

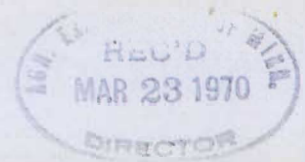
Technical Bulletin 272  
1970

# Characteristics of Selected Horizons from 16 Soil Series in Minnesota

D. J. Pluth, R. S. Adams, Jr.,  
R. H. Rust, and J. R. Peterson



Agricultural Experiment Station  
University of Minnesota



#### FOREWORD

The 16 soil series sampled in this study were chosen specifically for laboratory experiments concerned with the activity and persistence of pesticides in soils. Rather good information indicated that no persistent pesticides had been used in the fields where samples were taken. Further, these soils were selected because they are of considerable agricultural importance and have a broad range of properties. We believe these soil data will be valuable to professional soil scientists in the state, that permanent records should be kept on the sites for future use, and that the information published here will be valuable to those interpreting published reports of laboratory experiments using these soils.

Collection and analyses of these soil samples were supported in part by SWCRD, ARS, USDA Contract No. 12-14-100-8177 (41).

The able assistance of several soil scientists from the Soil Conservation Service in the location of suitable sites for sampling is gratefully acknowledged.

---

D. J. Pluth formerly was a research associate, Department of Soil Science, University of Minnesota, and presently is an assistant professor, Department of Soil Science, University of Alberta, Edmonton. R. S. Adams, Jr. is an associate professor and R. H. Rust is a professor, Department of Soil Science, University of Minnesota. J. R. Peterson formerly was a graduate assistant, Department of Soil Science, University of Minnesota, and presently is a soil scientist, Metropolitan Sanitary District of Greater Chicago.

# Characteristics of Selected Horizons from 16 Soil Series in Minnesota

D. J. Pluth, R. S. Adams, Jr., R. H. Rust, and J. R. Peterson

This report compiles and summarizes some chemical, physical, and mineralogical properties of samples collected in 1965 for studies on pesticide adsorption and desorption by soils. The 16 soil series sampled generally represent soils of agricultural importance and occur extensively in Minnesota. They include a wide range of soil properties found in agricultural soils in the state. The actual sampling site for each soil series met two criteria: it was close to a modal or typical profile\* and it had a known 5-year history of pesticide use. Supplementary profile descriptions and laboratory data were available prior to sampling from the Soil Conservation Service or the Bureau of Public Roads for a few of the soil series at their sampling sites.

## Materials and Methods

Two bulk soil samples, one of the A<sub>p</sub> horizon or its equivalent to a plow layer in depth (hereafter referred to as the A horizon) and the other representative of the B or C<sub>ca</sub> horizon with most intensive development (hereafter referred to as the B horizon), were collected for each soil series. In some cases, the bulk sample was a composite of more than one horizon, as may be noted in table 1. The bulk samples were air-dried, crushed with a hand roller, and sieved before the analyses. All analytical results are reported on an oven-dry weight basis.

### Physical and Mineralogical Analyses

Particle size analysis for the 2-0.05 millimeter (mm) (total sand), 0.05-0.02 mm (coarse silt), 0.02-0.002 mm (medium and fine silt), and < 0.002 mm (total clay) fractions was made using a modification of the pipette procedure according to Kilmer and Alexander (1949). Particle size distribution for the 5-2 micron ( $\mu$ ) (fine silt), 2-0.2  $\mu$  (coarse clay), and < 0.2  $\mu$  (fine clay) fractions was determined gravimetrically on aliquots from the soluble salt-, carbonate-, iron oxide-, and organic-free suspensions prepared for clay mineral analysis. The particle separation at 0.2  $\mu$  was attained by centrifugation with an International Model HR-1 with a Model 856 anglehead and other separations by sedimentation. Cleanup, fractionation, and solvation treatments for clay mineral analysis by x-ray diffraction of these three particle size fractions were accomplished by procedures modified from Jackson (1956). The cleanup procedures in-

involved dissolution of soluble salts and carbonates with normal sodium acetate buffered at pH 5, followed by oxidation with 30 percent hydrogen peroxide and removal of free iron oxides with sodium dithionite-citrate treatment.

The five treatments employed for x-ray diffraction analysis on specimens of preferred orientation in order to distinguish individual mineral species or species groups were: (1) magnesium (Mg)-saturated, air-dried, (2) Mg-saturated, glycerol-solvated, (3) potassium (K)-saturated, air-dried, (4) K-saturated, 300° C. heated, and (5) K-saturated, 550° C. heated. X-ray diffraction was accomplished with a General Electric XRD-5 unit operated under these conditions: 50 kilovolt potential, 15 milliamp, 3° take-off angle, nickel-filtered copper-K alpha radiation, 1.0° beam slit, medium resolution soller slit, 0.1° detector slit, scintillation counter, pulse height discrimination, 2° per minute scan rate, 2 second time constant, variable recorder scale, and a 1 inch/minute chart rate with mostly linear recording.

The species or species groups were identified according to d-spacings specific for each treatment as follows:

**Mica** (including illite) — 10 angstrom (A) (001) and 5A (002) spacings when Mg-saturated and air-dried.

**Montmorillonite** — 18A (001) spacing when Mg-saturated and glycerol-solvated, and collapse to 10A when 300° C. heated.

**Vermiculite** — 14A (001) spacing when Mg-saturated and air-dried, 14A persistent on glycerol solvation, and collapse to 10A when K-saturated and 300° C. heated.

**Chlorite** — 14A (001) spacing when Mg- and K-saturated and air-dried, 14A persistent on glycerol solvation, enhancement of 7A (002) peak when 300° C. heated, and persistent 14A when 550° C. heated.

**Kaolinite** — 7A (001) spacing when Mg- and K-saturated and air-dried, and 7A persistent when 300° C. heated but lost when 550° C. heated.

**Interstratified clay minerals** — variable spacing dependent upon nature and composition of intratification.

**Quartz** — 3.34A (011) spacing and 4.26A (100) spacing when Mg-saturated and air-dried.

**Feldspars** — 3.18-3.24A spacings when Mg-saturated and air-dried.

\* The Lester samples were the only exception. At this site the B<sub>2</sub> was atypical. Typical Lester B horizons contain 20 to 35 percent clay.

**Pyrophyllite** — 9A spacing when Mg-saturated and air-dried.

**Amphiboles** — 8.40-8.48A spacing when Mg-saturated and air-dried.

The estimation of the amounts of primary and clay minerals present was at best semiquantitative, since the factors affecting x-ray intensities were unknown or uncontrollable. Peak height was the semiquantitative measure for all diffraction intensities except those at d-spacings greater than 12A, where peak area was utilized. The diffraction intensities at low angles (large d-spacings) were corrected for an assumed Lorentz-polarization factor.

Vermiculite and chlorite were identified and estimated with some difficulty. The 14A peak of the Mg-saturated and glycerol-solvated treatment was not always accounted for by an increased intensity at 10A upon K-saturation and/or 300° C. heating (indicating vermiculite) or in a 14A peak upon 550° C. heating (indicating chlorite). The presence of vermiculite in small quantities was difficult to confirm. Chlorite was estimated from the (004) peak intensity of the air-dried, Mg-saturated clay,

where resolution of the (002) peak of kaolinite usually occurred. Jackson (1964) considered vermiculites not to exhibit higher order diffractions as chlorites do, an assumption made in this analysis.

The specific surface areas of the mineral fraction of the soil were determined by the 2-ethoxyethanol method (Heilman et al., 1965). Moisture retention was measured at 15 bar (pressure membrane) and 1/3 bar (pressure plate) according to procedures of the U.S. Salinity Laboratory (1954).

#### Chemical Analyses

The pH was determined potentiometrically on a 1:1 soil:water slurry. Organic-carbon and carbonate-carbon were determined in duplicate and by two methods: dry combustion with a Leco induction furnace (Young and Lindbeck, 1964) and wet combustion (Allison, 1960), in which the CO<sub>2</sub> evolved was absorbed by Ascarite and weighed. Where free carbonates were present, organic-carbon was calculated as the difference between total carbon and carbonate-carbon from the wet combustion method. Free iron oxides were extracted in duplicate with sodium dithionite and the ferrous iron (Fe<sup>2+</sup>) measured

**Table 1. Identification of the 32 soil samples according to soil series: Seventh Approximation classification, horizon, depth sampled, and location**

Soil series	Subgroup classification*	Horizon	Depth sampled, inches	Location by county†	
Svea‡	A	Pachic Udic Haploborolls	A <sub>p</sub>	0-6	Swift
	B		B <sub>21</sub> , B <sub>22</sub>	14-21	
Bearden	A	Aeric Calciaquolls	A <sub>p</sub>	0-6	Norman
	B		C <sub>1ca</sub> , C <sub>2ca</sub>	18-24	
Blue Earth	A	Cumulic Haplaquolls	A <sub>p</sub>	0-6	Watsonwan
	B		B <sub>g</sub>	18-24	
Brainerd	A	Aquic Fragiochrepts	A <sub>1</sub> , A <sub>2</sub>	0-6	Crow Wing
	B		A & B <sub>1</sub> , B & A	21-27	
Canisteo	A	Typic Haplaquolls	A <sub>t</sub>	0-5	Steele
	B		B <sub>g</sub>	17-23	
Fargo	A	Vertic Haplaquolls	A <sub>p</sub>	0-6	Norman
	B		B <sub>1g</sub>	14-18	
Fayette	A	Typic Hapludalfs	A <sub>1</sub> , A <sub>2</sub>	0-6	Olmsted
	B		B <sub>2t</sub>	16-22	
Hegne	A	Typic Calciaquolls	A <sub>p</sub>	0-6	Norman
	B		C <sub>2ca</sub>	14-18	
Hubbard	A	Udic Haploborolls	A <sub>p</sub>	0-6	Sherburne
	B		B <sub>2</sub>	16-20	
Kranzburg	A	Udic Haploborolls	A <sub>p</sub>	0-6	Pipestone
	B		B <sub>2t</sub>	15-21	
Lester	A	Mollic Hapludalfs	A <sub>1</sub> , A <sub>2</sub>	0-6	Steele
	B		B <sub>2t</sub>	16-22	
Mitaca	A	Typic Fragiochrepts	A <sub>1</sub> , A <sub>2</sub>	0-6	Benton
	B		B <sub>2xt</sub>	20-26	
Nicollet	A	Aquic Hapludolls	A <sub>p</sub>	0-5	Steele
	B		B <sub>2</sub>	15-21	
Ontonagon	A	Typic Eutroboralfs	A <sub>w</sub>	1-6	Carlton
	B		B <sub>2t</sub>	10-16	
Ulen	A	Aquic Haploborolls	A <sub>p</sub>	0-6	Norman
	B		(Aeric Calciaquolls)	C <sub>1ca</sub>	
Zimmerman	A	Alfic Udipsamment	A <sub>1</sub> , A <sub>2</sub>	0-6	Sherburne
	B		B or C <sub>1</sub>	15-21	

\* Reference: Soil Survey Staff. 1969. Tentative Classification of Soil Series of Minnesota in the Comprehensive System, Part I. USDA Soil Conservation Service and Univ. of Minn. Dept. of Soil Science, St. Paul, Minn. Mimeo. 21 p.

† Exact location and a summarized description of the sites are given in the appendix.

‡ Formerly included in the Aastad series.

by titration with potassium dichromate (Kilmer, 1960). Acid extractable iron and aluminum were determined in duplicate. To 50 milliliters of 0.1 normal hydrochloric acid (0.1N HCl), 12.5 grams of soils were added and shaken for 30 minutes on a reciprocal shaker. The extracts were recovered by filtration on a Büchner funnel and the iron content determined on a Perkin-Elmer 303 atomic adsorption spectrophotometer. Both iron and aluminum were determined on a Jarrell-Ash 1.5 Meter Atom Counter emission spectrograph. Cation exchange capacities were determined using the ammonium saturation method described by Chapman (1965). Exchangeable sodium, potassium, and calcium were extracted by shaking 10 grams of soil with 250 milliliters of 0.1N ammonium acetate (NH<sub>4</sub>OAC) for 30 minutes on a reciprocal shaker. The extracts were recovered by filtration on a Büchner funnel and analyzed by atomic adsorption spectroscopy. Phosphorus soluble in dilute HCl-NH<sub>4</sub>F (ammonium fluoride) was determined according to Bray number 1 extraction.

## Results and Discussion

An evaluation of the general relationships among the soil series sampled follows. Emphasis is placed upon interpretation of the clay mineralogy of the three particle size fractions: 5-2  $\mu$  (fine silt), 2.0-0.2  $\mu$  (coarse clay), and <0.2  $\mu$  (fine clay). The soil series, their classification to subgroup in the Seventh Approximation, the horizon and depths sampled, and the locations sampled are listed in table 1. Exact locations of the sample sites and some additional information are given in the appendix.

### Physical Characteristics

Table 2 presents the particle size distribution as determined by the pipette method. The particle size distribution of the <5  $\mu$  soil is presented in table 3. The percentages of the 2.0-0.2  $\mu$  and <0.2  $\mu$  fractions were adjusted proportionately so that their sum equaled that for the 2.0  $\mu$  fraction given in table 2.

The soil series had a wide range of textures, with ranges in clay contents of 3.1 to 59.4 percent and 2.3 to 91.0 percent for the A and B horizons, respectively. The textural B or argillic horizons of Fayette, Lester, and Ontonagon may be recognized by their greater total clay (<2.0  $\mu$ ) and fine clay (<0.2  $\mu$ ) contents compared to their A horizons, with most of the increase occurring in the fine clay fraction rather than in the coarse clay fraction. The Milaca B horizon fails to qualify as an argillic horizon on the basis of the total clay or fine clay distributions. The total clay and fine clay contents of the B horizons of Fargo, Hegne, and Nicollet suggest that some illuviation has occurred. A comparison of the fine clay/total clay, fine clay/fine silt, and total clay/medium silt ratios between the A and B horizons also identifies those horizons with illuvial clay. The absolute value of the ratios is dependent upon the particle size distribution in the parent material as well as on pedogenic changes.

The wide range in texture also is reflected in the total surface areas and moisture retentions given in table 4. Surface areas in the 16 soil series examined ranged from 19 to 382 m<sup>2</sup>/g. Table 5 gives the correlation matrix for the soil variables measured in this study.

Surface area was correlated very significantly (0.01 percent) with both the fine and coarse clay fractions for all samples. However, some soil samples had surface areas and clay contents that were not proportional. The B<sub>21x</sub> horizon of Milaca is an example where the surface area of 73 square meters per gram (m<sup>2</sup>g<sup>-1</sup>) of <2 mm soil is much higher than expected from the horizon's clay content of 6.2 percent. The calculated surface area for this horizon's clay is 1,180 m<sup>2</sup>g<sup>-1</sup>. This is an excessive surface area, since 2.0-0.2  $\mu$  montmorillonite, the mineral component of highest surface area, has approximately 810 m<sup>2</sup>g<sup>-1</sup> of total surface area (Jackson, 1964). This kind of discrepancy will be discussed further in the mineralogy section.

Moisture contents at 1/3 and 15 bar tensions were related about equally to medium and fine silt, coarse clay, fine clay, organic carbon, and surface area.

### Mineralogical Characteristics

Generally the relative amounts of minerals among the soil series and within identical particle size fractions were similar. Smoothed x-ray diffractograms of selected horizons and soil series illustrate this similarity in mineralogy and also indicate the basis for the semiquantitative estimates provided in table 6.

The kinds and relative amounts of clay minerals among the soil series and within their respective particle size fractions were similar, with a few exceptions (table 6). The fine silt (5-2  $\mu$ ) fractions were the most heterogeneous in composition, with no one mineral species or species group predominating. Mica, kaolinite, chlorite, quartz, and feldspars were identified in most fine silt fractions with vermiculite, montmorillonite, amphiboles, and pyrophyllite being found occasionally (figures 3, 6, 9, 12, 15, 18, 23, 26, 29). The coarse clay (2.0-0.2  $\mu$ ) fractions of most soil series contained an estimated 30 to 60 percent montmorillonite and smaller amounts of mica, kaolinite, quartz, and feldspars (figures 2, 5, 8, 11, 14, 17, 20, 22, 25, 28). Chlorite, vermiculite, and interstratified clay minerals were occasional components of the coarse clays in small amounts. The fine clay (<0.2  $\mu$ ) fractions were the least heterogeneous in composition and were dominated by montmorillonite with mica and kaolinite present in minor amounts (figures 1, 4, 7, 10, 13, 16, 19, 21, 24, 27).

