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CHARACTERIZATION OF ALASKA COAL OVERBURDEN

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ABSTRACT

Alaska coal overburdens from the Susitna lowland, Matanuska Valley, and Nenana basin are generally of high quality and should present few environmental problems during future mining and reclamation programs. The overburdens are low in sulfur, which occurs mainly in the organic form, as it does in coals. Minor quantities of framboidal pyrite, present as pyritic sulfur, have been documented in certain overburden samples. Although framboidal pyrite is responsible for most acid-mine drainage in coal-mining regions, problems are not expected in Alaska coal fields because of the minor amount of reactive framboidal pyrite. The overburdens in some cases also show relatively high trace-element contents of boron, lead, zinc, molybdenum, nickel, cobalt, and cadmium. However, the serious acid conditions commonly associated with eastern and midwestern United States coal mines and the high levels of soluble salts and adsorbed sodium found in the western United States coal fields are unlikely to be significant problems in Alaska.

New large-scale surface mines will probably be developed in Alaska coal fields in the next five to ten years. At that time, material textures in mine spoils, particularly with regard to clays and weathered gleys, may become significant problems (for proper drainage, revegetation, and maintenance of slopes) on certain tracts. In addition, siltation of streams may be problematic locally, and in areas of perched groundwater or springs, dewatering of trenches and pits will be necessary.

INTRODUCTION

The character of Alaska coal overburden has received very little attention until of late, mainly because of the lack of active coal-mining operations. However, new surface mining in Alaskan coal fields cannot be conducted without detailed studies of both consolidated and unconsolidated overburden materials. Because overburden (and interburden) materials form most coal-mine refuse, the Surface Mining Control and Reclamation Act of 1977 (and its later enforcement provisions) is addressed primarily toward overburden materials rather than coal.

The purpose of this paper is to consider the physical and geochemical character of coal overburden samples collected from three major coal-bearing regions of Alaska---the Susitna lowland, Matanuska Valley, and Nenana basin (Figure 1)---which hold high potential for new coal-mine developments in the near future. The ultimate goal of this examination is the prediction of possible environmental problems that could be associated with this increased mining.

Figure 1---NEAR HERE

Some 88 overburden samples were collected from coal-bearing strata of the Tertiary Kenai Group during geologic field work in the Susitna lowland in 1981. In 1982, 43 coal-overburden samples were collected from Tertiary coal-bearing group strata of the Nenana basin, and in 1983, 27 coal-overburden samples were collected from the Tertiary Chickaloon Formation of the Matanuska Valley (Table 1). Typically most of the overburden samples collected were either the roof rock or seat rock adjacent to significantly thick coal seams. The coal-bearing section of Figure 2 shows the general overburden sample configuration at a locality in the Mystic Creek coal field, Nenana basin. In each case, a fairly complete suite of

Table 1, Figure 2---NEAR HERE

overburden characterization analyses were performed that have yielded sufficient data to draw preliminary conclusions as to the nature of these ultimate minesoil materials.

OVERBURDEN CHARACTERIZATION

Qualitative coal overburden characterization is significant for several reasons (Merritt, 1983). The suitability of overburden materials for use as a subsoil medium during reclamation of a mine site is of prime importance. The breakup of unweathered rock materials and their placement into the zone of active leaching also creates potential deleterious effects on regional surface- and ground-water quality.

The character of overburden material varies---as does the quality of individual coal seams within a given basin---and is dependent on the geologic environment of deposition (paleoenvironment) of the material. The mineralogic content and character of overburden material is determined by this depositional regime, and is effected by such factors as Eh-pH conditions, temperature, and salinity within the paleoenvironment.

Pyrite, gypsum, dolomite, and clay minerals within the overburden affect the chemistry of ground water. Pyritic and argillaceous materials have the greatest potential for producing highly mineralized ground water. Sulfate ($SO_4^{=}$) and sodium (Na^+) concentrations are of particular concern (Groenewold and others, 1981).

Overburden is composed predominantly of inorganic sedimentary rocks. However, thin, unminable coal beds are also considered as part of the overburden at a mine site. Overburden includes both the unconsolidated profile and bedrock strata above minable coal seams. The unconsolidated profile includes soils (topsoil and subsoil horizons), other alluvial and colluvial materials, eolian (loess), and glacial deposits. Bedrock strata are composed of relatively soft materials (shales and weathered rock) and hard materials (conglomerate, sandstone, siltstone, and limestone). In this paper, only the character of overburden bedrock strata will be considered.

RESULTS OF ANALYSES

A broad spectrum of coal overburden characterization analyses were performed on the Alaska samples collected for the current investigation (Tables 2-4). Among the most important characteristics of overburden materials are texture, acidity and saline-sodic conditions, cation exchange capacity, organic matter, major oxide, trace element, macronutrient and micronutrient contents (Table 5). Each of these characteristics will be discussed below for the areas considered. In addition, a special type of overburden---that baked by the natural combustion of adjacent coal beds---will subsequently be briefly considered.

Tables 2-5---NEAR HERE

TEXTURE

A regraded spoil material derived from high sand (greater than 70 percent) or high clay (greater than 40 percent) content overburden, or with a resultant bouldery surface texture (as with glacial tills) may cause revegetation problems. High-clay zones produce effective aquicludes, high sand has unfavorable moisture-retention capabilities, and large boulders create a medium with little fine-grained matrix material and organic matter (Dollhopf and others, 1978).

Mixing high-clay-content overburden with high- or moderate-sand-content overburden during dragline spoiling can improve soil texture and drainage characteristics in some cases. Dollhopf and others (1978) cite an example of mixing a sample with 9 percent clay with a sample at 57 percent clay in proportions of 75:25, 50:50, and 25:75. This resulted in sample mixtures of 25, 40, and 49 percent clay content, which represented a near-linear relationship (which it should under ideal circumstances). Overburden often exhibits abrupt vertical and lateral changes in the clay contents, which represent rapid changes in the local depositional processes. Considerable improvement in texture can result from mixing the inhibitory clay strata and diluting the clay abundance.

This will produce a more desirable plant-root medium and allow water to percolate more easily through the material, thereby lessening runoff. Selective placement of materials may be required in combination with overburden blending.

A ternary plot of particle sizes and resultant textures for Alaska coal overburden samples show that several fall within poor texture zones based on their utility as a subsoil rooting medium during reclamation (Figure 3). Susitna lowland samples are characterized by rapid vertical and lateral changes in clay contents. Based on unconfined compressive strength tests of Capps coal field (Beluga area, Susitna lowland) core samples, Chleborad and others (1982) conclude that the materials range from soft soil to soft rock (Figure 4). The typical Susitna lowland overburden sample is composed of 40 percent sand, 42 percent silt, and 18 percent clay. Matanuska Valley coal overburden samples reveal variant textures; the typical sample is composed of 59 percent sand, 19 percent silt, and 22 percent clay. The typical Nenana basin overburden sample consists of 38 percent sand, 39 percent silt, and 23 percent clay.

Figures 3-4---NEAR HERE

ACIDITY

Acidity should not be a significant problem in most coal fields of Alaska. But overburden strata with as little as 0.3 percent sulfur as fine-grained disseminated pyrite (particularly as framboids) have been known to cause acidity and revegetation problems on reclaimed spoil. Pyrite framboids have been documented in certain coals of the regions examined in this study. In weathered (oxidized) overburden sequences, soluble sulfate salts may be abundant (Figure 5). The inherent alkalinity level (that is, $CaCO_3$ or lime content) acts to ameliorate acidity conditions.

Figure 5---NEAR HERE

Overburden strata at Fairview Mountain, northwest Susitna lowland, exhibit both low pH values (to 4.1; Figure 6) and, in at least two samples, deficiencies of ameliorating capacity over 5 tons $CaCO_3$ equivalent per 1,000 tons of material (Figure 6). However, the pyritic sulfur content of the roof and floor beds of coal seams C-F was less than 0.1 percent and the total sulfur content was less than 0.48 percent in all samples (Figure 7). The acidity in this case is believed to have resulted from the biochemical breakdown of organic matter, which ranged from 1.27 to 11.89 percent in those samples analyzed. Groenewold and others (1981) found that this process often led to higher acidity than that from the oxidation of disseminated pyrite.

Figures 6-7---NEAR HERE

Matanuska Valley samples had a mean paste pH of 7.3. Sulfur contents were very low (Figure 8); the mean total sulfur content was 0.12 percent with most of this (0.11 percent) present as organic sulfur. Lime contents were also low averaging less than 1 percent. The samples showed no significant potential for the development of acidic mine spoils. Acid potential was measured based on the pyritic sulfur content and on the total sulfur in the samples. Both methods arrived at mean excess values of inherent neutralizing capacity ranging from 1.9 tons $CaCO_3$ equivalent per 1,000 tons of material (total sulfur) to 5.4 tons $CaCO_3$ equivalent per 1000 tons of material (pyritic sulfur). An acid-base profile for a Wishbone Hill area section is shown in Figure 9. Sample codes and paste pH, pyritic sulfur, total sulfur, lime and organic matter values are annotated to the profile section for convenience in interpretation. This section reveals three samples with significant deficiencies of 10 to 20 tons $CaCO_3$ equivalent per 1,000 tons of material. However, most samples from other areas of the Matanuska Valley show prevalent excesses in inherent neutralizers.

Figures 8-9---NEAR HERE

Figure 10 is an acid-base account for a Shovel Creek, Nenana basin coal-bearing section. The samples from the Nenana basin generally reveal excesses of inherent neutralizers, neutral to slightly acid pH levels, low sulfur contents, and relatively high organic matter and lime contents.

Figure 10---NEAR HERE

SALINE-SODIC SPOIL

Although materials characterized by excess soluble salts and a high level of adsorbed sodium are common in the arid to semiarid regions of the western United States, results of analyses during the current study support the conclusions of Mitchell and others (1981) that saline and sodic spoil should not be a major problem for Alaskan coal basins. They found no zones of salt accumulation or sodium adsorption levels that would be detrimental to the establishment of plant growth in the materials they examined from four areas in Alaska (1-Usibelli Mine at Healy, Nenana basin; 2-the Capps area of the Beluga field, Susitna lowland; 3-an abandoned strip mine in Matanuska Valley near Sutton; and 4-an abandoned mine site at Meade River, northwest Alaska).

Electrical conductivities in the Susitna lowland samples analyzed in the current study range from 0.1 to 0.9 mmhos/cm at 25°C, and the mean sodium adsorption ratio is less than 1.0. Although a few samples exhibit anomalously high exchangeable sodium percentages, the mean value is 16.5 percent (Table 2).

Electrical conductivities, sodium adsorption ratios, and exchangeable sodium percentages for Matanuska Valley and Nenana basin coal overburden samples fall within limits set for good soil suitability characteristics (Tables 3-4). They show no potential for the development of salt or sodium accumulation. The study by Mitchell and others (1981) also confirms that sodium adsorption ratios are below the range associated with poor soil structure and its resultant effects on plant growth.

CATION-EXCHANGE CAPACITY

Generally, shales and mudstones have relatively high cation-exchange capacities (CEC), indicating that substantial clay is present and that adequate plant nutrients are available should the material be used as a subsoil medium. The CEC in sandstones rarely exceeds 5 meq/100 g unless they are argillaceous. The range in CEC in 54 overburden samples analyzed from the Susitna lowland (three sites) is 1.3 to 88.4 meq/100 g with a mean value of 20.0 meq/100 g.

