6-1969

A biosequence of soils formed from loess and volcanic ash in the Western Kenai Peninsula, Alaska

Robert B. Hinton

To the Graduate Council:

I am submitting herewith a thesis written by Robert B. Hinton entitled "A biosequence of soils formed from loess and volcanic ash in the Western Kenai Peninsula, Alaska." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

M. E. Springer, Major Professor

We have read this thesis and recommend its acceptance:

H. C. Smith, H. R. DeSelm

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

May 1, 1969

To the Graduate Council:

I am submitting herewith a thesis written by Robert B. Hinton entitled "A Biosequence of Soils Formed from Loess and Volcanic Ash in the Western Kenai Peninsula, Alaska." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

M. E. Springer
Major Professor

We have read this thesis
and recommend its acceptance:

H C Smith

H. R. DeSelm

Accepted for the Council:

Hilton A. Smith
Vice Chancellor for
Graduate Studies and Research

A BIOSEQUENCE OF SOILS FORMED FROM LOESS AND VOLCANIC ASH IN THE WESTERN KENAI PENINSULA, ALASKA

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

Robert B. Hinton

June 1969

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to all of the people who assisted in making this work possible. He wishes to express his gratitude to his committee chairman, Dr. Max E. Springer, for his guidance throughout this study. He wishes to thank Dr. Klaus Flach, Head of the Soil Survey Laboratory, Riverside, California, for his supervision of the laboratory work and the use of the laboratory facilities at Riverside. The author thanks Dr. Samuel Rieger, State Soil Scientist, Alaska, for suggesting the study and his assistance throughout its progress. He expresses his gratitude to Dr. Dennis Nelleton of the Riverside Laboratory, for the X-ray and DTA determinations and his aid in interpreting the data, and to Mr. Benny Brasher for his assistance in studies on water retention and bulk density determinations.

The author is grateful to his committee members, Dr. H. R. DeSelm and Mr. H. C. Smith, for their suggestions and the use of materials borrowed from them. He thanks Dr. W. L. Parks, Mr. T. J. Longwell, Mr. Brooks Robinson, and Mr. K. B. Sanders, of the Agronomy Department, for the use of laboratory space and equipment at The University of Tennessee. The author is especially grateful to Dr. R. E. Nelson, Messrs. L. H. Grant, Cliff Henry, and Leo C. Klameth, of the Riverside Soil Survey Laboratory, for their assistance in laboratory techniques.

The author thanks Mr. B. O. Halliday, State Conservationist, Alaska, and the U.S. Conservation Service for encouragement and the granting of leave to conduct this study.

ABSTRACT

In the western Kenai Peninsula, Alaska, the well drained Cohoe and Island soils have formed in a mixture of volcanic ash and loess. The Cohoe soils have some properties of Spodosols and support a climax spruce forest. The Island soils are classified as Inceptisols and occupy broad, shallow grass-covered depressions that occur as openings within areas of the forested Cohoe soils. Field evidence indicates that in western Alaska the forest is advancing at the expense of the grasslands.

In soils high in volcanic ash or other pyroclastic materials that yield high amounts of amorphous materials, it is sometimes difficult to distinguish between a spodic and a cambic horizon by the kinds of measurements commonly made in the laboratory. Several lines of evidence indicate that Andepts are converted to Spodosols in a relatively short time following their occupation by spruce forest in western Alaska.

The main objective of this study was to apply some of the physical and chemical studies which are commonly used to distinguish between spodic and cambic horizons high in amorphous materials. A second objective was to relate the soil forming factor of vegetation to the morphology of these soils.

Two transects extending from the grass-covered Island soils to the forested Cohoe soils were chosen near Ninilchik on the southwestern Kenai Peninsula. Samples from horizons were taken from representative pedons of an Island, a Cohoe, and a transitional soil on the forest-

grass border. Some of the chemical studies included: (1) cation exchange capacity, (2) exchangeable bases, (3) percent organic carbon, (4) percent nitrogen, (5) extractable acidity, (6) percent free iron, and (7) pH values determined in water paste, N KCl paste, and .01M $CaCl_2$. In addition, pH values were determined in 1N NaF. X-ray, DTA, bulk density, and pyrophosphate dithionite extractable C, Fe, and Al studies were made on the horizons of the sola. Percentage water retention at 15-bars was determined on air-dry, field-moist, and oven-dry samples. Particle size distribution was determined by the standard method of dispersion using hexametaphosphate preceding overnight shaking. In addition, results were compared on air-dry and field-moist samples. On selected horizons, ultrasonic sound was employed as an additional dispersant.

The difficulty of wetting and differences in percentage water retention at 15-bars on field-moist and air-dry samples showed that these soils dry irreversibly. Particle size distribution suggested incomplete dispersion by all methods used. X-ray, DTA, and NaF pH values indicated a high content of amorphous material, but not a high content of allophane. The organic fraction was almost as important a part of the active fraction as was the clay in the chemical properties that were measured. Pyrophosphate dithionite extractable C, Fe, and Al were similar at comparable depths in the three soils studied.

The forested Cohoe and Transitional soils have thin albic horizons over reddish B horizons that have some properties of spodic horizons; the grass-covered Island soils have thick, dark umbric epipedons. The laboratory studies, however, revealed that the difference in measured properties were small.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

CHAPTER I

INTRODUCTION

In the Western Kenai Peninsula, Alaska, the closely associated Cohoe and Island soils are moderately deep, well drained, and formed in mixed deposits of loess and volcanic ash. The Island soils are in grass covered shallow depressions of various sizes that are "islands" within the spruce forested Cohoe soils. These soils are mostly at elevations between 100 and 400 feet on broad nearly level to gently sloping uplands. The Cohoe soils are extensive, but the Island soils are limited in extent. The Cohoe soils support a climax spruce forest consisting of Sitka spruce (*Picea sitchensis* (Bong.) Carr.), white spruce (*Picea glauca* (Moench) Voss), hybrids of the two, and paper birch (*Betula papyrifera* Marsh.)

In the western Kenai Peninsula, well drained soils below 800 foot elevations are mostly forested; natural grasslands predominate above. Field evidence (Griggs, 1936) indicates that the forest in western Alaska is advancing at the expense of the grasslands. Field relationships between the Island and Cohoe soils indicate that the Island soils may be relicts from former extensive grasslands. Clumps of spruce and spruce seedlings have invaded the periphery and other higher portions of the depressions occupied by Island soils.

The Island soils have dark, thick surface horizons, but the Cohoe soils have thin gray A2 horizons over splotched brownish and reddish B horizons. The Island soils have properties typical of

Cryandepts. The Cohoe soils have some properties characteristic of Cryorthods. Simonson and Rieger (1967) cite evidence that Cryandepts are changed to Cryorthods after grass is succeeded by forests in western Alaska. It is sometimes difficult to distinguish between spodic and cambic horizons of soils developed in materials high in volcanic ash (Soil Survey Staff, 1967). Both kinds of horizons contain amorphous materials that are similar in the kinds of properties commonly measured.

Some of the methods and approaches in the 7th Approximation (Soil Survey Staff, 1967) will be used to distinguish and classify Cryandepts and Cryorthods. In addition it is hoped that clues will be given to the effect on the morphology of these soils by a change in vegetation from grass to forest.

CHAPTER II

REVIEW OF LITERATURE

I. LOCATION

The western Kenai Peninsula is a part of the Cook Inlet Lowland Physiographic Subprovince (Karlstrom, 1964). The area selected for this study (Fig. 1) is centered a few miles east and south of the village of Ninilchik, which is at 60° 03'N latitude and 151° 40'W longitude. Ninilchik is 38 miles southwest of the town of Kenai, the largest city on the Kenai Peninsula.

II. TOPOGRAPHY

The Cook Inlet Lowland is subdivided on the basis of topography and geology into seven areas (Karlstrom, 1964). The Cohoe and Island soils are mostly in the northern part of the area designated as the Ninilchik Lowland, a narrow terraced coastal bench 10 to 15 miles wide and 60 to 70 miles long between Cook Inlet and the Caribou Hills. It is mostly below 500 foot elevations. The Caribou Hills area is a partially glaciated upland with elevations ranging from 2,000 to 3,000 feet. Steep sea cliffs border Cook Inlet except at stream estuaries.

For the most part the coastal portion of the Ninilchik Lowland is a broad nearly level to gently sloping upland with the major streams in deeply incised, steep walled stream valleys with flat bottoms. These streams rise in the Caribou Hills to the east and flow west into Cook Inlet. Muskegs with poorly drained peat soils are

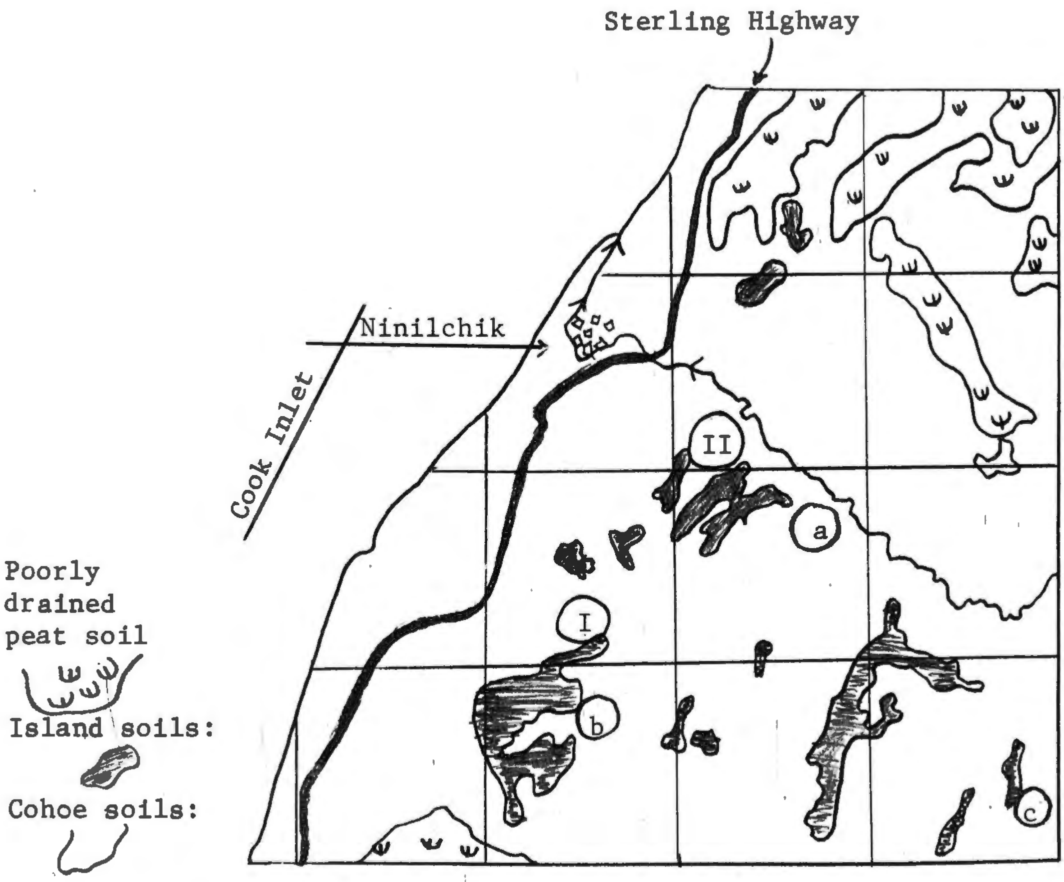


Figure 1. Area near Ninilchik, Alaska, showing location of Transects I and II.

Elevations: a. 150; b. 184; c. 257.

1 mile

commonly associated with broad, nearly level areas. The secondary drainage system is not highly developed and consists mostly of shallow drainageways and muskegs.

The Cohoe soils occupy nearly level to steep slopes but are most extensive on slopes with gradients of 2 to 5 percent. The Island soils are in flat bottomed shallow depressions mostly within nearly level areas of the Cohoe soils (Fig. 2). The depressions range from a few to several hundred acres in size. Most have shallow outlets, but wet spots and areas of peaty soils may occupy the lowest part of some depressions. Island soils have slow surface drainage. It is likely that formerly they were not well drained (Rieger et al., 1962).

III. CLIMATE

The Kenai Lowland has a cool moderately maritime climate. Characteristically, summers are cool and winters are long and moderately cold. Early summer is ordinarily sunny and somewhat dry, but by late summer and fall, cloudy rainy weather typically predominates. The mean annual temperature and precipitation line of 35°F and 20 inches lies a little north of Ninilchik.

Long-time climatic data are not available for Ninilchik, however, climatic conditions are similar to Kenai, 38 miles north, and Kasilof, 30 miles north. Climatic data are available for Kenai and Kasilof (U.S. Department of Commerce, 1965). Mean monthly and annual temperatures, inches of precipitation, and inches of snowfall are given in Table 1, for Kasilof, and in Table 2, for Kenai.

At Kasilof about half of the annual 17 inches of precipitation

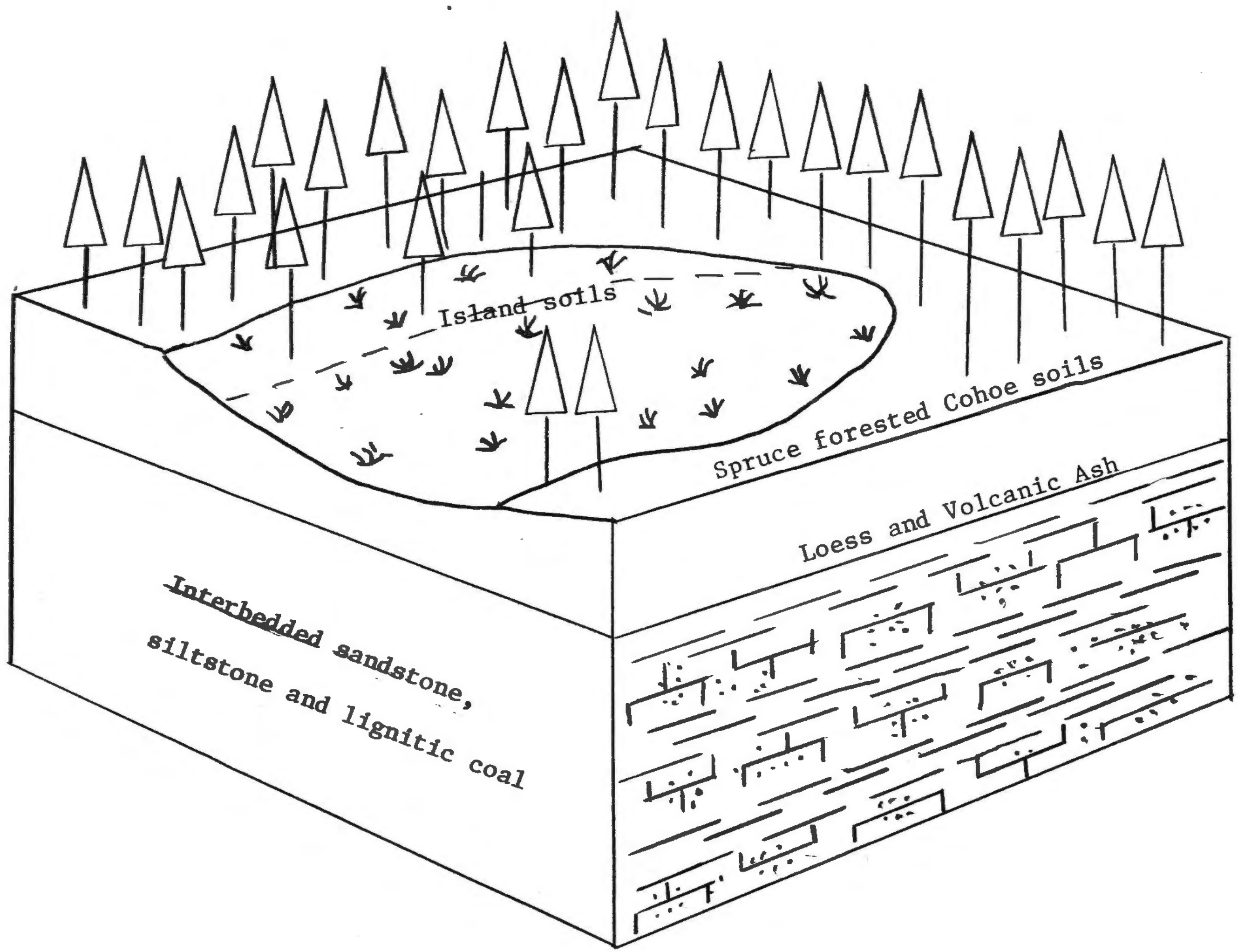


Figure 2. The Island soils occupy broad shallow depressions in nearly level areas of Cohoe soils.

Table 1. Mean Monthly Temperature, Precipitation, and Inches of Snowfall, Kasilof, Alaska (22-26 Year Record Through 1960)[a]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature, °F												
Mean												
13.3	19.2	22.9	34.5	43.7	51.0	54.8	54.2	47.2	36.1	23.9	14.6	34.60
Mean Maximum												
22.4	28.4	33.7	44.3	54.1	61.7	64.7	63.0	56.0	43.9	31.1	22.2	43.80
Mean Minimum												
4.8	10.0	12.1	24.7	33.3	40.5	45.1	45.3	38.4	28.2	16.6	7.4	25.50
Precipitation, inches of moisture												
1.08	.98	.75	.55	.72	1.12	2.09	2.40	2.96	1.69	1.44	1.23	17.01
Total Snowfall, inches												
11.2	8.4	8.0	2.7	.2	T[b]	.0	.0	.1	1.8	10.3	10.5	53.20

[a]Climatography of the United States No. 86-43, Supplement for 1951 through 1960 (Alaska). U.S. Department of Commerce.

[b]T indicates a trace.

Table 2. Mean Monthly Temperature, Precipitation, and Inches of Snowfall, Kenai, Alaska[a]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature, °F												
Mean (21 year record)												
11.5	16.5	22.0	32.8	43.3	49.7	53.6	53.2	46.3	34.9	22.4	13.2	33.30
Mean Maximum (17 year record)												
20.9	26.1	32.2	41.6	51.7	57.8	61.2	61.0	54.5	43.2	30.3	21.4	41.80
Mean Minimum (17 year record)												
1.6	5.9	9.1	24.5	34.7	42.0	46.2	45.8	38.1	26.5	16.3	4.9	24.60
Precipitation, inches of moisture (28-30 year record)												
.91	.91	.91	.79	.79	1.09	2.34	3.14	3.35	2.05	1.61	1.14	19.03
Total Snowfall, inches (25 year record)												
12.5	10.9	9.8	5.0	T[b]	.0	.0	.0	T	2.8	8.9	13.6	63.50

[a]Climatography of the United States No. 86-43, Supplemental for 1951 through 1960 (Alaska). U.S. Department of Commerce.

[b]T indicates a trace.

falls in late summer. The average annual snowfall is 53 inches. In an average winter the total accumulation is less than three feet. Considerable snow melt occurs during the winter.

The influence of the nearby ocean is reflected in the relatively cool summer temperatures. The highest temperature ever recorded at Kenai was 89°F in September 1883, and the record low was -48°F in February 1947 (Watson, 1962). In most years 70°F temperatures occur for a day or so at a time. Temperatures in the high sixties for a week or more at a time occur during most summers.

The average freeze-free season at Kenai is less than 100 days with a range from 67 to 133 days over a 16-year record (U.S. Department of Commerce, 1965). Table 3 gives the mean number of days at Kasilof with temperatures equal to or greater than 70°F and equal to or less than 32°F. In some years freezing temperatures have been recorded every month of the year. Long periods of daylight compensate for the relatively short growing season.

IV. GEOLOGY

The bedrock is the Kenai formation, a gently folded, fresh water deposit of the Eocene age and is several thousand feet thick.

Barnes and Cobb (1959) describe the formation:

> The Kenai formation consists of moderately indurated sand, silt, and clay in generally thin and intergrading beds and lenses, interbedded with a few thin lenses of fine conglomerate and many beds of subbituminous and lignitic coal ranging from a few inches to 7 feet in thickness. Thin layers of volcanic ash were found as partings in several coal beds near the head of Kachemak bay. Ferruginous masses in thick sandstone beds, and ironstone concretions, in distinct bands and scattered nodules, were common throughout the formation except to the north of Ninilchik, where they are

Table 3. Mean Number of Days with Temperatures $>$ 70°F or $<$ 32°F, Kasilof, Alaska[a]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
>70°F	0	0	0	0	+	3	7	4	4	0	0	0	14
Years	10	10	10	10	10	10	10	10	9	10	10	10	
<32°F	31	28	31	26	12	+	0	+	7	22	27	31	215
Years	10	10	10	10	10	10	10	10	10	10	10	10	

[a]Climatography of the United States No. 86-43, Supplement for 1951 through 1960 (Alaska), U.S. Department of Commerce.

Note: + indicates more than 0 but less than 0.5.

relatively scarce. The resistant masses of sandstone are particularly noticeable on some sections of beach where they have accumulated as irregular-shaped boulders as the wave-cut bluffs receded.

Glacial drift covers the Kenai formation in many parts of the Kenai Lowland, but is generally absent in the relatively flat terraces east of Ninilchik.

A loess mantle covers most of the Kenai Lowland. This silty mantle is generally two to four feet in thickness and consists of windblown material predominantly of silt size (Karlstrom, 1964). The origin of this silty material is probably from glacio-fluvial deposits washed from the fronts of retreating glaciers on the Kenai Peninsula, unvegetated drained proglacial lakes, and volcanic ash blown in from the Aleutian Range to the south and west. Kodiak Island, about 160 miles south of Ninilchik, received more than a foot of ash during the 1912 eruption of Mr. Katmai (Griggs, 1922). More than 30 active volcanoes occur in the Aleutian Range.

V. VEGETATION

Huesser (1960) has interpreted pollen studies and other sources to present a picture of vegetational changes along the north Pacific coast during late glacial and postglacial times. On the Kenai Peninsula the early postglacial climate was generally cool and moist but warmer than the final interval of the late glacial. He estimated it to have begun about 9000 B.P. (Before Present and to have lasted about 2,000 years. Sedges (Cyperaceae) and umbellifers (Umbelliferae) were the dominant plants during this period. Beginning about 7000 B.P. and lasting until 4000 B.P. was an interval of warmer temperatures than at present. This period is referred to as the Hypsithermal era. Pollen studies show that alder (Alnus), an early invader, was followed by birch (Betula). Sedges and grasses were associated plants. Coniferous species were poorly represented during the Hypsithermal period during which alder was predominant. The late postglacial, which began about 4000 B.P. was one of some cooling and a rise in humidity. Alder was still dominant but less so than in the Hypsithermal. Birch were achieving their maximum and were accompanied by the arrival of white and Sitka spruce.

Hulten (1937) postulated that there were two ice-free refugia, one on the southern Bering Sea and one in south central Alaska, from which plants migrated during the postglacial period. He cited evidence that Sitka spruce on the Kenai Peninsula migrated from the Seward refugium, and that white spruce and paper birch from the interior of Alaska had reached the Kenai prior to the last glaciation and had become established as part of the Seward refugium.

In interpreting pollen profiles from the vicinity of Homer, 40 miles south of Ninilchik, Huesser (1960) states, "These data show two major migrations of the interior forest onto the Kenai from unglaciated central Alaska, the most recent of which appears to have taken place during the last 4,000 years."

