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The Accuracy of Soil Mapping Units of Certain Pachic and Cumulic Soils in Northern Utah

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THE ACCURACY OF SOIL MAPPING UNITS OF CERTAIN PACHIC AND CUMULIC SOILS IN NORTHERN UTAH

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

ABSTRACT

The Accuracy of Soil Mapping Units of Certain

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by

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Utah State University, 1976

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The purpose of this study was to determine the accuracy of mapping of pachic and cumulic soils in Cache County. The soil maps that were used for this study as the basemap were the Atlas sheets of the published Soil Survey of Cache County.

Five map units from Mendon, Nebeker, Avon, Hendricks and Winn which include almost 52 percent of the pachic and cumulic soils in the survey area were selected for this study. These five soils cover large areas when compared to other soil series and they are distributed throughout the county. All these map units were recognized as pachic and cumulic in the published soil survey report. The thickness of the epipedon was therefore selected as the principal criterion for determining the accuracy of the map units.

About 400 samples from the major delineations were studied in the field and the necessary data were collected and interpreted statistically in order to find: (1) the accuracy of each map unit, (2) the inclusions, misclassified and not classified pedons and their proportions, and (3) the estimated thickness of the epipedons. Attempts were made to select the pedons on transects with appropriate interval, depending on landforms and continuity of soils.

Statistical interpretations were conducted by using the chi-square method. The results for each map units are as follows: for Mendon map unit (MeA) 42-56 percent and for Hendricks map unit (HdD) only 30-60 percent of the samples have characteristics required for the named soil in these map units. These values are less than 75 percent which is the critical value for the map units by definition. It is concluded therefore that with the available data the Mendon and Hendricks series have been mapped incorrectly. For Nebeker map unit (NbE) 77-93 percent and from Avon map unit (ArA) 85-99 percent of the samples have the characteristics required for the named soil in the map units. These values are more than the critical value (75) so it is concluded that with available data the Nebeker and Avon series have been mapped correctly. For Winn map unit (Wn) 54-82 percent of the samples have the required characteristics of this series. The statistical analysis did not reveal strictly whether the pedons are mapped correctly or not and additional samples are required to adequately test the accuracy of the Winn map unit.

It is concluded that in Cache County the influence of different geologic depositions and variations in topography are two major factors responsible for poor accuracy in mapping the Mendon and Hendricks series.

(69 pages)

INTRODUCTION

"A system of classification is an abstraction of the model of the subject with which it deals," (Cline, 1961, p. 444).

Soil maps are prepared based on soil classification systems that reflect the soil model or the soil concept of that system. For many years attempts have been made by soil scientists to formulate a model for soil to establish a system of soil classification and soil maps which is "essential for the orderly transfer of knowledge about soils from one place to another," (Overdal, 1963, p. 228).

Soils maps are prepared by using a combination of the following procedures: aerial photo interpretation, field examination, and using the available information such as geology, gemorphology, climate, vegetation, etc., about the mapping area. Precision of definitions of differentiating criteria, availability of detailed data and information of the nature of the soils under study and experience of the soil surveyor are some of the factors that determine the accuracy of soil maps. Complexity of soil patterns and scale of maps are two factors which directly influence the accuracy possible in making soil maps. Considering these problems Jenny (1941, p. 27) states, "Every soil surveyor knows that the boundaries between soil types are not always so sharply defined as one might assume from an inspection of soil maps. This is due not so much to lack of accurate observation and mapping, it is the consequence of inherent variability of soil types." Pomerening and Cline (1953, p. 817) evaluated the accuracy of soil maps prepared by various methods and concluded that "increasing complexity of the landscape greatly reduces the accuracy of aerial photo interpretation." The problem was also described by Johnson, (1963, p. 212) as: "one of the great difficulties in soil classification is that soils rarely exist as discrete individuals with closed boundaries, instead they grade into other soils across broad transition belts and their boundaries are determined by definition." He then proposed two new concepts, pedon and polypedon, to help clarify relationships between the soil continuum, soil taxonomic classes and soil map units.