Figure 11 shows considerable variation of ammonium acetate extractable cations and total CEC, expressed as milliequivalents per 100 g, for a Tyonek Formation, Kenai Group coal-bearing section near Peters Hills, Susitna lowland. Increases in extractable Mg^{++}, Ca^{++}, and K^{+} are mirrored by an increase in total CEC. Spears (1973) found a corresponding decrease in total CEC with increasing exchangeable magnesium. Changes in CEC are also directly related to changes in mineralogy. As in this example, a reduction in CEC simply reflects a decrease in the amount of clay, and is most likely related to provenance.

Figure 11---NEAR HERE

Cation exchange capacities of 43 Nenana basin coal overburden samples range from 2.7 to 79.7 meq/100 g with a mean value of about 19 meq/100 g. CEC values were not derived for Matanuska Valley samples but are believed to be similar to Susitna lowland and Nenana basin samples.

MAJOR-OXIDE ANALYSIS

Major-oxide analysis of overburden samples from the Susitna lowland and Nenana basin was performed and the results are shown in Figure 12 and Table 6. Matanuska Valley coal-overburden samples were not analyzed for major oxides. In general, the Susitna lowland and Nenana basin overburden samples are composed predominantly of silica and alumina oxides. The next most abundant oxides are Fe_2O_3, K_2O, MgO, and CaO. The contents of Na_2O, TiO_2, P_2O_5, and MnO are typically minor (less 1 percent on mean basis). Coarser-grained rocks (sandstones) contained higher abundances of SiO_2, CaO, Na_2O, and MnO, whereas finer-grained rocks (claystones) contained more Al_2O_3, MgO, K_2O, P_2O_5, and TiO_2.

Figure 12 and Table 6---NEAR HERE

TRACE ELEMENTS

Little baseline data exist for acceptable trace-element contents for overburden materials, particularly in Alaska. Hinckley and others (1982) concluded that considerable variation occurs in rock chemistry and depositional environments over short distances in the Beluga field, Susitna lowland, and that fine-grained rocks (claystones) typically contained higher abundances (by a factor of two or more) of most trace elements than coarse-grained rocks (sandstones; Table 7). Certain trace elements (for example, lead, zinc, nickel, cobalt, and cadmium) in samples of overburden materials at several localities in the Susitna lowland---Beluga River, Capps Glacier, Fairview Mountain, Peters Hills, Saturday Creek, and Wolverine Creek---appear to be at levels significantly higher than recommended for substitution of these materials as prime topsoil or subsoil media (Figure 13).

Table 7, Figure 13---NEAR HERE

The maximum content of selenium (Table 2) found in 20 samples analyzed from the Susitna lowland (two sites) was 0.05 ppm, well below the toxicity threshold level (2 ppm). The total boron content (Table 2) of the 20 samples analyzed ranged up to 100 ppm with a mean value of about 34 ppm, indicating that excess boron concentrations (greater than 5 ppm) in mine spoil material could be a problem. Molybdenum was less than 15 ppm in all Susitna lowland overburden samples analyzed; at this level, molybdenum may concentrate in plant tissues and result in the condition in grazing ruminants known as molybdenosis. Lead contents in the overburden samples ranged up to about 50 ppm; in general, materials with lead levels higher than 10 ppm should be selectively handled.

Dollhopf and others (1978) cite an example of mixing an inhibitory strata with a lead concentration of 15 ppm with overburden strata with a lead concentration of 1 ppm. This resulted in a spoil pile concentration of between 3 and 5 ppm, which if left near the reclaimed surface, would not be harmful to plant growth. In general, scattering the spoil material through the dragline swing cycle rather than dumping it at the end of the cycle results in a more homogeneous and environmentally acceptable spoil medium both chemically and physically.

Trace element contents of Matanuska Valley coal overburden samples fall within limits set for good soil suitability characteristics (Table 3). The levels of trace elements in Nenana basin coal overburden samples (Table 4) do not suggest the development of a toxicity or deficiency condition in mine soils developed from these overburden materials, and support the conclusions of Mitchell and others (1981). They concluded that trace metal concentrations at the four Alaskan sites examined during their study were in the 'adequate' range. They state that it is unlikely that a micronutrient deficiency would present a major problem in mine spoil revegetation. They also conclude that problems of metal phytotoxicity or accumulation of metals in plant tissue that might be toxic to wildlife are not indicated, nor should problems of excessive soil salinity or adsorbed sodium be anticipated.

MACRONUTRIENTS AND MICRONUTRIENTS

Extractable nutrient levels were analyzed in 43 coal overburden samples from six sites in the Susitna lowland (Table 2). The range and mean values for nitrate nitrogen are 2.1-13.8 and 4.0 ppm, respectively; for phosphorous 6.85-38.54 and 15.44 ppm; and for potassium 47.6-280.4 and 136.4 ppm. These results indicate that the samples are deficient in the major plant nutrients nitrogen and phosphorous and sometimes potassium, and that amendments with these compounds should aid revegetation if the materials are used as a subsoil medium. Of the common micronutrients (iron, manganese, zinc, boron, molybdenum, and copper), none appear to be deficient. Zinc, boron, molybdenum, and manganese levels in some samples may indicate a potential problem with metal phytotoxicity. Iron and copper appear to be at levels sufficient for normal plant growth.

The levels of extractable major nutrients in Matanuska Valley coal overburden samples may indicate the necessity of soil amendments, particularly of nitrates and phosphorous and locally potassium (Table 3). Mitchell and others (1981) of the University of Alaska Palmer Agricultural Experiment Station report that the limiting chemical constraints to plant reestablishment at an abandoned mine site at Jonesville near Sutton, Matanuska Valley are the major plant nutrients nitrogen, phosphorous, and less significantly potassium. A high pH (8.3), possibly controlled by a HCO_3 system yielding free carbonates, may hinder the availability of phosphorous and of certain micronutrients (as zinc, copper, manganese, and iron).

The Jonesville mine site spoil bank samples examined during the soil fertility and plant material studies of Mitchell and others (1981) reveal that they contain appreciable amounts of both coal and shale and remain nearly void of vegetation. Mining at the site ended over 15 years ago. The mine spoil materials are characterized by coarse textures that have led to rapid drying of the surface zone. Inadequate moisture levels during seed germination and early plant growth have resulted in seeding failures and poor stands. Test-plot trials in 1980 revealed that irrigation and particularly mulching aided plant growth (Kreig and Associates, 1983).

Analysis of extractable nutrients in Nenana basin coal overburden samples tend to confirm the conclusions reached by Mitchell and others (1981) on Healy area overburden and spoil bank materials (Table 4). They concluded that a positive growth response could be expected with applications of nitrogen, phosphorous, and potassium fertilizer. The sites examined were marginal with respect to potassium supply, but showed adequate calcium and magnesium levels. The overburden material was deficient in both the ammonium ion (NH_4^+) and nitrate (NO_3), whereas the spoil bank material demonstrated relatively high ammonium levels and slightly elevated nitrate levels.

ANALYSIS OF BAKED OVERBURDEN

Overburden rocks baked or burned by the natural combustion of adjacent coal beds are found at several locations in the Susitna lowland. These rocks are referred to variously as porcellanite, scoria, red dog, or clinker. The degree of alteration of the rocks is directly proportional to their distance from the burning seam. A contact aureole is formed surrounding the burned zone caused by metamorphism.

A series of baked rocks (CnC3-1 through CnC3-5) were sampled at an upper Canyon Creek locality of the western Susitna lowland (Figure 14). It is likely that these rocks were baked by the burning of an adjacent coal seam underground. Table 8 shows certain geochemical trends that occur from relatively unaltered rocks to highly altered rocks: 1) an increase in total iron as Fe_2O_3; 2) an increase in Na_2O and K_2O; and 3) an expected decrease in $H_2O\cdot$ and LOI.

Figure 14, Table 8---NEAR HERE

There is little evidence for natural burning of coal beds in Matanuska Valley because of the relatively lower volatile matter contents and bituminous rank. Natural burning is more prevalent in Tertiary coal fields of Alaska with abundant subbituminous coal and lignite possessing high volatile matter contents. There are a few occurrences of whitened shales in the Matanuska Valley that are similar in appearance to porcellanite (which forms by natural baking), but these may be due to mineralized water circulating through porous zones in the rocks.

Burned coal beds and baked rocks are common in the Tertiary coal-bearing group on Healy Creek, more rarely on Lignite Creek and other areas of the Nenana basin. Rocks fired and baked by the combustion of coal can be underclay, other seatrock, or a roof rock. Some of the baked rocks are resistant to erosion and stand in relief with coal beds, while others weather and break down to form varicolored gleys (Figure 15). Gleys and melting of permafrost may cause slope-instability problems (Schmoll and Yehle, 1978). Leaf impressions are also often preserved in baked rocks. Although typically of local extent in the Nenana basin, burned coal zones can be significantly detrimental to resources and reserves.

Figure 15---NEAR HERE

SUMMARY AND CONCLUSIONS

Evaluations of coal overburden character of Susitna lowland, Alaska samples indicate that 1) poor texture zones could result in regraded spoil materials causing problems for proper drainage and revegetation; 2) acidity problems should be minor and localized; 3) there is little potential for the development of saline-sodic soil conditions; 4) toxic levels of certain trace elements, including boron, molybdenum, and lead in spoil materials could result locally; 5) positive growth response can be expected with additions of the macronutrients nitrogen and phosphorous; and 6) certain micronutrients, including zinc, boron, molybdenum, and manganese are not deficient but could actually cause problems of metal phytotoxicity locally.

The overburden character of Matanuska Valley, Alaska samples examined during this evaluation generally support conclusions of earlier research. Overall, this shows that few problems can be expected with regard to the physical and geochemical properties of these ultimate minesoil materials and that future reclamation and revegetation programs should be successful.

Similarly, both field observations and the results of overburden analyses to date suggest that few environmental problems can be expected with regard to the quality of Nenana basin, Alaska overburden and interburden materials. Reclamation programs at the Usibelli Coal Mine over the past 15 years have generally been very successful.

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Table 1. Alaska coal-overburden sample location and inventory list.

COAL REGION	SITE	COAL LOCALITY	QUADRANGLE	TOWNSHIP	RANGE	SECTION	LATITUDE	LONGITUDE
I. Susitna lowland	BR1 (11)	Beluga River	Tyonek A-4	13N.	11W.	14	61°12'46"	151°11'03
	CG3 (8)	Capps Glacier	Tyonek B-5	14N.	14W.	13	61°17'57"	151°43'03
	CnC8 (3)	Canyon Creek	Tyonek D-5	20N.	13W.	19	61°48'05"	151°41'36
	FM1 (9)	Fairview Mountain	Talkeetna B-4	26N.	12W.	7	62°21'52"	151°34'40
	JC3 (4)	Johnson Creek	Talkeetna A-4	23N.	14W.	30	62°03'21"	151°54'18
	PA1 (34)	Peters Hills	Talkeetna B-3	28N.	10W.	36	62°28'28"	151°02'06
	SC4 (8)	Saturday Creek	Tyonek C-5	18N.	13W.	2	61°40'53"	151°35'03
	WC2 (11)	Wolverine Creek	Tyonek C-3	17N.	9W.	24	61°33'15"	150°50'04
II. Matanuska Valley	CC3 (2)	Coal Creek	Anchorage D-4	20N.	6E.	31	61°46'34"	148°25'36
	CM1 (4)	Castle Mountain	Anchorage D-5	20N.	5E.	15	61°49'09"	148°32'12
	MM1 (5)	Mrak Mine	Anchorage C-6	19N.	3E.	10	61°44'57"	148°52'51
	MR2 (6)	Matanuska River	Anchorage D-3	20N.	8E.	27	61°47'44"	147°58'51
	PC6 (4)	Purinton Creek	Anchorage D-4	20N.	7E.	23	61°48'46"	148°08'27
	WH3 (6)	Wishbone Hill	Anchorage C-6	19N.	3E.	17	61°44'24"	148°56'44
III. Nenana basin	BC1 (5)	Bonanza Creek	Fairbanks A-4	10S.	6W.	27	64°00'44"	148°42'00
	BM1 (7)	Bonanza-Marguerite Creeks	Fairbanks A-4	10S.	6W.	27	64°01'11"	148°41'57
	DC2 (1)	Davis Creek	Healy D-3	11S.	5W.	35	63°55'16"	148°28'24
	EC2 (4)	Emma Creek	Fairbanks A-4	10S.	6W.	33	64°00'27"	148°44'43
	MC2 (15)	Mystic Creek	Healy D-2	11S.	2W.	15	63°58'02"	147°55'42
	MM2 (1)	Mystic Mountain	Healy D-2	11S.	2W.	1	63°59'41"	147°50'39
	MM3 (1)	Mystic Mountain	Healy D-2	11S.	2W.	1	63°59'44"	147°50'22
	MMb (1)	Mystic Mountain	Healy D-2	11S.	2W.	1	63°59'11"	147°50'18
	SC1 (8)	Shovel Creek	Healy D-3	11S.	5W.	25	63°55'40"	148°26'46

( ) = Number of samples.

