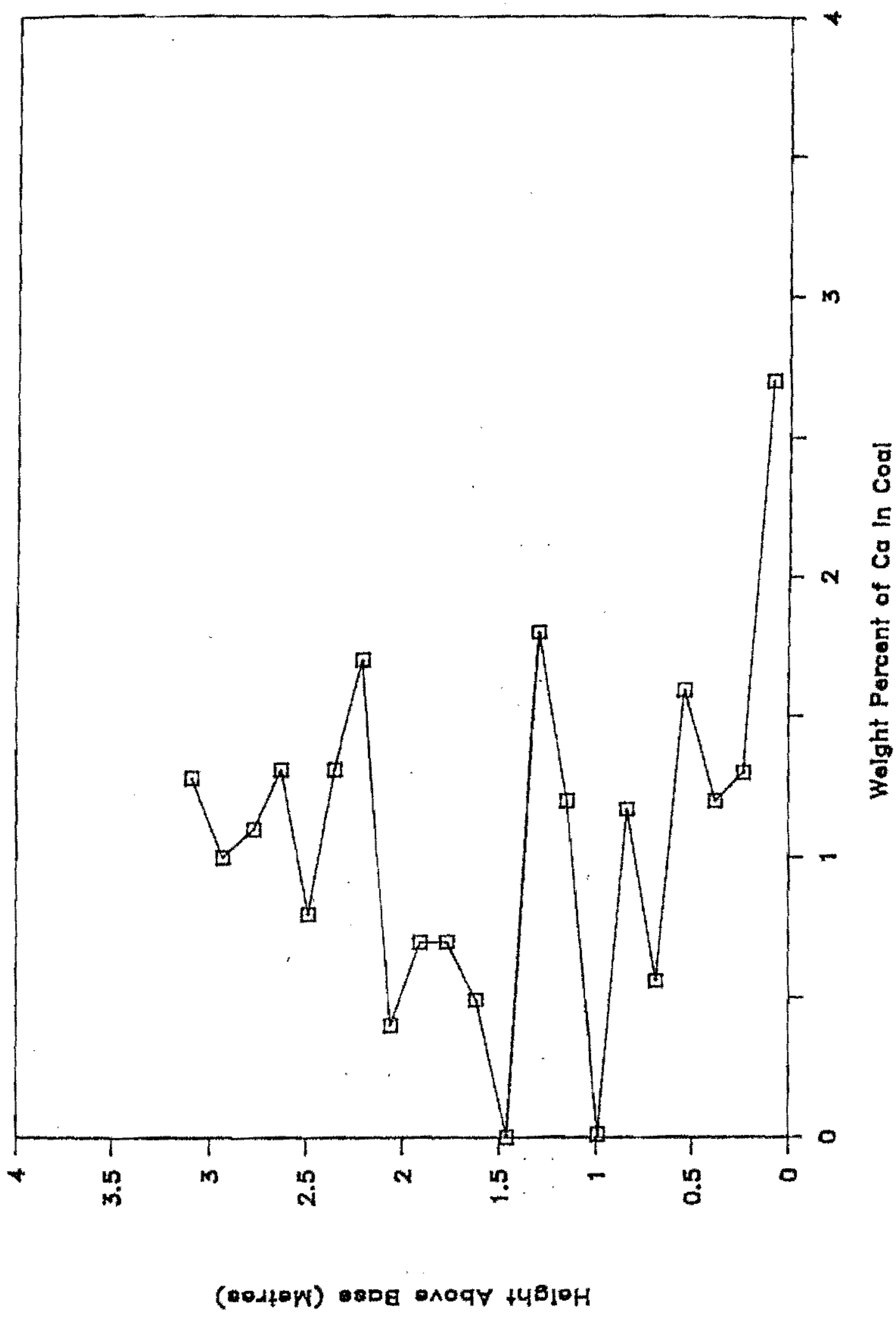
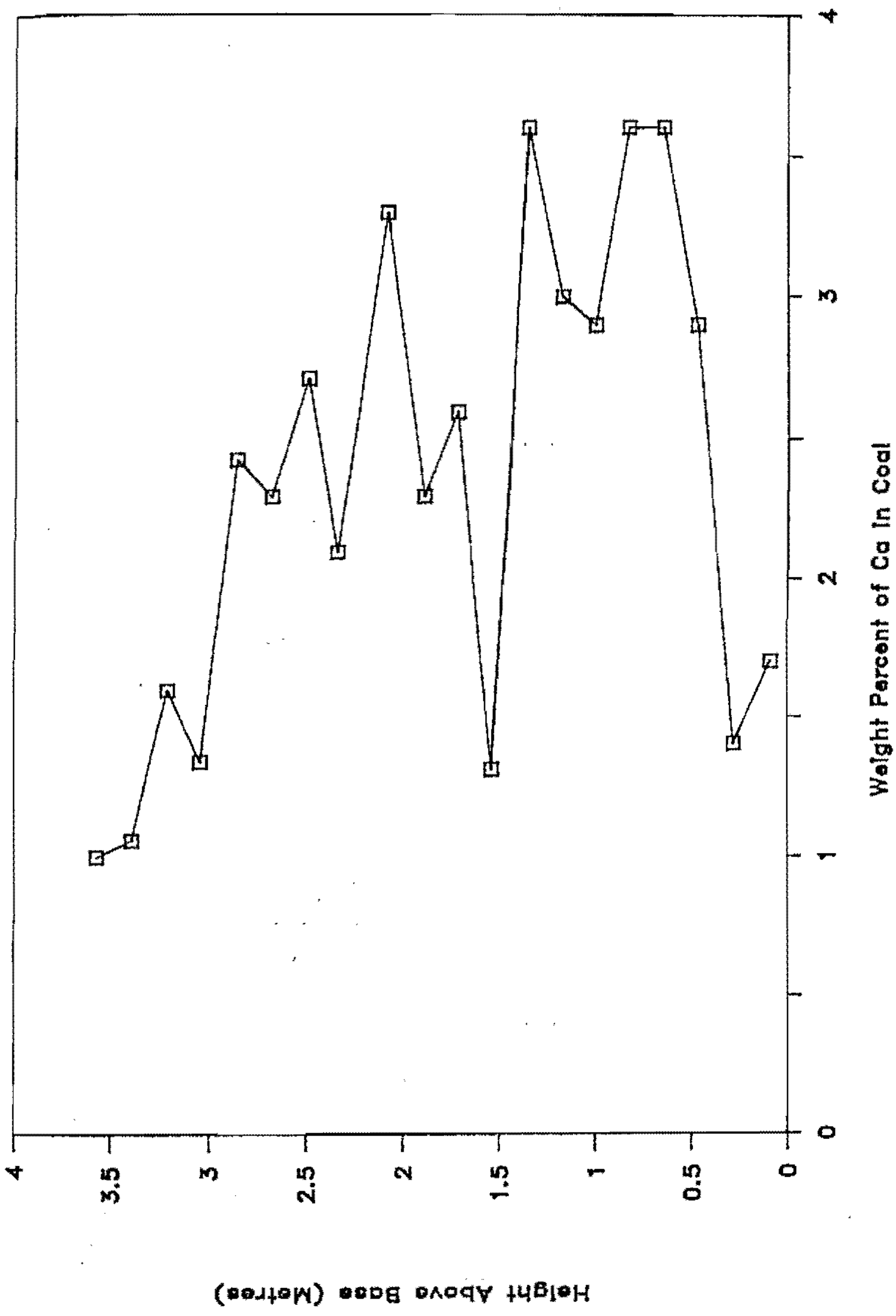

Height Above Base (Metres)
Weight Percent of Na in Coal
0
0.5
1
1.5
2
2.5
3
3.5
4
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

Figure 9. Vertical distribution of calcium content for Beulah-Zap lignite samples from Pit 11. Compiled from Table 2.



Height Above Base (Metres)
Weight Percent of Ca in Coal
0
0.5
1
1.5
2
2.5
3
3.5
4

Figure 10. Vertical distribution of calcium content for Beulah-Zap lignite samples from Pit 12. Compiled from Table 3.


Weight Percent of Ca In Coal
Height Above Base (Metres)
0
1
2
3
4
0
0.5
1
1.5
2
2.5
3
3.5
4

Calcium content is variable in both pits with a slight decrease in concentration toward the top of the seam in Pit 12.

Sulfur content is slightly higher in the lignite samples from Pit 12 than those from Pit 11. No distinct vertical trend is evident in either sampling location (Figures 11 and 12). Certain samples within the vertical sampling sequence have high sulfur contents.

Iron concentrations are also higher in Pit 12 than in Pit 11 (Figures 13 and 14). A decrease in iron is observed toward the bottom of Pit 12 whereas the iron content in Pit 11 increases toward the lower part of the seam.

Figures 15 and 16 present the vertical distribution of calcium versus sulfur concentrations in Pits 11 and 12, respectively. Figures 17 and 18 present the vertical distribution of iron versus sulfur concentrations in Pits 11 and 12, respectively. Iron and sulfur contents of the lignite samples in the middle and upper part of the seam in Pit 11 correlate well, indicating the presence of pyrite. The lower part of the seam seems to indicate a correlation between calcium and sulfur. No specific trends are evident between iron, calcium, and sulfur in Pit 12.

Aluminum and silicon concentrations in Pits 11 and 12 (Figures 19 and 20, respectively) show increases at identical locations within each of the vertical profiles indicating the predominance of clay rather than quartz. In Pit 12, there is a significant increase in the content of these two elements which follows an earlier observation that there is a gradational boundary between the lignite and the overburden. The contact between the lignite and the overburden in Pit 11 is sharper without as significant an increase in

Figure 11. Vertical distribution of sulfur content for Beulah-Zap lignite samples from Pit 11. Compiled from Table 2.

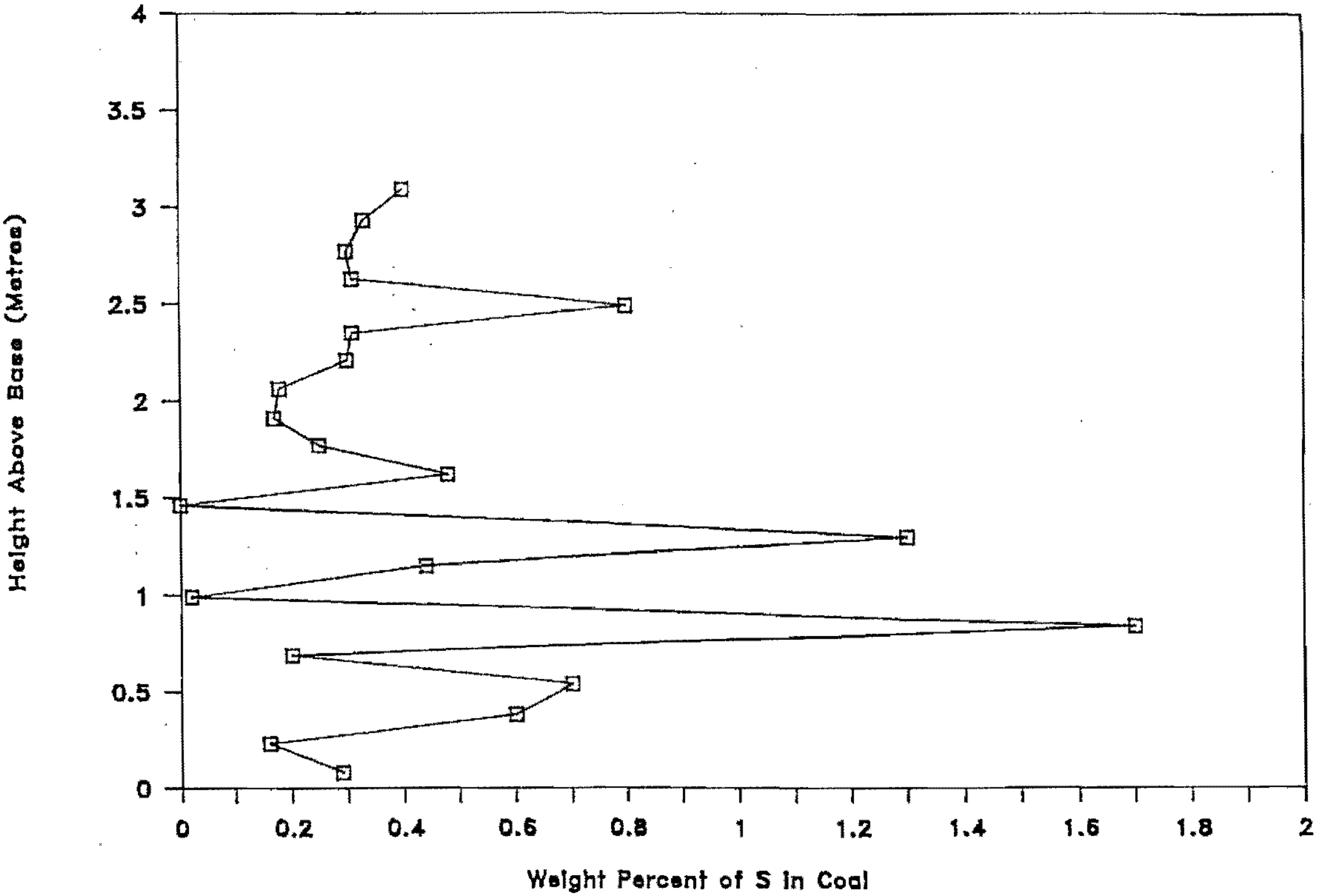

Height Above Base (Metres)
0
0.5
1
1.5
2
2.5
3
3.5
4
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Weight Percent of S in Coal

Figure 12. Vertical distribution of sulfur content for Beulah-Zap lignite samples from Pit 12. Compiled from Table 3.

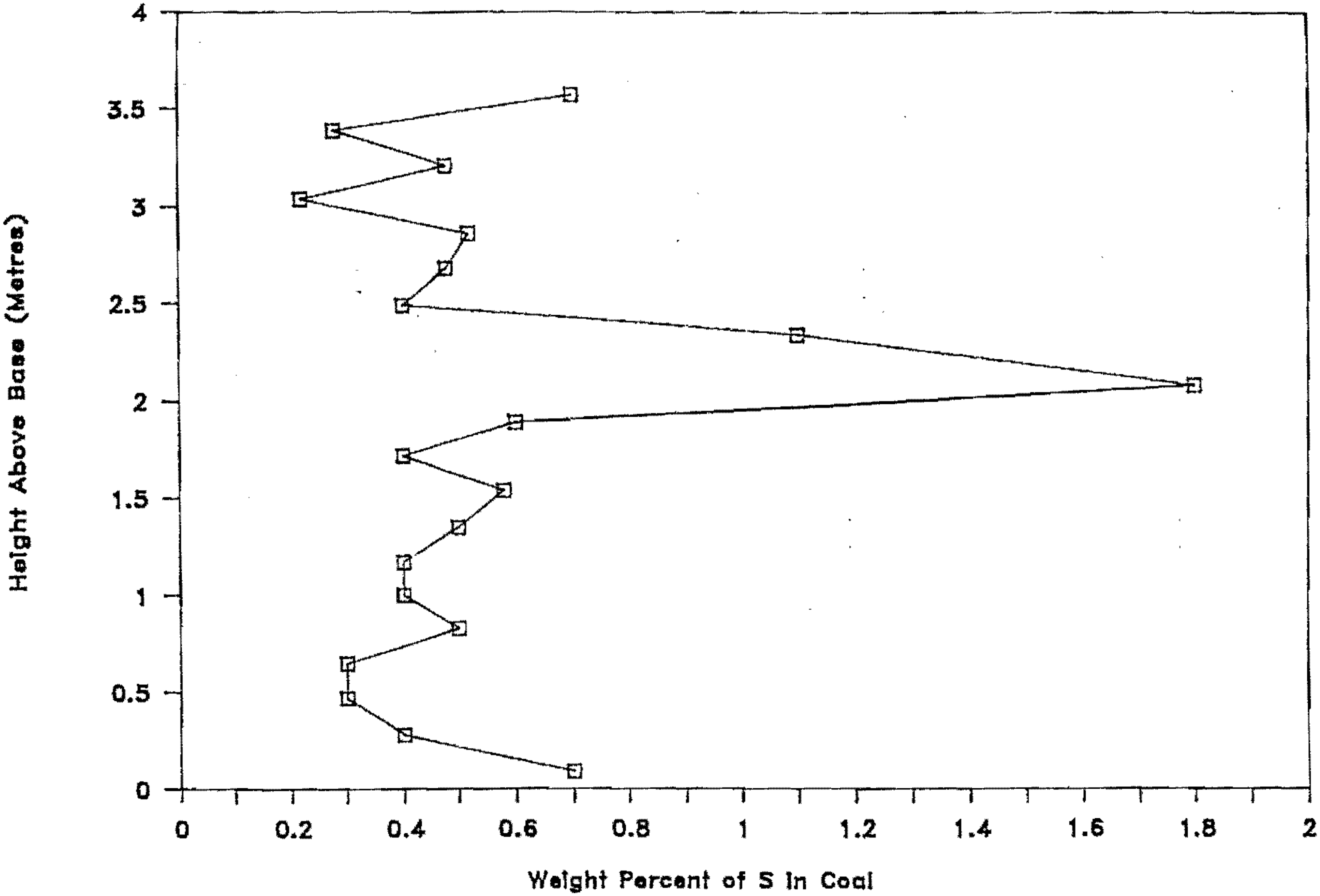

Height Above Base (Metres)
4
3.5
3
2.5
2
1.5
1
0.5
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Weight Percent of S in Coal

Figure 13. Vertical distribution of iron content for Beulah-Zap lignite samples from Pit 11. Compiled from Table 2.

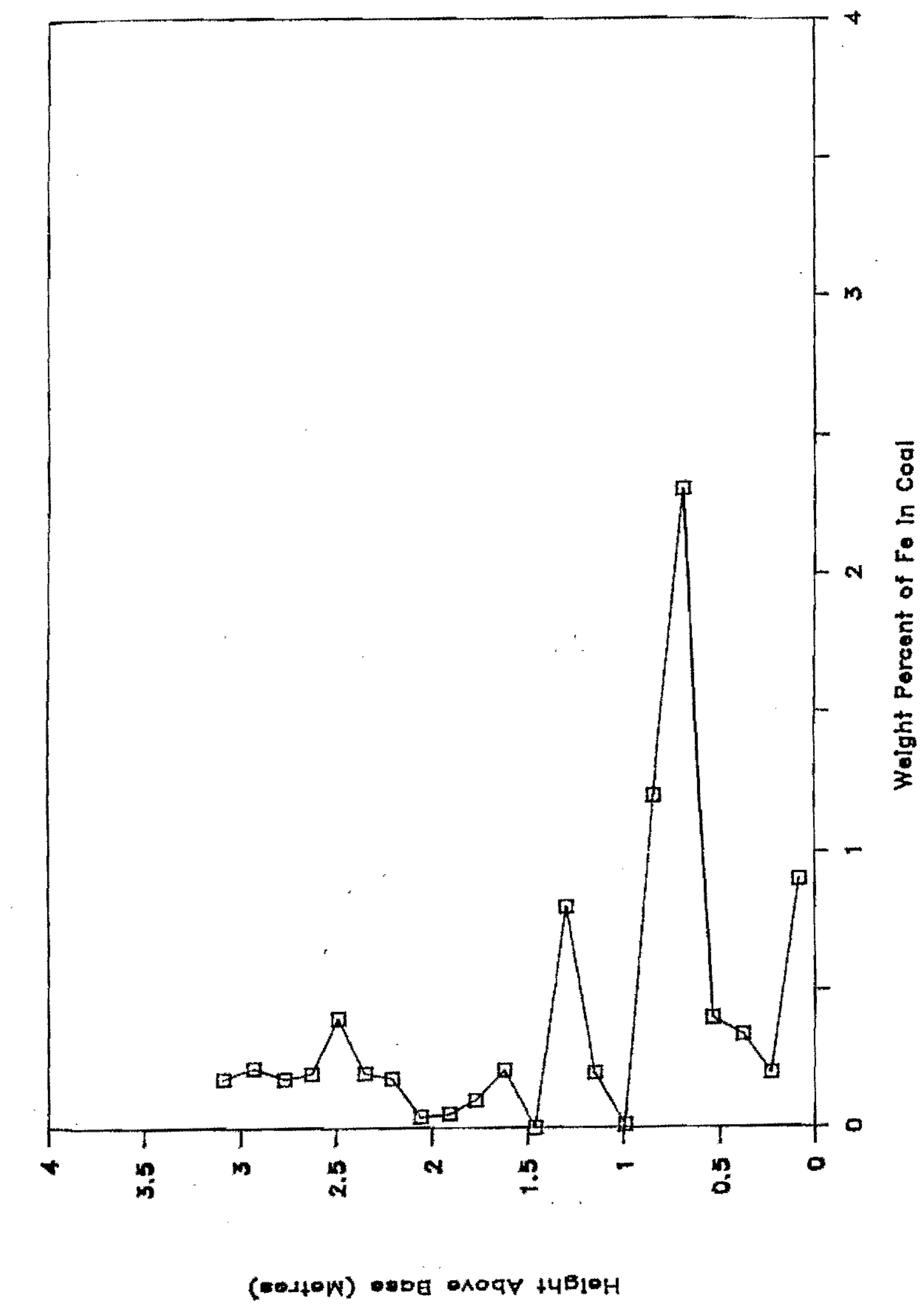
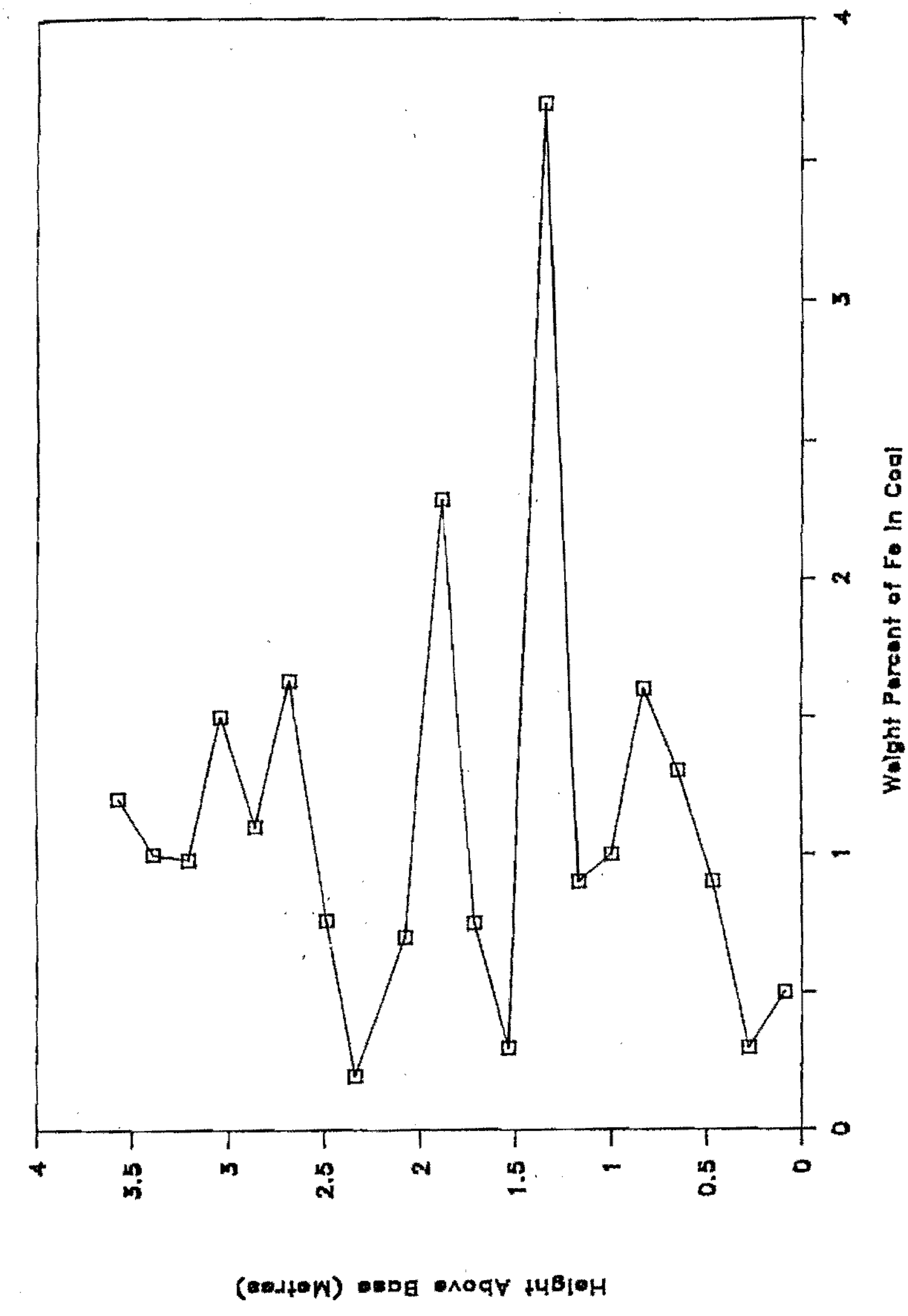

Weight Percent of Fe In Coal
0
1
2
3
4
Height Above Base (Metres)
0
0.5
1
1.5
2
2.5
3
3.5
4

Figure 14. Vertical distribution of iron content for Beulah-Zap lignite samples from Pit 12. Compiled from Table 3.