Notable exceptions to the above generalizations on mineralogical composition occurred in horizons and fractions of the Brainerd, Hubbard (figures 10-15), Milaca (figures 16-18), and Zimmerman series (figures 27-29). Both horizons from these series contained lesser proportions of montmorillonite in the coarse and fine clay fractions. The coarse and fine clay fractions had some interstratified materials, along with increased amounts of primary minerals. The fine clay fractions failed upon

Table 2. Particle size distribution determined by the pipette method

Sample		Silt				Sand separates*					Texture
		Sand 2-0.05	Coarse 0.05-0.02	Medium and fine 0.02-0.002	Clay <0.002	Very coarse 2-1	Coarse 1-0.5	Medium 0.5-0.25	Fine 0.25-0.1	Very fine 0.1-0.05	
		percent of < 2 mm soil									
Svea	A	23.3	24.5	25.5	26.6						Silt loam
	B	22.5	28.2	23.9	25.4						Silt loam
Bearden	A	7.3	37.8	24.2	30.7						Silty clay loam
	B	12.6	33.5	30.3	23.6						Silt loam
Blue Earth	A	9.3	20.3	35.9	34.5						Silt loam
	B	15.7	22.5	30.2	31.6						Silt loam
Brainerd	A	52.9	10.3	24.4	12.4	2.3	8.3	16.8	14.1	11.4	Fine sandy loam
	B	74.1	8.1	11.5	6.3	9.8	16.8	19.1	19.5	8.7	Sandy loam
Canisteo	A	37.3	13.3	19.0	30.4						Loam
	B	46.4	11.1	17.6	24.9						Clay loam
Fargo	A	1.2	9.9	39.0	49.9						Silty clay
	B	1.0	8.6	36.1	54.3						Silty clay
Fayette	A	6.8	46.3	29.9	17.0						Silt loam
	B	6.6	40.2	26.3	26.9						Silt loam
Hegne	A	4.4	21.4	27.9	46.3						Silty clay
	B	1.5	11.3	37.8	49.4						Silty clay
Hubbard	A	83.1	4.3	5.8	6.8	3.5	19.9	29.5	22.7	7.4	Loamy sand
	B	83.9	4.7	5.7	5.7	3.3	15.5	25.0	30.1	9.1	Loamy sand
Kranzburg	A	7.5	30.8	29.6	32.1						Silty clay loam
	B	5.4	31.5	31.1	32.0						Silty clay loam
Lester	A	61.2	12.9	12.2	13.7	4.0	10.3	15.6	22.2	8.9	Fine sandy loam
	B	58.5	10.4	11.2	19.9	5.4	9.7	13.9	19.8	9.6	Fine sandy loam
Milaca	A	62.0	14.4	16.8	6.8	4.1	8.9	15.3	23.0	10.7	Fine sandy loam
	B	68.1	12.3	13.4	6.2	6.5	11.6	15.7	22.7	11.6	Sandy loam
Nicollet	A	40.1	15.1	22.9	21.9						Loam
	B	45.9	12.1	18.0	24.0						Loam
Ontonagon	A	8.8	7.4	24.4	59.4						Clay
	B	1.7	1.7	5.6	91.0						Clay
Ulen	A	77.3	8.2	2.1	12.4	0.7	5.9	10.2	23.8	36.5	Very fine sandy loam
	B	85.7	5.4	2.4	6.5	0.5	2.4	4.6	21.1	57.1	Loamy very fine sand
Zimmerman	A	93.7	2.0	1.0	3.1	0.0	3.0	20.8	57.1	12.3	Fine sand
	B	95.1	0.9	1.7	2.3	0.1	3.3	24.1	55.1	12.3	Fine sand

\* Determined only where sand content was &gt; 50 percent.

Table 3. Particle size distribution determined by gravity and centrifugal sedimentation on the  $< 5 \mu$  soil, and ratios of particle size fractions

Sample		Particle size fraction			$< 0.2 \mu$ $< 2 \mu$	$< 0.2 \mu$ $< 5 \mu$	$< 2 \mu$ $20-2 \mu$
		Fine silt 5-2 $\mu$	Coarse clay 2-0.2 $\mu$	Fine clay $< 0.2 \mu$			
		..... percent of $< 2$ mm soil .....					
Svea	A	5.6	7.7	18.9	0.71	0.59	1.05
	B	5.5	8.8	16.6	0.65	0.54	1.06
Bearden	A	5.7	13.5	17.2	0.56	0.47	1.27
	B	6.6	10.4	13.2	0.56	0.44	0.78
Blue Earth	A	8.6	15.6	18.9	0.55	0.44	0.96
	B	13.3	24.1	7.5	0.23	0.17	1.05
Brainerd	A	6.3	6.7	5.7	0.46	0.30	0.51
	B	4.2	4.5	1.8	0.29	0.17	0.55
Canisteo	A	0.2	11.6	18.8	0.62	0.62	1.60
	B	3.2	6.8	18.1	0.73	0.64	1.41
Fargo	A	10.0	21.3	28.6	0.57	0.48	1.28
	B	11.2	18.1	36.2	0.67	0.55	1.50
Fayette	A	8.0	9.4	7.6	0.45	0.30	0.57
	B	5.1	11.1	15.8	0.59	0.49	1.02
Hegne	A	7.3	22.1	24.2	0.52	0.45	1.66
	B	12.4	17.3	32.1	0.65	0.52	1.31
Hubbard	A	2.7	3.5	3.3	0.49	0.35	1.17
	B	1.4	3.1	2.6	0.46	0.37	1.00
Kranzburg	A	5.6	12.7	19.4	0.60	0.52	1.08
	B	7.7	8.0	24.0	0.75	0.61	1.03
Lester	A	2.9	6.0	7.7	0.56	0.46	1.12
	B	6.7	6.2	13.7	0.69	0.52	1.95
Milaca	A	5.5	5.3	1.5	0.22	0.12	0.41
	B	3.5	5.0	1.2	0.19	0.12	0.46
Nicollet	A	6.6	8.6	13.3	0.61	0.47	0.96
	B	6.1	8.8	15.2	0.63	0.51	1.33
Ontonagon	A	12.4	41.6	17.8	0.30	0.25	2.43
	B	4.7	42.5	48.5	0.53	0.51	1.62
Ulen	A	3.6	11.1	1.3	0.10	0.08	5.91
	B	0.5	4.5	2.0	0.31	0.29	2.70
Zimmerman	A	0.5	1.8	1.3	0.42	0.36	3.10
	B	0.2	1.2	1.1	0.48	0.42	1.35

550° C. heating to collapse completely to 10A, as indicated by a broad peak (001) asymmetrical towards the low angle side.

Interstratified clay minerals were identified in small quantities in several of the soil series. For example, the fine silt, coarse clay, and fine clay fractions of both horizons from Hubbard (figures 10-15) contained either randomly interstratified clay minerals or hydroxy aluminum interlayering. Primary evidence for interstratified materials was (001) peaks between 14 and 10A upon K-saturation and incomplete collapse to 10A upon 550° C. heating. The d-spacings after 550° C. heating and lack of integral higher order diffractions suggest chlorite to be one component of a random interstratification. The evidence for interstratified clay minerals in the A horizon of Hubbard (figure 10) was formation of a 13.5A peak with air drying, a doublet at 12.6 to 11.6A after 300° C. heating, and a broad peak between 11.3 and 10.8A after 500° C. heating of the K-saturated clay. The Mg-saturated, 25° C.-dried treatment only showed asymmetry on the low angle side of the 14A peak. Jackson (1963) attributed the presence of 12, 14, 18, and 24-28A peaks after 550° C. heating to hydroxy aluminum interlayering with formation of montmorillonite-chlorite. The multiple peaks were not discernible in the soil fractions investigated.

The particle size fractions for Zimmerman contained questionably moderate quantities of interstratified materials. The uncertainty of the identification of interstratified materials arose from the lack of definite peaks, resulting in a broad plateau of diffraction in the 14 to 10A region, as illustrated in figure 27. Hydroxy aluminum interlayers or possibly amorphous materials may explain this type of pattern.

The coarse and fine clay fractions of Milaca (figures 16-17) and Nicollet (figures 19-20) also exhibited interstratified materials in small amounts. In the coarse clay, a peak persisted near 12A on K-saturation and 550° C. heating (figure 17). In the fine clays, incomplete collapse to 10A upon 550° C. heating indicated interstratification. Hirekerur (1964) reported interstratified clay minerals along with illite to be predominant in the fine clay of Milaca.

A comparison of x-ray diffractograms for identical fractions from surface horizons of Fargo (figures 1-3) and Ontonagon (figures 21-23) indicates that Fargo has a higher proportion of montmorillonite and a lower proportion of chlorite. The parent material for both soil series was glacio-lacustrine, but of different lithology. The surface area for the Fargo A horizon was 649 m<sup>2</sup>g<sup>-1</sup> of total clay, whereas that for the Ontonagon A horizon

Table 4. Total surface area for mineral soil and moisture content at 1/3 and 15 bar tensions

Sample	Surface area	Moisture content	
		1/3 bar	15 bar
	$m^2 g^{-1}$	percent	
Svea	A 175	33.1	19.4
	B 162	31.9	21.3
Bearden	A 187	37.0	23.6
	B 96	27.3	13.6
Blue Earth	A 186	62.5	40.2
	B 178	59.2	37.8
Brainerd	A 87	23.7	14.8
	B 94	9.4	5.4
Canisteo	A 160	37.3	28.6
	B 270	24.9	14.6
Fargo	A 324	43.2	31.8
	B 382	39.3	28.4
Fayette	A 85	28.7	12.8
	B 155	27.5	13.8
Hegne	A 343	42.9	30.9
	B 269	30.5	21.8
Hubbard	A 60	8.9	4.3
	B 52	8.2	3.6
Kranzburg	A 224	17.9	16.1
	B 227	18.2	15.7
Lester	A 100	17.7	8.9
	B 172	18.8	8.4
Milaca	A 24	16.8	6.2
	B 73	10.7	4.1
Nicollet	A 150	24.1	12.4
	B 166	22.6	11.1
Ontonagon	A 209	36.3	21.6
	B 341	47.4	27.3
Ulen	A 101	15.1	8.0
	B 48	7.4	3.2
Zimmerman	A 19	5.5	3.3
	B 52	3.2	2.0

was  $352 m^2 g^{-1}$ , another indication of the higher proportion of montmorillonite in Fargo. The Hegne B horizon (figures 7-9) was mineralogically similar to the Fargo A horizon, except for a higher proportion of chlorite in the Hegne B horizon and for alkaline-earth minerals.

As previously indicated, montmorillonite predominated in most of the fine clay fractions, occurred in moderate amounts in the coarse clays, and occurred in minor amounts in some fine silt fractions. Both A and B horizons had montmorillonite in their fine silt fractions. This occurrence of montmorillonite may be related to an actual particle size separation at a mean diameter somewhat greater than  $2 \mu$ . Since the particle density of fully hydrated montmorillonite is about 2.2 grams per cubic centimeter ( $g cm^{-3}$ ) (Jackson, 1956) and  $2.65 g cm^{-3}$  was assumed in the calculation of sedimentation times, a separation was effected at a diameter greater than the nominal  $2 \mu$ . Therefore, the presence of montmorillonite in the fine silt fraction may be an artifact of the separation technique.

The x-ray technique used did not differentiate between primary and secondary or pedogenic chlorite. Thus the estimation of chlorite was confounded by the differences in diffraction intensities related to differences in amounts of primary and secondary chlorites. Also, the

secondary mica (illite) was not distinguished from primary mica (biotite, muscovite).

Quartz and the feldspar were ubiquitous in the fine silt and coarse clay fractions, with a trace of amphiboles and quartz in a few fine clay fractions. Pyrophyllite occurred infrequently and mostly in the fine silt fraction. The (001) peak height (4.26A) was used to estimate quartz content. Since diffraction intensity for quartz varied with particle size and composition of the particle surface (Gordon and Harris, 1955), only relative peak heights within a size fraction were compared.

Thus, among the soil series sampled, wide ranges occurred in some of their physical and chemical characteristics, but they had similar mineralogy in their  $<5 \mu$  fractions, with a few exceptions. Interstratification in the clay minerals was found in several of the soil series.

#### Chemical Characteristics

Tables 7, 8, and 9 present some chemical characteristics for the soil series. The A and B horizons ranged in organic-carbon contents from 0.7 to 11.0 percent and from 0.1 to 8.3 percent, respectively. The maximum organic-carbon content in each horizon was represented by the Blue Earth series. The carbonate-carbon contents are a measure of the total calcium and magnesium carbonates. These soils were preselected so that organic matter content and clay content would not be correlated.

The iron extracted by sodium dithionite-citrate and expressed as percent of iron oxides ( $Fe_2O_3$ ) ranged from 0.2 to 3.0 (table 8). The iron thus extracted is commonly referred to as free iron oxide (Kilmer, 1960). McKeague and Day (1966) indicated that a sodium dithionite-citrate solution extracts iron of both amorphous forms and crystalline oxides, which are recent weathering products, and, therefore, secondary in origin. In the soils examined, only slight increases in free iron oxides occurred from the A horizon to the B horizon. The two horizons from Ontonagon contained the highest free iron oxides as well as the most total clay. The free iron oxide/total clay ratios for the horizons of Ontonagon were reversed to the expected relative ratios; i.e., the ratio for the  $A_2$  horizon was about twice that of the  $B_{2t}$  horizon. However, statistical evaluation indicated that the free iron oxides were related to the coarse clay fraction. When calculating these ratios (free iron oxides/coarse clay), there is little difference between A and B horizons (table 8). The other Alfisols exhibited free iron oxide/total clay ratios where the B horizon ratio was nearly equal to or slightly greater than the ratio of the A horizon. Except for the Blue Earth and Ontonagon series, calculating iron oxide/coarse clay ratios produced B horizon ratios clearly greater than A horizon ratios.

A comparison of the free iron oxide/total clay ratio with the calculated surface area for total clay shows an interesting relationship. The B horizons of the Brainerd, Hubbard, Milaca, and Zimmerman soil series, which had the highest free iron oxide/total clay ratios, also had the



Table 5. Correlation matrix for soil variables on all soil samples

	Sand	Coarse silt	Medium fine silt	Coarse clay	Fine clay	Surface area	1/3 bar water	15 bar water	Carbonate carbon	Organic carbon	Iron oxide	Acid iron	Acid aluminum	pH	Exchangeable calcium	Exchangeable potassium	Exchangeable sodium	C. E. C.	Phosphorus
Sand	1.00																		
Coarse silt	-0.60	1.00																	
Medium fine silt	-0.86	0.58	1.00																
Coarse clay	-0.66	-0.02	0.34	1.00															
Fine clay	-0.78	0.10	0.53	0.69	1.00														
Surface area	-0.76	0.08	0.58	0.67	0.92	1.00													
1/3 bar water	-0.85	0.38	0.73	0.70	0.68	0.71	1.00												
15 bar water	-0.79	0.26	0.71	0.68	0.68	0.74	0.97	1.00											
Carbonate carbon	-0.24	0.21	0.27	0.12	0.08	0.07	0.28	0.31	1.00										
Organic carbon	-0.41	0.21	0.47	0.34	0.16	0.25	0.75	0.77	0.24	1.00									
Iron oxide	-0.17	-0.07	-0.03	0.46	0.19	0.09	0.04	-0.06	-0.56	-0.22	1.00								
Acid iron	0.45	-0.29	-0.53	-0.16	-0.29	-0.31	0.51	-0.56	-0.43	-0.46	-0.33	1.00							
Acid aluminum	-0.25	-0.05	-0.07	0.51	0.40	0.22	0.14	0.02	0.46	0.22	0.79	0.43	1.00						
pH	-0.29	0.12	0.25	0.16	0.30	0.37	0.40	0.46	0.75	0.36	-0.62	-0.41	-0.39	1.00					
Exchangeable calcium	-0.52	0.36	0.44	0.33	0.37	0.36	0.63	0.63	0.82	0.54	-0.46	-0.54	-0.28	0.79	1.00				
Exchangeable potassium	-0.64	0.06	0.61	0.53	0.68	0.74	0.60	0.67	0.04	0.39	-0.00	-0.41	0.06	0.27	0.30	1.00			
Exchangeable sodium	-0.41	0.15	0.42	0.25	0.38	0.32	0.27	0.31	0.73	0.05	-0.33	-0.38	-0.25	0.49	0.52	0.25	1.00		
C. E. C.	-0.76	0.13	0.59	0.76	0.78	0.81	0.83	0.86	0.05	0.60	0.18	0.28	-0.28	0.32	0.44	0.74	0.21	1.00	
Phosphorus	0.22	0.10	-0.17	-0.21	-0.41	-0.49	-0.31	-0.37	-0.31	-0.14	0.17	0.10	0.15	-0.47	-0.43	-0.24	-0.24	-0.36	1.00

Significance at the 1 percent level = 0.45.

Table 6. Mineralogical composition of the 5-2  $\mu$  (fine silt), 2.0-0.2  $\mu$  (coarse clay), and < 0.2  $\mu$  (fine clay) fractions estimated by a semiquantitative technique

Soil series	Horizon		Fraction	Mineralogical composition*									
				Mica	Mont.	Verm.	Kaol.	Chlorite	Interstr.	Quartz	Fldsp.	Other	
Svea	A	A <sub>v</sub>	esd in $\mu$ †										
			5-2	15-30	<15	?	15-30	<15	.....	15-30	<15	<15	
			2.0-0.2	15-30	30-60	<15	15-30	?	.....	<15	<15	..	
	<0.2	<15	>60	.....	<15	.....	.....	.....	..	..			
	B	B <sub>st1</sub> , B <sub>st2</sub>	5-2	15-30	<15	?	<15	<15	.....	15-30	<15	<15	
			2.0-0.2	15-30	30-60	?	15-30	<15	.....	<15	<15	..	
<0.2			<15	>60	.....	<15	.....	.....	.....	..	..		
Bearden	A	A <sub>v</sub>	5-2	30-60	<15	?	15-30	<15	.....	<15	<15	<15	
			2.0-0.2	15-30	30-60	?	<15	<15	.....	<15	<15	..	
			<0.2	<15	>60	.....	<15	.....	.....	.....	..	..	
	B	C <sub>st1</sub> , C <sub>st2</sub>	5-2	30-60	<15	?	<15	15-30	.....	<15	<15	<15	
			2.0-0.2	15-30	30-60	?	15-30	<15	.....	<15	<15	..	
			<0.2	<15	>60	.....	<15	.....	.....	.....	..	..	
Blue Earth	A	A <sub>p</sub>	5-2	15-30	<15	?	<15	?	.....	15-30	<15	<15	
			2.0-0.2	15-30	30-60	?	<15	<15	.....	<15	<15	<15	
			<0.2	<15	>60	.....	<15	.....	.....	.....	?	..	
	B	B <sub>g</sub>	5-2	15-30	<15	?	<15	<15	.....	<15	<15	<15	
			2.0-0.2	<15	>60	.....	<15	?	.....	<15	<15	..	
			<0.2	<15	>60	.....	<15	.....	.....	.....	..	..	
Brainerd	A	A <sub>1</sub> , A <sub>2</sub>	5-2	15-30	<15	?	15-30	<15	.....	15-30	<15	<15	
			2.0-0.2	<15	15-30	15-30	15-30	?	15-30	15	15	..	
			<0.2	<15	30-60	?	<15	.....	15-30	.....	..	..	
	B	A & B, B & A	5-2	15-30	<15	?	15-30	15-30	?	15-30	<15	<15	
			2.0-0.2	<15	15-30	?	<15	15-30	<15	<15	<15	<15	
			<0.2	<15	30-60	?	<15	<15	15-30	<15	..	..	

\*? indicates uncertain identification and, if present, only in small amount.

T indicates trace amount, just above the limit of detection by x-ray diffraction.

† esd = equivalent spherical diameter.