Table 2. Summary results of coal overburden characterization analyses of Susitna lowland samples.

PARAMETER		NUMBER OF SAMPLES	NUMBER OF LOCALES	RANGE IN CONTENTS	MEAN CONTENT	UNITS
paste pH		88	8	4.1 - 7.8	6.4	pH
Electrical conductivity		88	8	0.1 - 0.9	0.3	mmhos/cm @ 25°C
Saturation percentage		88	8	24.2 -94.1	52.8	%
Saturation extract cations	Ca	28	3	0.1 - 6.3	1.9	meq/liter
	Mg			<0.1 - 4.4	1.3	
	Na			0.4 - 0.8	0.6	
Sodium adsorption ratio		28	3	0.3 - 2.2	0.6	ratio
Exchangeable sodium percentage		54	3	0.7 - 506.4	16.5	%
Particle size		54	3	Variable	---	---
Texture		54	3	Variable	---	---
Organic matter		36	4	0.82-11.89	4.7	%
Lime percentage		36	4	7.7 - 10.1	9.9	%
Boron (total)		20	2	1.3 -100.0	33.8	ppm
Selenium (total)		20	2	<0.01 - 0.05	---	ppm
Extractable nutrients	NO_3-N	43	6	2.1 - 13.8	4.0	ppm
	P			6.85 - 38.54	15.44	
	K			<47.6 -280.4	136.4	
Ammonium acetate extractable cations	Ca	54	3	2.5 - 45.4	10.3	meq/100 g
	Mg			0.3 - 9.0	3.3	
	Na			0.6 - 39.5	1.4	
	K			<0.1 - 0.7	0.2	
Cation exchange capacity		54	3	1.3 - 88.4	20.0	meq/100 g
Base saturation		54	3	16.7 -100.0	83.4	%
Sulfur	Sulfate	28	3	<0.1	---	%
	Pyritic			<0.01 -0.09	---	
	Total			0.00 -0.48	0.07	
Acid potential		88	8	0.0 - 30.0	4.1	meq H^+/100 g
Neutralization potential		88	8	3.85 - +213.84	+24.2	tons $CaCO_3$ equivalent/ 1000 tons
Potential acidity*		88	8	-5.55 - +212.99	+22.3	tons $CaCO_3$ equivalent/ 1000 tons

* Positive values indicate excess $CaCO_3$ or basic overburden material.

Table 3. Summary geochemical and physical characteristics of 27 analyzed coal overburden samples from the Matanuska Valley.

Overburden parameter	Range	Mean	Units
Paste pH	4.7-9.0	7.3	pH
Electrical conductivity	0.1-2.2	0.6	umho/cm
Saturation percentage	20-56	36.3	%
Water soluble cations			
Calcium	0.3-9.9	1.1	meq/liter
Magnesium	0.1-7.0	1.7	
Sodium	0.4-24.0	3.5	
Potassium (saturated paste)	1.4-17.2	7.4	mg/l
Sodium adsorption ratio	0.2-36.9	5.8	ratio
Exchangeable sodium percentage	1.0-55.7	12.2	%
Particle size			
Sand	9-85	59.2	%
Silt	9-53	18.8	
Clay	5-49	22.0	
Texture	C, CL, L, LS, SL, SCL, SiCL*	- -	- -
Organic matter	0.9-32.0	5.1	%
Extractable nutrients			
Nitrate nitrogen (NO_3-N)	0.5-5.0	2.3	ppm
Phosphorous	<1.0-10.4	<1.6	
Potassium	39-252	128	
Pyritic sulfur	<0.01-0.4	<0.02	%
SO_4 sulfur	<0.01-0.1	<0.01	%
Organic sulfur	<0.01-0.76	0.11	%
Total sulfur	<0.01-0.78	0.12	%
Lime	<0.01-1.5	0.6	%
Acid potential (total sulfur)	-19.4-12.4	1.9	Tons $CaCO_3$ equivalent/ 1,000 tons
Acid potential (pyritic sulfur)	-0.9-14.4	5.4	do.
Trace elements			
Boron	1.50-5.30	3.05	ppm
Copper	0.24-18.88	3.53	
Molybdenum	<0.10-1.45	<.16	
Lead	0.14-7.04	1.12	
Selenium	<0.01	<0.01	

*C = clay; CL = clay loam; L = loam; LS = loamy sand; SL = sandy loam; SCL = sandy clay loam; and SiCL = silty clay loam.

Table 4. Summary geochemical and physical characteristics of 43 coal overburden samples from six general areas of the Nenana basin.

Overburden parameter	Range	Mean	Units
paste pH	5.2-7.3	6.2	pH
Electrical conductivity	0.2-1.6	0.5	mmhos/cm
Saturation percentage	20.7-101.6	50.3	%
Water soluble cations			
Calcium	0.1-42.2	3.8	meq/liter
Magnesium	0.1-11.4	2.2	
Sodium	0.4-4.9	1.8	
Sodium adsorption ratio	0.3-5.4	1.6	ratio
Exchangeable sodium percentage	0.4-8.7	3.2	%
Particle size			
Sand	6-83	38	%
Silt	4-68	39	
Clay	7-42	22	
Texture	LS, L, SL, SCL, SiL, SiCL, CL, C, SiC*	- -	- -
Bulk density	0.81-1.39	1.10	gms/cm^3
Organic matter	0.14-11.67	4.58	%
Total organic carbon	2.9-50.5	16.2	%
Extractable nutrients			
Nitrate nitrogen (NO_3)	1.1-31.5	5.9	ppm
Phosphorous	0.4-18.9	6.0	
Potassium	13-273	158	
Ammonium acetate extractable cations			
Calcium	0.2-161.2	17.5	meq/100 gms
Magnesium	0.8-16.1	6.0	
Sodium	0.0-1.5	0.4	
Potassium	0.1-0.9	0.4	
Cation exchange capacity	2.7-79.7	19.1	meq/100 gms
Base saturation	34-100	89	%
Total sulfur	0.01-0.34	0.08	%
Lime	4.6-25.1	7.4	%
Acid potential	0.01-21.25	4.79	meq H+/100 gms
Neutralization potential	13.8-60.6	21.6	tons $CaCO_3$ equivalent per 1000 tons
Potential acidity	11.9-50.6	19.2	tons $CaCO_3$ equivalent per 1000 tons
Trace elements			
Boron	0.45-6.85	2.17	ppm
Copper	0.31-32.14	10.34	
Molybdenum	0.12-0.76	0.44	
Lead	0.07-68.18	11.50	
Selenium	<0.01	<0.01	

*LS = loamy sand; L = loam; SL = sand loam; SCL = sandy clay loam; SiL = silt loam; SiCL = silty clay loam; CL = clay loam; C = clay; and SiC = silty clay.

Table 5. Comparison of overburden characteristics with their affected chemical or physical property in soils and mine spoil material (from Merritt, 1983).

PARAMETER	AFFECTED PROPERTY
pH	Acidity/alkalinity
Electrical conductivity (Ec)	Salinity
Sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP)	Salinity/physical texture
Soil (spoil) texture	Infiltration/ moisture retention capacity
Cation exchange capacity (CEC)	Texture/clay content/ nutrient levels
Organic matter	Productive capacity
Macronutrients (NO_3-N, PO_4, K)	Productive capacity
Micronutrients (Fe,Mn,Cu,Zn,B,Mo)	Productive capacity

Table 6. Range and mean values for the major-oxide contents of Nenana basin overburden samples.

MAJOR OXIDE	RANGE(%)	MEAN(%)
SiO_2	50.10-91.15	67.91
Al_2O_3	5.42-42.31	21.88
Total Fe as Fe_2O_3	0.00-19.48	3.16
MgO	0.20- 2.14	1.27
CaO	0.09-11.90	1.15
Na_2O	0.25- 1.77	0.64
K_2O	0.24- 4.38	2.74
TiO_2	0.19- 1.31	0.96
P_2O_5	0.03- 3.19	0.22
MnO	0.00- 0.31	0.04
TOTAL	94.94-102.34	99.97

Table 7. Geometric means (ppm) for certain trace element contents in Susitna lowland overburden samples (current study), Capps coal field and overburden suites from other areas in the conterminous United States (Hinckley and others, 1982).

Trace Element	Rock Type*	Susitna Lowland overburden	Capps coal field overburden, Beluga area, 1979	Capps coal field overburden, Beluga area, 1980	Ft. Union Formation overburden	Kimbeto, New Mexico overburden	Cretaceous overburden suite	San Juan Basin Topsoils	San Juan Basin Minesoils
Boron	1	22	17	--	42	13	14	7	13
	2	37	26	--	59	19	28		
Chromium	1	--	35	39	46	19	16	22	14
	2	--	61	70	72	30	43		
Cobalt	1	12	7	6	11	8	4	6	9
	2	16	9	8	9	12	9		
Copper	1	28	41	23	34	14	7	10	18
	2	51	40	43	38	39	30		
Lead	1	15	11	22	12	10	6	11	11
	2	26	20	37	11	16	13		
Manganese	1	761	167	412	233	183	75	260	340
	2	804	302	303	300	105	209		
Molybdenum	1	<10	2	--	2	2	2	2	3
	2	<10	2	--	6	3	2		
Nickel	1	26	23	24	26	12	10	9	12
	2	52	36	38	30	23	27		
Vanadium	1	--	60	71	75	60	37	45	56
	2	--	119	117	86	90	91		
Yttrium	1	--	17	15	30	26	19	27	32
	2	--	28	21	19	33	30		
Zinc	1	60	61	102	62	61	35	48	56
	2	100	108	143	59	80	105		

* 1--Coarse-grained rocks (sandstones)
2--Fine-grained rocks (claystones)

Table 8. Major oxide geochemistry of a gradational series of baked rocks from an upper Canyon Creek, Susitna lowland locality.