Weight Percent of Fe In Coal
0
1
2
3
4
Height Above Base (Metres)
0
0.5
1
1.5
2
2.5
3
3.5
4

Figure 15. Vertical distribution of calcium versus sulfur content for Beulah-Zap lignite samples from Pit 11. Compiled from Table 2.

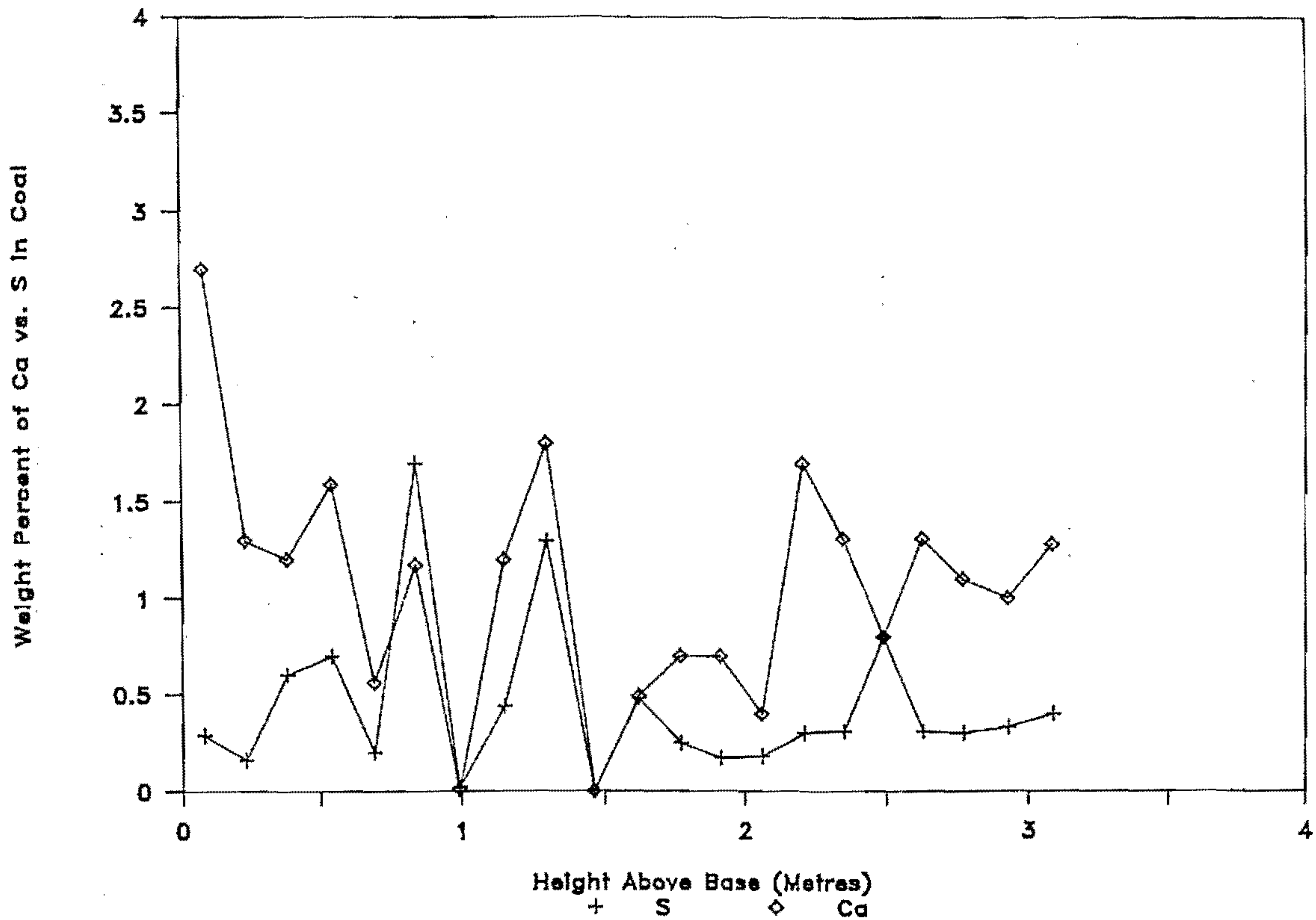

Weight Percent of Ca vs. S in Coal
0
0.5
1
1.5
2
2.5
3
3.5
4
0
1
2
3
4
Height Above Base (Metres)
+ S
◇ Ca

Figure 16. Vertical distribution for calcium versus sulfur content for Beulah-Zap lignite samples from Pit 12. Compiled from Table 3.

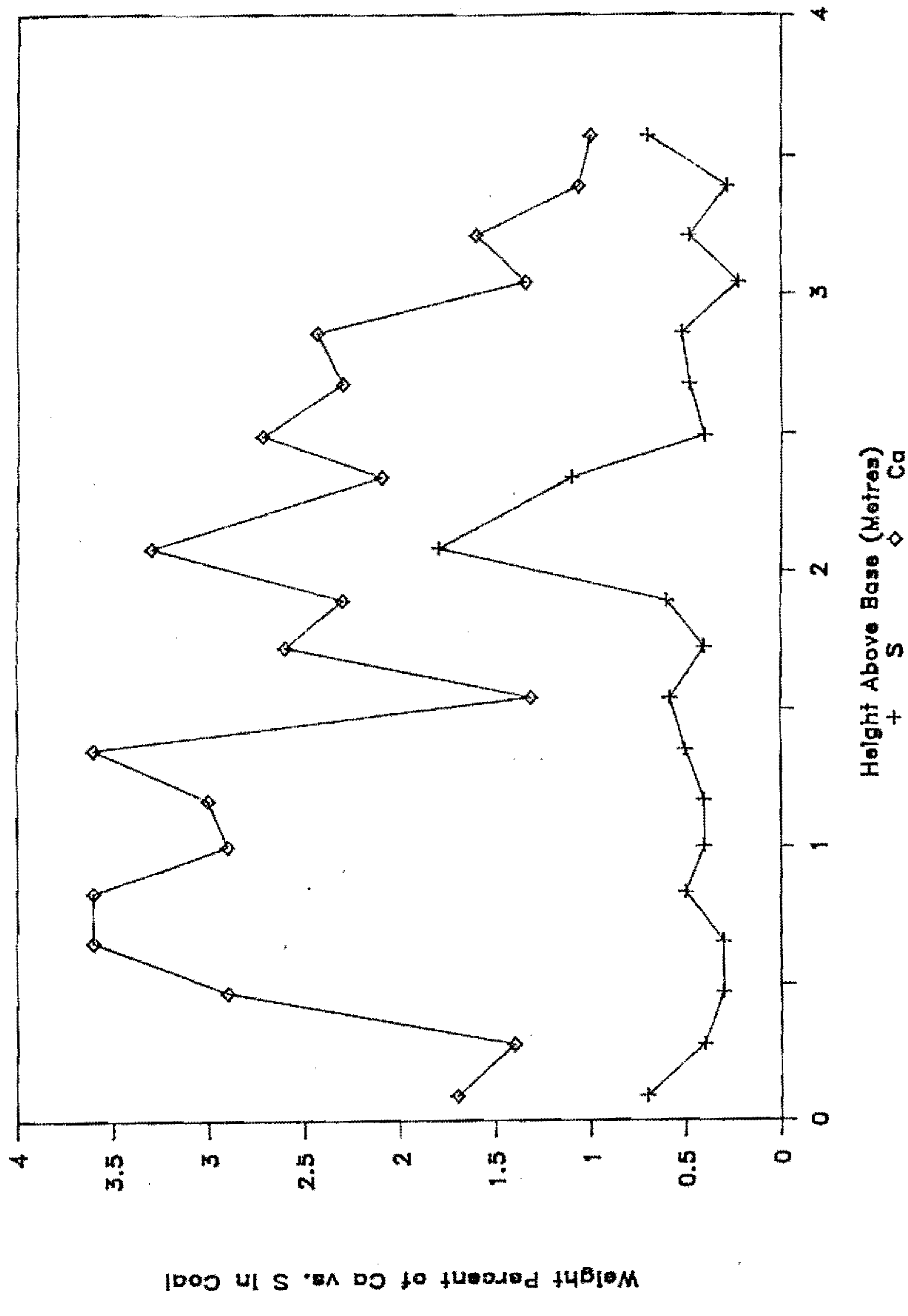

Weight Percent of Ca vs. S in Coal
Height Above Base (Metres)
+ S
◇ Ca
0
0.5
1
1.5
2
2.5
3
3.5
4
0
1
2
3
4

Figure 17. Vertical distribution of iron versus sulfur content for Beulah-Zap lignite samples from Pit 11. Compiled from Table 2.

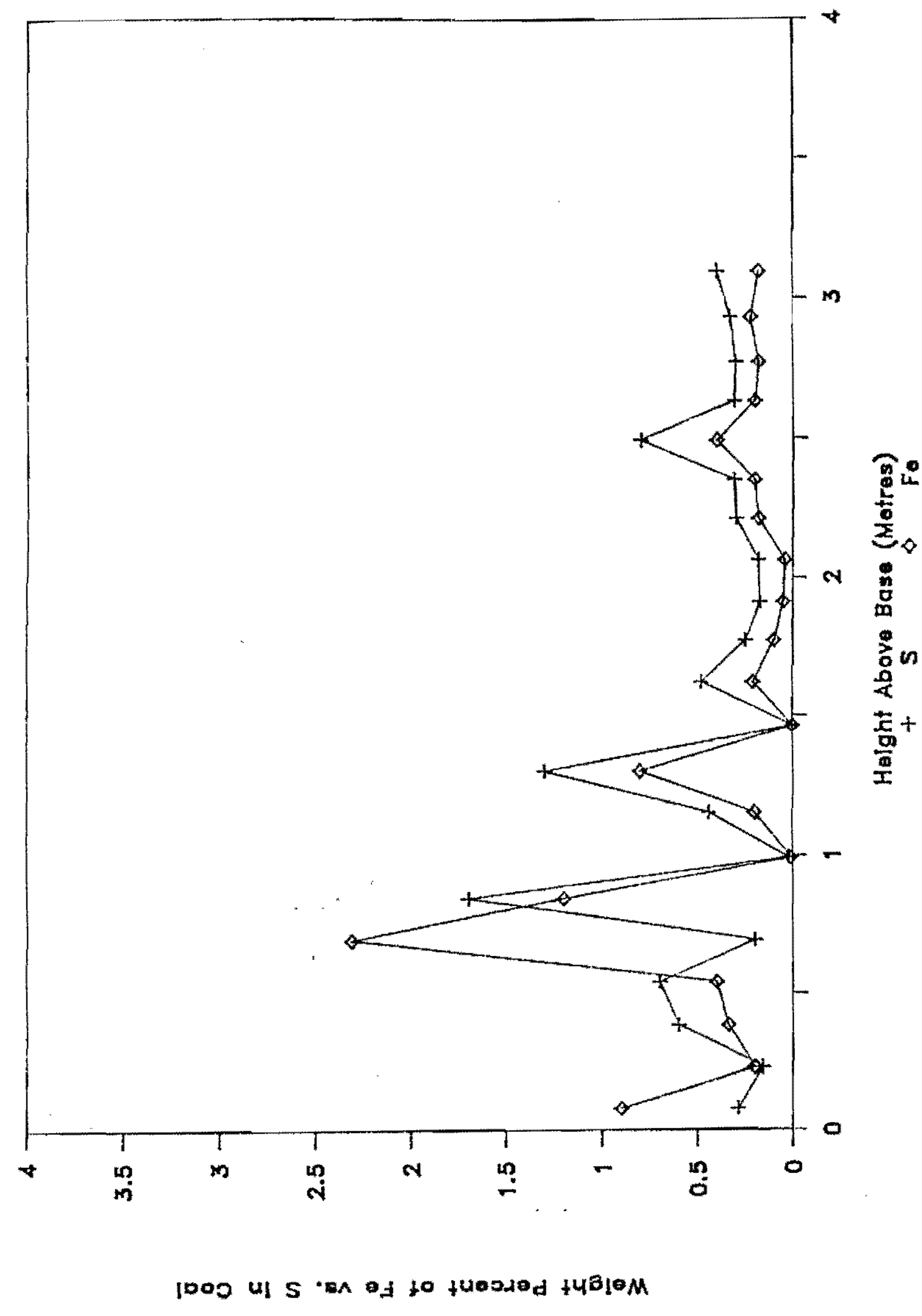

Weight Percent of Fe vs. S in Coal
Height Above Base (Metres)
+ S
◇ Fe
0
0.5
1
1.5
2
2.5
3
3.5
4
0
1
2
3
4

Figure 18. Vertical distribution of iron versus sulfur content for Beulah-Zap lignite samples from Pit 12. Compiled from Table 3.

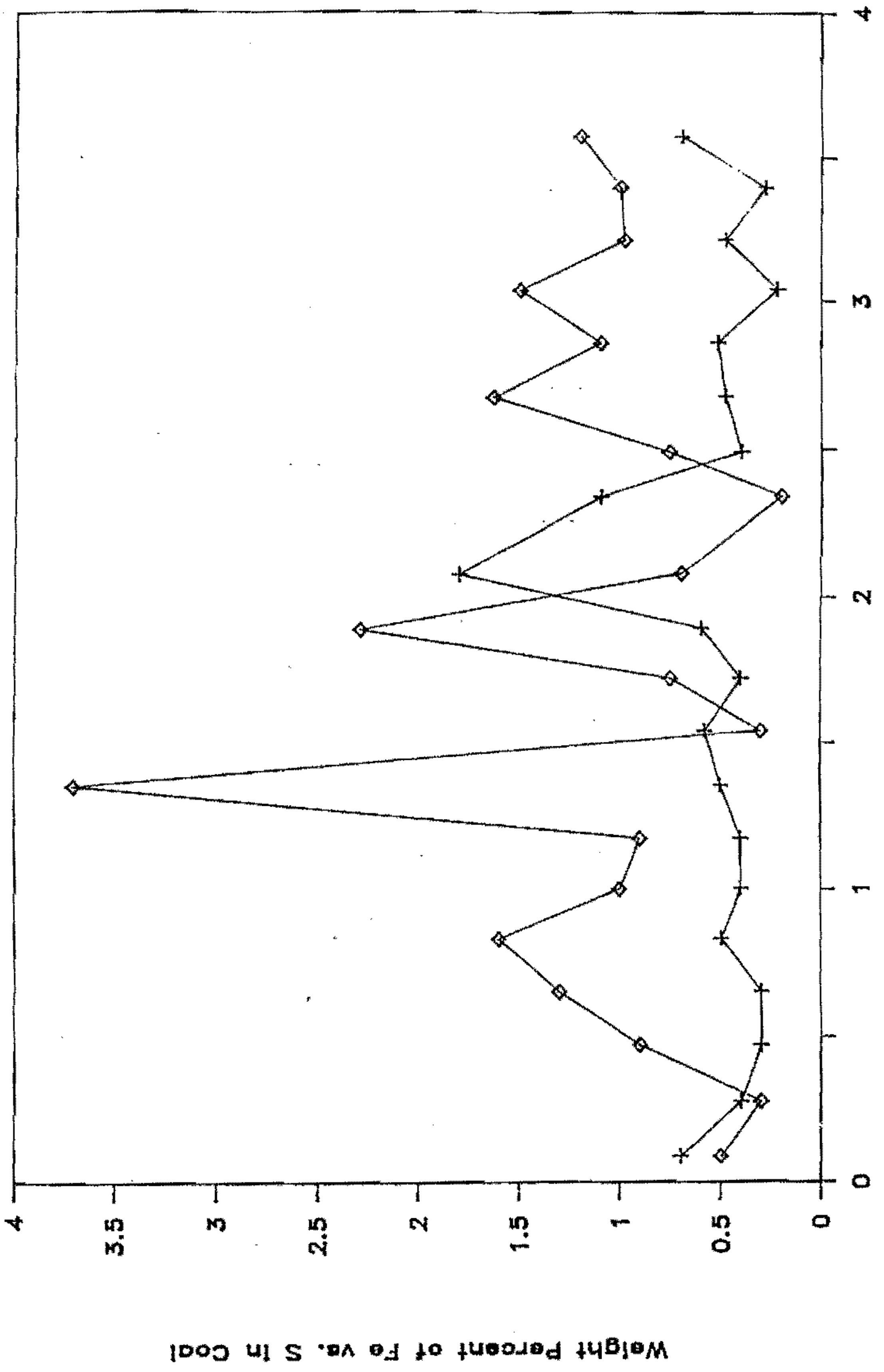

Weight Percent of Fe vs. S in Coal
Height Above Base (Metres)
+ S
◇ Fe
0
0.5
1
1.5
2
2.5
3
3.5
4
0
1
2
3
4

Figure 19. Vertical distribution of aluminum versus silicon content for Beulah-Zap lignite samples from Pit 11. Compiled from Table 2.

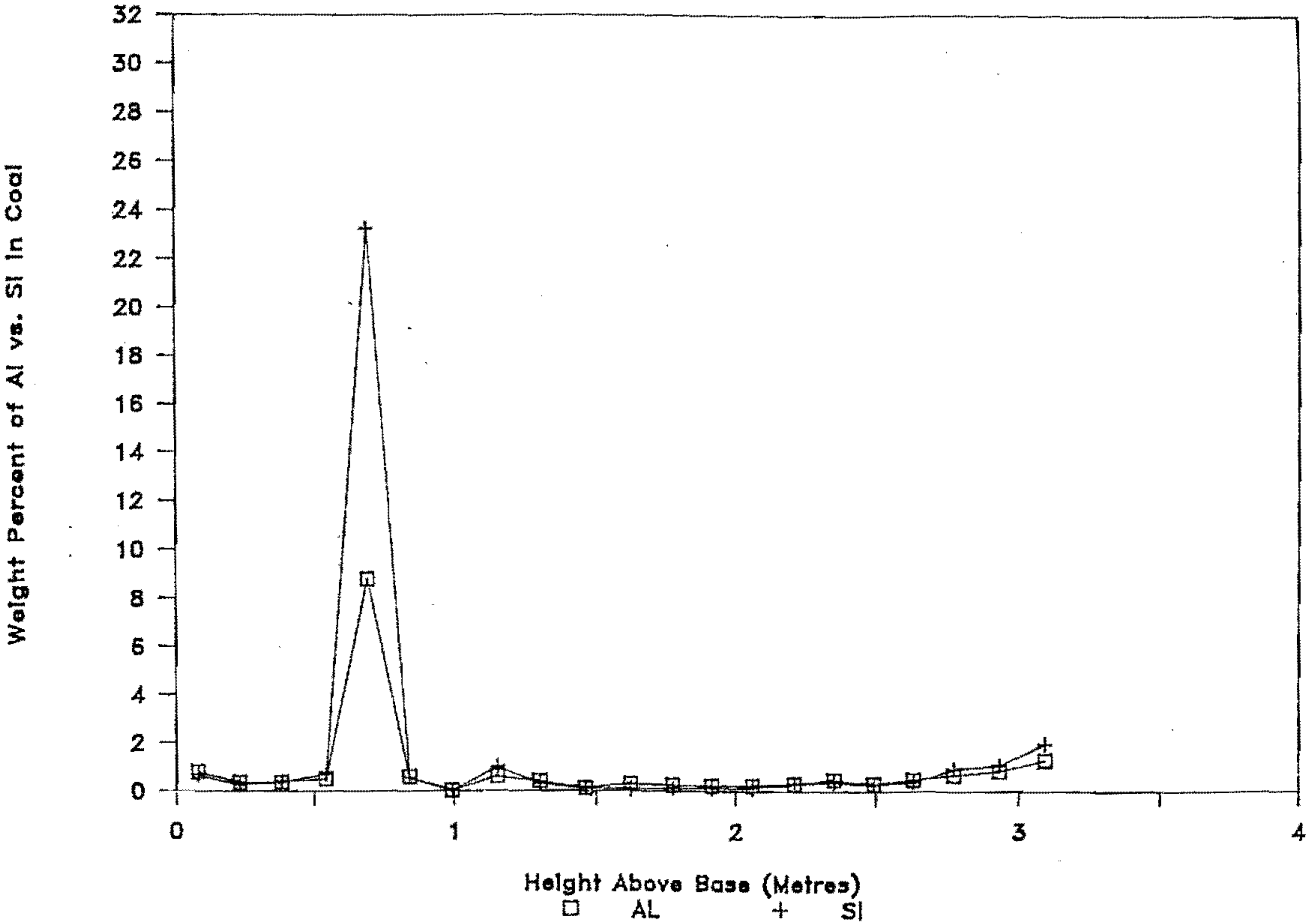
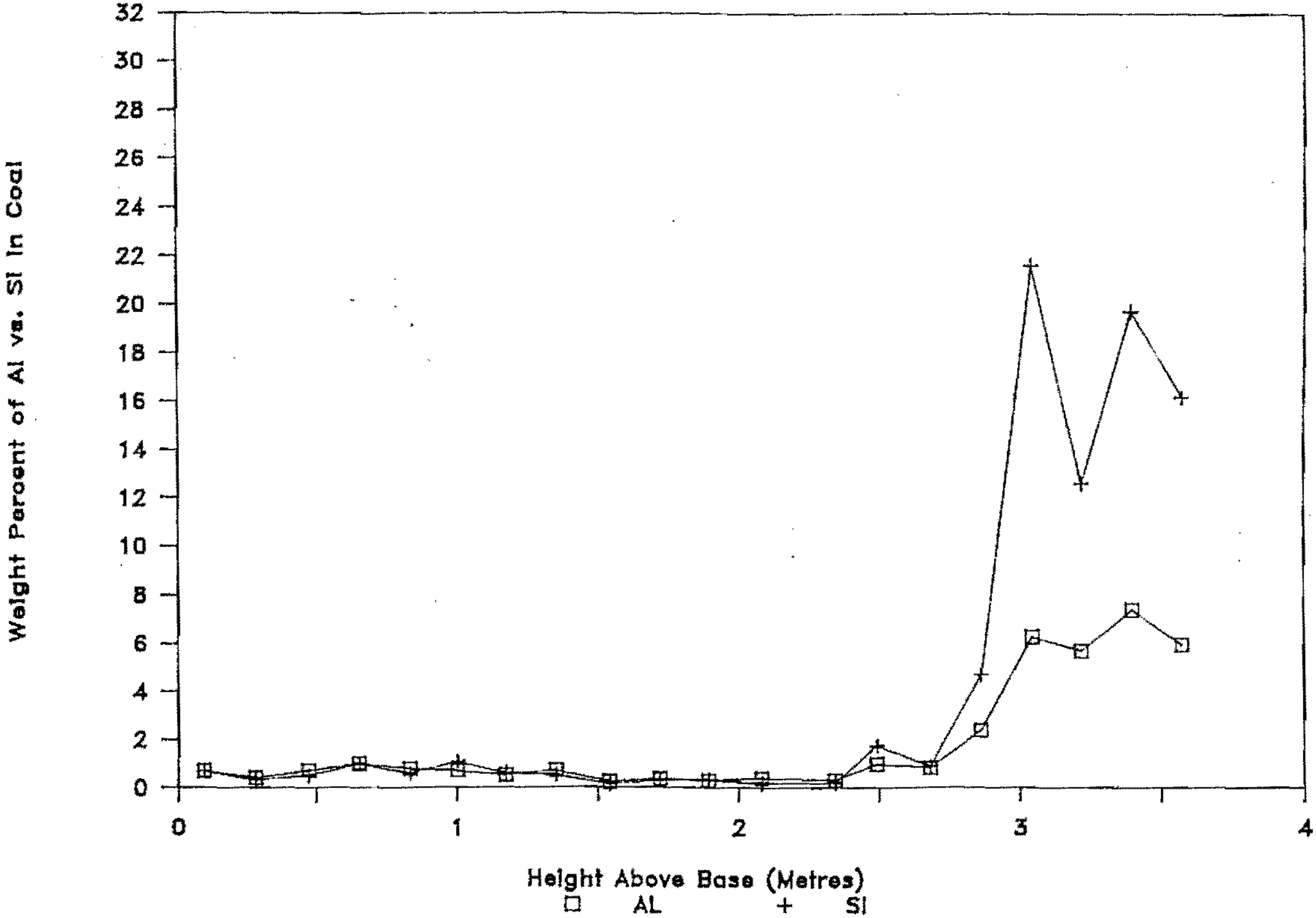

Weight Percent of Al vs. SI In Coal
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
0
1
2
3
4
Height Above Base (Metres)
□ AL + SI

Figure 20. Vertical distribution of aluminum versus silicon content of Beulah-Zap lignite samples from Pit 12. Compiled from Table 3.


32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Weight Percent of Al vs. Si in Coal
0
1
2
3
4
Height Above Base (Metres)
AL
SI

these elements. Pit 11 does have a clay-rich zone at approximately two-thirds of a metre above the base that corresponds to field observations of a thin clay parting at this location.

