CHARACTERISTICS AND FERTILITY STATUS OF SOILS AND MINESOILS IN SELECTED AREAS OF USIBELLI COAL MINE, HEALY, ALASKA

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Introduction

Alaska has been proven to contain not only bountiful oil and gas reserves, but also vast coal fields occurring from the southcentral coastline to the Interior and the Arctic zone to the north. Because of concerns for stable sources of energy, particularly by the energy-short, industrial nations of the Orient, more exploration and stripmining for coal can be expected in the near future. Therefore, it is important to know the consequences of large-area soil disturbances in the subarctic and how the effects of man's reclamation efforts and natural processes combine in reestablishing vegetative community. The culmination or synthesis of these processes is soil development and is of great importance in successful stripmine reclamation.

The Usibelli Coal Mine Company in the Healy coal field, located in interior Alaska, commenced stripmining in 1943. Its operation has been continuous, moving from area to area, for the last 40 years. Stripmining requires the excavation of overburden and subsequent redeposition, therefore the Healy operation has exposed minespoils from different strata on various topography. In 1972, the Usibelli Coal Mine company initiated a reclamation program and, over the ensuing 10 years, has seeded and fertilized over 2000 acres. Nevertheless, there remain barren areas and areas undergoing natural revegetation. Additionally, experimental trials in seeding and fertilization were started in 1980. Large areas of intact native plant communities adjoin the mined areas. The company property provides opportune sites to study the processes of soil formation under different sets of conditions.

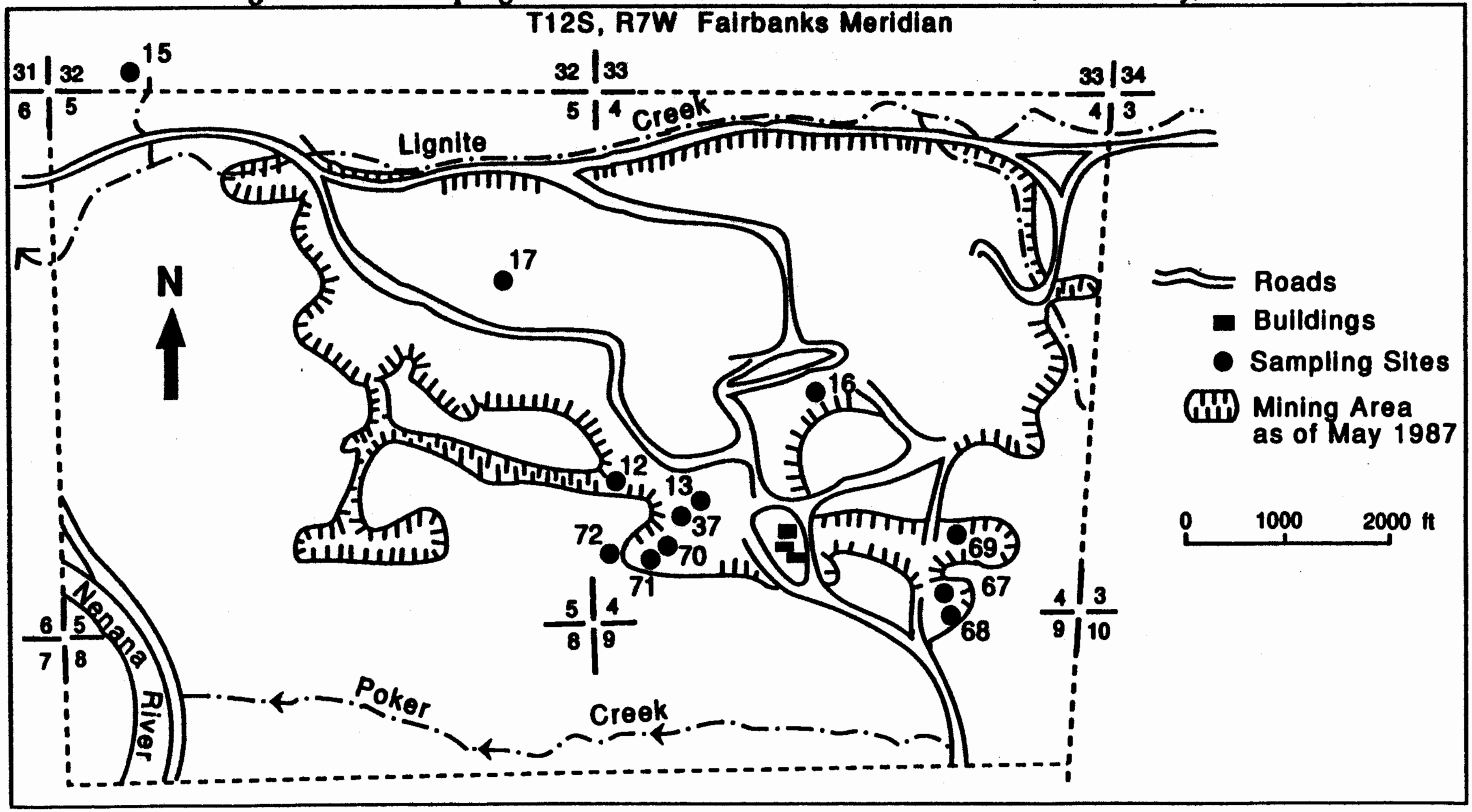
The objectives of this study were to (1) characterize the soils on the mine lease area for baseline data, (2) to characterize the minesoils with various history, (3) to study the process of soil formation under different sets of conditions, and (4) to evaluate the nutrient levels of both soils and minesoils to form a basis for establishing soil-handling requirements to promote reclamation practices.

Materials and Methods

It was not the purpose of this study to do a soil survey of the area, rather to study the soil-vegetation-landscape relationships. Soil pits (pedons) were excavated on representative land forms on Poker Flats and major terraces along Healy Creek. Eight pits representing four major soil subgroups were sampled, and 23 pits representing six major minespoil depositions were sampled. Four pits of minesoils were pair-sampled on revegetated and nonvegetated (or eroded) sites to compare the difference in minesoil development. All soils and minesoils pits were described following the revised Soil Survey Manual (Soil Survey Staff 1980), and the soils were classified according to Soil Taxonomy (Soil Survey Staff 1975). Vegetation was recorded for each site along with other physiographic features such as land form and slopes. Soils on steep slopes or ravines, and along the stream that lack diagnostic horizons were not sampled but field-described in a narrative form. Aerial photographs from 1972 flights with a scale of 1:12,000 were used as a base map to show the sampling sites in the Poker Flats and Healy Creek areas (Fig. 1), the Hydraulic Pit and Vitro Pit areas (Fig. 2), and U-2 infrared imagery enlarged to a scale of 1:6,000 was used for the Gold Run Pass area (Fig. 3). The distribution of soils and minesoils was approximated by correlating landforms, vegetation, and drainage with photo images verified by soil pits and spot checks.

All samples were submitted to the Soil and Plant Tissue Analysis Laboratory at the Palmer Research Center of the Agricultural and Forestry Experiment Station, University of Alaska Fairbanks. All samples were air-dried and sieved to remove the fraction greater than 2 mm in diameter. All characterization analyses follow the National Soil Survey Laboratory (NSSL) procedures defined in Soil Survey Investigation Report (SSIR) No. 1 (Soil Conservation Service 1984) unless otherwise specified. The pH was measured in water (1:1) and SMP buffer solution. Organic carbon was determined by the Walkley-Black wet-combustion method. Cation exchange capacity (CEC) and exchangeable cations were extracted by 1 N NH_4OAc at pH 7.0

Figure 1 — Soil sampling sites in Poker Flats area of Usibelli Coal Mine, east of Healy, Alaska



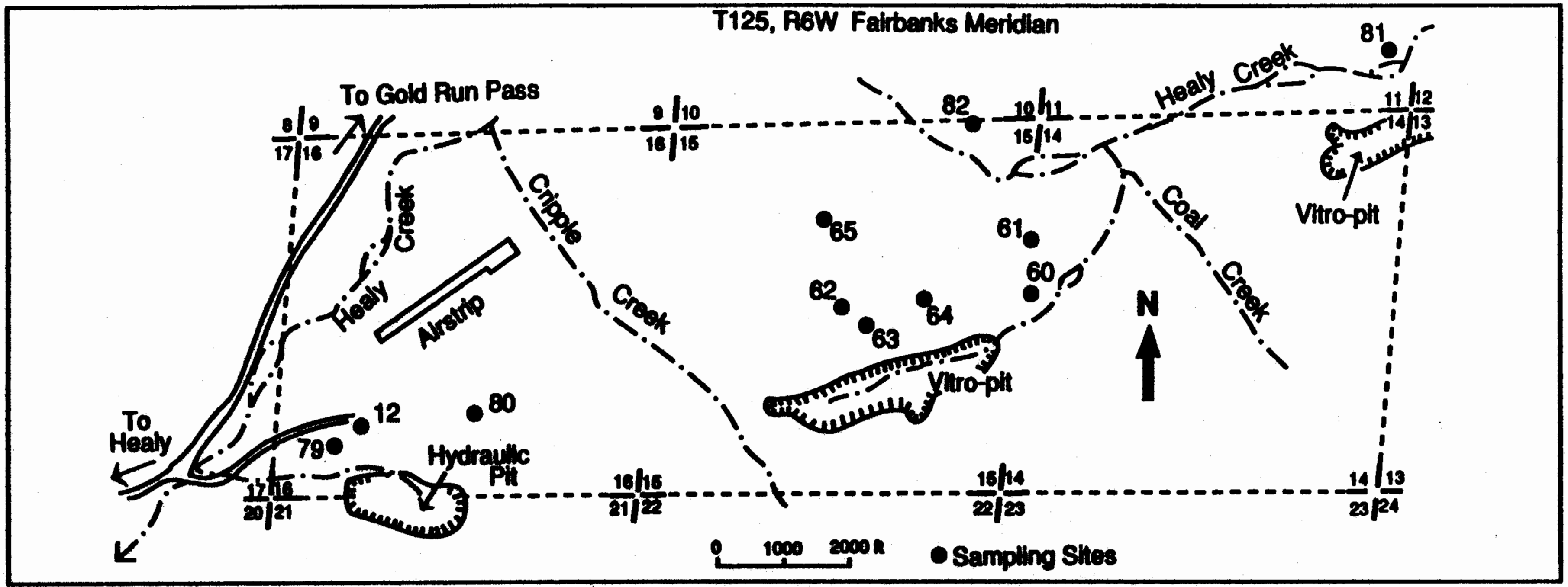


Figure 2 — Soil sampling sites in Hydraulic Pit and Vitro Pit area, Usibelli Coal Mine, Healy, Alaska

and determined by steam distillation and atomic absorption, respectively. Total nitrogen was determined by the micro-Kjeldahl method.

Extractable Al and Fe were extracted by dithionite-citrate and sodium pyrophosphate solutions. Particle size distribution was determined by the hydrometer method. Bulk density was measured by the core method. The soil samples and the minespoils were also analyzed for nutrient levels of available nitrogen (2N KCl), phosphorus (Bray-1), and available Zn, Mn, Fe, and Cu (DTPA-TEA), soluble Ca, Mg, K, and Na (saturated extracts) and electrical conductivity (saturated extracts) according to standard soil-testing procedures used in Alaska (Michaelson et al. 1987). In addition, the Usibelli Coal Mine submitted 14 overburden and spoil samples for fertility analysis. The mine also submitted samples from two drill holes in Poker Flats for overburden and interburden analysis. Clay mineralogy of selected soil samples was determined by X-ray diffraction analysis using the oriented clay specimens (<0.002 mm) after the following treatments: Mg saturation and glycerol solvation, K saturation, and heating at 550 degrees Celsius for 1 hour (Whittig and Allardice 1986).

Soil Environments

The study areas are located 3 to 10 miles east of Healy. The Poker Flats area includes sections 4 and 5, the west half of section 3, and the northern halves of sections 8 and 9 of T12S, R7W, Fairbanks Meridian. The Vitro-Hydraulic pit areas are in sections 11, 14, 15, 16, and 17 of T12S, R6W Fairbanks Meridian. The Gold Run Pass area includes the SW portion of Section 35, T11S, R6W Fairbanks Meridian, (Fig. 3).

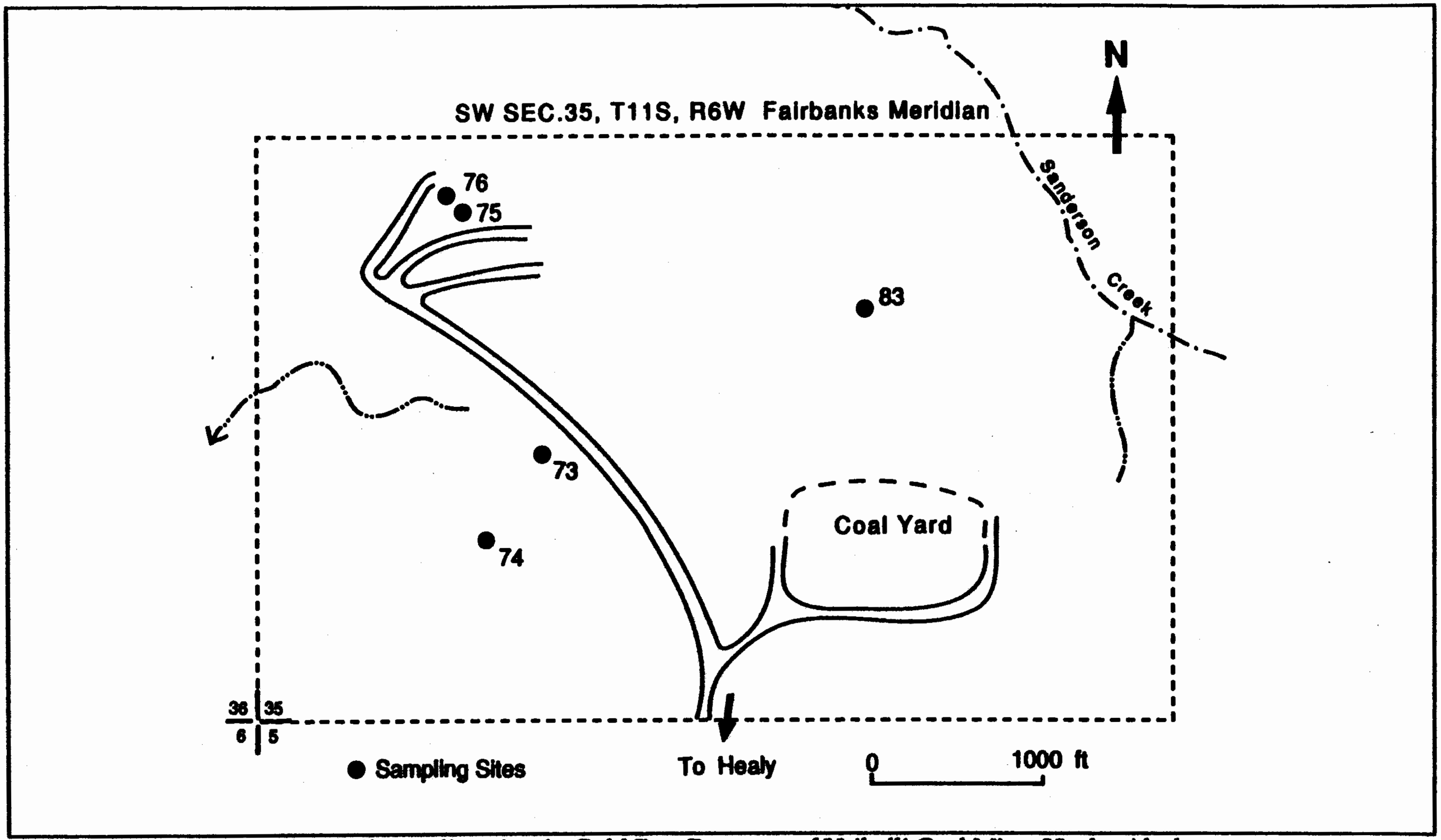


Figure 3 — Soil sampling sites in Gold Run Pass area of Usibelli Coal Mine, Healy, Alaska

Physiography and Drainage

The Poker Flats area consists mainly of nearly level to gently sloping glacial outwash terraces with an elevation of 1750 feet above sea level. The area is bound to the north by Lignite Creek which generally follows the fault zone of the Suntrana Formation and other coal-bearing formations (Denton 1980). The valleys, carved by the creek and its tributaries, are generally V-shaped with a relief up to 500 feet. Major coal-mining activities are on the south side of the creek. To the west, the Flats break steeply toward the Nenana River which drains north. To the south, the Flats are bound to the south by narrow V-shaped valleys dissected by Poker Creek and its tributaries. The area is banked on rounded hills and ridges to the east with elevations of 3000 feet. Extensive stands of aspen, paper birch, and white spruce grow on most of the well-drained sites. Permafrost forms in depressions with mosses, sedges, low-growing shrubs and sparse black spruce.