MAJOR OXIDE	SAMPLE	CnC3-1[a]	CnC3-2[b]	CnC3-3[c]	CnC3-4[d]	CnC3-5[e]
SiO_2		49.32	69.60	49.03	46.06	67.56
Al_2O_3		29.26	18.22	36.50	34.96	15.06
Fe_2O_3		1.93	1.02	2.17	4.36	4.20
MnO		0.01	0.01	0.02	0.15	0.07
MgO		0.21	0.04	0.25	0.56	0.20
CaO		0.70	0.55	1.00	2.34	0.47
Na_2O		0.22	0.24	0.26	0.66	4.71
K_2O		0.46	0.48	0.56	1.12	3.50
TiO_2		0.62	0.96	0.67	0.74	0.41
P_2O_5		0.18	0.17	0.27	0.44	0.14
LOI		9.97	3.88	2.91	2.65	1.07
$H_2O\cdot$		6.37	2.54	2.44	2.25	0.68
SUM		96.25	97.71	96.08	96.29	97.97

[a] -Shale, carbonaceous, relatively unaltered

[b] -Light gray baked claystone with abundant plant fossils

[c] -Cream-colored (beige) baked claystone

[d] -Pink to light red scoriaceous clinker, abundant hematite

[e] -Dark red to maroon burn, high hematite

FIGURE CAPTIONS

Figure 1...General location of major coal-overburden sampling areas of Alaska---the Susitna lowland, Matanuska Valley, and Nenana basin. Site-specific information is listed in Table 1.

2...Coal and coal-overburden sample configuration at a site in the Mystic Creek field, Nenana basin. Most of the overburden samples collected and analyzed represent the roof rock or seat rock adjacent to significantly thick coal seams.

3...Particle sizes and textures for Alaska coal overburden samples showing those rock materials that would tend to form poor texture zones in spoil material.

4...Range of unconfined compressive strength related to soil and rock hardnesses for Capps coal field, Susitna lowland samples (after Chleborad and others, 1982).

5...Weathered sulfate compounds coating surfaces and filling voids at a coal/overburden contact in the Matanuska Valley. The roof rock is a coarse-grained sandstone.

6...Overburden/interburden characteristics for a Fairview Mountain coal-bearing section (Tyonek Formation, northwest Yentna basin, Susitna lowland).

7...Histograms for pH and total sulfur content for Susitna lowland overburden samples. The frequency expresses the number of samples exhibiting a particular value.

8...Bar graph showing the range and arithmetic mean values for the percent total sulfur and sulfur forms of 27 analyzed Matanuska Valley coal-overburden samples.

Figure 9A...Acid-base account and other geochemical characteristics for overburden samples of a Wishbone Hill, Matanuska Valley, coal-bearing section (site WH3, top).

9B...Acid-base account and other geochemical characteristics for overburden samples of a Wishbone Hill, Matanuska Valley, coal-bearing section (site WH3, bottom).

10...Acid-base account and other geochemical characteristics for overburden samples of a Shovel Creek, Nenana basin, coal-bearing section.

11...Variation in the ammonium acetate extractable cations and total cation exchange capacity for a Peters Hills area (east Yentna basin, Susitna lowland, Tyonek Formation) coal-bearing section.

12...Histograms of major oxide analysis results for Susitna lowland coal overburden samples. Range and mean values are also listed. LOI (mean content 14.45%) and H_2O· (mean content 1.53%) are not shown.

13...Comparison of the range for certain trace element contents in overburden materials at six locales in the Susitna lowland (BR=Beluga River; CG=Capps Glacier area; FM=Fairview Mountain ; PA=Peters Hills area; SC=Saturday Creek; and WC=Wolverine Creek).

14...Gradational zones of burn material at an upper Canyon Creek coal-bearing section, Tyonek Formation, southwest Yentna basin, Susitna lowland.

15...Varicolored gleys weathering from burn material at a Tyonek Formation coal-bearing exposure near the Chuitna River, Beluga coal field, Susitna lowland.

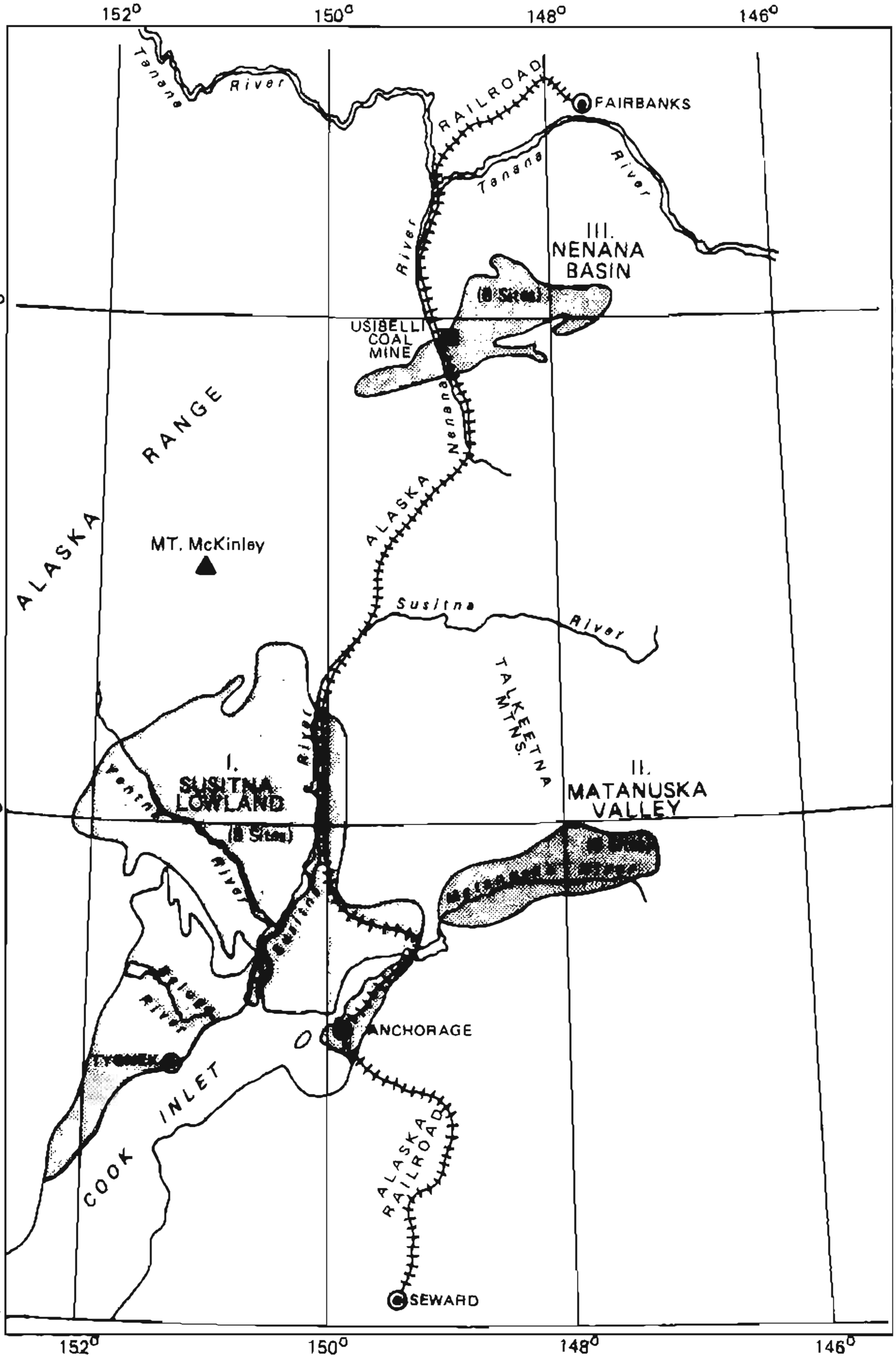

152°
150°
148°
146°
64°
62°
60°
Tanana River
RAILROAD
FAIRBANKS
Tanana River
River
III.
NENANA
BASIN
(8 Sites)
USIBELLI
COAL
MINE
Nenana
ALASKA RANGE
MT. McKinley
ALASKA
Susitna River
TALKEETNA MTNS.
I.
SUSITNA
LOWLAND
(8 Sites)
Yentna
River
River
Susitna
II.
MATANUSKA
VALLEY
River
TYONEK
ANCHORAGE
COOK INLET
ALASKA RAILROAD
SEWARD

Figure 1

Figure 2

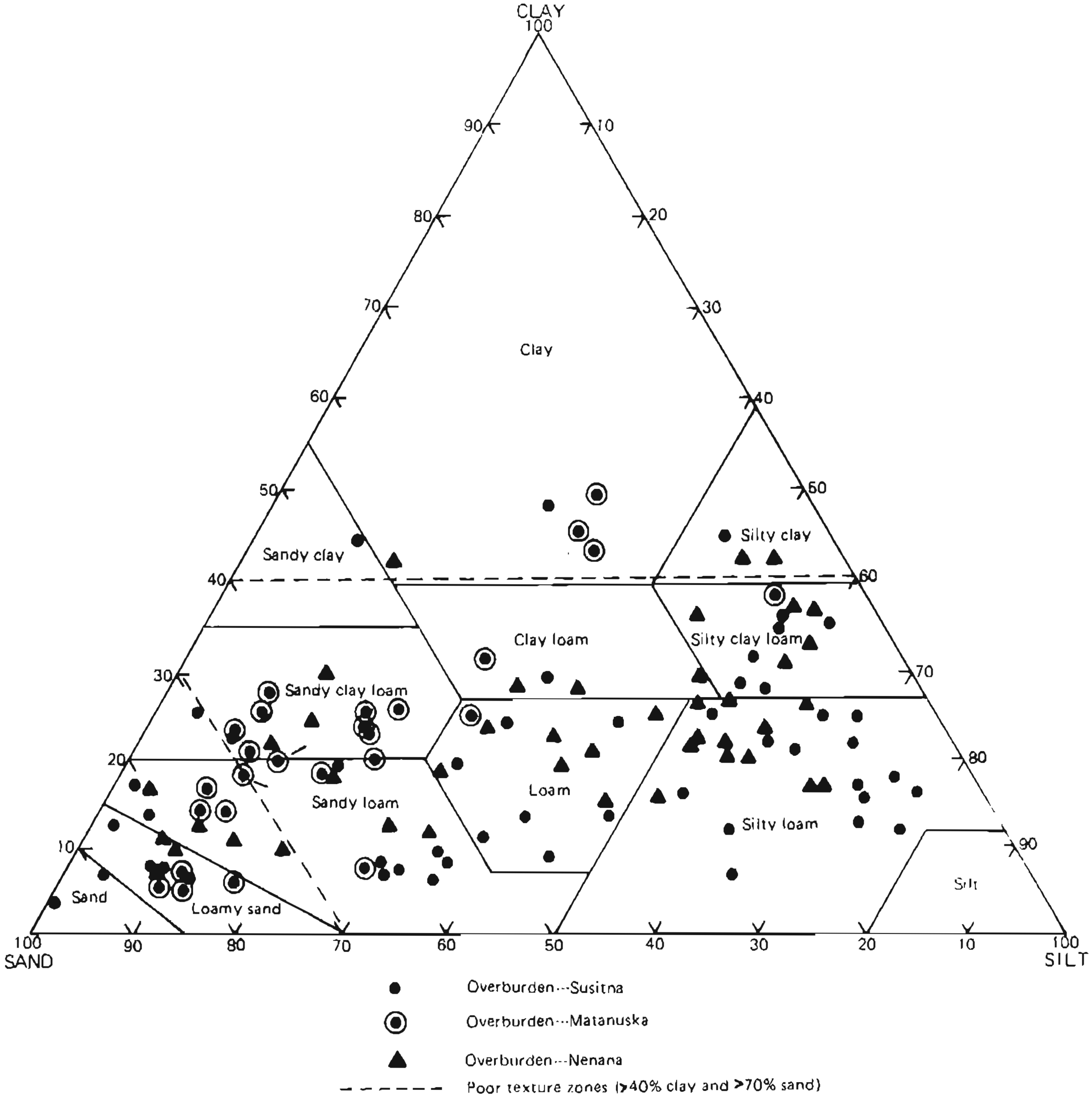

CLAY
100
90
80
70
60
50
40
30
20
10
10
20
30
40
50
60
70
80
90
100
SAND
90
80
70
60
50
40
30
20
10
100
SILT
Clay
Sandy clay
Silty clay
Clay loam
Silty clay loam
Sandy clay loam
Sandy loam
Loam
Silty loam
Sand
Loamy sand
Silt
● Overburden---Susitna
◉ Overburden---Matanuska
▲ Overburden---Nenana
– – – – – – Poor texture zones (>40% clay and >70% sand)