The proximate, ultimate, and heating value data obtained from analysis of each of the composite lignite samples used in the combustion tests is presented in Table 4. All reported values in Table 4 are on a moisture-free basis. The Pit 11 composite lignite sample is distinquished from the Pit 12 composite sample by a higher carbon content and BTU value and a lower sulfur and ash content. The ash contents and BTU values, which are inversely related, are 7.98 percent and 10,597 BTU/lb, respectively, in Pit 11 and 21.52 percent and 8,729 BTU/lb, respectively, in Pit 12. Sulfur content in the Pit 12 composite lignite sample is higher at 1.40 percent than in the composite Pit 11 lignite sample (0.59 percent).

The values shown in Table 5 are presented as oxide weight percent of the ash. The sodium concentration in Pit 11 is an order of magnitude higher than in Pit 12. Calcium and magnesium are also present in higher concentrations in Pit 11 than in Pit 12. Aluminum, silicon, and potassium have higher concentrations in Pit 12 than in Pit 11. Iron is present in a slightly higher concentration in Pit 12 than in Pit 11, also.

Fly-Ash Composition

The elemental compositions for the fly-ash samples are provided in Appendix D. Average chemical oxide weight percentages for each of the four fly-ash samples are shown in Table 6. Sodium, calcium, magnesium, and iron concentrations are higher in the ash samples

Table 4. Proximate, ultimate, and heating value data from composite Beulah-Zap lignite samples used in combustion tests (percent, moisture-free basis).

Component	Pit 11	Pit 12
Volatile Matter	42.25	38.35
Fixed Carbon	49.77	40.13
Ash	7.98	21.52
Hydrogen	4.20	3.87
Total Carbon	63.72	53.27
Nitrogen	0.84	0.77
Sulfur	0.59	1.40
Oxygen	22.65	19.15
BTU/LB	10,597	8,729

Table 5. Chemical oxide weight percents in composite Beulah-Zap lignite samples.

Component	Pit 11	Pit 12
Na_2O	12.1	0.0
MgO	8.4	4.3
Al_2O_3	13.5	20.3
SiO_2	21.2	50.9
P_2O_5	1.5	0.6
K_2O	0.1	1.4
CaO	34.1	12.7
TiO_2	1.3	1.2
Fe_2O_3	7.8	8.7

Table 6. Average chemical oxide weight percents in fly-ash samples from utilization tests by electron microprobe analysis.

Component	Pit 11 Composite Sample		Pit 12 Composite Sample	
	1300°C	1500°C	1300°C	1500°C
Na_2O	4.7	0.6	0.9	0.8
MgO	8.3	8.1	1.5	1.5
Al_2O_3	14.3	15.1	16.1	15.9
SiO_2	21.0	23.9	57.9	57.4
P_2O_5	0.6	0.6	0.1	0.1
ClO	0.0	0.0	0.0	0.0
K_2O	0.0	0.0	0.4	0.2
CaO	40.7	43.0	19.4	21.2
TiO_2	1.2	1.0	0.8	0.8
Fe_2O_3	9.3	7.8	2.8	2.0

derived from the high-sodium lignite and aluminum, silicon, and potassium are present in higher concentrations in the ash samples derived from the low-sodium lignite.

DISCUSSION

Correlation of Ash Properties and Lignite Geochemistry

From proximate, ultimate, and heating value data presented in Table 4, the lignite from Pit 11 would make a better industrial boiler feed than the lignite from Pit 12 because of higher heating value and lower ash and sulfur contents. Chemical analysis of the two composite lignite samples (Table 5), however, shows that the sodium content in the Pit 11 composite lignite sample is an order of magnitude higher than in the Pit 12 sample. The high sodium content in the Pit 11 lignite sample is an important factor in determining the fouling potential of this coal and its desirability as a fuel.

In addition to higher sodium content in the Pit 11 sample, the magnesium and calcium contents were also higher than in the Pit 12 lignite. Aluminum, silicon, potassium, and iron contents were higher in the Pit 12 sample.

Each of the two composite lignite samples was burned at two combustion temperatures, 1300°C and 1500°C. Average chemical oxide compositions, calculated on a SO_3-free basis, are similar for the two different temperature ashes from a specific coal. Comparisons are made on a SO_3-free basis because of the volatility and subsequent loss of sulfur during combustion. As expected, the combustion (flue gas) temperature does not affect the chemical composition of the ash.

The average chemical oxide compositions for the fly-ash samples (Table 6), when calculated on a SO_3-free basis, are very similar to the compositions of the original composite lignite samples (Table 5), with the exception of sodium in Pit 11 and iron in Pit 12. The lower concentrations of sodium in the Pit 11 fly-ash samples, when compared to the original sodium concentration in lignite, are believed to result from the loss of volatile sodium in the flue gas during the combustion tests. The concentration of sodium in the Pit 12 composite lignite sample was low and loss of sodium during combustion of this sample would not be as noticeable. The concentration of iron in the Pit 12 fly-ash samples was lower than in the original Pit 12 lignite sample. The iron concentrations in the Pit 11 fly-ash samples was similar to the original iron concentrations in the Pit 11 lignite sample. An explanation for the differences is related to the form of iron in each of the lignite samples. From field descriptions, electron microprobe analysis, and petrographic examination of the Pit 11 lignite samples, much of the iron occurs as pyrite. In the Pit 12 lignite, less pyrite was found although the iron concentration was found to be slightly higher than in Pit 11. It is suggested that a greater percentage of iron is associated with organic material in the Pit 12 lignite. Combustion of the Pit 12 lignite could result in the loss of a greater percentage of the iron because of concentration in the smaller particulates which are not collected as efficiently by the fly-ash sampling probe. This would then be reflected in the fly-ash analysis.

Although the chemical composition of the fly ash reflects the chemical composition of the original lignite, the mineralogical composition of the fly ash is a function of the original lignite chemical composition and the combustion temperature at which the fly ash was produced. The crystalline species identified in fly ash from the combustion of lignite are different from those of the respective ash deposits and most silicates are amorphous or glass-like (Benson, 1987). Scanning electron microscope/electron microprobe point-count analysis of the fly-ash samples provides elemental data but does not identify the crystalline phases present. Chemical composition and molar ratios at points determined by a point-count scheme may indicate compositions similar to certain minerals (Kalmanovitch, 1987).

Montmorillonite- and illite-type compositions, which were identified in the Pit 12 fly-ash samples, and kaolinite-type compositions, which were identifed in the Pit 11 fly-ash samples, are not believed to be crystalline phases. It is not likely that these minerals would survive the combustion temperatures used in the utilization tests and they are interpreted as phases formed from the original clay minerals. For discussion purposes, however, these compositions will be referred to as minerals. The mineral phases present in each of the fly-ash samples are summarized in Table 7. A greater number of mineral phases are present in the lower temperature fly ashes. Estimates for quantity of mineral phases also indicated higher contents in the lower temperature fly ashes.

The data derived from scanning electron microscope/electron microprobe point-count analysis of the fly-ash samples were also

Table 7. Mineral-type phases inferred from scanning electron microscope/electron microprobe analysis of fly-ash samples derived from the utilization tests.

Pit 11		Pit 12	
1300°C	1500°C	1300°C	1500°C
Calcium Oxide	Calcium Oxide	Hauyne	Montmorillonite
Iron Oxide	Kaolinite	Montmorillonite	Quartz
Kaolinite	Melilite	Illite	
Analcime		Iron Oxide	
Melilite		Quartz	
Nepheline		Melilite	

applied to a classification scheme developed by Stevenson et al. (1986). This scheme is based on the major chemical components of ASTM C-618 Class C fly ash (CaO, SiO_2, Al_2O_3, and Fe-oxide) and is illustrated by oxide weight percent CaO-SiO_2-Al_2O_3 ternary diagrams.

Oxide weight percent CaO-SiO_2-Al_2O_3 ternary diagrams for the four fly ashes (Figures 21-24) illustrate the chemical composition of the fly-ash particles in each of the fly-ash samples. Although a complete evaluation of these diagrams is not within the scope of this study, several observations can be made. The first observation regards the general patterns shown by the lignite fly ashes on the ternary diagrams. Stevenson et al. (1986) reported that general patterns were evident for lignite, subbituminous, and bituminous fly ashes derived from utility boilers when the chemical compositions were plotted on ternary diagrams. The patterns observed in the CaO-SiO_2-Al_2O_3 ternary diagrams (Figures 21-24) from the Pit 11 and Pit 12 lignite-derived fly ashes fit the general pattern for lignite fly ashes (Stevenson et al., 1986) when the chemical compositions of Pit 11 and 12 fly ashes are plotted on the same diagram. When plotted separately, the Pit 11 fly ash plots in the CaO-rich area of the ternary diagram and the Pit 12 fly ash plots in the SiO_2-rich area. Because high-sodium lignite causes fouling in utility boilers, high- and low-sodium coals are blended to maintain sodium concentrations at levels which will minimize the fouling potential. Fly ashes derived from utility boilers operating on these blended coals would not show the patterns found in this study.

Specific trends are evident for the Pit 11 and Pit 12 fly ashes to plot along lines that would indicate a relationship between the

Figure 21. Oxide weight percent $CaO-SiO_2-Al_2O_3$ ternary diagram for Pit 11 fly-ash particles derived from combustion tests at a flue-gas temperature of 1300°C (S = smectite/illite, K = kaolinite).

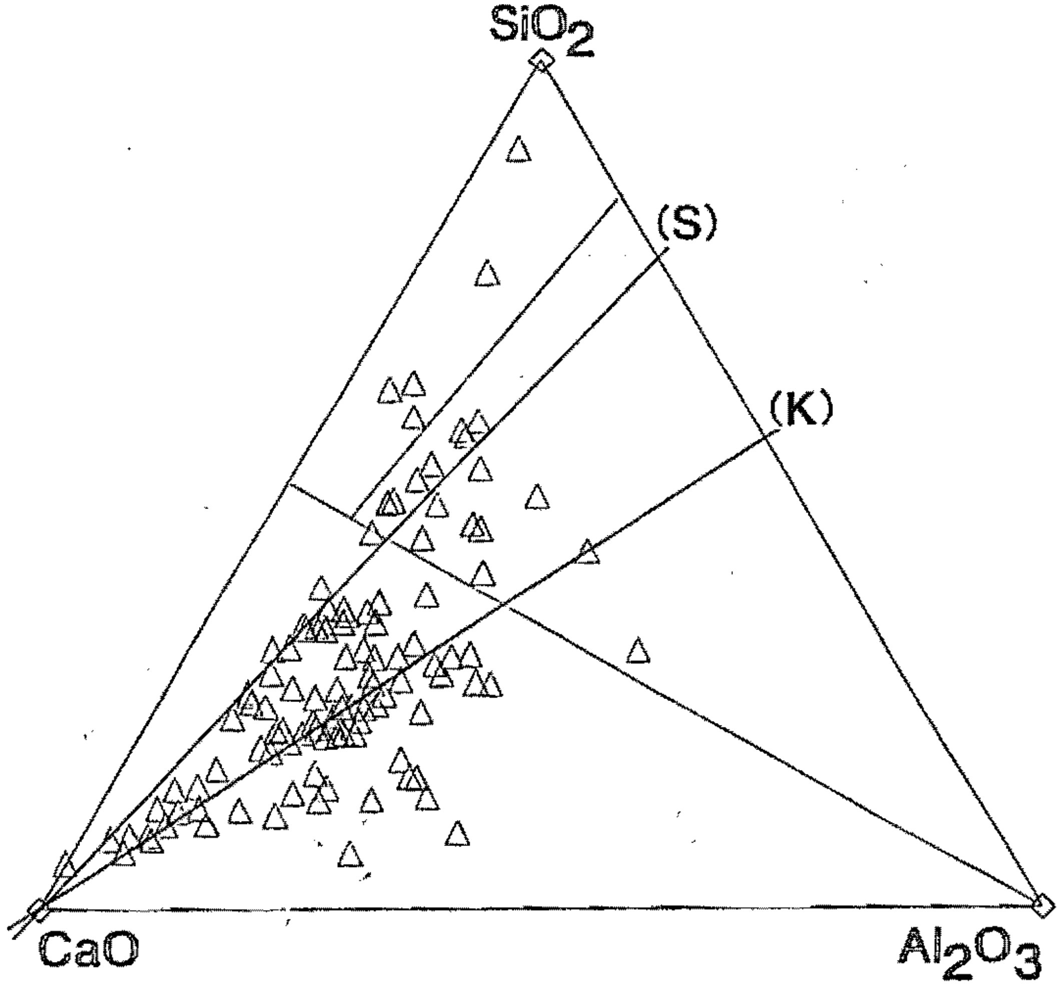

SiO2
(S)
(K)
CaO
Al2O3

Figure 22. Oxide weight percent $CaO-SiO_2-Al_2O_3$ ternary diagram for Pit 11 fly-ash particles derived from combustion tests at a flue-gas temperature of 1500°C (S = smectite/illite, K = kaolinite).

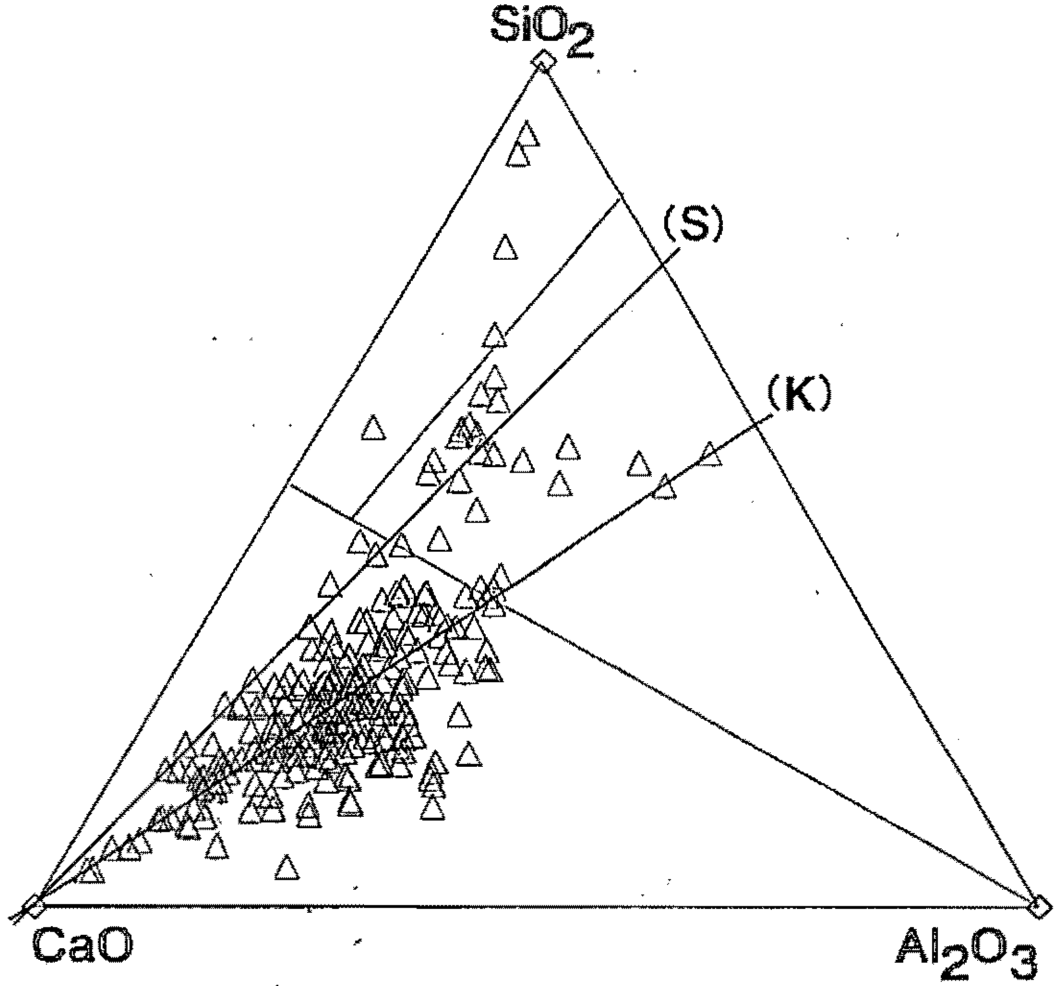

SiO2
(S)
(K)
CaO
Al2O3

Figure 23. Oxide weight percent CaO-SiO_2-Al_2O_3 ternary diagram for Pit 12 fly-ash particles derived from combustion tests at a flue-gas temperature of 1300°C (S = smectite/illite, K = kaolinite).

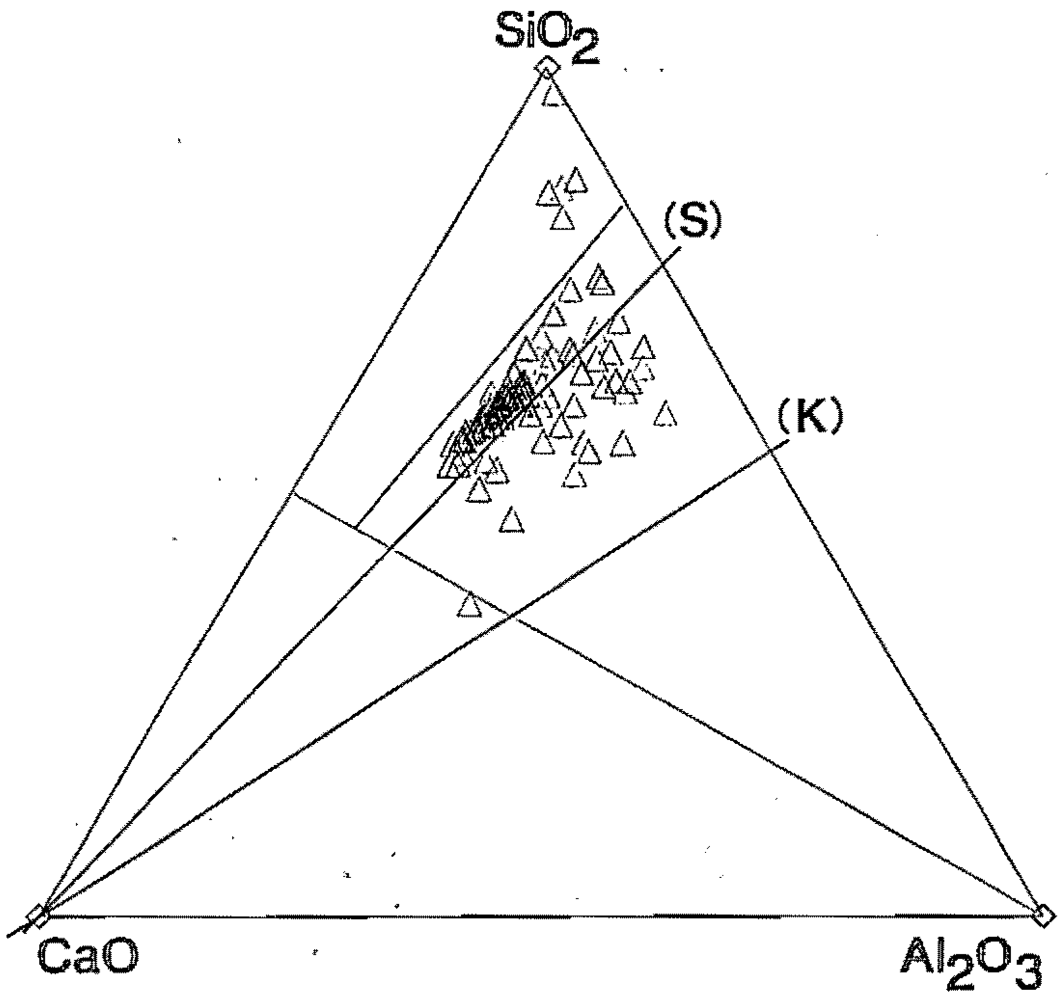
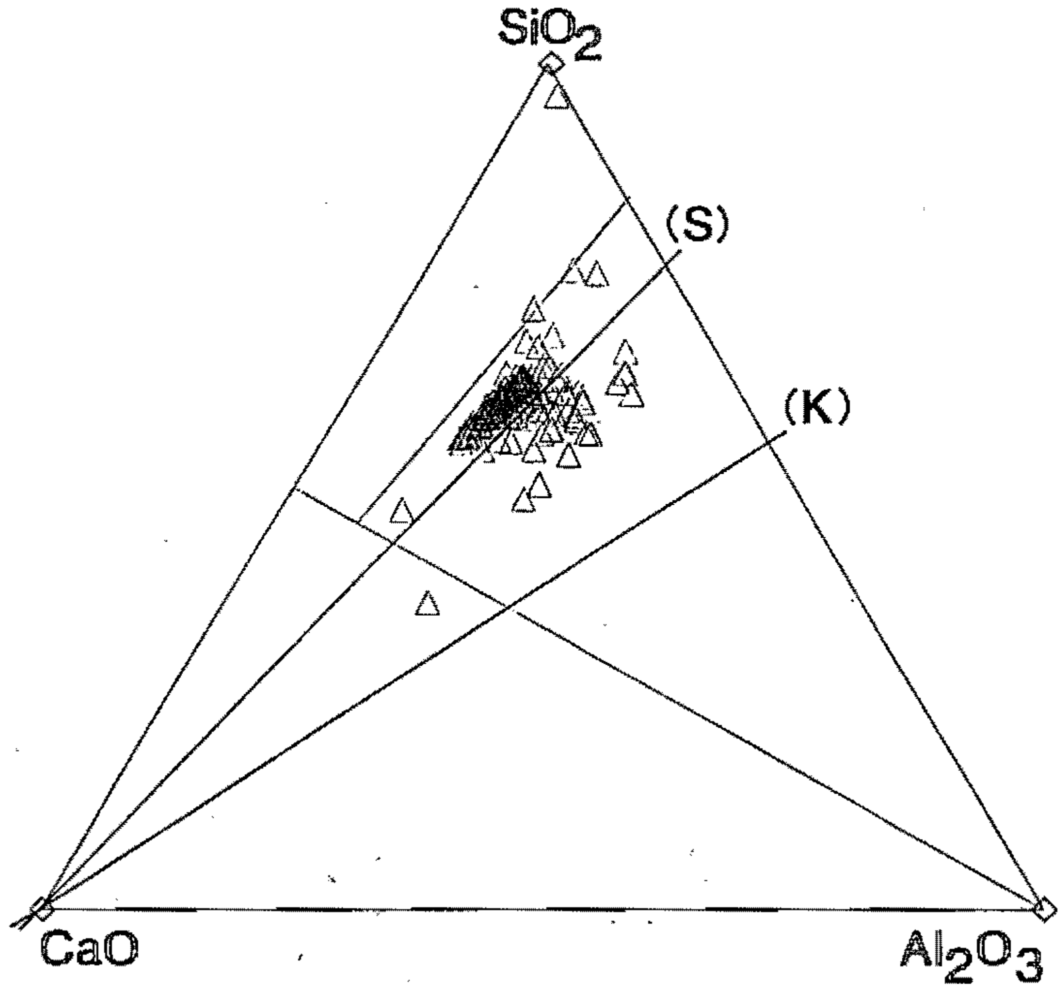

SiO2
(S)
(K)
CaO
Al2O3

Figure 24. Oxide weight percent CaO-SiO_2-Al_2O_3 ternary diagram for Pit 12 fly-ash particles derived from combustion tests at a flue-gas temperature of 1500°C (S = smectite/illite, K = kaolinite).


SiO2
(S)
(K)
CaO
Al2O3

fly-ash composition and the clay minerals originally present in the lignite. The compositions of smectite/illite (S) and kaolinite (K) are shown on each of the ternary diagrams. Lines drawn on the diagrams indicate that the Pit 11 fly ashes plot along the line drawn for kaolinite-derived minerals and the Pit 12 fly ashes plot along the line drawn for smectite/illite-derived minerals. In order to determine whether the characteristic trends for the fly ashes seen in this study are true of all high- and low-sodium lignites, additional samples should be tested. Also the original clay minerals in high- and low-sodium lignites should be identified in addition to mineralogical characterization of the fly ashes derived from combustion of the high- and low-sodium lignites. Finally, the interaction between different sodium concentrations and the different clay minerals should be studied to determine possible affects in fouling potential of the fly ash.

One final observation is made regarding the fly ash samples analyzed by point-count techniques with a scanning electron microscope/electron microprobe. Although general trends for each of the fly-ash samples are evident from the average chemical characterization data (Table 6), considerable variation is seen in the chemical composition of the fly-ash particles within a specific fly-ash sample (Appendix D). This reflects the complexity of reaction mechanisms involved in the formation of the fly ash.

Depositional and Post-depositional Processes

Recent work on the Sentinel Butte Formation has placed more emphasis on lacustrine depositional models. Logan (1981) and Wallick (1984) have suggested lacustrine systems with fluvial involvement as the primary depositional environment. This study did not focus on a depositional environment for the "Main Beulah" seam lignite. Rather, the study was directed toward the determination of possible relationships between lignite properties and depositional and post-depositional processes.

Depositional conditions, mainly relative to water depth, can be deduced from the lithotype distribution and abundance (Kleesattel, 1985). The "Main Beulah" seam sampled at the two locations in the Indian Head mine showed the same general trends of attritus being the dominant lithotype in the upper part of the seam and vitrain being the dominant lithotype in the middle and lower parts of the seam. Vitrain is representative of deposition at moderate (1 to 1.5 metres deep) water depths under conditions of steady, rapid subsidence (Kleesattel, 1985). Attritus is representative of deposition in deeper water where subsidence and burial rates are lower. Based on this information, it appears that during the period of deposition for the "Main Beulah" seam, there was a tendency for increasing water depth. Attritus dominated by fusain fragments at the top of the seam in both sampling locations would indicate that there was a major decrease in water depth towards the end of the lignite deposition sequence.