Table 6 (continued). Mineralogical composition of the 5-2  $\mu$  (fine silt), 2.0-0.2  $\mu$  (coarse clay), and <0.2  $\mu$  (fine clay) fractions estimated by a semiquantitative technique

Soil series	Horizon		Fraction	Mineralogical composition*									
				Mica	Mont.	Verm.	Kaol.	Chlorite	Interstr.	Quartz	Fldsp.	Other	
Canisteo	A	A <sub>1</sub>	esd in $\mu$ †										
			5-2	15-30	<15	?	15-30	<15	..	15-30	<15	<15	
			2.0-0.2	15-30	30-60	?	15-30	<15	..	<15	T	<15	
		<0.2	<15	>60	....	<15	..	..	....	..	..		
	B	B <sub>g</sub>	5-2	30-60	<15	?	<15	<15	?	<15	<15	<15	
			2.0-0.2	15-30	30-60	15-30	15-30	?	..	<15	T	..	
<0.2			<15	>60	....	<15	..	..	....	..	..		
Fargo	A	A <sub>p</sub>	5-2	15-30	<15	?	<15	?	..	15-30	<15	<15	
			2.0-0.2	15-30	30-60	?	15-30	T	..	<15	T	T	
			<0.2	<15	>60	....	<15	..	..	....	..	..	
	B	B <sub>1g</sub>	5-2	15-30	<15	?	15-30	<15	..	15-30	<15	<15	
			2.0-0.2	15-30	30-60	?	15-30	T	..	<15	T	T	
			<0.2	<15	>60	....	<15	..	..	....	..	..	
Fayette	A	A <sub>1</sub> , A <sub>2</sub>	5-2	30-60	<15	?	<15	<15	..	<15	<15	<15	
			2.0-0.2	30-60	15-30	<15	15-30	?	?	<15	T	..	
			<0.2	<15	>60	....	<15	..	..	....	..	..	
	B	B <sub>2t</sub>	5-2	15-30	T	?	15-30	T	..	<15	<15	..	
			2.0-0.2	15-30	15-30	15-30	15-30	?	<15	<15	T	..	
			<0.2	<15	>60	....	<15	..	..	....	..	..	
Hegne	A	A <sub>p</sub>	5-2	15-30	<15	....	15-30	T	..	15-30	<15	<15	
			2.0-0.2	15-30	30-60	....	<15	<15	..	<15	T	T	
			<0.2	<15	>60	....	<15	..	..	....	..	..	
	B	C <sub>dec</sub>	5-2	30-60	<15	....	15-30	<15	..	<15	T	<15	
			2.0-0.2	15-30	30-60	....	15-30	<15	..	<15	T	..	
			<0.2	<15	>60	....	<15	..	..	....	..	..	

\*? indicates uncertain identification and, if present, only in small amount.  
 T indicates trace amount, just above the limit of detection by x-ray diffraction.  
 † esd = equivalent spherical diameter.

Table 6 (continued). Mineralogical composition of the 5-2  $\mu$  (fine silt), 2.0-0.2  $\mu$  (coarse clay), and  $<0.2$   $\mu$  (fine clay) fractions estimated by a semiquantitative technique

Soil series	Horizon	Fraction	Mineralogical composition*								Quartz	Fldsp.	Other
			Mica	Mont.	Verm.	Kaol.	Chlorite	Interstr.	percent				
Hubbard	A	A <sub>p</sub>	esd in $\mu$ †										
			5-2	15-30	.....	?	<15	<15	?	15-30	<15	T	
			2.0-0.2	15-30	15-30	?	<15	<15	15-30	<15	.....	.....	
	<0.2	<15	15-30	.....	<15	.....	30-60	T	.....	.....			
	B	B <sub>2</sub>	5-2	15-30	<15	?	<15	<15	.....	15-30	T	<15	
			2.0-0.2	<15	15-30	?	15-30	<15	15-30	<15	T	.....	
<0.2			.....	15-30	.....	<15	<15	30-60	.....	.....	.....		
Kranzburg	A	A <sub>p</sub>	5-2	30-60	<15	?	15-30	<15	.....	15-30	T	T	
			2.0-0.2	15-30	30-60	<15	15-30	?	T	T	.....		
			<0.2	<15	>60	.....	<15	.....	.....	.....	.....	.....	
	B	B <sub>21</sub>	5-2	30-60	<15	?	15-30	15-30	.....	<15	<15	T	
			2.0-0.2	15-30	30-60	?	<15	<15	?	<15	T	.....	
			<0.2	<15	>60	.....	<15	.....	.....	.....	.....	.....	
Lester	A	A <sub>1</sub> , A <sub>2</sub>	5-2	15-30	.....	?	<15	<15	.....	15-30	<15	15-30	
			2.0-0.2	30-60	15-30	?	15-30	<15	?	<15	T	.....	
			<0.2	<15	>60	.....	<15	.....	.....	.....	.....	.....	
	B	B <sub>2</sub>	5-2	15-30	T	?	<15	<15	.....	15-30	<15	<15	
			2.0-0.2	15-30	30-60	?	15-30	<15	?	<15	T	.....	
			<0.2	<15	>60	.....	<15	.....	.....	.....	.....	.....	
Milaca	A	A <sub>1</sub> , A <sub>2</sub>	5-2	15-30	.....	?	<15	15-30	.....	<15	<15	15-30	
			2.0-0.2	<15	15-30	?	<15	15-30	.....	<15	T	.....	
			<0.2	<15	>60	?	<15	.....	?	T	.....	.....	
	B	B <sub>21x</sub>	5-2	15-30	T	?	15-30	<15	.....	15-30	<15	<15	
			2.0-0.2	15-30	<15	<15	15-30	<15	<15	<15	T	.....	
			<0.2	<15	15-30	<15	<15	.....	15-30	T	.....	.....	

\*? indicates uncertain identification and, if present, only in small amount.  
 † indicates trace amount, just above the limit of detection by x-ray diffraction.  
 ‡ esd = equivalent spherical diameter.

Table 6 (continued). Mineralogical composition of the 5-2  $\mu$  (fine silt), 2.0-0.2  $\mu$  (coarse clay), and < 0.2  $\mu$  (fine clay) fractions estimated by a semiquantitative technique

Soil series	Horizon	Fraction	Mineralogical composition*									
			Mica	Mont.	Verm.	Kaol.	Chlorite	Interstr.	Quartz	Fldsp.	Other	
		esd in $\mu$ †										
Nicollet	A	A <sub>p</sub>	5-2	15-30	T	?	<15	<15		15-30	<15	15-30
			2.0-0.2	<15	30-60	?	15-30	T	<15	<15	T	T
			<0.2	<15	>60	..	<15	..	..	T	..	..
	B	B <sub>2</sub>	5-2	15-30	..	?	15-30	?	..	15-30	<15	15-30
			2.0-0.2	<15	30-60	<15	<15	..	..	<15	T	T
			<0.2	<15	>60	..	<15	..	..	..	..	..
Ontonagon	A	A <sub>2</sub>	5-2	15-30	..	?	15-30	<15	..	15-30	<15	<15
			2.0-0.2	15-30	15-30	?	15-30	15-30	?	<15	<15	T
			<0.2	<15	>60	..	<15	<15	..	..	..	..
	B	B <sub>2t</sub>	5-2	15-30	T	?	15-30	15-30	..	<15	<15	<15
			2.0-0.2	<15	15-30	<15	15-30	15-30	?	<15	<15	<15
			<0.2	<15	>60	..	<15	T	..	..	..	..
Ulen	A	A <sub>p</sub>	5-2	15-30	15-30	?	<15	<15	..	<15	<15	<15
			2.0-0.2	<15	>60	..	<15	T	..	<15	T	..
			<0.2	<15	>60	..	<15	..	..	..	..	..
	B	C <sub>1ca</sub>	5-2	15-30	T	?	15-30	<15	?	15-30	<15	<15
			2.0-0.2	15-30	30-60	?	15-30	<15	..	<15	..	..
			<0.2	<15	>60	..	<15	..	..	T	..	..
Zimmerman	A	A <sub>1</sub> , A <sub>3</sub>	5-2	15-30	..	?	<15	<15	..	15-30	<15	15-30
			2.0-0.2	15-30	<15	<15	15-30	<15	15-30	<15	T	..
			<0.2	<15	?	?	<15	..	30-60	T	..	..
	B	B or C <sub>1</sub>	5-2	15-30	T	?	<15	15-30	..	15-30	<15	<15
			2.0-0.2	<15	15-30	<15	15-30	<15	..	<15	T	T
			<0.2	..	15-30	?	<15	..	30-60	..	..	..

\*? indicates uncertain identification and, if present, only in small amount.  
 † indicates trace amount, just above the limit of detection by x-ray diffraction.  
 ‡ esd = equivalent spherical diameter.

Table 7. Carbon content determined by dry and wet combustion

Sample		Total carbon		CO <sub>2</sub> -carbon	Organic-carbon
		Dry	Wet		
		percent			
Svea	A	3.1	...	...	...
	B	0.8	...	...	...
Bearden	A	9.3	7.7	2.2	5.4
	B	5.3	4.9	4.7	0.2
Blue Earth	A	13.5	13.1	2.2	11.0
	B	10.7	10.7	2.4	8.3
Brainerd	A	2.6	3.0	...	...
	B	0.1	0.1	...	...
Canisteo	A	7.7	8.2	1.0	7.3
	B	1.5	1.8	1.1	0.6
Fargo	A	5.2	...	...	...
	B	2.1	2.0	0.2	1.7
Fayette	A	2.3	...	...	...
	B	0.5	0.5	...	...
Hegne	A	6.4	6.0	1.7	4.3
	B	3.8	4.0	3.3	0.6
Hubbard	A	1.2	1.0	...	...
	B	0.4	...	...	...
Kranzburg	A	2.9	3.0	...	...
	B	1.0	1.0	...	...
Lester	A	2.3	...	...	...
	B	0.4	0.4	...	...
Milaca	A	1.7	...	...	...
	B	0.2	...	...	...
Nicollet	A	2.8	...	...	...
	B	0.6	...	...	...
Ontonagon	A	3.5	...	...	...
	B	0.6	...	...	...
Ulen	A	2.9	3.0	1.2	1.8
	B	3.2	3.0	2.7	0.3
Zimmerman	A	0.7	...	...	...
	B	0.2	...	...	...

highest surface areas expressed as m<sup>2</sup>g<sup>-1</sup> for total clay. These surface areas are considered abnormally high, since montmorillonite in soil clays has not more than 810 m<sup>2</sup>g<sup>-1</sup> surface area. This relationship, as well as x-ray diffraction evidence, suggests an amorphous component in the mineralogy of clays of the B horizons of the Brainerd, Hubbard, Milaca, and Zimmerman series. The nonsignificant correlation between free iron oxide and surface area (table 5) was not interpreted for the above discussion, since all soil samples were submitted to the correlation analysis.

In an effort to determine easily exchangeable iron and aluminum, 1N NH<sub>4</sub>OAc extractions were performed. Only very small amounts of iron and aluminum were obtained, in some cases only traces. To recover more iron, 0.1N HCl extractions were attempted. Using these extractions, measurable quantities of iron and aluminum were obtained with nearly every soil sample. More acid soluble iron generally was recovered in the subsoil, indicating that illuvial iron was being recovered. The recovery of acid soluble iron was particularly associated with the coarse textured soils. We hoped this extraction would give some indication of aluminum and iron coating the surfaces of soil particles. However, neither acid extractable iron nor acid extractable aluminum was sig-

nificantly related to surface area. Acid extractable iron was not correlated with free iron oxides. Large amounts of acid extractable iron appeared to be associated with soils low in carbonates, organic matter, and moisture retention capacities. This iron may impart some of the hydrophobic characteristics present in some soils. The latter characteristic was particularly noticeable with the Zimmerman samples. On the other hand, acid extractable aluminum appeared to be associated with the coarse clay fractions and the free iron oxides. Like acid extractable iron, less acid extractable aluminum was found in soils containing carbonates.

Table 9 gives pH, exchangeable cations, cation exchange capacity, and acid extractable phosphorus. The pH's of the A horizons ranged from 5.2 for Ontonagon to 8.3 for Ulen. The pH's of the B horizons ranged from 5.3 for Milaca to 8.6 for Ulen.

Exchangeable calcium normally is not determined on calcareous samples. For those samples with a pH near 8.0 or greater, the extracting solution would be near or at saturation with calcium. These data were determined and included only to make statistical analyses complete. Soils below a pH of 6 (Brainerd, Hubbard, Milaca, and Zimmerman) were quite low in exchangeable calcium.

Exchangeable potassium varied from a low of 40 parts per million (ppm) in the Zimmerman A horizon to a high of 780 ppm in the Fargo A horizon. In the B horizon the range was from 20 ppm in the Hubbard series to 350 ppm in the Fargo series. Exchangeable potassium was significantly correlated with clay content and associated variables.

Exchangeable sodium was associated with the calcareous soils, showing a very high correlation to carbonate content. The Hegne B horizon contained significant amounts of sodium, suggesting that at this particular site excess sodium might give salt toxicity problems. The Bearden, Blue Earth, and Hegne soil series contained sodium at 100 ppm or more in both the A and B horizons.

Of the three cations, only calcium showed a significant correlation with organic matter. Apparently these cations are associated primarily with the clay fraction or the carbonates in the case of sodium.

Cation exchange capacities varied in the A horizon from 3.8 milliequivalents per 100 grams (meq/100 g) in the Zimmerman series to 45.2 meq/100 g in the Fargo series. The B horizon samples ranged from 2.2 meq/100 g in the Ulen series to 44.4 meq/100 g in the Ontonagon series. The latter contained 91 percent clay in the B horizon. As expected, the cation exchange capacity was a function of clay and organic matter content, with a particularly high correlation to surface area and moisture retention capacities.

Small amounts of Bray number 1 extractable phosphorus were found in most of these soils, a common feature of many virgin soils in this region. No strong correlation of extractable phosphorus with any of the soil variables was observed.

Table 8. Free iron oxide, acid extractable iron and aluminum, and free iron oxide/clay ratios

Sample	Free iron oxide	Free iron oxide clay × 100		Acid extractable	
		Total clay	Coarse clay	Iron	Aluminum
	percent			ppm	
Svea	A 0.9	3.37	11.68	8	100
	B 1.2	4.72	13.63	40	220
Bearden	A 0.2	0.65	1.48	8	<30
	B 0.2	0.84	1.92	4	<30
Blue Earth	A 0.5	1.44	3.20	4	<30
	B 0.4	1.26	1.65	4	<30
Brainerd	A 1.1	8.87	16.41	70	275
	B 1.3	20.63	28.88	104	100
Canisteo	A 0.3	0.98	2.58	8	<30
	B 0.2	0.80	2.94	68	<30
Fargo	A 0.7	1.40	3.28	28	150
	B 0.9	1.65	4.97	26	52
Fayette	A 1.0	5.88	10.63	65	280
	B 1.4	5.20	12.61	125	170
Hegne	A 0.2	0.43	0.90	8	<30
	B 0.3	0.60	1.73	6	<30
Hubbard	A 0.6	8.82	17.14	155	190
	B 0.7	12.28	22.58	194	100
Kranzburg	A 1.2	3.73	9.44	185	338
	B 1.2	3.75	15.00	185	550
Lester	A 0.8	5.83	13.33	14	170
	B 1.1	5.52	17.74	44	120
Milaca	A 1.5	22.05	28.30	32	160
	B 1.6	25.80	32.00	375	263
Nicollet	A 0.7	3.19	8.13	206	250
	B 0.8	3.33	9.09	180	250
Ontonagon	A 2.9	4.88	6.97	130	540
	B 2.3	2.52	5.41	190	950
Ulen	A 0.2	1.61	1.80	194	<30
	B 0.3	4.61	6.66	105	<30
Zimmerman	A 0.5	16.12	27.77	195	120
	B 0.6	26.08	50.00	220	93

**Summary of Research Completed Using These Soils**

Two Ph.D. theses have been completed using all or part of these soil samples:

Krentos, V. D. *Micronutrient Supply of Surface Horizons from Selected Minnesota Soils to the Soybean Plant, Glycine Max. (L.) Merrill as Related to Certain Rhizobium Japonicum Strains.* Ph.D. Thesis, Univ. of Minn. Oct. 1967.

Peterson, J. R. *Soil Properties Influencing DDT Bioactivity.* Ph.D. Thesis. Univ. of Minn., Oct. 1969.

Detailed accounts of these studies will be published elsewhere.

In 10 of the surface samples described here, Krentos determined total and extractable zinc and copper, the effectiveness of three strains of rhizobium in inoculating the Chippewa variety of soybeans, the mineral composition of soybeans grown on these soils, and their response to micronutrient treatments. The results obtained from these studies indicated the contrasting properties of the

soils with respect to their supply potential, especially of nitrogen, strontium, iron, zinc, and molybdenum. Several observations were noteworthy. Soybeans grown on the Svea\* soil responded to added molybdenum. Strontium was below detectable limits in soybean tops grown on the Hegne surface. The Kranzburg surface and Fayette surface exhibited a high supplying power to soybeans of iron and manganese, respectively. The uptake of manganese from the Fayette soil was sufficient to generate toxicity symptoms.

Peterson ran bioassays using *Drosophila melanogaster* to determine DDT bioactivity in each of these samples. Because certain samples had to be treated differently in the bioassay, the soils were divided into two groups for statistical analyses. Regression equations were developed relating soil properties to DDT bioactivity. The smaller group contained the Brainerd and Fargo B horizons and Hubbard, Milaca, Ulen, and Zimmerman samples. The fact that the Brainerd, Hubbard, Milaca, and Zimmerman samples, which fall into this group, were the only samples to contain interstratified material and the fact that

\* Referred to as Aastad in the thesis.