Figure 3

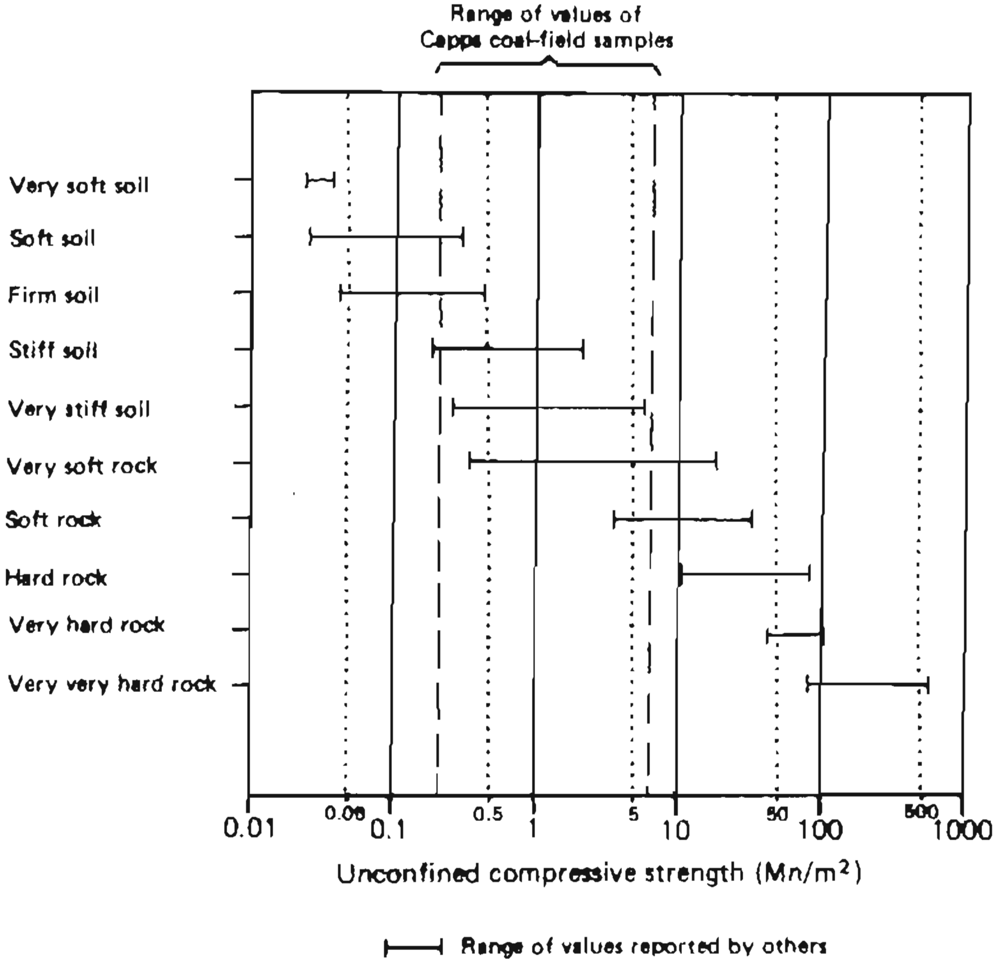

Range of values of
Capps coal-field samples
Very soft soil
Soft soil
Firm soil
Stiff soil
Very stiff soil
Very soft rock
Soft rock
Hard rock
Very hard rock
Very very hard rock
0.01
0.05
0.1
0.5
1
5
10
50
100
500
1000
Unconfined compressive strength (Mn/m²)
Range of values reported by others

Figure 4

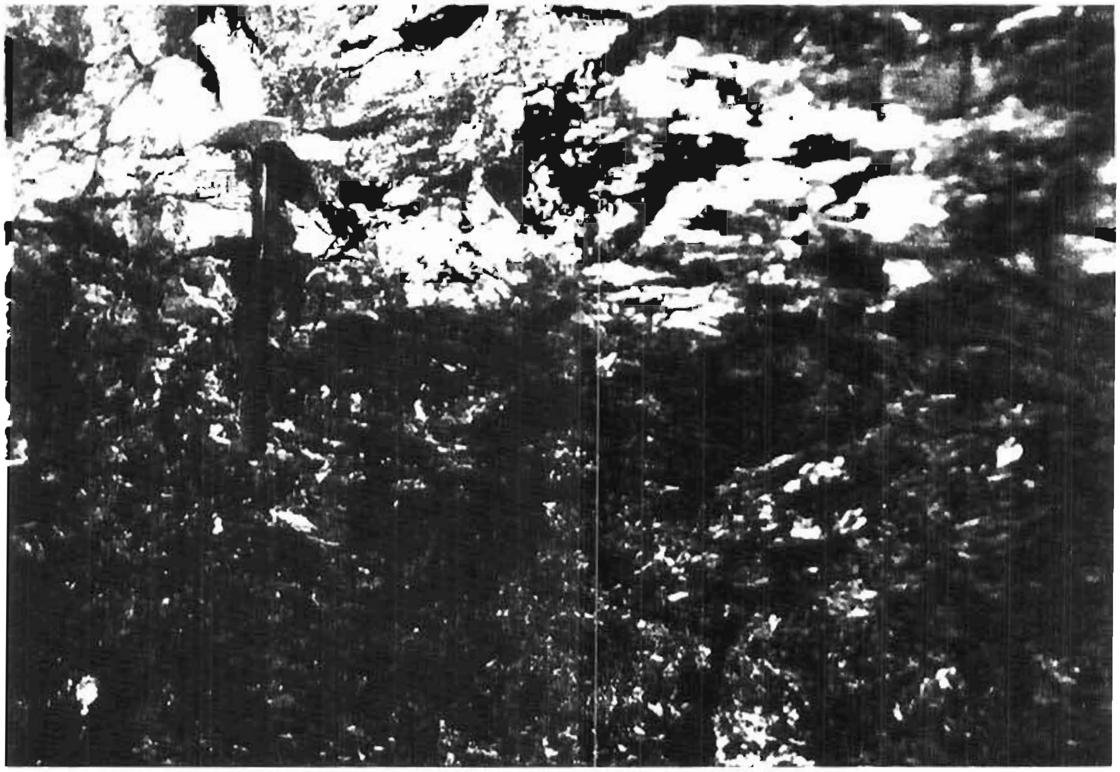
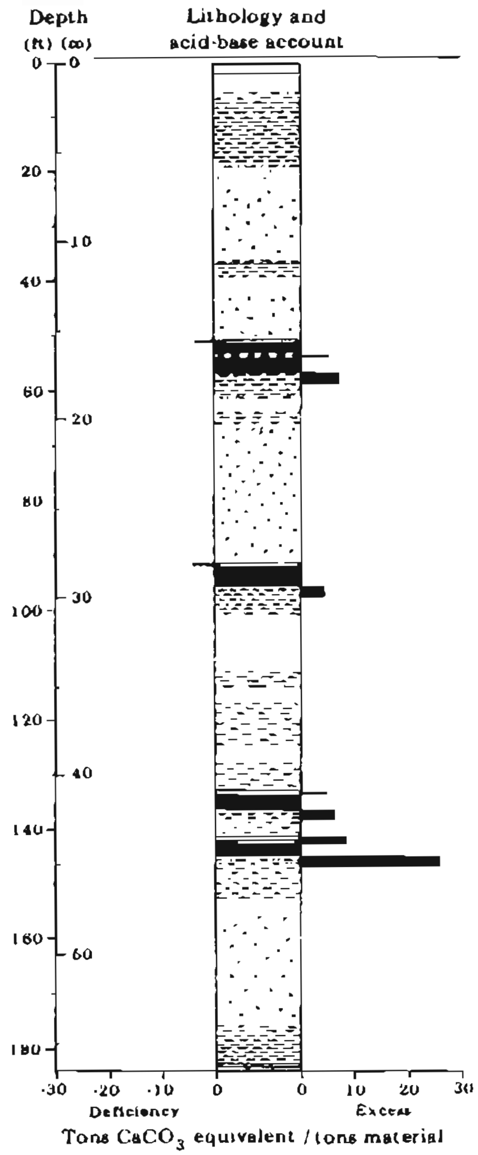


Figure 5



Sample number	Coal-seam designation	Description	Paste pH	Sulfur (%) Pyritic total	Lime (%)	Organic matter (%)
FM1-1	F Seam	Roof. carbonaceous shale	4.1	0.06 / 0.30	10.0	9.46
FM1-3		Parting. carbonaceous claystone	4.8	0.02 / 0.06	9.8	6.10
FM1-5		Seatrock: claystone	5.1	0.01 / 0.02	9.9	1.59
FM1-6	E Seam	Roof. carbonaceous shale	4.2	0.01 / 0.48	9.0	8.63
FM1-8		Seatrock. claystone	4.7	0.02 / 0.02	10.0	2.32
FM1-9	D Seam	Roof. carbonaceous shale	4.6	0.01 / 0.14	9.3	11.89
FM1-11		Seatrock claystone	5.1	0.01 / 0.01	9.9	1.27
FM1-12	C Seam	Roof: carbonaceous shale	4.8	0.04 / 0.32	8.2	9.56
FM1-14		Seatrock. sandy claystone	7.2	0.04 / 0.04	10.1	1.94