In addition to the same general vertical trend for lithotype abundances at each sampling location, the average percentages for the lithotypes at each location, were the same with attritus being 45, vitrain 50, and fusain 5. These values were identical to those observed by Kleesattel (1985) in his study of the Beulah-Zap lignite sampled at nine locations.

Maceral groups, because they are to some extent related to certain lithotypes, can also be used to determine depositional conditions. The huminite group was the dominant maceral group in Pit 11 and Pit 12. Huminite macerals typically form in moderately deep water under weakly oxidative conditions (Stach et al., 1982). The dominance of the huminite macerals also indicates that humification was the dominant coalification process. The humification process, by means of bacteria and fungi, hydrolyzes the starches, celluloses, and proteins of the plants to form humic acids.

Maceral group abundances at both sampling locations in the Indian Head mine showed a similar vertical trend. Inertinite percentages tended to increase upwards within the seam and the huminite percentages tended to increase downwards within the seam. This trend has also been noted by Kleesattel (1985).

Based on the maceral group and lithotype trends and abundances, depositional processes for the "Main Beulah" seam lignite at both sampling locations are believed to be the same. Differences in the Beulah-Zap lignite in Pit 11 and Pit 12 should then be due to post-depositional processes. The most obvious difference in the chemical composition of the lignite from the two sampling areas is the sodium content. The average sodium concentration for the lignite from Pit

11 is an order of magnitude higher than for the lignite from Pit 12. Calcium and magnesium concentrations are also higher for the Pit 11 lignite.

Analysis of coal (Kalmanovitch et al., 1987) has shown that sodium, calcium, and magnesium are generally associated with the organic matrix of lignite whereas silicon, aluminum, iron, potassium, and titanium are associated with mineral phases. The Pit 12 Beulah-Zap lignite has a higher inorganic content and would be expected to have higher concentrations of those elements associated with mineral phases. The Pit 11 Beulah-Zap lignite would be expected to have higher sodium, calcium, and magnesium concentrations because of lower ash content or more organic material. The concentration of sodium in the Pit 11 lignite, however, is considerably higher than seen in the Pit 12 lignite.

Groenewold et al. (1983) presented a conceptual hydrogeochemical model for groundwater quality in coal-bearing sediments in western North Dakota. The critical hydrogeochemical processes include CO_2 production in organic horizons of the soil, oxidation of pyrite, dissolution of calcite and dolomite, precipitation and dissolution of gypsum, and cation exchange (Ca^{2+} for Na^+ on clay). The hydrogeochemical processes operate almost exclusively in the zone above the water table. Alternate wetting and drying of the upper portion of the landscape is the key mechanism in the chemical evolution of subsurface water and controls the quality of water in shallow (<150 metres) aquifers.

Groenewold et al. (1983) reported that movement of water through fine-textured sediments is generally vertical and downward.

They also found that the dominant clay mineral in the fine-textured sediments is sodium montmorillonite. The conceptual hydrogeochemical model developed by Groenewold et al. (1983) provides an understanding of the hydrogeochemical processes that appear to be responsible for the formation of high- and low-sodium coals. According to the model, clay is a likely source of sodium found in the high-sodium coal. Downward movement of water through the clay during periods of recharge results in cation exchange (Ca^{2+} for Na^{+} on clay). The high-sodium waters move through the lignite where there is a strong organic affinity for the sodium (Karner, 1985).

The overburden above the high-sodium lignite in Pit 11 consists mainly of clay grading downward into interbedded clay and shale. The overburden above the low-sodium lignite in Pit 12 consists mainly of sand grading downward into interbedded clay and silt. Based on the sodium concentrations in the lignite at each sampling location and the characteristics of the overburden, it appears there is a correlation between the lignite sodium concentration and the overburden using the model presented by Groenewold et al (1983).

To verify the mechanisms for development of high-sodium coals, samples of water from the overburden and coal should be collected and analyzed in both high- and low-sodium coal areas. The chemistry of the water will provide further evidence for mechanisms and the source of major cation concentrations present in the coal. In addition, samples of lignite should be collected relative to major fractures present in the coal seam and overburden to determine the effect of the fractures and subsequent groundwater flow on sodium levels in the lignite.

SUMMARY AND CONCLUSIONS

Sodium concentrations were found to be an order of magnitude higher in the Beulah-Zap lignite in Pit 11 than in Pit 12. Calcium and magnesium concentrations were also found to be higher in Pit 11 lignite. Iron, aluminum, silicon, and sulfur concentrations were found to be higher in Pit 12 lignite.

Iron and sulfur contents in Pit 11 were consistent with high pyrite content as determined during field descriptions and in microscopic evaluation of the samples.

The overburden at Pit 11 was mainly clay grading downward into interbedded clay and shale and at Pit 12 was mainly sand grading downward into clay and silt. The overburden thickness in Pit 11 was approximately 20 to 25 metres and in Pit 12 was approximately 15 metres.

Average lithotype abundances for each of the sampling sites were estimated to be vitrain 50%, attritus 45%, and fusain 5%. Attritus occured more frequently in the upper part and vitrain in the middle and lower parts of the seam.

Maceral groups, identified microscopically, were (in order of decreasing abundance): huminite, inertinite, and liptinite. The percentage of huminite macerals increased toward the bottom and inertinite macerals toward the top of the seam at each sampling location.

Similar lithotype and maceral group abundances and trends between Pit 11 and Pit 12 lignites indicate similar depositional processes for both locations.

Differences in sodium concentrations at the two sampling locations relate to the hydrogeochemical model presented by Groenewold et al. (1983). High-sodium coal corresponds with fine-textured overburden sediments. The source of the sodium in the high-sodium coal is believed to be sodium montmorillonite clays in the overburden at Pit 11.

Scanning electron microscopy/electron microprobe analysis of fly-ash particles indicates extremely variable chemical compositions. This reflects the complexity of reaction mechanisms involved in the formation of the fly ash.

Average oxide concentrations of the fly ash reflect oxide concentrations in the lignite, indicating the fly ash composition can be directly related to the lignite composition.

Mineral and amorphous phases present in the fly ash are interpreted to be a function of elemental composition of the lignite and combustion conditions, specifically the temperature.

APPENDICES

APPENDIX A

DESCRIPTIONS OF MEASURED SECTIONS

DESCRIPTIONS OF MEASURED SECTIONS

These descriptions of the Beulah-Zap lignite were compiled from both field and laboratory examination of the samples.

Measured Section in PIT 11

Measured section in the Indian Head mine, Pit 11, "Main Beulah" seam. Total thickness of the "Main Beulah" seam at this location was 3.17 metres. Overburden and underclays were collected as part of the sample series.

SAMPLE	INTERVAL (HT. ABOVE BASE in METRES)	DESCRIPTION
2	6.12--20	OVERBURDEN; Grey shale, laminated, grading upward into light-grey clay; "Schoolhouse" lignite bed about 0.5 metres thick near top.
3	5.76-6.12	OVERBURDEN; Light-grey, laminated shale interbedded with carbonaceous shale; some pyrite; intermixing of layers; middle layer approximately 12 centimetres thick; well consolidated.
7	5.41-5.76	OVERBURDEN; Grey, non-laminated clay with fusain clasts; well consolidated.
8	4.98-5.41	OVERBURDEN; Dark-grey, carbonaceous shale with layers of clayey shale about 12 centimetres thick.
11	4.34-4.98	OVERBURDEN; Grey, fibrous, shaly clay with fusain clasts; contact with lower blackjack lignite is gradational.
12	3.48-4.34	OVERBURDEN; Blackjack lignite; dull, dark-grey, massive, carbonaceous shale; gradual contact with lower banded clay, shale and lignite.
13	3.17-3.48	OVERBURDEN; Banded clay, shale and lignite; shale clasts in lignite bands; sandy clay band high in quartz at contact with lignite.
42	3.01-3.17	LIGNITE; Dull, hard, attrital coal; thin vitrain layers.
41	2.84-3.01	LIGNITE; Dull, hard, attrital coal; thin vitrain layers.

40	2.70-2.84	LIGNITE; Dull, massive, friable, attrital coal; thick vitrain layers; fusain fragments abundant on bedding plane surfaces; highly fractured; clay lenses; iron stained.
39	2.56-2.70	LIGNITE; Moderate to bright, massive, friable, attrital coal; thick vitrain layers; fusian fragments abundant on bedding plane surfaces; highly fractured; iron stained; some pyrite nodules.
38	2.42-2.56	LIGNITE; Moderate to bright, attrital coal; thick vitrain layers; fusain fragments abundant on bedding plane surfaces; highly fractured; finely laminated; some pyrite nodules.
37	2.28-2.42	LIGNITE; Moderate to bright, attrital coal; thick vitrain layers; fusain fragments abundant on bedding plane surfaces; highly fractured; finely laminated; some pyrite nodules; clay lenses.
36	2.13-2.28	LIGNITE; Moderate to bright, massive, soft, attrital coal; thick vitrain layers; fusain fragments abundant on bedding plane surfaces; highly fractured; some pyrite nodules.
35	1.98-2.13	LIGNITE; Moderate to bright, massive, soft, attrital coal; thick vitrain layers; fusain fragments abundant on bedding plane surfaces; highly fractured; some pyrite nodules.
34	1.84-1.98	LIGNITE; Moderate to bright, hard, vitreous coal; thick vitrain layers with some preserved plant structures; some fusain fragments on bedding plane surfaces.
33	1.70-1.84	LIGNITE; Moderate to bright, massive, hard, vitreous coal; thick vitrain layers with some preserved plant structures; some fusain fragments on bedding plane surfaces; clay lenses; some pyrite nodules.

32	1.54-1.70	LIGNITE; Dull, massive, hard, vitreous coal; thick vitrain layers with some preserved plant structures; some fusain fragments on bedding plane surfaces; highly fractured; some pyrite nodules; iron stained.
31	1.38-1.54	LIGNITE; Dull, massive, hard, vitreous coal; thick vitrain layers with some preserved plant structures; some fusain fragments on bedding plane surfaces; highly fractured; some pyrite nodules; iron stained.
30	1.22-1.38	LIGNITE; Dull, massive, hard, attrital coal; thick vitrain layers; some fusain fragments on bedding plane surfaces; highly fractured; some pyrite nodules; iron stained.
29	1.07-1.22	LIGNITE; Bright, massive, vitreous coal; thick vitrain layers; some fusain fragments on bedding plane surfaces; clay lenses; some pyrite nodules.
28	0.91-1.07	LIGNITE; Dull, attrital coal; thick vitrain layers with some preserved plant structures; some fusain fragments on bedding plane surfaces; highly fractured; clay lenses; some pyrite nodules.
27	0.76-0.91	LIGNITE; Dull, massive, very hard, attrital coal; thick vitrain layers with some preserved plant structures; some fusain fragments on bedding plane surfaces; some pyrite nodules.
26	0.61-0.76	LIGNITE; Moderate to bright, massive, very hard, vitreous coal; thick vitrain layers with some preserved plant structures; some fusain fragments on bedding plane surfaces.

25	0.46-0.61	LIGNITE; Bright, massive, very hard, vitreous coal; thick vitrain layers with some preserved plant structures; some fusain fragments on bedding plane surfaces; some pyrite nodules; iron stained.
24	0.30-0.46	LIGNITE; Moderate to bright, vitreous coal; thick vitrain layers with some preserved plant structures; some fusain fragments on bedding plane surfaces; highly fractured; some pyrite nodules.
23	0.15-0.30	LIGNITE; Bright, massive, hard, attrital coal; vitrain lenses; some fusain fragments on bedding plane surfaces; finely laminated; some pyrite nodules.
22	0.00-0.15	LIGNITE; Bright, massive, very hard, attrital coal; vitrain lenses; some fusain fragments on bedding plane surfaces; some pyrite nodules.
20	-0.91-0.00	UNDERCLAY; Light-grey, finely laminated, clay with high silt content; numerous pyrite nodules.

Measured Section in Pit 12

Measured section in the Indian Head mine, Pit 12, "Main Beulah" seam. Total thickness of the "Main Beulah" seam at this location was 3.66 metres. Overburden and underclays were collected as part of the sample series.

SAMPLE	INTERVAL (HT. ABOVE BASE in METRES)	DESCRIPTION
1	4.67--15	OVERBURDEN; Reddish, silty clay grading upwards into very fine sand. Some cross-bedding of sand.
2	4.09-4.67	OVERBURDEN; Brownish-grey, non-laminated clay; soft.
3	3.87-4.09	OVERBURDEN; Brownish-grey, finely laminated, soft, carbonaceous clay.
4	3.78-3.87	OVERBURDEN; Dark-brownish-grey, finely laminated, carbonaceous clay; well consolidated.
5	3.66-3.78	OVERBURDEN; Dark-brown to black, finely laminated, silty, carbonaceous clay; pyrite nodules.
6	3.48-3.66	LIGNITE; Dull, medium to hard, attrital coal; some fusain fragments on bedding plane surfaces.
7	3.30-3.48	LIGNITE; Dull, friable, attrital coal; thin vitrain layers; some fusain fragments on bedding plane surfaces; iron stained.
8	3.12-3.30	LIGNITE; Dull, friable, attrital coal; thin vitrain layers.
9	2.95-3.12	LIGNITE; Dull, massive, friable, attrital coal; some fusain fragments on bedding plane surfaces; large cherty concretion layer.
10	2.77-2.95	LIGNITE; Moderate to bright, massive, friable, attrital coal; thick vitrain layers with well preserved plant structures; some fusain fragments on bedding plane surfaces; iron staining.

11	2.59-2.77	LIGNITE; Moderate to bright, massive, friable, attrital coal; thin vitrain layers.
12	2.39-2.59	LIGNITE; Moderate to bright, massive, hard, attrital coal; thin vitrain layers.
13	2.18-2.39	LIGNITE; Dull, hard, attrital coal; thick vitrain layers with some preserved plant structures; some fusain fragments on bedding plane surfaces; finely laminated.
14	1.98-2.18	LIGNITE; Dull, hard, attrital coal; thick vitrain layers with some preserved plant structures; finely laminated.
15	1.80-1.98	LIGNITE; Dull, hard, attrital coal; thick vitrain layers with some preserved plant structures; finely laminated.
16	1.63-1.80	LIGNITE; Moderate to bright, massive, hard, vitreous coal; thick vitrain layers with some preserved plant structures.
17	1.45-1.63	LIGNITE; Bright, massive, hard, vitreous coal; thick vitrain layers with some preserved plant structures.
18	1.24-1.45	LIGNITE; Moderate to bright, massive, hard, vitreous coal; thick vitrain layers with some preserved plant structures.
19	1.09-1.24	LIGNITE; Bright, massive, hard, vitreous coal; thick vitrain layers with some preserved plant structures; some fusain fragments on bedding plane surfaces.
20	0.91-1.09	LIGNITE; Moderate to bright, massive, hard, vitreous coal; thick vitrain layers with some preserved plant structures; some fusain fragments on bedding plane surfaces.

21	0.74-0.91	LIGNITE; Moderate to bright, massive, hard, vitreous coal; thick vitrain layers with some preserved plant structures; some fusain fragments on bedding plane surfaces, small pyrite nodules.
22	0.56-0.74	LIGNITE; Moderate to bright, hard, attrital coal; thick vitrain layers with some preserved plant structures.
23	0.38-0.56	LIGNITE; Moderate to bright, attrital coal; thick vitrain layers with some preserved plant structures; small pyrite nodules.
24	0.18-0.38	LIGNITE; Bright, massive, hard, vitreous coal; thick vitrain layers with some preserved plant structures.
25	0.00-0.18	LIGNITE; Moderate to bright, massive, hard, vitreous coal; thick vitrain layers; some fusain fragments on bedding plane surfaces; finely laminated; iron stained.
26	-? -0.00	UNDERCLAY; Medium to dark grey carbonaceous clay; finely laminated; well consolidated.

APPENDIX B

MACERAL POINT COUNT DATA FOR MEASURED SECTIONS

MACERAL POINT COUNT PERCENTAGES FOR EACH OF THE MEASURED SECTIONS

Maceral point count data was obtained from petrographic examination of the samples. In addition clay, quartz, and pyrite percentages in the samples was determined.

PIT 11

SAMPLE NUMBER	Ht. above base-metres	HUM	LIP	INER	CLAY	QTZ	PYR
42	3.1	73.8	2.4	23.4	0.0	0.2	0.2
41	2.9	73.8	0.6	25.0	0.6	0.0	0.0
40	2.8	69.2	3.4	27.0	0.2	0.2	0.0
39	2.6	66.0	0.6	32.0	1.0	0.2	0.2
38	2.5	73.2	0.6	26.2	0.0	0.0	0.0
37	2.4	46.4	0.0	53.6	0.0	0.0	0.0
36	2.2	69.0	0.4	30.0	0.0	0.0	0.6
35	2.1	80.0	1.2	17.6	0.2	0.0	1.0
34	1.9	74.0	0.8	25.2	0.0	0.0	0.0
33	1.8	88.4	3.4	7.8	0.2	0.0	0.2
32	1.6	76.6	9.8	13.6	0.0	0.0	0.0
31	1.5	85.6	4.6	6.2	3.6	0.0	0.0
30	1.3	90.4	3.0	6.6	0.0	0.0	0.0
29	1.2	89.4	2.4	8.2	0.0	0.0	0.0
28	1.0	92.0	4.4	3.6	0.0	0.0	0.0
27	0.8	89.6	1.6	5.6	0.0	0.4	2.8
26	0.7	89.8	1.2	6.0	2.8	0.0	0.2
25	0.5	95.6	0.6	0.8	1.2	0.0	1.8
24	0.4	94.4	4.2	0.8	0.4	0.0	0.2
23	0.2	85.0	3.2	11.8	0.0	0.0	0.0
22	0.1	95.0	5.0	0.0	0.0	0.0	0.0

PIT 12

SAMPLE NUMBER	Ht. above base-metres	HUM	LIP	INER	CLAY	QTZ	PYR
6	3.6	46.8	0.4	6.8	45.4	0.2	0.4
7	3.4	22.6	0.0	2.0	74.8	0.0	0.6
8	3.2	48.8	1.4	3.0	46.8	0.0	0.0
9	3.0	5.8	0.0	32.6	61.4	0.2	0.0
10	2.9	58.8	5.2	23.2	12.2	0.4	0.2
11	2.7	68.2	0.2	27.4	4.2	0.0	0.0
12	2.5	60.6	4.0	34.6	0.6	0.0	0.2
13	2.3	44.4	0.0	54.4	1.2	0.0	0.0
14	2.1	58.4	0.0	40.8	0.6	0.0	0.2
15	1.9	59.2	5.0	35.2	0.6	0.0	0.0
16	1.7	80.4	1.0	17.8	0.8	0.0	0.0
17	1.5	87.0	0.0	11.6	1.0	0.0	0.4
18	1.4	75.4	7.2	16.8	0.6	0.0	0.0
19	1.2	86.0	1.0	12.6	0.2	0.0	0.2
20	1.0	67.4	3.0	28.4	1.0	0.0	0.2
21	0.8	87.0	1.2	10.6	1.2	0.0	0.0
22	0.7	78.8	3.0	16.0	2.2	0.0	0.0
23	0.5	76.2	3.0	19.2	1.0	0.2	0.4
24	0.3	92.6	4.0	1.8	0.6	0.0	1.0
25	0.1	90.6	6.6	0.6	2.2	0.0	0.0

APPENDIX C

CHEMICAL CHARACTERIZATION DATA FOR MEASURED SECTIONS

CHEMICAL CHARACTERIZATION DATA FOR MEASURED SECTIONS

The data reported here were determined by electron microprobe analysis as described in the Methods section of this report. Values are reported as weight percent of coal.

PIT 11

SAMPLE	NA	MG	AL	SI	P	S	CL	K	CA	TI	MN	FE	O
2	0.62	1.62	9.16	25.70	0.20	0.07	0.02	2.48	0.89	0.52	0.22	6.10	52.41
	0.77	1.70	9.19	25.80	0.13	0.09	0.00	2.42	0.80	0.53	0.17	6.27	52.17
3	0.62	0.78	7.90	22.71	0.08	0.32	0.00	1.67	0.60	0.52	0.04	1.39	63.36
	0.56	0.67	7.60	22.37	0.08	0.32	0.02	1.59	0.54	0.42	0.03	1.39	64.38
7	0.40	0.68	8.52	30.76	0.09	0.02	0.00	1.98	0.30	0.67	0.06	1.36	55.06
	0.35	0.68	8.47	30.31	0.11	0.03	0.00	2.06	0.27	0.70	0.04	1.32	55.68
8	0.34	0.59	7.50	27.67	0.06	0.15	0.04	1.86	0.34	0.71	0.06	0.96	59.73
	0.32	0.58	7.37	27.62	0.11	0.13	0.00	1.81	0.43	0.64	0.09	0.99	59.93
11	0.31	0.63	8.87	31.30	0.09	0.09	0.00	2.05	0.19	0.57	0.04	1.53	54.29
12	0.62	0.69	7.68	24.43	0.06	0.15	0.00	1.55	0.59	0.56	0.00	1.62	62.12
	0.34	0.81	8.05	24.40	0.04	0.18	0.00	1.61	0.55	0.58	0.00	1.64	61.84
13	0.24	0.15	7.02	31.08	0.65	0.81	0.00	0.49	0.54	1.27	0.00	1.23	56.45
	0.25	0.14	7.20	30.10	0.73	0.96	0.00	0.58	0.63	1.36	0.00	1.36	56.70
42	0.73	0.39	1.27	1.96	0.11	0.32	0.00	0.09	1.28	0.06	0.03	0.18	93.53
	0.78	0.49	1.32	1.99	0.10	0.38	0.00	0.10	1.33	0.07	0.03	0.26	93.16
41	0.80	0.43	0.82	1.08	0.11	0.33	0.03	0.07	1.19	0.05	0.00	0.22	94.86
	0.72	0.39	0.76	1.04	0.08	0.25	0.00	0.06	0.82	0.03	0.00	0.15	95.71
40	0.87	0.48	0.64	1.01	0.00	0.30	0.00	0.04	1.23	0.06	0.03	0.18	95.15
	1.38	0.42	0.50	0.86	0.00	0.27	0.43	0.06	1.00	0.04	0.07	0.15	94.82
39	0.84	0.41	0.48	0.49	0.08	0.31	0.00	0.00	1.31	0.04	0.04	0.25	95.75
	0.69	0.45	0.48	0.33	0.05	0.31	0.02	0.06	1.35	0.05	0.03	0.23	95.94
38	0.84	0.37	0.36	0.27	0.03	0.60	0.00	0.05	0.74	0.02	0.00	0.27	96.46
	0.70	0.33	0.29	0.27	0.05	0.90	0.00	0.04	0.77	0.03	0.00	0.42	96.20
37	0.84	0.41	0.48	0.49	0.08	0.31	0.00	0.00	1.31	0.04	0.04	0.25	95.75
	0.69	0.45	0.48	0.33	0.05	0.31	0.02	0.06	1.35	0.05	0.03	0.23	95.94
36	0.91	0.42	0.41	0.38	0.00	0.37	0.03	0.00	2.27	0.00	0.06	0.18	94.97
	0.41	0.19	0.19	0.16	0.02	0.17	0.00	0.01	1.05	0.01	0.00	0.15	97.63
35	0.54	0.29	0.23	0.15	0.00	0.18	0.00	0.02	0.54	0.00	0.00	0.04	98.01
	0.67	0.27	0.19	0.16	0.01	0.13	0.01	0.00	0.34	0.00	0.00	0.04	98.18
34	0.67	0.36	0.22	0.12	0.02	0.17	0.00	0.00	0.57	0.00	0.00	0.05	97.82
	0.74	0.38	0.26	0.13	0.04	0.20	0.02	0.00	0.74	0.02	0.03	0.09	97.34
33	0.64	0.28	0.25	0.13	0.00	0.25	0.02	0.02	0.57	0.02	0.00	0.04	97.78
	0.80	0.31	0.25	0.08	0.04	0.30	0.00	0.00	0.79	0.02	0.00	0.10	97.31