The Vitro-Hydraulic pits area lies south of Healy Creek. The area was largely disturbed by early mining activities. The area east of Hydraulic pit is composed of glacial outwash plains and river terraces with nearly level slopes, with extensive stands of white spruce and shrubs. Further east, across one of the tributaries of Healy Creek, is a north-facing, gently sloped tundra with permafrost, which is joined by Vitro-pit to the east. The Gold Run Pass area lies south of Lignite Creek with an average elevation of 2500 feet. The area consists mainly of rounded hills and ridges with permafrost formed on some gentle, north-facing slopes.

Parent Materials

The well-drained upland positions of the Poker Flats area are covered with 10 to 20 inches of loess deposits. Lacustrine and other sediments are found along the edge of the steep slopes south of Lignite Creek, and depressions on the Flat. The loess and lacustrine deposits overlay a layer of glacial outwash known as the Nenana Gravel with thickness ranging from a few feet along the northern edge of the terrace break facing Lignite Creek, to more than several hundred feet deep to the south of the Flat. This outwash layer is composed mainly of cobbles, pebbles, and coarse sand which are iron-stained in the top 40 to 60 feet. Based on recent study (Thorson 1986), this outwash terrace is older than the drift of Healy age, and is assigned as Lignite Creek age of late Cenozoic time. Below the outwash layer is the coal-bearing Suntrana Formation which outcrops along the south valley walls of Lignite Creek and dips southward. There are six coal seams in this formation, and some of the coal seams are 17 to 24 feet thick. The coal seams are separated by 30 to 150 feet of unconsolidated sandy material with thin lenses of finer textured deposit near the top of some coal seams (Usibelli Coal Mine, 1982. These sandy materials comprise the bulk of overburden and coal spoils.

Climate

The climatic data were summarized from two weather stations in the Healy area (Table 1). The Poker Flats station is located on a plateau, about 1 mile east of Healy Station and is 330 feet higher than the latter and experiences cooler temperatures and more precipitation.

The areas have a continental climate. The mean annual air temperature (MAAP) is about 30 degrees Fahrenheit in Healy and 26 degrees Fahrenheit in Poker Flats. December, January, and February are the coldest months. The Arctic High moves south in the winter with cold and dry air masses. The mean annual precipitation (MAP) is about 15 inches in Healy, and 17 inches in Poker Flats. The mean winter (Dec.-Feb.)snowfall is equivalent to 5-7 inches of precipitation. The summer is the wettest season, caused by the moist air from the ocean to the south. Two-thirds of the MAP comes between June and September. The distribution of monthly precipitation and air temperature is summarized in Table 1. The moisture regime of the area is udic based on precipitation distribution. The temperature regime of well-drained soils is cryic based on studies of similar soil environments (Rieger 1973). Calculated from 7 years of complete records, the average frost-free season is about 90 days with a maximum of 120 days and a minimum of 50 days based on 32 degrees Fahrenheit. The area has frequent strong winds occurring either in the summer or winter. The average wind speed ranges from 20 to 35 miles per hour with occasional gusts of 40 to 55 miles per hour.

Vegetation

The major vegetation types associated with the major soil-landscape associations consist of open black spruce forest, open mixed paper birch-spruce forest, closed birch forest, and ericaceous shrub tundra (Helm 1985). Soils supporting these vegetation types are represented by sites 1, 5, 16, 72, and 74. The native vegetation associated with the deep, well-drained soils on broad upland terraces and hillsides consist mainly of open mixed paper birch-spruce forest, and secondarily of open black spruce forest. The major tree species include *Picea glauca, Picea marianna, Betula papyrifera, Populus tremuloides.* The major shrub species include *Vaccinium uliginosum, Vaccinium vitis-idaea, Ledum groenlandicum, Alnus crispa, Empetrum nigrum, Linnaea borealis,* and *Salix* sp. Major forbs and graminoids include *Cornus canadensis, Epilobium angustifolium, Calamagrostis canadensis, Lycopodium,* and *Rubus arcticus.* The ground layer is dominated by moss and lichens.

The native vegetation associated with the tundra soils with permafrost consists mainly of the ericaceous shrub tundra type. Soils supporting this vegetation type are represented by sites 12, 62, and 69. The major tree species are scattered *Picea mariana.* The major shrub species include *Vaccinium uliginosum, Vaccinium vitis-idaea, Ledum groenlandicum, Betula glandulosa, Alnus crispa,* and *Salix* sp. Major forbs and graminoids include *Carex bigelowii, Equisetum pratensis,* and *Eriophorum vaginatum.* The ground layer is dominated by moss and lichen.

The native vegetation associated with well-drained steeper slopes along the valley walls and drainage consists mainly of closed birch forest. The overstory is dominated by *Betula papyrifera* with some *Picea glauca.* The understory is dominated by shrubs, forbs, and graminoids including *Calamagrostis canadensis, Carex* sp., *Vaccinium uliginosum, Alnus crispa, Vaccinium vitis-idaea, Ledum groenlandicum, Rosa acicularis, Cornus canadensis, Epilobium angustifolium,* and *Lycopodium.* The ground layer includes some moss and lichens.

The native vegetation associated with the alluvial terraces along the major streams and their tributaries consists mainly of open alder shrublands and some closed birch forests. There are scattered *Betula papyrifera* and *Picea mariana.* But the stand is dominated by shrubs and graminoids including *Ledum groenlandicum, Vaccinium uliginosum, Alnus crispa, Betula glandulosa,* and *Vaccinium vitis-idaea.* Moss is common on the ground layer.

Results and Discussion

Morphological and Physical Properties

Part 1. Natural Soils

The morphological properties of natural soils are described and discussed according to soil subgroups.

Dystric Cryochrepts

These deep, well-drained soils are on broad upland terraces and hillsides. They formed in loess mixed with or without volcanic ash over deep glacial outwash (Nenana Formation) west of Poker Flats, and over a thin layer of glacial outwash or drift over sandstone from east of Poker Flats to Gold Run Pass. Slopes range from 0 to 40 percent. Elevation ranges from 1700 to 2500 feet. The major vegetation types associated with these soils are open mixed paper birch-spruce forest and open black spruce forest. Profile numbers 16, 65, 72, and 74 were studied and sampled.

The following is the profile description of a Dystric Cryochrept (no.72) on a 0 to 5 percent slope; 900 feet southwest of test plots on Poker Flats; SW 1/4 SE 1/4 of Sec. 4, T12S, R7W, Fairbanks Meridian.

Oi—3 to 2 inches; mat of fresh moss and litter.

Oe—2 to 1 inch; dark reddish-brown (5YR 3/2) peat muck consisting of decomposing moss; abrupt smooth boundary.

Oa—1 to 0 inch; dark brown (7.5YR 3/2) muck; weak, fine granular structure; very friable, nonsticky and nonplastic; common fine, and medium roots; moderately acid; clear wavy boundary.

E—0 to 1 inch; brown (7.5YR 4/2) silt loam; weak, fine and medium granular structure; very friable, slightly sticky and nonplastic; common fine roots; very strongly acid; clear wavy boundary.

Bs1—1 to 3 inches; dark brown (10YR 3/3) silt loam; weak, fine subangular blocky structure; friable, slightly sticky and nonplastic; few fine and medium roots; slightly acid; clear smooth boundary.

Bs2—3 to 7 inches; dark yellowish brown (10YR 4/6) silt loam; many large patches of dark grayish brown (2.5Y 4/2); weak, fine subangular blocky structure; friable, slightly sticky and nonplastic; few medium and fine roots; moderately acid; clear smooth boundary.

Bs3—7 to 9 inches; yellowish brown (10YR 5/6) silt loam; many large patches of light brownish gray (2.5Y 6/2); weak, fine subangular blocky structure; friable, slightly sticky and nonplastic; few medium and fine roots; moderately acid; clear smooth boundary.

2BC—9 to 13 inches; olive brown (2.5Y 4/4) gravelly silt loam; weak, fine subangular blocky structure; friable, nonsticky and nonplastic; few fine roots, 30 percent gravel; slightly acid; clear wavy boundary.

3C1—13 to 18 inches; multicolored extremely gravelly sand; single grained; loose; few fine roots; 60 percent gravel and few cobbles; moderately acid; gradual smooth boundary.

3C2—18 to 40 inches; multicolored very cobbly sand; single grained; loose; 20 percent cobbles and 40 percent gravel; slightly acid.

Except for profile 65, the thickness of the topsoil (A, E, and Bs horizons) ranges from 12 to 20 inches, and the coarse fragments, mostly gravel, account for less than 10 percent of the volume. The texture of the topsoil ranges from loam to silt loam with lenses of fine sandy loam. Profile 65 has only 6 inches of topsoil (Table 3).

The A horizon has a hue of 7.5YR or 10YR; a value of 3 and chroma of 2 or 3. The E horizon ranges from 1 to 3 inches thick, has hue of 7.5YR or 10YR;value of 4 or 5 and chroma of 1 or 2. The Bs horizons have hues of 7.5YR or 10YR; value from 3 to 5 and chroma from 4 to 6. It is common to have large patches of gray in the Bs horizons. The very gravelly substratum (3C1 and 3C2) contains 50 to 80 percent of gravel, cobbles, and occasional stones. Most of these coarse fragments have iron stains.

Permeability is moderate in the silt loam or sandy loam layers, and rapid in the very gravelly substratum. Water-holding capacity is moderate in the silt loam or loamy topsoil, but low in the substratum. Plant roots can penetrate to the upper part of the very gravelly substratum, ranging from 14 to more than 20 inches deep. These soils do not have permafrost but a seasonal frost zone.

Histic Pergelic Cryaquepts

These deep, poorly-drained soils are in depressions and on toe slopes. These soils formed in muck over stratified silty, loamy, or occasionally gravelly layers. The soils are usually perennially frozen a few inches below the surface. The landform is depressions and plains with hummocky microrelief ranging from 6 inches to 1 foot. Slopes range from 0 to 25 percent. Elevation ranges from 1,500 to 3,000 feet. The major vegetation type associated with these soils consists of ericaceous shrub tundra. Profile nos. 62 and 69 were studied and sampled. The following is the profile description of a Pergelic Cryaquept (no. 62), 0 to 5 percent slope; west of Vitro pit, south of Healy Creek, NE 1/4 SW 1/4 of Sec. 15, T12 S, R6 W, Fairbanks Meridian:

Oi—8 to 4 inches; raw fibrous sphagnum moss, leaves and twigs; many roots; clear smooth boundary.

Oe—4 to 0 inches; very dark brown (10YR 2.5/2) decomposing fibrous moss peat muck; many woody particles; many roots; very strongly acid; clear smooth boundary.

Af– 0 to 5 inches; dark reddish brown (5YR 2.5/2) mucky silt loam; frozen; few roots; strongly acid; clear smooth boundary.

Oaf1 – 5 to 8 inches; dark brown (7.5YR 3/2) muck, frozen; strongly acid; distinct smooth boundary.

Abf– 8 to 11 inches; dark grayish brown (7.5YR 4/2) mucky silt loam; sticky and slightly plastic; frozen, large clear lenses of ice; strongly acid; abrupt smooth boundary.

Cf1 – 11 to 14 inches; dark grayish brown (2.5Y 4/2) silt loam; sticky and slightly plastic; frozen, large clear lenses of ice; strongly acid; abrupt smooth boundary.

Oaf2– 14 to 16 inches; very dark gray (10YR 3/1) muck, frozen; strongly acid; abrupt smooth boundary.

Cf2– 16 to 30 inches; dark grayish brown (2.5Y 4/2) silt loam; large clear lenses of ice.

The thickness of the organic layer ranges from 8 to 14 inches. In mid-summer, permafrost occurs 6 to 10 inches from the surface of organic layer, and the zone above permafrost is generally saturated. The mineral horizon has a texture of mucky silt loam or silt clay loam, always frozen, and in places with stratified layers of gravel (Table 4). Frost churning of organic matter into the mineral horizons is common to these soils.

Pergelic Cryohemists

These deep, poorly-drained organic soils occur in depressions and on toe slopes at Poker Flats, Gold Run Pass, and south of Healy Creek. These soils are formed in organic matter over stratified silty, loamy, or occasionally gravelly layers. The soils are usually perennially frozen. The landform is hummocky tundra with microrelief ranging from 3/4 to 1 1/2 feet. Slopes range from 0 to 25 percent. Elevation ranges from 1,500 to 2,500 feet. The major vegetation type associated with these soils is ericaceous shrub tundra.

The following is the profile description of a Pergelic Cryohemist (no.12), 0 to 5 percent slope; 100 feet west of test plots on Poker Flats, NW 1/4 SW 1/4 of Sec. 4, T 12 S, R 7 W, Fairbanks Meridian:

Oi– 0 to 3 inches; raw fibrous sphagnum moss, leaves and twigs; many roots; clear smooth boundary.