The southwestern Kenai Peninsula is a transitional zone between the coastal type forest of western hemlock (Tsuga heterophylla) and Sitka spruce, and the interior forest of white spruce and paper birch. This transitional zone has a close relationship with the mean annual temperature and precipitation line of 35°F and 20 inches (Karlstrom, 1964).

Bennett (1916), in describing the portion of the Kenai Peninsula from Homer to Point Possession, noted that the deeper soils supported dense forests of spruce and birch. In part, his description is cited below:

> The larger trees are on the deeper soil; white spruce attains a diameter upward of 24 to 36 inches and birch up to about 18 or 20 inches. Some medium to large sized aspen and large cottonwood trees are found locally in these spruce-birch forests. Associated with these trees is usually an undergrowth in which high-bush cranberry, currant, buckbush, devil's club, wild rose, huckleberry, alder, and willow are very common.
>
> Other common plants in the woods are sphagnum moss, bunchberry, joint grass, redtop, low-bush cranberry, and fern. In the open places or natural glades through the forest the growth of redtop is dense and rank, and frequently associated with this are fireweed, wild celery, redberry elder, and tall lupine. . . . In places bunch grass if found in these open situations, especially at the higher elevations.

The forest on the western Kenai Peninsula is transitional to the climax white spruce forest of the interior. Lutz (1956) describes the climax white spruce forest as self perpetuating unless destroyed by fire or cutting.

VI. SOILS

An early reconnaissance soil survey (Bennett, 1916) named the soil forming materials of the Kenai Peninsula: (1) glacial and residual material, (2) glacial outwash material, (3) alluvial material, (4) marine sedimentary material, (5) wind-blown material, and (6) cumulose material. In that early reconnaissance soil survey the Cohoe and Island soils were included in the mapping unit called Knik soils, the principal soils of the benchlands. They were described as being formed in wind-blown materials, brown in the surface portion, grading beneath into light brown or yellowish brown, at the depth just beneath the moss or leaf mold, was a silty gray layer from a fraction of an inch to about three inches thick. Bennett (1916) stated that the gray surface was looked upon locally as consisting of volcanic ash, but he suggested that only a portion was ash and that the gray color was brought about by leaching from the overlying leaf mold.

Kellogg and Nygard (1951) placed the soils of the western Kenai Peninsula in the soil association of Subartic Brown Forest, Podzol, and Half Bog soils. They designated the dark soils formed under grass on the Aleutian Islands, Kodiak Island, and the Alaska Peninsula, and the Southwestern Kenai Peninsula as tundra soils without permafrost.

Rieger et al. (1962) described the Cohoe soils as being formed in moderately deep silty material, and displaying most of the properties of Podzols--a mat of relatively undecomposed organic material, a gray horizon of eluviation, an incipient horizon of illuviation, and a strongly acid reaction in the solum. He stated, however, they were among the less highly developed Podzols of the area.

In the Kenai-Kasilof Soil Survey Report (Rieger et al., 1962), the Island soils were classified as Regosols, but it was stated that they had some characteristics of the Ando great soil group.

Rieger and Dement (1965), in a study of Cryorthods of the Cook Inlet-Susitna Lowland, Alaska, stated that if the amount of illuvial organic matter in the B horizon is accepted as a measure of the intensity of development of Orthods (in that study), then the Cohoe soils are not as strongly developed as Orthods in nearby areas where the precipitation is somewhat higher. Because of the common volcanic minerals in the fine sand fraction of all the soils studied in the Area, they further suggested that the parent material was of comparable age, and that the differences were not due to differences in age.

Simonson and Rieger (1967), in a study of the Andept Suborder in Alaska (including the Island series on the southwest Kenai Peninsula), described the Alaska Cryandepts as characterized by profiles with thick dark A horizons, low base saturation, strongly acid, little textural differentiation, and the clay fraction dominated by allophane. They pointed out the similarity to other soils formed in volcanic ash in Japan, New Zealand, and South America. In the same paper it is stated that the Andepts and Spodosols are closely related in tension zones between regions of forest and grass vegetation, and that the field relationships and shared physical characteristics of horizons suggest that Andepts are readily converted to Orthods following occupation by spruce forest.

Summary of Factors of Soil Formation

Parent material. These soils have formed in silty windlaid material, which is a mixture originating in glacial drift on the Kenai Peninsula and volcanic ash from the Aleutian Range to the west. The thickness of the silty mantle is commonly about 40 inches. Sediments of the Kenai formation of Tertiary (Eocene) age underlie the silty mantle. The sediments consist of poorly consolidated strata of sand, silt, and clay, and thin beds of lignite.

Climate. The climate is dominated by maritime conditions, characterized by cool, humid summers and moderately cool winters. The rates of evaporation and transpiration are comparatively low. A large proportion of the precipitation that falls percolates through the soil and is effective in leaching. Under the native vegetation the well-drained soils are cool and moist throughout the summer; however, the surface of the Island soils dries out more during warm, sunny days than the Cohoe surface. Temperatures rise high enough so there is no permafrost, but in cool summers frost may persist under forest cover until early June. The Island soils are in depressions where temperature inversions cause occasional summer frosts, which do not occur in adjacent higher areas.

Living matter. The Cohoe soils support a climax spruce forest. It is somewhat open and may be described as park-like. There is complete ground cover of low-growing shrubs, forbs, mosses, and lichens. The surface organic mat consists of about two inches of fresh spruce litter over about three inches of partially decomposed organic matter containing a large amount of volcanic ash.

The Island soils support a dense growth of low-growing vegetation dominated by grasses and associated plants. Lutz (1959) states that two conditions are necessary for the establishment of white spruce seedlings: (1) a source of viable seed, and (2) exposed mineral soil. Lack of exposed mineral soil may retard the invasion of spruce into these grasslands. In Manitoba, Waldron (1963) found a very high mortality rate of young white spruce seedlings when Calamagrostis was not controlled in experimental plants.

Relief. In this area of Alaska the soils are comparatively young and the effect of relief and topographic position is not nearly as great as in older areas (Rieger *et al.*, 1962). Soil development is generally as far advanced on steep uplands as it is on the more gently sloping or nearly level uplands. Soils in many depressions are not well drained and exhibit characteristics associated with wetness. The irregular surface of the Island soils indicates that formerly they may not have been well drained.

Time. These soils have developed in the relatively short time that has elapsed since the recession of the last ice sheet that formerly covered much of the Kenai Peninsula.

CHAPTER III

METHODS AND PROCEDURES

I. FIELD METHODS

Soil maps of the western Kenai Peninsula helped locate areas of Cohoe and Island soils. A post hole spade and a soil sampling tube were used to locate representative transects from Island and Cohoe soils. In many places a short escarpment forms the border between the grass covered Island soils and the forested Cohoe soils or between the depression and adjacent uplands. Transects were chosen with slight slope breaks at the forest and grassland border to provide a more representative transition profile. Figure 1 (page 4) shows the location of the transects.

Many suitable transects were found, but only two were picked for detailed study. One of these was selected for additional study in the laboratory. All of the areas investigated were undisturbed and in virgin vegetation. Excavations were made on a representative pedon of a Cohoe, a transition, and an Island soil. The soil profile was described from the face of the pit using Munsell color notations on moist soil. On sites at Transect I, samples were taken first from the bottom of the pit to avoid contamination from the horizons above during sampling. Samples were placed in clean polyethylene bags and then into heavy canvas bags for transport to the laboratory.

Clod samples for bulk density determinations were taken from the A and B horizons for the Cohoe soil and the A horizons of the Island soils. The clods were dipped in Saran-solvent solution, dried, and transported to the laboratory in metal containers to prevent crushing.

At each site the dominant plants were listed. An increment borer was used to determine the age of the dominant trees. The circumference at breast height and the height of the trees were measured. In the forest, density of stand per one-tenth acre plot was determined.

II. LABORATORY PROCEDURES

All soil samples were thoroughly mixed and, excepting those layers from recent volcanic ash at the soil surface, were divided. One group including the recent volcanic ash samples was air dried, ground with a rubber pestle, sieved through a 2 mm sieve, mixed thoroughly, and stored in quart glass containers with tightly sealed lids. Subsamples were later ground to pass an 80 mesh sieve for organic matter, nitrogen, and free iron determinations.

All determinations on the A2, B2, and B3 horizons of the Cohoe and Transition profile, and on the A11 and A12 of the Island soils were duplicated to serve as checks of precision.

Mechanical analyses on air dry and moist samples were made by the pipette method of Kilmer and Alexander (1949) with the modifications that two ten-gram samples were initially weighed. One was used to determine the oven dry-organic matter free weight. The undried sample was used for the particle-size distribution. This procedure was used because of the discovery that some of the colloidal matter dried irreversibly as aggregates in the sand-size fractions. For additional studies selected field-moist samples were treated with ultrasonics for

30 minutes preceding overnight shaking in hexametaphosphate solution. In addition, particle-size analyses on the A2, B2, and B3 of the Cohoe and Transition profiles and on the A11 and A12 of the Island profiles were made after the successive treatments: (1) pyrophosphate-dithionite extraction (Franzmeier et al., 1965) to remove extractable carbon, iron, and aluminum; (2) 2 percent sodium carbonate (Jackson, 1956) to remove silica and alumina; and (3) preceding overnight shaking in hexametaphosphate solution, the samples were treated with ultrasonics for 30 minutes. For the ultrasonic treatment the samples were weighed into tight-sealing, soft polyethylene bottles which were placed into the vat of the vibrator and covered with water. The vibrator was a Sonogen manufactured by Branson Instrument, Inc., with six transducers. The generator was 300 watts with an output of 25 kilocycles. The clay fraction from these samples was saved for X-ray and differential thermal analyses (DTA).

pH was determined with a Beckman Zeromatic pH meter on a soil-water paste and on a soil-N KCl paste. Both a moist and air-dry set of samples were used. pH was also determined in 0.01M $CaCl_2$ solution as described by Peech (1965).

Cation exchange capacity (CEC) was determined by the distillation of adsorbed ammonia after leaching the soil with normal ammonium acetate as described by Peech et al. (1947), with the modifications used in the Riverside Soil Survey Laboratory; 6 rather than 25 gram samples were used, and the samples were stirred between leachings with EtOH. Exchangeable Na and K were estimated with a Beckman Model D. U. Spectrophotometer with flame attachment (Soil Conservation Service, 1967).

Exchangeable Ca and Mg were estimated with a 290 Atomic Adsorption Spectrophotometer (Soil Conservation Service, 1967). Organic C was determined by the method of Allison (1960). NaF pH was determined by the procedure used in the Riverside Soil Survey Laboratory (R. E. Nelson, Research Soil Scientist, Soil Survey Laboratory, Riverside, California, personal communication). One normal NaF with the following analysis was used:

Insoluble matter	0.01 percent
Sulfate (SO_4)	0.01 percent
Heavy metals (as Pb)	0.003 percent
Iron (Fe)	0.003 percent
Chloride (Cl)	0.003 percent
Potassium (K)	0.003 percent
Free Acid (as HF)	0.01 percent
Free Alkali (as Na_2CO_3)	absent
Sodium Fluosilicate (Na_2SiF_6)	absent

The 1N NaF solution had a pH of 9.0. To one gram of air-dry soil in a 100 ml beaker was added 50 ml of 1N NaF. The suspension was stirred for one minute. The pH was read after two minutes and again after 60 minutes.

Extractable acidity was determined by the $BaCl_2$-triethanolamine method as outlined by Peech <u>et al</u>. (1947).

The pressure membrane method outlined by the Soil Conservation Service (1967) was used to measure water at tension of 15 atmospheres. Because these soils were believed to dry irreversibly, water retention at 15 atmospheres was determined in field-moist samples, air-dry samples, and oven-dry samples at 110°C, and oven-dry samples at 500°C. Another group of samples consisting of field-moist, air-dry, and oven-dry soil was treated with H_2O_2 to remove the organic matter, and afterwards the water retention at 15 atmospheres was determined.

Nitrogen was determined by the Kjeldahl digestion method (Association of Official Agricultural Chemists, 1945) and ammonium distillation process (Soil Conservation Service, 1967).

Free iron was estimated according to the dithionite-citrate extraction method of Holmgren (1967). Pyrophosphate-dithionite extractable carbon, iron, and aluminum were extracted as outlined by Franzmeier, Hajek, and Simonson (1965). Aluminum and acidity expressed as meq/100 grams of soil were estimated by the KCl (30 minute) method as described by McLean (1965).

Bulk density determinations were made by the method outlined by Brasher *et al*. (1966).

Figure 4. Area of Island soil (Transect I) that shows the characteristic uneven hummocky surface.

Note: A few spruce seedlings have become established on the higher places.

Figure 5. Young spruce have become established on the peri-periphery of the grass covered Island soils.

while the grasses and associated broadleaf plants that formerly dominated are being replaced.

In some of the soils there is a distinct layer of volcanic ash at the base of the O horizons. In others, the ash is incorporated into the O horizons. Frequent references are made to comparable horizons, e.g., the B2 horizons of the Transitional and Cohoe soils. If Soil Survey Staff (1960, 1962) terminology were used strictly, the B2 of the Transitional could be called IIB2 and in the Cohoe where the overlying ash is not in a distinct layer B2 could remain. Therefore, in these profile descriptions, the Soil Survey Staff (1962) designations are enclosed in parentheses for simplicity in comparisons. The thin layers of ash are simply called recent volcanic ash in the discussion.

The Cohoe site is in an open forest dominated by spruce but contains a few paper birch. The many openings in the canopy let sunlight through to the forest floor. The more open places (Fig. 6) support stands of bluejoint reedgrass and associated broadleaf plants. The dominant trees are fairly even-aged spruce. Younger trees are generally lacking. Table 4 gives the age, circumference, and height of the dominant spruce trees at each of the sampled sites; Table 5 gives the number and kind of tree per one-tenth acre plots at the Cohoe site.

<u>Transect I: Island Silt Loam</u>

O1 (O1)	2.5-0 inches	Very dark brown (10YR 2/2) organic mat with silt loam admixture; thin layer of fine sand size volcanic ash at base; abrupt smooth boundary.
Ash (C1)	0-1.5 inches	Recent volcanic ash. Brown (10YR 4/3) silt loam, weak fine granular structure; very friable;

Figure 6. The spruce forest near the Cohoe sample site of Transect I.

Note: On the Cohoe soils the forest contains many small grassy openings as shown here.

Table 4. Age, Height, and Circumference of Dominant Spruce Trees in Vicinity of Sample Sites of Transect I

Soil	Tree	Age	Circumference (inches)	Height (feet)
Cohoe	Spruce	97	48	64
		115	60	59
		102	45	60
		128	63	63
		94	43	55
		103	29	57
		109	37	71
		70	39	52
		95	33	63
		85	38	50
		103	44	69
		105	53	75
	Average	101	43	61
Transitional	Spruce[a]	73	31	40
		94	43	64
	Average	83	37	52
Island	Spruce[b]	29	24	25
		54	42	45
		24	14	22
		20	10	11
		24	17	23
		31	18	25
		31	24	20
		16	9	13
		67[c]	36	51
	Average	33	21	26

[a]Only two large trees; all others less than 20 feet high.

[b]Scattered trees and seedlings.

[c]Oldest and largest tree on Island soils area.

Table 5. Number and Kind of Tree[a] Per 1/10 Acre Plot on Cohoe Soils

Transect	Spruce	Paper Birch	Total
I	29	7	36
I	26	7	33
II	32	7	39
II	26	5	31
II	26	10	36

[a]This includes only trees more than 6 feet high; those less than 6 feet high are virtually nonexistent.

		many roots; abrupt smooth boundary.
A11 (IIA11)	1.5-6 inches	Very dark brown (10YR 2/2) silt loam; weak very thin platy structure; smeary; many roots; few small fragments of charcoal; clear wavy boundary.
A12 (IIA12)	6-19.5 inches	Very dark brown (10YR 2/2) silt loam with streaks and patches of brown (10YR 4/3); weak very thin platy structure; smeary; common roots; few small charcoal fragments; patches of brown (10YR 4/3) ash at 16 inches and fine streaks throughout horizon; abrupt wavy boundary.
B (IIB)	19.5-27 inches	Brown (10YR 4/3) silt loam with patches of very dark brown (10YR 3/2); weak very thin platy structure; smeary; few roots; many fine pores, abrupt wavy boundary.
A1B (IIAb)	27-30 inches	Very dark brown (10YR 3/2) silt loam with streaks of brown (10YR 4/3); dark yellowish brown (10YR 4/4), and olive brown (2.5Y 4/4); very weak very thin platy structure; smeary; few roots; many fine vesicles and pores; contains streaks similar to horizon below; abrupt broken boundary.
C1 (IIC1b)	30-37 inches	Brown (10YR 4/3) silt loam; very weak very thin platy structure; smeary, few roots; many fine vesicles and pores, abrupt smooth boundary.
C2 (IIIC2)	37-42 inches	Olive gray (5Y 5/2) silt loam with common large faint mottles of olive (2.5Y 5/4); weak thin platy structure; very friable; few dead roots; many

		vesicles and pores; this horizon possibly derived from soft sediments rather than aeolian material; abrupt smooth boundary.
IIC3 (IIIC3)	42-48 inches	Olive gray (5Y 4/2) fine sand; with common medium distinct mottles of yellowish brown (10YR 5/4) weak thin platy structure; loose; strong brown (10YR 5/6) stains along pores.

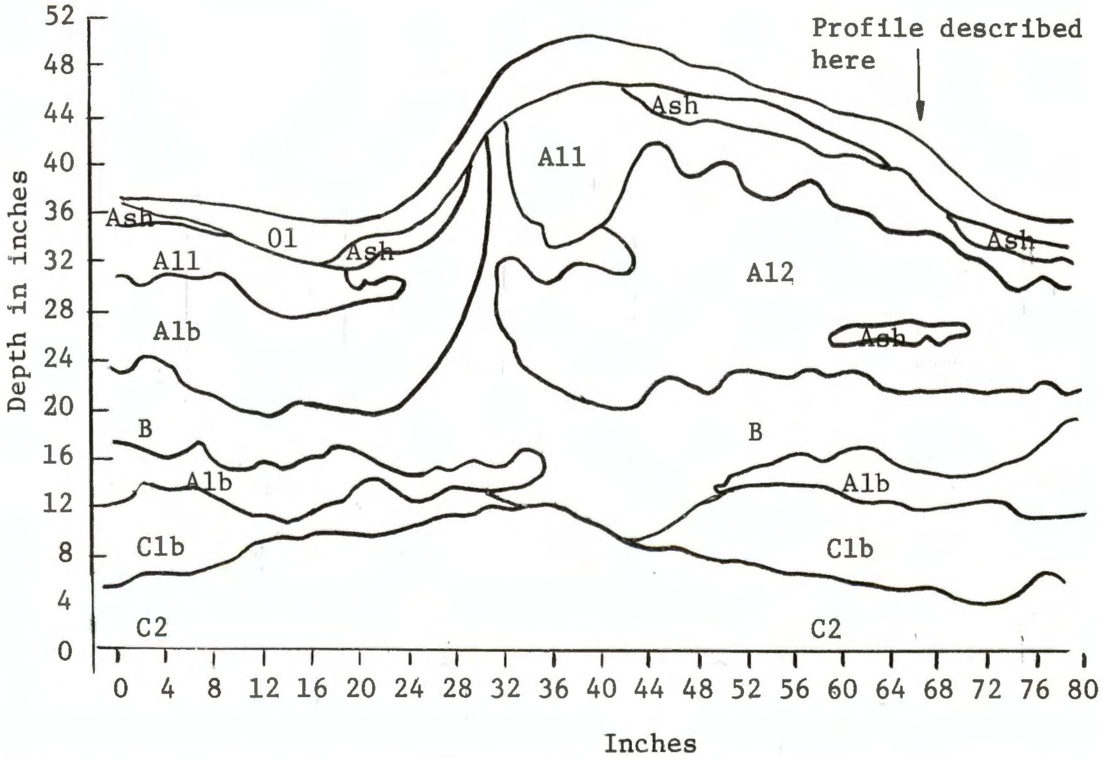
Location: About 1.25 miles south of Ninilchik, Alaska. SW 1/4 SE 1/4, Sec. 3, 25S, R 14 W. Seward Meridian.

Vegetation: Dominantly bunchgrass (Festuca spp.), bluejoint reedgrass (Calamagrostis canadensis (Michx.) Beauv.), foxtail (Alopecurus spp.), lupine (Lupinus nootkanensis Donn.), fireweed (Epilobium angustifolium L.), yarrow (Achillea spp.) goldenrod (Solidago multiradiata Ait.), monkshood (Aconitum spp.), horsetail (Equisetum spp.), and a few scattered Sitka spruce (Picea sitchensis (Bong.) Carr.), white spruce (Picea glauca (Moench) Voss.), and lichens (Cladonia spp.).

Remarks: Figure 7 shows a sketch and picture of Island silt loam.

Transect I: Transitional Soil

01 (01)	3-0 inches	Dark reddish brown (5YR 2/2) mat of decomposing organic matter with silty admixture; many mycelia; abrupt smooth boundary.
Ash (C1)	0-1 inches	Recent fine volcanic ash. Mixed dark reddish brown (5YR 3/3) and brown (10YR 4/3) silt loam; weak very thin platy structure; friable; many roots; few fine charcoal fragments; abrupt smooth boundary.



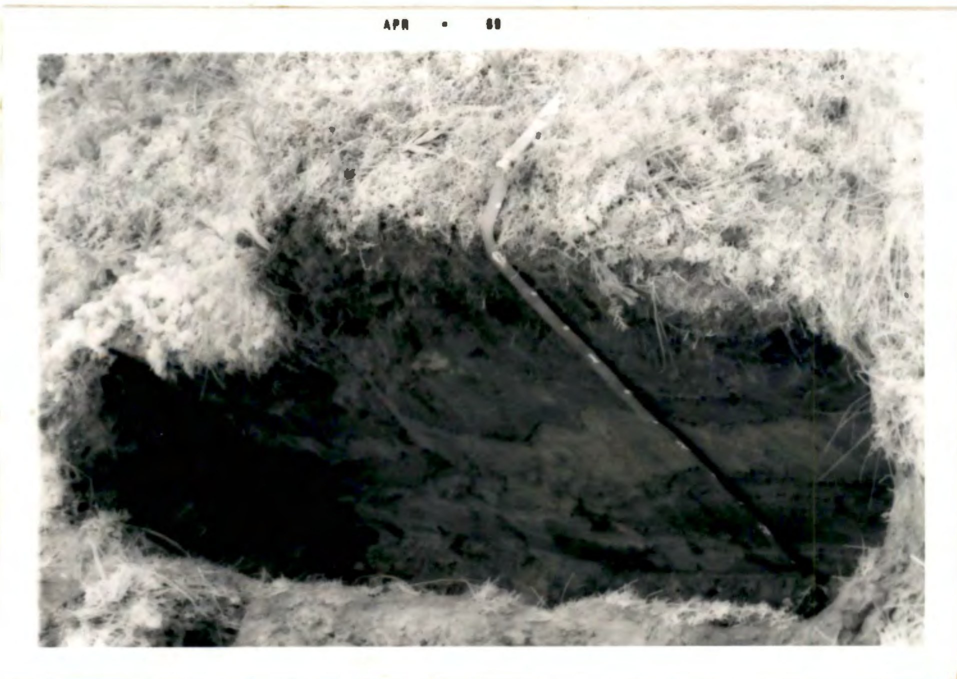


Figure 7. Sketch and picture of Island silt loam profile.