32	0.62	0.31	0.24	0.15	0.00	0.48	0.00	0.00	0.49	0.03	0.00	0.21	97.47
	0.65	0.34	0.25	0.12	0.00	0.53	0.00	0.00	0.58	0.00	0.00	0.24	97.30
31	0.03	0.05	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	99.85
	0.16	0.08	0.11	0.12	0.00	0.06	0.01	0.00	0.02	0.00	0.00	0.00	99.43
30	0.71	0.34	0.34	0.22	0.03	1.19	0.00	0.03	1.90	0.00	0.00	0.66	94.58
	0.78	0.41	0.41	0.35	0.05	1.34	0.00	0.03	1.66	0.08	0.00	0.87	94.02
29	0.69	0.39	0.61	1.03	0.00	0.44	0.00	0.04	1.30	0.04	0.00	0.27	95.18
	0.76	0.44	0.59	1.00	0.00	0.34	0.00	0.04	1.12	0.02	0.00	0.20	95.50
28	0.00	0.02	0.04	0.02	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.01	99.88
	0.00	0.04	0.03	0.02	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.01	99.88
27	0.90	0.43	0.60	0.56	0.00	1.79	0.00	0.03	1.17	0.05	0.00	1.28	93.21
	0.76	0.45	0.57	0.66	0.00	1.68	0.00	0.03	1.20	0.06	0.00	1.08	93.52
26	0.10	0.91	8.85	23.23	0.00	0.13	0.00	2.35	0.56	0.40	0.04	2.31	61.10
	0.00	0.88	8.66	23.22	0.00	0.16	0.00	2.30	0.57	0.44	0.00	2.26	61.47
25	0.07	0.38	0.55	0.61	0.00	0.70	0.00	0.00	1.59	0.00	0.00	0.48	95.62
	0.00	0.40	0.53	0.81	0.00	0.66	0.00	0.03	1.61	0.04	0.00	0.41	95.51
24	0.10	0.37	0.36	0.23	0.00	0.42	0.00	0.03	1.40	0.00	0.00	0.34	96.76
	0.68	0.42	0.44	0.48	0.00	0.68	0.00	0.00	1.04	0.05	0.00	0.35	95.87
	0.72	0.37	0.51	0.43	0.00	0.67	0.00	0.07	1.06	0.00	0.00	0.32	95.91
	0.00	0.30	0.29	0.20	0.00	0.42	0.00	0.05	1.43	0.03	0.00	0.33	96.95
23	0.00	0.36	0.35	0.24	0.01	0.16	0.00	0.02	0.94	0.00	0.00	0.13	97.78
	0.07	0.51	0.43	0.24	0.00	0.20	0.00	0.00	1.62	0.02	0.05	0.31	96.56
22	0.00	0.63	0.74	0.68	0.00	0.29	0.00	0.02	2.62	0.03	0.16	0.95	93.87
	0.00	0.70	0.78	0.72	0.00	0.25	0.00	0.04	2.80	0.00	0.12	0.88	93.71
20	0.05	0.57	0.57	0.68	0.00	0.43	0.00	0.06	2.94	0.06	0.03	0.95	93.64
	0.00	0.52	0.51	0.73	0.02	0.42	0.03	0.02	2.62	0.11	0.00	0.82	94.19
21	0.00	0.46	0.46	0.36	0.00	0.23	0.00	0.00	1.19	0.03	0.00	0.27	97.01
	0.00	0.47	0.44	0.40	0.00	0.26	0.00	0.02	1.47	0.03	0.05	0.40	96.46

SAMPLE	NA	MG	AL	SI	P	S	CL	K	CA	TI	MN	FE	O
						PIT 12							
1	0.34	2.19	8.35	27.16	0.15	0.04	0.00	1.89	2.42	0.49	0.09	5.10	51.76
	0.41	2.07	8.08	26.24	0.15	0.06	0.00	1.91	2.38	0.46	0.16	4.86	53.24
2	0.51	2.08	8.89	27.00	0.17	0.15	0.03	2.35	1.52	0.57	0.15	5.25	51.33

	0.61	2.13	9.04	26.68	0.17	0.21	0.00	2.37	1.43	0.51	0.14	5.21	51.58
3	0.49	1.85	9.58	26.51	0.18	0.10	0.03	2.40	0.72	0.46	0.14	5.14	52.45
	0.38	1.76	9.40	26.33	0.23	0.15	0.00	2.41	0.81	0.47	0.09	5.14	52.76
4	0.30	1.83	10.03	27.59	0.18	0.19	0.00	2.59	0.56	0.55	0.00	3.75	52.42
	0.32	1.73	9.78	26.99	0.18	0.20	0.00	2.56	0.58	0.54	0.00	3.51	53.55
5	0.36	0.74	6.86	25.52	0.10	0.47	0.00	1.40	0.87	0.39	0.05	2.33	60.92
	0.41	0.87	6.88	24.60	0.10	0.56	0.00	1.42	1.00	0.43	0.11	2.49	61.26
6	0.00	0.71	5.97	15.93	0.00	0.83	0.00	0.87	1.06	0.37	0.00	1.36	72.82
	0.00	0.70	6.02	16.47	0.00	0.56	0.00	0.93	0.96	0.33	0.00	1.05	72.95
7	0.08	0.71	7.34	19.23	0.00	0.28	0.00	1.12	1.06	0.42	0.08	0.94	68.75
	0.00	0.69	7.52	20.24	0.00	0.23	0.04	1.17	1.12	0.42	0.08	1.08	67.31
8	0.09	0.72	5.84	12.86	0.00	0.48	0.00	0.78	1.53	0.37	0.00	0.98	76.34
	0.00	0.74	5.56	12.39	0.00	0.49	0.00	0.78	1.65	0.33	0.00	0.94	77.15
9	0.00	0.63	6.78	21.76	0.00	0.22	0.00	0.66	1.34	0.69	0.09	1.61	66.18
	0.00	0.53	5.89	21.46	0.00	0.24	0.00	0.64	1.20	0.58	0.00	1.43	68.02
10	0.00	0.68	2.47	4.71	0.00	0.52	0.02	0.04	2.43	0.13	0.00	0.97	88.02
	0.00	0.73	2.31	4.62	0.00	0.47	0.00	0.08	2.33	0.06	0.08	1.23	88.10
11	0.00	0.69	0.83	0.84	0.00	0.48	0.00	0.03	2.24	0.00	0.00	1.63	93.35
	0.00	0.64	0.81	0.87	0.00	0.53	0.00	0.06	2.28	0.00	0.03	1.63	93.15
12	0.00	0.81	0.97	1.76	0.00	0.48	0.00	0.07	2.72	0.10	0.09	0.76	92.22
	0.00	0.77	1.09	1.76	0.00	0.39	0.00	0.11	2.63	0.10	0.04	0.78	92.32
13	0.00	0.51	0.32	0.26	0.04	1.20	0.04	0.02	2.21	0.04	0.07	0.20	95.09
	0.00	0.50	0.33	0.19	0.03	1.05	0.03	0.02	2.06	0.00	0.03	0.21	95.54
	0.00	0.45	0.34	0.25	0.04	1.20	0.05	0.02	2.05	0.03	0.10	0.20	95.28
	0.00	0.44	0.35	0.18	0.04	1.04	0.03	0.02	1.91	0.00	0.05	0.21	95.73
14	0.10	0.55	0.38	0.18	0.00	1.68	0.00	0.04	3.12	0.05	0.03	0.59	93.26
	0.00	0.58	0.35	0.17	0.06	1.93	0.00	0.04	3.46	0.07	0.03	0.70	92.61
15	0.00	0.52	0.27	0.37	0.00	0.53	0.00	0.02	2.24	0.04	0.00	2.29	93.72
	0.00	0.63	0.28	0.29	0.00	0.57	0.03	0.04	2.37	0.03	0.00	2.32	93.44
16	0.05	0.68	0.36	0.24	0.00	0.34	0.03	0.02	2.36	0.03	0.00	0.75	95.15
	0.08	0.77	0.39	0.26	0.03	0.42	0.02	0.03	2.83	0.05	0.00	0.84	94.29
17	0.00	0.39	0.21	0.13	0.00	0.58	0.02	0.04	1.31	0.00	0.00	0.30	97.04
	0.00	0.50	0.24	0.15	0.00	0.70	0.00	0.02	1.37	0.03	0.04	0.33	96.61
18	0.00	0.73	0.65	0.46	0.00	0.49	0.03	0.04	3.72	0.11	0.05	3.60	90.11
	0.06	0.87	0.67	0.48	0.00	0.51	0.00	0.00	3.75	0.07	0.03	3.68	89.88
	0.00	0.65	0.70	0.43	0.00	0.49	0.04	0.03	3.45	0.09	0.07	3.66	90.39

	0.12	0.77	0.71	0.46	0.00	0.51	0.00	0.00	3.47	0.06	0.04	3.75	90.11
19	0.00	0.75	0.51	0.63	0.00	0.43	0.00	0.00	3.03	0.14	0.03	0.88	93.59
	0.04	0.76	0.52	0.62	0.00	0.43	0.00	0.04	3.16	0.10	0.00	0.93	93.41
	0.00	0.67	0.55	0.60	0.00	0.42	0.00	0.00	2.81	0.11	0.04	0.89	93.90
	0.10	0.67	0.55	0.59	0.00	0.42	0.00	0.03	2.92	0.08	0.00	0.94	93.68
20	0.07	0.73	0.70	1.04	0.00	0.38	0.00	0.05	2.97	0.11	0.03	0.97	92.95
	0.00	0.66	0.67	1.10	0.00	0.40	0.00	0.00	2.95	0.05	0.00	1.00	93.17
	0.15	0.65	0.75	0.99	0.00	0.37	0.00	0.04	2.75	0.09	0.05	0.98	93.17
	0.00	0.58	0.71	1.05	0.00	0.40	0.00	0.00	2.74	0.04	0.00	1.02	93.46
21	0.03	0.82	0.81	0.64	0.00	0.44	0.00	0.03	3.77	0.06	0.00	1.63	91.77
	0.03	0.84	0.81	0.62	0.00	0.46	0.00	0.03	3.62	0.03	0.08	1.58	91.89
	0.07	0.72	0.87	0.61	0.00	0.44	0.00	0.03	3.50	0.05	0.00	1.66	92.07
	0.07	0.74	0.86	0.59	0.00	0.46	0.00	0.02	3.35	0.03	0.11	1.61	92.15
22	0.04	0.82	0.96	0.92	0.00	0.30	0.03	0.04	3.78	0.05	0.10	1.28	91.66
	0.00	0.82	1.01	1.03	0.00	0.32	0.00	0.03	3.67	0.05	0.09	1.30	91.68
	0.08	0.73	1.03	0.88	0.00	0.30	0.04	0.04	3.51	0.04	0.14	1.31	91.93
	0.00	0.72	1.07	0.98	0.00	0.32	0.00	0.03	3.40	0.04	0.12	1.32	91.99
23	0.00	0.74	0.68	0.46	0.00	0.35	0.00	0.00	3.26	0.05	0.06	0.95	93.46
	0.08	0.75	0.58	0.46	0.00	0.31	0.00	0.00	2.77	0.00	0.00	0.76	94.29
	0.00	0.66	0.72	0.44	0.00	0.35	0.00	0.00	3.02	0.04	0.08	0.96	93.74
	0.18	0.66	0.62	0.44	0.00	0.31	0.00	0.00	2.57	0.00	0.00	0.78	94.45
24	0.00	0.42	0.39	0.32	0.00	0.44	0.00	0.04	1.41	0.00	0.00	0.27	96.72
	0.00	0.40	0.36	0.24	0.00	0.38	0.00	0.00	1.47	0.07	0.02	0.28	96.78
	0.00	0.37	0.41	0.30	0.00	0.44	0.00	0.04	1.30	0.00	0.00	0.28	96.86
	0.00	0.35	0.39	0.23	0.00	0.38	0.00	0.00	1.36	0.05	0.03	0.29	96.92
25	0.07	0.52	0.68	0.74	0.00	0.63	0.04	0.07	1.76	0.06	0.00	0.57	94.86
	0.00	0.44	0.61	0.63	0.00	0.67	0.00	0.05	1.69	0.03	0.00	0.46	95.41
	0.16	0.46	0.73	0.71	0.00	0.63	0.04	0.06	1.63	0.05	0.00	0.58	94.96
	0.00	0.39	0.65	0.60	0.00	0.67	0.00	0.05	1.56	0.02	0.00	0.47	95.59
26	0.05	1.13	10.03	26.52	0.00	0.13	0.00	2.62	0.52	0.47	0.00	2.55	55.96
	0.00	1.06	10.19	26.73	0.00	0.16	0.00	2.81	0.50	0.50	0.08	2.67	55.30
	0.11	1.00	10.17	25.41	0.00	0.13	0.00	2.25	0.48	0.39	0.00	2.60	56.91
	0.00	0.94	10.87	25.61	0.00	0.16	0.00	2.41	0.46	0.41	0.12	2.72	56.30

APPENDIX D

CHEMICAL CHARACTERIZATION DATA FROM FLY-ASH SAMPLES

CHEMICAL CHARACTERIZATION DATA FROM FLY-ASH SAMPLES

The data reported here were determined by electron microprobe analysis as described in the Methods section of this report. Values are reported as weight percent of coal.

ANALYSIS OF FLY-ASH DERIVED FROM COMBUSTION OF PIT 11 COMPOSITE LIGNITE AT A FLUE GAS TEMPERATURE OF 1300°C

Analysis Point	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Fe	O
1	1.1	0.9	4.1	14.3	0.1	1.2	0.0	0.1	14.1	0.4	1.4	62.3
2	0.9	0.6	5.7	19.6	0.0	0.4	0.1	0.0	15.0	0.4	0.8	56.7
3	1.0	0.8	5.2	18.1	0.1	0.5	0.1	0.0	15.1	0.5	1.8	56.9
4	3.2	2.8	8.4	21.1	0.2	1.7	0.1	0.0	16.7	0.5	2.1	43.2
5	0.3	3.5	3.9	5.4	0.2	0.7	0.0	0.0	13.7	0.3	40.8	31.2
6	6.0	7.7	7.7	7.5	0.0	6.0	0.2	0.0	26.7	0.6	3.8	33.9
7	3.9	4.0	6.3	8.1	0.2	5.3	0.0	0.1	25.9	0.3	2.8	43.2
8	3.6	5.3	7.0	7.3	0.2	4.4	0.1	0.0	25.5	0.3	3.7	42.7
9	3.3	3.0	5.7	8.0	0.1	2.4	0.2	0.0	19.7	0.5	4.2	52.9
10	3.5	3.6	5.8	7.1	0.1	2.4	0.1	0.0	22.5	0.5	5.4	49.1
11	1.2	1.8	3.6	6.0	0.8	2.4	0.2	0.1	21.8	0.6	3.3	58.3
12	1.0	1.0	1.5	2.7	0.0	6.3	0.1	0.0	19.8	0.2	2.6	64.9
13	3.4	3.2	9.0	11.6	0.2	1.5	0.0	0.0	15.5	0.5	7.6	47.5
14	2.2	5.7	8.4	8.4	0.0	1.8	0.2	0.0	24.3	0.4	3.4	45.3
15	2.8	5.8	6.0	5.8	0.2	3.4	0.1	0.1	26.1	0.5	8.9	40.4
16	6.6	3.1	8.3	17.5	0.1	1.7	0.1	0.1	12.9	0.4	4.0	45.3
17	1.0	3.1	6.0	6.4	0.2	1.1	0.1	0.0	22.6	0.7	4.2	54.6
18	2.8	6.3	5.5	5.6	0.0	4.0	0.0	0.0	24.5	0.7	5.5	45.3
19	7.6	5.4	7.5	6.9	0.1	8.0	0.1	0.0	23.8	0.4	3.3	36.9
20	2.3	5.6	4.9	5.5	0.1	4.5	0.0	0.0	29.4	0.6	5.1	42.0
21	2.7	3.5	8.8	8.3	0.6	2.1	0.2	0.0	19.6	0.5	6.5	47.2
22	3.9	7.5	9.8	6.6	0.1	4.6	0.2	0.0	26.6	0.7	7.4	32.6
23	2.4	1.3	5.5	11.1	0.0	0.9	0.1	0.1	11.9	0.4	3.1	63.2
24	2.5	2.7	3.9	6.1	0.2	3.0	0.2	0.1	17.6	0.2	9.3	54.4
25	1.9	3.2	5.1	6.0	0.1	1.7	0.0	0.0	24.1	0.4	5.3	52.3
26	3.7	5.9	7.1	5.4	0.1	2.7	0.2	0.0	25.3	0.4	18.5	30.9
27	1.8	1.2	3.6	5.3	0.6	1.5	0.1	0.0	17.1	0.5	3.6	64.8
28	2.1	5.2	7.4	6.0	0.1	2.4	0.1	0.0	23.5	0.4	5.9	46.9
29	1.8	1.9	5.9	8.0	0.0	1.5	0.0	0.1	15.0	0.4	5.1	60.3
30	1.8	4.7	11.2	4.7	1.2	2.6	0.1	0.0	25.2	0.6	3.4	44.5
31	0.6	1.0	1.9	4.1	0.0	0.9	0.1	0.1	15.3	0.4	4.7	70.8

32	5.6	7.7	8.6	6.8	0.2	5.1	0.2	0.1	23.5	0.6	5.7	36.1
33	1.7	2.1	2.1	2.1	0.0	2.2	0.0	0.0	7.8	0.1	1.4	80.5
34	3.2	3.2	5.5	7.5	0.2	2.7	0.3	0.0	21.4	0.4	5.3	50.3
35	3.4	6.9	6.5	3.8	0.0	6.1	0.1	0.1	23.1	0.4	3.3	46.5
36	2.6	6.1	7.1	5.3	0.1	4.5	0.1	0.0	26.3	0.6	4.9	42.4
37	1.6	2.4	2.8	2.3	0.3	1.8	0.1	0.0	11.5	0.3	3.9	73.1
38	5.0	5.3	7.2	7.0	0.1	3.8	0.1	0.0	20.2	0.6	5.5	45.1
39	0.6	1.3	5.1	7.0	0.1	1.2	0.1	0.4	2.9	0.1	1.6	79.8
40	2.5	2.3	4.8	18.4	0.1	1.5	0.0	0.1	10.4	0.4	2.8	56.7
41	2.0	5.2	6.2	5.7	0.2	2.2	0.2	0.0	25.9	0.5	6.4	45.5
42	1.5	3.4	11.0	5.3	2.0	1.3	0.0	0.0	24.3	1.0	3.2	47.2
43	2.3	2.4	7.5	20.4	0.0	1.6	0.1	0.1	16.8	0.4	2.8	45.6
44	1.5	9.4	10.5	6.2	0.1	1.8	0.1	0.0	27.8	0.7	4.7	37.2
45	3.8	3.5	5.9	7.8	0.3	4.9	0.1	0.0	17.6	0.4	5.0	50.8
46	1.6	8.2	13.2	11.2	0.2	1.3	0.0	0.0	26.6	0.6	8.7	28.5
47	1.7	2.4	4.5	8.8	0.2	2.2	0.2	0.0	20.3	0.3	4.0	55.6
48	2.8	8.3	9.6	6.0	0.1	4.3	0.0	0.0	26.6	0.5	4.9	36.9
49	5.3	4.6	6.1	5.9	0.1	8.0	0.1	0.1	25.8	0.4	4.2	39.4
50	4.7	5.6	10.4	11.2	0.2	2.7	0.3	0.1	20.6	0.4	6.4	37.5
51	1.9	3.4	6.7	10.7	0.1	1.9	0.1	0.0	18.7	0.5	3.9	52.1
52	2.8	3.3	6.3	5.5	0.4	2.2	0.0	0.0	18.5	0.8	15.5	44.7
53	1.3	1.5	2.5	5.1	0.1	3.0	0.1	0.0	17.5	0.6	3.4	64.9
54	5.4	7.0	10.7	14.2	0.3	2.3	0.2	0.0	22.9	0.6	3.8	32.6
55	1.4	2.4	4.4	6.1	0.4	1.3	0.0	0.0	23.2	0.5	5.1	55.4
56	3.4	1.4	2.4	3.9	0.2	8.5	0.2	0.0	19.5	0.1	2.3	58.3
57	1.4	4.5	9.3	6.8	0.0	1.8	0.1	0.0	29.8	0.6	4.8	40.9
58	5.1	4.2	6.7	7.8	0.5	3.6	0.1	0.0	18.4	0.5	5.3	48.0
59	2.8	6.8	8.8	7.9	0.1	1.9	0.2	0.0	25.7	1.2	5.9	38.7
60	9.6	3.2	5.3	20.4	0.4	1.9	0.2	0.1	13.2	0.2	2.5	43.2
61	0.4	0.7	1.0	2.5	0.0	0.8	0.1	0.0	10.9	0.7	3.0	79.9
62	0.4	0.4	1.8	5.8	0.0	0.6	0.0	0.1	12.0	0.4	0.8	77.9
63	2.1	5.0	5.0	7.4	0.0	2.1	0.1	0.0	24.9	0.4	4.7	48.3
64	1.2	0.8	3.6	12.1	0.0	0.5	0.1	0.1	12.8	0.3	1.2	67.4
65	0.8	0.8	2.1	2.5	0.1	1.6	0.0	0.1	5.2	0.1	1.0	85.7
66	3.4	7.5	8.8	6.1	1.4	2.9	0.2	0.0	26.0	0.8	5.2	37.6
67	1.5	3.0	4.3	5.5	0.0	1.7	0.0	0.0	21.8	0.7	6.7	54.8

68	2.2	2.8	3.5	4.5	0.3	3.4	0.1	0.0	25.4	0.4	3.5	53.9
69	2.9	4.3	9.4	5.0	0.1	5.0	0.1	0.1	25.2	0.4	3.2	44.4
70	1.8	3.1	4.2	5.3	0.2	3.4	0.2	0.1	23.1	0.4	5.5	52.9
71	2.3	3.2	4.9	6.4	0.9	2.3	0.2	0.0	19.3	0.8	6.7	53.1
72	9.6	1.2	2.5	23.6	0.0	2.2	0.2	0.1	6.8	0.2	0.7	53.1
73	0.6	1.3	4.8	8.9	0.0	1.3	0.1	0.3	5.0	0.2	2.6	75.0
74	2.7	4.0	5.0	5.1	0.4	3.9	0.2	0.0	24.1	0.6	4.7	49.4
75	0.0	0.1	0.5	1.5	0.0	0.3	0.0	0.1	9.3	0.4	3.4	84.6
76	2.0	5.4	4.5	5.8	0.2	2.4	0.1	0.0	25.3	0.4	4.9	49.0
77	0.7	7.6	7.9	4.8	0.1	3.6	0.0	0.0	31.4	1.3	6.2	36.5
78	3.0	2.1	5.2	7.8	0.0	2.0	0.2	0.0	15.1	0.6	6.2	58.0
79	1.4	2.6	5.0	3.7	0.0	2.1	0.0	0.0	30.3	0.5	5.0	49.4
80	2.4	8.0	6.1	10.4	0.3	2.0	0.1	0.1	31.8	0.7	2.5	35.8
81	3.1	5.0	7.1	6.3	0.3	2.6	0.2	0.0	22.7	0.4	6.4	45.9
82	1.2	2.2	4.3	3.4	0.1	1.8	0.0	0.0	21.2	0.8	6.3	58.8
83	2.9	3.7	5.1	5.9	0.1	3.5	0.1	0.0	20.9	0.5	7.5	49.9
84	0.6	0.9	1.8	1.8	0.2	1.5	0.0	0.1	18.7	0.3	3.6	70.7
85	1.5	3.2	4.4	3.5	0.1	2.3	0.1	0.0	23.8	0.6	4.4	56.1
86	3.2	3.6	5.2	7.2	0.2	3.4	0.1	0.0	24.6	0.5	4.6	47.6
87	1.1	2.0	2.8	3.6	0.2	1.7	0.0	0.0	22.2	0.1	4.1	62.2
88	1.5	2.6	4.0	6.0	0.3	1.5	0.2	0.0	19.0	0.3	5.4	59.2
89	10.5	3.3	5.3	14.0	0.2	2.6	0.1	0.0	14.0	0.2	5.5	44.4
90	0.7	1.0	1.7	4.6	0.0	0.7	0.1	0.0	11.9	0.2	3.1	76.0
91	2.3	2.6	5.5	6.6	0.3	2.0	0.3	0.1	16.8	0.5	4.2	59.0
92	1.6	2.0	3.4	5.0	0.1	1.8	0.2	0.1	16.3	0.6	7.2	61.5
93	1.9	1.6	6.6	20.5	0.0	1.2	0.3	0.1	15.9	0.4	1.5	49.9
94	1.1	2.4	10.1	1.8	0.0	6.0	0.1	0.0	43.1	1.0	3.3	31.2
95	2.7	4.3	5.2	6.4	0.2	2.6	0.2	0.0	20.3	0.5	5.4	52.2
96	2.1	5.7	12.9	6.0	0.1	1.7	0.2	0.0	24.3	0.4	4.0	42.8
97	2.8	5.4	5.3	7.4	0.0	6.6	0.3	0.0	33.7	0.4	2.9	35.3
98	2.0	2.9	5.7	2.5	0.0	8.2	0.1	0.0	41.4	0.1	2.6	34.5
99	2.8	1.3	1.8	2.3	0.0	0.7	0.0	0.0	4.4	0.1	0.6	86.1
100	0.5	1.0	1.9	3.8	0.1	1.1	0.1	0.0	16.2	0.3	5.0	70.2
101	2.1	6.3	8.1	9.0	0.2	2.1	0.2	0.0	28.5	0.6	6.3	36.7
102	0.7	1.1	2.1	2.2	0.1	1.8	0.1	0.0	18.9	0.3	5.2	67.7
103	2.8	8.9	4.8	4.6	0.0	5.5	0.2	0.0	25.4	0.5	4.8	42.6