Oe1 – 3 to 11 inches; very dark gray (10YR 3/1) peat muck; many roots; very strongly acid; abrupt smooth boundary.

Oe2– 11 to 17 inches; very dark gray (10YR3/1) peat muck; increased mineral content; many fine roots; very strongly acid; abrupt wavy boundary.

Cf1– 17 to 19 inches; dark grayish brown(2.5Y 4/2) silt loam; many, medium, distinct brown (10YR 4/3) and olive (5Y 4/3) mottles; frozen; slightly sticky and slightly plastic when thawed; common fine roots; strongly acid; many fine ice lenses; abrupt wavy boundary.

Cf2– 19 to 24 inches; dark brown (10YR 3/2) mucky silt loam; frozen; slightly sticky and slightly plastic when thawed; common fine roots; strongly acid; large clear lenses of ice; abrupt smooth boundary.

2Cf3– 24 to 40 inches; light olive brown (2.5Y 5/4) very gravelly loam; frozen; slightly sticky and plastic when thawed; strongly acid; large clear lenses of ice; about 40 percent gravel and 10 percent cobbles.

The thickness of the organic layer ranges from 16 to 24 inches. In mid-summer, permafrost ranges from 10 to 18 inches from the surface, and the zone above permafrost is generally saturated. Observations from cut banks and excavation sites show the substratum (Cf horizons) contains stratified silty, sandy, organic, and gravelly layers to several feet. Frost churning of organic horizon into the mineral horizons is common to these soils.

Typic Cryochrepts

These deep, well-drained soils are on old river terraces along the streams at intermediate levels above the flood zones but lower than the position of Dystric Cryochrepts. They are found north of Lignite Creek and south of Healy Creek. These soils formed in loess over stratified alluvial sediments. Slopes range from 0 to 15 percent. Elevation ranges from 1,500 to 2,000 feet. The major vegetation type associated with these soils is the open mixed birch-spruce forest. Profile nos. 15 and 82 were studied and sampled.

The following is a profile description of Typic Cryochrept, (no. 15); north of Lignite Creek; NW 1/4 NW 1/4 of Sec. 32, T 11S, R 7 W, Fairbanks meridian:

Oe–3 inches to 0; very dark grayish brown (10YR 3/2) mat of decomposing leaves and twigs; many medium and fine roots; strongly acid; clear smooth boundary.

A–0 to 5 inches; very dark grayish brown (10YR 3/2) loamy sand; weak, medium granular structure; very friable non-sticky and nonplastic; many coarse, medium and fine roots; moderately acid; abrupt smooth boundary.

2A–5 to 7 inches; very dark grayish brown (10YR 3/2) sandy loam; weak, medium platy structure; friable, non-sticky and nonplastic; many medium and fine roots; moderately acid; charcoal layer in pockets near the top 2 inches; abrupt smooth boundary.

2Bw–7 to 9 inches; brown (10YR 4/3) sandy loam; many medium faint olive brown (2.5Y 4/4) mottles; weak, medium subangular blocky structure; friable, nonsticky and nonplastic; many medium and fine roots; moderately acid; clear smooth boundary.

3BC–9 to 13 inches; dark grayish brown (2.5Y 4/3) loamy sand; many medium faint dark brown (10YR 3/3) mottles; massive; friable, nonsticky and nonplastic; common medium and fine roots; few root channels; slightly acid; clear smooth boundary.

3C1–13 to 38 inches; stratified layers of sandy loam and loamy sand; color varies, with hue of 10YR or 2.5Y, value of 3 or 4 and chroma from 1 through 4; many fine to medium faint or prominent mottles with hue of 7.5YR, 10YR, and 2.5Y, value and chromas from 2 to 4; massive structure; friable, nonsticky and nonplastic; common fine roots; slightly acid; clear smooth boundary.

4C2–38 to 60 inches; dark grayish brown (2.5Y 4/3) to olive brown (2.5Y 4/2) silt loam and fine sandy loam, interstratified; many medium to coarse distinct dark yellowish brown (10YR 4/4) and dark brown (7.5Y 4/4) mottles; weak thin to thick platy structure; friable to firm, slightly sticky and nonplastic; common fine roots; band of charcoal layer occurs immediately below 38 inches; slightly acid.

The stratification varies with relief due to past deposition and subsequent erosional processes. The average texture in the 10 to 40 inches control section is sandy loam (Table 5). In places, there are thin bands of gravel with lime coating occurring in the lower part of the profile. Soils represented by no. 82 have very shallow topsoils usually less than 6 inches, overlying very gravelly sand. Permeability is moderate to rapid. Available moisture capacity is low to moderate. Plant roots can penetrate to more than 5 feet.

Typic Cryorthents

These shallow, excessively drained soils are on younger river terraces along the Healy Creek, Lignite Creek and their tributaries. Their positions are generally lower than that of Dystric Cryochrepts and Typic Cryochrepts but higher than that of Typic Cryofluvents. These soils occupy terrace breaks and steep, eroded slopes along the streams, ravines and drainage ways with slopes ranging from 30 to 90 percent. The elevation ranges from 1900 to 2600 feet. The major vegetation types associated with these soils are open mixed birch-spruce forest and closed birch forest.

These soils are developed on stratified sediments and outwash material modified by mass wasting. It is well to excessively drained. The texture includes sandy loam, silt loam, or loamy sand and very gravelly sand. Permeability is moderate within the few inches of topsoil horizons and excessive in the very gravelly substratum. The available water capacity is low. Runoff is very rapid and erosion hazard is high. These soils were not sampled but a narrative description was made in the field.

Typic Cryofluvents

These deep, well-drained soils are on level to gently sloping alluvial plains and low terraces along the major streams and their tributaries. These soils formed in alluvium on slopes of 0 to 15 percent. The vegetation types are closed alder shrubland and closed birch forest. Elevation ranges from 1200 to 2200 feet. The profiles of these soils vary widely because of the fluvial and alluvial processes. These soils were not sampled but a narrative description was made in the field.

In a typifying profile, a dark brown mat of partly decomposed moss, leaves, and twigs overlies a surface layer of very dark grayish-brown silt loam and fine sandy loam. Below are grayish brown and olive-gray stratified fine sand and very gravelly coarse sand that contains many rounded pebbles and cobblestones. Streaks of brown and gray caused by frost churning are common in the upper 20 inches.

Permeability of these soils is moderately rapid. Runoff is slow. The hazard of water and wind erosion is slight, except where these soils are scarred by narrow, abandoned stream channels. When thawing occurs in the spring, the soil above the layer that remains frozen may be saturated, but the water drains out rapidly once the frozen layer melts. These soils are subject to seasonal flooding.

Part 2. Minesoils and Overburden

The morphology of the minesoils was studied during field characterization and description. The discussion is based on groupings by their parent materials and unique landforms.

Sandstone Minesoils

This is the most extensive minesoil in the mining areas of the Usibelli Coal Mine. These well-drained minesoils are formed in overburden from poorly consolidated sandstone and sandy stratum between coal seams. There are many chunks of sandstone, broken by excavating equipment, mixed in the profile.

These minesoils were deposited at different phases of the mining operation, hence, were revegetated at different times since 1971. All these units are grass seeded, and the establishment of ground cover varies widely. A total of 3 sites were studied, and at each site pits were excavated and described on both vegetated and unvegetated grounds (profile nos. 60A, 60B, 63A, 63B, 64, 71, 87A, and 87B).

The following is a profile description of a vegetated sandstone minesoil (no. 60A); next to the test plots in Vitro Pit; half section between Sec. 14 and 15, T12S, R6W Fairbanks Meridian:

A1—0 to 3.5 inches; dark grayish brown (10YR4/2) sandy loam; weak, medium granular structure; very friable, nonsticky, nonplastic; many medium and fine roots; estimated 10 to 15 percent fine gravel and coal particles mixed in the root mat; slightly acid; abrupt smooth boundary.

A2—3.5 to 5 inches; dark brown (10YR 3/3) sandy loam weak, medium granular structure; friable, slightly sticky and sightly plastic; 10 to 15 percent fine gravel and coal particles mixed in the root mat; many fine, medium roots; moderately acid; abrupt smooth boundary.

AC—5 to 8 inches; olive brown (2.5Y 4/3) sandy loam; weak, medium granular structure; friable, slightly sticky, nonplastic; less than 5 percent gravel and few coal particles; common fine roots; neutral; clear smooth boundary.

C1—8 to 15 inches; dark grayish brown (2.5Y4/2) sandy loam; massive structure; friable, slightly sticky, slightly plastic; very fine roots; neutral; diffuse smooth boundary.

C2—15 to 40 inches; dark grayish brown (2.5Y 4/2) sandy loam; massive; friable, slightly sticky and slightly plastic; neutral.

The profile description of an unvegetated sandstone minesoil (no. 60B) is next to no. 60A:

C1—0 to 2 inches; olive brown (2.5Y 4/3) sandy loam; coarse platy structure; friable, slightly sticky and nonplastic; 5

to 10 percent gravel and coal particles; few fine roots; neutral; clear smooth boundary.

C2—2 to 40 inches; dark grayish brown (2.5Y 4/2) sandy loam; massive structure; firm, slightly sticky and slightly plastic; neutral.

On revegetated sites, the thickness of A horizon ranges from 2 to 5 inches. The color has a hue of 10YR or 2.5Y, value of 2 to 4, and a chroma of 2 or 3. It is moderate to slightly acid. The texture is sandy loam, may be very gravelly, and in places there is a layer of heavy textured overburden on top with a texture of sandy clay loam. The substratum to a depth of 40 to 60 inches are either sandy loam or very gravelly sandy loam. The color has a hue of 2.5Y and 10YR, a value from 3 to 6, and chromas from 2 to 4.

The content of coarse fragment ranges from 5 to 50 percent. The soil reaction is slightly acid to neutral. The rooting depth ranges from 12 to 20 inches, but in spots it is more than 4 feet deep. The A horizon of the unvegetated sites was eroded away and a thin crust formed on the surface. The roots of sparse vegetation are generally within the top 5 inches. There is less coloration in the C1 horizon, and the color remains unchanged to a greater depth, reflecting the color of the parent material. The sandstone minesoils have uniform particle size distribution. The clay content ranges from 14 to 18 percent, and sand content ranges from 60 to 70 percent. The amount of fragment larger than 2 mm in diameter varies from place to place depending on the portions of coal particles mixed with the overburden during the stripping process. The sandstone minesoils are from overburden which was dumped and graded in a terrace or bench-like form, and at some sites the surface was furrowed. The soil material on this level ground is compact due to heavy equipment impact. Such compactness decreases the downward movement of water and therefore increases the surface runoff. Sheet erosion is common to this unit, and such erosion is detrimental to seeded grass establishment. Around the edge of this unit, gully erosion is common and tends to undercut the steep banks. Wind erosion and scour is severe due to the flat and open locations. Native species have started to invade the revegetated areas. Seedlings and saplings of white spruce, alder, willow and poplar were noted in many sites. A small reclaimed area near the Hydraulic Pit is used as a hay field.

Mudslide

This well-drained unit was originally a Pergelic Cryaquept that was modified by mass wasting and sliding downslope. The slope ranges from 0 to 90 percent. The mass wasting was triggered by the thawing of the permafrost layer caused by mining activities, such as truncating the insulating moss layer or undercutting the exposed banks.

The parent material is from glaciofluvial deposits with thickness varying from 4 to 7 feet. The relief follows the original gravel terrace, and the mass wasting process has mixed the glaciofluvial deposits well with the underlying gravelly material. The following is the profile description of profile no. 80, 45 to 90 percent slopes; 1/3 mile each of Hydraulic Pit; NW 1/4 SW 1/4 of Sec. 16, T12S, R6W, Fairbanks Meridian:

A—0 to 2 inches; brown to dark brown (10YR 4/3) very gravelly sandy loam or loam; weak, fine to medium granular structure; slightly sticky nonplastic; many very fine and fine roots; 40 percent gravel and 5 percent cobbles; neutral; clear smooth boundary.

C1—2 to 20 inches; brown (10YR 4/3) very gravelly sandy loam; weak, fine granular structure; slightly sticky, nonplastic; common fine roots; 55 percent gravel; neutral to mildly alkaline; clear smooth boundary.

C2—20 to 40 inches; olive brown (2.5Y 4/4) very gravely sandy loam; weak to moderate, medium granular structure; slightly sticky, slightly plastic; few fine roots; 52 percent gravel; neutral to mildly alkaline; abrupt smooth boundary.

Oib—40 to 41 inches; buried very dark gray (10YR 3/1) sandy loam; strongly acid; abrupt smooth boundary.

Cb—41 to 60 inches; dark olive (5YR 3/3) very gravelly loamy sand; strongly acid.

Clayey Minesoils

These somewhat poorly drained minesoils are formed in fine textured overburden in the Gold Run Pass area. The elevation ranges from 2400 to 2500 feet. The overburden was mixed with coal particles and mudstones. They were deposited as nearly level terraces, benches, and undulating concave slopes and steep terrace breaks. Three sites were selected to characterize this type of minesoil (Profile numbers 75, 76, and 83).

The following is the profile description of no. 75; south of Sanderson Creek; SW 1/4 NW 1/4 SW 1/4 of Sec. 35, T11S, R6W, Fairbanks Meridian:

A—0 to 2.5 inches; dark grayish brown (10YR 4/2) gravelly clay; moderate fine to medium subangular block structure; friable, sticky and plastic; many very fine and fine roots; 20 percent coal particles and sedimentary chips; neutral; clear smooth boundary.

C1—2.5 to 8 inches; dark gray (10YR 4/1) gravelly clay and clay loam; strong fine to coarse subangular blocky structure; firm, sticky and plastic; common fine roots; 20 percent coal shale and sedimentary chips; neutral to mildly alkaline; gradual wavy boundary.

C2—8 to 17 inches; dark gray (5Y 4/1) very gravelly clay loam and silty clay loam; moderate to strong, fine to coarse subangular blocky and platy structures; firm, sticky and plastic; common to few very fine roots; 30 percent gravel-size coal and sediment chips, 10 percent cobble-size chunks; neutral to mildly alkaline; gradual wavy boundary.

C3—17 to 50 inches; dark gray (2.5Y 4/0) very gravelly clay; massive structure; firm, sticky and plastic; no roots; 50 percent chunks and chips of coal shale and sedimentary materials; mildly alkaline.