Table 9. pH, exchangeable cations, cation exchange capacity, and acid extractable phosphorus

Sample		pH	Ca	K	Na	C.E.C.	P
				ppm		meq/100 g	ppm
Svea	A	6.6	5,250	170	43	23.1	1.6
	B	6.4	3,400	135	43	18.7	0.4
Bearden	A	7.7	11,000	230	530	30.6	0.8
	B	8.0	14,100	80	530	9.4	0.4
Blue Earth	A	7.7	10,800	215	157	36.4	0.8
	B	7.6	9,000	125	218	27.0	0.8
Brainerd	A	5.4	1,640	100	30	15.2	8.0
	B	5.4	492	30	30	5.8	1.0
Canisteo	A	7.8	8,900	170	80	43.5	0.8
	B	7.9	7,050	135	92	18.8	0.6
Fargo	A	7.0	5,860	780	62	45.2	0.6
	B	7.2	4,100	350	205	38.4	0.0
Fayette	A	5.4	2,460	165	50	15.1	15.4
	B	5.5	2,620	120	30	37.8	3.0
Hegne	A	8.0	6,720	300	305	37.8	1.1
	B	7.8	6,440	280	1,210	35.6	1.5
Hubbard	A	5.8	1,150	65	22	6.4	4.4
	B	6.0	1,150	20	20	4.9	1.6
Kranzburg	A	6.6	4,400	135	50	26.8	1.2
	B	7.3	3,895	130	65	23.8	0.8
Lester	A	6.3	3,525	100	30	16.4	3.0
	B	5.5	2,830	85	30	9.0	1.2
Milaca	A	5.7	2,130	60	25	6.2	11.0
	B	5.6	1,480	45	25	22.0	1.6
Nicollet	A	6.0	4,180	95	35	20.4	5.2
	B	5.3	3,200	95	40	15.4	1.0
Ontonagon	A	5.2	3,030	200	85	40.2	3.2
	B	6.5	5,860	265	135	44.4	2.4
Ulen	A	8.3	5,150	60	85	11.7	4.0
	B	8.6	6,230	25	100	2.2	2.0
Zimmerman	A	5.5	780	40	17	3.8	5.4
	B	5.7	492	20	22	3.2	6.4

these soils also showed evidence of considerable amorphous material seem particularly noteworthy. DDT activity was very high in this group and could be best estimated using organic carbon content and field capacity. In the larger group, organic carbon, fine clay, acid-extractable iron, and cation exchange capacity best described the activity of DDT. DDT activity in the Blue Earth samples was particularly low.

A study going beyond the work of Peterson has been completed. It involved using all these soils to examine the adsorption and desorption of lindane from the soil.

This work also will be published elsewhere. The adsorption of lindane by the soil was significantly correlated to the bioactivity of DDT. The adsorption of lindane was best described by using a regression equation containing only organic carbon as a variable. Adsorption of lindane from water ranged from as little as 4 percent by the Zimmerman B horizon to as much as 90 percent by the Blue Earth samples. Except for the Blue Earth samples, the lindane was readily desorbed and desorption was unrelated to any soil property.



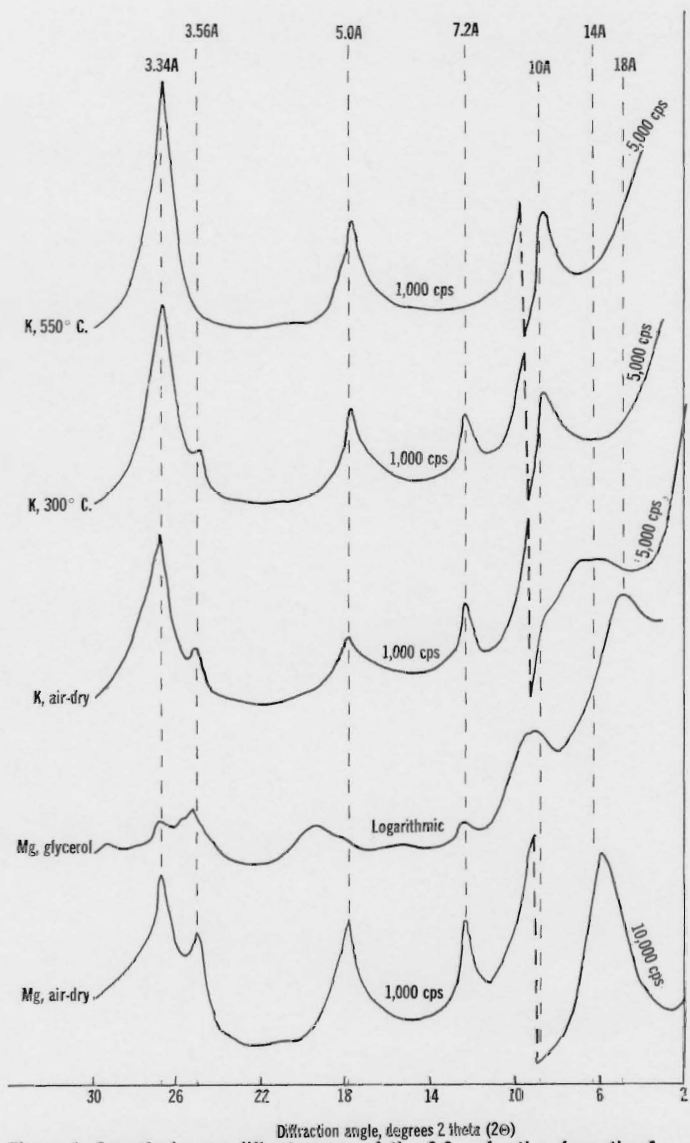


Figure 1. Smoothed x-ray diffractograms of the  $0.2 \mu$  fraction from the  $A_p$  horizon of the Fargo soil series.

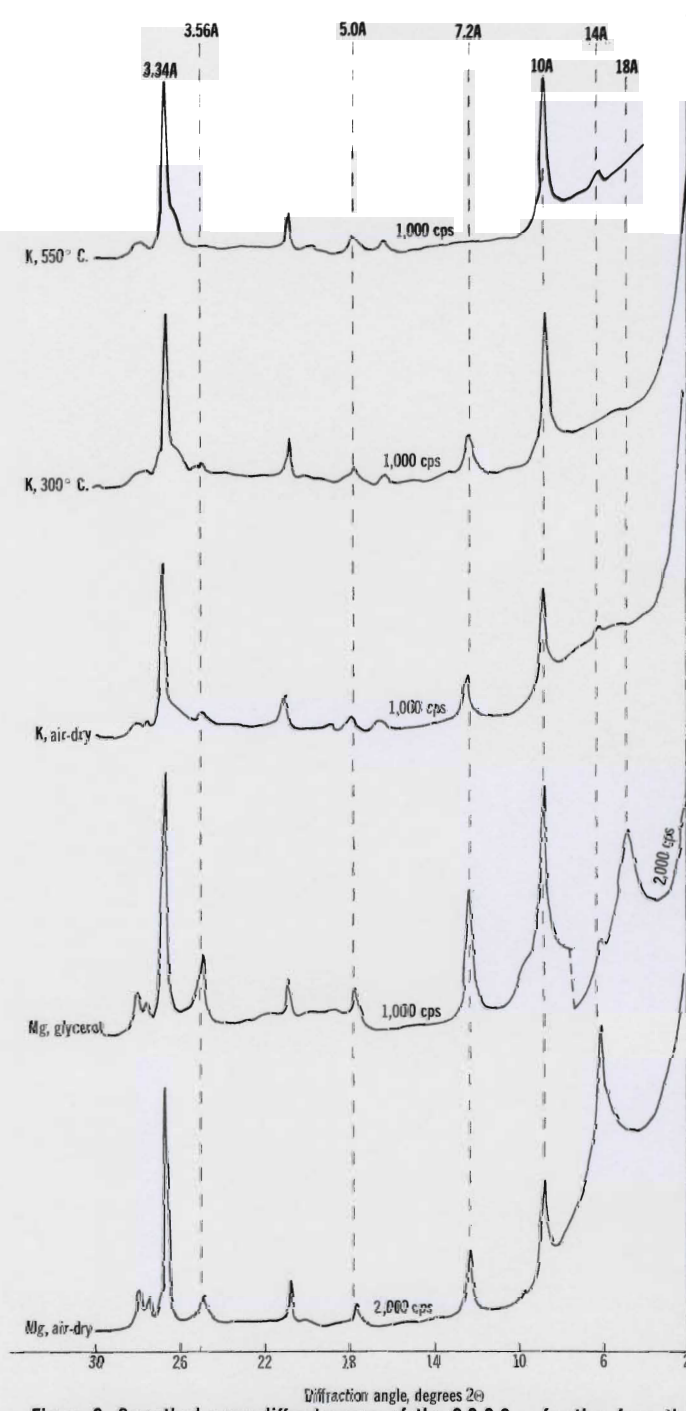


Figure 2. Smoothed x-ray diffractograms of the  $2.0-0.2 \mu$  fraction from the  $A_p$  horizon of the Fargo soil series.

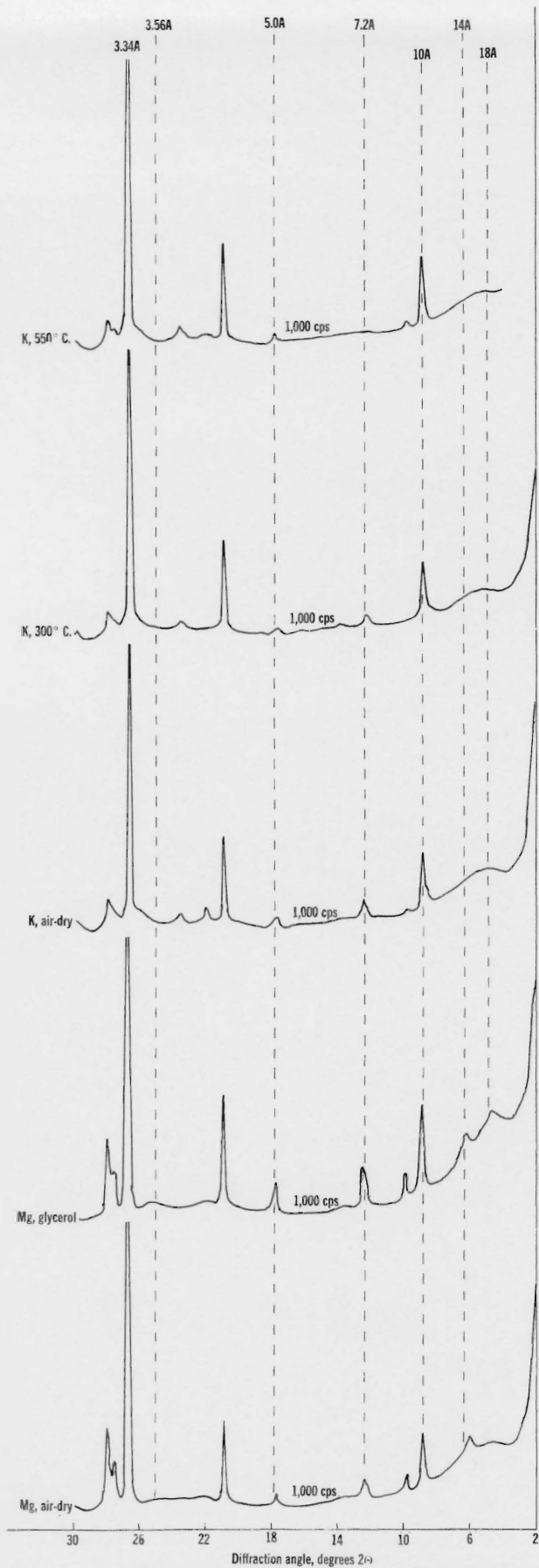


Figure 3. Smoothed x-ray diffractograms of the 5-2  $\mu$  fraction from A<sub>1</sub> horizon of the Fargo soil series.

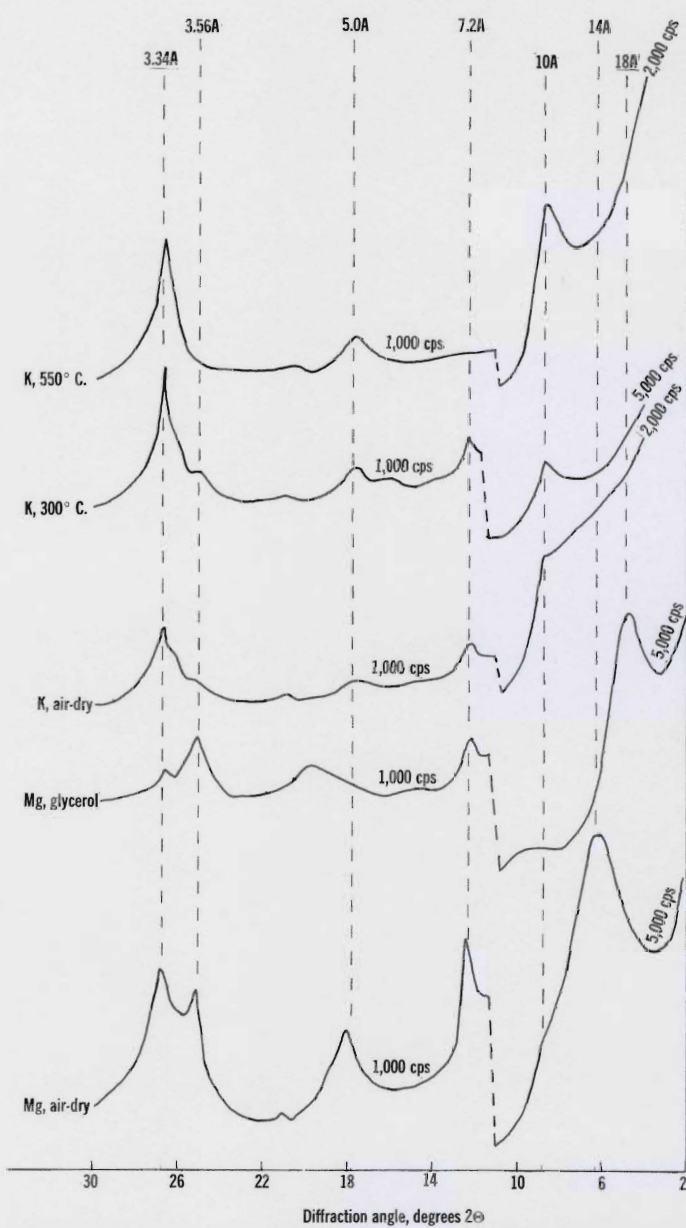


Figure 4. Smoothed x-ray diffractograms of the 0.2  $\mu$  fraction from the A<sub>1</sub> and A<sub>2</sub> horizons of the Fayette soil series.

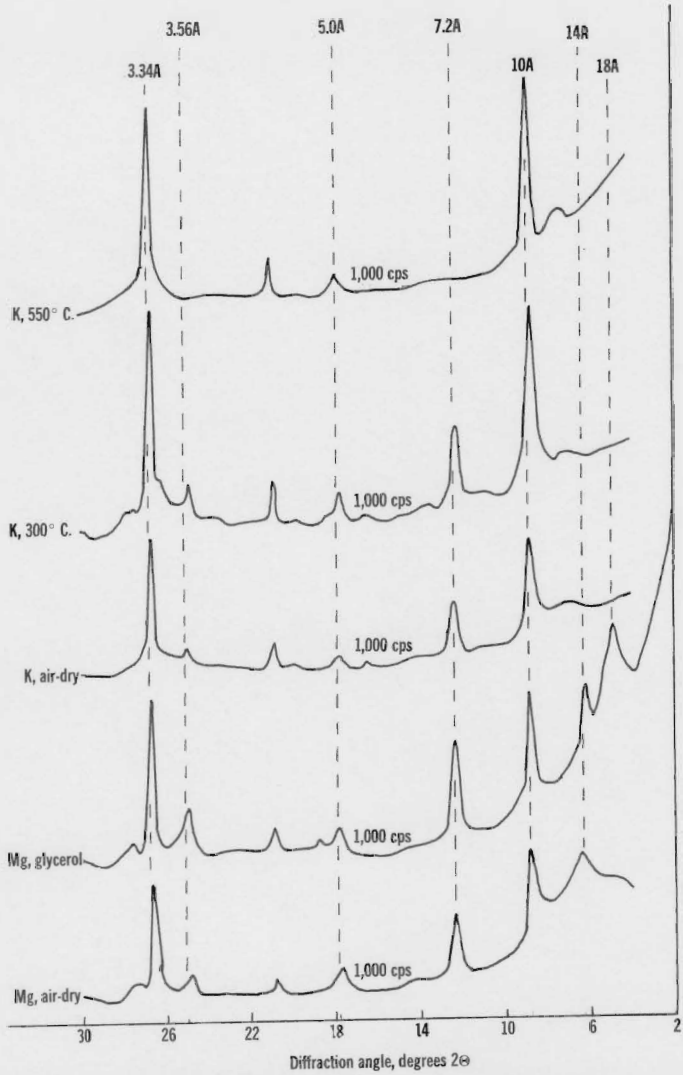


Figure 5. Smoothed x-ray diffractograms of the 2.0-0.2  $\mu$  fraction from the  $A_1$  and  $A_2$  horizons of the Fayette soil series.



Figure 6. Smoothed x-ray diffractograms of the 5-2  $\mu$  fraction from the  $A_1$  and  $A_2$  horizons of the Fayette soil series.

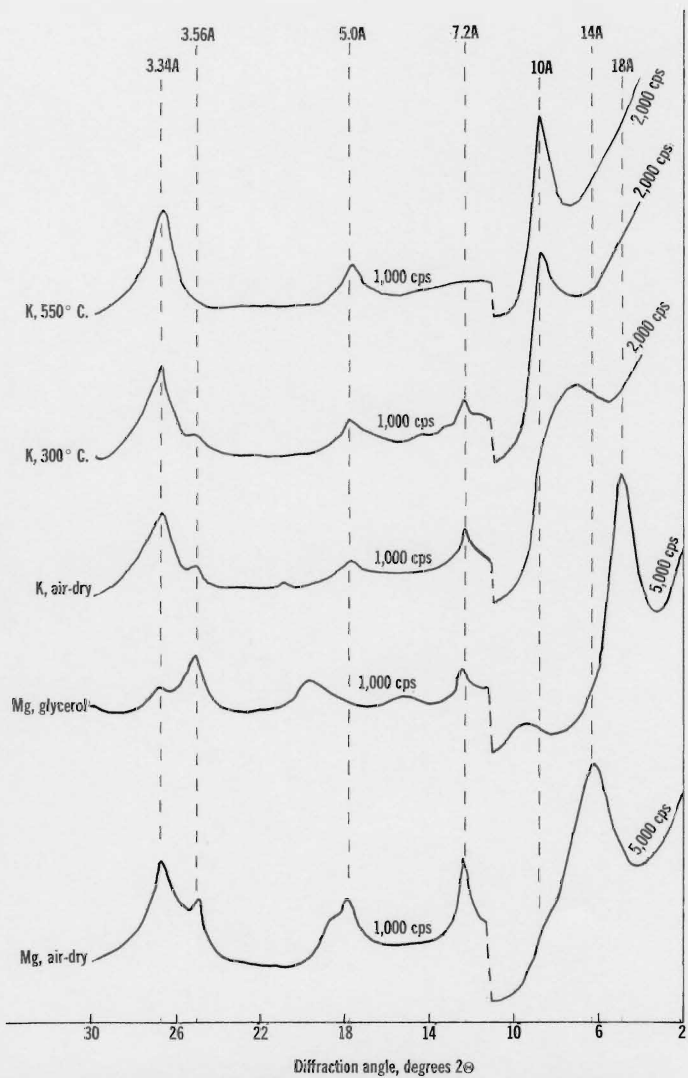


Figure 7. Smoothed x-ray diffractograms of the 0.2  $\mu$  fraction from the  $C_{2ca}$  horizon of the Hegne soil series.