104	1.4	4.3	5.5	7.2	0.2	1.6	0.0	0.0	21.6	0.3	12.5	45.4
105	1.9	5.5	7.6	13.8	0.3	1.0	0.1	0.0	26.0	0.6	4.9	38.4
106	4.9	8.2	4.7	4.6	0.0	8.1	0.2	0.0	27.1	0.7	5.4	36.2
107	1.6	4.7	8.2	7.8	0.2	2.7	0.0	0.0	32.1	1.1	3.9	37.7
108	2.3	5.9	13.0	5.0	0.0	4.0	0.2	0.1	28.6	0.4	2.6	37.9
109	1.3	1.1	2.2	4.2	0.1	1.2	0.3	0.0	11.3	0.3	2.4	75.7
110	2.8	9.0	6.6	3.3	0.0	10.3	0.2	0.0	27.9	0.9	3.6	35.5
111	2.7	10.7	5.3	3.6	0.0	8.2	0.4	0.0	29.4	0.1	4.4	35.1
112	0.9	1.5	3.1	3.2	0.2	1.9	0.0	0.0	18.9	0.4	4.2	65.9
113	14.3	2.2	19.1	22.3	0.0	0.3	0.0	0.2	8.8	0.2	1.6	31.1
114	4.6	5.8	9.0	8.4	0.6	4.8	0.1	0.0	22.4	0.4	5.9	38.0
115	3.6	3.0	5.7	8.5	0.3	2.0	0.1	0.0	20.0	0.4	5.9	50.4
116	1.9	2.1	3.2	3.8	0.0	2.9	0.1	0.1	18.6	0.7	5.4	61.4
117	0.9	1.1	1.5	1.6	0.0	0.6	0.0	0.0	19.6	0.2	6.1	68.5
118	2.6	1.6	3.4	2.8	0.0	10.2	0.3	0.0	35.1	0.2	1.6	42.3
119	3.9	5.8	10.6	12.1	0.2	1.5	0.0	0.0	23.3	0.5	4.5	37.5
120	0.0	0.2	0.6	1.8	0.0	0.4	0.1	0.0	13.2	0.2	4.1	79.3
121	1.5	5.7	12.8	9.2	0.2	0.4	0.1	0.0	33.9	0.8	5.4	30.1
122	2.2	8.1	7.7	8.1	0.0	2.1	0.1	0.0	35.2	0.4	4.4	31.8
123	4.9	3.6	4.7	9.2	0.1	2.6	0.3	0.0	18.4	0.4	5.5	50.1
124	3.0	3.9	7.7	7.4	0.4	2.6	0.1	0.0	22.3	0.6	5.5	46.5
125	1.6	2.0	2.7	4.4	0.2	3.3	0.2	0.0	17.8	0.4	6.4	61.1
126	6.6	0.8	22.0	25.9	0.0	0.8	0.0	0.3	4.8	0.2	1.1	37.7
127	1.9	5.5	11.1	4.9	0.2	3.2	0.2	0.1	24.8	0.4	5.6	42.2
128	1.0	1.3	3.1	3.4	0.2	0.6	0.1	0.0	14.4	0.4	22.3	53.2
129	0.4	0.5	1.0	1.3	0.1	1.2	0.0	0.0	15.6	0.3	4.8	74.8
130	2.3	24.4	7.0	6.9	0.0	2.2	0.1	0.0	24.4	0.4	4.9	27.4
131	2.1	5.0	6.0	4.8	0.7	1.6	0.0	0.1	16.6	0.4	10.9	51.8
132	1.9	4.9	6.2	4.5	0.4	3.7	0.0	0.0	24.9	1.3	5.5	46.6
133	3.0	5.0	4.2	3.4	0.1	5.9	0.1	0.0	37.7	0.0	5.0	35.6
134	1.6	3.7	5.0	4.4	0.5	2.7	0.2	0.0	18.4	0.6	6.2	56.7
135	0.3	0.8	0.9	1.0	0.0	2.1	0.1	0.0	18.6	0.5	5.2	70.5
136	0.9	1.7	2.1	2.6	0.1	1.1	0.0	0.0	21.3	0.6	4.1	65.7
137	0.6	1.1	1.9	1.5	0.0	2.1	0.0	0.1	19.1	0.2	1.9	71.6
138	2.6	9.9	9.8	5.6	0.1	2.8	0.0	0.0	29.5	0.6	5.5	33.5
139	2.4	9.5	8.4	5.5	0.9	2.6	0.0	0.1	17.1	0.4	5.7	47.6

140	2.9	3.5	4.7	7.6	0.3	2.2	0.1	0.0	16.2	0.3	12.7	49.5
141	0.7	1.1	2.0	4.0	0.1	0.6	0.1	0.0	11.2	0.2	3.5	76.6
142	2.8	6.0	7.1	13.3	0.1	1.8	0.0	0.0	23.8	0.5	4.2	40.4
143	4.7	3.1	5.9	12.3	0.2	2.0	0.1	0.1	16.5	0.2	3.2	51.6
144	1.5	1.4	1.5	1.8	0.0	3.5	0.0	0.0	60.2	0.2	0.9	29.2
145	1.3	1.6	4.4	7.0	0.0	1.7	0.0	0.0	12.5	0.4	4.2	67.1
146	1.4	2.1	3.9	5.6	0.1	2.8	0.2	0.0	26.5	0.4	4.4	52.7
147	2.3	2.5	4.9	7.7	0.2	2.0	0.1	0.0	19.5	0.4	4.6	55.7
148	1.7	3.8	5.5	4.0	0.0	2.6	0.0	0.0	24.0	0.7	5.4	52.3
149	3.4	5.4	10.9	8.9	0.0	1.5	0.1	0.0	19.7	0.4	6.4	43.4
150	3.8	5.0	7.1	9.7	0.5	3.2	0.3	0.0	21.6	0.6	5.5	42.9
151	1.2	8.1	11.1	9.5	0.1	0.7	0.0	0.0	34.3	0.6	4.8	29.6
152	16.8	0.8	1.3	40.2	0.0	0.8	0.0	0.0	3.9	0.1	0.8	35.3
153	2.8	5.5	9.9	6.4	0.1	2.9	0.1	0.0	25.1	0.4	3.8	43.1
154	2.9	4.2	6.5	5.0	1.3	1.5	0.1	0.0	21.8	0.4	8.6	47.7
155	0.9	1.4	3.7	9.3	0.0	0.7	0.0	0.1	14.0	0.4	2.4	67.4
156	2.5	5.6	6.5	6.7	0.2	3.1	0.3	0.0	25.5	0.7	5.9	43.0
157	1.3	1.6	2.5	3.0	0.0	2.6	0.0	0.0	22.5	0.4	3.8	62.5
158	8.2	5.2	14.3	23.3	0.0	0.7	0.1	0.0	16.4	0.9	2.2	28.6
159	2.1	1.1	1.6	42.4	0.0	1.0	0.0	0.1	5.7	0.1	1.8	44.2
160	2.7	2.3	4.0	5.9	0.1	3.8	0.1	0.1	20.3	0.4	3.3	57.0
161	2.3	2.1	4.0	7.4	0.0	1.8	0.1	0.0	16.7	2.1	3.2	60.2
162	0.9	0.9	2.8	7.8	0.0	0.7	0.1	0.1	13.0	0.4	2.1	71.4
163	1.4	5.0	4.6	2.9	0.0	2.3	0.0	0.0	28.7	0.7	13.0	41.3
164	2.5	3.2	4.8	4.2	0.2	3.8	0.1	0.1	22.6	0.4	5.0	53.2
165	3.2	2.4	6.0	7.4	0.1	1.5	0.1	0.2	10.7	0.3	3.4	64.8
166	2.8	3.3	4.6	9.9	0.2	3.2	0.0	0.0	25.3	0.3	3.1	47.5
167	0.3	0.5	0.8	1.1	0.0	1.1	0.1	0.0	13.2	0.7	6.5	75.9
168	0.2	0.2	0.5	0.7	0.0	1.3	0.0	0.0	13.8	0.2	3.6	79.5
169	1.2	2.1	2.9	3.5	0.2	2.8	0.0	0.0	19.7	0.4	6.0	61.3
170	0.5	1.1	1.5	3.4	0.0	0.5	0.1	0.0	25.2	1.2	2.8	63.8
171	0.3	1.8	3.4	2.9	0.0	1.1	0.0	0.0	22.0	1.0	4.2	63.3
172	7.1	2.6	4.1	21.3	0.0	1.7	0.0	0.1	10.1	0.2	1.8	51.0
173	0.6	0.6	1.5	1.8	0.0	0.4	0.0	0.0	12.9	0.1	1.4	80.7
174	0.5	0.7	1.4	2.1	0.0	0.5	0.1	0.0	16.2	0.4	2.5	75.8
175	3.4	5.6	5.6	5.2	0.1	3.7	0.1	0.0	28.8	0.5	5.0	42.0

176	3.3	5.1	8.9	3.7	0.0	5.2	0.2	0.0	29.5	0.5	4.8	38.8
177	1.2	2.2	2.6	2.6	0.3	2.2	0.0	0.0	51.4	0.3	1.3	36.0
178	1.7	2.6	3.2	4.2	0.1	2.0	0.2	0.1	15.6	0.3	8.1	62.1
179	0.7	1.4	2.0	2.8	0.0	2.0	0.2	0.0	17.8	1.2	3.7	68.2
180	3.4	5.6	3.8	5.0	0.2	7.0	0.2	0.0	24.5	0.5	4.3	45.7
181	4.3	5.4	8.2	9.8	0.3	2.6	0.2	0.0	19.2	0.6	5.5	44.0
182	1.3	1.1	3.2	4.6	0.1	1.4	0.1	0.0	16.9	0.3	4.9	66.1
183	0.8	2.3	4.0	7.0	0.0	1.1	0.0	0.0	24.3	0.4	4.0	56.2
184	0.6	0.8	1.8	2.0	0.1	2.3	0.2	0.0	16.3	0.4	5.6	70.0
185	4.0	4.7	6.2	7.3	0.0	4.7	0.1	0.0	19.9	0.7	4.1	48.2
186	0.3	0.3	1.0	1.5	0.0	1.0	0.1	0.0	10.2	0.3	3.2	82.1
187	0.0	0.2	2.0	7.1	0.0	0.2	0.0	0.1	11.6	0.0	0.6	78.3
188	5.3	4.0	8.7	10.5	0.3	2.6	0.2	0.1	16.1	0.4	4.7	47.3
189	0.8	1.4	1.9	2.8	0.2	1.3	0.1	0.1	21.4	0.3	3.3	66.3
190	4.1	6.2	6.1	6.2	0.3	6.5	0.1	0.0	25.6	0.4	4.4	40.3
191	2.9	7.2	7.8	4.4	0.0	5.9	0.1	0.0	27.0	0.3	4.1	40.5
192	6.1	2.4	4.7	16.8	0.2	2.5	0.2	0.2	13.6	0.3	3.0	50.1
193	1.3	1.9	3.2	3.8	0.2	1.9	0.1	0.0	21.0	0.7	10.1	55.9
194	1.7	1.6	2.5	2.6	0.2	5.6	0.1	0.0	44.1	0.1	1.5	40.0
195	2.7	9.2	12.5	11.1	0.2	1.6	0.0	0.0	22.5	0.7	7.0	32.5
196	0.6	0.8	1.6	3.3	0.1	1.1	0.0	0.0	19.2	0.6	3.2	69.6
197	2.1	3.9	5.4	5.4	0.2	2.8	0.1	0.0	27.2	0.4	3.2	49.5
198	0.5	0.6	1.3	3.7	0.1	0.9	0.0	0.0	13.9	0.2	4.5	74.3
199	1.2	1.6	3.5	3.8	0.2	1.7	0.1	0.0	19.1	0.8	8.5	59.6
200	4.3	5.5	5.7	6.0	0.3	4.8	0.2	0.0	22.3	1.7	7.0	42.3
201	2.2	1.7	3.5	6.7	0.2	3.6	0.2	0.0	27.7	0.3	3.4	50.7
202	1.5	5.6	8.2	3.6	0.9	3.1	0.1	0.0	27.4	0.9	6.7	42.1
203	5.3	3.4	7.0	9.9	0.2	3.0	0.1	0.0	19.3	0.4	4.8	46.6
204	0.9	0.9	1.5	2.3	0.2	1.5	0.1	0.1	14.9	0.4	7.9	69.6
205	2.3	5.8	4.2	3.2	0.1	9.8	0.2	0.0	17.5	7.6	2.9	46.5
206	2.5	2.8	4.6	7.3	0.2	2.5	0.2	0.0	20.3	0.4	4.4	54.9
207	3.8	8.7	5.5	7.2	0.1	6.4	0.1	0.1	27.7	0.5	3.6	36.4
208	1.2	6.1	4.9	5.8	0.0	2.9	0.1	0.0	28.3	1.0	2.6	47.1
209	1.0	1.3	1.9	5.2	0.0	1.1	0.3	0.1	13.5	0.4	3.6	71.7
210	0.8	2.5	5.0	5.5	0.1	1.0	0.0	0.0	27.7	0.6	3.7	53.1
211	7.3	1.3	2.6	26.1	0.0	0.7	0.0	0.0	27.0	1.1	1.2	32.9

212	0.7	2.2	5.3	2.3	0.8	0.6	0.0	0.0	21.8	0.6	4.5	61.3
213	2.7	3.4	5.1	6.4	0.2	3.1	0.1	0.0	22.1	0.5	5.9	50.7
214	0.6	0.5	1.6	3.2	0.1	0.7	0.0	0.1	11.6	0.3	3.2	78.3
215	2.6	9.3	9.5	6.2	1.2	1.8	0.0	0.0	25.5	0.4	4.5	39.0
216	4.8	6.7	7.0	13.1	0.2	2.5	0.1	0.0	24.6	0.5	3.9	36.8
217	2.5	4.3	5.8	5.9	0.1	2.0	0.0	0.0	24.1	0.6	3.3	51.4
218	0.7	2.7	4.5	2.5	0.3	2.3	0.1	0.0	23.8	0.7	6.1	56.1
219	1.5	4.1	12.6	9.0	0.5	0.9	0.1	0.0	38.1	0.7	5.4	27.1
220	1.8	10.9	12.7	3.9	0.9	2.2	0.0	0.0	27.6	0.6	6.5	33.0
221	3.9	3.0	4.3	4.9	0.3	4.4	0.0	0.1	19.0	0.6	4.6	54.9
222	5.0	6.8	9.6	9.8	0.3	3.8	0.1	0.0	22.0	1.8	4.4	36.6
223	2.1	4.5	12.4	14.1	0.3	0.8	0.0	0.0	22.0	0.4	3.7	39.7
224	2.9	6.9	10.7	6.2	1.8	3.5	0.2	0.0	31.6	1.1	3.5	31.6
225	1.4	3.1	6.0	6.9	0.3	2.0	0.0	0.0	25.5	0.5	2.7	51.6
226	1.6	1.4	7.6	25.2	0.2	0.8	0.0	0.1	15.6	0.4	1.0	46.3
227	2.8	4.6	5.2	6.7	0.1	4.0	0.1	0.1	21.1	0.5	5.3	49.7
228	3.4	7.8	13.2	10.3	0.5	1.9	0.0	0.1	23.1	0.5	4.0	35.2
229	0.5	1.0	2.1	3.0	0.3	1.9	0.1	0.0	19.6	0.4	3.9	67.4
230	1.0	1.2	1.8	3.8	0.1	0.6	0.1	0.0	11.0	0.2	4.1	76.2
231	1.1	1.1	1.8	2.2	0.2	1.9	0.0	0.0	18.5	5.1	4.0	64.1
232	2.8	2.5	4.1	4.7	0.1	3.9	0.0	0.0	28.5	0.3	2.6	50.6
233	0.2	0.2	0.6	2.0	0.0	0.2	0.0	0.0	8.6	0.2	1.6	86.5
234	1.1	1.1	1.7	1.8	0.1	3.1	0.2	0.0	59.3	0.0	0.4	31.3
235	3.2	2.7	4.8	5.7	0.1	4.6	0.1	0.0	22.7	0.4	3.0	52.7
236	0.0	0.3	1.1	2.6	0.0	0.3	0.0	0.0	11.5	0.3	4.7	79.2
237	1.9	2.5	4.3	4.2	0.0	2.6	0.0	0.0	17.1	1.0	14.6	51.8
238	4.5	2.2	7.0	9.1	0.3	1.1	0.0	0.1	13.7	0.3	14.5	47.2
239	3.3	7.0	11.2	11.5	0.3	1.6	0.1	0.0	25.6	0.4	3.2	36.0
240	1.0	2.3	3.2	4.5	0.1	2.2	0.2	0.0	20.8	0.7	3.8	61.2
241	4.8	6.8	6.7	7.3	0.1	5.3	0.2	0.0	22.0	0.5	4.5	41.9
242	0.9	1.2	2.6	3.2	0.1	2.3	0.1	0.0	25.1	0.2	2.3	62.0

ANALYSIS OF FLY-ASH DERIVED FROM COMBUSTION OF PIT 11 COMPOSITE LIGNITE AT A FLUE GAS TEMPERATURE OF 1500^{o}C

Analysis Point	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Fe	O
1	0.0	0.4	1.9	4.9	0.1	0.1	0.1	0.0	11.4	0.5	3.1	77.6
2	0.2	8.5	9.9	2.0	0.0	0.6	0.0	0.0	31.0	0.3	1.8	45.8
3	0.7	2.7	7.5	18.5	0.1	0.3	0.1	0.1	16.4	0.4	1.8	51.4
4	0.0	0.4	2.7	9.8	0.0	0.1	0.1	0.0	13.0	0.3	0.6	73.1
5	0.0	2.3	4.1	4.3	0.3	0.5	0.0	0.0	19.2	0.4	4.4	64.7
6	0.7	5.5	13.1	21.7	0.0	0.2	0.0	0.0	17.8	0.4	4.5	36.1
7	0.0	6.5	11.8	8.9	0.4	0.3	0.0	0.0	22.0	0.7	5.0	44.5
8	0.0	1.1	2.1	2.1	0.1	0.4	0.1	0.0	21.3	1.3	2.6	69.0
9	0.5	0.7	4.8	16.7	0.0	0.1	0.0	0.1	13.5	0.2	0.6	62.9
10	0.7	4.3	5.9	13.7	0.5	0.4	0.0	0.0	31.1	0.5	3.3	39.7
11	0.7	4.3	5.6	7.6	0.0	0.7	0.2	0.0	36.5	0.6	3.2	40.7
12	0.3	0.9	5.1	16.6	0.1	0.1	0.0	0.0	13.5	0.4	1.2	61.9
13	0.0	0.5	1.5	4.0	0.0	0.1	0.0	0.0	12.0	0.5	3.7	77.8
14	0.6	3.5	9.0	15.9	0.2	0.4	0.0	0.0	18.3	0.5	1.9	49.9
15	0.1	0.5	1.3	3.1	0.1	0.4	0.0	0.0	14.5	0.2	1.7	78.1
16	0.4	4.8	8.8	12.1	0.4	0.4	0.0	0.1	16.9	0.3	5.2	50.7
17	0.0	2.5	4.7	8.9	0.2	0.4	0.1	0.0	18.2	0.3	3.7	61.1
18	0.0	0.6	1.3	2.3	0.0	0.2	0.0	0.0	20.2	0.3	2.1	73.0
19	0.4	0.9	2.7	5.7	0.0	0.6	0.1	0.0	13.6	0.3	1.6	74.3
20	0.3	6.2	7.7	4.9	0.4	2.7	0.1	0.0	37.6	0.3	3.6	36.2
21	0.0	1.1	4.0	2.2	0.0	0.1	0.0	0.0	10.7	0.1	14.9	66.8
22	0.4	2.6	5.2	10.0	0.2	0.5	0.0	0.0	21.8	0.6	3.6	55.1
23	0.2	0.3	1.1	3.4	0.0	0.1	0.1	0.1	10.4	0.2	1.2	83.1
24	0.0	0.4	1.8	4.9	0.0	0.1	0.0	0.0	12.9	0.5	1.6	77.8
25	0.7	9.6	19.3	11.4	0.0	0.5	0.1	0.0	14.3	0.6	9.2	34.4
26	0.0	9.2	9.5	9.7	0.1	0.5	0.0	0.0	27.5	0.4	3.3	40.0
27	0.5	21.8	9.7	3.5	0.4	0.6	0.1	0.0	21.9	0.8	5.1	35.6
28	0.0	4.5	5.7	5.1	0.2	0.7	0.1	0.0	22.8	0.4	4.3	56.4
29	0.7	3.8	10.7	9.9	3.5	0.2	0.0	0.0	21.1	0.8	3.3	46.0
30	0.0	1.5	3.0	6.6	0.1	0.4	0.1	0.0	15.1	0.5	4.4	68.4
31	0.4	1.7	3.3	8.3	0.2	0.7	0.0	0.0	21.4	0.5	3.0	60.5

32	1.3	4.0	7.7	14.6	0.1	0.4	0.1	0.0	16.8	0.3	4.8	50.1
33	0.4	5.1	7.0	6.2	0.2	0.5	0.1	0.0	27.1	0.5	3.8	49.1
34	0.6	8.4	12.1	10.9	0.1	0.3	0.0	0.0	27.8	0.8	5.9	33.1
35	0.0	8.4	9.9	4.1	0.2	0.8	0.0	0.0	29.4	0.3	3.8	43.1
36	0.0	4.1	7.1	3.6	0.4	0.7	0.1	0.0	28.7	0.4	5.5	49.4
37	0.3	1.0	2.7	3.1	0.0	0.4	0.0	0.0	17.1	0.3	5.9	69.3
38	0.0	1.6	2.4	3.1	0.2	0.2	0.0	0.0	16.8	0.4	4.9	70.4
39	0.0	3.1	4.6	7.5	0.3	0.4	0.0	0.0	21.1	0.5	4.7	57.9
40	0.0	5.9	8.8	13.7	0.1	0.5	0.0	0.0	24.3	0.6	4.0	42.2
41	0.6	4.4	12.7	10.2	0.8	0.3	0.1	0.0	27.5	0.6	8.4	34.6
42	0.0	0.6	1.7	1.7	0.4	0.4	0.1	0.0	26.5	0.4	5.7	62.7
43	0.0	0.8	1.5	1.7	0.2	0.2	0.0	0.0	21.3	0.4	3.3	70.8
44	0.6	4.7	4.0	9.0	0.1	0.4	0.1	0.1	23.2	0.5	4.2	53.2
45	0.0	2.4	4.5	5.0	0.0	0.8	0.0	0.0	18.7	0.3	7.8	60.5
46	0.0	3.0	4.6	4.9	0.5	0.7	0.0	0.0	19.7	0.9	5.3	60.5
47	0.0	0.5	1.2	1.4	0.1	0.6	0.0	0.0	28.0	0.2	2.5	65.5
48	0.5	3.8	15.4	3.3	0.4	0.6	0.0	0.0	29.6	0.3	2.5	43.5
49	0.3	2.2	4.7	5.7	0.1	0.3	0.1	0.0	16.9	1.0	3.2	65.5
50	0.3	1.2	6.4	21.2	0.1	0.1	0.0	0.0	15.5	0.4	1.1	53.8
51	0.4	3.6	3.1	3.0	0.2	0.4	0.0	0.0	13.2	0.2	4.1	72.0
52	0.0	4.3	15.9	11.4	0.1	0.3	0.0	0.0	27.5	0.4	3.3	36.8
53	0.0	3.0	10.5	7.9	0.2	0.3	0.0	0.0	26.1	0.4	7.0	44.7
54	0.1	0.6	1.9	1.4	0.0	0.1	0.0	0.0	17.3	0.2	5.3	73.0
55	0.7	3.2	2.3	3.6	0.3	0.8	0.1	0.0	54.7	0.0	0.7	33.7
56	0.0	0.4	1.5	4.4	0.0	0.1	0.1	0.0	11.4	0.3	2.5	79.4
57	2.8	1.5	1.6	40.4	0.0	0.0	0.0	0.0	5.1	0.2	1.1	47.5
58	0.1	0.7	1.4	1.7	0.2	0.3	0.1	0.0	18.2	0.3	4.3	72.8
59	0.1	0.7	1.4	12.5	0.1	0.2	0.1	0.0	4.6	0.1	1.1	79.3
60	0.8	8.5	6.2	6.5	0.4	0.7	0.1	0.0	23.8	0.4	3.6	49.1
61	0.3	3.2	8.2	21.1	0.2	0.1	0.0	0.0	24.7	0.5	2.1	39.6
62	0.0	0.4	1.0	2.5	0.0	0.1	0.0	0.1	10.2	0.4	1.0	84.2
63	0.7	3.8	7.9	4.5	0.2	1.1	0.0	0.0	31.2	1.0	3.1	46.5
64	0.3	6.8	7.3	7.0	0.0	0.8	0.1	0.0	24.2	0.5	5.1	47.9
65	0.0	3.5	4.5	5.0	0.3	0.7	0.0	0.0	25.4	0.4	5.5	54.7
66	0.0	3.2	6.3	7.1	0.1	0.3	0.0	0.0	21.9	0.5	5.1	55.5
67	0.0	0.5	1.4	3.2	0.1	0.2	0.0	0.0	13.4	0.2	2.3	78.6