The texture of these minesoils range from silty-clay loam, clay loam to clay. The clay content ranges from 35 to 45 percent and sand fraction varies from 12 to 35 percent. The coarse fragments in the profile ranges from 30 percent in the upper horizon to 50 to 80 percent in the lower portion. However, most of the coarse fragments consist of coal particles and coal shales and of fragments of unconsolidated sediments of silt and clay, rather than hard rock. The spoil materials are generally compact. Permeability of this minesoil is slow. Runoff is slow on the level to gently sloped areas, and medium to rapid along the steep terrace breaks. The nearly level terraces were furrow graded, and the minesoil is saturated. The water table is only 2 inches below the surface in mid-summer. The furrows have intervals of about 1.5 feet and microrelief of 8 to 16 inches. Grass roots are generally concentrated in the top 3 to 5 inches where the A horizon has formed due to the accumulation of organic matter, or the shallow water table.

The Gold Run Pass area was grass seeded in 1974 and 1975. The ground cover is nearly 90 percent including red fescue, smooth brome, bluejoint and timothy. The uncovered areas are paved with coal particles.

Reclaimed Topsoils

This type of minesoil consists of mixed soil material from the topsoils of Dystric Cryochrepts and the very gravelly sandy substratum. The soil was removed as overburden during the mining operation to expose the poorly consolidated sandstones and coal seams in the Vitro area. Most of the material has been dumped by earthmoving equipment and then graded into benches with hummocks and steep slopes up to 90 percent. The elevation is about 2000 feet. Two sites were studied (profile nos. 61 and 81) on this type of minesoil.

The following is the profile description of no. 61; NW 1/4 NW 1/4 SW 1/4 of Sec. 14, T12S, R6W, Fairbanks Meridian:

A—0 to 2 inches; dark yellowish brown (10YR4/4) sandy loam; weak, medium granular structure; friable, slightly sticky and nonplastic; many fine roots; 10 percent gravel; medium acid; clear smooth boundary.

C1—2 to 6 inches; dark yellowish brown (10YR 4/5) cobbly sandy loam; massive structure; friable, nonsticky and nonplastic; common fine roots; 18 percent cobbles; slightly acid;

clear smooth boundary.

C2–6 to 12 inches; brown (7.5 4/4) extremely cobbly sandy loam; massive structure; friable, nonsticky and nonplastic; very few fine roots; 64 percent cobble and gravel; neutral; diffused smooth boundary.

C3–12 to 40 inches; brown (7.5 4/4) extremely cobbly loamy sand; massive structure; very friable, nonsticky and nonplastic; 71 percent cobble and gravel; moderately alkaline.

The dark yellowish brown and brown color of the fine earth portion are characteristic of the Dystric Cryochrept. The high cobble content indicates the mixing of topsoil with the very cobbly substratum. The texture ranges from very gravelly loam to very cobbly sandy loam. The coarse fragment ranges from 20 to 70 percent by volume. The permeability of this minesoil is moderate to moderately rapid. Runoff is slow on the bench or hummocky areas but very rapid along the steep slopes where erosion is severe. Wind scour is moderate to severe and is a limiting factor to vegetation establishment in some sites.

This type of minesoil and the adjacent areas were grass seeded in 1972. The native species that have reestablished include bluejoint, alder, mosses, and a few white spruce seedlings. The ground cover is about 40 percent grass, 40 percent mosses, 10 percent gravel and bare ground.

Coal Minesoils

These somewhat excessively drained minesoils are formed in minespoils mixed with coal particles with less than 15 percent soil materials. The acreage is not extensive and mainly limited to the Gold Run Pass Area. The surface was furrow graded on a slope of 2 to 8 percent with furrows often following the slope. The microrelief of the furrows is about 8 to 14 inches. The elevation is about 2470 feet.

The following is the soil profile description of profile no. 73; SW 1/4 NW 1/4 SW 1/4 of Sec. 35, T11S, R6W, Fairbanks Meridian:

A–0 to 6 inches; black (10YR 2/1) coarse sandy loam; weak, very fine granular structure; very friable, nonsticky and nonplastic; 42 percent coal particles in gravel size (2 to 7.5 mm) and 20 percent in cobble size; many very fine and fine roots; slightly acid; clear smooth boundary.

C1–6 to 22 inches; black (7.5YR 2/0) loamy coarse sand; massive structure; very friable, nonsticky and nonplastic; 65 percent coal particles in gravel size and 20 percent in cobble size; common very fine and fine roots; slightly acid; diffused smooth boundary.

C2–22 to 50 inches; black (7.5YR 2/0) loamy coarse sand; massive structure; very friable, nonsticky and nonplastic; 65 percent coal particles in gravel size and 20 percent in cobble size; slightly acid; very few fine roots.

The colors of the coal minesoil are invariably dark due to the presence of coal and coal shale particles.

The fine earth fraction of this type of minesoil is loamy sand or sand in texture. The coarse fragment in the minesoils is not hard rock or outwash gravel, instead, it is coal and coal shale particles and chips The area was grass seeded in 1974 with a variety of grasses. Most of the grasses are well established in the trenches of the furrows and slopes of the ridges between furrows. The ridges are generally bare but covered with coal particles which seem able to resist wind erosion well. At the lower edge of the slopes some native species such as white spruce, poplar and alder seedlings have established.

Miscellaneous Land Types

The miscellaneous land types include the active mining excavation areas on the Poker Flats, the precipitous testing pits in Gold Run Pass, Vitro and Hydraulic areas, and coal yards.

The excavation has produced nearly vertical walls and exposed the soil and stratified overburden and coal seams. In places, underlying bedrock are also exposed. Mass wasting and colluvium along the walls are active and in places talus slopes have formed. Ponds of water are common in the bottom of pits due to interrupted subsurface water flow and their collective positions.

Overburden

The analyses of overburden and interburden samples are based on 18 samples. The textures of these materials are dominantly sandy loam, ranging from loamy sand to loam. Merritt (1985) analyzed 43 coal overburden samples from 6 general areas of the Nenana Coal Fields and found only 3 samples with clay content of 42 percent, and 7 samples with texture coarser than sandy loam, the majority with a loamy texture. When excavated, most of these materials have firm massive structure; some are loose, single grained. They typically have a light gray (2.5Y 7/0) to white color (2.5Y 8/0) because of the high quartz content. Some of the loamy materials are light brownish gray (2.5Y 6/2). The loamy sand and sandy loam material are nonsticky and nonplastic, whereas the loamy material is slightly sticky and slightly plastic.

Chemical and Fertility Properties

Part 1. Natural Soils

The selected chemical, and fertility properties of natural soils were are discussed according to the soil subgropus.

Dystric Cryochrepts

The selected properties of Dystric Cryochrepts are listed in Tables 2 and 3, and their fertility status is presented in Table 6. Soil reactions, as indicated by pH values, range from moderately acid to slightly acid. The pH values generally increase with depth indicating the decreased leaching with depth. The increased acidity toward the soil surface is apparently the result of organic matter accumulation. The organic carbon is used as an index of organic matter which concentrates in the surface horizons, especially in the O horizons. The organic carbon content in the B horizons generally is less than 1 percent. The total nitrogen (N) distribution follows the same trend as that of carbon, decreasing with depth. The carbon to nitrogen ratio (C/N) decreases with depth, indicating the increased degree of decomposition of organic matter.

The cation exchange capacity (CEC) is highest in the surface A and E horizons, then decreases in subsurface (B) horizons, and is very low in the gravelly sandy substratum (C horizons). The variation of CEC with depth corresponds more with organic carbon than with clay content in the upper part of the profile, suggesting the dominance of pH-dependent charges on the exchange sites. In most mineral horizons, the ratio of CEC to clay content is more than 0.5 which suggests the dominance of expandable minerals such as smectite in the clay fraction.

The base saturation is generally less than 30 percent in the medium textured B horizons which are loess in origin. The low pH values and the low base saturation suggest that the exchange sites is dominated by aluminum, followed by Ca, Mg, K, and Na. The dominance of Ca in the exchangeable bases may be due to the weathering of plagioclase in the primary mineral fraction (Table 11). The exchangeable cations are largely accumulated near the surface horizons, and decrease sharply with depth. This is apparently caused by the nutrient recycling in the forest floor biomass which tied up most of the available nutrients (Van Cleve et. al. 1983). According to agricultural standards, nutrients levels of Dystric Cryochrepts are inadequate. The P levels are especially low. The micronutrient levels tested by DTPA-TEA (Table 6) are adequate for Cu, Mn, and Fe, but may be borderline to deficient for Zn. In spite of the poor fertility levels, most of these soils can be stockpiled for topsoil purposes because of their favorable physical properties and operable thickness. The nutrient deficiency can be amended in the reclamation processes.

Histic Pergelic Cryaquepts and Pergelic Cryohemists

The selected properties and fertility status of these two soils are listed in Table 4. They occur in a complex pattern on the hummocky tundra so they cannot be separated on a detailed soils map. For practical purposes, they will be managed and handled as one unit, therefore, they are discussed together. The organic horizons of Cryaquepts range from 8 to 14 inches thick, and that of Cryohemists are over 14 inches thick. The reactions of the Cryohemists are strongly acid to very strongly acid, and that of Cryaquepts are medium to strongly acid. The base saturation of Cryaquepts are higher than that of Cryohemists because of the higher exchangeable bases. There are very high levels of available N in Histic Pergelic Cryaquepts, but lower in Pergelic Cryohemists. Higher carbon/nitrogen ratios in the latter may explain the difference. The available P and K are low in both soils. The permafrost layers of these soils may present a physical limitation to the topsoil stockpiling operation. Liming may be necessary for acid-sensitive species to establish if these soils are used for topsoils.

Typic Cryochrepts

The selected properties of one Typic Cryochrept are listed in Table 5, and their fertility status is listed in Tables 5 and 6. The base saturation is higher (31-63 percent) than that of Dystric Cryochrepts because of higher pH and exchangeable Ca and Mg. The soil reaction is medium to slightly acid. Liming is not required when used as topsoil. The available N, P, and K levels are low, and Zn is borderline to deficient. The soils of profile no. 15 do not have a restricting layer, thus favor the topsoil stockpiling operation. Soils represented by profile no. 82 are too gravelly to be used for such purposes.

Part 2. Minesoils and Overburden

Selected physical and chemical properties and fertility status of minesoils and overburdens are listed in Tables 7 through 10, and are discussed according to the soil properties.

Soil Reaction and Electric Conductivity

Soils formed in coal spoils and overburden materials elsewhere in the U.S. are generally faced with problems of severe acidity or salinity (Mitchell et al. 1980). The minesoils in the Healy area generally have favorable soil reactions. The SMP buffer pH values range from 6.5 to 7.5. Within this pH range the availability of most nutrients is near optimal. SMP buffer pH values are nearly a unit higher in most cases, than that measured in water suspension. An apparent exception are those minesoils developed in coal spoils (Table 9). The pH in water is medium acid and the SMP pH is slightly lower. This indicates a minesoil that has considerable reserve acidity, which could limit the nutrient availability, especially P.

The electric conductivity (EC) of saturated pastes are generally below 0.5 dS m^{-1}. The values for the clayey minesoil (Table 8) are slightly higher but still less than 1. Electrical conductivity values in this range would not indicate soluble salt problems. This is in agreement with Merritt's (1985) data. He measured an average sodium adsorption ratio (SAR) of 1.6, and an exchangeable sodium percentage of 3.2 from 43 overburden samples. Salt problems are not expected within these ranges.

Texture

The texture of most minesoils on Poker Flats, Hydraulic and Vitro Pits are sandy loam or loam. This is the result of the sandy loam texture of the overburden material between coal seams in these areas. The sandstone minesoils (Table 7) developed from materials which are generally free of coarse fragments vary little in texture with depth except when mixed with underlying materials. The clay content ranges from 14 to 20 percent, and the silt content ranges from 16 to 22 percent. The sandstone overburden materials were sometimes mixed with gravelly substratum of Dystric Cryochrepts and Typic Cryochrepts during the excavation and formed minesoils with wide ranges of coarse fragment content. Most of these coarse fragments are hard rocks.

In the Gold Run Pass area, minesoils have formed in fine textured overburden. The clay content ranges from 37 to 45 percent and the minesoils have very high water holding capacity. Water tables within 5 inches of the surface were observed in late August 1983 during profile examinations. These minesoils generally have 20 to 40 percent "coarse fragment" which are either coal particles or mudstones. The mudstones and some coal particles retain moisture and are active in nutrient exchange. They do not behave as rock fragments and are not entered into the texture modifier as is done with other soils. In the case of coal minesoils, the coal particle made up nearly 90 percent of the soil material.

On vegetated sites (Table 7), the clay content in the subsurface horizon increased slightly as compared with that of the surface layer. It is caused by the increased sand fraction on the surface intercepted by the vegetation and litter, not as a result of illuviation – a process of translocation of clay from upper horizon to lower horizon. In summary, the texture of the minesoils reflect the particle size distribution of the overburden material.

Organic Carbon and Cation Exchange Capacity

The organic matter contents are calculated by multiplying the organic carbon content (percent O.C.) by the empirical factor of 1.724. The organic carbon content of most minesoils decreases drastically with depth, which indicates organic matter accumulation in the topsoil. Generally, the organic carbon content ranges from 0.7 to 1.8 percent in the top 3 to 5 inches of the vegetated sites. On barren or eroded sites stripped of vegetation, the organic carbon content is generally less than 0.5 percent. The high organic carbon content of the clayey mine soil is not likely the result of vegetation residue alone. The presence of considerable amounts of coal particles in the profile has contributed to this high value. Another evidence is the fact that organic carbon and total N contents of all three profiles (nos. 75, 76, 83) do not decrease with depth, and in some cases, even increase. Therefore the organic carbon and total N must be largely inherent to the minesoil.

The coal minesoils are high in organic carbon (9 to 14 percent). These minesoils have an average of 89 percent total weight combustible, and only 11 percent minerals. In this case, the value calculated from the percent O.C. does not give a valid measurement of organic matter content (Cummins, et. al. 1965). The total N content of this minesoil is also the highest – over 0.5 percent. In spite of its high percent O.C. and high total N values, the available N levels of the coal minesoils are no higher than other minesoils free of coal particles. The coal particles are not readily weatherable, thus the nitrogen is only slowly released over a period of time.

However, coal particles are chemically active at the surface which provides sites for nutrient adsorption and exchange. This is suggested by the unusually high cation exchange capacity (CEC) of coal minesoils, even though their clay contents are very low. In many other minesoils, especially the sandstone minesoils, the clay content remains constant with depth, but both the CEC and organic carbon decrease with depth. Therefore, organic matter in these soils would appear to provide most of the exchange sites for bases.

Fertility Status

Available nitrogen levels in all minesoils are medium in the top 3 to 5 inches and low in the lower portion of the vegetated sites, and low throughout the barren or eroded sites. The higher concentration of N at or near the surface may be due to nutrient cycling and fixation of ammonium forms.