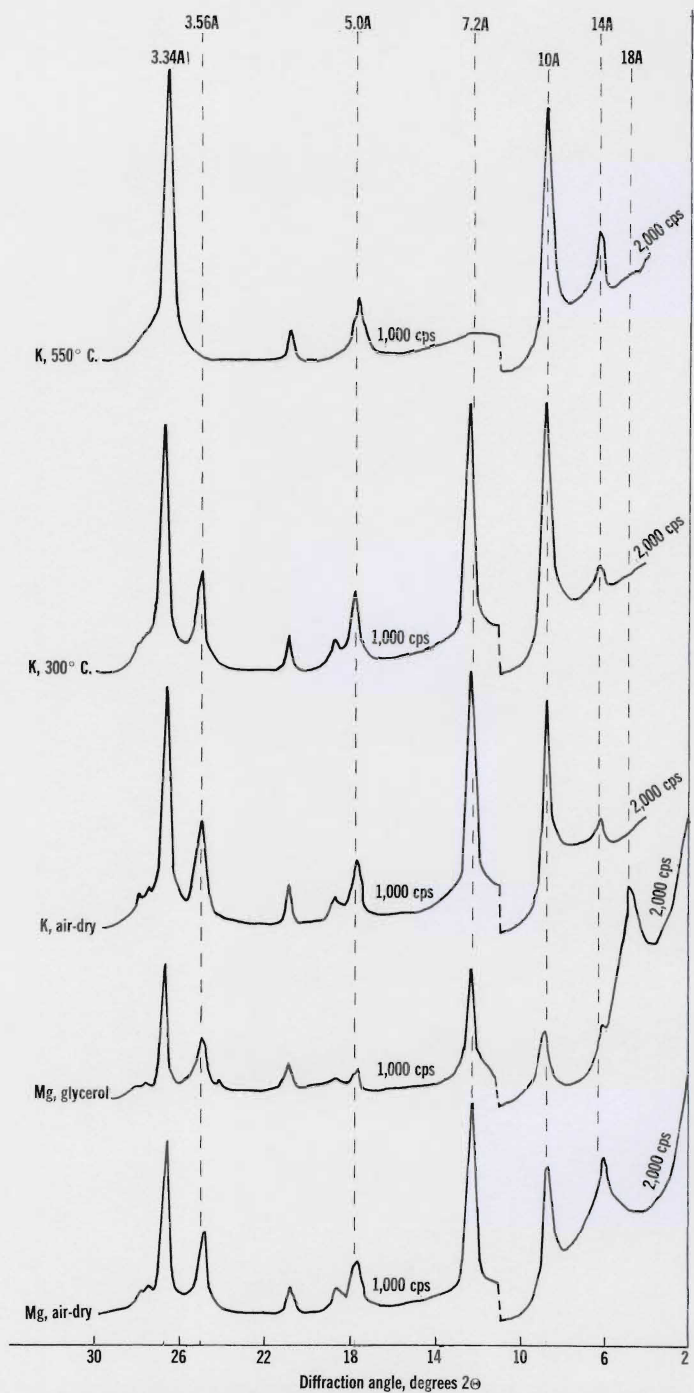


Figure 8. Smoothed x-ray diffractograms of the 2.0-0.2  $\mu$  fraction from the  $C_{2ca}$  horizon of the Hegne soil series.

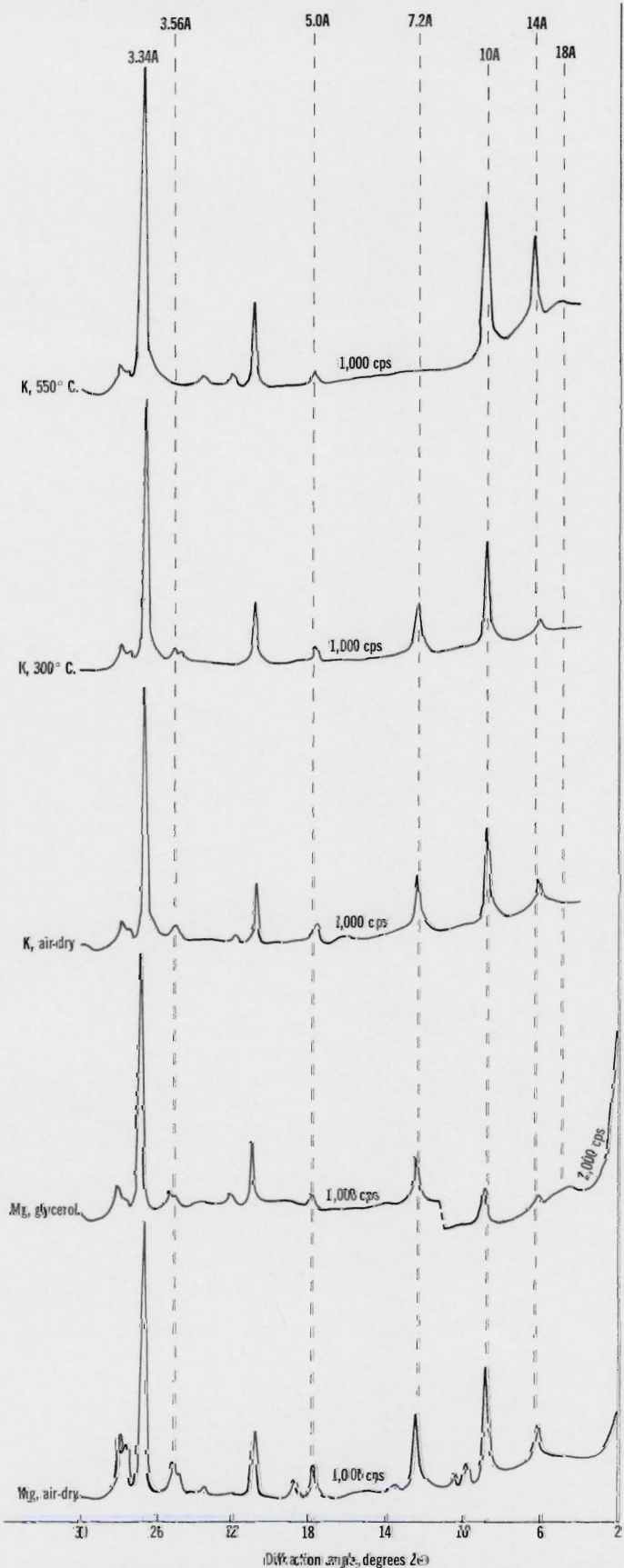


Figure 9. Smoothed x-ray diffractograms of the 5-2  $\mu$  fraction from the C<sub>2en</sub> horizon of the Hegre soil series.

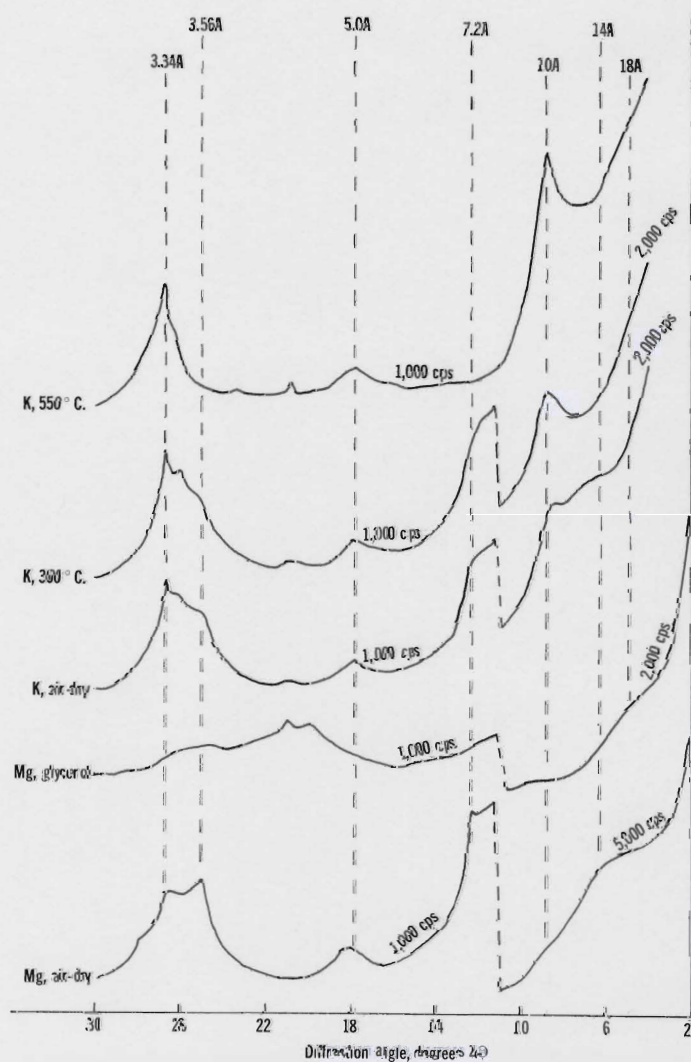


Figure 10. Smoothed x-ray diffractograms of the  $<0.2 \mu$  fraction from the A<sub>1</sub> horizon of the Hubbard soil series.

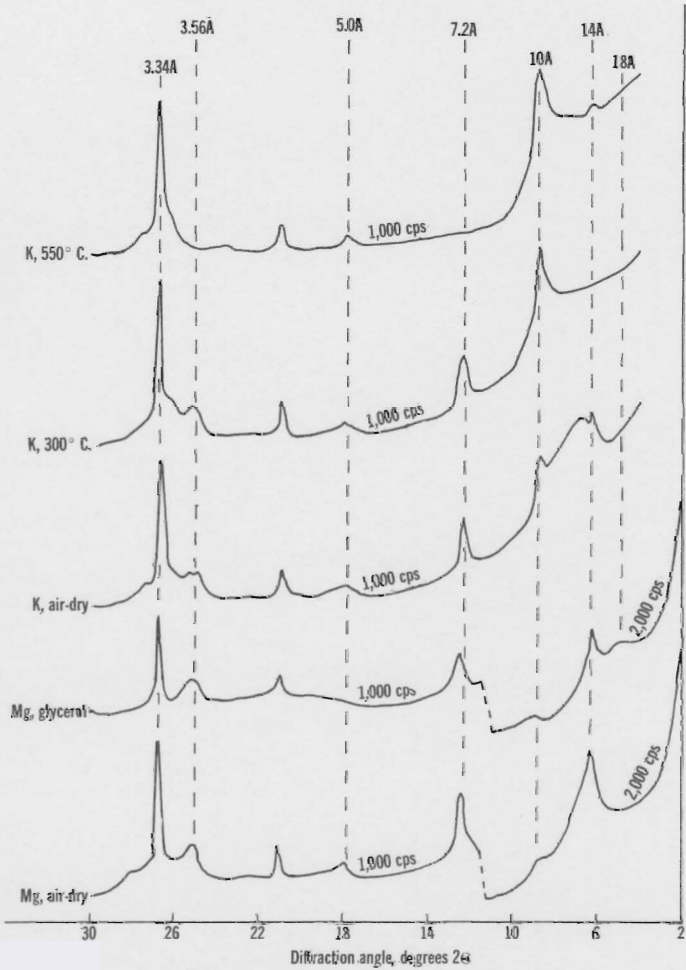


Figure 11. Smoothed x-ray diffractograms of the 2.0-0.2  $\mu$  fraction from the A<sub>p</sub> horizon of the Hubbard soil series.

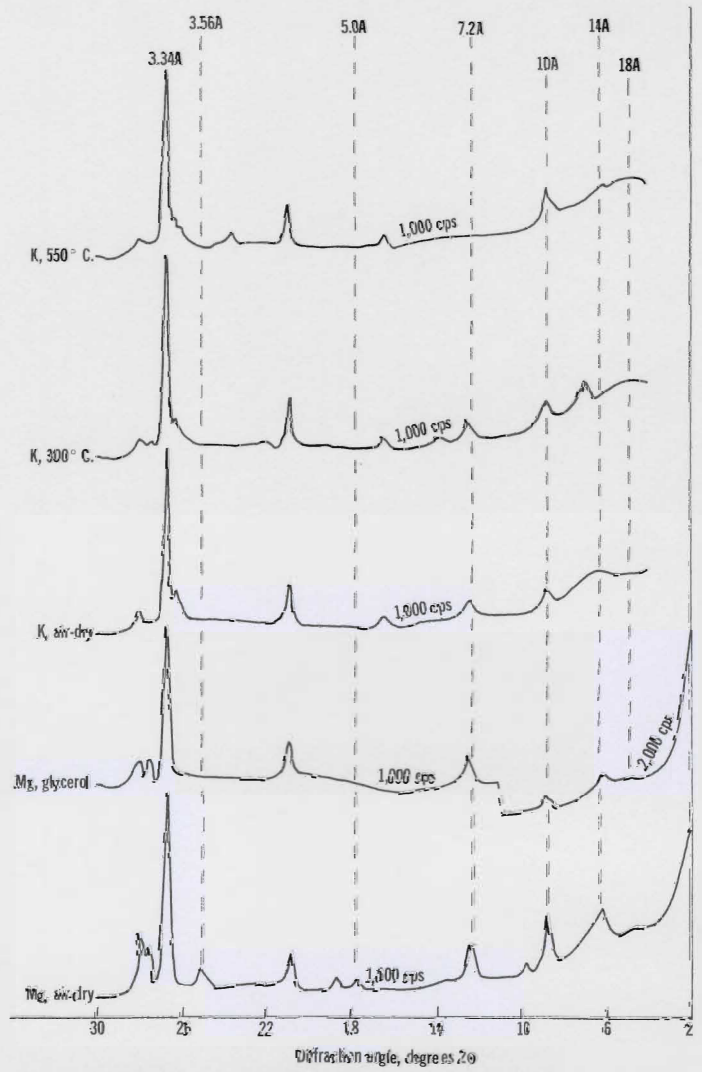


Figure 12. Smoothed x-ray diffractograms of the 5-2  $\mu$  fraction from the A<sub>p</sub> horizon of the Hubbard soil series.

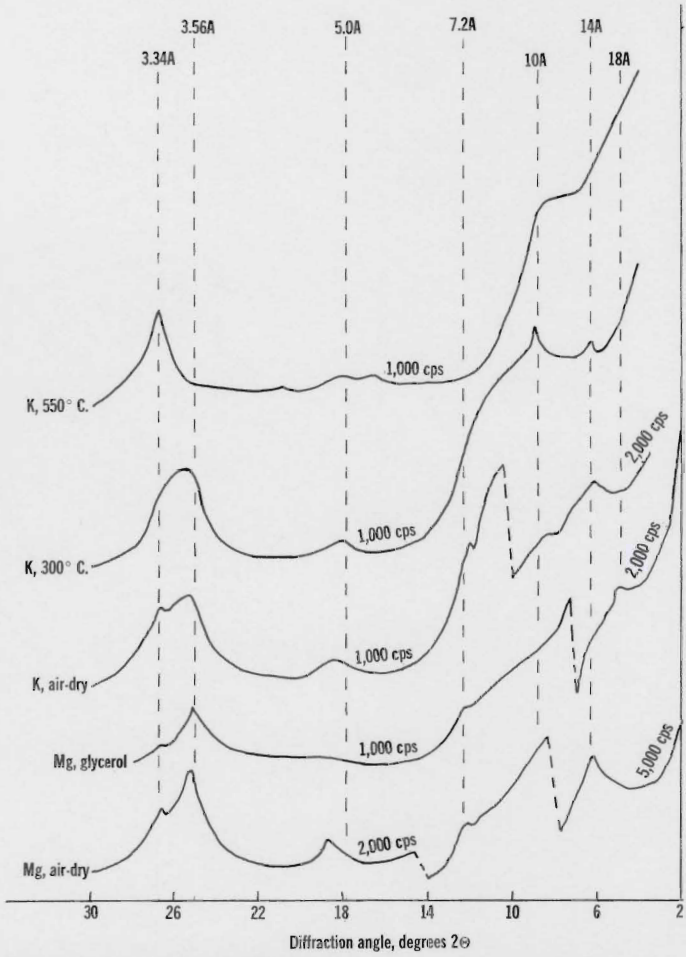


Figure 13. Smoothed x-ray diffractograms of the  $<0.2 \mu$  fraction from the B<sub>2</sub> horizon of the Hubbard soil series.