68	0.2	1.8	2.0	3.9	0.1	0.5	0.0	0.0	16.3	0.4	2.9	71.8
69	1.0	6.9	7.3	7.3	0.5	0.6	0.0	0.0	23.3	0.6	3.8	48.8
70	0.0	2.5	2.9	3.8	0.2	0.8	0.0	0.0	17.7	0.4	3.6	68.2
71	0.0	4.6	7.0	8.6	0.3	0.7	0.0	0.0	19.7	0.3	3.6	55.3
72	0.4	7.8	11.9	5.5	0.0	1.1	0.0	0.0	29.7	0.4	4.5	38.8
73	0.2	0.6	0.9	2.1	0.2	0.4	0.2	0.0	34.9	0.1	2.9	57.6
74	0.0	0.5	1.6	5.6	0.0	0.2	0.0	0.1	12.0	0.2	1.5	78.3
75	0.0	0.5	0.8	1.4	0.1	0.3	0.1	0.0	15.1	0.4	3.3	78.2
76	0.3	1.9	2.2	3.4	0.0	0.8	0.0	0.0	23.2	0.4	10.6	57.3
77	0.0	6.0	13.4	13.0	0.2	0.5	0.0	0.0	29.4	0.4	3.2	33.9
78	0.3	3.5	5.7	7.4	0.4	0.6	0.1	0.0	25.1	0.5	3.5	53.0
79	0.5	6.4	7.1	12.1	0.2	0.3	0.0	0.0	27.2	0.6	3.5	42.3
80	0.3	1.9	9.1	6.4	0.3	0.7	0.0	0.0	39.4	0.1	1.5	40.4
81	0.6	3.0	6.7	6.6	0.1	0.4	0.0	0.0	16.3	1.1	4.9	60.3
82	0.6	4.2	10.2	4.5	0.4	1.0	0.1	0.0	24.4	0.3	5.2	49.2
83	0.4	3.5	5.2	4.8	0.2	0.6	0.1	0.0	18.7	0.3	6.4	59.9
84	0.3	0.7	0.9	10.5	0.1	0.1	0.0	0.0	9.0	0.3	2.1	76.0
85	0.2	2.9	7.1	3.8	0.0	2.1	0.0	0.0	37.0	0.3	2.8	43.8
86	0.0	0.6	3.7	12.7	0.1	0.2	0.0	0.0	14.2	0.4	1.6	66.6
87	0.7	2.7	5.2	7.9	0.2	0.6	0.1	0.0	20.7	0.4	2.8	58.7
88	0.0	2.8	5.3	7.4	0.2	0.5	0.0	0.0	27.2	0.5	2.3	53.9
89	0.0	2.1	5.8	7.9	0.2	0.1	0.0	0.0	21.0	1.1	3.9	58.0
90	0.0	0.8	1.7	4.4	0.1	0.6	0.0	0.0	17.6	0.3	3.1	71.4
91	0.2	2.2	5.5	5.6	0.1	2.4	0.1	0.0	23.4	0.6	2.3	57.8
92	0.0	0.6	1.0	6.0	0.0	0.0	0.0	0.0	5.3	0.2	1.4	85.6
93	0.5	2.2	12.5	13.5	0.1	0.3	0.0	0.0	11.9	0.3	4.1	54.7
94	0.8	3.7	5.4	12.2	0.0	0.3	0.0	0.1	17.0	0.5	4.7	55.5
95	0.7	3.6	5.9	7.1	0.2	0.5	0.0	0.0	18.0	0.7	4.0	59.5
96	0.3	5.2	6.1	5.7	0.4	0.5	0.0	0.0	26.4	0.6	3.8	51.1
97	0.0	0.6	1.6	4.1	0.1	0.1	0.1	0.0	14.2	0.4	2.3	76.4
98	0.3	0.6	2.8	9.7	0.0	0.2	0.1	0.0	15.0	0.4	1.5	69.5
99	0.0	3.1	3.7	9.1	0.1	0.2	0.0	0.0	22.8	0.8	3.6	56.8
100	0.3	0.3	3.4	11.8	0.0	0.1	0.0	0.1	12.0	0.2	0.2	71.6
101	0.4	5.0	8.6	8.5	0.4	0.7	0.2	0.0	30.6	0.8	4.8	40.1
102	0.0	0.5	2.5	9.1	0.1	0.2	0.0	0.0	11.7	0.3	0.9	74.8
103	0.3	1.6	1.9	2.1	0.1	1.7	0.1	0.0	32.0	0.1	1.9	58.2

104	0.0	0.9	1.7	2.4	0.1	1.0	0.1	0.0	19.6	0.2	4.0	70.2
105	0.0	9.7	4.4	5.1	0.2	0.7	0.0	0.0	21.8	0.7	4.9	52.5
106	0.5	5.5	3.7	6.7	0.0	0.8	0.0	0.0	24.3	0.3	3.3	55.0
107	0.4	1.3	2.1	17.3	0.1	0.3	0.0	0.0	13.5	0.4	3.0	61.8
108	0.5	16.2	6.0	5.0	0.4	1.4	0.0	0.0	21.7	0.1	8.7	40.1
109	0.3	3.8	4.0	4.4	0.3	0.6	0.0	0.0	20.7	0.6	4.3	61.1
110	0.2	1.9	3.1	2.2	0.0	0.3	0.0	0.0	21.7	0.8	3.2	66.7

ANALYSIS OF FLY-ASH DERIVED FROM COMBUSTION OF PIT 12 COMPOSITE LIGNITE AT A FLUE GAS TEMPERATURE OF 1300°C

Analysis Point	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Fe	O
1	0.8	0.8	6.8	24.1	0.0	0.2	0.0	0.9	3.4	0.2	1.4	61.4
2	0.5	0.5	5.2	16.2	0.0	0.1	0.1	0.5	8.7	0.2	1.2	66.9
3	0.0	0.5	4.0	15.8	0.0	0.1	0.0	0.2	6.7	0.3	1.1	71.5
4	0.7	1.7	7.7	17.2	0.0	0.2	0.1	0.1	10.5	0.4	1.1	60.4
5	0.3	1.4	11.5	25.9	0.0	0.2	0.0	1.2	3.9	0.3	2.1	53.1
6	0.3	0.3	4.3	15.7	0.0	0.1	0.1	0.2	8.6	0.3	0.4	69.7
7	0.4	0.3	4.7	15.7	0.0	0.1	0.0	0.1	10.1	0.3	0.4	68.1
8	0.7	0.6	4.4	12.0	0.1	0.2	0.0	0.1	6.7	0.3	0.6	74.4
9	0.3	0.4	5.1	17.1	0.0	0.1	0.0	0.0	10.8	0.3	0.2	65.8
10	0.2	0.2	3.4	10.5	0.0	0.2	0.0	0.1	9.6	0.3	0.3	75.3
11	0.8	0.4	6.5	21.8	0.0	0.1	0.0	0.0	11.1	0.2	0.2	58.8
12	0.4	0.2	4.0	13.8	0.0	0.0	0.0	0.1	10.2	0.2	0.3	70.7
13	0.5	1.2	8.2	17.7	0.0	0.0	0.0	0.6	4.8	0.7	1.8	64.6
14	0.4	0.2	4.1	14.2	0.0	2.0	0.0	0.1	11.5	0.2	0.0	67.3
15	0.9	0.5	6.4	20.3	0.0	0.1	0.0	0.0	11.4	0.2	0.2	60.0
16	0.6	0.4	6.8	21.7	0.1	0.0	0.0	0.1	11.9	0.3	0.2	58.0
17	1.5	0.4	5.8	21.7	0.0	0.1	0.0	0.1	10.9	0.3	0.0	59.3
18	0.4	0.2	6.1	20.2	0.0	0.1	0.0	0.0	11.5	0.3	0.3	60.9
19	0.3	0.4	5.1	16.4	0.0	0.1	0.1	0.1	10.8	0.3	0.4	66.0
20	0.2	0.3	4.3	14.4	0.0	0.0	0.0	0.0	10.3	0.3	0.4	69.8
21	0.2	1.2	7.0	26.4	0.0	0.1	0.0	0.8	3.8	0.2	1.3	59.1
22	0.6	0.5	6.9	22.5	0.0	0.1	0.0	0.1	11.5	0.2	0.2	57.5
23	0.3	0.2	4.5	15.0	0.0	0.0	0.0	0.0	10.7	0.3	0.2	68.8
24	0.5	0.3	4.3	15.2	0.0	0.0	0.0	0.1	10.0	0.2	0.0	69.3
25	0.4	0.2	4.5	16.1	0.0	0.1	0.0	0.0	11.4	0.3	0.1	66.9
26	0.0	0.2	3.4	12.3	0.0	0.2	0.0	0.0	10.0	0.3	0.1	73.7
27	0.6	0.3	5.9	19.8	0.0	0.1	0.0	0.1	11.1	0.3	0.3	61.4
28	0.0	0.1	3.8	13.3	0.0	0.0	0.0	0.0	10.0	0.2	0.4	72.1
29	0.4	0.4	5.0	16.6	0.0	0.1	0.1	0.1	10.4	0.3	0.3	66.3

30	0.9	1.4	8.0	24.8	0.1	0.0	0.1	0.6	8.0	0.4	4.4	51.3
31	0.5	0.2	5.2	17.6	0.0	0.1	0.0	0.0	10.7	0.3	0.0	65.4
32	0.3	0.2	3.3	11.8	0.0	0.0	0.0	0.1	9.8	0.2	0.3	74.0
33	0.5	0.4	5.0	17.1	0.0	0.1	0.3	0.1	10.6	0.2	0.3	65.6
34	0.5	0.4	6.2	21.7	0.0	0.1	0.0	0.0	12.1	0.3	0.1	58.8
35	0.5	0.3	5.6	19.6	0.0	0.1	0.0	0.0	11.2	0.3	0.3	62.2
36	0.2	0.6	3.9	31.0	0.0	0.1	0.0	0.6	2.0	0.1	1.4	60.2
37	0.0	0.2	3.4	12.1	0.0	0.0	0.0	0.0	10.0	0.3	0.3	73.8
38	0.2	0.2	3.6	13.2	0.0	0.0	0.1	0.1	10.3	0.2	0.0	72.1
39	0.2	0.3	5.1	17.6	0.0	0.1	0.0	0.1	10.8	0.3	0.2	65.3
40	0.4	0.5	5.0	14.9	0.1	0.2	0.1	0.1	8.4	0.2	0.5	69.8
41	0.4	1.9	12.1	24.8	0.2	0.3	0.0	0.9	6.0	0.4	2.8	50.2
42	0.0	1.9	6.0	15.6	0.0	0.2	0.1	0.4	5.3	0.7	2.1	67.8
43	0.3	0.3	3.3	12.0	0.0	0.1	0.1	0.1	10.3	0.3	0.7	72.8
44	1.0	1.7	8.9	19.8	0.2	0.3	0.1	0.6	6.3	0.3	6.9	53.9
45	0.5	0.8	6.3	18.5	0.0	0.6	0.1	0.8	6.0	0.4	2.0	64.2
46	0.4	0.3	3.9	12.9	0.0	2.6	0.0	0.1	12.2	0.2	0.5	66.9
47	0.3	0.3	4.4	15.5	0.0	0.0	0.0	0.0	10.6	0.3	0.2	68.5
48	0.6	3.7	7.3	17.5	0.2	0.1	0.0	0.1	16.6	0.5	1.3	52.2
49	0.4	0.2	4.3	13.9	0.0	0.2	0.0	0.0	9.5	0.3	0.3	70.9
50	0.5	1.1	8.3	18.6	0.0	0.1	0.0	0.1	9.6	0.5	7.6	53.6
51	0.2	0.2	4.2	15.1	0.0	0.0	0.0	0.0	10.8	0.3	0.2	69.1
52	0.4	0.3	6.1	20.1	0.0	0.1	0.1	0.1	11.4	0.3	0.3	61.0
53	0.5	0.7	3.1	30.8	0.0	0.3	0.0	0.2	4.0	0.2	1.0	59.2
54	0.7	0.3	5.9	20.3	0.0	0.0	0.0	0.0	11.3	0.2	0.1	61.2
55	0.5	0.2	4.8	16.5	0.1	0.1	0.0	0.1	10.4	0.4	0.0	66.9
56	0.4	0.3	5.0	17.4	0.0	0.1	0.0	0.1	10.7	0.3	0.4	65.6
57	0.6	0.3	5.5	19.3	0.0	0.1	0.0	0.0	11.2	0.3	0.3	62.3
58	0.0	0.2	4.2	14.9	0.0	0.0	0.0	0.1	10.4	0.1	0.0	70.1
59	0.4	0.4	5.4	18.5	0.0	0.0	0.1	0.0	10.8	0.3	0.3	63.9
60	0.4	0.4	5.2	18.1	0.0	0.1	0.0	0.0	11.1	0.3	0.3	64.1
61	0.2	0.2	4.3	15.7	0.0	0.1	0.1	0.1	10.7	0.2	0.3	68.2
62	0.4	0.2	5.4	19.1	0.0	0.0	0.0	0.0	11.7	0.4	0.2	62.5
63	0.6	0.4	5.9	19.5	0.0	0.1	0.0	0.1	11.3	0.3	0.1	61.8
64	0.3	0.5	5.0	16.4	0.0	0.1	0.0	0.1	10.3	0.3	0.4	66.7
65	0.7	0.4	6.3	21.2	0.1	0.1	0.0	0.1	11.4	0.3	0.4	59.1

66	0.5	0.4	6.8	22.6	0.0	0.1	0.1	0.1	11.4	0.4	0.5	57.0
67	0.4	0.3	4.1	14.1	0.0	0.0	0.0	0.0	9.9	0.3	0.4	70.4
68	0.3	1.3	9.6	26.6	0.1	0.1	0.0	1.0	4.4	0.2	1.5	54.9
69	0.6	0.3	5.1	17.4	0.1	0.0	0.1	0.0	10.8	0.2	0.4	65.1
70	0.3	0.4	5.2	16.6	0.0	0.1	0.0	0.0	10.6	0.3	0.4	66.2
71	0.7	0.3	7.1	23.9	0.0	0.3	0.0	0.0	11.8	0.3	0.4	55.1
72	0.5	1.3	7.3	13.0	0.0	0.2	0.1	0.6	6.5	0.4	5.7	64.4
73	0.2	0.3	4.3	15.2	0.1	0.0	0.0	0.1	10.4	0.3	0.2	69.0
74	0.4	0.3	4.7	16.0	0.1	0.1	0.0	0.1	10.3	0.3	0.4	67.4
75	0.0	0.3	6.2	20.4	0.0	0.0	0.0	0.0	11.3	0.3	0.2	61.3
76	0.3	2.3	5.1	20.8	0.0	0.8	0.0	0.6	6.2	0.3	3.4	60.5
77	0.8	0.8	8.8	20.3	0.0	0.1	0.1	0.4	8.7	0.3	0.9	59.0
78	0.4	0.2	4.7	16.0	0.0	0.0	0.0	0.0	10.6	0.3	0.3	67.7
79	0.4	0.2	3.7	13.1	0.0	0.0	0.0	0.1	10.1	0.3	0.0	72.2
80	0.7	0.5	2.7	4.7	0.0	0.1	0.1	0.0	4.5	0.3	33.8	52.8
81	0.5	0.3	5.6	18.8	0.0	0.0	0.0	0.0	11.0	0.4	0.4	63.1
82	0.8	0.4	6.8	22.9	0.0	0.1	0.0	0.1	12.0	0.2	0.4	56.4
83	0.5	1.1	8.7	22.5	0.2	0.1	0.0	0.9	6.3	0.3	2.0	57.5
84	0.9	2.6	11.5	18.8	0.1	0.5	0.0	0.4	7.3	1.3	7.7	49.0
85	0.0	0.3	3.5	11.3	0.0	0.2	0.0	0.1	9.8	0.3	0.4	74.2
86	0.4	0.2	4.8	16.2	0.0	0.4	0.0	0.1	10.9	0.3	0.4	66.3
87	0.5	0.5	6.2	20.1	0.0	0.0	0.0	0.1	10.7	0.4	0.5	61.0
88	0.4	0.4	5.6	18.4	0.1	0.1	0.0	0.1	10.8	0.4	0.4	63.4
89	0.4	1.1	7.6	19.1	0.0	0.3	0.1	1.0	4.5	0.5	3.4	62.2
90	0.0	0.3	6.0	20.0	0.0	0.2	0.0	0.0	11.2	0.3	0.3	61.7
91	0.2	0.2	3.4	12.2	0.0	0.1	0.0	0.1	10.0	0.2	0.2	73.5
92	0.3	0.2	3.5	12.4	0.0	0.0	0.1	0.0	9.8	0.2	0.2	73.4
93	0.0	0.3	4.6	14.7	0.0	0.1	0.1	0.1	10.1	0.2	0.2	69.7
94	0.4	0.4	5.0	16.7	0.0	0.2	0.0	0.0	10.6	0.3	0.5	66.1
95	0.0	0.3	4.9	15.3	0.0	0.2	0.0	0.1	9.8	0.2	0.7	68.7
96	0.3	0.2	1.0	39.9	0.0	0.0	0.1	0.2	0.5	0.0	0.2	57.7
97	0.6	0.6	6.9	21.4	0.0	0.2	0.0	0.2	11.1	0.2	0.5	58.4
98	0.4	0.4	3.8	12.3	0.0	0.1	0.0	0.2	9.5	0.2	0.5	72.8
99	0.0	1.0	6.3	18.9	0.0	0.2	0.0	0.4	8.7	0.2	1.3	62.9
100	0.7	0.6	6.8	18.5	0.0	0.0	0.0	0.3	9.5	0.3	1.1	62.0
101	0.6	1.6	10.1	20.3	0.0	0.1	0.0	0.9	5.5	0.3	2.6	58.0

102	0.3	0.9	6.5	12.1	0.1	0.1	0.0	0.8	6.1	0.2	3.4	69.5
103	0.4	0.8	6.2	10.5	0.0	0.1	0.0	0.4	6.5	0.3	3.3	71.6
104	0.6	1.7	7.8	23.3	0.0	0.2	0.0	0.5	5.4	0.4	2.8	57.3
105	0.4	0.6	3.7	14.6	0.0	0.1	0.0	0.5	5.3	0.2	2.3	72.3
106	0.8	1.5	10.2	21.3	0.0	0.0	0.0	1.1	4.0	0.4	9.1	51.6
107	0.2	0.6	2.3	20.3	0.0	0.2	0.2	0.3	2.0	0.2	1.3	72.5
108	0.0	0.5	5.4	17.7	0.0	0.1	0.1	0.5	7.2	0.2	1.1	67.4
109	0.5	1.3	13.5	21.7	0.1	0.1	0.0	0.5	4.6	0.4	1.8	55.5
110	0.2	0.6	4.9	20.6	0.1	0.3	0.0	0.5	4.5	0.1	1.2	67.0
111	0.5	4.5	7.5	9.9	0.1	1.2	0.0	0.4	16.0	0.6	2.8	56.5
112	0.3	0.7	5.9	16.3	0.0	0.1	0.0	0.5	7.7	0.5	2.2	65.8
113	0.0	0.7	3.6	9.7	0.0	1.2	0.0	0.1	8.0	2.1	1.9	72.6
114	0.3	0.5	4.0	12.9	0.1	0.1	0.0	0.1	8.5	0.3	0.8	72.6
115	0.5	0.3	4.9	16.4	0.0	0.1	0.0	0.1	10.9	0.3	0.4	66.2
116	0.7	0.5	6.8	22.6	0.0	0.1	0.0	0.1	11.7	0.4	0.5	56.6
117	0.2	2.1	6.1	14.8	0.0	0.0	0.0	0.1	12.3	0.4	2.7	61.3
118	0.5	0.4	5.9	19.4	0.0	0.0	0.1	0.0	11.0	0.1	0.2	62.4
119	0.2	0.2	3.8	12.8	0.0	0.0	0.0	0.1	10.2	0.2	0.4	72.1
120	0.5	0.8	6.0	19.8	0.0	0.2	0.0	0.3	7.4	0.4	1.5	63.2
121	0.6	0.9	4.2	29.3	0.0	0.1	0.0	0.6	3.9	0.2	1.7	58.6
122	1.3	0.3	4.2	16.6	0.0	0.1	0.1	0.1	10.1	0.1	0.3	67.0
123	0.8	0.3	5.7	19.4	0.0	0.0	0.1	0.1	11.4	0.3	0.1	61.8
124	0.3	0.4	4.7	16.5	0.0	0.0	0.0	0.0	11.6	0.1	0.2	66.3
125	0.4	0.3	4.7	16.0	0.0	0.1	0.1	0.0	10.7	0.3	0.2	67.3
126	0.0	0.3	5.0	18.1	0.0	0.0	0.0	0.1	11.5	0.2	0.2	64.7
127	0.4	0.3	4.3	15.3	0.0	0.2	0.0	0.1	10.7	0.3	0.3	68.1
128	0.4	0.3	5.5	19.5	0.0	0.1	0.0	0.0	11.5	0.2	0.4	62.1
129	0.7	0.4	5.4	17.9	0.0	0.1	0.0	0.0	11.0	0.3	0.3	64.0
130	0.3	0.3	5.7	18.7	0.0	0.1	0.0	0.0	11.1	0.3	0.1	63.5
131	0.5	0.4	4.9	16.4	0.0	0.1	0.1	0.0	10.8	0.2	0.4	66.3

ANALYSIS OF FLY-ASH DERIVED FROM COMBUSTION OF PIT 12 COMPOSITE LIGNITE AT A FLUE GAS TEMPERATURE OF 1500°C

Analysis Point	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Fe	O
1	0.0	0.6	3.8	18.4	0.0	1.7	0.0	0.4	6.3	0.2	1.3	67.3
2	0.4	0.5	4.6	15.6	0.0	0.0	0.0	0.2	9.0	0.3	1.0	68.5
3	0.4	2.2	8.0	18.1	0.1	0.0	0.0	0.0	10.2	0.5	1.5	59.0
4	0.6	1.0	7.0	19.8	0.1	0.2	0.0	0.3	8.4	0.3	1.5	60.8
5	0.4	1.1	7.2	18.1	0.1	0.1	0.0	0.5	7.9	0.4	2.3	61.9
6	0.8	0.9	5.5	10.0	0.0	0.1	0.1	0.6	7.7	0.5	3.9	69.9
7	0.1	0.8	5.2	9.8	0.0	0.1	0.0	0.6	4.6	0.5	3.0	75.2
8	0.0	0.7	5.4	10.0	0.0	0.0	0.0	0.4	5.9	0.4	2.4	74.8
9	0.2	0.4	4.3	14.2	0.1	0.1	0.0	0.1	9.1	0.2	0.8	70.6
10	0.6	0.8	6.8	19.7	0.1	0.2	0.0	0.2	9.9	0.2	1.0	60.6
11	0.5	0.4	4.4	14.5	0.0	0.2	0.0	0.1	9.7	0.2	0.4	69.8
12	0.4	0.4	5.2	16.5	0.0	0.1	0.1	0.1	10.0	0.3	0.5	66.5
13	0.5	0.4	4.8	15.4	0.0	1.2	0.1	0.1	10.2	0.2	0.6	66.6
14	0.0	0.4	5.4	16.2	0.0	0.1	0.0	0.3	9.6	0.2	1.1	66.9
15	0.5	1.0	8.4	18.8	0.0	0.1	0.1	0.4	7.8	0.2	1.7	61.2
16	0.8	0.8	6.1	17.9	0.0	0.2	0.0	0.2	9.5	0.2	0.8	63.7
17	0.0	0.1	3.2	11.4	0.0	0.1	0.0	0.1	9.4	0.2	0.4	75.3
18	0.0	0.3	3.7	12.7	0.0	0.2	0.0	0.0	9.4	0.3	0.3	73.2
19	0.5	0.4	5.6	19.3	0.0	0.1	0.0	0.1	10.6	0.3	0.3	62.8
20	0.0	0.2	3.1	11.3	0.0	0.1	0.0	0.1	9.1	0.9	0.3	74.9
21	0.5	0.3	4.0	13.8	0.0	0.1	0.0	0.0	9.8	0.3	0.3	71.0
22	0.2	0.3	4.8	16.7	0.0	0.1	0.0	0.0	10.1	0.3	0.3	67.2
23	1.0	0.4	5.6	19.5	0.0	0.8	0.4	0.3	10.0	0.3	0.3	61.4
24	0.4	0.4	5.0	17.0	0.0	0.1	0.0	0.1	10.5	0.2	0.1	66.3
25	0.7	0.5	6.0	20.2	0.0	0.1	0.0	0.1	11.1	0.2	0.5	60.7
26	0.4	0.3	5.9	19.9	0.0	0.4	0.0	0.0	11.0	0.3	0.3	61.5
27	0.4	0.4	5.8	19.6	0.1	0.1	0.1	0.0	11.1	0.4	0.3	61.8
28	0.3	0.3	4.4	15.3	0.0	0.1	0.1	0.0	10.3	0.3	0.3	68.6
29	0.3	0.3	4.2	15.4	0.0	0.1	0.0	0.0	10.3	0.4	0.4	68.5
30	0.4	0.2	4.0	13.6	0.0	0.1	0.0	0.1	10.0	0.2	0.3	71.1