Available phosphorus ranges from low to high in the top 3 inches, and decreases drastically with depth. The available P levels below 3 inches are low to very low. Phosphorus tends to be immobilized once it is added to the soil, therefore it concentrates on the surface. On sites where severe sheet erosion has been observed (unvegetated sites), the surface soil does not demonstrate surface P accumulation. In minesoils with higher contents of coal particles the P levels in the surface layer are very high. This may be due to the high adsorption capacity of the coal particles. When comparing the vegetated sites with the barren (unvegetated) sites, the nutrient loss due to erosion is obvious. The barren sites were stripped of vegetation caused by either strong wind scour, accelerated sheet erosion, or a combination of both.

The potassium levels are low to very low in sandstone minesoils, medium in clayey minesoils, and medium to high in minesoils high in coal particles. There is less variation of K levels with depth in clayey minesoils and sandstone minesoils. Potassium content decreases sharply with depth in coal minesoils. Again, the presence of coal particles may be responsible for this surface accumulation. In general, all major nutrients are deficient in most of the minesoils; N and P are especially low on the eroded or barren sites.

In a previous report, Mitchell et al. (1980) analyzed coal spoil samples taken from the same area. They found the micronutrient levels (such as Fe, Mn, and Cu) are adequate, except for Zn, which is borderline to deficient. Our analyses of the soils of this study showed similar results. Applications of micronutrients to annual cereals at Poker Flats, showed no yield response to Fe, Mn, Cu, or Zn (G.A. Mitchell, personal communication). In another report, Merritt (1985) reported an average level of 2.17 parts per million B, 10.34 parts per million Cu, 0.44 parts per million Mo, 11.5 parts per million of Pb, and < 0.01 parts per million Se in 43 overburden samples. This also indicates that the micronutrient levels of B, Cu, and Mo in the minesoils are adequate.

Mineralogical Properties

The results of the microscopic analysis of the very fine sand fraction are presented in Table 11. Only profiles 72 and 74 were analyzed for primary minerals. Plagioclase, mica, and quartz are the dominant minerals in the loess portion of the profiles, which consists of the E and Bs horizons. These minerals constituted about 99 percent of the primary minerals in both profiles. Hornblende and opaque minerals comprise less than 1 percent. There are small amounts of hypersthene and volcanic glass detected in the E horizon of profile 74, suggesting traces of volcanic ash. Due to the insignificant amount of volcanic ash present, the light color of the E horizon is not likely the result of tephra falls, rather of pedogenic process, i.e. leaching.

The clay mineralogy of the soil samples from 4 profiles is mixed (Table 11). The major layered silicate clay minerals include vermiculite, chlorite, mica, smectite, kaolinite, and Al-interlayers (Fig. 4-7). There are also vermiculite-mica regular stratification. Quartz and plagioclase are the major components of the clay-sized primary minerals. Amphiboles were detected in the BC horizon (9 to 13") of profile 72. When the clays were saturated with Mg-ions, chlorite, smectite, and vermiculite gave a first-order basal-plane reflection at about 14 Angstroms(Å). Smectite gives a first- order basal-plane reflection at 17-18 Å when treated with Mg-glycerol, thus it is separated from vermiculite and chlorite. Vermiculite will collapse to 10 Å when it is saturated with potassium (KCl). The incomplete collapse of 14 Å to 10 Å after K -saturation indicates the presence of Al-interlayers. Chlorite maintains its 14 Å peak even after heated to 550°C. Kaolinite has a first-order basal-plane reflection about 7 Å which overlaps the second-order basal-plane reflection of chlorite. However, the crystal lattice of kaolinite is destroyed by heating to 550°C, and the 7 Å peak will thus disappear. The regular stratification of mica-vermiculite can be identified by the presence of first-order basal-plane reflections of 24 Å. Mica can be identified by a 10 Å peak regardless of treatment. Quartz has a strong 3.5 Å and weaker 4.26 Å peaks. Feldspars have one or more spacings in the zone 3.25 to 3.10 Å, and amphiboles have

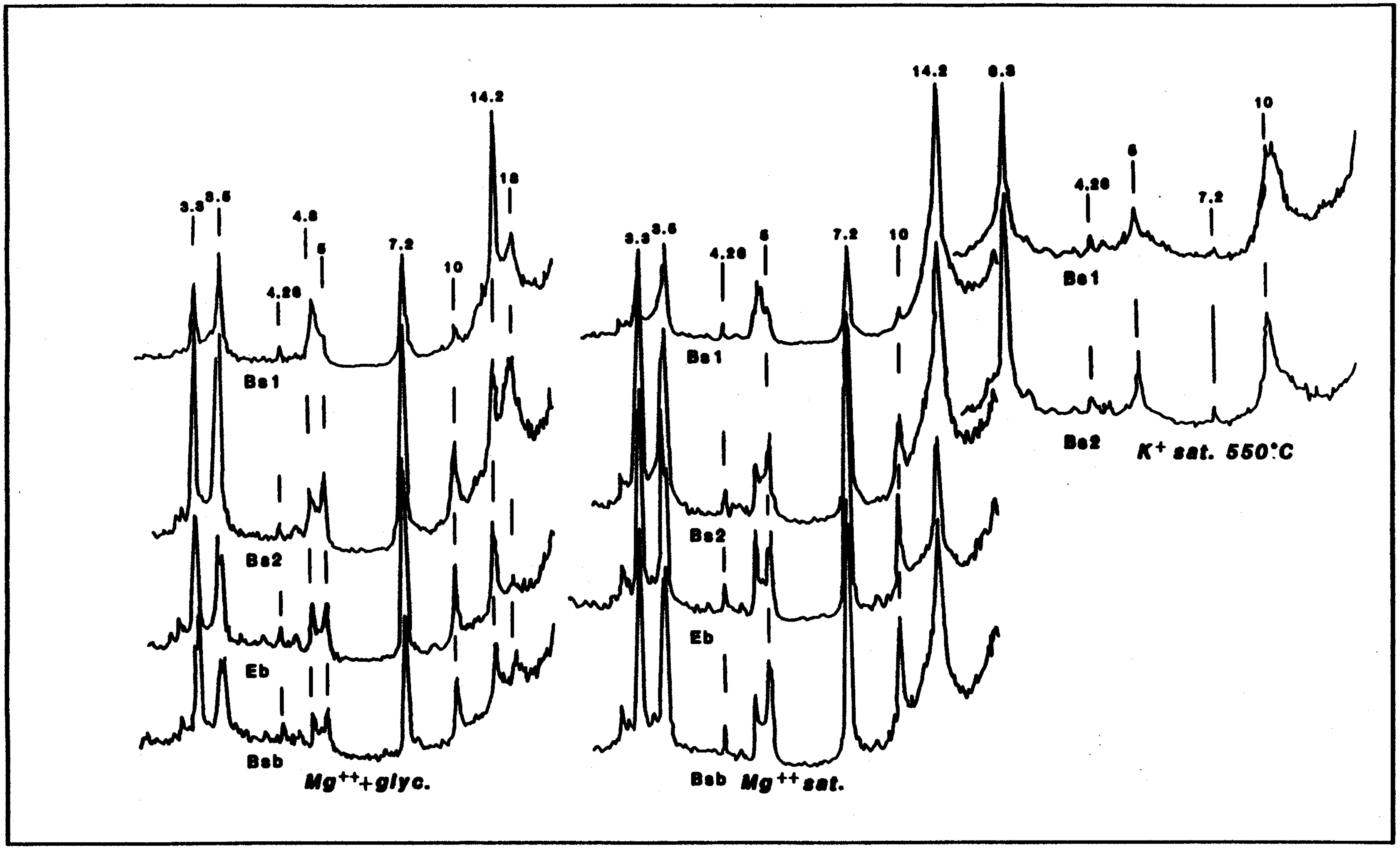


Figure 4 — X-ray diffactograms of the <2μ fraction of Profile 16, a Dystric Cryochrept from the Poker Flats area of Usibelli Coal Mine, Healy, Alaska

reflection at about 8.5 Å.

The composition of the clay mineralogy reflects the parent material, i.e. loess. These clay minerals were also found in soils formed of loess deposits in central Alaska (DeMent 1962). As discussed earlier, the high CEC to clay ratio suggests the clay minerals are dominated by clays with high cation exchange capacities such as smectite and vermiculite. Thus, vermiculite and smectite are likely the dominant species. The presence of quartz and feldspar contribute very little to the cation exchange capacity. Mica and vermiculite were inherent in the parent material (DeMent 1962). Smectite was found in all loess horizons of the 4 profiles, thus the presence of this mineral is not

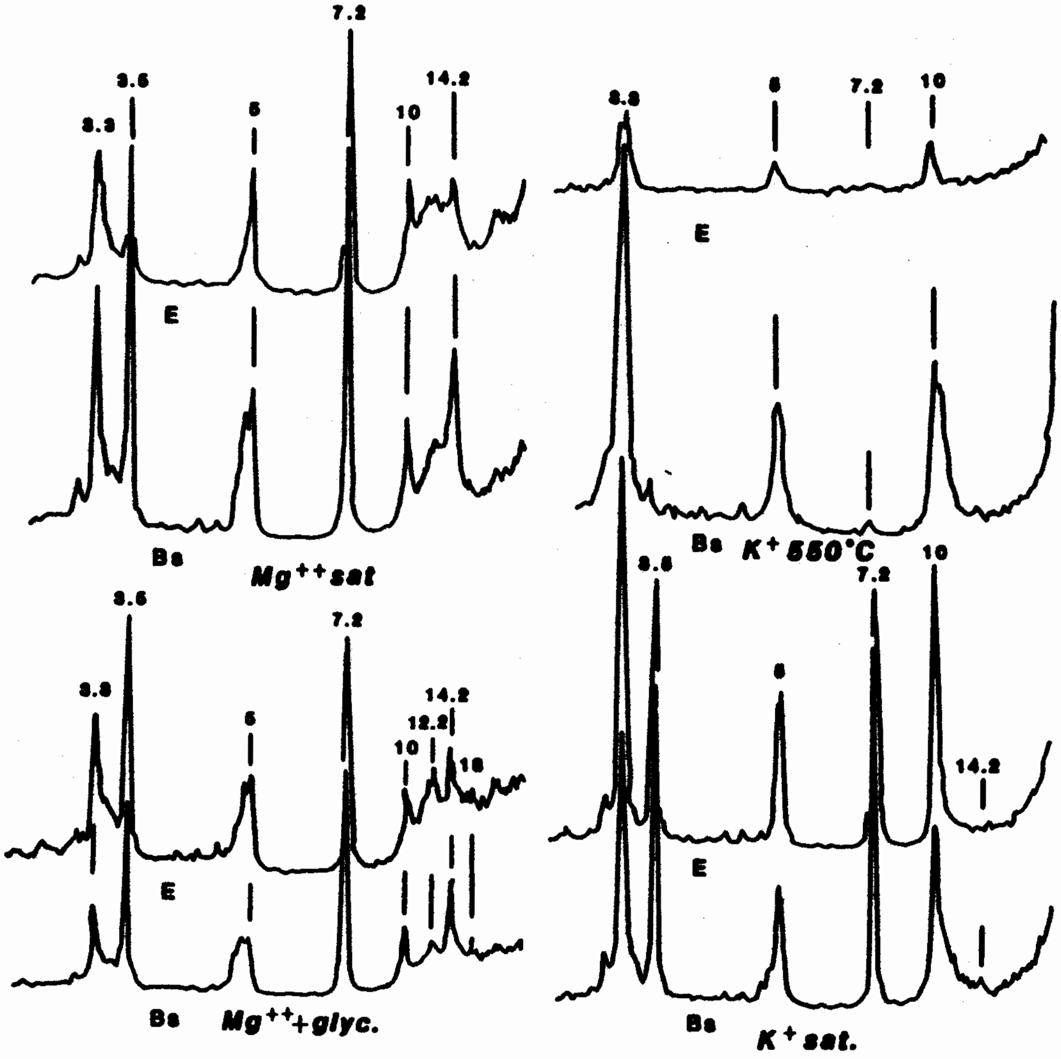


Figure 5 — X-ray diffractograms of the <2μ fraction of Profile 65, a Dystric Cryochrept from the Vitro Pits area of Usibelli Coal Mine, Healy, Alaska

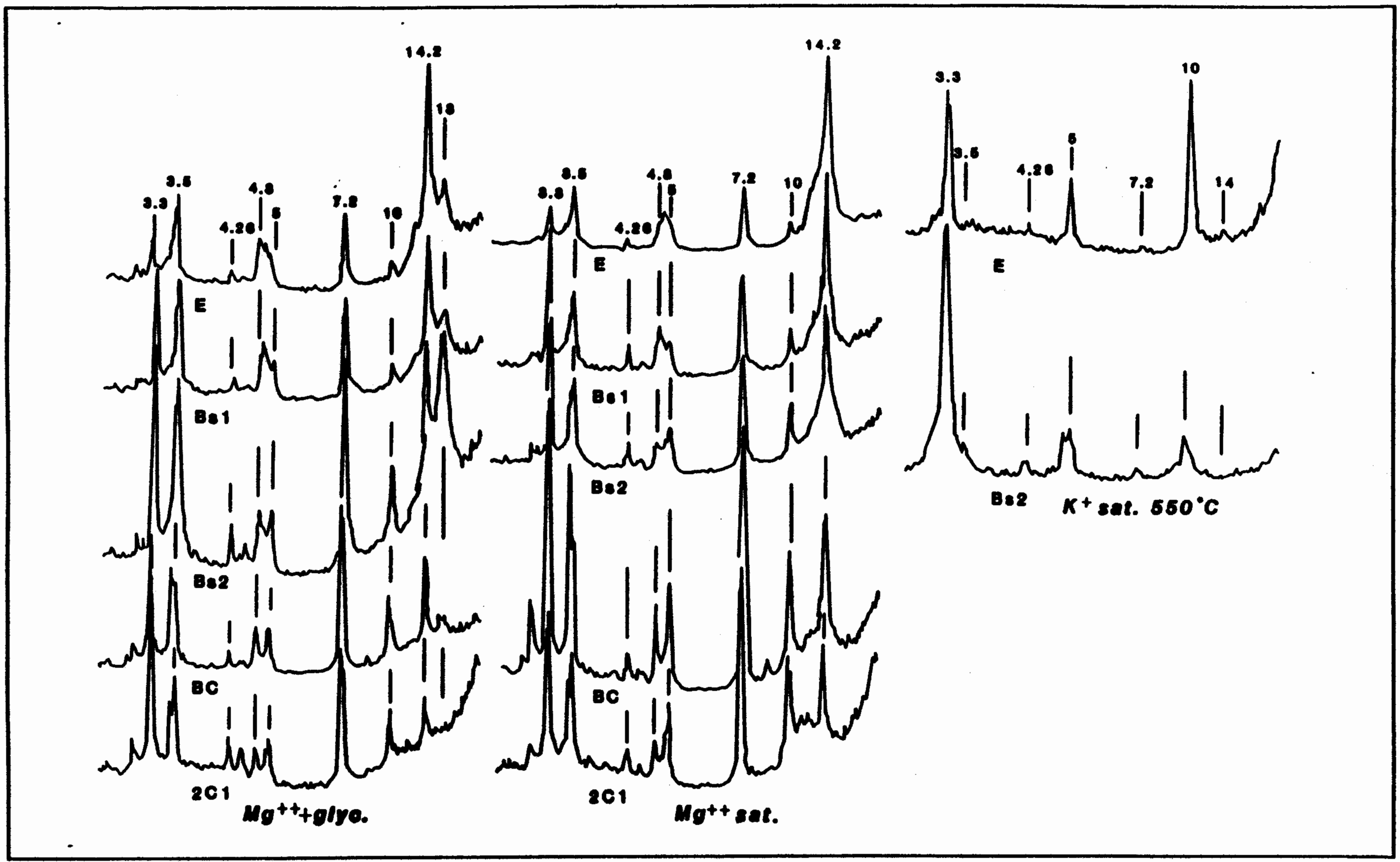


Figure 6 — X-ray diffractograms of the <2µ fraction of Profile 72, a Dystric Cryochrept from Poker Flats area of Usibelli Coal Mine, Healy, Alaska

likely the result of translocation rather inherited to the loess parent material. Field morphology of clay translocation is also absent. Kaolinite is usually related to an advanced stage of weathering and chlorite is related to an early stage of weathering. Yet both chlorite and kaolinite were found in all horizons regardless of depth. Thus, both chlorite and kaoline were inherited in the parent material. The presence of clay minerals that are separated in a wide range of weathering stages suggests