Ash (C2)	1-1.5 inches	Recent volcanic ash. Patchy dark grayish brown (10YR 4/2) and light gray (10YR 7/2) sand; structureless; loose; many roots; abrupt smooth boundary.
A2 (IIA2)	1.5-3 inches	Dark grayish brown (10YR 4/2) silt loam with patches of very dark grayish brown (10YR 3/2); weak very thin platy structure; very friable; many roots; few fine pieces of charcoal; abrupt wavy boundary.
B2 (IIB2)	3-8.5 inches	Dark reddish brown (5YR 3/3) with patches of dark reddish brown (5YR 3/2) and (5YR 2/2); very weak; very thin platy structure; smeary; many roots; contains patches of A2 material; abrupt wavy boundary.
B3 (IIB3)	8.5-11 inches	Dark brown (7.5YR 3/2) silt loam with irregular streaks of strong brown (7.5YR 5/6) very weak; very thin platy structure; common roots, abrupt wavy boundary.
A'1 (IIA'1)	11-18 inches	Mixed very dark grayish brown (60 percent) (10YR 3/2) and brown (40 percent) (10YR 4/3), silt loam; very weak; very thin platy structure; smeary; common roots; abrupt irregular boundary.
B (IIB)	18-20.5 inches	Mixed in patches, brown (30 percent) (10YR 4/3), yellowish brown (30 percent) (10YR 5/4), and very dark grayish brown (10 percent) (10YR 3/2) silt loam; very very thin platy structure; smeary; common roots; abrupt wavy boundary.

A1b (IIA1b)	20.5-24.5 inches	Mixed in patches, very dark grayish brown (50 percent) (10YR 3/2), brown (30 percent)(10YR 4/3) and grayish brown (20 percent) (10YR 5/2) silt loam; very weak very thin platy structure; smeary; common roots; abrupt wavy boundary.
C1b (IIC1b)	24.5-32 inches	Horizontal streaks of olive (5YR 4/3), dark yellowish brown (10YR 4/4) and light olive brown (2.5 Y 5/4) silt loam; weak very thin platy structure; smeary; few roots; many vesicles and pores; abrupt wavy boundary.
C2 (IIC2)	32-42 inches	Olive gray (5Y 4/2) very fine sandy loam with patches and streaks of light olive brown (2.5Y 5/4) and yellowish brown (10YR 5/4); weak thin platy structure; very friable; few roots; lenses of fine silt loam; few fine pores; very strongly acid; abrupt smooth boundary.
IIC3 (IIC3)	42-53 inches	Streaked, brown (10YR 4/3) and dark yellowish brown (10YR 4/4) fine sand with streaks of silt loam and very fine sandy loam; friable to firm; few roots; very strongly acid; abrupt smooth boundary.
IIC5 (IIIC5)	59-64+ inches	Gray (5YR 5/1) gravelly fine sand with silt loam lenses and common large prominent mottles of strong brown (7.5YR 5/6) massive; firm; contains a few mica flakes.

Location: About 1.25 miles south of Ninilchik, Alaska. SW 1/4 SE 1/4, Sec. 3, T2S, R14W, Seward Meridian.

Vegetation: Scattered Sitka spruce (Picea sitchensis (Bong.) Carr), or white spruce (Picea glauca (Moench) Voss), low growing willow (Salix spp.), bunch grass (Festuca spp.), fireweed (Epilobium angustifolium), horsetail (Equisetum spp.), monkshood (Aconitum spp.), lowbush cranberry (Vaccinium vitis-idaea L.), mosses (Hypnum crista-castrensis Hedw.), (Polytrichum commune Hedw.).

Remarks: Figure 8 shows a sketch and picture of the Transitional soil.

Transect I: Cohoe Silt Loam

01	3-0 inches	Black (5YR 2/1) mat of decomposing organic matter with silty admixture; silt arranged in soft pellets; mycelia; abrupt smooth boundary.
A2	0-2 inches	Mixed gray (10YR 5/1) and dark grayish brown (10YR 4/2) silt loam; weak very thin platy structure; very friable; common roots; few charcoal fragments; thin layer of silty and sandy volcanic ash at top of horizon; abrupt wavy boundary.
B2	2-6 inches	Patches and streaks of (60 percent) dark reddish brown (5YR 3/3), (30 percent) of dark reddish brown (5YR 3/2), and (10 percent) dark grayish brown (10YR 4/2) silt loam; weak very thin platy structure breaking to weak very fine granular structure; smeary; common roots; few charcoal fragments; abrupt wavy boundary.
B3	6-7.5 inches	Brown (10YR 4/3) silt loam with streaks of dark grayish brown (10YR 4/2) and very dark grayish

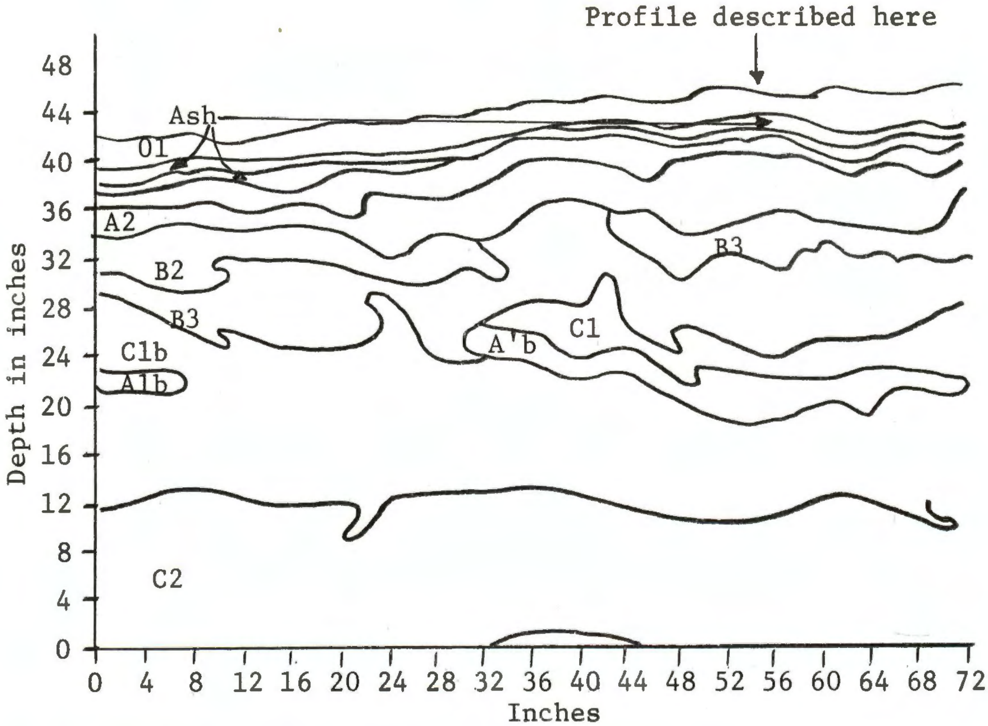


Figure 8. Sketch and picture of the Transitional soil.

		brown (10YR 3/2); very weak very thin platy structure; smeary, few roots; few charcoal fragments; few fine pores; clear wavy boundary.
A'1	7.5-13 inches	Dark brown (10YR 3/3) silt loam with streaks of very dark grayish brown (10YR 3/2); very weak very thin platy structure; smeary; few roots; few fine charcoal fragments; few fine pores; clear wavy boundary.
B	13-15 inches	Brown (10YR 4/3) silt loam with streaks of dark grayish brown (10YR 4/2) and very dark grayish brown (10YR 3/2); very weak very thin platy structure; smeary; few roots; very fine pores; clear wavy boundary.
C1b	16-26 inches	Brown (10YR 4/3) silt loam with streaks of very dark grayish brown (10YR 3/2); very weak thin platy structure; very friable; few roots; very fine pores; abrupt smooth boundary.
C2	26-34 inches	Olive gray (5YR 4/2) very fine sandy loam with streaks of brown (10YR 4/3); very weak very thin platy structure; very friable; few dead roots; many fine pores and vesicles; abrupt smooth boundary.
IIC3	34-40 inches	Olive gray (5YR 4/2) fine sand with streaks of brown (10YR 4/3), massive structure (moderately compact in place but loose when removed); friable to firm; no roots; few fine rounded pebbles.

Location: About 1.25 miles south of Ninilchik, Alaska. SW 1/4 SE 1/4, Sec. 3, T2S, R14W, Seward Meridian.

Vegetation: Sitka spruce (Picea sitchensis), white spruce (Picea glauca), paper birch (Betula papyrifera), spreading wood fern (Dryopteris austrica (Jacq.) Woyner), watermelon berry (Streptopus amplexifolius (L.) DC), wild geranium (Geranium erianthum DC), bluejoint reedgrass (Calamagrostis canadensis), lowbush cranberry (Vaccinium vitis-idaea), mooseberry viburnum (Viburnum edule (Mich.) Raf), bunchberry dogwood (Cornus candensis L.), prickly rose (Rosa acicularis Lindl.), cloudberry (Rubus chamaemorus L.), mountain ash (Sorbus scopulina Greene), mosses (Hypnum crista-castrensis), (Polytrichum commune).

Remarks: Figure 9 shows a sketch and picture of Cohoe silt loam.

II. DESCRIPTION OF SOILS IN TRANSECT II

Transect II is about 1.3 miles southeast of the Ninilchik Post Office (Fig. 1, page 4). The Island soils are in an elliptical depression containing about 50 acres. Figure 10 shows the location of the Island, Transitional, and Cohoe sample sites. Except for a few balsam cottonwood (Populus trichocarpa Torr. and A. Gray) along the forest border, the vegetation at each sample site is similar to that along Transect I. Table 6 gives the age, circumference, and height of the dominant spruce trees at each of the sites; Table 5, page 30, gives the number and kind of tree per one-tenth acre plots at the Cohoe site.

Transect II: Island Silt Loam

011	4-2.5 inches	Black (5YR 2/1) decomposing organic materials with considerable silt loam admixture; arranged in very fine soft pellets; many roots; few fine charcoal

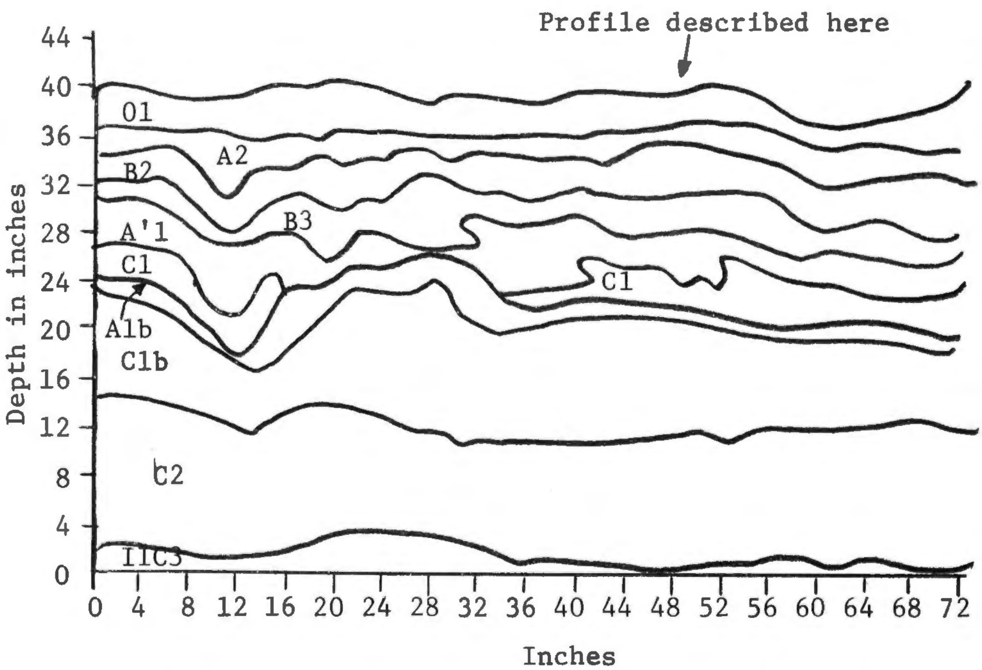


Figure 9. Sketch and picture of Cohoe silt loam.

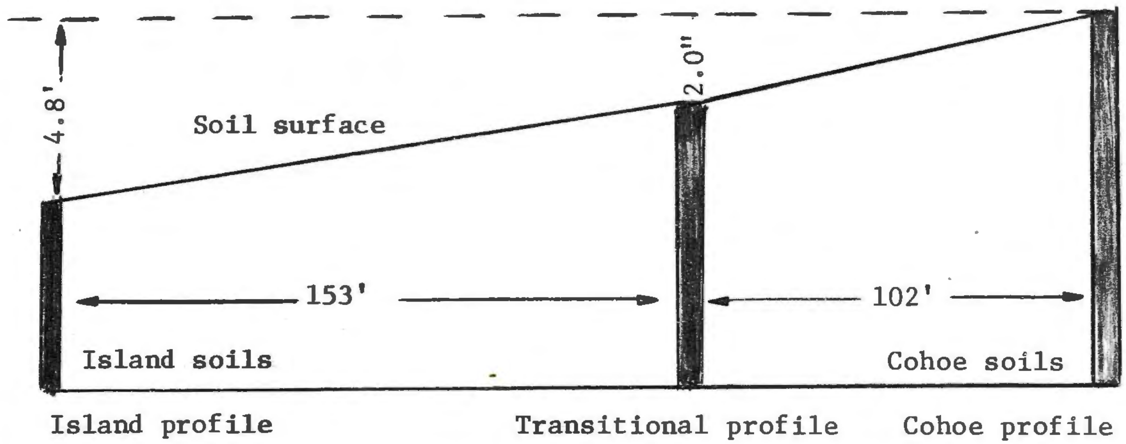


Figure 10. Diagram of Transect II showing the distance between the soil profiles and the differences in elevation relative to the Cohoe profile.

Table 6. Age, Height, and Circumference of Dominant Spruce Trees in Vicinity of Sample Sites of Transect II

Soil	Tree	Age	Circumference (inches)	Height (feet)
Cohoe	Spruce	111	42	65
		69	38	42
		84	34	46
		144	49	55
		100	47	72
		115	46	55
		108	44	65
		121	43	66
		108	42	68
		113	37	61
		108	43	56
		136	49	60
	Average	110	43	56
Transitional	Spruce	58	28	58
		68	27	28
		60	29	37
		81	40	53
		69	38	41
		94	53	54
		76	52	58
		72	38	59
	Average	72	38	49
Island	Spruce	62	50	37
		32	20	25
		27	17	26
		20	11	17
		23	12	20
		76	23	45
	Average	40	28	28

		fragments; thin lenses of dark brown (7.5YR 3/2) fine sandy loam volcanic ash at bottom; abrupt smooth boundary.
O12	2.5-0 inches	Dark reddish brown (5YR 2/2) moderately decomposed organic matter with silt loam admixture as above; many roots; thin lenses of volcanic ash as above; abrupt smooth boundary.
A11	0-6 inches	Very dark brown (10YR 2/2) silt loam with patches of black (10YR 2/1); weak very thin platy structure breaking to weak very fine granular; smeary; many roots; few small charcoal fragments; clear smooth boundary.
A12	6-11 inches	Very dark grayish brown (10YR 3/2) silt loam with streaks of brown (10YR 4/3); weak very thin platy structure breaking to weak very fine granular; smeary; common roots; few charcoal fragments; clear wavy boundary.
AC	11-21 inches	Dark brown (10YR 3/3) silt loam with large patches of dark yellowish brown (10YR 4/4) probably fresh volcanic ash; weak very thin platy structure; smeary; few roots; few tubular pores; clear wavy boundary.
C1	21-28 inches	Brown (10YR 4/3) silt loam with streaks of very dark brown (10YR 3/2) at 27 inches; weak very thin platy structure; smeary; few roots; common tubular pores; clear wavy boundary.

C2	28-38 inches	Olive (5YR 5/3) silt loam; weak very thin platy structure; very friable; no roots; common tubular pores; clear wavy boundary.
IIC3	38-46 inches	Strong brown (7.5YR 5/6) very fine sand; weak very thin platy structure (soft sandstone), moderately firm; no roots.
IIIC	46+ inches	Very gravelly sand, colors are of individual particles; structureless; loose.

Location: About 1.3 miles southeast of the Ninilchik Post Office NW 1/4 NE 1/4, Sec. 2, T2S, R14W, Seward Meridian.

Vegetation: Bunchgrass (*Festuca* spp.), bluejoint reedgrass (*Calamagrostis canadensis*), bluegrass (*Poa* spp. L.), foxtail (*Alopecurus* spp.), lupine (*Lupinus* nootkatensis), fireweed (*Epilobium angustifolium*), goldenrod (*Solidago multiradiata*), lichens (*Cladonia* spp.).

Transect II: Transitional Soil

01	3-0 inches	Black (5YR 2/1) partially decomposed organic materials with silty admixture; silt arranged in soft pellets; many roots; common woody charcoal fragments up to 1 inch in diameter; lenses of sandy volcanic ash at bottom of horizon; abrupt smooth boundary.
A2	0-1 inches	Dark grayish brown (10YR 4/2) silt loam with admixture of sand size volcanic ash; medium fine granular structure; very friable; many roots; common small charcoal fragments; smeary when rubbed; abrupt smooth boundary.

A11	1-9 inches	Dark brown (7.5YR 3/2) silt loam with pockets of dark brown (10YR 3/3) and small patches of dark reddish brown (5YR 3/3); weak very fine platy structure breaking to weak very fine granular; smeary; common roots; few small charcoal fragments; clear smooth boundary.
A12	9-12 inches	Dark brown (10YR 3/3) silt loam with streaks of dark yellowish brown (10YR 4/4) and a streak of very dark brown (10YR 2/2); weak very thin platy structures; smeary; common roots; few very fine pores; few small charcoal fragments; clear wavy boundary.
AC	12-16 inches	Dark brown (10YR 3/3) silt loam; weak very thin platy structure; smeary; few roots; common very fine pores; abrupt wavy boundary.
Ab	16-19 inches	Very dark grayish brown (10YR 3/2) silt loam; weak very thin platy structure; smeary; few roots; common very fine pores; abrupt wavy boundary.
C2	28-30 inches	Olive (5YR 4/3) silt loam; weak very thin platy structure; smeary; no roots; common very fine pores; abrupt smooth boundary.
IIC3	30-40 inches	Olive (5YR 4/3) silt loam with common medium distinct mottles of brown (10YR 4/3); fine sand (sandstone that contains hard stone); weak very platy structure.

Location: About 1.3 miles southeast of Ninilchik Post Office. NW 1/4 NE 1/4, Sec. 2, T2S, R14W, Seward Meridian.

Vegetation: Scattered spruce (Picea spp.), black cottonwood (Populus trichocarpa), bunchgrass (Festuca spp.), fireweed (Epilobium angustilfolium), monkshood (Aconitum spp.), lowbush cranberry (Vaccinium vitis-idaea), horsetail (Equisetum arvense L.), bluejoint reedgrass (Calamagrostis canadensis).

Transect II: Cohoe Silt Loam

01	3-0 inches	Dark reddish brown (5YR 2/2) decomposing organic matter with silt loam admixture, arranged in fine soft pellets; many roots; many charcoal fragments at bottom of horizon; lenses of sand size volcanic ash near bottom; abrupt smooth boundary.
A2	0-1.5 inches	Dark gray (10YR 4/1) silt loam with many sand size grains of volcanic ash; weak very fine granular structure; very friable; many roots; many fine charcoal fragments; abrupt smooth boundary.
B2	1.5-5 inches	Dark reddish brown (5YR 3/3) silt loam with patches of black (5YR 2/1) and brown (7.5YR 4/4); weak very thin platy structure; smeary; common roots; few fine charcoal fragments; clear wavy boundary.
B3	5-11 inches	Brown (7.5YR 4/4) silt loam with patches of dark brown (10YR 3/3); weak very thin platy structure; smeary; common roots; few fine charcoal fragments; few very fine pores; clear wavy boundary.
C1	11-18 inches	Brown (10YR 4/3) silt loam with streaks of very dark brown (10YR 2/2) at top of horizon and in old root

		channels; weak very thin platy structure; smeary; few roots; common very fine pores; gradual boundary.
C2	18-27 inches	Olive brown (2.5YR 4/3) silt loam with streaks of dark brown at 23-25 inches; weak very thin platy structure; smeary; few roots; many fine pores; abrupt wavy boundary.
C3	27-36 inches	Olive gray (5YR 5/2) silt loam with streaks of dark grayish brown (2.5YR 4/2); moderate very thin platy structure; very friable; no roots; clear wavy boundary.
IIC4	36-42 inches	Olive gray (5YR 4/2) fine sand; moderate very thin platy structure; friable.

Location: About 1.3 miles southeast of Ninilchik Post Office. NW 1/4 NE 1/4, Sec. 2, T2S, R14W, Seward Meridian.

Vegetation: Sitka spruce (*Picea sitchensis*), white spruce (*Picea glauca*), paper birch (*Betula papyrifera*), watermelon berry (*Streptopus amplexifolius*), bluejoint reedgrass (*Calamagrostis canadensis*), lowbush cranberry (*Vaccinum vitis-idaea*), mooseberry (*Viburnum edule*), bunchberry dogwood (*Cornus candensis*), spreading wood fern (*Dryopteris austriaca*), prickly rose (*Rosa acicularis*), mosses (*Hypnum crista-castrensis*), (*Polytrichum commune*).

III. PHYSICAL AND CHEMICAL PROPERTIES OF HORIZON SAMPLES

Table 7 presents data for particle-size distribution as determined from air-dry samples by the standard pipette method using hexametaphosphate as a dispersing agent. The presence of aggregates in the sand

Table 7. Particle Size Distribution by Horizons of Three Soils of Transect I (Hexametaphosphate is Dispersing Agent)

Horizon	Depth (inches)	2 mm	Sand 2.0-0.25 mm	Sand 0.25-0.10 mm	Sand 0.10-0.05 mm	Silt 0.05-0.02 mm	Silt 0.02-0.002 mm	Clay >0.002 mm	Textural Class
		%							
	Cohoe soil								
01	3-0	--	----	----	----	----	----	---	---
A2	0-2	Tr	32.5	7.3	9.7	13.3	32.1	5.1	l
B2	2-6	--	13.0	5.7	15.0	18.1	40.4	7.8	sil
B3	6-7.5	--	4.4	4.3	17.0	27.0	40.4	6.9	sil
A'1	7.5-13	--	9.1	6.4	14.5	4.1	58.4	7.5	sil
C1	13-15	--	7.3	6.0	14.3	29.9	36.6	5.9	sil
A1b	15-16	--	10.9	5.5	13.3	23.6	38.4	8.3	sil
C1b	16-26	--	4.1	4.5	16.7	28.6	38.8	7.3	sil
C2	26-34	--	15.5	11.3	18.6	27.1	22.8	4.7	sil
IIC3	34-40	Tr	26.1	19.7	27.8	18.2	7.4	0.8	sil
	Transitional soil								
01	3-0	--	----	----	----	----	----	---	---
Ash	0-1]	Tr	39.7	5.6	9.3	14.3	26.8	4.3	sl
Ash	1-1.5]								
A2	1.5-3	--	20.7	5.4	10.3	22.9	34.2	6.5	sil
B2	3-8.5	--	14.8	6.6	13.1	25.0	33.1	7.4	sil
B3	8.5-11	--	5.3	4.9	18.6	18.1	44.6	8.5	sil

Table 7 (continued)

Horizon	Depth (inches)	2 mm	Sand 2.0-0.25 mm	Sand 0.25-0.10 mm	Sand 0.10-0.05 mm	Silt 0.05-0.02 mm	Silt 0.02-0.002 mm	Clay 0.002 mm	Textural Class
		%							
A'1	11-18	--	11.7	8.9	16.1	15.0	38.5	9.8	sil
C1	18-20.5	--	12.2	10.7	15.1	19.4	34.9	7.7	sil
Alb	20.5-24.5	--	10.4	9.4	15.7	19.5	37.0	8.0	sil
Clb	24.5-32	--	15.6	10.2	16.7	24.0	29.5	4.0	sil
C2	32-42	--	13.4	10.9	19.2	24.3	27.2	5.0	sil
IIC3	42-53	Tr	28.4	22.8	26.1	10.4	10.1	2.2	sil
	Island soil								
01	--	--	----	----	----	----	----	---	---
Ash	0-1.5	Tr	32.7	6.2	12.3	5.6	33.2	10.0	l
A11	1.5-6	--	15.5	7.3	15.9	8.6	41.5	10.3	sil
A12	6-19.5	--	11.6	7.8	16.5	8.4	43.9	11.8	sil
B	19.5-27	--	5.7	4.3	16.0	24.8	41.1	8.1	sil
Alb	27-30	--	5.2	6.9	15.5	19.9	44.0	8.5	sil
Clb	30-37	--	4.4	4.1	16.9	25.1	42.1	7.4	sil
C2	37-42	Tr	6.4	8.7	17.1	28.5	33.6	5.7	sil
IIC3	42-48	Tr	32.7	21.1	24.1	11.0	7.7	2.8	sl

fractions gave evidence of poor dispersion in these soils. Soils high in amorphous material may not be completely dispersed with hexametaphosphate (Birrell, 1964; Soil Survey Staff, 1967). X-ray, DTA, and NF pH studies indicated that these soils contain appreciable amorphous materials. Other studies (Rieger and Dement, 1965; Simonson and Rieger, 1967) of similar soils in the Cook Inlet Lowland, Alaska, suggest a relatively high amount of amorphous material and incomplete dispersion by standard methods in the laboratory.