Figure 6

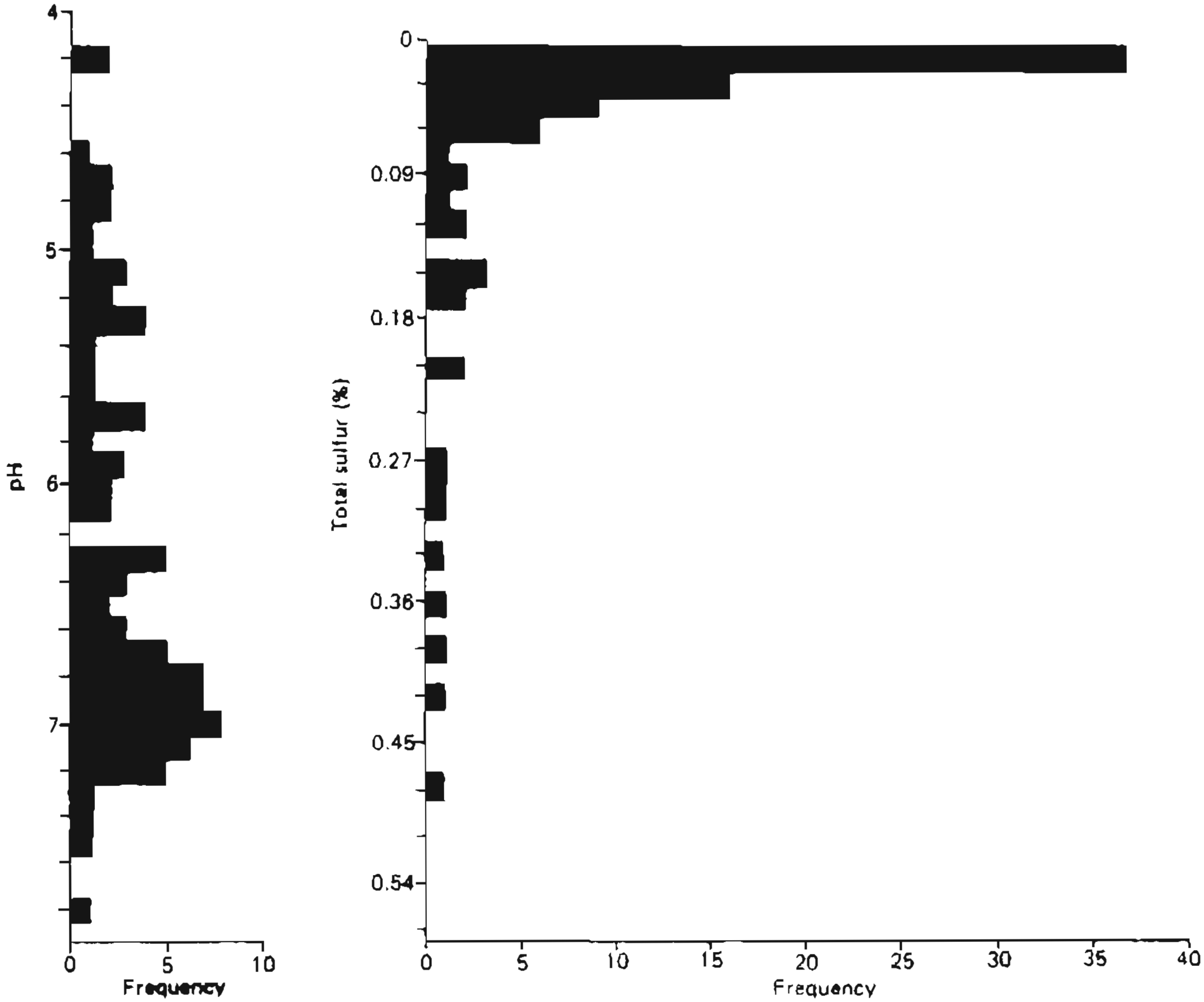

pH
4
5
6
7
0
5
10
Frequency
Total sulfur (%)
0
0.09
0.18
0.27
0.36
0.45
0.54
0
5
10
15
20
25
30
35
40
Frequency

Figure 7

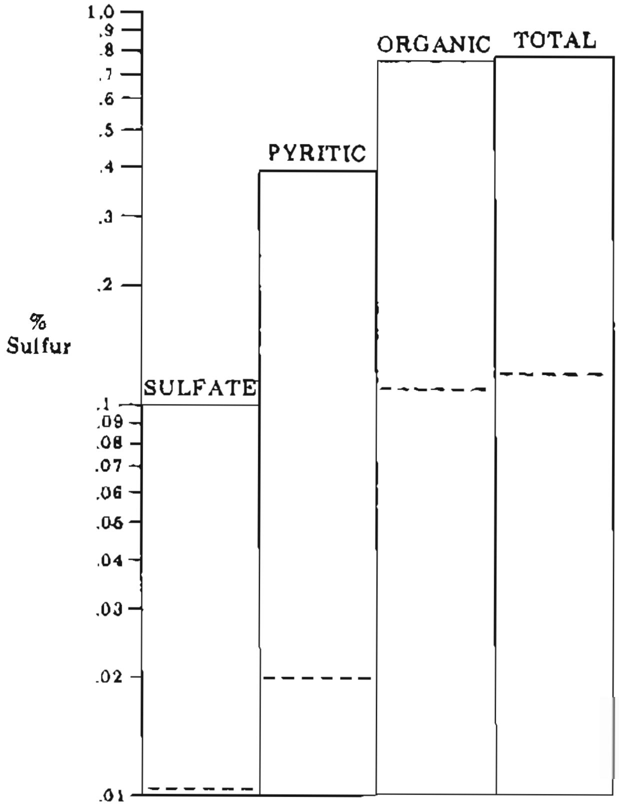
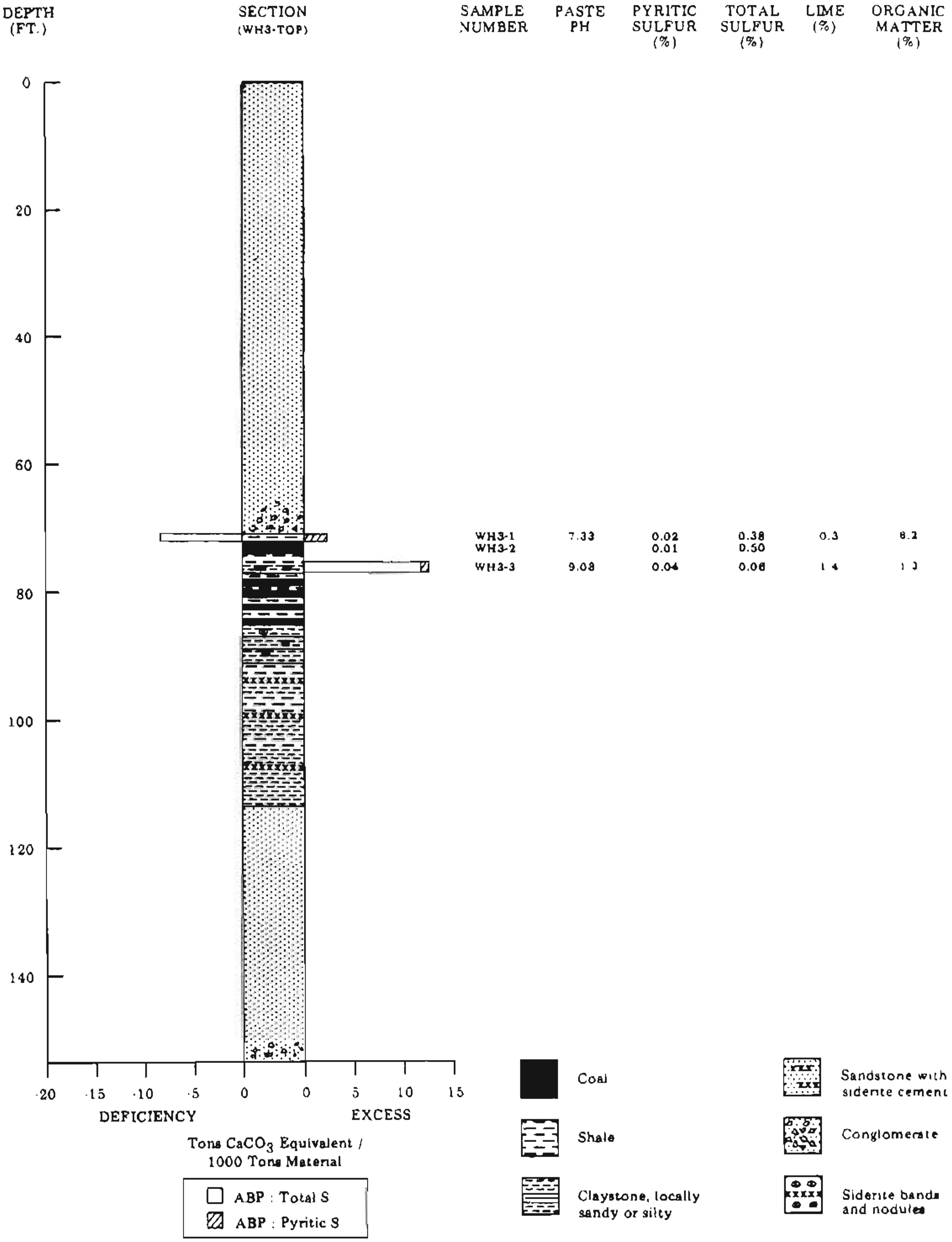
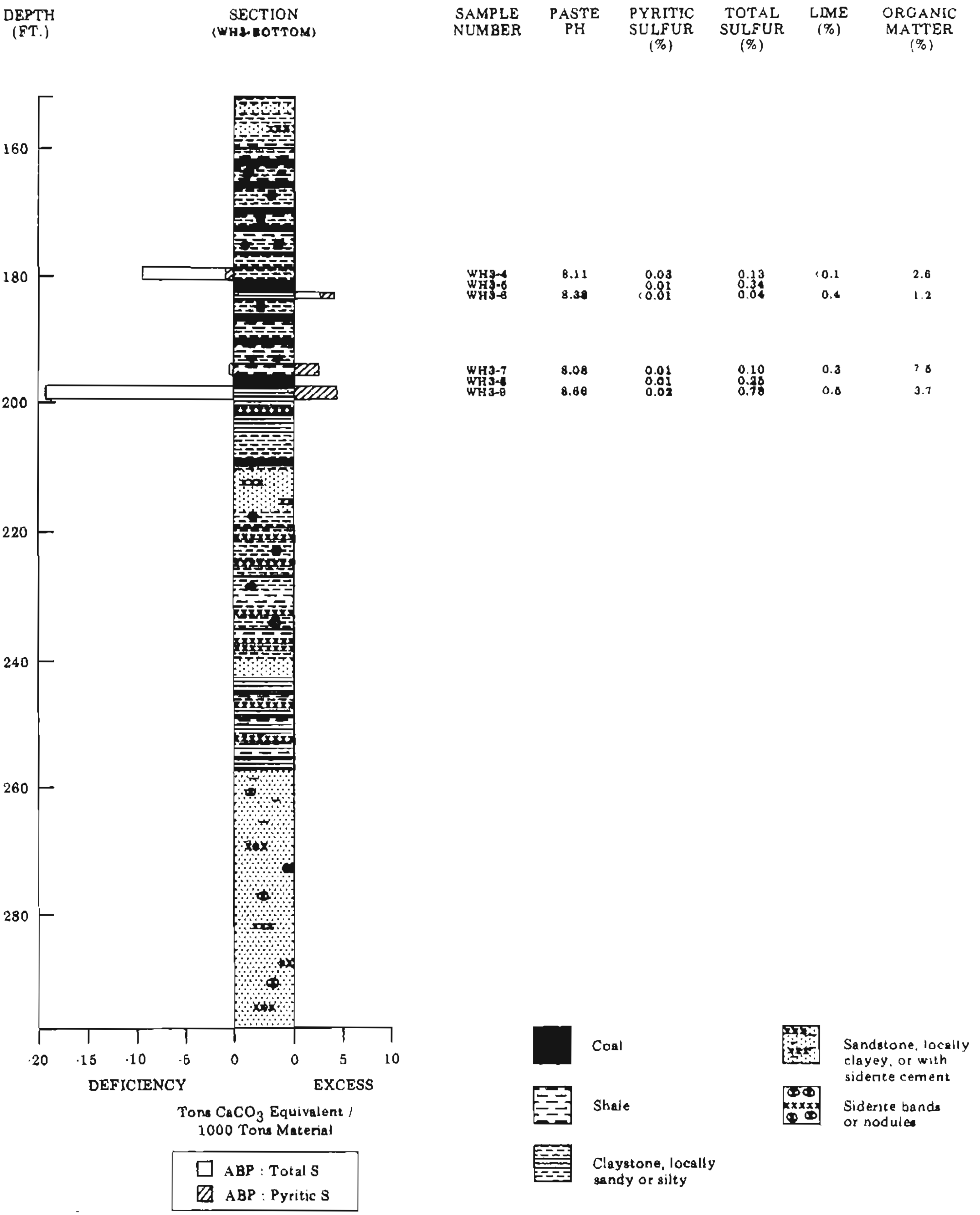