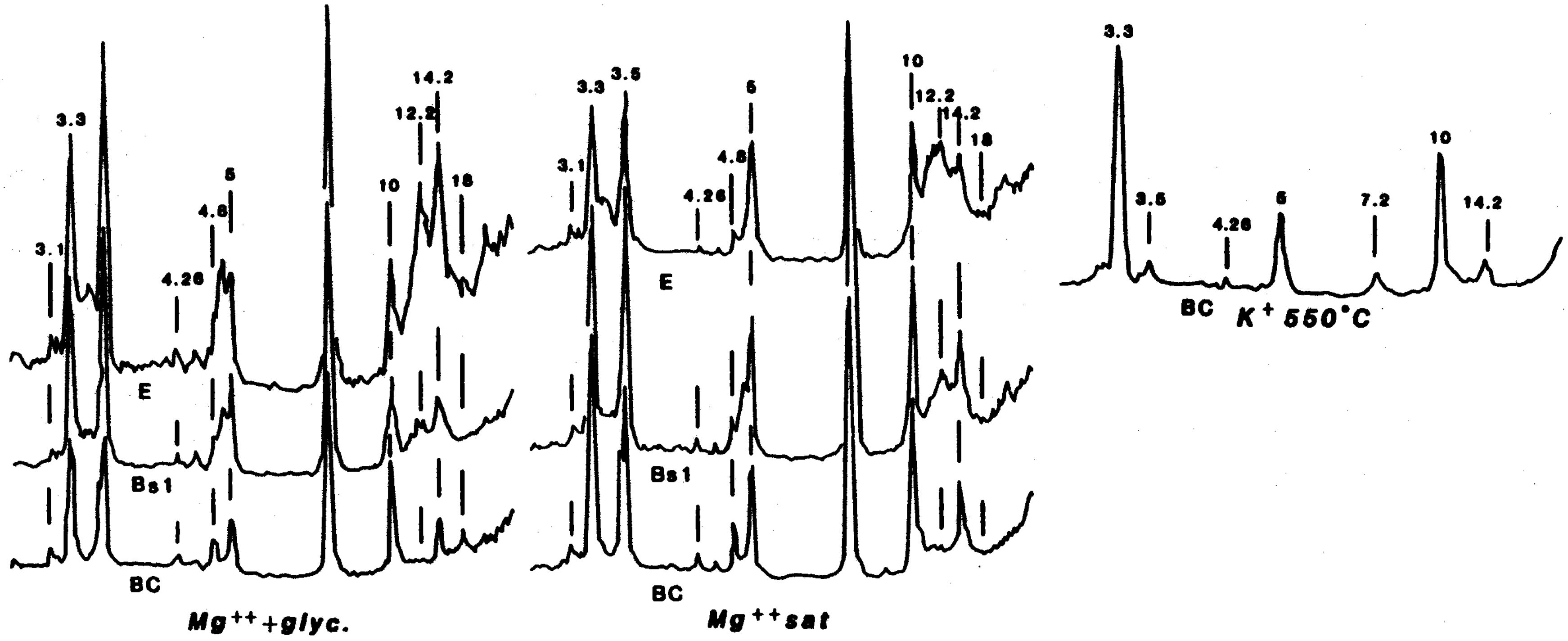


Figure 7 — X-ray diffractograms of the <2μ fraction of Profile 74, a Dystric Cryochrept from Gold Run Pass area of Usibelli Coal Mine, Healy, Alaska

that they are not pedogenic but inherited in the parent material. Thus these layered silicate clay minerals were formed in other locations before they were transported to and deposited in the current locations. However, the presence of Al-interlayers suggests in-situ weathering.

Soil Classification

The soils described in this report were all classified according to Soil Taxonomy (Soil Survey Staff 1975). There are ten soil orders recognized in Soil Taxonomy: Entisols, Vertisols, Inceptisols, Aridisols, Mollisols, Spodosols, Alfisols, Ultisols, Oxisols, and Histosols. In addition, there is a new one being proposed: the Andisol Order (Leamy, 1988). Of these eleven orders, three are identified in the study area, i.e. Entisols, Histosols, and Inceptisols. Histosols are composed primarily of organic material. They are represented in the study area by Pergelic Cryohemists, which are moderately deep over a mineral substratum, and have permafrost within 20 inches to the surface. There are more than 75 percent fibers in the organic material after rubbing.

Inceptisols are those soils in which the parent material has been modified, have weakly expressed horizons such as the Bs horizons. The letter B designates a modified horizon that results from weathering. In the Usibelli Coal Mine study area, the weathering is weak, limited only to iron and aluminum accumulation, as designated by the subscript s of Bs horizons. The yellowish brown color of the Bs horizons is an indication of the iron accumulation. Inceptisols in the study area are represented by Dystric Cryochrepts, Typic Cryochrepts, and Histic Pergelic Cryaquepts. Profiles 16, 65, 72, and 74 are classified as Dystric Cryochrepts because of the low base saturation (<60 percent) throughout the top 30 inches. Profiles 15 and 82 are classified as Typic Cryochrepts because the base saturation is higher than 60 percent in some horizons within the top 30 inches.

Profiles 16, 65, 72, and 74 resemble Spodosols because they have a thin (1-2 inches), but distinct, bleached surface horizon, the E horizon, right below the forest floor (O horizon). The color of these E horizons qualifies for an albic horizon according to Soil Taxonomy. The Bs horizons below the E horizon have colors resembling some weakly developed spodic horizon. Thus, the E-Bs sequum resembles the field morphology of a Spodosol. In order to qualify as a Spodosol, the soils should either have the micromorphology or the chemical properties of a spodic horizon (Soil Survey Staff 1975). However, upon field and microscopic examination, these soils do not have cracked coatings on the mineral grains, or an ortstein layer. In the chemical criteria for spodic horizon, the ratio of pyrophosphate-extractable iron (Fep) plus aluminum (Alp) to dithionate-extractable iron (Fed) plus aluminum (Ald) is equal or greater than 0.5, the ratio of Fep + Alp to percentage of clay is equal or greater than 0.2, and the combined index of accumulation is 65 or more. None of the three sites have horizons meeting these chemical criteria (Table 12), thus they are not Spodosols. The low Fep + Alp to Fed + Ald ratio suggests that major portions of the Fe and Al are "free" oxides rather than complexed with organic matter.

Profiles 62 and 69 are classified as Histic Pergelic Cryaquepts. Cryaquepts are Inceptisols formed under cold-wet conditions. These soils are grayish with brown or reddish-brown mottles and streaks. Pergelic refers to the presence of permafrost and Histic Pergelic Cryaquepts have a fairly thick (7 to 14 inches) accumulation of organic material on the surface.

Entisols have few, if any, clearly expressed characteristics. In the study area, they occur along the river channels, as alluvial plains in material recently deposited by water, and along terrace breaks where active erosion or mass wasting is taking place. The former group is represented by Typic Cryofluvents, and the latter by Typic Cryorthents. Furthermore, all the minesoils are Entisols because they are very young and lack clearly expressed horizons except a dark surface horizon due to organic matter accumulation.

The classification of minesoils deserves special attention because of the increased extent of disturbed land in Alaska and management interpretations. A new suborder of Spolents has been proposed to accommodate highly disturbed or man-made soils, which include minesoils (Smith and Sobek 1978). We suggest a great group of Cryospolents to accommodate all Spolents in the Cryic or Pergelic temperature regime. We also suggest a Bitumious subgroup of Cryospolents to accommodate the minesoils dominated by coal particles.

All the soil profiles studied are classified to the family level according to Soil Taxonomy, and listed in Table 13.

SUMMARY AND CONCLUSIONS

The natural soils in the Usibelli Coal Mine area vary widely over the landscape. A total of five subgroups of soil were identified. The five subgroups belong to eight soil families. The Cryofluvents and Cryorthents vary widely in texture but generally are very gravelly or sandy. Their landscape positions are either along major river channels or ravines. These soils have very limited potential for topsoil stockpiling. The Pergelic Cryaquepts and Pergelic Cryohemists occur mainly in the depressions and north-facing tundra slopes. These soils have nutrient rich organic layers, but the permafrost layer would present severe physical limitations to stockpiling operation. The Typic Cryochrepts have rather limited distribution in the mining area. The Dystric Cryochrepts are the dominant soils on upland positions. They have 12 to 18 inches of medium-textured topsoil worthy of stockpiling for reclamation purposes. However, the extent of these soils does not seem to provide enough topsoil to cover all the disturbed area.

The minesoils appear to be less variable than the natural soils in the area because of the uniformity of the overburden materials which are dominantly loamy. A new great group of Cryospolents is suggested to accommodate these minesoils in subarctic and arctic areas. There are only small portions of the overburdens with a clayey texture. Minesoils and the overburden material tested so far do not have adverse properties in terms of acid or salt effects and toxic heavy metal levels. Thus, the overburden can be used as a topsoil substitute for reclamation purposes when there is insufficient topsoil available. Fertilizer amendment is necessary to ensure establishment and maintenance of revegetation seedings. Terrain reshaping should be incorporated to minimize erosion. Furrowing appeared to benefit revegetation efforts.

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Table 1. Monthly air temperature, precipitation, snowfall, and frost-free days at Healy area, Alaska (SD = standard deviation)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean Annual
						Healy 2 NW Station, † elev. 1490 ft.							
Air temperature, °F	10.0	10.3	15.9	27.3	46.4	54.9	58.2	54.4	43.4	26.7	12.7	4.9	30.4
SD	14.6	7.4	7.3	5.3	3.2	1.7	2.5	3.5	3.4	6.1	9.9	14.9	0.9
Precipitation, inch	0.57	0.51	0.33	0.62	0.82	2.68	3.00	2.31	1.71	1.28	0.64	0.66	15.2
SD	0.37	0.34	0.18	0.59	0.49	0.71	1.18	0.86	0.78	0.44	0.38	0.09	1.2
Frost free days, 28°F													128
SD													16
Frost free days, 32°F													90
SD													21
						Poker Flats station, ◊ elev. 1820 ft.							
Air temperature, °F	5.2	-2.6	9.4	25.9	41.9	50.0	54.3	48.3	39.6	21.8	10.7	6.1	25.9
SD	12.5	11.6	17.2	8.3	6.6	3.7	3.3	4.6	5.5	8.8	10.4	12.5	4.2
Precipitation, inch	0.7	0.4	0.4	0.5	1.0	2.8	3.1	3.1	2.1	1.4	0.9	0.6	16.9
SD	0.6	0.3	0.7	0.5	0.7	1.0	1.3	1.0	1.2	0.6	0.7	0.7	2.7
Snow, inch													75
SD													26
Frost-free days 32°F													91
SD													19

† DOC/NOAA, records from 1977 to 1986

◊ Usibelli Coal Mine records from 1978 to 1987

Table 2. Selected properties of Dystric Cryochrepts in Usibelli Coal Mine area

Horizon	Depth (in.)	pH 1:1	pH SMP	Org. C	Total N	Sand	Clay	USDA† Texture	Exch. Cations Ca	Exch. Cations Mg	Exch. Cations K	Exch. Cations Na	CEC (pH 7)	Base Sat.
				---------------	-----%	---------------			-------------	-------meq/100g	-------	-------------		%
							Profile 72							
Oe	3-1	—	—	— —	— —	—	—	mk-peat	— —	— —	— —	— —	—	—
Oa	1-0	4.7	5.5	15.3	0.80	—	—	mk-sil	5.00	2.53	0.76	0.30	60	14
E	0-1	4.6	5.1	0.7	0.20	32	16	sil	1.28	0.61	0.16	0.23	29	8
Bs1	1-3	5.8	6.2	0.9	0.09	33	21	l	0.66	0.33	0.11	0.13	15	8
Bs2	3-7	6.0	6.4	0.3	0.05	38	24	l	1.82	2.11	0.04	0.10	15	27
Bs3	7-9	5.8	6.5	0.2	0.05	31	23	l	1.64	1.81	0.04	0.08	12	30
BC	9-13	6.3	6.6	0.3	0.05	21	18	grv-sil	0.78	0.44	0.03	0.13	10	14
2C1	13-18	5.9	7.0	0.1	0.03	77	11	grx-sl	1.06	0.68	0.03	tr	5	37
2C2	18-40	6.2	7.2	0.1	0.02	85	6	grx-ls	1.33	0.56	0.02	0.04	4	48
							Profile 74							
Oe	1-0	—	—	— —	— —	—	—	mk-peat	— —	— —	— —	— —	—	—
E	0-2	4.7	6.4	4.7	0.20	27	12	l	0.96	0.27	0.09	tr	23	6
Bs1	2-9	5.5	6.7	1.2	0.07	35	16	sil	0.43	0.05	0.02	0.06	9	6
Bs2	9-13	6.0	6.9	0.6	0.07	36	16	l	0.37	0.04	0.03	0.03	3	6
BC	13-17	6.3	7.0	0.3	0.04	60	11	sl	0.45	0.07	0.02	0.06	5	12
2C1	17-22	5.8	7.2	0.1	0.02	87	8	grx-ls	0.78	0.30	0.02	tr	4	31
2C2	22-40	5.9	7.2	0.1	0.02	87	6	grx-s	0.56	0.22	0.01	tr	3	31
							Profile 16							
Oe	3-0	— —	—	— —	— —	—	—	mk-peat	— —	— —	— —	— —	—	—
E	0-2	— —	—	— —	— —	—	—	sil	— —	— —	— —	— —	—	—
Bs1	2-5	5.9	—	1.7	0.10	36	15	l	2.00	0.72	2.24	0.16	16	32
Bs2	5-7	6.1	—	1.0	0.07	33	16	sil	1.18	0.51	0.16	0.09	14	14
Eb	7-10	6.4	—	0.6	0.04	15	17	sil	0.75	0.31	0.17	0.05	11	12
Bsb	10-12	6.3	—	0.9	0.07	37	16	l	1.04	0.40	0.15	0.19	14	13
2BC	12-19	—	—	—	— —	—	—	cbv-s	— —	— —	— —	— —	—	—
2C	19-60	—	—	—	— —	—	—	cbv-cos	— —	— —	— —	— —	—	—

† mk - mucky; gr - gravelly; grv - very gravelly; grx - extremely gravelly; cb - cobbly; cbv - very cobbly; cbx - extremely cobbly; s - sand; cos - coarse sand; ls - loamy sand; sl - sandy loam; l - loam; sil - silt loam; c - clay; cl - clay loam; sic - silt clay; scl - silt clay loam.