Birrell and Fields (1952) and Schalscha and Gonzalez (1965) found in soils developed in volcanic ash in New Zealand and Chile, respectively, that even air drying rendered them much less dispersible than when in the natural field-moist state. In light of this, particle-size distribution on selected field moist samples was determined by the standard pipette method with hexametaphosphate as a dispersing agent for comparison with results from like treatment of air-dry samples. Results are in Table 8. The percentage of clay was similar in both groups, but in the field-moist samples, better dispersion apparently occurred in the sand-size fractions of some horizons giving a decrease in medium and coarse and an increase in the fine and very fine sand. This effect was greatest in the A2 horizon of the Cohoe profile. Results from other horizons in both conditions are similar. However, the small differences may be due to experimental error rather than to difference in dispersion.

Kobo (1964) reported that aggregates in some apparently dispersed volcanic ash soils could be destroyed by ultrasonics. He also reported that "surface soils rich in humus can be, in most cases, well dispersed

Table 8. Particle Size Distribution Data for Air-Dry and Field-Moist Samples with Hexametaphosphate Dispersant and Moist Samples with Ultrasonics Plus Hexametaphosphate

Horizon	Depth (inches)	Treatment	Sand 2.0–0.25 mm	Sand 0.25–0.10 mm	Sand 0.10–0.05 mm	Silt 0.05–0.02 mm	Silt 0.02–0.002 mm	< 0.002 mm	Total sand	Total silt	Silt and clay
			%								
	Cohoe soil										
A2	0-2	air dry	32.5	7.3	9.7	13.3	32.1	5.1	49.5	45.4	50.5
		moist	21.6	13.9	8.8	19.2	29.3	7.2	44.3	48.5	55.7
		ultra-sonics	17.7	13.9	8.1	23.8	28.4	8.1	39.7	52.2	60.3
B2	2-6	air dry	13.0	5.7	15.0	18.1	40.4	7.8	33.7	58.5	65.3
		moist	15.6	8.2	13.9	22.1	32.5	7.7	37.7	54.6	62.3
		ultra-sonics	13.5	7.6	12.3	23.7	30.7	12.7	33.4	53.9	74.6
B3	6-7.5	air dry	4.4	4.3	17.0	27.0	40.4	6.9	26.7	67.4	74.3
		moist	4.9	8.2	17.8	25.6	36.9	6.4	30.9	62.7	69.1
		ultra-sonics	2.7	6.2	15.9	27.9	34.0	13.3	24.8	61.9	75.2
C1b	16-26	air dry	4.1	4.5	16.7	28.6	38.8	7.3	25.3	67.4	74.4
		ultra-sonics	1.4	7.3	14.7	36.2	29.9	10.5	23.4	66.1	76.6
	Transitional soil										
A2	1.5-3	air dry	20.7	5.4	10.3	22.9	34.2	6.5	26.4	57.1	63.6
		moist	17.3	11.6	7.9	23.2	32.0	8.0	36.8	55.2	63.2
		ultra-sonics	14.1	12.4	10.9	22.3	31.5	8.8	37.4	53.8	62.6

Table 8 (continued)

Horizon	Depth (inches)	Treatment	Sand 2.0–0.25 mm	Sand 0.25–0.10 mm	Sand 0.10–0.05 mm	Silt 0.05–0.02 mm	Silt 0.02–0.002 mm	< 0.002 mm	Total sand	Total silt	Silt and clay
			%								
B2	3-8.5	air dry	14.8	6.6	13.1	25.0	33.1	7.4	35.5	58.1	65.5
		moist	14.8	12.7	12.9	22.3	29.4	7.9	40.4	51.7	59.6
		ultra-sonics	11.4	11.4	12.7	24.6	27.8	12.1	35.5	52.4	64.5
B3	8.5-11	air dry	5.3	4.9	18.6	18.1	44.5	8.5	28.5	67.2	75.7
		ultra-sonics	2.0	6.4	16.9	27.9	34.2	12.6	25.3	62.1	74.7
C1b	24.5-32	air dry	15.6	10.2	16.7	24.0	29.5	4.0	42.5	53.5	57.5
		ultra-sonics	7.9	22.1	16.0	19.0	24.0	11.0	46.0	43.0	54.0
	Island soil										
A11	1.5-6	air dry	15.5	7.3	15.9	8.6	41.5	10.3	39.5	50.1	60.4
		moist	15.0	7.0	15.0	8.7	42.5	12.9	37.3	51.2	64.1
		ultra-sonics	14.4	8.4	12.8	25.4	27.9	11.1	35.6	53.3	64.4
A12	6-19.5	air dry	11.6	8.7	16.5	8.4	43.9	11.8	35.9	52.3	63.1
		moist	11.4	7.4	16.5	9.7	43.7	11.9	34.7	53.4	65.3
		ultra-sonics	10.1	8.7	14.7	25.0	29.1	12.4	33.5	54.1	66.5
C1b	30-37	air dry	4.4	4.1	16.9	25.1	52.1	7.4	25.4	57.2	73.6
		ultra-sonics	1.3	9.1	12.6	31.3	30.9	14.6	23.0	62.2	76.8

by Calgon." The Riverside Soil Survey Laboratory (R. E. Nelson, personal communication) has found that some soils high in amorphous materials can be dispersed better with ultrasonics. Edwards and Bremner (1967) reported good dispersion on many kinds of soils with ultrasonics as dispersant.

Selected field-moist samples from each soil were treated with ultrasonics for 30 minutes prior to overnight shaking in hexametaphosphate. Table 8 gives the results along with those for air-dry and field-moist samples dispersed only with hexametaphosphate. Ultrasonic treatment had the greatest effect on the A2 horizon of the Cohoe sample. Clay, silt, and very fine sand were increased at the expense of the coarse, medium, and fine sand fractions. This effect was much less on the A2 horizon of the Transitional profile and on both the A11 and A12 of the Island soil. In all horizons except the A11 and A12 horizon of the Island, the clay content was increased.

In the B horizon of the Cohoe and Transitional profiles there was a slight increase in clay and a decrease in silt. Coarse and medium sand were decreased slightly in the B and C horizon.

The most noticeable effect on the Island samples was the significant decrease in fine silt with a corresponding increase in the coarse silt. Ultrasonics is apparently less effective in dispersion of these horizons. A similar trend is indicated in almost every horizon treated with ultrasonics. In the A11 and A12 of the Island, the total sand was decreased which indicates a little better dispersion.

A thin layer of recent volcanic ash, which may have come from the 1912 eruption at Katmai, is present throughout the lower Cook

Inlet Lowland. In many places it is mixed with the decomposing organic materials on the soil surface. In Transect I this recent ash is a distinct layer below the organic horizons of the Island and Transitional soils, but on the Cohoe it is incorporated into the decomposing forest litter. In the forest the falling ash may have been impeded by the tree foliage and subsequently became mixed in the raw humus litter which is slower to decompose than the grass litter of the Island soils. In addition, the 01 horizons of the Cohoe soil is characterized by small pellets composed of organic matter and mineral material that is probably volcanic ash.

The 01 horizons contain a relatively high content of coarse volcanic ash. The percent organic-carbon content of the Cohoe, Transitional, and Island soils, respectively, is 12.39, 14.23, and 11.38. The organic-matter content can be estimated by multiplying the percent organic carbon by the conversion factor of 1.724. By applying this, the Cohoe 01 has 21.4 percent organic matter, the Transitional 01, 24.5, and the Island 01, 19.6. The Soil Survey Staff (1960) defined an O horizon. Among other requirements the organic-matter content must exceed 20 percent if the mineral fraction has no clay. When clay is present, a higher proportional organic-matter content is required. These horizons by definition are then questionable as 01 horizons. Broadbent (1953), however, believes that the conversion factor of 1.724 is too low in the majority of cases and that a value of 1.9 for surface soils might be more satisfactory.

Although by definition the 01 horizons are borderline, they are designated as such because they are "certainly" borderline, they were identified as 01 horizons in the field, and it seems quite possible that some of the coarse organic matter, straw, woody particles, and charcoal, were not thoroughly digested in the laboratory determination.

Table 9 gives 15 bar water retention for the three soils in Transect I. Birrell (1964) pointed out that soils derived from volcanic ash may have moisture release curves that are largely reversible up to pF 4.2, beyond which moisture release may occur irreversibly. In view of this, 15-bar water retention was determined on samples handled in four ways: (1) field-moist, (2) air-dry, (3) oven-dry to 110°C, and (4) oven-dry to 500°C.

In addition, 15-bar water retention was determined on selected samples following treatment with H_2O_2 to destroy the organic matter.

Another set of samples was weighed in the field-moist and air-dry condition and then placed in the furnace and dried for a period of 24 hours at succeeding higher temperatures of 110°C, 175°C, 200°C, and 500°C. After each 24-hour period, the samples were cooled in a dessicator and reweighed. The differences in weight were calculated relative to the weight of each sample at 500°C (Table 10).

Those field-moist samples of horizons (B2's, B3's, and A11 and A12) that were relatively high in organic matter held from one-third to one-half more water than the same samples when air dried. Oven-drying to 110°C further reduced water retention. The horizons that were highest in organic matter held about one-third less water after oven drying than when air dried.

In the samples treated with H_2O_2, the percent water retention was in general about the same on the moist, the air-dry, and the oven-dry

Table 9. Percent Moisture Retention for Field-Moist, Air-Dry and Oven-Dry Samples

		Moisture retention percent 15-bar						
		Whole soil				H_2O_2 treated soil		
Horizon	Depth (inches)	Moist sample	Air dry	Oven dry to 110°C	Oven dry to 500°C	Moist Sample	Air dry sample	Oven dry 110°C
	Cohoe soil							
01	3-0	50.0	51.3	43.7	5.9			
A2	0-2	12.0	8.1	5.9	2.9	4.4	4.4	6.1
B2	2-6	21.2	12.1	9.6	4.3	9.1	10.5	8.4
B3	6-7.5	17.5	10.7	7.7	4.4	13.7	9.3	8.5
A'1	7.5-13	20.0	11.3	7.7	5.0			
C1	13-15	18.3	10.9	7.1	5.1	13.8	7.2	6.0
A1b	15-16	22.4	11.7	8.1	4.6			
C1b	16-26	12.8	8.2	5.9	4.1			
C2	26-34	4.0	3.4	2.7	2.6			
IIC2	34-40	2.3	2.1	1.7	1.9			
	Transitional soil							
01	3-0	61.1	65.2	45.6	5.7			
Ash	0-1	----	16.4	9.7	---			
Ash	1-1.5	----	5.5	4.9	2.1			
A2	1.5-3	13.1	10.8	9.5	3.4	5.1	4.6	6.2
B2	3-8.5	25.0	19.0	13.2	5.2	11.9	10.8	10.9
B3	8.5-11	22.9	15.9	10.8	4.6	17.8	13.2	11.2
A'1	11-18	18.5	11.7	8.2	5.3			
C1	10-20.5	18.7	11.9	7.3	4.3			

Table 9 (continued)

Horizon	Depth (inches)	Moisture retention percent-15 bar						
		Whole soil				H_2O_2 treated soil		
		Moist sample	Air dry	Oven dry to 110°C	Oven dry to 500°C	Moist sample	Air dry sample	Oven dry 110°C
A1b	20.5-24.5	16.2	10.3	7.1	4.8			
C1b	24.5-32	8.4	6.3	4.4	3.4	5.2	5.3	3.3
C2	32-42	4.6	3.8	2.7	2.5			
IIC3	42-53	4.3	4.2	3.2	3.6			
	Island soil							
O1	3-0	38.4	31.2	29.0	5.4			
Ash	0-1.5	----	13.9	11.7	---			
A11	1.5-6	28.1	16.4	14.9	3.9	12.7	13.7	15.3
A12	6-19.5	20.9	11.3	9.1	4.1	15.6	10.4	9.8
B	19.5-27	16.6	9.4	6.3	4.3			
A1b	27-30	20.7	11.7	12.6	4.9			
C1b	30-37	18.5	9.5	7.0	4.6	13.6	8.4	6.9
C2	37-42	3.5	3.4	3.0	2.6	4.1	3.9	3.2
IIC3	42-48	2.9	2.5	2.4	1.9			

(110°C) samples. These samples were not duplicated so that some part of the difference in percent water retention may be due to experimental error. Experiments (Robinson, 1927) have shown that H_2O_2 may not destroy all the organic matter. That the differences are small and inconsistent may indicate that in these soils the property of irreversible drying may be more closely associated with organic matter than with the nature of the clay.

Interpretations of the X-ray patterns of the clay-size fractions from the A2 and B2 horizons of the Cohoe profile and from the A11 and A12 horizons of the Island soil are given in Table 11. The patterns of the clay samples dispersed with hexametaphosphate suggest a high amount of amorphous material. The patterns of the duplicate samples that were purified by treatment with pyrophosphate dithionite and dilute sodium carbonate had greatly enhanced peaks for the relatively small content of vermiculite, illite, and kaolinite clay.

Differential thermal analysis curves for clays from the A2 and B2 horizons of the Cohoe and Transitional profiles and for the A11 horizon of the Island are in Figure 11. All have fairly broad low temperature endotherms (120-180°C). The endotherms have fairly rapid initial temperature change but slow recovery rates. Clay of the Cohoe A2 and B2 horizons have strong sharp endotherms (120-160°C).

Water adsorbed by vermiculite may account for the endotherms at approximately 145°C, and the water adsorbed by the dithionite-sodium carbonate soluble material for the remainder of the low temperature endotherm. It is also likely that the sharp endotherm at 120° to 160°C may be due to allophane.

Table 11. Mineralogy of Clay Fraction from Selected Horizons Before and After Purification with Dithionite and $NaCO_3$

Horizon	Depth (inches)	Treatment	Clay Minerology (<.002mm, 3A1) X-Ray Diffraction (7A2)				
			Montmorillonite	Vermiculite	Illite	Kaolinite	Relative intensity of 14.0 Å peak[a]
	Cohoe soil						
A2	0-2	(standard)		xx	tr	x	19
		(dithionite + Na_2CO_3)		xx	tr	x	40
B2	2-6	(standard)		tr		tr	7
		(dithionite + Na_2CO_3)		xx	tr	x	30
B3	6-7.5	(dithionite + Na_2CO_3)		xx	tr	x	40
	Transitional soil						
A2	1.5-3	(standard)		x	x	x	9
		(dithionite + Na_2CO_3)		xx		x	22
B2	3-8.5	(standard)		x	tr	tr	9
		(dithionite + Na_2CO_3)		xxxx		xx	90
B3	8.5-11	(dithionite + Na_2CO_3)	tr	xxx		x	76
	Island soil						
A11	1.5-6	(standard)		x	tr	tr	15
		(dithionite + Na_2CO_3)		xxx	x	xx	51

Note: xxxx = dominant, xxx = abundant, xx = moderate, x = small, tr = trace.

[a]Units of peak height for oriented clay sides with Cu K radiation, 35 KV, 15 ma.

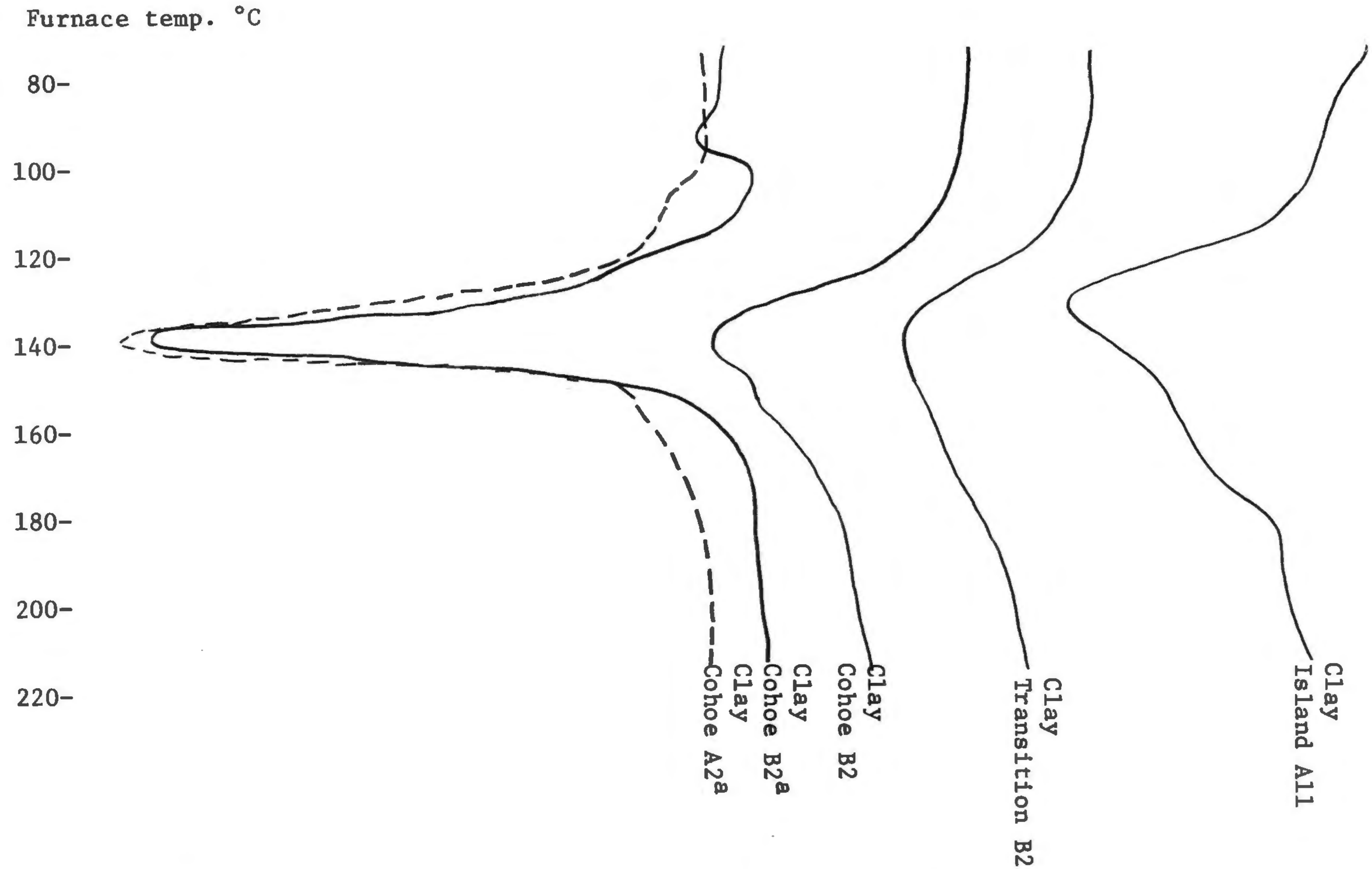


Figure 11. DTA curves for the clay fraction[b] from some horizons of the sola.

[a]Sodium dithionite and Na_2CO_3 treated clay.

[b]Samples were mixed with equal weight of Al_2O_3, ground to pass 100 mesh sieve, and equilibrated at 52 percent R.H. for 1 week before DTA.

Table 12 gives pH values as determined in water pastes, N KCl solution paste, and a 1 to 2 ratio with 0.01M $CaCl_2$ solution. These soils are acid throughout. The reaction, as measured in water paste, ranges from very strongly acid in the surface layers to medium acid in the lower C horizons. The pH value of the 01 horizon of the Cohoe soil is a little lower than that of the 01 horizon of either the Transitional or Island profiles. This would be expected in acid forest litter.

The pH values determined in N KCl are about one-half unit lower than those in water paste in the A and B horizons of the Cohoe and Transitional profiles and in the A horizons of the Island. Below these horizons the difference is generally about a whole unit lower than those in water.

The pH values determined by 0.01M $CaCl_2$ are one-tenth to three-tenths of a unit higher than the N KCl values.

Extractable acidity (page 67) is high to moderate and varies almost directly with the organic matter content. The amount of extractable acidity is highest in the A horizons of the Island soil and in the B horizons of the Cohoe and Transitional soils. The amount is about the same in the A11 horizon of the Island soil and in the B2 horizon of the Transitional soil. The B2 of the Cohoe contains about 1/4 less than either. Secondary subsurface maxima occur in the buried A horizons, but otherwise the extractable acidity decreases with depth below the horizons of the highest amounts.