31	0.7	0.8	6.5	18.1	0.0	0.2	0.1	0.1	9.1	0.3	1.5	62.7
32	0.3	0.3	5.2	17.9	0.1	0.2	0.1	0.1	10.4	0.3	0.3	64.8
33	1.0	0.4	5.6	19.1	0.0	0.1	0.4	0.1	10.2	0.3	0.2	62.6
34	0.3	0.4	5.5	17.5	0.0	0.2	0.0	0.0	9.9	0.2	0.6	65.5
35	0.6	0.4	6.0	18.3	0.1	0.3	0.1	0.1	9.6	0.4	0.7	63.4
36	0.8	0.5	6.3	19.8	0.1	0.1	0.0	0.0	10.4	0.3	0.6	61.1
37	0.6	0.3	5.8	19.9	0.0	0.3	0.0	0.1	10.2	0.2	0.2	62.5
38	0.6	0.4	4.7	16.6	0.0	0.0	0.0	0.0	10.1	0.3	0.6	66.5
39	0.2	0.3	5.2	17.2	0.0	0.1	0.1	0.1	10.1	0.2	0.6	65.9
40	0.3	0.6	5.0	15.5	0.0	0.2	0.0	0.1	9.6	0.3	3.7	64.8
41	0.0	0.5	5.6	18.3	0.0	0.2	0.1	0.1	10.4	0.2	0.5	64.2
42	0.2	0.2	3.5	12.0	0.0	0.1	0.0	0.1	8.4	0.2	1.2	74.1
43	0.2	0.3	5.1	17.2	0.0	0.1	0.0	0.0	10.4	0.3	0.3	66.2
44	0.5	0.5	6.0	19.5	0.1	0.2	0.0	0.0	9.9	0.2	0.7	62.4
45	0.4	0.5	4.5	16.3	0.0	2.2	0.0	0.1	9.4	0.2	0.6	65.9
46	0.3	0.4	3.9	13.0	0.0	0.2	0.1	0.1	8.9	0.2	0.5	72.4
48	0.3	1.3	6.6	14.4	0.1	0.1	0.0	0.2	6.7	0.3	15.6	54.5
49	0.3	0.3	6.1	20.1	0.0	0.0	0.0	0.1	11.1	0.3	0.3	61.4
50	0.2	3.2	8.0	17.9	0.0	0.3	0.0	0.0	12.0	0.4	2.6	55.4
51	0.5	1.6	7.2	27.7	0.0	0.1	0.1	0.8	4.2	0.2	1.6	56.2
52	0.5	2.0	9.6	20.5	0.1	0.0	0.0	0.5	5.8	0.3	2.7	58.0
53	0.3	0.4	6.4	21.2	0.0	0.1	0.0	0.1	11.0	0.4	0.6	59.4
54	0.4	0.3	3.9	13.2	0.0	0.2	0.0	0.0	9.7	0.2	0.3	71.7
55	0.5	0.7	5.6	17.6	0.1	0.2	0.0	0.2	9.7	0.2	0.8	64.5
56	0.3	0.5	5.6	17.1	0.0	0.1	0.0	0.1	10.5	0.4	0.5	65.0
57	0.7	1.1	7.0	19.6	0.1	0.2	0.0	0.3	8.0	0.3	1.8	61.0
58	0.6	0.5	4.8	13.0	0.0	0.1	0.9	0.4	7.8	0.1	1.7	69.9
59	0.5	1.5	9.4	22.2	0.0	0.2	0.0	0.9	4.7	0.3	2.4	57.9
60	0.0	0.1	3.3	13.8	0.0	0.0	0.0	0.3	5.7	0.2	0.6	75.9
61	0.3	0.5	6.2	17.2	0.0	0.1	0.1	0.1	9.2	0.4	0.6	65.4
62	0.3	0.4	5.1	16.9	0.1	0.2	0.1	0.1	10.3	0.4	0.4	65.9
63	0.2	0.2	3.3	11.7	0.0	0.1	0.0	0.0	9.3	0.3	0.2	74.8
64	0.0	0.1	3.7	13.4	0.0	0.1	0.0	0.1	10.1	0.3	0.2	72.2
65	0.0	0.3	4.9	17.3	0.1	0.1	0.1	0.1	10.6	0.4	0.7	65.4
66	0.2	0.3	3.4	12.2	0.0	0.0	0.1	0.0	9.5	0.2	0.4	73.7
67	0.2	0.2	4.4	15.5	0.0	0.0	0.1	0.1	9.9	0.3	0.5	68.9

68	0.4	0.4	5.9	20.1	0.0	0.3	0.1	0.1	10.2	0.2	0.3	62.1
69	0.3	0.2	4.1	14.6	0.0	0.1	0.1	0.0	10.0	0.3	0.2	70.3
70	0.2	0.2	3.4	11.7	0.0	0.1	0.0	0.1	9.9	0.3	0.0	74.1
71	0.6	0.3	4.6	15.8	0.0	0.2	0.0	0.1	10.3	0.3	0.3	67.6
72	0.3	0.2	3.7	13.0	0.1	0.0	0.0	0.0	9.1	0.1	0.0	73.5
73	0.5	0.6	5.7	18.5	0.1	0.5	0.1	0.1	10.9	0.3	0.5	62.5
74	0.7	0.6	6.3	20.0	0.0	0.2	0.0	0.0	10.5	0.3	0.4	61.3
75	0.6	0.6	6.4	20.7	0.1	0.3	0.0	0.3	8.9	0.2	1.5	60.5
76	0.3	0.3	4.2	15.2	0.1	0.1	0.0	0.0	10.5	0.1	0.5	68.8
77	0.5	0.5	5.3	17.6	0.0	0.2	0.0	0.0	10.3	0.2	0.5	65.0
78	0.5	0.4	5.4	18.3	0.0	0.1	0.0	0.0	10.6	0.3	0.6	64.0
79	0.2	0.2	3.5	13.8	0.1	0.0	0.0	0.2	7.4	0.1	0.5	73.8
80	0.0	0.5	4.3	12.5	0.0	1.8	0.0	0.1	10.2	0.3	0.7	69.6
81	0.3	0.6	6.3	20.2	0.0	0.1	0.0	0.1	10.0	0.3	0.8	61.3
82	0.5	0.4	6.6	20.5	0.1	0.1	0.1	0.1	10.4	0.4	0.3	60.6
83	0.6	0.6	5.7	18.4	0.1	0.2	0.0	0.1	10.7	0.3	0.7	62.7
84	0.0	0.8	6.8	17.6	0.0	0.1	0.0	0.4	7.6	0.3	2.2	64.2
85	0.6	0.9	5.0	22.7	0.0	0.3	0.0	0.4	4.5	1.4	1.2	63.1
86	0.5	0.6	5.6	20.4	0.0	0.3	0.0	0.4	7.1	0.5	1.7	62.9
87	0.4	1.0	7.0	17.5	0.1	0.2	0.0	0.4	7.5	0.4	2.0	63.6
88	0.3	0.4	5.8	18.5	0.0	0.2	0.1	0.2	10.3	0.3	0.6	63.2
89	0.2	0.9	7.3	16.3	0.1	0.2	0.1	0.1	8.5	0.5	1.9	64.0
90	0.5	0.4	5.7	19.2	0.0	0.1	0.0	0.1	10.9	0.4	0.6	62.1
91	0.8	0.4	7.1	23.0	0.0	0.1	0.0	0.1	11.5	0.3	0.1	56.6
92	0.2	0.3	4.7	16.4	0.1	0.2	0.0	0.1	10.9	0.3	0.2	66.7
93	0.3	0.2	3.4	11.7	0.0	0.0	0.0	0.0	9.3	0.3	0.3	74.4
94	0.7	0.4	6.2	20.4	0.0	0.6	0.0	0.2	10.4	0.3	0.6	60.3
95	0.4	0.4	5.1	17.7	0.0	0.2	0.0	0.1	10.5	0.4	0.3	65.1
96	0.6	0.4	4.7	15.9	0.0	0.1	0.1	0.1	10.6	0.4	0.2	67.1
97	0.6	0.4	4.9	16.5	0.0	0.1	0.1	0.1	10.4	0.3	0.4	66.5
98	0.6	0.5	6.7	22.3	0.0	0.1	0.1	0.1	11.5	0.3	0.2	57.6
99	0.3	0.4	4.3	15.1	0.1	0.1	0.0	0.1	10.4	0.3	0.5	68.5
100	0.4	0.4	4.4	15.8	0.0	0.1	0.0	0.1	10.1	0.2	0.3	68.2
101	0.6	0.5	7.1	22.4	0.0	0.0	0.1	0.1	11.4	0.3	0.1	57.4
102	0.5	0.7	5.0	16.1	0.0	0.3	0.0	0.1	10.4	0.2	0.4	66.4
103	0.7	0.5	7.4	24.3	0.0	0.2	0.0	0.1	11.7	0.4	0.3	54.5

104	0.4	0.5	5.7	18.9	0.0	0.0	0.1	0.1	10.8	0.3	0.5	62.8
105	0.5	0.4	5.2	18.1	0.0	0.1	0.0	0.1	11.0	0.2	0.3	64.2
106	0.4	0.4	5.3	17.7	0.1	0.2	0.1	0.1	10.9	0.2	0.3	64.4
107	0.0	0.4	4.0	13.6	0.0	0.1	0.1	0.1	10.1	0.2	0.6	70.9
108	0.7	0.3	5.8	19.4	0.0	0.2	0.1	0.1	10.9	0.2	0.3	62.0
109	0.7	0.5	5.9	19.9	0.0	0.2	0.1	0.2	10.1	0.3	0.6	61.7
110	0.6	2.1	11.8	22.7	0.0	0.1	0.1	0.9	6.2	0.6	2.9	51.9
111	0.2	0.4	3.9	13.2	0.0	0.1	0.1	0.1	9.8	0.3	0.3	71.7
112	0.3	0.6	5.6	19.0	0.1	0.1	0.0	0.1	10.9	0.4	0.5	62.6
113	0.5	0.3	4.8	17.3	0.0	0.2	0.0	0.0	10.3	0.3	0.3	66.0
114	0.7	0.4	6.8	23.5	0.1	0.1	0.0	0.0	11.8	0.4	0.3	56.0
115	0.6	0.5	5.5	19.4	0.0	0.4	0.0	0.1	10.9	0.2	0.4	62.2
116	0.0	0.3	4.4	15.5	0.0	0.5	0.0	0.0	10.6	0.2	0.2	68.3
117	0.0	0.1	3.1	11.4	0.0	0.1	0.1	0.0	9.5	0.3	0.5	74.9
118	0.7	0.4	6.7	22.4	0.0	0.1	0.1	0.0	12.0	0.3	0.4	57.0
119	0.4	0.5	5.5	18.5	0.1	0.1	0.0	0.1	10.6	0.3	0.6	63.3
120	0.4	0.3	6.6	22.1	0.0	0.3	0.0	0.0	11.1	0.4	0.3	58.6
121	0.9	0.4	5.9	19.7	0.0	0.1	0.0	0.0	10.6	0.3	0.6	61.5
122	0.5	0.5	4.7	16.4	0.1	0.3	0.1	0.0	10.4	0.2	0.6	66.4
123	0.6	0.5	5.5	18.5	0.0	0.2	0.0	0.1	10.8	0.1	0.3	63.5
124	0.4	0.4	4.1	14.1	0.0	0.1	0.0	0.1	9.9	0.2	0.5	70.2
125	0.5	0.4	6.4	21.0	0.0	0.1	0.0	0.0	11.2	0.3	0.2	59.9
126	0.0	0.4	4.8	16.2	0.1	0.1	0.0	0.1	10.0	0.3	1.0	67.2
127	0.7	0.5	6.2	18.7	0.0	0.1	0.0	0.1	10.5	0.3	0.3	62.6
128	0.0	0.2	3.9	12.5	0.0	0.1	0.0	0.1	8.9	0.3	0.5	73.4
129	0.5	0.4	4.4	14.2	0.0	0.1	0.0	0.1	9.3	0.4	0.8	69.9
130	0.2	0.5	5.8	17.6	0.0	0.1	0.0	0.1	9.9	0.8	1.3	63.8
131	0.3	0.4	4.7	16.2	0.0	0.1	0.0	0.0	10.6	0.3	0.3	67.2
132	0.5	0.8	6.3	17.8	0.1	0.2	0.1	0.2	7.8	0.6	2.6	63.2
133	0.3	0.6	5.6	14.1	0.1	0.1	0.0	0.2	7.3	0.3	2.4	68.9
134	0.4	0.7	6.1	19.3	0.1	0.3	0.0	0.2	10.0	0.5	1.1	61.3
135	0.4	0.7	6.6	19.1	0.1	0.3	0.1	0.1	9.3	0.3	11.4	51.7
136	0.0	0.3	3.9	12.8	0.0	0.0	0.0	0.0	10.1	0.3	0.4	72.2
137	0.0	0.7	5.1	15.2	0.0	0.2	0.0	0.2	8.8	0.2	1.2	68.5
138	0.5	1.4	7.3	17.4	0.1	0.3	0.0	0.3	7.1	1.4	2.3	62.1
139	0.4	0.5	6.2	20.7	0.1	0.1	0.1	0.0	10.9	0.3	0.6	60.2

140	0.4	0.4	6.0	20.7	0.0	0.1	0.0	0.0	11.6	0.3	0.2	60.4
141	0.5	0.3	5.3	19.0	0.0	0.2	0.1	0.1	11.5	0.3	0.4	62.4
142	0.5	0.4	5.7	18.4	0.0	0.0	0.0	0.1	10.8	0.4	0.4	63.5
143	0.2	0.4	4.2	14.5	0.0	0.1	0.0	0.0	9.8	0.3	0.4	70.1
144	0.4	0.3	4.4	14.9	0.0	0.1	0.0	0.1	10.6	0.3	0.2	68.9
145	0.5	0.4	5.2	18.3	0.0	0.1	0.1	0.0	10.9	0.2	0.5	63.9
146	0.7	0.4	6.0	20.6	0.0	0.4	0.1	0.0	10.4	0.2	0.3	60.9
147	0.2	0.3	4.2	14.2	0.0	0.1	0.1	0.0	10.7	0.2	0.3	69.8
148	0.4	0.2	3.9	13.7	0.0	0.1	0.1	0.0	10.3	0.3	0.2	70.9
149	0.4	5.6	10.8	20.8	0.0	0.0	0.0	0.0	10.0	0.5	3.5	48.5
150	0.7	0.4	6.0	19.4	0.0	0.5	0.0	0.1	10.5	0.3	0.3	61.9
151	0.3	0.5	5.7	19.7	0.1	0.1	0.0	0.1	10.8	0.3	0.2	62.3
152	0.4	0.3	4.1	14.4	0.0	0.2	0.0	0.2	10.1	0.2	0.3	69.9
153	0.2	0.2	3.8	12.3	0.1	0.2	0.1	0.0	9.1	0.2	0.5	73.4
154	0.5	0.3	5.7	19.1	0.0	0.2	0.1	0.1	10.6	0.2	0.6	62.6
155	0.3	0.5	6.3	20.4	0.0	0.2	0.1	0.1	11.1	0.3	0.4	60.5
156	0.8	0.4	6.4	21.3	0.0	0.1	0.0	0.0	11.2	0.4	0.3	59.3
157	0.7	0.6	7.2	23.0	0.0	0.1	0.0	0.1	11.8	0.3	0.2	56.1
158	0.3	0.4	5.4	18.8	0.0	0.1	0.1	0.0	10.5	0.3	0.3	63.8
159	0.4	0.4	5.7	18.9	0.0	0.3	0.0	0.0	10.6	0.3	0.5	62.9
160	0.4	0.3	4.1	14.7	0.1	0.1	0.1	0.0	10.4	0.3	0.4	69.2
161	0.8	0.5	6.3	20.4	0.0	0.1	0.0	0.1	11.2	0.3	0.4	60.0
162	0.0	0.3	5.8	19.6	0.0	0.0	0.0	0.1	11.6	0.2	0.3	62.1
163	0.6	0.4	6.1	20.4	0.0	0.2	0.1	0.1	10.8	0.3	0.4	60.8
164	0.6	0.4	6.4	22.0	0.0	0.2	0.0	0.1	11.5	0.4	0.0	58.5
165	0.3	1.1	10.5	22.6	0.0	0.2	0.0	0.7	5.6	0.4	1.8	56.7
166	0.3	0.4	5.4	18.5	0.0	0.1	0.1	0.1	10.3	0.4	0.4	64.1
167	0.6	0.5	6.1	18.1	0.0	2.8	0.0	0.2	11.7	0.3	0.6	59.2
168	0.2	0.4	4.3	13.5	0.0	0.0	0.0	0.1	8.8	0.3	1.0	71.4
169	0.4	0.6	5.5	19.0	0.0	0.2	0.0	0.1	10.2	0.2	0.8	63.0
170	0.3	0.8	6.4	14.8	0.0	0.2	0.1	0.7	6.0	0.3	1.5	69.0
171	0.4	0.3	5.1	16.7	0.0	0.2	0.0	0.1	9.6	0.3	0.2	67.1
172	0.3	0.3	4.9	16.3	0.0	0.1	0.0	0.0	9.7	0.2	0.3	67.9
173	0.6	0.4	5.6	18.2	0.0	0.1	0.0	0.1	9.4	0.2	0.6	64.7
174	0.7	0.4	4.9	16.2	0.0	0.1	0.0	0.0	9.4	0.3	0.5	67.6
175	0.2	0.3	3.7	12.1	0.0	0.1	0.1	0.1	8.7	0.3	0.3	74.2

176	0.3	0.3	4.5	15.0	0.0	0.1	0.0	0.0	9.2	0.7	0.4	69.6
177	0.4	0.5	5.2	17.1	0.0	0.1	0.0	0.1	9.7	0.4	0.4	66.2
178	0.2	0.8	5.7	15.1	0.0	0.4	0.1	0.1	8.2	0.4	1.5	67.6
179	0.2	0.4	4.9	13.6	0.1	0.1	0.1	0.1	10.0	0.2	0.5	69.8
180	0.3	0.6	4.7	14.4	0.0	0.2	0.0	0.2	7.7	0.1	1.4	70.5
181	0.3	0.6	5.1	14.7	0.1	0.1	0.0	0.1	9.1	0.2	1.1	68.5
182	0.2	0.8	5.6	17.5	0.1	0.2	0.0	0.4	7.3	0.4	1.7	65.9
183	0.3	0.7	4.6	17.0	0.1	0.2	0.0	0.3	6.8	0.2	1.6	68.2
184	0.2	1.0	5.0	11.5	0.0	0.2	0.0	0.3	6.9	0.2	2.0	72.9
185	0.2	0.5	4.8	14.6	0.0	0.1	0.0	0.1	9.1	0.3	1.2	69.3
186	0.0	0.3	5.3	18.1	0.0	0.1	0.0	0.0	10.7	0.3	1.1	64.1
187	0.7	0.5	6.4	19.9	0.0	0.1	0.1	0.1	10.1	0.2	0.3	61.7
188	0.4	0.3	5.2	17.8	0.1	0.3	0.1	0.1	11.0	0.3	0.3	64.1
189	0.5	0.4	6.3	21.0	0.0	0.2	0.0	0.0	11.6	0.3	0.4	59.5
190	0.5	0.4	6.7	22.8	0.0	0.1	0.0	0.1	11.5	0.4	0.1	57.5
191	0.0	0.2	4.1	14.4	0.0	0.1	0.0	0.0	10.9	0.3	0.3	69.8
192	1.1	0.6	5.1	16.7	0.0	0.8	0.0	0.1	8.9	0.3	2.1	64.3
193	0.7	0.4	7.4	24.0	0.1	0.1	0.1	0.0	12.3	0.3	0.3	54.5
194	0.3	2.8	7.5	16.0	0.0	0.0	0.0	0.0	7.6	0.4	11.3	54.2
195	0.5	0.3	6.7	22.3	0.0	0.2	0.1	0.1	11.4	0.3	0.5	57.7
196	0.4	0.4	6.2	21.2	0.0	0.0	0.0	0.0	11.9	0.2	0.4	59.5
197	0.7	0.5	6.4	21.5	0.0	0.2	0.1	0.2	11.0	0.3	0.3	58.7
198	0.4	0.4	5.5	18.7	0.0	0.2	0.0	0.1	11.6	0.3	0.5	62.2
199	0.4	0.4	4.9	16.5	0.0	0.2	0.0	0.0	10.9	0.3	0.5	66.1
200	0.4	0.3	5.4	18.6	0.0	0.8	0.0	0.0	11.7	0.3	0.5	62.1
201	0.7	0.6	6.1	20.1	0.0	0.2	0.0	0.0	11.1	0.2	0.5	60.7
202	0.2	0.3	4.7	16.2	0.0	0.1	0.0	0.0	10.9	0.2	0.5	67.1
203	0.5	0.4	6.9	23.0	0.0	0.1	0.0	0.1	12.0	0.4	0.0	56.8
204	0.3	0.4	5.9	19.3	0.0	0.2	0.0	0.1	11.5	0.3	0.5	61.6
205	1.0	0.5	7.2	23.5	0.1	1.0	0.0	0.1	12.5	0.4	0.3	53.5
206	0.6	0.4	5.1	16.8	0.0	0.2	0.1	0.0	10.2	0.4	0.6	65.7
207	0.8	0.7	8.0	24.0	0.0	0.2	0.2	0.1	11.1	0.2	0.7	54.0
208	0.8	0.5	6.9	23.0	0.1	0.2	0.1	0.0	11.7	0.2	0.4	56.1
209	0.3	0.4	4.2	14.5	0.0	0.2	0.0	0.1	9.9	0.2	0.7	69.6
210	0.2	0.3	3.6	12.3	0.1	0.1	0.0	0.1	10.0	0.2	0.6	72.7
211	0.3	0.3	3.8	13.8	0.0	0.1	0.0	0.1	10.7	0.3	0.3	70.4

212	0.0	0.3	4.7	17.1	0.0	1.0	0.0	0.1	10.9	0.3	0.7	65.1
213	0.4	4.4	9.5	17.2	0.0	0.4	0.0	0.0	15.0	0.8	4.1	48.3
214	0.4	0.2	4.5	16.3	0.0	0.1	0.0	0.0	10.9	0.3	0.0	67.3
215	0.6	0.6	6.8	22.4	0.1	0.2	0.1	0.2	11.9	0.4	0.3	56.6
216	0.2	0.8	4.8	12.3	0.0	0.1	0.1	0.1	8.7	0.2	2.8	69.8
217	0.6	0.4	6.6	22.3	0.1	0.3	0.1	0.1	11.8	0.2	0.2	57.3
218	0.3	0.4	5.5	19.2	0.1	0.4	0.0	0.1	10.7	0.4	0.3	62.7
219	0.9	0.6	6.8	21.9	0.0	0.4	0.0	0.1	10.9	0.4	0.7	57.4
220	0.0	2.2	6.3	14.6	0.0	0.0	0.0	0.4	6.9	0.2	3.9	65.7
221	0.5	0.9	7.6	21.1	0.0	0.4	0.0	0.2	9.8	0.3	2.4	57.0
222	0.5	0.5	5.9	19.6	0.0	0.1	0.0	0.1	11.4	0.2	0.5	61.2
223	0.4	1.2	8.0	17.6	0.1	0.4	0.1	0.3	8.2	0.3	3.9	59.5
224	0.8	0.6	6.6	22.0	0.1	0.4	0.1	0.1	11.9	0.3	0.6	56.6
225	0.3	0.5	6.1	19.6	0.1	0.3	0.0	0.2	10.7	0.4	0.9	61.0
226	0.0	0.6	5.3	16.1	0.1	0.3	0.0	0.1	9.4	0.3	1.8	66.0
227	0.0	0.6	5.9	18.8	0.0	0.3	0.0	0.2	10.2	0.4	1.2	62.5
228	0.2	1.2	7.5	18.1	0.1	0.2	0.0	0.3	9.3	0.5	2.6	60.1
229	0.6	0.4	4.9	16.2	0.0	0.2	0.0	0.0	10.7	0.3	0.3	66.5
230	0.5	0.7	6.8	22.0	0.0	0.3	0.1	0.1	11.1	0.3	1.4	56.7
231	0.2	0.8	6.2	17.4	0.0	0.2	0.1	0.2	9.2	0.9	1.9	63.0
232	0.6	0.5	5.4	18.9	0.0	1.1	0.1	0.1	12.1	0.2	0.3	60.7
233	0.8	0.4	6.3	20.7	0.0	0.5	0.2	0.1	11.4	0.2	0.2	59.2
234	0.5	0.2	5.9	20.4	0.0	0.0	0.0	0.1	12.3	0.3	0.5	59.8
235	0.0	0.2	4.2	14.3	0.0	0.1	0.0	0.0	10.1	0.2	0.4	70.6
236	0.2	6.3	7.6	11.9	0.0	0.2	0.0	0.0	21.8	0.4	3.6	48.0
237	0.8	0.4	4.0	13.8	0.0	9.3	0.1	0.0	18.1	0.1	0.2	53.2
238	0.6	0.4	6.3	22.8	0.0	0.2	0.1	0.0	11.9	0.3	0.0	57.6
239	0.7	0.4	6.5	22.4	0.1	0.1	0.0	0.1	11.8	0.2	0.2	57.6
240	0.7	0.6	7.6	24.8	0.0	0.1	0.1	0.1	12.7	0.3	0.3	52.9
241	0.6	0.6	6.2	21.6	0.0	0.3	0.1	0.1	11.0	0.4	0.3	59.0
242	0.0	0.2	4.3	15.4	0.0	0.1	0.1	0.0	11.0	0.3	0.7	68.0

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