Table 3. Selected properties of Dystric Cryochrept with shallow topsoil in Usibelli Coal Mine area

Horizon	Depth (in.)	pH 1:1	pH SMP	Org. C	Total N	Sand	Clay	USDA† Texture	Exch. Cations Ca	Exch. Cations Mg	Exch. Cations K	Exch. Cations Na	CEC (pH 7)	Base Sat'n	Avail. N	Bray1 P	E.C.
				---------------%---------------					-------------meq/100 g-------------					%	----ppm----		dS m^{-1}
								Profile 65									
Oi	1-0	–	–	–	–	–	–	peat	–	–	–	–	–	–	–	–	–
A	0-1	5.0	6.1	8.0	0.36	50	13	sil	4.35	1.47	0.31	0.10	23	27	64	12	0.21
E	1-2	4.7	5.9	3.6	0.18	34	15	sil	0.97	0.38	0.07	tr	17	8	36	3	0.13
Bs	2-6	5.2	6.2	1.2	0.08	36	19	l	0.36	0.11	0.05	tr	13	4	47	2	0.10
2BC1	6-10	5.6	6.8	0.4	0.04	87	7	grv-ls	0.25	0.04	0.02	tr	6	5	13	8	0.05
2BC2	10-14	5.9	6.9	0.3	0.04	90	5	grv-s	0.25	0.03	0.01	tr	4	7	13	12	0.05
3C1	14-16	6.1	7.3	0.2	0.04	80	7	ls	0.29	0.04	0.01	tr	4	9	26	10	0.09
4C2	16-20	6.0	7.2	0.1	0.02	86	7	grx-ls	0.27	0.04	0.01	tr	2	16	12	10	0.09
4C3	20-60	5.9	7.3	0.1	0.01	92	5	cbx-s	0.30	0.09	tr	tr	2	20	11	14	0.05

† See footnote in Table 2

Table 4. Selected properties of two Histic Pergelic Cryaquepts and one Pergelic Cryohemist in Usibelli Coal Mine area

Horizon	Depth (in.)	pH 1:1	pH SMP	Org. C	Total N	Sand	Clay	USDA† Texture	Exch. Cations Ca	Exch. Cations Mg	Exch. Cations K	Exch. Cations Na	CEC (pH 7)	Base Sat.	Avail. N	Bray1 P	E.C.
				%	%	%	%		meq/100 g	meq/100 g	meq/100 g	meq/100 g	meq/100 g	%	ppm	ppm	$dS\ m^{-1}$
								Profile 62 Histic Pergelic Cryaquept									
Oi	8-4	–	–	– –	–	–	–	peat	– –	– –	– –	– –	–	–	–	–	– –
Oe	4-0	–	–	– –	–	–	–	mk-peat	– –	– –	– –	– –	–	–	–	–	– –
Af	0-5	5.3	5.3	8.6	1.0	61	19	mk-sl	6.45	1.00	0.44	0.77	13	64	508	1	0.22
Oaf1	5-8	5.3	5.8	14.3	1.4	–	–	muck	5.45	1.00	0.18	0.85	59	16	212	1	0.20
Abf	8-11	5.2	5.7	11.3	1.1	–	–	mk-sl	5.85	0.96	0.18	1.00	129	6	194	1	0.22
Cf1	11-14	5.2	6.1	2.9	0.1	33	24	l	– –	– –	0.06	– –	87	–	105	6	0.20
Oaf2	14-16	5.2	5.3	16.9	0.7	–	–	muck	6.70	0.62	0.11	0.72	92	9	246	1	0.22
Cf2	16-20	–	–	– –	–	–	–	sil	– –	– –	– –	– –	–	–	–	–	– –
								Profile 69 Histic Pergelic Cryaquept									
Oi	11-9	–	–	– –	–	–	–	peat	– –	– –	– –	– –	–	–	–	–	– –
Oa1	9-5	5.2	5.2	18.8	0.3	–	–	muck	4.89	2.25	0.31	0.43	67	12	146	2	0.16
Oa2	5-2	5.2	4.8	14.6	0.6	–	–	muck	3.15	1.64	0.12	0.20	52	10	103	1	0.13
Oa3	2-0	5.5	5.3	14.4	0.5	–	–	muck	3.98	1.16	0.06	0.18	42	13	130	2	0.12
A1	0-3	5.5	5.4	6.6	0.3	42	12	mucky l	2.77	0.96	0.06	0.12	35	11	112	1	0.14
A2	3-5	5.5	5.5	6.2	0.3	34	11	mucky l	2.67	1.00	0.07	0.16	28	14	192	2	0.20
C1	5-7	5.5	6.1	0.8	0.1	51	17	l	1.97	1.27	0.04	0.11	12	28	39	5	0.15
C2	7-9	5.6	5.6	2.6	0.1	30	22	l	2.20	0.87	0.07	0.05	17	19	55	5	0.18
C3	9-11	5.6	6.0	1.6	0.1	50	19	l	2.24	1.14	0.06	0.13	13	29	39	4	0.16
Cf1	11-12	5.6	5.8	2.6	0.1	35	22	l	2.08	0.87	0.07	0.12	17	18	66	6	0.14
Cf2	12-20	5.7	7.0	0.2	tr	76	10	gr-sl	1.49	0.55	0.04	0.03	4	53	19	7	0.14
								Profile 12 Pergelic Cryohemist									
Oi	0-3	–	–	– –	–	–	–	peat	– –	– –	– –	– –	–	–	–	–	– –
Oe1	3-11	4.5	–	38.9	0.92	–	–	muck	3.61	1.69	0.36	0.17	124	5	32	2	– –
Oe2	11-17	4.7	–	24.6	0.61	56	15	mk-sl	2.05	0.76	0.15	0.13	59	5	20	5	– –
Cf1	17-19	5.3	–	2.9	0.12	31	10	sil	1.44	0.07	0.09	0.05	19	9	13	2	– –
Cf2	19-24	5.1	–	7.5	0.25	41	19	l	1.20	0.53	0.10	0.07	31	6	16	2	– –
2Cf3	24-30	5.2	–	0.5	0.04	62	17	grv-sl	1.87	0.78	0.09	0.10	9	33	15	2	– –

† See footnote in Table 2

Table 5. Selected properties of Typic Cryochrepts in Usibelli Coal Mine area

Horizon	Depth (in.)	pH 1:1	pH SMP	Org. C	Total N	Sand	Clay	USDA† Texture	Exch. cations Ca	Exch. cations Mg	Exch. cations K	Exch. cations Na	CEC (pH 7)	Base Sat.
				%	%	%	%		meq/100 g	meq/100 g	meq/100 g	meq/100 g	meq/100 g	%
							Profile 15							
Oe	3-0	—	—	—	— —	—	—	peat	— —	— —	— —	— —	—	—
A	0-5	5.6	—	2.9	0.17	68	11	sl	4.92	2.62	0.18	0.06	17	47
2A	5-7													
2Bw	7-9	5.7	—	0.7	0.05	74	9	sl	2.91	1.01	0.09	tr	10	41
3BC	9-13													
3C1	13-38	6.2	—	0.6	0.04	71	10	sl	4.00	1.53	0.08	0.11	9	63
4C2	38-60	6.2	—	2.1	0.08	42	14	l	3.60	2.10	0.12	0.04	17	31
							Profile 82							
Oi	1-0	—	—	—	— —	—	—	peat	— —	— —	— —	— —	—	—
A	0-3	5.5	6.4	6.1	0.27	52	6	sl	5.15	1.89	0.17	0.12	18	40
Bs1	3-4	6.5	6.8	0.7	0.07	64	6	sl	1.23	0.44	0.03	tr	5	34
Bs2	4-6	6.5	7.1	0.4	0.04	78	5	ls	1.33	0.37	0.02	0.03	3	58
BC	6-9	7.3	7.3	0.3	0.04	84	5	grv-ls	1.79	0.25	0.02	0.02	3	69
2C	9-50	—	—	—	— —	—	—	grx-ls	— —	— —	— —	— —	—	—

† See footnotes in Table 2.

Table 6. Soil fertility status of two Dystric Cryochrepts and one Typic Cryochrept in Usibelli Coal Mine area

	Depth	Extractable Nutrition			DTPA-TEA Extractable					
Horizon	(in.)	N	P	K	Cu	Zn	Mn	Fe	E.C.	B.D.
		ppm							dS m^{-1}	g/cm^3
Profile 72. Dystric Cryochrept										
Oe	1-0	95	15	300	0.6	1.4	1.3	255	0.30	--
E	0-1	60	2	62	0.5	0.5	0.3	340	0.15	1.15
Bs1	1-3	120	1	44	0.8	0.2	1.6	53	0.12	1.15
Bs2	3-7	32	1	17	0.7	0.1	3.5	27	0.08	1.20
Bs3	7-9	40	1	18	0.7	0.2	4.5	30	0.09	1.20
BC	9-13	33	7	12	0.5	0.1	1.1	26	0.05	--
2C1	13-18	13	9	12	0.4	0.1	4.5	23	0.05	--
2C2	18-40	14	9	10	0.3	0.2	2.0	16	0.08	--
Profile 74. Dystric Cryochrept										
A/E	0-2	38	3	35	2.1	8.0	72.3	213	0.11	--
Bs1	2-9	61	2	10	1.2	0.4	0.9	197	0.05	1.24
Bs2	9-13	75	4	11	1.6	0.7	7.3	97	0.10	1.22
BC	13-17	45	9	9	3.2	1.2	7.8	60	0.11	1.22
2C1	17-22	14	10	10	4.3	0.9	14.3	77	0.05	--
2C2	22-40	13	10	5	4.2	2.0	18.1	241	0.01	--
Profile 15. Typic Cryochrept										
A & 2A	0-7	37	6	71	0.7	0.6	0.2	400	--	--
2Bw & 3BC	7-13	16	7	35	0.6	0.1	0.7	65	--	--
3C	13-38	15	4	42	0.5	0.1	2.6	36	--	--
4C2	38-60	14	56	40	0.1	0.1	3.0	12	--	--

Table 7. Selected properties of sandstone minesoils in Usibelli Coal Mine area

Horizon	Depth (inch)	pH		Org. C	Total N	Sand	Clay	Coarse fragment (>2mm)	USDA† texture	CEC pH 7	Extractable Nutrients				E.C.
		1:1	SMP								NH$_4$-N	NO$_3$-N	P	K	
				%						meq/100 g	ppm				dS m^{-1}
						Profile 60A (vegetated)									
A1	0-3	6.1	7.2	1.2	0.14	75	15	8	sl	9	27	6	6	42	0.30
A2	3-5	5.7	7.0	1.6	0.23	58	20	7	sl	16	50	6	21	77	0.32
AC	5-8	6.9	7.5	0.3	0.03	62	19	2	sl	6	40	6	10	28	0.29
C1	8-15	7.1	7.6	0.2	0.02	62	18	2	sl	5	17	5	4	35	0.25
C2	15-40	7.1	7.5	0.3	0.03	62	18	20	gr-sl	6	12	5	3	35	0.40
						Profile 60B (unvegetated)									
C1	0-2	6.9	7.5	0.2	0.02	62	15	2	sl	5	13	5	8	37	0.18
C2	2-40	7.0	7.5	0.2	0.02	64	15	2	sl	6	10	5	3	43	0.20
						Profile 63A (vegetated)									
A1	0.2	6.2	7.3	0.7	0.05	73	14	8	sl	9	21	4	7	49	0.16
A2	2-3	6.8	7.4	0.4	0.04	69	15	7	sl	6	39	5	17	53	0.18
C1	3-6	6.7	7.5	0.2	0.02	66	16	7	sl	6	22	5	10	48	0.15
C2	6-13	6.8	7.5	0.3	0.03	66	17	7	sl	7	16	5	2	40	0.15
C3	13-40	6.8	7.5	0.1	0.02	67	15	7	sl	6	9	5	1	41	0.13
						Profile 63B (unvegetated)									
C1	0-2	6.8	7.5	0.2	0.02	68	16	7	sl	7	18	6	6	45	0.30
C2	2-8	7.0	7.5	0.1	0.02	68	15	7	sl	5	6	15	2	33	0.11
C3	8-40	6.7	7.5	0.2	0.02	68	15	9	sl	6	6	15	2	36	0.14