Free iron has similar patterns in the Cohoe and Transitional profiles (Fig. 12). The amount in the B2 horizons is more than twice

Table 12. Comparison of pH Values Determined in Water-Paste, N KCl-Paste and in .01 M $CaCl_2$

Horizon	Depth (inches)	pH Water-Paste	pH N KCl Paste	pH .01 M $CaCl_2$
	Cohoe soil			
O1	3-0	4.5	4.1	4.2
A2	0-2	4.6	4.1	4.3
B2	2-6	5.1	4.5	4.6
B3	6-7.5	5.4	4.6	4.7
A'1	7.5-13	5.5	4.7	4.8
C1	13-15	5.5	4.7	4.8
A1b	15-16	5.5	4.5	4.7
C1b	16-26	5.7	4.5	4.7
C2	26-34	5.5	4.0	4.6
IIC2	34-40	5.4	4.2	4.7
	Transitional soil			
O1	3-0	4.9	4.3	4.5
Ash	0-1	5.8	4.4	---
Ash	1-1.5	5.1	4.0	---
A2	1.5-3	4.9	3.9	4.2
B2	3-8.5	5.1	4.4	4.6
B3	8.5-11	5.5	4.6	4.7
A'1	11-18	5.7	4.6	4.7
C1	18-20.5	5.6	4.7	4.7
A1b	20.5-24.5	5.7	4.5	4.7
C1b	24.5-32	5.7	4.5	4.8
C2	32-42	5.5	4.4	4.8
IIC3	42-53	5.9	4.5	4.9
	Island soil			
O1	3-0	5.0	4.2	4.4
Ash	0-1.5	4.7	4.2	---
A11	1.5-6	5.0	4.4	4.5
A12	6-19.5	5.5	4.6	4.7
B	19.5-27	5.7	4.6	4.8
A1b	27-30	5.7	4.6	4.8
C1b	30-37	5.8	4.5	4.8
C2	37-42	5.5	4.3	4.7
IIC3	42-48	5.7	4.4	4.9

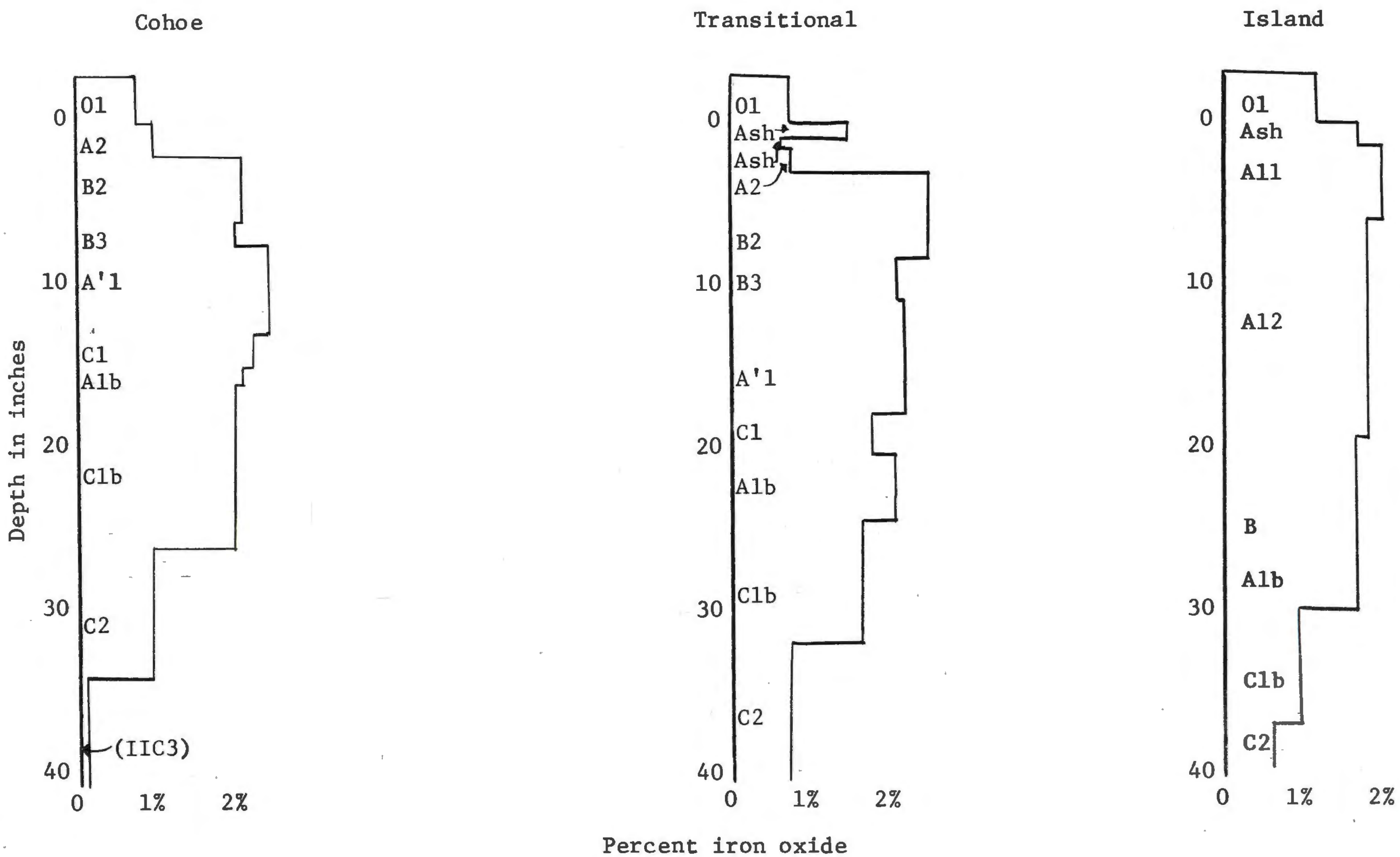


Figure 12. Free iron oxide in Cohoe, Transitional, and Island soils.

as much as in the A2's. The B2 of the Transitional profile has a little more free iron than does the B2 of the Cohoe. However, the Cohoe profile exhibits a slightly more uniform distribution of free iron to a greater depth. In the Island profile free iron is highest in the A11 horizon and slowly decreases with depth to a sharp decline in the C2. The C1b horizons of the Cohoe and Transitional profile compared to the C2 of the Island have about twice the amount of free iron. This may be a result of deeper movement.

Cation exchange capacity (Table 13), determined by neutral ammonium acetate, is greatest in the horizons with the most organic matter. It is relatively high with a range from 25 to 37 milliequivalents in the B2 horizons of the Cohoe and Transitional profiles and in the A11 horizon of the Island. The CEC parallels the organic matter content and decreases with depth.

When amorphous materials are present, methods for determining CEC may be subject to considerable error from adsorptive and pH dependent charge effects (Birrell and Bradwell, 1956; Birrell, 1961). In these soils values for CEC by the summation of extractable bases and extractable acidity determined in $BaCl_2$-Triethanolamine I, pH 8.2 are much higher than by neutral NH_4OAC. The difference is more than two-fold in the B horizons of the Cohoe and Transitional soils and about 30 percent greater in the A11 of the Island.

Exchangeable calcium (Table 13) is greatest in the 01 horizons for each profile. The amount in the 01 of the Island, however, is about half as much as in the 01 of the Cohoe and Transitional soils. Calcium increases from the A2 to the B horizons in the Cohoe and

Table 13. Some Chemical Characteristics of Soils of Transect I

Horizon	Depth (inches)	pHw	Organic Matter O.C. %	Organic Matter N %	Organic Matter C/N ratio	Free Fe_2O_3	CEC	Ca	Mg	Na	K	Ext. acidity	Al	Sum	Base Sat.[a] %	CA/Mg Ratio	CEC/ 100g clay[b]
								Extractable Cations (meq/100g soil)									
	Cohoe soil																
01	3-0	4.5	12.39	0.38	35.3	0.7	42.0	11.1	3.9	0.3	1.8	34.1	0.5	51.2	33.3	2.9	---
A2	0-2	4.6	3.66	0.14	26.9	0.9	15.9	2.0	0.3	0.2	0.2	24.1	1.1	26.9	10.3	6.2	312
B2	2-6	5.1	4.61	0.16	28.5	2.0	25.0	3.1	0.3	0.2	0.1	47.9	0.6	51.6	7.2	9.6	320
B3	6-7.5	5.4	3.24	0.12	27.7	1.9	17.4	2.3	0.3	0.2	0.4	32.3	0.3	35.5	9.0	6.9	252
A'1	7.5-13	5.5	3.13	0.13	24.6	2.3	20.7	2.3	0.4	0.2	0.9	33.6	0.2	37.3	9.9	6.3	276
C1	13-15	5.5	2.74	0.13	21.9	2.1	18.4	1.8	0.4	0.2	0.9	31.7	0.2	35.0	9.5	4.2	312
Alb	15-16	5.5	3.82	0.15	18.9	2.0	19.5	2.2	0.8	0.2	0.1	40.3	0.5	43.3	7.5	2.8	235
Clb	16-26	5.7	1.63	0.09	17.7	1.9	12.8	0.9	0.5	0.2	0.1	21.2	0.5	22.9	7.5	1.9	175
C2	26-34	5.5	0.26	0.02	14.5	0.9	5.4	0.9	0.5	0.1	0.1	6.5	0.7	8.1	20.3	1.8	115
IIC3	34-40	5.4	0.12	0.01	10.9	0.1	4.8	0.7	0.4	0.1	0.2	6.6	0.4	8.0	17.5	1.8	60
	Transitional soil																
01	3-0	4.9	14.23	0.70	20.3	0.7	48.9	10.7	4.0	0.4	1.8	41.8	0.6	58.7	28.8	2.7	---
Ash	0-1	5.8	4.13	0.30	13.7	1.4	17.9	1.3	0.6	0.3	0.3	28.1	0.6	30.6	8.2	2.3	---
Ash	1-1.5	5.1	2.43	0.10	23.6	0.6	10.1	0.7	0.3	0.2	0.2	15.9	1.0	17.3	7.8	2.5	---
A2	1.5-3	4.9	4.05	0.17	23.1	0.7	16.7	1.5	0.4	0.3	0.2	29.0	2.2	31.5	7.9	3.9	257
B2	3-8.5	5.1	6.84	0.26	26.1	2.4	36.1	5.6	0.7	0.3	0.1	62.2	0.9	69.0	9.9	8.1	488
B3	8.5-11	5.5	4.95	0.18	27.8	2.0	30.1	3.8	0.5	0.3	0.1	53.8	0.4	58.5	8.0	8.2	354
A'1	11-18	5.7	3.29	0.16	20.8	2.1	20.7	2.4	0.4	0.2	0.1	34.6	0.3	37.7	8.3	5.9	211
C1	18-20.5	5.6	2.83	0.14	20.4	1.7	16.9	1.2	0.4	0.2	0.1	31.9	0.4	33.8	5.7	3.1	219
Alb	20.5-24.5	5.7	2.78	0.14	19.4	2.0	16.2	1.6	0.4	0.2	0.1	33.9	0.5	36.2	6.4	3.5	203
Clb	24.5-32	5.7	1.24	0.07	18.2	1.6	10.3	1.0	0.3	0.2	0.1	14.6	0.5	16.2	9.7	3.7	257
C2	32-42	5.7	0.46	0.03	15.3	0.7	6.4	0.7	0.2	0.2	0.3	4.4	0.5	5.8	24.4	3.0	128
IIC3	42-53	5.9	0.33	0.02	17.4	0.4	5.6	0.1	0.1	0.1	0.3	3.9	0.4	4.4	10.8	1.3	255
	Island soil																
01	3-0	5.0	11.38	0.51	22.1	1.1	34.4	4.5	1.6	0.3	0.6	43.4	1.3	50.2	13.6	2.9	---
Ash	0-1.5	4.7	5.73	0.39	14.0	1.6	23.3	1.7	0.8	0.3	0.1	43.0	2.8	45.9	6.3	2.2	233
A11	1.5-6	5.0	7.56	0.31	24.5	1.9	37.8	2.8	0.6	0.3	0.1	60.7	1.2	64.4	5.7	5.1	367
A12	6-19.5	5.5	4.62	0.22	21.3	1.7	22.5	2.4	0.5	0.3	0.1	38.3	0.5	41.5	7.8	4.8	191
B	19.5-27	5.7	2.32	0.14	16.3	1.6	15.8	1.5	0.5	0.2	0.1	26.5	0.3	28.6	7.4	3.3	195
Alb	27-30	5.7	4.10	0.23	18.0	1.6	20.9	1.6	0.5	0.2	0.1	35.2	0.4	37.4	5.9	3.4	246
C1	30-37	5.8	2.56	0.15	16.5	0.9	16.8	1.9	0.5	0.2	0.1	26.9	0.4	29.5	8.9	3.7	227
C2	37-42	5.5	0.36	0.03	12.9	0.6	6.2	0.6	0.2	0.2	0.1	6.9	0.7	8.0	13.4	2.7	109
IIC3	42-48	5.7	0.09	0.02	4.3	0.4	4.4	1.1	0.4	0.2	0.1	3.4	0.3	5.1	33.7	2.9	157

[a] $\frac{\text{Extractable bases}}{\text{Extractable cations}}$ X 100.

[b] $\frac{\text{CEC (meq/100 g whole soil)}}{\text{\% clay}}$ = CEC (meq/100 g clay).

Transitional profiles. In the Island soil the amount is greatest in the A horizons. Below the horizons with maximum amounts in the upper sola, the exchangeable calcium decreases with depth except for slight gains in the thin buried A horizons of the Cohoe profile. In general the amount of calcium is very low in the horizons below the maximum concentration.

Magnesium (Table 13, page 67) is low in all horizons and is concentrated in the 01 horizons. Amounts are similar in the Cohoe and Transitional 01's; the 01 of the Island contained about one-half as much. The exchangeable magnesium was very low in the mineral horizons of all the soils.

Calcium-magnesium ratios (Table 13) are nearly the same in the 01 horizons of each of the profiles. In the Cohoe and Transitional soils the ratios (Fig. 13) increase from the A2 to reach a maximum in the B2 horizons and then decline with depth. In the Island soil the ratio is greatest in the All horizon and decreases with depth.

Exchangeable Na and K (Table 13) are low in the mineral horizons of each soil. K is considerably higher in the 01 horizons, especially in the Cohoe and Transitional soils, than in the underlying mineral horizons. This greater amount of K in the O horizons may be related to active biological absorption of K by the microorganisms.

Base saturation (Table 13) is low for all horizons. No horizon was greater than 34 percent and most ranged between 7 and 10 percent (Fig. 14). The values were highest in the 01 horizons and the lower C horizons. The base saturation in the 01 horizon of the Cohoe was higher than in the 01 of the Transitional profile and more than twice as high as the 01 of the Island.

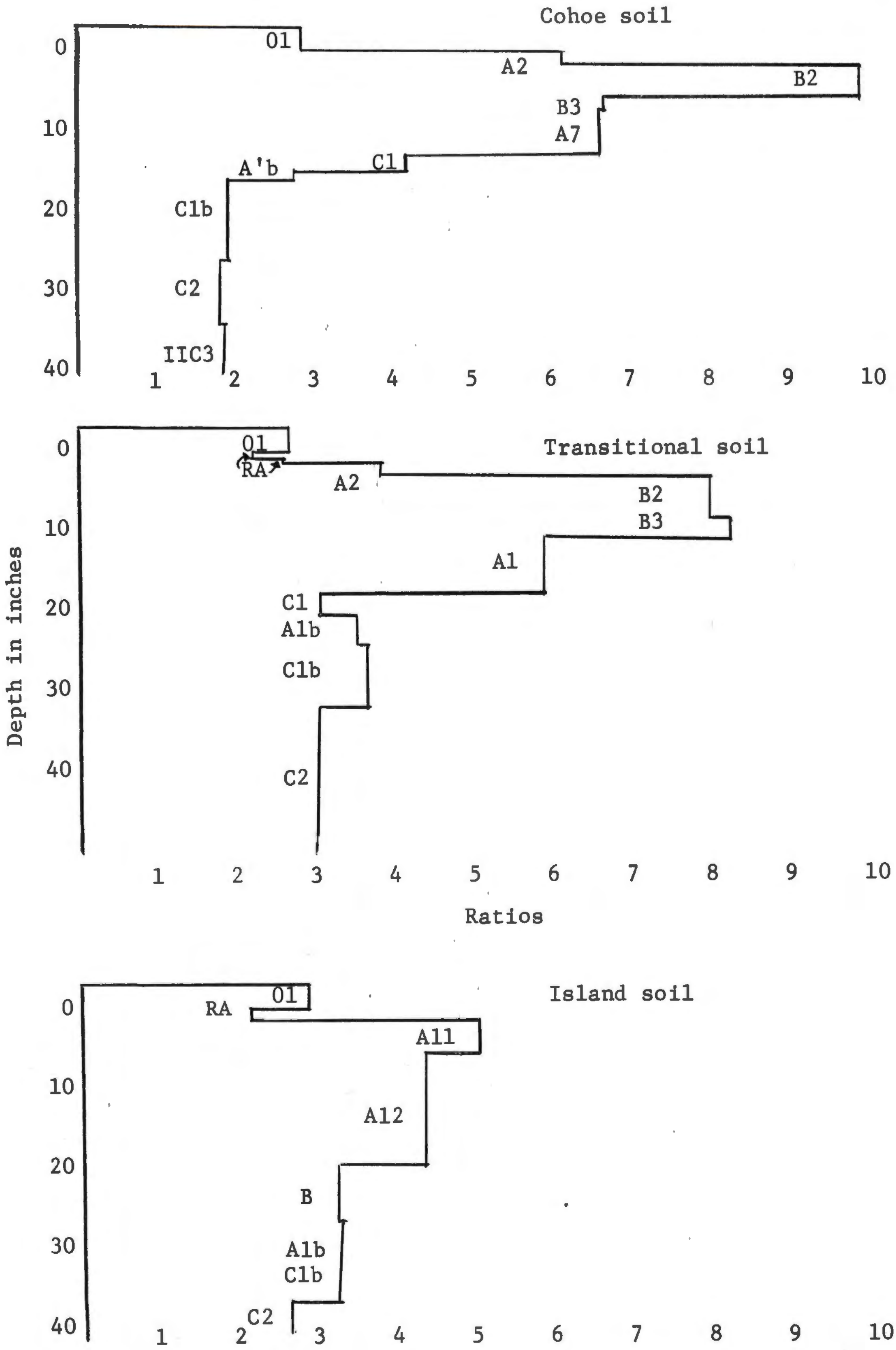


Figure 13. Ratios of calcium to magnesium in the soils along Transect I.

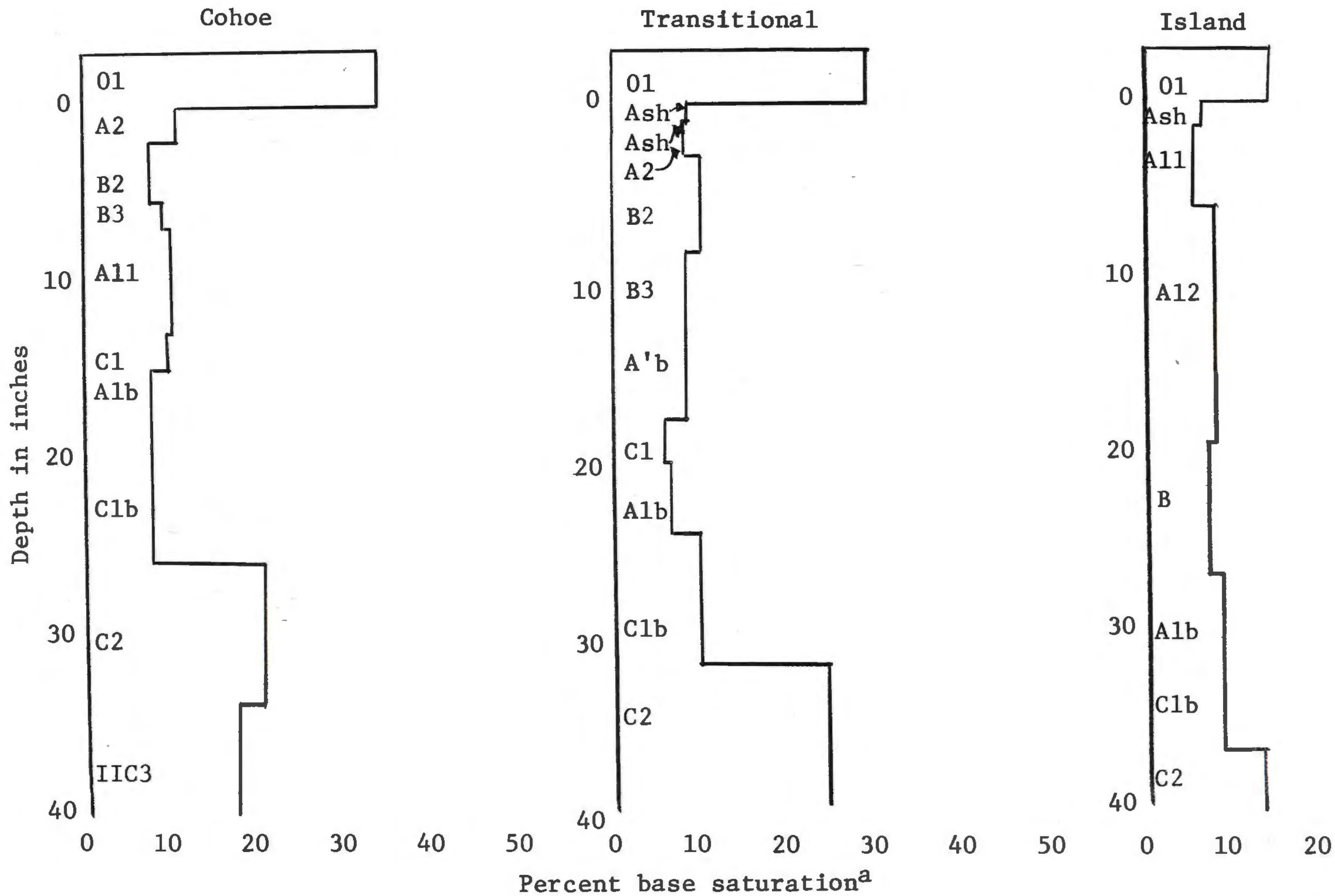


Figure 14. Percentage base saturation of Cohoe, Transitional, and Island soils.

[a] $\frac{\text{Extractable bases}}{\text{Extractable cations}}$ x 100.

Organic carbon, as would be expected, is highest in the O1 horizons. In the Cohoe and Transitional profiles, there is a sharp increase from the A2 to the B2 horizons and then a regular decrease (Fig. 15) with depth except in the buried A horizons. In the A'1 horizons of both the Cohoe and Transitional profiles the percentage of carbon is lower than in the overlying B3 horizon but higher than the C1 horizon below. In the mineral horizons of the Island the organic carbon is highest in the A11 horizon and decreases with depth to 27 inches, when a secondary increase occurs in the A1b horizon (Table 14).

The Island has a higher content of organic carbon to a greater depth than the Transitional profile, which in turn has slightly more than the Cohoe. This may be related, in part, to the distribution of fine grass roots through the Island and to more rapid decomposition of the above ground parts of the grass. See Table 15.

Total nitrogen is highest in the O1 horizons of all soils. However, in the slowly decaying coniferous litter on the Cohoe, the total nitrogen is much less than in the litter dominated by grass vegetative parts on the Transitional and Island profiles. In the Cohoe and Transitional profiles the nitrogen increases from the A2 to the B2 horizons and then decreases. In the Island profile the nitrogen decreases with depth except for a slight bulge in the buried A horizon.

The C/N ratio (Table 13, page 67) of the O1 is much wider in the Cohoe than in either of the other soils. In the A2, B2 and B3 horizons the ratios are similar in the Cohoe and Transitional soils. In the Island, the ratio is highest in the A11 horizon and in general, declines with depth. Figure 16 shows C/N ratios.