1.0
.9
.8
.7
.6
.5
.4
.3
.2
%
Sulfur
.1
.09
.08
.07
.06
.05
.04
.03
.02
.01
SULFATE
PYRITIC
ORGANIC
TOTAL

Figure 8



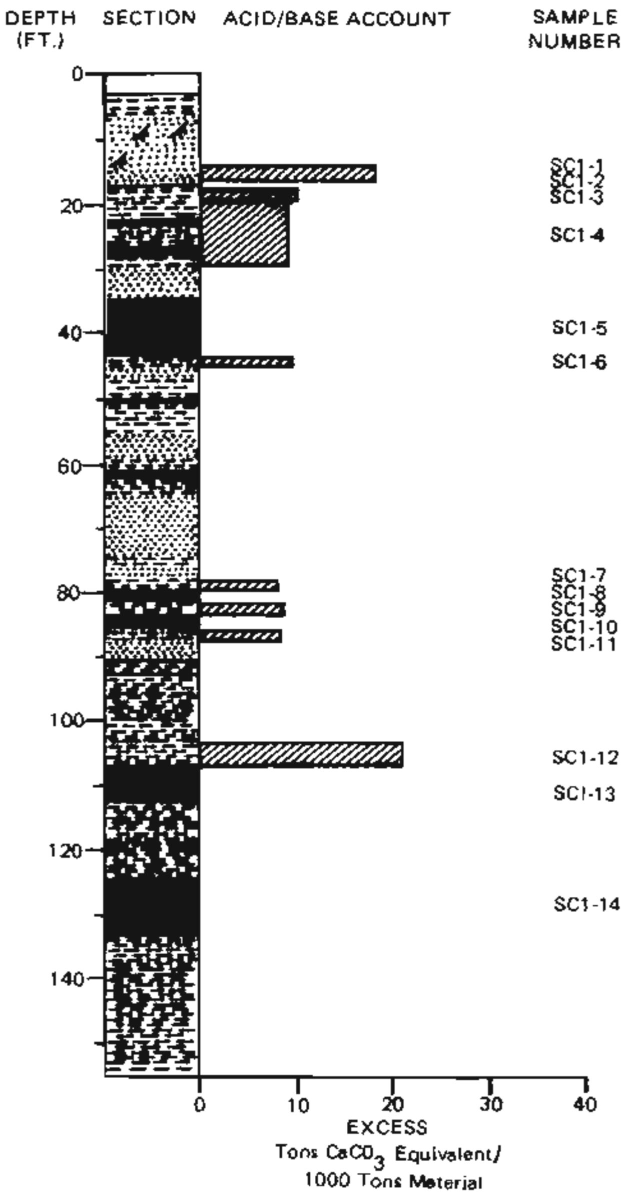
SAMPLE NUMBER	PASTE PH	PYRITIC SULFUR (%)	TOTAL SULFUR (%)	LIME (%)	ORGANIC MATTER (%)
WH3-1	7.33	0.02	0.38	0.3	8.2
WH3-2		0.01	0.50		
WH3-3	9.08	0.04	0.06	1.4	1.3

Figure 9A



SAMPLE NUMBER	PASTE PH	PYRITIC SULFUR (%)	TOTAL SULFUR (%)	LIME (%)	ORGANIC MATTER (%)
WH3-4	8.11	0.03	0.13	<0.1	2.6
WH3-5		0.01	0.34		
WH3-6	8.39	<0.01	0.04	0.4	1.2
WH3-7	8.08	0.01	0.10	0.3	7.6
WH3-8		0.01	0.25		
WH3-9	8.66	0.02	0.78	0.5	3.7

Figure 9B



SAMPLE NUMBER	LITHOLOGIC DESCRIPTION	PASTE pH	TOTAL SULFUR (%)	ORGANIC MATTER (%)	TOTAL ORGANIC CARBON (%)	LIME (%)
SC1-1	Sandstone, reddish brown to medium brown, medium grained	6.6	0.14	7.56	24.5	10.6
SC1-2	Coal		0.41			
SC1-3	Claystone, dark grayish brown, carbonaceous	6.6	0.03	5.54	10.5	5.2
SC1-4	Claystone, shale, carbonaceous, and coal, dark brownish gray to black	6.2	0.12	7.31	24.5	5.8
SC1-5	Coal		0.30			
SC1-6	Claystone, medium brown	5.7	0.02	4.98	8.9	5.1
SC1-7	Claystone, dark grayish brown	5.8	0.11	6.43	13.5	5.1
SC1-8	Coal		0.44			
SC1-9	Claystone, medium brown	6.3	0.04	4.45	8.1	4.8
SC1-10	Coal		0.37			
SC1-11	Claystone, medium grayish brown	6.3	0.04	4.23	6.9	4.6
SC1-12	Claystone, medium brown	7.0	0.04	4.97	11.1	11.1
SC1-13	Coal		0.39			
SC1-14	Coal		0.31			

Figure 10

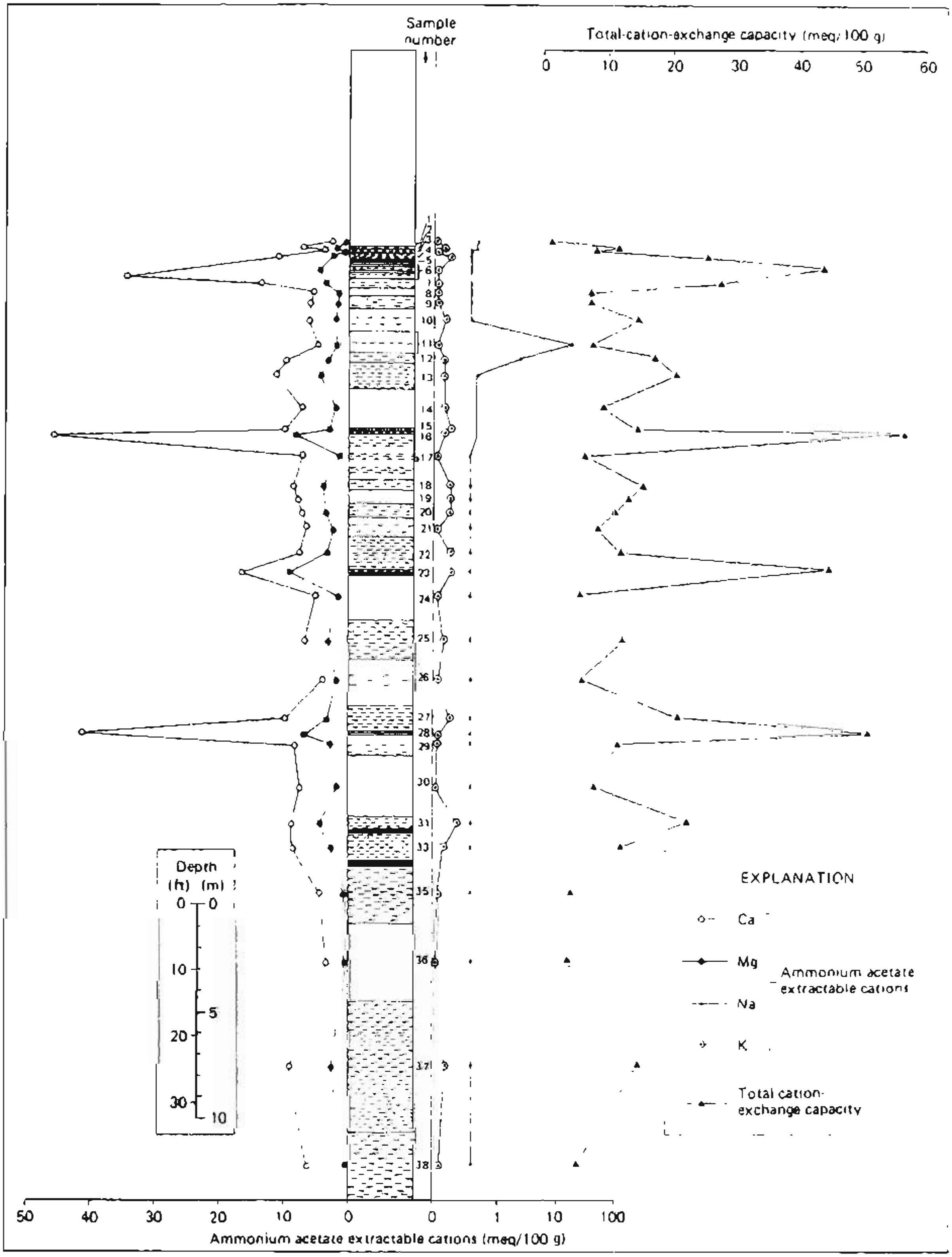

Sample number
Total-cation-exchange capacity (meq/100 g)
0
10
20
30
40
50
60
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
33
35
36
37
38
Depth
(ft)
(m)
0
0
10
5
20
30
10
EXPLANATION
Ca
Mg
Na
K
Ammonium acetate extractable cations
Total cation-exchange capacity
50
40
30
20
10
0
0
1
10
100
Ammonium acetate extractable cations (meq/100 g)