Table 7, continued

Horizon	Depth (inch)	pH 1:1	pH SMP	Org. C	Total N	Sand	Clay	Coarse fragment (>2mm)	USDA† texture	CEC pH 7	Extractable Nutrients NH$_4$-N	Extractable Nutrients NO$_3$-N	Extractable Nutrients P	Extractable Nutrients K	E.C.
				---------	---------	%	---------	---------		meq/100 g	-------	------- ppm	-------	-------	dS m^{-1}
						Profile 64 (vegetated)									
A1	0-2	6.1	7.1	1.5	0.12	65	13	0	sl	9	29	6	42	117	0.34
A2	2-3	6.2	7.2	1.0	0.05	61	15	0	sl	9	29	11	20	74	0.35
AC	3-8	6.5	7.3	0.6	0.04	65	14	0	sl	7	24	4	5	26	0.38
Ab	8-16	6.2	7.0	1.9	0.08	72	13	20	gr-sl	13	20	6	4	20	0.28
ACb	16-33	6.2	7.3	0.7	0.04	67	13	18	gr-sl	6	11	5	5	25	0.31
C	33-50	6.5	7.4	0.8	0.03	68	14	16	gr-sl	5	11	7	4	28	0.48
						Profile 71 (vegetated)									
A1	0-3	6.8	7.4	0.7	0.05	71	11	0	sl	6.6	22	8	30	76	0.52
AC	3-6	7.6	7.5	0.4	0.03	75	11	0	sl	5.5	9	6	15	16	0.40
C1	6-9	7.9	7.6	0.3	0.02	74	11	0	sl	5.0	15	7	22	13	0.47
C2	9-19	7.8	7.6	0.2	0.05	72	11	0	sl	4.0	11	5	16	14	0.31
C3	19-29	8.0	7.4	0.3	0.03	75	11	0	sl	6.8	14	8	22	22	0.37
C4	29-50	7.3	7.3	0.3	0.03	77	11	0	sl	6.2	8	8	16	17	0.28
						Profile 87A ◊ (vegetated)									
A1	0-2	6.4	7.0	1.4	0.09	63	16	45	sl	11	17	5	22	97	0.33
A2	2-4	7.2	7.3	0.6	0.04	58	20	56	sl	8	27	5	32	29	0.23
AC	4-12	7.6	7.4	0.6	0.03	56	18	55	sl	8	29	7	36	29	0.30
C1	12-20	7.5	7.4	0.7	0.03	63	15	70	sl	8	20	7	27	25	0.26
C2	20-36	7.1	7.4	1.4	0.06	63	15	51	sl	9	11	5	16	15	0.50
C3	36-60	7.6	7.5	0.3	0.03	61	14	57	sl	4	10	5	15	18	0.72
						Profile 87B ◊ (unvegetated)									
A	0-2	7.2	7.4	0.7	0.04	60	17	62	sl	8	27	6	33	41	0.26
AC	2-3	7.5	7.4	0.6	0.04	59	18	55	sl	8	24	6	30	28	0.28
C1	3-12	7.6	7.4	0.5	0.03	57	18	52	sl	7	15	6	21	22	0.30
C2	12-15	7.5	7.4	0.9	0.05	55	19	71	sl	11	19	9	28	33	0.47
C3	15-60	7.3	7.4	0.7	0.03	60	14	50	sl	7	11	6	17	22	0.60

† See footnotes in Table 2

◊Coarse fragments in Profiles 87A and 87B are coal particles

Table 8. Selected properties of mudslide and clayey minesoils in Usibelli Coal Mine area

Horizon	Depth (inch)	pH		Org. C	Total N	Sand	Clay	Coarse fragment (>2mm)	USDA† texture	CEC pH 7	Extractable Nutrients					E.C.
		1:1	SMP								NH_4-N	Total NO_3-N	N	P	K	
				%						meq/100 g	ppm					dS m^{-1}
Profile 80. mudslide																
A	0-5	6.8	7.2	1.6	0.10	52	13	52	grv-sl	8	30	6	36	4	31	0.25
C1	5-20	7.5	7.3	1.1	0.08	53	13	55	grv-l	8	27	8	38	2	20	0.26
C2	20-40	7.2	7.2	1.1	0.08	50	17	52	grv-l	7	34	6	40	3	23	0.44
Oib	40-41	5.1	5.9	13.4	0.63	—	—	—	muck	51	184	12	196	15	32	0.32
C3	41-60	4.6	5.9	1.0	0.08	80	7	39	grv-ls	12	30	10	40	22	15	0.27
Profile 75. Minesoil, clayey ◊																
A	0-3	6.8	7.3	2.7	0.13	18	43	0	sic	21	30	7	37	4	96	0.46
C1	3-8	7.3	7.4	2.2	0.12	26	38	0	cl	20	28	8	36	2	84	0.66
C2	8-17	7.4	7.3	1.4	0.09	27	34	0	cl	10	20	8	28	4	67	0.63
C3	17-50	7.3	7.2	2.3	0.12	20	43	0	c	18	29	9	38	2	85	0.96
Profile 83. Minesoil-clayey ◊																
A	0-2	5.4	6.2	6.6	0.27	35	33	25	cl	25	27	5	32	34	68	0.45
AC	2-4	5.5	6.3	5.6	0.20	32	37	30	cl	27	22	7	29	10	43	0.38
C	4-40	5.4	6.4	3.6	0.16	30	37	45	cl	20	30	6	36	6	36	0.32
Profile 76. Minesoil-clayey																
A	0-3	6.6	7.2	2.7	0.14	36	32	19	cl	15	31	6	37	6	72	0.60
C1	3-14	7.0	7.3	2.4	0.11	19	40	23	sic	17	30	5	35	3	72	0.50
C2	14-50	6.4	6.9	3.7	0.18	18	48	30	C	33	40	6	46	3	128	0.60

† See footnotes in Table 2

◊ coarse fragments are soft siltstones

Table 9. Selected properties of reclaimed topsoils and coal minesoils in Usibelli Coal Mine area

Horizon	Depth (inch)	pH		Org. C	Total N	Sand	Clay	Coarse fragment (>2mm)	USDA† texture	CEC pH 7	Extractable Nutrients					E.C.
		1:1	SMP								NH_4-N	NO_3-N	Total N	P	K	
				%						meq/100 g	ppm					dS m^{-1}
						Profile 61. Reclaimed topsoils										
A	0-2	5.9	7.0	1.4	0.07	65	15	10	sl	9	30	5	35	17	57	0.20
C1	2-6	6.2	7.2	0.6	0.04	63	16	18	cb-sl	8	25	6	31	8	36	0.26
C2	6-12	7.3	7.5	0.2	0.02	73	11	70	cbx-sl	4	11	7	18	2	18	0.22
C3	12-40	8.0	7.5	0.03	0.02	70	8	68	cbx-sl	3	11	6	17	tr	14	0.22
						Profile 81. Reclaimed topsoils ◊										
A	0-2	8.1	7.4	1.7	0.10	70	13	50	grv-sl	9	24	7	31	2	33	0.40
AC	2-12	7.9	7.4	2.0	0.77	77	10	53	grv-sl	11	21	7	28	1	15	0.38
C1	12-28	8.1	7.5	0.2	0.02	73	12	32	gr-sl	2	7	6	13	2	7	0.23
C2	28-40	7.5	7.5	0.1	0.02	70	12	7	sl	2	6	6	12	2	8	0.22
						Profile 73A. Coal Minesoils ◊ (vegetated)										
A	0-6	6.1	6.0	9.3	0.53	75	15	52	grv-sl	48	43	9	52	57	162	0.34
C1	6-22	6.2	5.9	12.0	0.55	87	9	58	grv-sl	61	18	9	27	8	35	0.41
C2	22-50	6.2	5.8	13.6	0.55	87	8	67	grv-sl	74	20	10	30	4	50	0.46
						Profile 73B. Coal Minesoils ◊ (unvegetated)										
A	0-6	6.0	6.0	21.8	0.54	87	8	45	grv-ls	47	46	19	65	47	72	0.50
C1	6-12	6.1	6.1	21.1	0.53	85	9	60	grv-ls	61	20	12	32	6	50	0.48
C2	12-50	6.1	4.5	11.9	0.60	88	7	66	grv-ls	77	19	12	31	3	43	0.47

† See footnotes in Table 2

◊ all coarse fragments are coal particles

Table 10. Fertility status of overburden materials from Usibelli Coal Mine

Code	Sample Description	pH (1:1)	pH SMP	Org. C	Sand	Clay	USDA Texture	CEC	Extractable Nutrients NH_4	NO_3	P	K	Ca	Mg	Na	SAR	E.C.
				-------%	-------	-------		meq/100g	--------------	------------	-----------	-------	ppm -------	-----------	-----------		dS m $^{-1}$
1	Drill Hole #83-1-A	5.9	6.2	15.5	32	19	l	78	16	5	1	163	3444	429	120	0.51	0.41
2	Drill Hole #83-1B	7.7	7.5	0.4	41	23	l	12	20	5	3	72	1500	344	37	0.22	0.65
3	Drill Hole #83-1C	9.1	7.6	0.1	40	26	l	10	10	6	2	71	1650	26	315	2.11	0.62
4	Drill Hole #83-2-A	7.0	7.1	1.7	23	26	sil	19	36	4	4	84	1810	350	78	0.44	0.42
5	S.S. below foot wall clays	8.7	7.6	0.1	57	12	sl	4	14	4	3	20	388	66	36	0.45	0.58
6	Bottom 3 seam ft. wall clays	8.3	7.6	0.3	23	24	sil	12	24	3	7	58	1850	347	35	0.20	1.51
7	Cross bed silt band	7.6	7.5	0.6	49	14	l	6	11	5	3	36	855	141	54	0.45	0.84
8	3' above 3 seam	8.4	7.6	0.2	50	12	l	1	8	5	3	23	284	87	43	0.57	0.67
9	4-6' below seam 4	7.7	7.5	0.8	4	62	c	20	32	8	10	129	2490	556	80	0.38	0.47
10	6-16' below seam 4	6.6	7.3	1.0	10	28	sicl	15	20	9	4	98	2090	388	82	0.43	2.80
11	15-18' below seam 4	7.5	7.5	1.0	18	26	sil	13	18	6	5	82	2000	366	58	0.31	0.96
12	sand band, below FW 4	7.8	7.6	tr	65	8	sl	2	9	4	3	21	302	51	31	0.43	0.77

Table 11. Primary mineral composition of light minerals in sand fraction 0.05-0.20 mm, clay components of selected soil samples from Usibelli Coal Mine area

Horizon	Depth (inch)	Primary Mineral†		Clay mineral components ◊
		Major constituents	Minor constituents	
			Profile 72	
E	0-1	plagioclase, quartz	hornblende, opaque min	ver, smc, mica, chl, kao qtz, fds,
Bs1	1-3	"	"	ver, smc, mica, kao, chl, qtz, fds
Bs2	3-7	"	"	smc, ver, mica, kao, chl, chl-ver, qtz
Bs3	7-9	"	opaque min.	n.d.
BC	9-13	n.d.§		ver, mica, chl, smc, amphiboles, qtz, fds
2C	13-18	n.d.		ver, mica, kao, chl, chl-ver, qtz, fds
			Profile 74	
E	0-2	plagioclase, quartz	hypersthene, hornblende opaque min. vol. glass	ver, kao, mica, chl, mica-ver, chl-ver, qtz, fds
Bs1	2-9	"	hornblende and opaque min	ver, chl, kao, mica, mica-ver, mica-chl, qtz, fds
Bs2	9-13	"	"	n.d.
BC	13-17	n.d.		kao, ver, mica, chl, smc, qtz
			Profile 16	
Bhs	2-5	n.d.		mica, ver, kao, smc, chl, qtz
Bs	5-7	n.d.		ver, smc, mica, kao, chl, qtz, fds
E1	7-10	n.d.		mica, ver, smc, kao, chl, qtz
Bsb	10-12	n.d.		smc, mica, ver, kao, chl, qtz
			Profile 65	
E	1-2	n.d.		ver, kao, mica, mica-ver, qtz
Bs	2-6	n.d.		kao, ver, smc, chl, mica-ver, qtz

† Source: Robert M. Thorsen, Alaska Tephrochronology Center, University of Alaska Fairbanks Museum (unpublished)

◊ chl = chlorite; kao = kaolinite; smc = smectite; quz = quartz; fed = feldspar; chl-ver, mica-ver, mica-chl = intergrades of the two minerals.

§ n.d. = not determined

Table 12. Extractable iron and aluminum for Dystric Cryochrepts in Usibelli Coal Mine area

Horizon	Depth (inch)	Color (moist)	Pyrophosphate Extractable Fep	Pyrophosphate Extractable Alp	Dithionite Extractable Fed	Dithionite Extractable Ald	Spodic Criteria $\frac{Fep+Alp}{Clay}$	Spodic Criteria $\frac{Fep+Alp}{Fed+Ald}$
			---------------------	%	---------------------		≥0.2	≥0.5
					Profile 16			
E	0-2	10YR 4/1	--	--	--	--	--	--
Bs1	2-5	10YR 4/3	0.39	0.44	2.42	0.47	0.05	0.28
Bs2	5-7	10YR 4/6	0.08	0.32	1.79	0.58	0.02	0.17
Eb	7-10	10YR 4/2	0.01	0.27	0.53	0.33	0.02	0.32
2BC	10-12	7.5 YR 4/4	0.62	0.25	2.82	0.69	0.02	0.08
					Profile 65			
A	0-1	10YR 3/3	0.15	0.09	1.99	0.13	0.03	0.11
E	102	10YR 4/2	0.18	0.10	2.38	0.11	0.02	0.11
Bs	2-6	10YR 4/5	0.24	0.22	3.14	0.33	0.02	0.13
2BC1	6-10	7.5YR 4/4	0.06	0.17	2.86	0.34	0.03	0.07
					Profile 72			
E	0-1	7.5YR 4/2	0.37	0.15	1.38	0.19	0.03	0.33
Bs1	1-3	10YR 3/3	0.24	0.24	2.41	0.54	0.02	0.16
Bs2	3-7	10YR 4/6	0.11	0.32	1.92	0.31	0.02	0.19
Bs3	7-9	10YR 5/5	0.08	0.15	1.95	0.24	0.01	0.11
BC	9-13	2.5Y 4/4	0.4	0.12	1.95	0.35	0.01	0.07
					Profile 74			
E	0-2	7.5YR 4/2	0.31	0.12	1.69	0.14	0.04	0.23
Bs1	2-9	10YR 4/6	0.59	0.19	2.65	0.26	0.05	0.27
Bs2	9-13	10YR 4/6	0.30	0.18	3.07	0.41	0.01	0.05
BC	13-17	7.5YR 4/4	0.13	0.11	2.69	0.30	0.02	0.08

Table 13. ***Classification of the soils and minesoils in Usibelli Coal Mine area***

Profile no.	Family	Subgroup	Order
		Natural soils	
16, 72, 74	Coarse-loamy over sandy or sandy-skeletal, mixed	Dystric Cryochrepts	Inceptisols
65	Sandy-skeletal, mixed	Dystric Cryochrepts	Inceptisols
15	Coarse-loamy, mixed	Typic Cryochrepts	Inceptisols
82	Sandy-skeletal, mixed	Typic Cryochrepts	Inceptisols
62, 69	Fine-loamy, mixed	Histic Pergelic Cryaquepts	Inceptisols
12	Euic	Pergelic Cryohemist	Histosols
		Minesoils	
60A, 60B, 63A, 63B 64, 71, 81, 87A, 87B	Coarse-loamy, mixed	Typic Cryospolents	Entisols
80	Coarse-loamy over sandy or sandy-skeletal, mixed	Typic Cryospolents	Entisols
75, 76, 83	Clayey, mixed	Typic Cryospolents	Entisols
61, 81	Loamy-skeletal, mixed	Typic Cryospolents	Entisols
73A, 73B	Sandy, mixed	Butiminous Cryospolents	Entisols