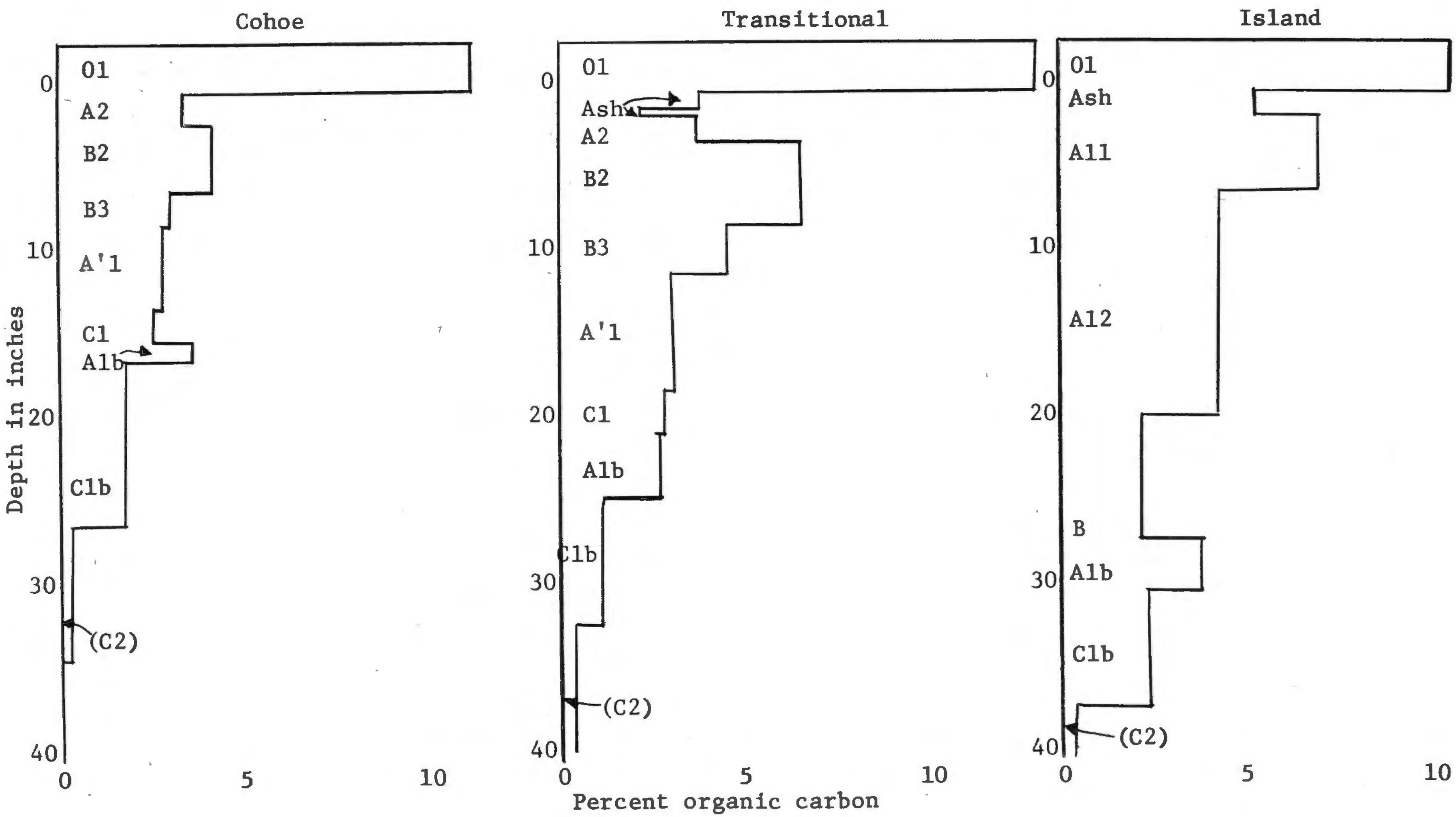


Figure 15. Organic carbon content of Cohoe, Transitional, and Island soils.

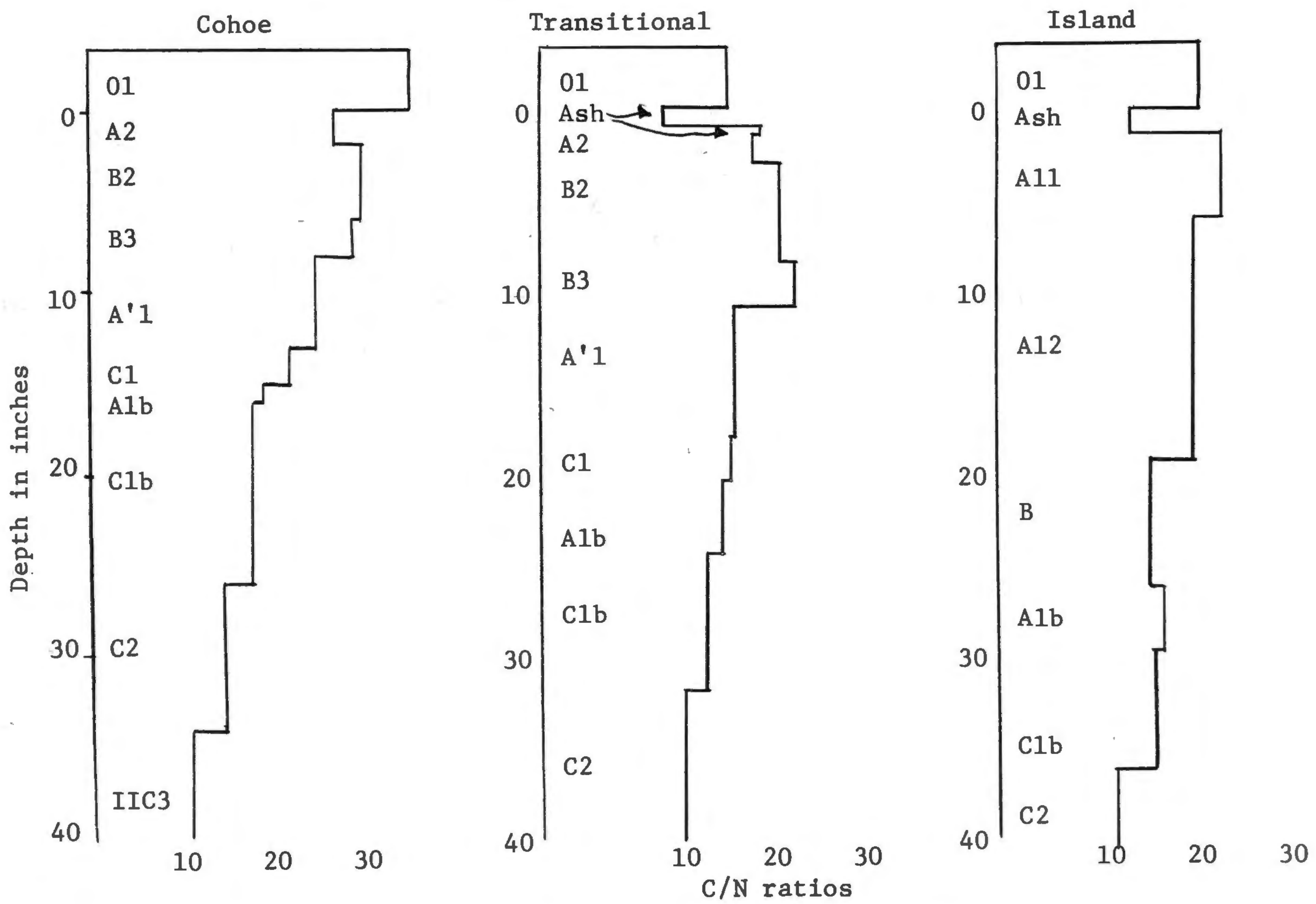


Figure 16. Ratios of carbon to nitrogen in soils along Transect I.

Table 14. pH Values of Horizons Determined in N NaF Solution

Horizon	Depth (inches)	pH after 2 min.	pH after 60 min.
	Cohoe soil		
01	3-0	7.6	7.7
A2	0-2	9.5	9.5
B2	2-6	11.0	11.2
B3	6-7.5	10.9	11.2
A'1	7.5-13	10.9	11.2
C1	13-15	10.9	11.2
A1b	15-16	10.9	11.2
C1b	16-26	10.8	11.1
C2	26-34	9.7	10.0
IIC3	34-40	9.5	9.9
	Transitional soil		
01	3-0	7.4	7.5
Ash	0-1	9.4	9.3
Ash	1-1.5	9.2	9.1
A2	1.5-3	9.3	9.3
B2	3-8.5	10.8	11.0
B3	8.5-11	11.0	11.2
A'1	11-18	11.0	11.1
C1	18-20.5	10.8	11.2
A1b	20.5-24.5	10.9	11.1
C1b	24.5-32	10.8	11.1
C2	32-42	10.4	10.7
IIC3	42-53	10.3	10.6
	Island soil		
01	3-0	9.3	9.1
Ash	0-1.5	10.1	10.2
A11	1.5-6	11.1	11.2
A12	6-19.5	10.9	11.0
B	19.5-27	10.6	10.9
A1b	27-30	10.8	11.0
C1b	30-37	10.7	10.9
C2	37-42	10.0	10.3
IIC3	42-48	9.6	10.1
	Dewey silty clay loam, Knox County, Tennessee[a]		
B22	---	9.2	9.6
B23	---	9.2	9.6

[a]A representative Dewey soil has B horizons with: Kaolinite clay > 60%; Vermiculite clay < 10%; Illite clay < 10%; Quartz < 10%.

Table 15. Pyrophosphate-Dithionite Extractable C, Fe, and Al in Percent for Selected Horizons (Oven-Dry Basis)

Horizon	Depth (inches)	C percent	Fe percent	Al percent	Clay[a] percent	C+Fe+Al/clay ratio
	Cohoe soil					
01	3-0	3.12	0.43	0.54	---	----
A2	0-2	1.61	0.47	0.32	5.1	0.47
B2	2-6	3.20	0.88	1.37	7.8	0.70
B3	6-7.5	2.06	0.86	1.45	6.9	0.63
	Transitional soil					
01	3-0	2.70	0.36	0.22	---	----
A2	1.5-3	1.82	0.38	0.32	6.5	0.39
B2	3-8.5	4.24	0.92	1.58	7.4	0.91
B3	8.5-11	3.74	0.90	2.00	8.5	0.78
	Island soil					
01	3-0	3.65	0.41	0.71	---	----
A11	1.5-6	4.34	0.99	1.69	10.3	0.68
A12	6-19.5	2.66	0.87	1.42	10.8	0.45

[a]Clay determined by standard pipette method following dispersion with hexametaphosphate.

NaF pH values (Table 14) for the horizons formed in the silty mantle in general exceeded 10.9 after two minutes and 11.0 after 60 minutes. Values for the A2 horizons were lower than for the B horizons in the Cohoe and Transitional soils, and the values for the A2 horizons did not change after 60 minutes.

Table 15 gives pyrophosphate dithionite extractable carbon, iron, and aluminum for selected horizons. Both the Cohoe and Transitional A2 horizons have less than in horizons above and below. The B2 horizons are highest in carbon and iron, and the B3 horizons are highest in aluminum. In the Island soil the iron, carbon, and aluminum are highest in the A11 or surface mineral horizon.

The KCl extractable acidity and extractable aluminum are given in Table 13, page 67. The amounts are low in all horizons of the profiles. In most cases extractable acidity is almost equal to the extractable aluminum. This indicates that the initial titration for total exchangeable acidity is also a measure of exchangeable aluminum (McLean, 1965).

CHAPTER V

DISCUSSION

I. PHYSICAL AND CHEMICAL PROPERTIES

The Cohoe, Transitional, and Island soils have bisequel sola. Particle-size data show that the material is dominantly silty and that clay percentages are uniformly low. However, because of the difficulty of dispersion and the flocculation of fine to coarse silt in some horizons even when ultrasonics are applied, it is doubtful if complete dispersion resulted by any of the methods used. There is no evidence of textural stratification within the silty mantle in which these soils are formed except the thin layer of surface ash. The boundary with the underlying layered silty, sandy, and clayey sediments is abrupt at depths of 32 to 40 inches.

No horizon in any of the profiles has structure more strongly developed than weak thin platy. Consistence in all horizons above the substrata is very friable and becomes smeary when rubbed. The soil material in the silty mantle can be described as "fluffy," which indicates low bulk density. Low plasticity and lack of stickiness are other common shared properties. Organic matter content is relatively high to depths of 24 inches. The properties of "fluffiness," "smeariness," low plasticity and stickiness, and high organic matter content are characteristics of soils developed in volcanic ash (Birrell, 1952; 1964; Taylor, 1964, Aonine, 1955). These are also properties that are characteristic for Andepts.

The Island soils occur under grass and are distinguished, in part, by a thick dark surface horizon with colors in hue 10YR, values of 2 or 3, and chromas of 2 to 4. The Cohoe soils always occur under forest and, in part, are recognized by a thin gray surface A2 horizons over splotched reddish and brownish B horizons in hues of 5YR to 10YR, in values of 3 or 4, and chromas of 2 to 4. Petrographic examination of the soil particles reveal that the mineral grains are "bleached" clean in the A2 horizons and that in the B horizons the mineral grains are commonly coated with amorphous coverings, probably of humus and iron.

At the forest-grassland border, the Island soils extend into the environs of the forest where young trees predominate. Individual and clumps of older trees also occur in places. In this transitional zone the soils vary within small distances. More typical Cohoe soils tend to be under older clumps of trees. In some places under comparatively young trees the soil is more like Island, but a thin discontinuous A2 horizon has formed at the surface of the dark A11. Where trees are older and, especially, in clumps, yellowish brown to reddish brown streaks are below the A2 horizon.

Although Transect II was not sampled for laboratory study, field evidence indicates that it is a close replica of Transect I. From a comparison of the profiles it is seen that the Transitional profile of Transect II is definitely transition between the Cohoe and Island soils. The presence of a thin A2 horizon overlying the splotched dark brown and reddish brown A11 horizon suggests the beginning of an illuvial B horizon.

During the progress of the soil survey of the western Kenai

Peninsula, the author observed forested depressions with soils having many of the characteristics of the Cohoe series but yellower and more splotched B horizons than are typical of Cohoe. In these areas the surface is hummocky as in areas of Island soils. This condition suggests recent establishment of the forest in these depressions.

Particle-size analyses after ultrasonic treatment suggests some clay illuviation from the A2 to the B2 horizon in the Cohoe and Transitional soils. The B2 horizons contain about 4 percent more clay than the overlying A2 horizons. There is no suggestion of clay illuviation in the Island profile.

The low broad X-ray peaks of unpurified clay fractions from the A and B horizons indicate that amorphous material caused poor orientation of any crystalline clays that were present. Removal of the amorphous material greatly enhanced the peaks for the crystalline clays. Table 11, page 61, presents the interpretation of the relative amounts of crystalline clays before and following the removal of the amorphous material by (1) pyrophosphate-dithionite, and (2) sodium-carbonate treatment. The presence of allophane or amorphous material was indicated by the differential thermal analysis (Fig. 8, page 37), which showed a sharp endotherm at 120° to 160°C, especially sharp in the A2 and B2 of the Cohoe profile.

Sodium fluoride pH values (Table 14, page 74) indicated high amounts of amorphous material, but the pH after two minutes did not exceed pH 11.0, which may indicate a low total amount of allophane (Field and Perrott, 1966).

Bulk density (Table A-1, appendix) of clods from the A and B horizons of the Cohoe and Island soils at field moisture ranged from 0.72 to 0.80. This low bulk density is another indication of a high amount of amorphous materials.

Moisture retention (Table 9, page 56) at 15 atmospheres is influenced by the treatment after sampling. Air drying (Fig. 17) reduces the percentage of water retention by as much as one half in the horizons highest in organic matter content, and oven drying to 110°C further reduces the amount. Moisture retention at 15 atmospheres determined on samples heated to 500°C shows a continuous weight loss (Table 10, page 58) through the sequence as the water is driven off. Swindale (1964) states that the irreversible drying of soils high in amorphous materials is related to the increasing contact between the mineral particles, which have highly charged surfaces. Bonds result and the surface available for resorption of water is permanently decreased. Statistical analyses relating percent water retention at 15 atmospheres to the percent clay content shows that the correlation is much better between clay in field-moist samples and water retention than between clay in air-dry samples and water retention (Table A-2, appendix).

The chemical properties, as were the physical properties, are quite similar in the three soils. Most of the chemical properties are related to the organic matter content and its distribution in the profile. In the Cohoe and Transitional soils, the organic matter (Fig. 15, page 72) has subsurface maxima in the B2 horizons and secondary maxima in the buried A horizons. In the Island soil the organic matter content is highest in the A11 and decreases with depth except for

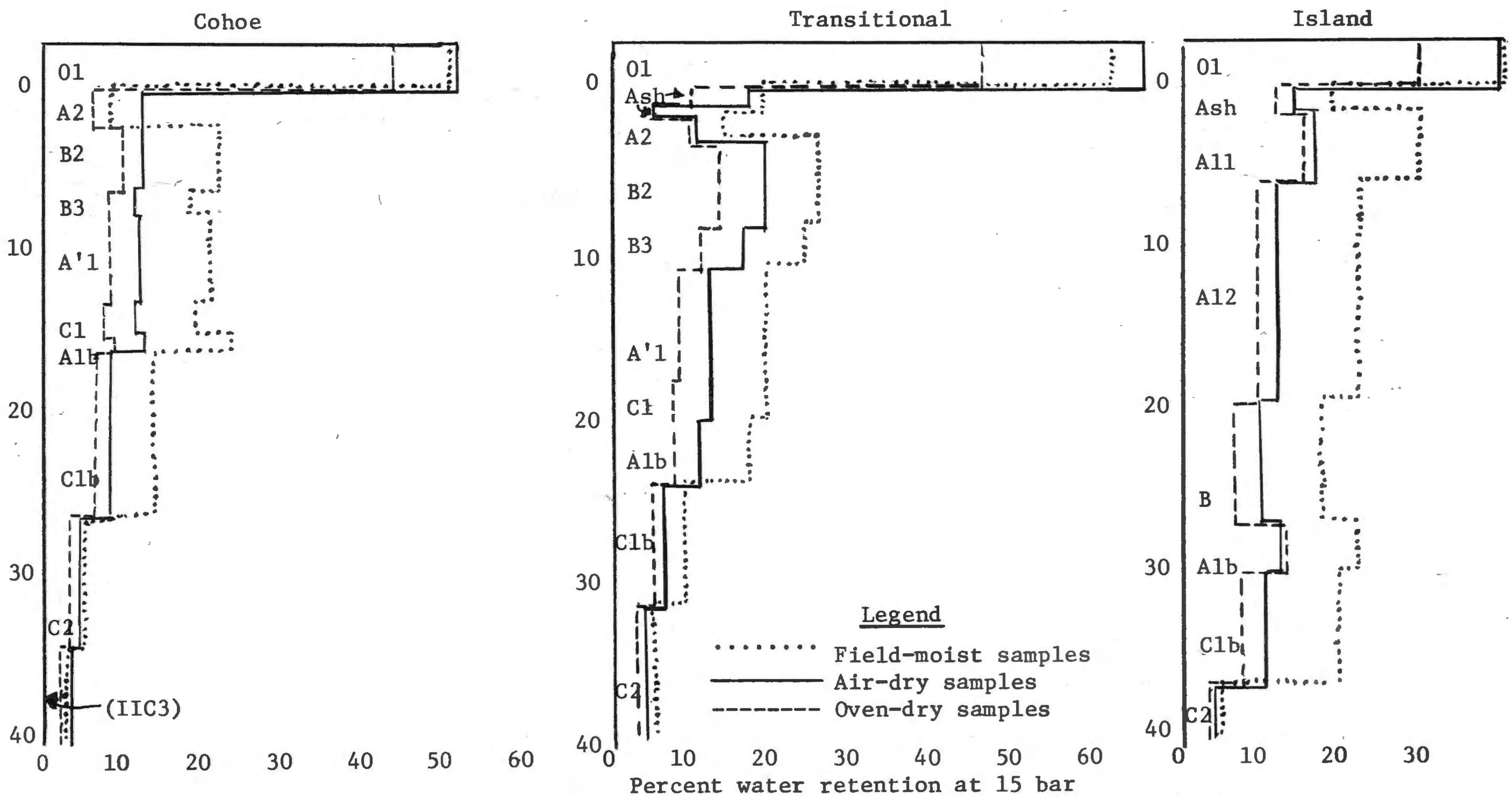


Figure 17. Moisture retention at 15 atmospheres for soils along Transect I after different treatments.

slight gains in the Alb horizon. However, the organic matter is higher to a greater depth, probably as a result of the fibrous grass roots.

Free iron, cation exchange capacity, extractable acidity, exchangeable bases, percentage base saturation are highest in the mineral horizons containing the highest organic matter content. This points out that the organic fraction is a very important component of the "active" part of these soils.

Differences in the amount and the distribution of the organic matter in the soils appear to be the result of the kind of vegetation with resulting dissimilar properties of litter composition and rooting characteristics of trees versus the grass. In the Cohoe and Transition soils there has been movement and accumulation of humus and sesquioxides from the A2 to the B2 horizons. (Particle size distribution data [Table 7, page 48] faintly suggests that a little movement of clay has occurred.) This movement and accumulation of humus and sesquioxides and the reactions involved has been called podzolization (Stobbe and Wright, 1959). Rhode (1937) states that vegetation is the decisive part in podzolization and that in Russia, spruce has the most podzolizing influence of any type. In summarizing a review of the concept of the genesis of podzols, Stobbe and Wright (1959) wrote:

> The percolating decomposition products, organic matter, particularly the organic acids and other complexing substances, bring about the solution of sesquioxides, the reduction of iron and the formation of soluble metal organic complexes, some of which may be chelated. The complexes move to the lower horizons and are precipitated under oxidizing conditions probably by the destruction of ligands by microorganisms and/ or by sorption.

In a study of the effect of volcanic ash on accumulation and distribution of mobile compounds in frozen podzolic soils of the

Madadan region of Russia, Naumov, Tsyurupe, and Andreyeva (1964) concluded that the presence of volcanic ash in the soil parent material intensified the podzolic illuvial processes quantitatively and that the volcanic ash was an active source of readily soluble forms of Al_2O_3 and SiO_2.

The pH values in the surface layers of the Cohoe soil are a little lower than in the other soils. This reflects a longer influence of the extremely acid spruce litter and its decomposition. The acidity of Sitka spruce needles in Canada has been reported as pH 4.4 (Handley, 1954). The larger sum of cations and higher base saturation in the O1 of the Cohoe and Transitional soils than in the Island are probably the result of cycling by the forest trees and accumulation in the slowly decomposing needles and other litter as suggested by Broadbent (1953). The small amount of exchangeable bases in these soils may suggest little weathering of the parent material or low base content of the parent material or the replacement of exchangeable bases by hydrogen in the course of leaching.

The differences in the pH values in the soils are minor at comparable depths. The pH values are relatively high considering the low base status. Birrell (1964) pointed out that pH values in immature volcanic ash soils tended to range from pH 5 to 6 because of the strong buffering effect of allophane and its isoelectric point. In these soils it is likely that the buffering effect from the high organic matter is also significant.

The cation exchange capacity is highly pH-dependent as indicated by the difference when measured by neutral ammonium acetate and when calculated as the sum of exchangeable bases and extractable acidity.

Carbon/nitrogen ratios (Fig. 16, page 87) are much lower in the 01 (22) of the Island and 01 (20) of the Transition than in the 01 (35) of the Cohoe profile. Faster decomposition of the grass litter would account for the lower ratios. The C/N ratio was highest in the 01 horizon of the Cohoe profile, in the B3 of the Transition, and in the All of the Island soil. In general the C/N ratios were highest in the Cohoe profile, intermediate in the Transitional profile, and lowest in the Island profile. The Transitional soil probably started with a higher amount of organic matter, mostly from the influence of the grass vegetation, than the Cohoe, and lower ratios might be expected. Higher ratios in the mineral horizons of all the profiles are related to higher carbon content.