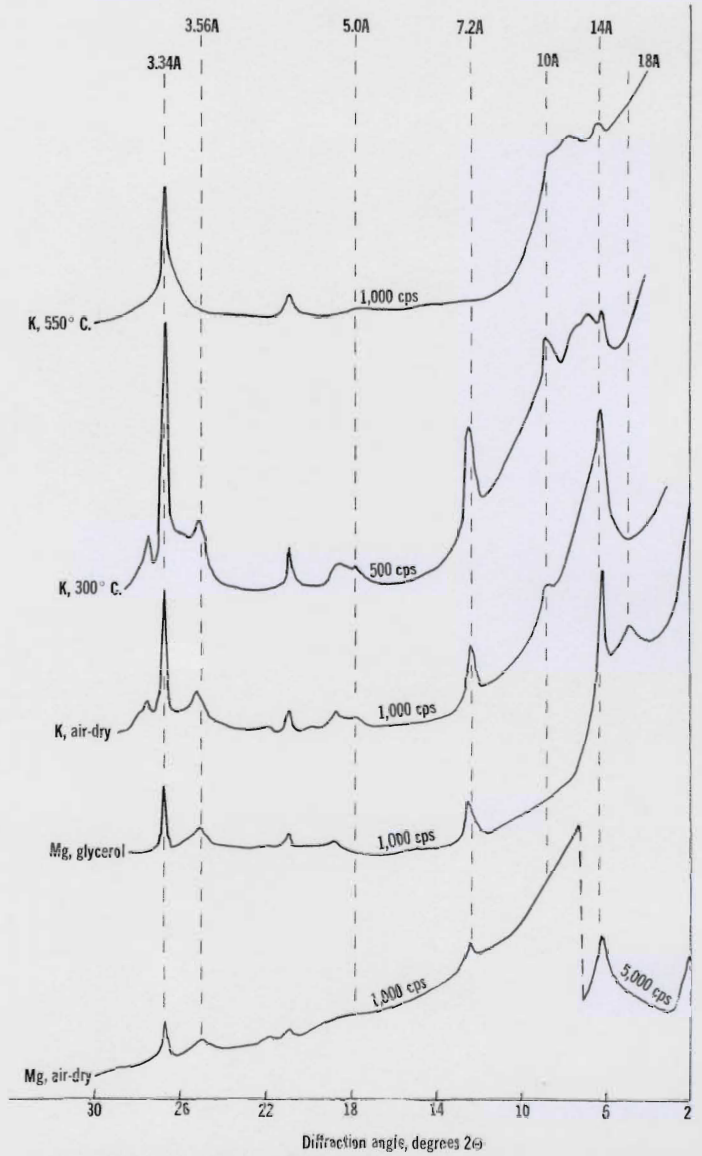


Figure 14. Smoothed x-ray diffractograms for the 2.0-0.2  $\mu$  fraction from the B<sub>2</sub> horizon of the Hubbard soil series.

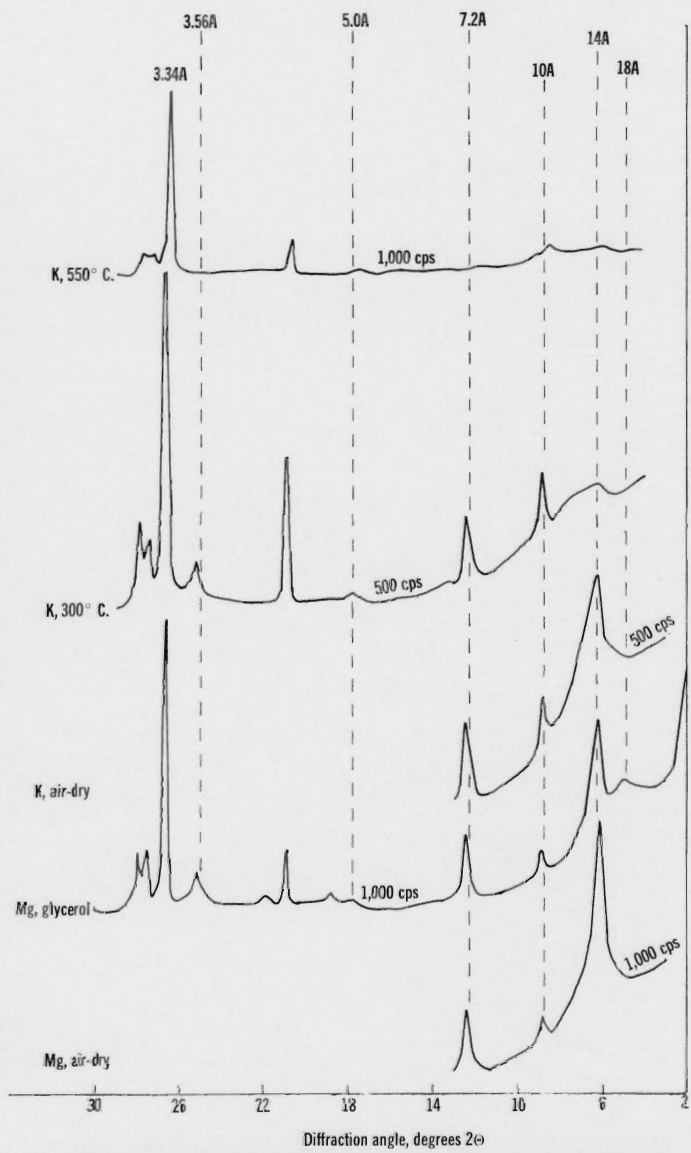


Figure 15. Smoothed x-ray diffractograms of the 5-2  $\mu$  fraction from the  $B_{2s}$  horizon of the Hubbard soil series.

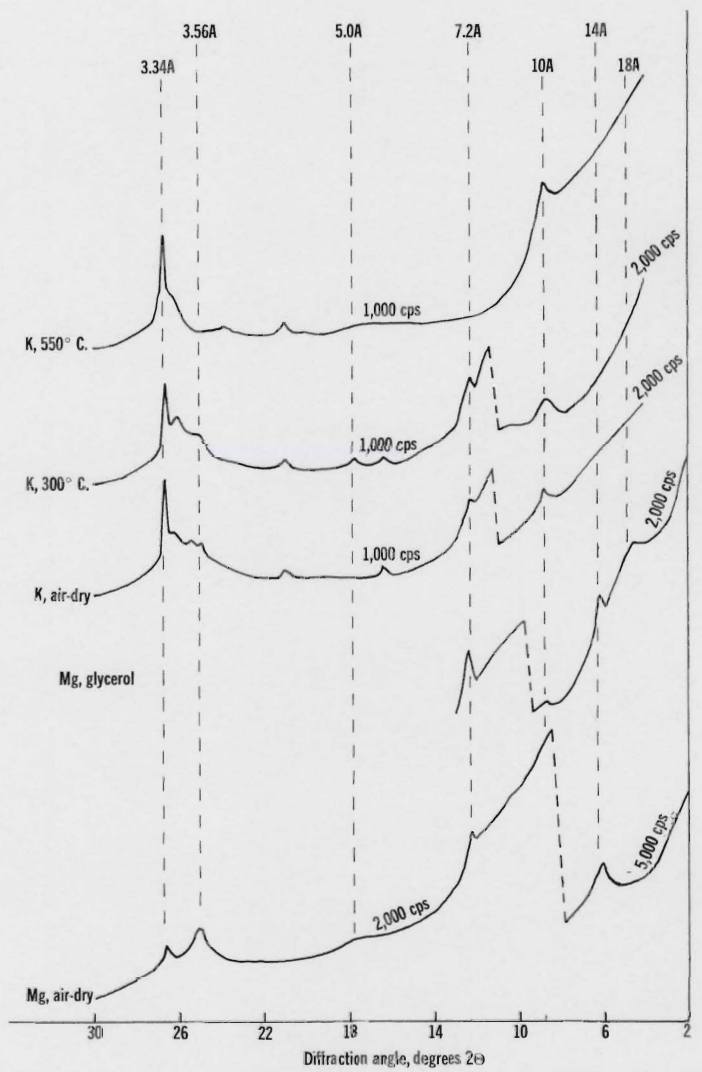


Figure 16. Smoothed x-ray diffractograms of the  $<0.2 \mu$  fraction from the  $B_{21x}$  horizon of the Milaca soil series.



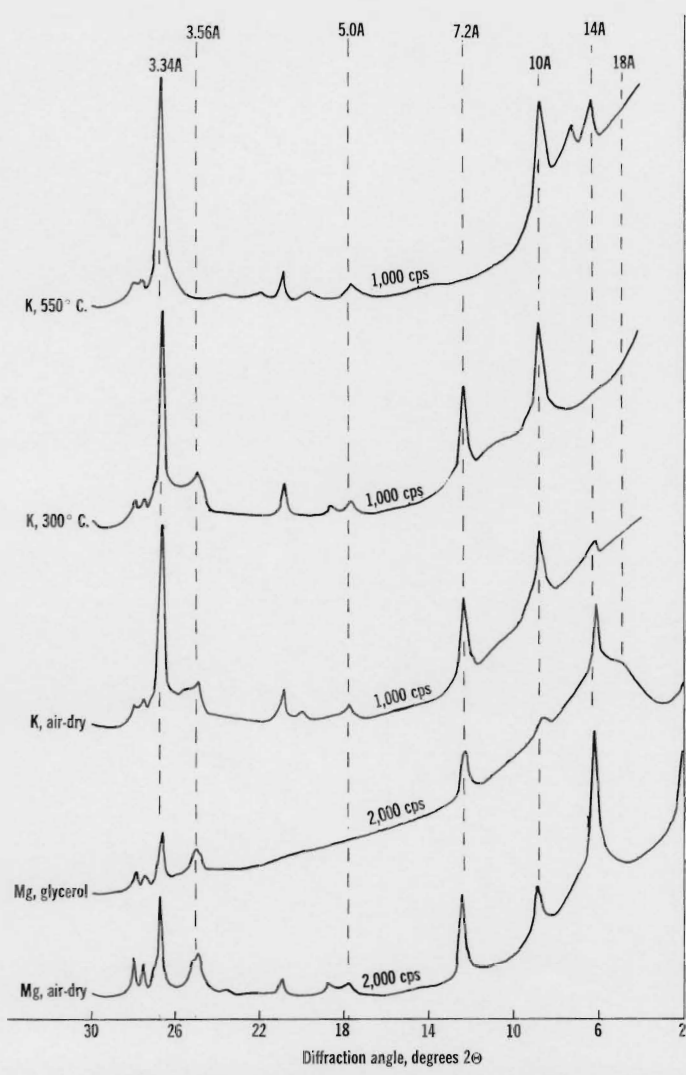


Figure 17. Smoothed x-ray diffractograms of the 2.0-0.2  $\mu$  fraction from the B<sub>21x</sub> horizon of the Milaca soil series.

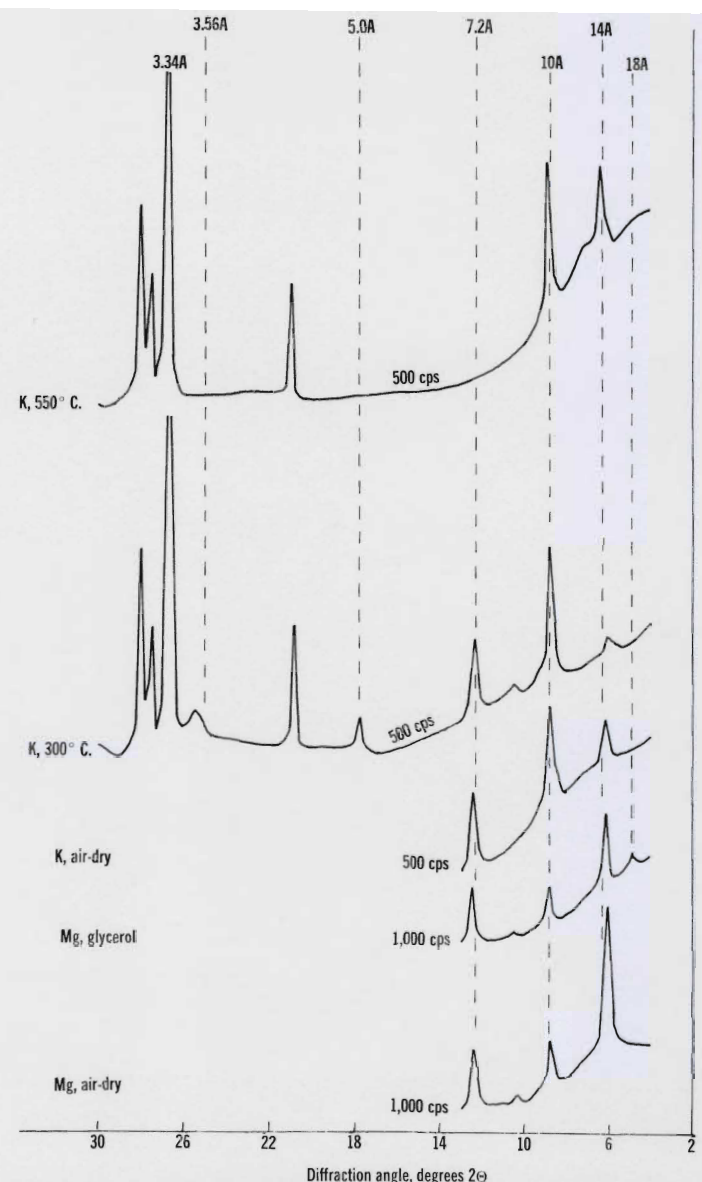


Figure 18. Smoothed x-ray diffractograms of the 5-2  $\mu$  fraction from the B<sub>21x</sub> horizon of the Milaca soil series.

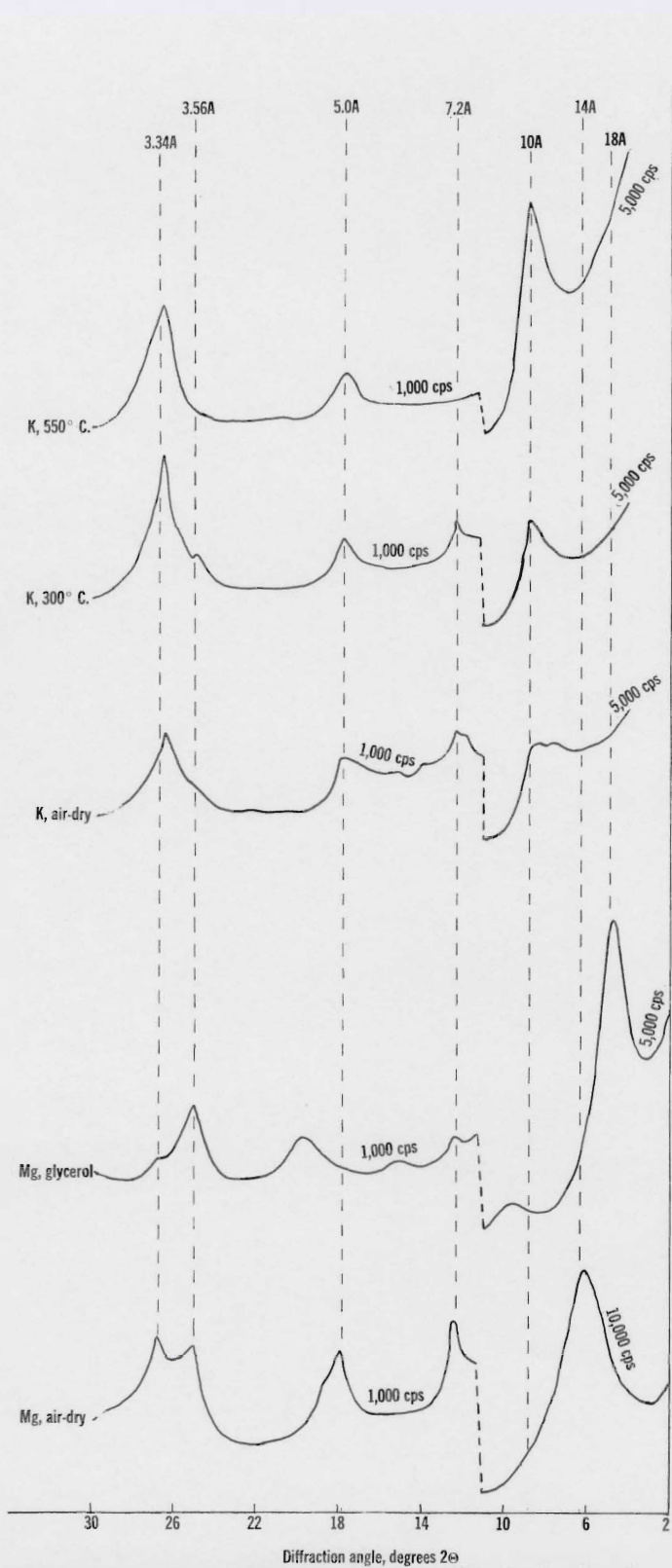


Figure 19. Smoothed x-ray diffractograms of the  $<0.2 \mu$  fraction from the  $A_p$  horizon of the Nicollet soil series.

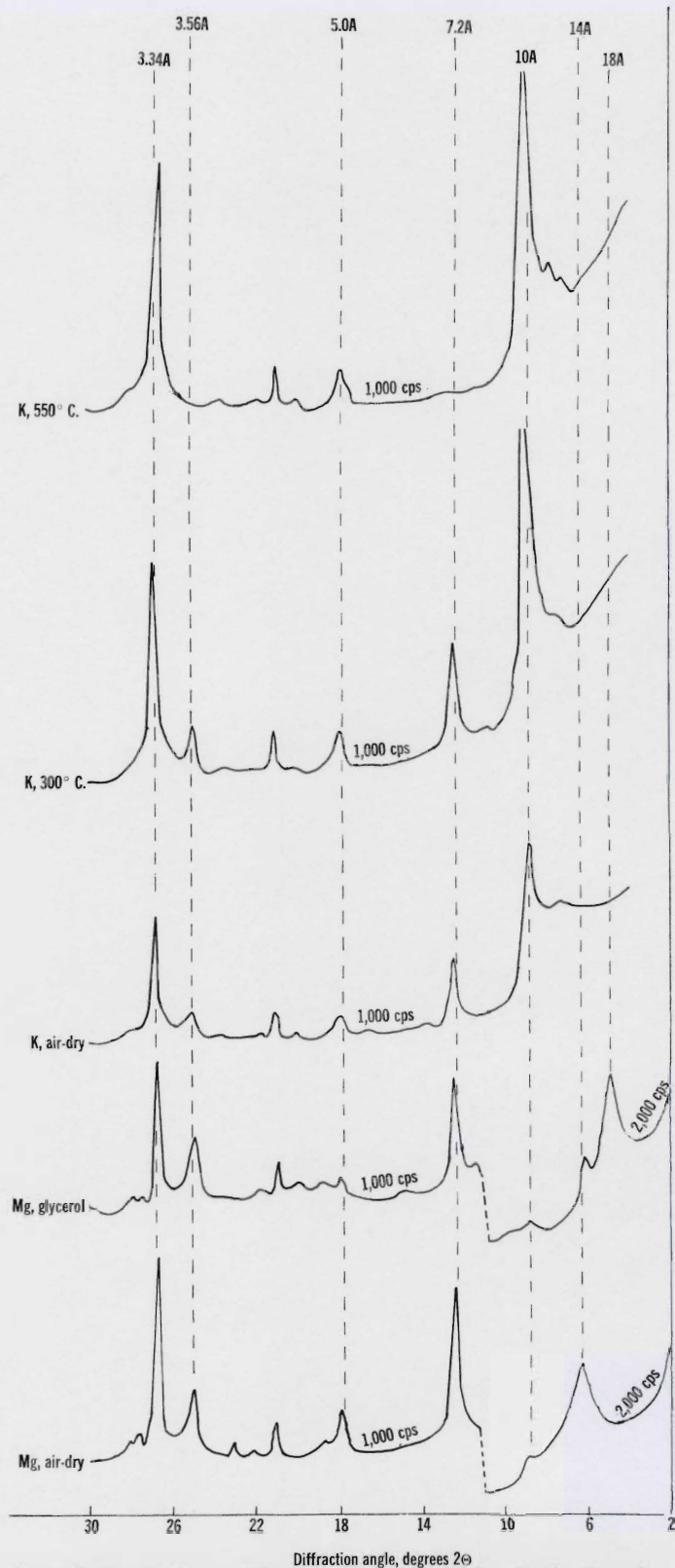


Figure 20. Smoothed x-ray diffractograms of the  $2.0-0.2 \mu$  fraction from the  $A_p$  horizon of the Nicollet soil series.