Figure 11

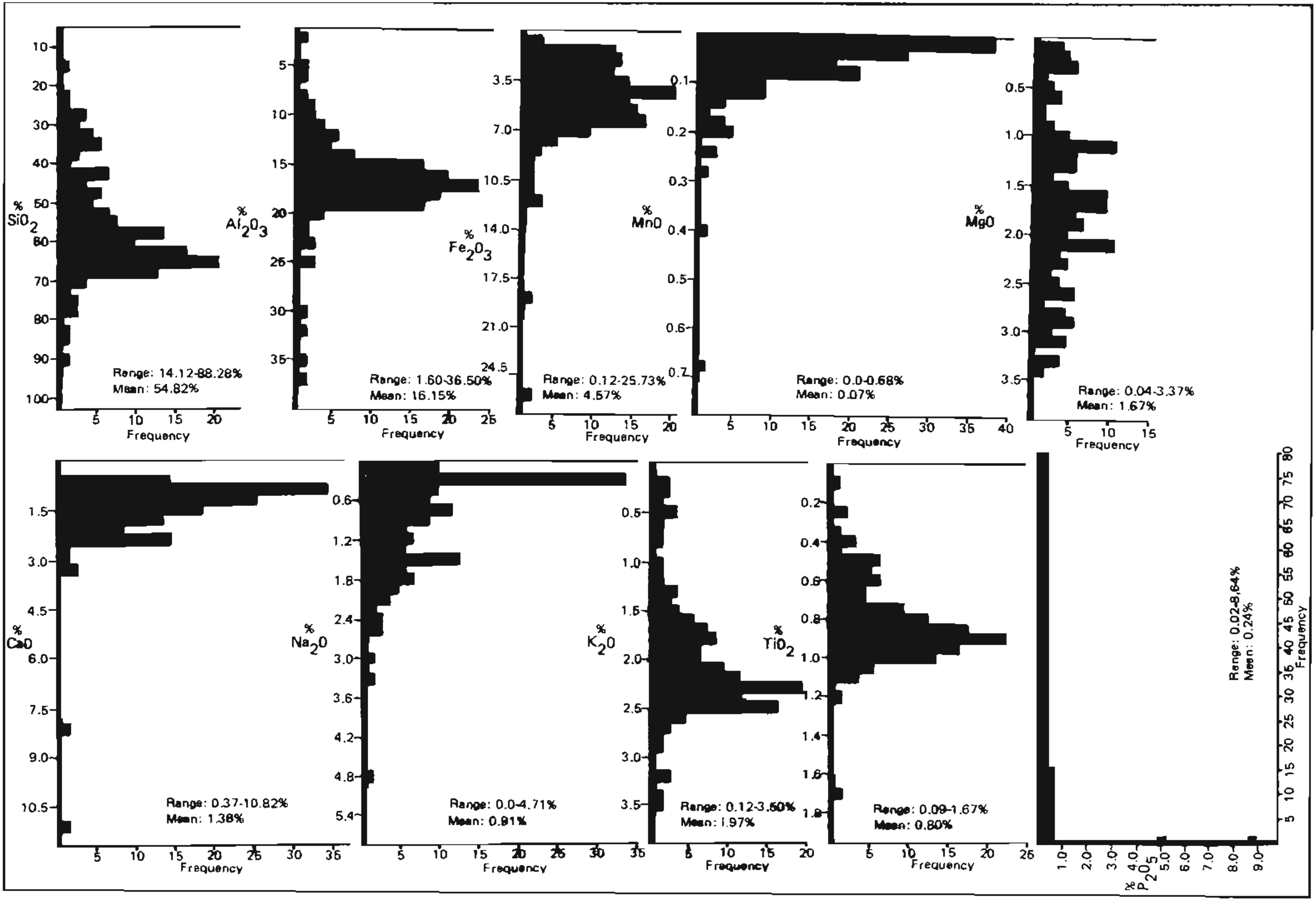
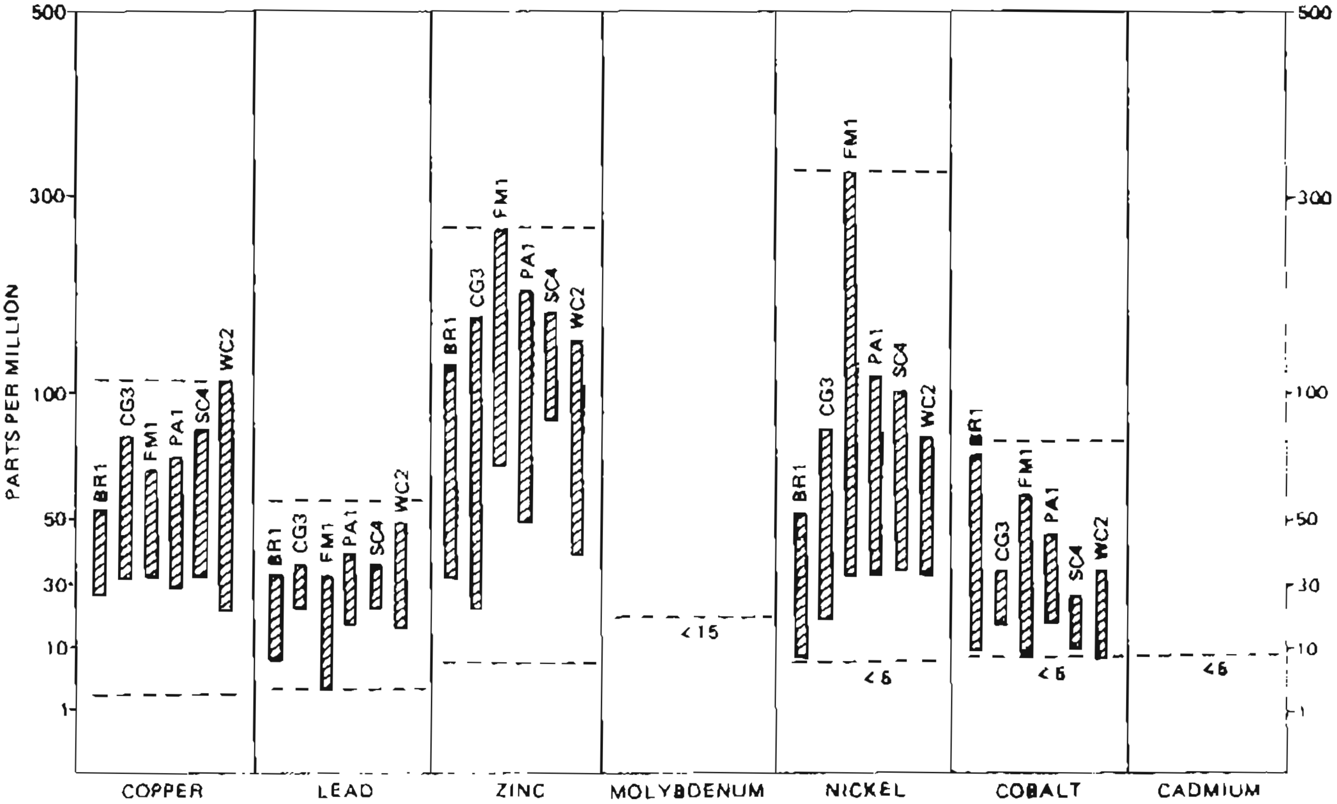

% SiO$_2$
Range: 14.12-88.28%
Mean: 54.82%
% Al$_2$O$_3$
Range: 1.60-36.50%
Mean: 16.15%
% Fe$_2$O$_3$
Range: 0.12-25.73%
Mean: 4.57%
% MnO
Range: 0.0-0.68%
Mean: 0.07%
% MgO
Range: 0.04-3.37%
Mean: 1.67%
% CaO
Range: 0.37-10.82%
Mean: 1.38%
% Na$_2$O
Range: 0.0-4.71%
Mean: 0.81%
% K$_2$O
Range: 0.12-3.60%
Mean: 1.97%
% TiO$_2$
Range: 0.09-1.67%
Mean: 0.80%
% P$_2$O$_5$
Range: 0.02-8.64%
Mean: 0.24%
Frequency

Figure 12



PARTS PER MILLION
500
300
100
50
30
10
1
BR1
CG3
FM1
PA1
SC4
WC2
<15
<6
COPPER
LEAD
ZINC
MOLYBDENUM
NICKEL
COBALT
CADMIUM

Figure 13

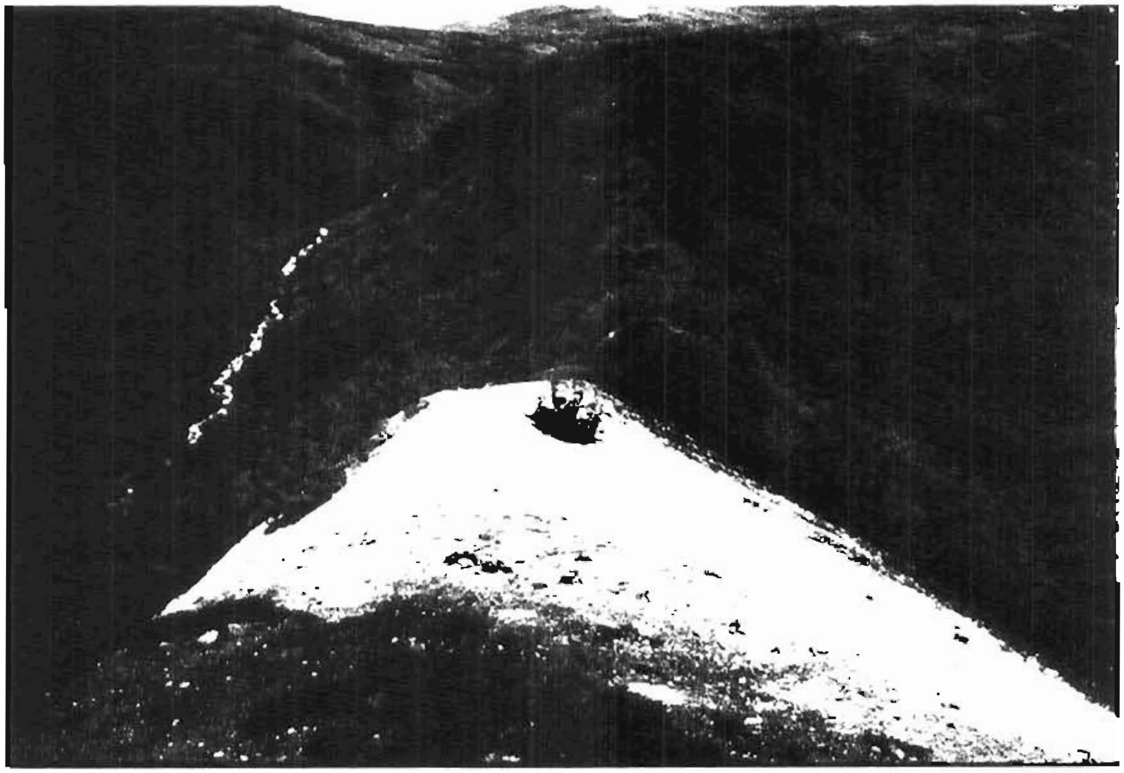


Figure 14

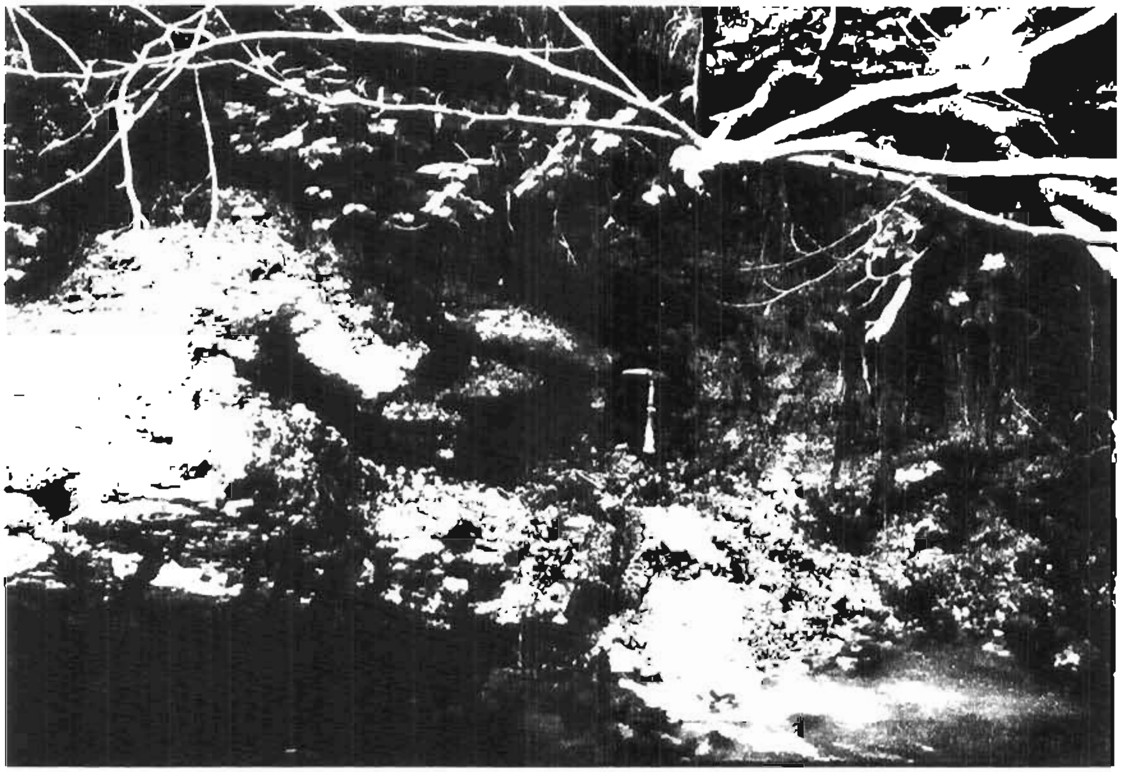


Figure 15