Content of free iron was similar in the 01 horizons of the Cohoe and Transitional profiles but was a little higher in the 01 horizon of the Island. Free iron was less in the A2 than in the B2 horizons of the Cohoe and Transitional soils. The amount in the B2 is greater in the Transitional than in the Cohoe; however, a deeper bulge in the Cohoe indicates slightly deeper movement. In the Island soil, free iron decreases with depth below the All horizon and the decrease is more uniform than in the Transitional and Cohoe soils. Other studies (Brydon, 1965) of Podzols have found that free iron varied in a manner similar to organic carbon. In light of this, a higher content of free iron might be expected in the Transitional soil because of its relatively higher content of organic carbon as compared to the Cohoe profile.

Results of pyrophosphate-dithionite extractable aluminum, iron and carbon are in Table 15, page 75. In the Cohoe and Transitional soils aluminum maxima are in the B3 horizons, and the iron and organic carbon maxima are in the B2 horizons. Franzmeier and Whiteside (1963) from a study of podzols in Michigan suggested that there is a tendency for aluminum to accumulate slightly deeper in the podzol sequel than iron. Other studies, including Brydon (1965) and Richard (1944) have also illustrated this. In the Island soil the maxima of Fe, C, and Al are in the A11 horizon.

Franzmeier et al. (1965) proposed that a ratio of pyrophosphate-dithionite extractable Al + Fe + C to clay greater than .15 would separate spodic horizons from some competing similar horizons, especially cambic horizons. He pointed out, however, that some Hawaiian Andepts (from ash) would be included with spodosols by this criterion. (By extension most Andepts would be included.) However, if the ratio criterion is applied to either the A11 or A12 of the Island soil, the ratio is well above .15 (Table 15) and in the range of the B horizon of the Transitional soil. This similarity of ratio values points out the large amount of amorphous materials present.

The NaF pH values (Table 14, page 74) indicate a high content of amorphous material but a low amount of allophane. The Soil Survey Staff (1968) suggested that a NaF pH reading higher than 9.4 after two minutes may indicate that the collodial matter is dominated by amorphous material. The B and upper C horizons of the Cohoe and Transitional profiles and the A, B, and upper C horizons of the Island profile gave pH values of 10.6 and 10.9 after two minutes. A pH of 11.0 after two minutes may indicate a high amount of allophane (personal communication, R. E. Nelson, Riverside Soil Survey Laboratory).

The Soil Survey Staff (1967) lists some criteria indicating the domination of the collodial material of a soil by amorphous material:

1. The exchange capacity of the measured clay (at pH 8.2) is very high, more than 150 meq/100 grams measured clay, and commonly more than 500 meq. This is in part the result of poor dispersion.
2. If there is enough clay to have a 15-bar water content of 20 percent or more, the pH of 1 gram of soil in 50 ml of 1N NaF is greater than 9.4 after 2 minutes.
3. The 15-bar water retention/measured clay ratio is more than 1.0.
4. O.M. exceeds 1 percent.
5. Differential thermal analysis shows a low temperature endotherm.

Table 16 summarizes these data for the soils. These data emphasize the similarity of these properties in all of these soils.

All of these soils have formed in common parent material and are high in amorphous material. There are definite evidences of illuviation in the B horizon of the Transitional and Cohoe soils. Although both the Cohoe and Transitional soils have properties that are typical of Spodosols, they still have some of the characteristics of Andepts including high organic matter content to a considerable depth in the profile. In iron distribution there are relatively small differences between the three soils. More representative Spodosols in southcentral Alaska differ from the Cohoe in not having as high organic matter content distribution below the sola and in having B horizons with a greater amount of iron accumulation (Rieger and Dement, 1965).

Climatic changes and invasion by forests of previously existing grasslands on the Southern Kenai Peninsula have been supported by pollen studies by Huesser (1960). The degree of change would not have had to be very great, since the area is very close to the climatic boundary between forest and grassland. In the Caribou Hills, which are

Table 16. Properties Relevant to Characteristics of Amorphous Material (For Upper Horizons Formed in Silty Mantle)

Horizon	Depth (inches)	CEC/100g clay ratio[a]	Na F pH after 2 min.	15-bar H_2O/ clay ratio[b]	O.C.
	Cohoe soil				
A2	0-2	312	9.5	2.4	3.7
B2	2-6	320	11.0	2.7	4.5
B3	6-7.5	252	10.9	2.5	3.2
A'1	7.5-13	276	10.9	2.7	3.1
C1	13-15	312	10.9	3.1	2.7
Alb	15-16	235	11.0	2.7	3.8
Clb	16-26	175	10.8	1.7	1.6
C2	26-34	115	9.7	0.8	0.3
	Transitional soil				
A2	1.5-3	257	9.3	2.0	4.0
B2	3-8.5	488	10.8	3.4	6.8
B3	8.5-11	354	11.1	2.7	5.0
A'1	11-18	211	11.0	1.9	3.3
C1	18-20.5	219	10.8	2.4	2.8
Alb	20.5-24.5	203	10.9	2.0	2.8
Clb	24.5-32	257	10.8	2.1	1.2
	Island soil				
All	1.5-6	367	11.1	2.7	7.6
A12	6-19.5	191	10.9	1.8	4.6
B	19.5-27	195	10.7	2.0	2.3
Alb	27-30	246	10.9	2.4	4.1
Clb	30-37	227	10.7	2.5	2.6

[a]CEC determined in NH_4OAC pH7.

[b]15-bar water retention for field-moist samples; clay determined by pipette method with hexametaphosphate as a dispersing agent.

only a few hundred feet higher than the sample sites, summers are slightly cooler and only now is the forest beginning to replace the grass.

II. CLASSIFICATION OF THE SOILS

In the classification of soils series of the Western States (Soil Conservation Service, 1967), the Cohoe series is placed in a coarse-silty, mixed family of Typic Cryorthods, and the Island series in a Thixotropic family of Dystric Cryandepts. Criteria are given in the appendix.

The Soil Survey Staff (1967) recognized that in soils developed in volcanic ash and other pyroclastic materials it was sometimes difficult to distinguish between a spodic and a cambic horizon. Both kinds of horizons contain amorphous materials that are similar in the kinds of properties commonly measured. The Cohoe and Island soils are high in amorphous materials, and the laboratory studies point out the similarity of their chemical and some of their physical properties. This makes the classification and correlation difficult, especially for the Cohoe soils.

Formerly the Cohoe soils were classified as Podzols and the Island soils as Ando soils. In the field, Cohoe soils with their thin albic horizon overlying reddish B horizons contrast strongly with the thick, dark-colored epipedon of the Island soils. The B horizons of the Cohoe soils have characteristics of spodic horizons. In addition to underlying an albic horizon, these include: (1) humus coatings on the mineral grains, (2) high content of amorphous materials, (3) colors in hues redder than 10YR, and (4) hues, values, and chromas change markedly in a few inches with the lowest values and redder hues in the upper B horizons. It should be noted that the Cohoe soil sampled for laboratory study expresses the minimum development allowable in the Cohoe Series range. For comparison, a modal Cohoe profile is presented in the appendix.

The 7th Approximation (Soil Survey Staff, 1967) states that if plowing to a depth of six or seven inches obliterates all traces of a questionable spodic horizon then it is not a spodic horizon. When the soils of the western Kenai Peninsula were mapped in 1961, most of the area was in virgin vegetation of forest and natural grasslands. Where agricultural use had increased, questions arise as to whether the Cohoe and Island soils can still be separated and especially can a spodic horizon of the Cohoe be identified by the present criteria. The Soil Survey Staff (1967) states that if an Ap horizon is present and is not underlain by a diagnostic subsurface horizon other than a fragipan, with or without an albic horizon, the Ap is considered spodic if it has the following properties:

1. contains more than 3 percent organic matter (1.7 percent organic carbon);
2. $\frac{\text{percent extractable C + Fe + Al}}{\text{percent clay}} > .20$;
3. fragments of amorphous coatings can be clearly identified;
4. the hue is redder than 10YR and the moist color value less than 3, or the chroma is 3 or more in hues of 10YR or redder;
5. a 15-bar water content of less than 20 percent;
6. less than 60 percent vitric volcanic ash, pumice, and other pyroclastic materials in the 20 to 200 micron fraction.

Each of these rules will be applied separately as follows:

1. from table 13 it appears certain that the Ap would contain more than 1.7 percent organic carbon for both the Cohoe and Island soils;
2. the ratio of .20 for percent $\frac{\text{extractable C + Fe + Al}}{\text{percent clay}}$ would be exceeded in both cases;

3. amorphous coatings should be readily identifiable in the Cohoe Ap and present but much less evident in the Ap of the Island;

4. it is likely that in the Ap of the Cohoe that hues would be redder than 10YR and that the Island would have hues of 10YR; it is evident from the modal Cohoe profile in the appendix that the chromas would exceed 3;

5. the 7th Approximation fails to state if the 15-bar water content is for field-moist or air-dry samples. If air-dry samples were used, both the Cohoe and Island would likely have less than 20 percent retention at 15-bar. If field-moist samples were used, the Cohoe Ap would likely be slightly less than 20, and Island Ap would exceed 20. The amount of the 01 horizon that would be incorporated in the Ap would influence this;

6. the amount of ash or other pyroclastic material is presently difficult to ascertain (Flach, 1964).

Under all conditions, certain limits must be met for a horizon to qualify as spodic. In addition to the depth requirement, discussed above, others are enough amorphous material that the ratio of percent extractable C + Fe + Al to percent clay must be greater than 0.15. In both the Cohoe and Transitional soils (Table 15, page 75) the A2's, B2's, and B3's satisfy this requirement. In the Island soil (Table 15) both the A11 and A12 exceed 0.15. A spodic horizon must have a 15 bar water content of less than 20 percent. From Table 9, page 56, it is seen that there is a large variation in retention depending on the treatment of the samples because of the property of irreversibly drying. The B horizons of the Cohoe hold about 20 percent if kept field-moist and much less if air-dry. The pH (paste) in water should be less than 5.0 and the pH (paste) 1 N KCl in some part should be at least 0.5 pH units lower than in water. Table 12, page 64, shows that the B horizons in the Cohoe and Transitional soils do not have a pH in water paste of less than 5.0. The pH (paste) in 1N KCl is more than 0.5 units lower than in water paste in both the A and B horizons of all the soils. Apparently this criterion for the recognition of Spodic horizons is inadequate.

In summary, the properties commonly measured in the laboratory do not separate distinctly these closely related soils. In both the Cohoe and Island soils the major horizons of the sola contain high amounts of amorphous materials. The ratio of percent extractable C + Fe + Al to the percent clay exceeds 0.15 in both soils. The 15-bar water retention of field-moist samples is almost 20 percent in the B horizons of the Cohoe and is more than 20 percent in the B horizons of the Transitional soils and in the A11 horizon of the Island soil. Amorphous coatings are present in the sola of both the Cohoe and Island soils but to a much greater expression in the B horizons of the Cohoe and Transitional soils. The pH values in water (paste) are greater than 5.0 in the B horizons of the Cohoe and Transitional soils and are 5.0 in the A11 and 5.5 in the A12 of the Island soil. In the A and B horizons of the Cohoe and in the A horizons of the Island the bulk density was 0.80 or less (see Table A-1, appendix).

The Island soils are not as difficult to classify by the criteria of the 7th Approximation. They have no spodic, natric, or oxic horizon. They are Inceptisols with an umbric epipedon, a bulk density of the fine earch fraction of less than 0.85 g/cc, and the exchange complex is dominated by amorphous materials. This makes them fit in the suborder of Andepts. Cold temperatures place them into Cryandepts. They are further placed into Dystric Cryandepts because it was assumed that the 15-bar water retention averaged more than 20 percent for the series control section. However, results for the Island soil (Table 9, page 56) show that it is borderline for water retention and might be classified with the Typic Cryandepts, which have less than 20 percent 15-bar water retention. Requirements for a Thixotropic family are met.

CHAPTER VI

SUMMARY AND CONCLUSIONS

In the western Kenai Peninsula, Alaska, the well-drained soils of the uplands are formed in a mixture of volcanic ash and loess. The dominant vegetation is spruce forest, but openings of natural grasslands occur as "islands" within the forest. Field evidence exists that would seem to indicate that the forest in south-central Alaska is advancing at the expense of the grasslands. The grass-covered Island soils have been classified as Cryandepts and the forested Cohoe soils as Cryorthods. Both soils are high in amorphous materials.

Two transects extending from grass to forest were studied in the field. One of the transects was sampled at three sites: (1) an Island pedon under grass, (2) a Transitional pedon at the forest-grass border, and (3) a Cohoe pedon in the spruce forest. Studies in the laboratory were centered on the properties of amorphous materials, and especially on those properties which are used to separate spodic horizons from cambic horizons.

Interpretation of pH values determined in N NaF solution, and X-ray and DTA results showed that although these soils were high in amorphous materials they were not especially high in allophane. X-ray peaks for the crystalline clays present in the sola of these soils were greatly enhanced by the removal of amorphous materials by (1) pyrophosphate-dithionite, and (2) sodium-carbonate treatment.

The organic fraction was almost as important a part of the active fraction of these soils as was the clay. In the Cohoe and Transitional soils, the organic matter had subsurface maxima in the B2 horizons, and in the Island soil the content was highest in the A11 horizon. Free iron, CEC, extractable acidity, exchangeable bases, percentage base saturation were highest in the mineral horizons containing the highest organic matter content. The pH values were relatively high considering the low base status. This was probably due to the strong buffering effect of the amorphous material. The CEC was highly pH dependent.

Post-sampling treatment of samples greatly influenced some properties because these soils dry irreversibly. Even air-drying greatly reduced the 15-bar water retention. Oven-drying to 110°C greatly reduced 15-bar water retention, especially in the horizons which were highest in amorphous material. Water retention in 15-bar was strongly influenced by the organic matter content. This was pointed out by removal of the organic matter by H_2O_2 before determination of 15-bar water retention.

Aggregates in the sand fraction showed that these soils were poorly dispersed by the standard method of hexametaphosphate followed by overnight shaking. In some horizons of the sola, even air drying reduced dispersion. The use of ultrasonics in addition to the standard method of hexametaphosphate followed by overnight shaking appeared to result in better dispersion.

The effect of vegetation on the morphology of these soils was emphasized. Although the sola of these soils differ significantly in horizonation and color, differences in properties measured in the laboratory were not great. In the Cohoe and Transitional soils, the organic carbon decreased with depth with more uniformity than in the Cohoe or Transitional soil. Total nitrogen in the upper part of the soils decreased from the Island to the Cohoe soil. In general the C/N ratios were highest in the Cohoe, intermediate in the Transitional, and lowest in the Island soil. Free iron had a slightly deeper bulge in the Cohoe than in the Transitional soil, however the iron distribution shows relatively small differences among the three soils. The pH values were slightly lower in the surface layers of the Cohoe than in the Transitional or the Island soils. Pyrophosphate-dithionite extractable aluminum, iron, and carbon showed aluminum maxima in the B3 horizons of the Cohoe and Transitional profiles, and iron and organic carbon maxima in the B2 horizons. In the Island soil, the iron, organic carbon, and aluminum maxima are in the A11 horizon.

This evidence suggests that all of these soils were once under grass and that the dominant soils were Andepts. Apparently after invasion of grasslands by spruce trees, the development of a thin albic and an illuvial B horizon is fairly rapid.

From the limited study, it appears that in soils high in amorphous materials formed in volcanic ash or other pyroclastic materials, more precisely defined criteria are needed for separation of spodic and cambic horizons. Further study might be given to the establishment of an Andic subgroup in Cryorthods. This would accommodate soils with spodic horizons which were formed in vitric volcanic ash or other pyroclastic materials that weather to amorphous materials, e.g., the Cohoe soils.

If further work is done with 15-bar water retention on H_2O_2 treated samples of similar soils, it is suggested that two sets of samples consisting of air-dry and field-moist soil be used to study the effect of air-drying. Ultrasonic sound treatment should be further investigated as a method to effect better dispersion in volcanic soils, which dry irreversibly. The method and length of treatment should be studied. Further work would be needed to determine apparent phenomenon of increase of coarse silt over fine silt following ultrasonic sound treatment as compared to the standard hexametaphorphate-overnight shaking method.

LITERATURE CITED

LITERATURE CITED

Allison, L. E. 1960. Wet combustion apparatus and procedure for organic and inorganic carbon. Soil Sci. Soc. Amer. Proc. 24:36-40.

Aomine, S. and N. Yoshinaga. 1955. Minerals of some drained volcanic soils in Japan. Soil Sci. 79:349-358.

Association of Official Agricultural Chemists. 1950. Official and tentative methods of analysis of the Association of Official Agricultural Chemists. Ed. 7, 910 pp. illus. Washington, D.C.

Barnes, F. F. and E. H. Cobb. 1959. Geology and coal resources, Homer District, Alaska. Geol. Survey Bull. 1058-F. Government Printing Office, Washington, D.C.

Bennett, H. H. 1916. Report on a reconnaissance of the soils, agriculture, and other recourses of the Kenai Peninsula Region of Alaska. U.S. Bur. Soils Field Operations 1916, Advance sheets pp. 142.

Birrell, K. S. 1964. Some properties of volcanic ash soils. In F. A. O. of the U. N. Meeting on the Classification and Correlation of Soils from Volcanic Ash., Tokyo, Japan. Pp. 74-79.

Birrell, K. S. and M. Fields. 1952. Allophane in volcanic ash soils. Jour. Soil Sci. 3:156-166.

Birrell, K. S. and M. Gradwell. 1956. Ion-exchange phenomena in some soils containing amorphous mineral constituents. Jour. Soil Sci. 7:130-147.

Bloomfield, A. 1954. A study of podzolization; IV, the mobilization of iron and aluminum by picked and fallen larch needles. Jour. Soil Sci. 5:46-49.

Bloomfield, A. 1955. A study of podzolization; VI, the immobilization of iron and aluminum. Jour. Soil Sci. 6:284-292.

Brasher, B. R., D. P. Franzmeir, V. T. Valassis, and S. E. Davidson. 1966. Use of saran resin to coat natural soil clods for bulk-density and water-retention measurements. Soil Sci. 101:108.

Bremner, J. M. 1949. Studies on soil organic matter, Part I. the chemical nature of soil organic nitrogen. Jour. Agric. Sci. 39:183-193.

Bremner, J. M. 1965. Total nitrogen In C. A. Black, ed., Methods of Soil Analysis. A. S. of Argon. Monograph No. 9, part 2:1149-1178.

Broadbent, F. E. 1953. The soil organic fraction. In Advances in Agronomy. Edited by A. G. Norman. Academic Press, Inc. New York. Vol. V, 153-181.

Broadbent, F. E., R. H. Jackson, and Joy McNicoll. 1964. Mineralization of carbon and nitrogen in some New Zealand allophanic soils. Soil Sci. 98:118-128.

Brydon, J. E. 1965. Clay illuviation of some orthic Podzols of eastern Canada. Soil Sci. 45:127-128.

Chandler, R. F., Jr. 1942. The time required for Podzol profile formation as evidenced by the Mendenhall glacial deposits near Juneau, Alaska. Soil Sci. Soc. Amer. Proc. 7:454-459.

Clark, J. S. and R. G. Hill. 1964. The pH percent base saturation relationships in soils. Soil Sci. Soc. Amer. Proc. 28:490-492.

Crocker, R. L., B. A. Dickson, and J. Major. 1955. Soil development in relation to vegetation and surface age at Glacier Bay, Alaska. Jour. of Ecology 43:427-448.

Deb, B. C. 1949. The movement and precipitation of iron oxides in Podzol soils. Jour. Soil Sci. 1:112-122.

Dickson, B. A. and R. L. Crocker. 1953. A Chromosequence of soils and vegetation near Mr. Shasta, California. Jour. Soil Sci. 4:123-154.

Edwards, A. P. and J. M. Bremner. 1967. Dispersion of soil particles by sonic vibration. Jour. Soil Sci. 18:47-63.

Fields, M. and K. W. Perrott. 1966. The nature of allophane in soils, Part 3. rapid field and laboratory test for allophane. New Zealand Jour. of Sci. 9:623-629.

Flach, K. 1964. Genesis and morphology of ash-derived soils in the United States of America. In F. A. O. of U. N. Meeting on the classification and correlation of soils from volcanic ash, Tokyo, Japan.

Franzmeier, D. P., B. F. Hajek, and C. H. Simonson. 1965. Use of amorphous material to identify spodic horizons. Soil Sci. Soc. Amer. Proc. 29:737-743.

Franzmeier, D. P. and E. P. Whiteside. 1963. A Chromosequence of Podzols in northern Michigan. Michigan State University Quarterly Bulletin. Vol 46, No. 1.

Griggs, R. F. 1922. The Valley of Ten Thousand Smokes. Nat. Geog. Soc., Washington, D.C.

Griggs, R. F. 1934. The edge of the forest in Alaska and the reason for its position. Ecology 15:80-96.

Griggs, R. F. 1936. The vegetation of the Katmai District. Ecology 17:380-417.

Handley, W. R. C. 1954. Mull and mor formation in relation to forest soils. Forestry Commission Bulletin No. 23. Her Majesty's Stationary Office, London. Pp. 115.

Hashimoto, I. and M. L. Jackson. 1960. Proc. 7th Natl. Conf. Clays, Clay Minerals. Pergamon Press, New York. Pp. 102-113.

Huesser, Calvin J. 1955. Pollen profiles from Prince William Sound and Southeastern Kenai Peninsula, Alaska. Ecology 36:185-202.

Huesser, Calvin J. 1960. Late-Pleistocene Environments of North Pacific North America. American Geographic Society, published under the patronage of the Louise A. Boyd Pub. Fund, New York.

Holmgren, George G. S. 1967. A rapid citrate-dithionite extractable iron procedure. Soil Sci. Soc. Amer. Proc. 31:210-211.

Hultén, E. 1937. Flora of the Aleutian Islands and westernmost Alaska Peninsula with notes on the flora of the Commander Islands. Bokforlags Aktiebolaget, Thule, Stockholm.

Jackson, M. L. 1964. Soil mineralogical analysis. In C. I. Rich and G. W. Kunze, eds. Soil Clay Minerology. University of N.C. Press, Chapel Hill. Pp. 330.

Jackson, M. L. 1956. Soil chem. analysis advanced course. Publ. by Prof. M. L. Jackson, Madison, Wisconsin.

Joffe, J. S. 1931. Soil profile studies, III. the process of podzolization. Soil Sci. 32:303-322.

Kanchio, Y. and L. D. Whittig. 1961. Amorphous mineral colloids of soils of the Pacific region and adjacent areas. Pacific Sci. 15:477-482.

Karlstrom, Thron N. V. 1964. Quaternary geology of the Kenai Lowland and glacial history of the Cook Inlet Region, Alaska. Geological Survey Prof. Paper--443. Government Printing Office, Washington, D.C.

Kellogg, C. E. and I, J. Nygard. 1951. Exploratory study of the principal soil groups of Alaska. U.S.D.A. Monogram 7. Government Printing Office, Washington, D.C.

Kilmer, V. J. 1960. The estimation of free iron oxides in soils. Soil Sci. Soc. Amer. Proc. 24:420.

Kilmer, V. J. and L. T. Alexander. 1949. Methods for making mechanical analysis of soils. Soil Sci. 68:15-24.

Kubota, J. and L. D. Whittig. 1960. Podzols in the vicinity of the Nelchina and Tazlina glaciers, Alaska. Soil Sci. Soc. Amer. Proc. 24:133-136.

Knox, E. G., J. F. Carliss, and M. Williams. 1956. Dark colored acid, forest soils of western Oregon. Soil Sci. Soc. Amer. Proc. 29:732-736.