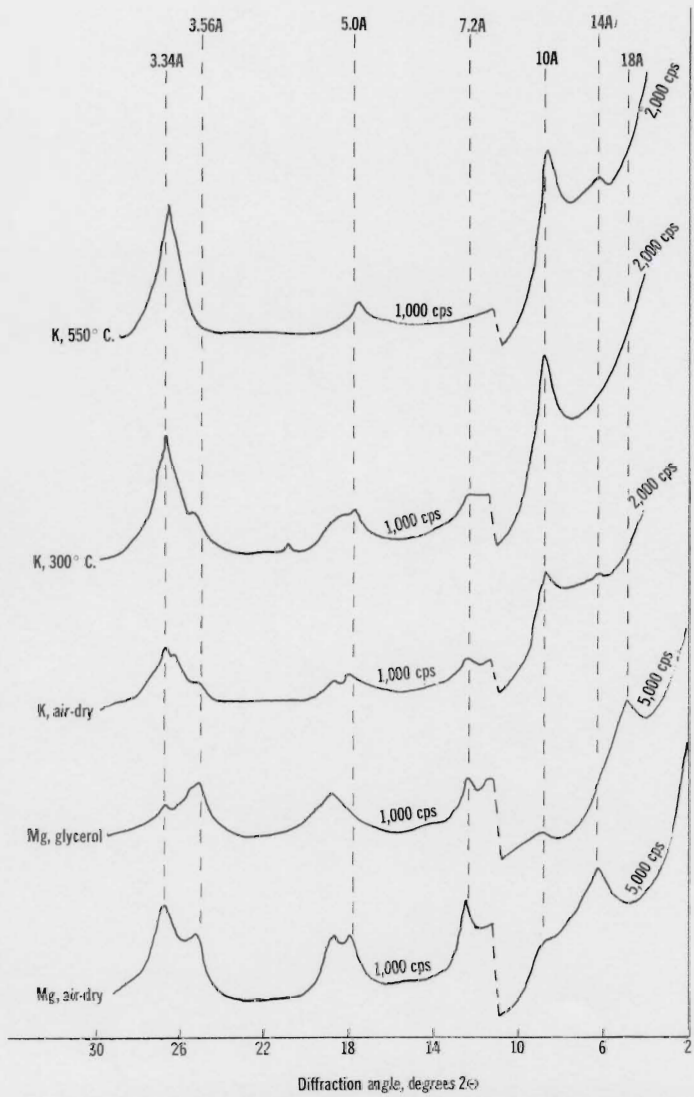


Figure 21. Smoothed x-ray diffractograms of the  $<0.2 \mu$  fraction from the  $A_2$  horizon of the Ontonagon soil series.

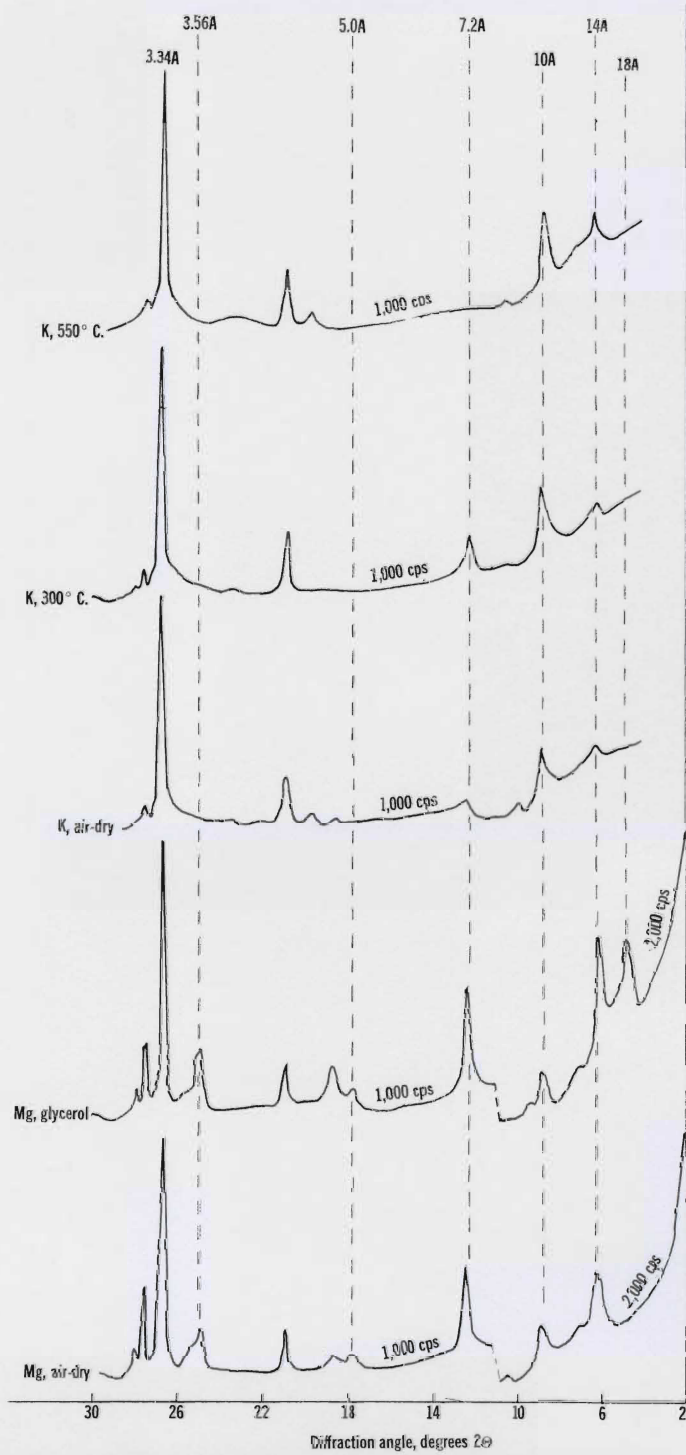


Figure 22. Smoothed x-ray diffractograms of the  $2.0-0.2 \mu$  fraction from the  $A_2$  horizon of the Ontonagon soil series.

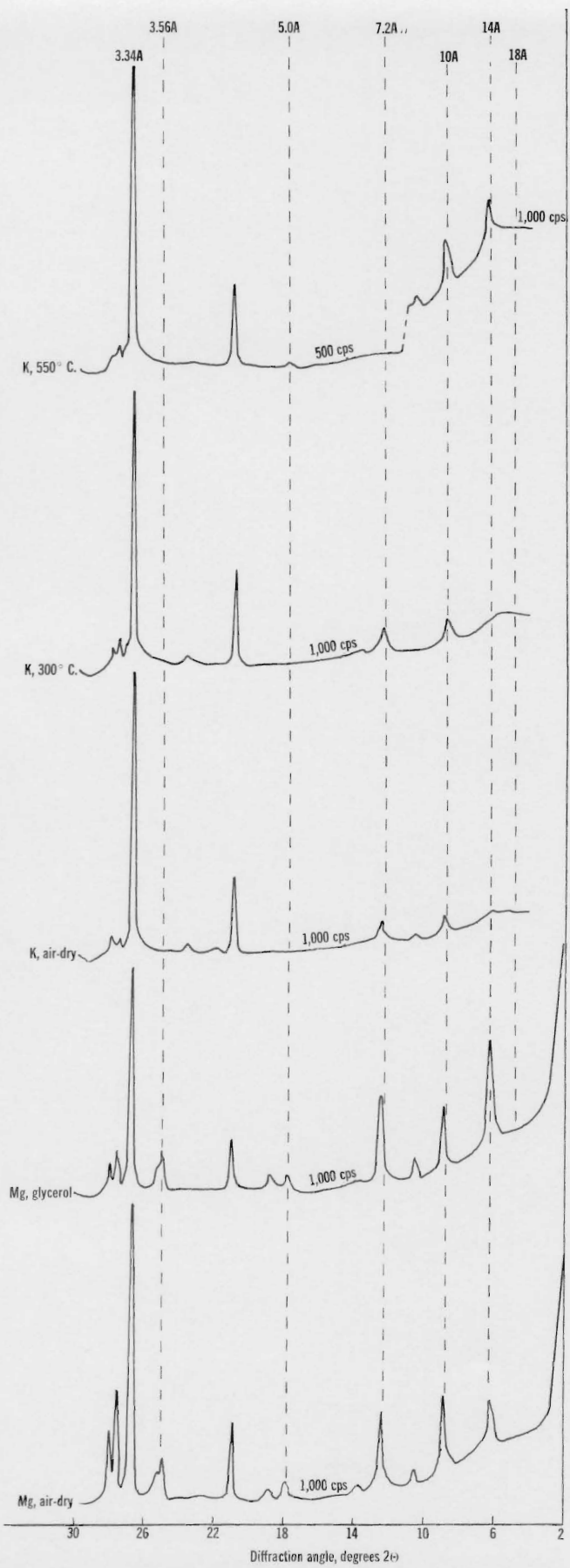


Figure 23. Smoothed x-ray diffractograms of the 5-2  $\mu$  fraction from the A<sub>2</sub> horizon of the Ontonagon soil series.

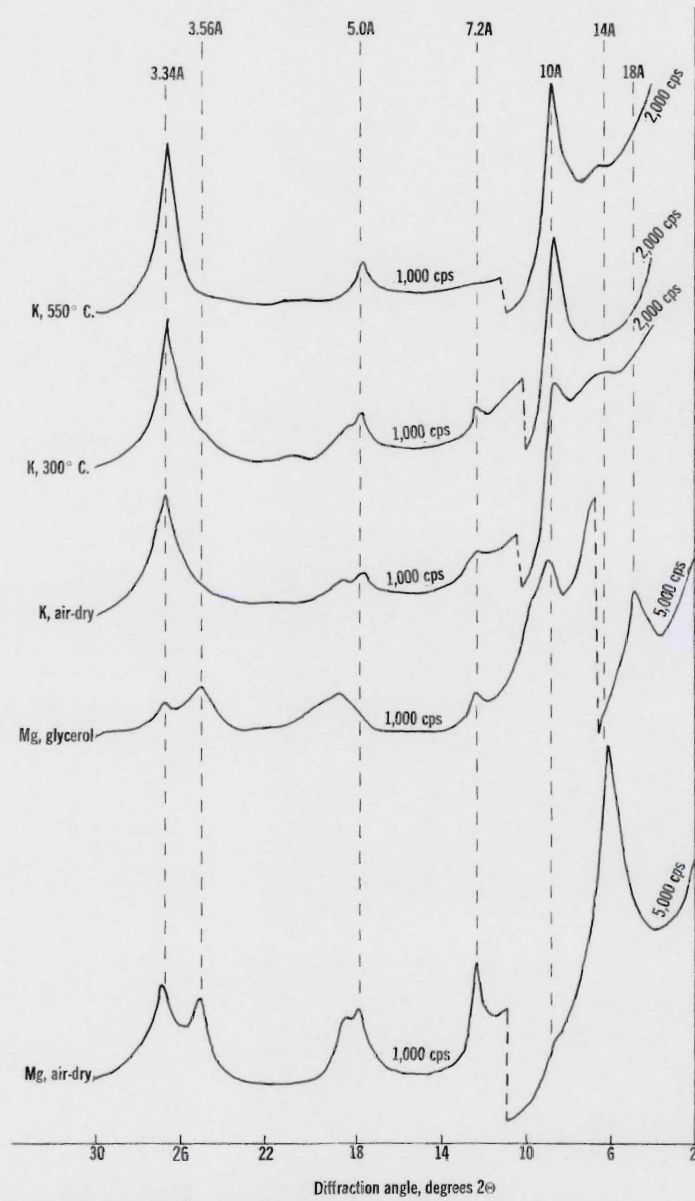


Figure 24. Smoothed x-ray diffractograms of the <0.2  $\mu$  fraction from the B<sub>2t</sub> horizon of the Ontonagon soil series.



Figure 25. Smoothed x-ray diffractograms of the 2.0-0.2  $\mu$  fraction from the  $B_{2t}$  horizon of the Ontonagon soil series.

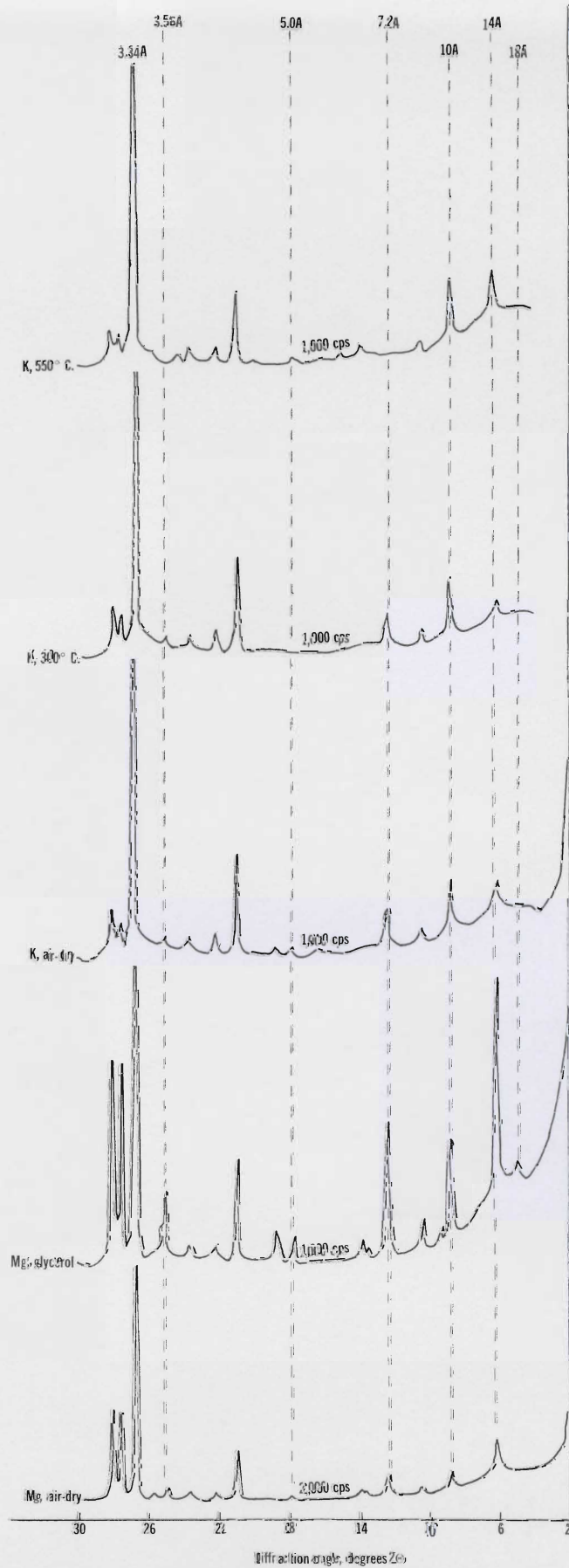


Figure 25. Smoothed x-ray diffractograms of the 5-2  $\mu$  fraction from the  $B_{2t}$  horizon of the Ontonagon soil series.

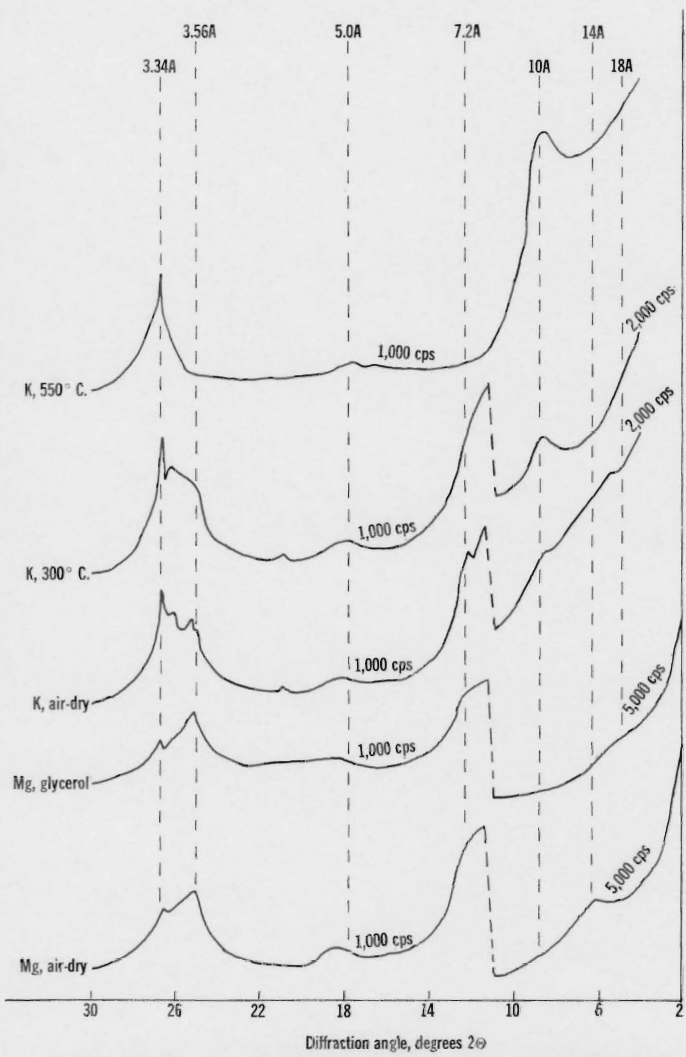


Figure 27. Smoothed x-ray diffractograms of the  $<0.2 \mu$  fraction from the  $A_1$  and  $A_3$  horizons of the Zimmerman soil series.

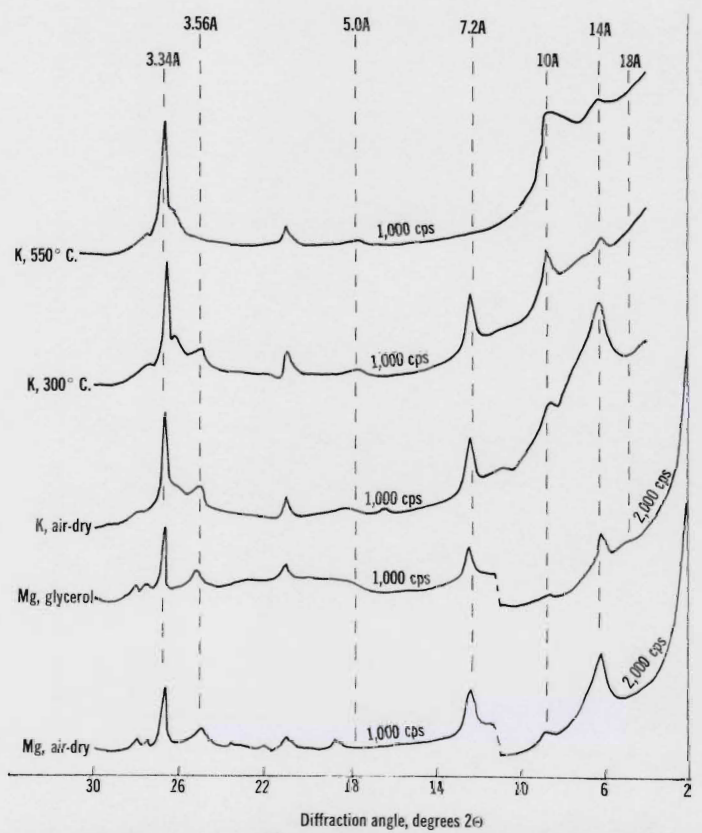


Figure 28. Smoothed x-ray diffractograms of the  $2.0-0.2 \mu$  fraction from the  $A_1$  and  $A_3$  horizons of the Zimmerman soil series.

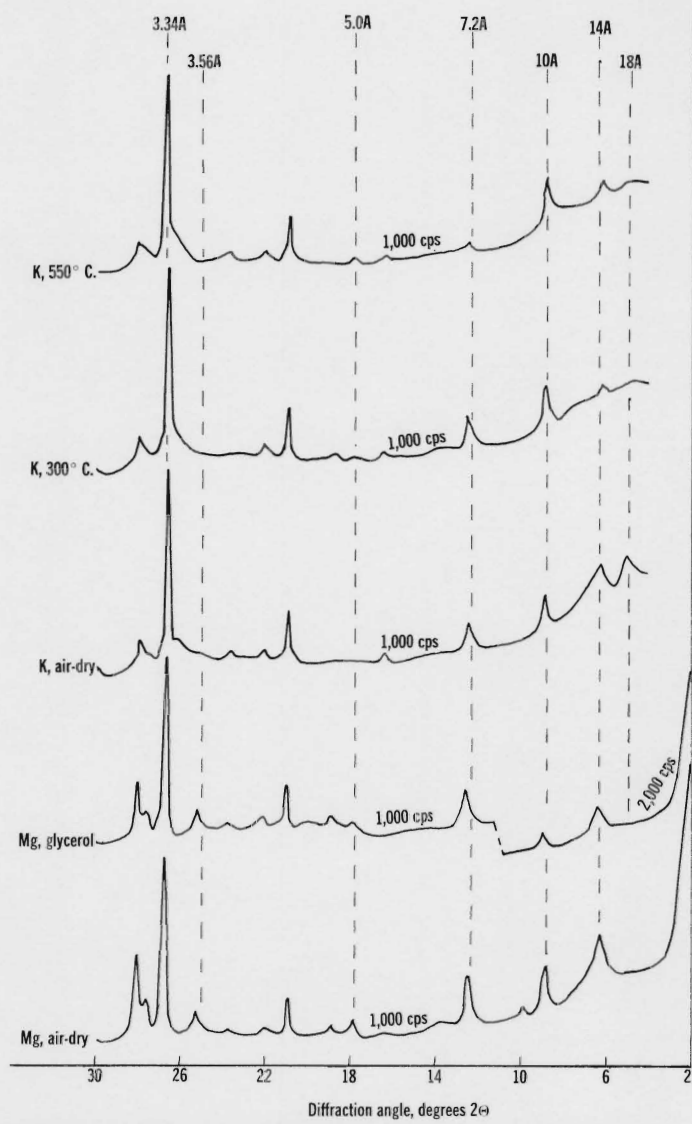


Figure 29. Smoothed x-ray diffractograms of the 5-2  $\mu$  fraction from the A<sub>1</sub> and A<sub>3</sub> horizons of the Zimmerman soil series.

## Literature Cited

- Allison, L. E. 1960. "Wet-Combustion Apparatus and Procedure for Organic and Inorganic Carbon in Soil." *Soil Sci. Soc. Amer. Proc.* 24: 36-40.
- Arneman, H. F. 1963. *Soils of Minnesota*. Univ. of Minn. Extension Bulletin 278. 8 pp.
- Chapman, H. D. 1965. "Cation-Exchange Capacity." in *Methods of Soil Analysis, Part 2*. Agronomy No. 1, Amer. Soc. of Agron., Madison, Wis., pp. 891-901.
- Gordon, R. L. and G. W. Harris. 1955. "Effect of Particle Size on the Quantitative Determination of Quartz." *Nature, Lond.* 175: 1135.
- Heilman, M.D., D. L. Carter, and C. L. Gonzalez. 1965. "The Ethylene Glycol Monoethylether (EGME) Technique for Determining Soil Surface Area." *Soil Sci.* 100: 409-413.
- Hirekerur, L. R. 1964. *Clay Mineralogy and Release and Fixation of Potassium in Some Soil Series of Minnesota*. Unpub. Ph.D. Thesis, Univ. of Minn.
- Jackson, M. L. 1956. *Soil Chemical Analysis — Advanced Course*. Published by author, Madison, Wis.
- . 1963. "Interlayering of Expansible Layer Silicates in Soils by Chemical Weathering." *Clays and Clay Materials*, Proc. 11th Nat. Conf., pp. 29-46.
- . 1964. "Soil Clay Mineralogical Analysis." in *Soil Clay Mineralogy* (C. I. Rich and G. W. Kunze, eds.). Univ. of N.C. Press, Chapel Hill, pp. 245-94.
- Kilmer, V. J. 1960. "The Estimation of Free Iron Oxides in Soils." *Soil Sci. Soc. Amer. Proc.* 24: 420-421.
- Kilmer, V. J. and L. T. Alexander. 1949. "Methods of Making Mechanical Analyses of Soils." *Soil Sci.* 68: 15-24.
- McKeague, J. A. and J. H. Day. 1966. "Dithionite- and Oxalate-Extractable Fe and Al as Aids in Differentiating Various Classes of Soils." *Can. J. Soil Sci.* 46: 13-22.
- U.S. Salinity Laboratory Staff. 1954. *Diagnosis and Improvement of Alkali Soils*. Agriculture Handbook No. 60. U.S. Government Printing Office, Washington, D.C.
- Young, J. L. and M. R. Lindbeck. 1964. "Carbon Determination in Soils and Organic Materials with a High-Frequency Induction Furnace." *Soil Sci. Soc. Amer. Proc.* 28: 377-381.

## Appendix

The data given here include directions to the exact location of the sampling site. Where available, the slope and part of the horizon description are given. The horizon differentiation is listed so the reader can picture the profile above and just below the B horizon examined in this study. A few references to additional information are given.

### Svea (Pachic Udic Haploborolls)

#### Site location:

Swift County, SE  $\frac{1}{4}$  of SE  $\frac{1}{4}$ , Sec. 13, T 121 N, R 42 W; 45 yards west and 42 yards north of the center of the intersection of U.S. Highway 12 and a Swift County gravel road.

Slope: 0 percent

Horizons and depth: A<sub>p</sub> — 0-8 inches  
A<sub>12</sub> — 8-13 inches  
B<sub>21</sub> — 13-18 inches  
B<sub>22</sub> — 18-22 inches  
B<sub>ca</sub> — 22-24 inches

### Bearden (Aeric Calciaquolls)

#### Site location:

Norman County, SE  $\frac{1}{4}$  of SW  $\frac{1}{4}$ , Sec. 4, T 143 N, R 46 W; 88 yards north of center of east-west gravel road and 14 yards east of center of the driveway into the field.

Slope: 0 percent

Horizons and depth: A<sub>p</sub> — 0-7 inches  
A<sub>12</sub> — 7-9 inches  
A<sub>13ca</sub> — 9-16 inches  
C<sub>1cag</sub> — 16-21 inches  
C<sub>2cag</sub> — 21-27 inches

Additional information on this site will be available in the Norman County Minnesota soil survey, tentatively scheduled for publication in 1972.

### Blue Earth (Cumulic Haplaquolls)

#### Site location:

Watsonwan County, SE  $\frac{1}{4}$  of SW  $\frac{1}{4}$ , Sec. 13, T 107 N, R 30 W; approximately 0.7 mile west-southwest from Watsonwan-Blue Earth County line on Minnesota Highway 60 and perpendicular southeast from the highway, or about 110 yards south and 60 yards west from a house on the north side of the bog margin.

#### Horizon information:

Weak horizon differentiation, A<sub>p</sub> discernible, calcareous at surface, numerous shells throughout the profile, water table at 28 inches.

### Brainerd (Aquic Fragiochrepts)

#### Site location:

Crow Wing County, SW  $\frac{1}{4}$  of NW  $\frac{1}{4}$ , Sec. 28, T 44 N, R 30 W; approximately 32 yards north and 38 yards east of a field driveway.

Slope: 4 percent, northeast-facing

Horizons and depth: A<sub>1</sub> — 0-3 inches  
A<sub>21</sub> — 3-6 inches  
A<sub>22</sub> — 6-10 inches  
A<sub>23</sub> — 10-15 inches  
A<sub>24</sub> — 15-21 inches  
A&B — 21-25 inches  
B&A — 25-34 inches

Additional information on this site is available in the Crow Wing County Minnesota soil survey, published in 1965.

### Canisteo (Typic Haplaquolls)

#### Site location:

Steele County, SE  $\frac{1}{4}$ , Sec. 23, T 107 N, R 21 W; approximately 102 yards north from road center through the field driveway and about 18 yards east.

Slope: 0 percent to slightly depressional

### Fargo (Vertic Haplaquolls)

#### Site location:

Norman County, NW  $\frac{1}{4}$  of NW  $\frac{1}{4}$ , Sec. 18, T 143 N, R 48 W; east end of the north row of trees in the long three-row farmstead shelterbelt. The surface A was



sampled within the shelterbelt. There was evidence of recent aeolian deposition in the surface.

To avoid tongues of A<sub>1</sub>, which penetrated the B<sub>1g</sub> and into the C, the subsurface B was sampled 150 yards north of the site for the surface A sample.

Horizons and depth: A<sub>p</sub> — 0-6 inches  
A<sub>1</sub> — 6-10 inches  
B<sub>1g</sub> — 10-20 inches

Additional information on this site will be available in the Norman County Minnesota soil survey, tentatively scheduled for publication in 1972.

#### Fayette (Typic Hapludalfs)

Site location:

Olmsted County, NE ¼ of NW ¼, Sec. 7, T 106 N, R 14 W; driveway to the site is 1.1 miles south of old U.S. Highway 14 on a gravel road, sampled 51 yards west from north-south fence line and 44 yards north from east-west fence line in the field.

Slope: 3 percent, northwest-facing

Horizons and depth: A<sub>1</sub> — 0-2 inches  
A<sub>2</sub> — 2-9 inches  
B<sub>1</sub> — 9-16 inches  
B<sub>2t</sub> — 16-32 inches

#### Hegne (Typic Calcicquolls)

Site location:

Norman County, NE ¼ of NE ¼, Sec. 23, T 146 N, R 47 W; sampled 95 yards south of the center of the east-west hard surface road and 65 yards west of north-south undeveloped road allowance. The surface A contained unseparable inclusion of C<sub>1ca</sub> of about 10 percent by volume. The subsurface B contained C<sub>2ca</sub>, including well delineated wedges and streaks of A<sub>1</sub> material.

Slope: 1 percent

Horizons and depth: A<sub>p</sub> — 0-6 inches  
C<sub>1cag</sub> — 6-10 inches  
C<sub>2cag</sub> — 10-19 inches  
C<sub>3cag</sub> — 19-29 inches

Additional information on this site will be available in the Norman County Minnesota soil survey, tentatively scheduled for publication in 1972.

#### Hubbard (Udic Haploborolls)

Site location:

Sherburne County, NE ¼ of NW ¼, Sec. 7, T 33 N, R 28 W; sampled approximately 90 yards west of the third power pole south of power substation on north-south gravel road and at an angle of about 220 degrees from the substation.

Slope: 1 percent

Horizon information:

A large mapping unit of Hubbard was present in the field, but wind erosion and deposition resulted in varying thicknesses of A<sub>1</sub>. Several gopher krotovinas were observed in the profiles exposed. The A<sub>1</sub> and A<sub>3</sub> extended to about 15 inches and were without gravel to 42 inches.

#### Kranzburg (Udic Haploborolls)

Site location:

Pipestone County, SE ¼ of NE ¼ of SE ¼, Sec. 32, T 106 N, R 46 W; approximately 17 yards west of east gate of field driveway.

Slope: 3 percent, west-facing

Horizons and depth: A<sub>p</sub> — 0-6 inches  
A<sub>12</sub> — 6-10 inches  
B<sub>1</sub> — 10-15 inches  
B<sub>21</sub> — 15-21 inches  
B<sub>22</sub> — 21-27 inches

#### Lester (Mollic Hapludalfs)

Site location:

Steele County, SE ¼ of NW ¼, Sec. 5, T 108 N, R 20 W; approximately 6 yards east and 12 yards north of "restricted access" right-of-way sign set within the fenceline on the west side of Interstate Highway 35. Sampled at highest elevation on the hill along the fenceline.

Slope: 2 percent variable, southwest-facing

Horizons and depth: A<sub>1</sub> — 0-3 inches  
A<sub>2</sub> — 3-9 inches  
B<sub>2t</sub> — 9-24 inches, with gravel and sand lenses not typical of Lester

#### Milaca (Typic Fragiochrepts)

Site location:

Benton County, NW ¼ of NW ¼, Sec. 33, T 38 N, R 29 W; approximately 140 yards into woodlot-pasture northwest from driveway at Minnesota Highway 25. A basswood tree is marked with a blaze on its north-east side at the pit site.

Slope: 6 percent, north-facing

Horizons and depth: O<sub>1</sub> — 1-0 inches  
A<sub>1</sub> — 0-1 inches  
A<sub>21</sub> — 1-4 inches  
A<sub>22</sub> — 4-10 inches  
B<sub>1x</sub> — 10-19 inches  
B<sub>21x</sub> — 19-28 inches  
B<sub>22x</sub> — 28-40 inches

Additional information on this site will be available in the Benton County Minnesota soil survey, tentatively scheduled for publication in 1972.

#### Nicollet (Aquic Hapludolls)

Site location:

Steele County, NW ¼ of NW ¼, Sec. 33, T 107 N, R 20 W; approximately 70 yards south of the east-west gravel road and 13 yards east from the field margin at the second telephone pole from the intersection of the east-west gravel road and the north-south, hard surfaced road paralleling Interstate Highway 35.

Slope: 0 to 1 percent

Horizons and depth: A<sub>p</sub> — 0-6 inches  
A<sub>12</sub> — 6-12 inches  
A<sub>3</sub> — 12-14 inches  
B — 14-24 inches (cambic)

#### Ontonagon (Typic Eutroboralfs)

Site location:

Carlton County, NW ¼ of NW ¼, Sec. 1, T 47 N, R 16 W; approximately 112 yards east and 85 yards south of natural gas pipeline pole marked "P8".

Slope: 0 percent

**Ulen** (Aquic Haploborolls or Aeric Calciaquolls)

Site location:

Norman County, SE ¼ of SE ¼ of SE ¼, Sec. 10, T 146 N, R 46 W; located about 83 yards west and 50 yards north of the center of the intersection.

Slope: 0 percent

Horizons and depth: A<sub>p</sub> — 0-10 inches

A<sub>12ca</sub> — 10-17 inches

C<sub>1ca</sub> — 17-24 inches

Additional information on this site will be available in the Norman County Minnesota soil survey, tentatively scheduled for publication in 1972.

**Zimmerman** (Alfic Udipsamments)

Site location:

Sherburne County, SW ¼ of NW ¼, Sec. 17, T 35 N, R 28 N; approximately 163 yards east and 45 yards north of the southwest section corner of section 17.

Slope: 2 percent, southwest-facing

Horizons and depth: A<sub>1</sub> — 0-4 inches

A<sub>3</sub> — 4-8 inches

B or C<sub>1</sub> — 8-21 inches, horizon not of uniform color

C<sub>2</sub> — 21-36 inches

Additional information on this site is available in the Sherburne County Minnesota soil survey, published in 1968, and the Department of Soil Science Soil Profile Characterization Central File No. 454.