Kobo, K. Properties of volcanic ash soils. 1964. In Meeting on the Classification and Correlation of Soils from Volcanic Ash. F. A. O. of the U. N., Tokyo, Japan.

Lutz, H. J. 1956. Ecological effects of forest fires on the interior of Alaska. Technical Bull. No. 1133. U.S.D.A.

McLean, E. O. 1965. Aluminum. In C. A. Black, ed., Methods of Soil Analysis. American Society of Agronomy Monogram No. 9, Part 2: 978-998.

Naumov, E. M., I. G. Tsyurupa, and N. A. Andreyva. 1964. Effect of volcanic ash on accumulation and distribution of mobile compounds in frozen Podzolic soils of Magadan region. Pochvovledenie No. 12: 71-84 (1299-1309).

Pawluk, S. and J. A. Carson. 1963. Evaluation of methods for determination of exchange acidity in soils. Canadian Jour. of Soil Sci. 43:325-335.

Peech, Michael. 1965. Hydrogen ion activity. In C. A. Black, ed., Methods of Soil Analysis. American Society of Agronomy Monogram No. 9, Part 2:914-926.

Peech, M., L. T. Alexander, L. A. Dean, and J. F. Reed. 1947. Methods of soil analysis for soil fertility investigations. U.S. Dept. Agr. C. 757. Pp. 25.

Pratt, P. F. and F. L. Blair. 1961. A comparison of the reagents for the extraction of aluminum from soils. Soil Sci. 91:357-369.

Richard, J. A. and R. F. Chandler. 1944. Some physical and chemical properties of mature Podzol profiles. Soil Sci. Soc. Amer. Proc. 8:379-383.

Rieger, Samuel, G. W. Allen, A. D. Backer. 1962. Soil Survey Kenai-Kasilof Area, Alaska. Government Printing Office, Washington, D.C.

Rieger, Samual and James A. Dement. 1965. Cryorthods of the Cook Inlet-Susitna Lowland, Alaska. Soil Sci. Soc. Amer. Proc. 29:448-453.

Rieger, Samuel and R. E. Wunderlich. 1960. Soil survey and vegetation, northeastern Kodiak Island Area, Alaska. U.S. Dept. of Agr. Soil Survey Series No. 17. Government Printing Office, Washington, D.C.

Robinson, W. O. 1927. The determination of organic matter in soils by means of hydrogen peroxide. Jour. Agric. Res. 34:339-356.

Rode, A. A. 1937. The process of podzolization. Pochvovedenie 32 (6):848-862. Read in Pedology, Ed. 2 by J. S. Joffe. Pedology Publications, New Brunswick, N.J.

Saly, Rudolf. 1967. Use of ultrasonic vibration for dispersing soil samples. Soviet Soil Sci. No. 11. Pp. 1547-1559.

Schalscha, E. B., C. Gonzalez, I. Vergara, et al. 1965. Effect drying on volcanic ash soils of Chili. Soil Sci. Soc. Amer. Proc. 29:481-482.

Sherman, D. and L. D. Swindale. 1964. Hawaiian Soils from volcanic ash. In Meeting on the Classification and Correlation of Soils from Volcanic Ash. F. A. O. of U. N., Tokyo, Japan. Pp. 36-42.

Simonson, Roy W. and Samuel Rieger. 1967. Soils of the Andept Sub-order in Alaska. Soil Sci. Soc. Amer. Proc. 31:692-699.

Soil Conservation Service. 1967. Soil Survey, Laboratory Methods and Procedures for Collecting Soil Samples. Soil Survey Investigations Report No. 1. Government Printing Office, Washington, D.C.

Soil Survey Staff. 1962. Identification and nomenclature of soil horizons. U.S. Dept. of Agr., Supplement to Agr. Handbook No. 18. Government Printing Office, Washington, D.C.

Soil Survey Staff. 1967. Supplement to Soil Classification System. 7th Approximation. U.S. Dept. Agr., Washington, D.C.

Sokolov, I. A. and Z. S. Karayeva. 1965. Migration of humus and some elements in the profile of volcanic forest soils of Kamchatka. Soviet Soil Sci. (No. 5):467-475.

Stevens, M. E. 1963. Podzol development on a moraine near Juneau, Alaska. Soil Sci. Soc. Amer. Proc. 27:357-358.

Stobbe, P. C. and Jr. Wright. 1959. 'Modern concepts of the genesis of podzols. Soil Sci. Soc. Amer. Proc. 23 (No. 2):161-164.

Swindale, L. D. 1964. The properties of soil derived from volcanic ash. In Meeting on the Classification and Correlation of Soils from Volcanic Ash. F. A. O. of the U. N., Tokyo, Japan.

Swindale, L. D. and M. L. Jackson. 1956. Genetic processes in some residual podzolised soils of New Zealand. Trans. Inter. Congr. Soil Sci., 6th Congr., Paris. E:233-239.

Taylor, N. H. 1964. The classification of ash-derived soils in New Zealand. In Meeting on the Classification and Correlation of Soils from Volcanic Ash. F. A. O. of U. N., Tokyo, Japan.

Thorp, James and Guy D. Smith. 1949. Higher categories of soil classification: order, suborder, and great soil groups. Soil Sci. 67:117-126.

Ulrich, H. P. 1946. Morphology and genesis of the soils of Adak Island, Aleutian Islands. Soil Sci. Soc. Amer. Proc. 11:438-441.

U.S. Department of Commerce. 1965. Climatography of the United States No. 86-43. Decennial Census of United States Climate. Climatic summary of the United States. Supplement for 1951 through 1960, Alaska. Government Printing Office, Washington, D.C.

U.S. Salinity Laboratory. In L. A. Richards, ed. 1964. Diagnosis and improvement of saline and alkali soils. U.S. Dept. Agr. Handbook 60.

U.S. Weather Bureau. 1960. Climatic Data for Alaska. Weather Bureau, Anchorage, Alaska. Office of the State Climatologist (unpublished climatic data).

Waldron, R. M. 1963. Planting white spruce in cut-over and undisturbed white spruce-aspen stands in Manitoba. Dept. of Forestry of Canada, Forest Research Branch, Manitoba-Saskatchewan District Report. 63-MS-9. Pp. 63.

Waldron, R. M. 1966. Factors affecting natural white spruce regeneration on prepared seedbeds at Riding Mountain Forest Experimental Area, Manitoba, Forestry Branch Departmental Publication. No. 1169. Pp. 41.

Watson, C. E. 1962. Climate. In Soil Survey Kenai-Kasilof Area, Alaska. Government Printing Office, Washington, D.C.

Wright, A. C. S. 1964. "The "Andosols" or "Humic Allophane" soils of South America. In Meeting on the Classification and Correlation of Soils from Volcanic Ash. F. A. O. of the U. N., Tokyo, Japan. Pp. 9-22.

APPENDIX

Placement of the Island soils according to the Seventh Approximation Criteria of March, 1967.

<u>Inceptisols</u>: Order 3

Inceptisols are mineral soils that have no spodic, natric, or oxic horizon unless it is a buried horizon; that have no plinthite that forms a continuous phase within 30 cm (12 inches) of the mineral surface; and <u>either</u>:

1.

2. Have an umbric, histic, or plaggen epipedon; or a mollic epipedon with <u>one or more</u> of the following;

    a. A bulk density of the fine earth fraction of less than 0.85 q per cc in the epipedon or the cambic horizon or both, and the exchange complex is dominated by amorphous materials,

    b.

    c.

<u>Andepts</u>: Suborder

1. Inceptisols that have one or both of;

    a. A bulk density of the fine earth fraction of the soil of less than 0.85 g per cc in the epipedon or the cambic horizon, or both, and the exchange complex is dominated by amorphous material,

    b. More than 60 percent of vitric volcanic ash, cinders, or other vitric pyroclastic material in the silt, sand, and gravel fraction,

2. Are not saturated with water at any period or lack the characteristics associated with wetness defined for Aquepts,

3. Lack a plaggen epipedon.

<u>Cryandepts</u>: Great Group

Andepts that have a mean annual soil temperature of less than 8°C (47°F) and a mean summer soil temperature at 50 cm (20 inches) or a lithic or paralithic contact, whichever is shallower, or less than 15°C (59°F) if cultivated or without an O horizon, or less than 8°C (47°F) if with an O horizon.

Dystric Cryandepts: Subgroup

a. Lack mottles with chromas 2 or less within 1 m (40 inches) of the surface,

b. Are thixotropic and the 15-bar water retention is more than 20 percent on the average of the series control section,

c. Lack a lithic contact within 50 cm (20 inches) of the surface,

d. Have an umbric epipedon or a horizon that meets the requirements of an umbric epipedon if its upper boundary is within 50 cm (20 inches) of the surface,

e. Have a mean annual soil temperature of more than 0°C (32°F).

Thixotropic: Family

Andepts, Andaquepts, and at least parts of andic subgroups of other great groups that cannot be dispersed readily for mechanical analysis. These soils are classified on the basis of combined texture, consistence, and mineralogical properties into 3 classes; cindery, ash, and thixotropic.[1]

---

[1]Thixotropy is a "reversible gel-sol transformation under isothermal shearing stress following rest." (Webster) The term means "to change by touch." Some natural (Untreated) soil materials exhibit this property. A field test of thixotropic soil is this: press a bit of wet soil between thumb and forefinger; at first it resists deformation, ... under greater pressure, suddenly the soil changes from a plastic solid to a liquid, and the fingers "skid." After the soil "smears in this fashion, usually free water can be seen on the fingers. In a matter of a second or two, the liquified soil sets again to its original solid state.

Placement of the Cohoe soils according to Seventh Approximation Criteria of March, 1967.

<u>Spodosols</u>: Order 6

Spodosols are mineral soils that have a spodic horizon, or a placic horizon cemented by iron that overlies a fragipon and meets all the requirements of a spodic horizon except thickness.

<u>Orthods</u>: Suborder

Spodosols that

1. Have a spodic horizon that has in some subhorizon a ratio of percentage of free iron (elemental) to percentage of carbon of 6 or less;

2. Have one of the following;

   a.

   b.

   c. A spodic horizon that lacks or has in less than 50 percent of each pedon, in any subhorizon that contains dispêrsed organic matter and aluminum and that lacks sufficient free iron to turn redder on ignition (less than 0.35 percent in the fine earth fraction, expressed as Fe).

3. Are never saturated with water or lack the characteristics associated with wetness of Aquods.

<u>Cryorthods</u>: Great Group

Orthods that

1. Have a mean annual soil temperature of less than 8°C (47°F) and a mean summer soil temperature at 50 cm (20 inches) or at a lithic or paralithic contact, whichever is shallower, or less than 15°C (59°F) if cultivated or without an O horizon or of less than 8°C (47°F) if with an O horizon;

2. Have no fragipan;

3. Have no placic horizon above the spodic horizon.

<u>Typic Cryorthods</u>: Subgroup

Cryorthods that

a. Have no argillic, horizon below the spodic horizon,

b. Have a cemented or undurated spodic horizon or 2 to 10 percent organic matter (1.16 to 5.8 percent carbon) in the upper 10 cm (4 inches) of the spodic horizon,

c. Have no lithic contact within 50 cm (20 inches) of the surface,

d. Have a mean annual soil temperature of more than 0°C (32°F).

Coarse silty, mixed: Family

1. Family criteria are defined as follows:

   Coarse silty: With less than 18 percent clay and less than 15 percent coarser than very fine sand (including coarse fragments up to 7.5 cm.

   Mixed: (Mineralogy) less than 40 percent of any one mineral other than quartz.

COHOE SERIES

O11	2.25-2 inches	Forest litter with some moss; charcoal particles.
O12	2-0 inches	Very dark grayish brown (10YR 3/2) mat of partially decomposed organic materials; contains fungal mycelia, some of which extend to the A2 and B21 horizons; abrupt smooth boundary.
A2	0-2 inches	Gray (5Y 5/1) silt loam, with few fine brown mottles; weak very fine granular structure; very friable; roots common; few white sand grains, probably volcanic ash, near top of horizon; abrupt irregular boundary.
B21	2-5 inches	Dark brown (7.5YR 4/4) and grayish brown (10YR 5/2) silt loam, mottled with dark reddish brown mostly in the upper part of the horizon; dark brown is the dominant color; weak fine subangular blocky structure; very friable; few roots; clear wavy boundary.
B22	5-8 inches	Grayish brown (2.5Y 5/2) and dark brown (7.5YR 4/4) silt loam; grayish brown is the dominant color; weak medium subangular blocky structure; very friable; few roots; clear wavy boundary.
B3	8-15 inches	Olive brown (2.5Y 4/4) and dark brown (10YR 4/3) silt loam; massive; very friable; few roots; many fine pores; gradual boundary.
C1	15-23 inches	Olive brown (2.5Y 4/4) silt loam; massive; very friable; fewer fine pores than horizon above; abrupt wavy boundary.
IIC2	23-53 inches	Olive (5Y 4/3) coarse silt; few fine mottles of dark brown, mostly along fine pores; massive, but breaks into fine subangular blocks when crushed; friable.
IIIC3	53+ inches	Olive (5Y 4/3) silty clay loam; massive; firm; Not sampled.

Site description: NW1/4 sec. 18, T 1 N, R 12 W, Seward Meridian; elevation about 300 feet; spruce-birch forest; 2 percent slope on nearly level plateau.

Table A-1. Some Physical Properties of Horizons from the Sola of the Cohoe and Island Soils

Soil	Horizon	Depth (inches)	Bulk density gr/cc	% water atmospheres 15	1/3[a]
Cohoe	A2	0-2	0.72	7.9	74.7
	B2	2-6	0.75	7.9	59.5
	B3	6-7.5	0.80	7.9	60.7
Island	A11	1.5-6	0.72	7.9	74.7
	A12	6-19.5	0.80	7.9	60.1

[a]Determinates were made on undisturbed clods.

Table A-2. Statistical Analyses of Relationship Between Percent Clay[a] and Percent Water Retention at 15 Atmospheres from Field-Moist and Air-Dry Samples

	x	y	z	xy	xz	yz
Means	6.7640	14.9360	9.4640			
Sdevm	2.6383	7.7011	4.4286			
Serrm	0.5277	1.5402	0.8857			
Coefv	39.0053	51.5605	46.7941			
Corcf				0.8597	0.7905	0.9567
Rgrcf				2.5094	1.3268	0.5502
Rgreq				-2.0375	0.4893	1.2467
Sdrgr				4.0184	2.7709	1.3167
Sdrcf				0.3109	0.2144	0.0349
Ttrgr				8.0714	6.1891	15.7644
Ttcor				8.0714	6.1891	15.7644

where x = clay content in weight percent measured with air-dry samples,
y = 15 bar percent measured with moist (field #20) samples, and
z = 15 bar percent measured with air-dry samples.

[a]Clay determined by standard method of dispersion with hexametaphosphate preceding overnight shaking.

Statistical analyses done by B. R. Brasher, Soil Research Scientist, Riverside Soil Survey Laboratory, Riverside, California.

Table A-3. Mineral Distribution in the Very Fine Sand Fraction (0.10-0.05 mm) of Selected Horizons of a Cohoe Soil

Soil	Horizon	Glass	Aggregate	Pyroxene	Quartz	Feldspar	Accessory
Cohoe	A2	FA	VC	VC	VC	VC	S
	B22	VC	VC	VC	VC	FA	S
	C1	C	VC	VC	VC	FA	S
	IIC2	R	C	C	VC	A	S

Source: Rieger and Dement, 1965.

Symbols used to indicate relative amounts of the various minerals are as follows: VA = very abundant (>75%); A = abundant (50-75%); FA = fairly abundant (25-50%); VC = very common (10-25%); C = common (5-10%); FC = fairly common (2-5%); S = scarce (1-2%); and R = rare (<1%).

Table A-4. Percent Loss at Increasing Temperatures Relative to 110°C Weight

Horizon	Depth (inches)	175°C	200°C	240°C	500°C
	Cohoe soil				
01	3-0	6.3	15.7	21.6	25.9
A2	0-2	1.9	4.1	5.7	6.8
B2	2-6	3.4	6.9	9.0	10.7
B3	6-7.5	2.6	5.0	6.3	8.3
A'1	7.5-13	2.8	5.0	6.4	8.5
C1	13-15	2.4	4.4	5.8	8.1
Alb	15-16	3.0	5.3	7.8	9.5
Clb	16-26	1.7	2.8	3.8	5.7
C2	26-34	0.3	0.5	0.7	2.1
IIC2	34-40	0.1	0.3	0.4	1.4
	Transitional soil				
01	3-0	7.0	16.4	24.0	47.2
Ash	0-1	3.1	5.9	7.2	---
Ash	1-1.5	1.5	2.6	3.8	4.7
A2	1.5-3	2.6	5.1	6.6	8.6
B2	3-8.5	5.6	9.3	12.1	15.0
B3	8.5-11	4.4	8.4	10.0	12.7
A'1	11-18	3.1	5.2	7.0	8.7
C1	18-20.5	2.3	4.2	5.8	8.2
Alb	20.5-24.5	2.3	3.9	5.3	7.6
Clb	24.5-32	1.3	2.2	2.9	4.7
C2	32-42	0.5	0.8	1.1	2.7
IIC3	42-53	0.6	0.9	1.2	2.3
	Island soil				
01	3-0	6.3	12.9	17.3	24.0
Ash	0-1.5	2.2	7.4	10.0	11.7
A11	1.5-6	5.1	9.3	12.4	16.4
A12	6-19.5	3.2	6.0	8.0	10.8
B	19.5-17	2.4	4.1	5.2	7.5
Alb	27-30	3.1	5.2	6.9	9.9
Cb	30-37	2.3	3.8	5.2	7.8
C2	37-42	0.3	0.5	0.8	0.9
IIC3	42-48	0.1	0.1	0.4	1.6

Table A-5. Particle Size Distribution Following Successive Treatments of (1) Pyrophosphate-Dithionite Extraction; (2) Sodium Carbonate Extraction; and (3) Ultrasonics for 30 Minutes Preceding Overnight Shaking

Horizon	Depth (inches)	>2 mm	2.0-0.25 mm	0.25-0.10 mm	0.10-0.05 mm	0.05-0.02 mm	0.02-0.002 mm	<0.002 mm
	Cohoe soil							
A2	0-2	tr	26.7	22.2	9.2	8.3	27.9	5.7
B2	2-6	--	16.2	9.7	15.9	14.2	37.1	6.9
B3	6-7.5	--	10.4	10.6	16.1	17.6	36.9	8.4
	Transitional soil							
A2	1.5-3	tr	17.0	14.5	12.3	8.7	38.2	8.3
B2	3-8.5	--	16.5	15.8	15.2	9.8	34.9	7.8
B3	8.5-11	--	4.5	9.1	25.1	6.4	46.7	8.2
	Island soil							
A11	1.5-6	--	18.9	12.7	17.5	8.1	35.9	6.9
A12	6-19.5	--	3.1	9.3	20.2	20.6	40.0	6.8

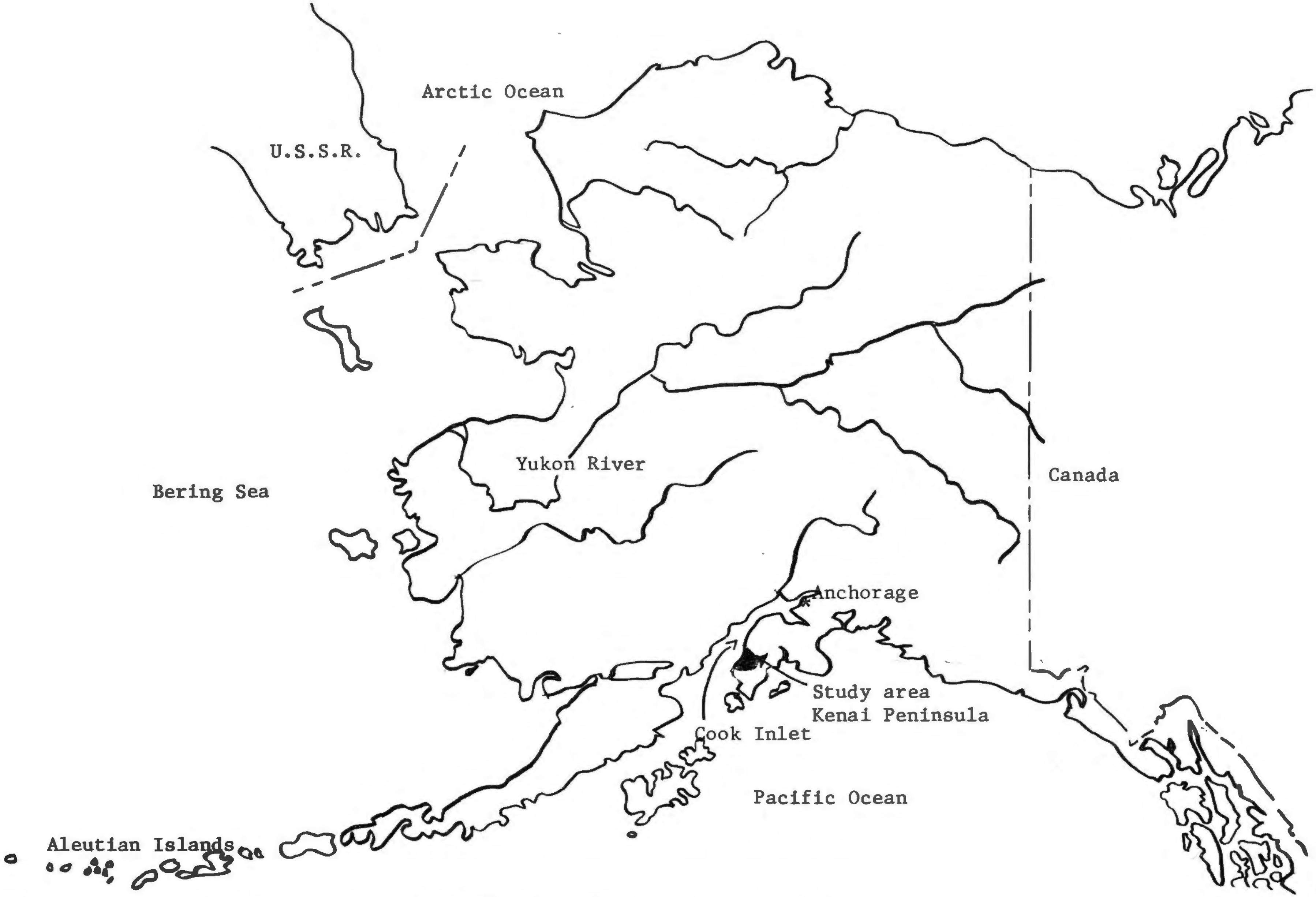


Figure A-1. Location of Cohoe and Island soils used in study.

Figure A-2. Relationship between the forest and natural grasslands at the Caribou Hills.

Note: The continuous spruce forest is confined to the lower elevations in the stream valleys. Only clumps of small-size spruce occur at higher elevations beyond the forest border. (Photograph taken looking west from 1,800 feet elevation on Bald Mountain, July 1964).

VITA

Robert B. Hinton was born October 25, 1935, in Cottontown, Sumner County, Tennessee; he attended public schools there. Following graduation from Gallatin High School, he attended East Tennessee State University for two years and then transferred to Tennessee Technological University where he received his Bachelor of Science degree in Agronomy. He has been employed by the U.S. Soil Conservation Service continuously since 1959 except for leaves generously granted to work towards his Master of Science degree at the University of Tennessee.