Statement of the problem

The purpose of this study is to determine the accuracy of mapping of pachic and cumulic soils in Cache County. The results will be generalized for all map units with thick mollic epipedons in Cache County. Soils of Cache County have been mapped and classified based on criteria in Soil Taxonomy (Erickson et al., 1974). The mapped area[1] is 210,409.15 ha. It includes about 687.95 ha of Box Elder County that is considered in this study. The total pachic soils in the area are 48,495 ha or 23.038 percent and cumulic soils are 2610.2 ha or 1.24 percent of the mapped area. Therefore, soils with thick mollic epipedon constitute 24.278 percent of total mapped area. Twenty-one pachic soils series, 48 pachic map units, 5 cumulic soil series and 10 cumulic map units have been identified in Cache County (Erickson, et al., 1974). For the purpose of this study four map units, Avon (0-3 percent slope), Hendricks (10-20 percent slope), Mendon (0-3 percent slope), and Nebeker (10-25 percent slope) from pachic subgroups

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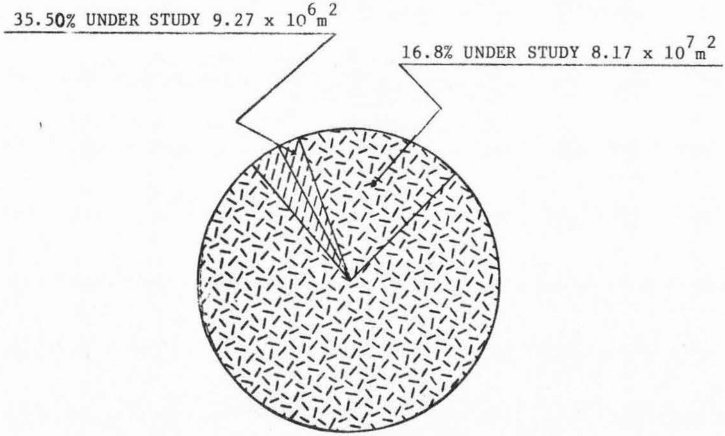
[1]The area of Cache National Forest, 93,076 ha is excluded.

and Winn from cumulic subgroups have been selected. The classification and area of these soils are shown in Table 1. Figure 1 also shows the relative proportions of the cumulic and pachic pedons under study. The reasons for this selection are: (1) The selected soils cover larger areas compared to other soil series in Cache County. (2) The selected soils are developed on different land forms, slopes, elevations, and parent materials. (3) The selected soils are distributed throughout Cache County (Figure 2).

Samples from the significant delineations of the above map units were observed in the field in order to find: (1) The accuracy of each map unit, (2) the inclusions, misclassified and not classified pedons and their proportions, and (3) the estimated thickness of the epipedons.

Table 1. Classification and areas of the soils under study in Cache County.

Soil series	Map unit	Symbol	Classification	Area ha	Percent of total pachic (cumulic) area	Percent of total mapped area
Avon	Silty clay loam 0-3% slope	ArA	Calcic Pachic Argixerolls, fine montmorillonitic, mesic	1392.1	2.87	0.66
Hendricks	Silt loam 10-20% slope	HdD	Pachic Argixerolls, fine-silty mixed, mesic	944.9	1.95	0.44
Mendon	Silt loam 0-3% slope	MeA	Calcic Pachic Argixerolls, fine-silty, mixed, mesic	3969.9	8.19	1.9
Nebeker	Silt loam 10-25% slope	NbE	Pachic, Argixerolls, fine, montmorillonitic, mesic	1861.5	3.84	0.88
Winn	Silt loam	Wn	Cumulic Haplaquoll, fine-loamy, mixed, (calcareous), mesic	926.7	35.50	0.44



TOTAL PACHIC AND CUMULIC SOILS IN THE SURVEY AREA 5.1 x $10^8 m^2$

CUMULIC (2.6 x $10^7 m^2$) or 1.24 percent of total area.

PACHIC (4.8 x $10^8 m^2$) or 23.038 percent of total area

Figure 1. Diagram showing relative proportions of the pedons under study as a percent of the total of pachic and cumulic pedons in the survey area.

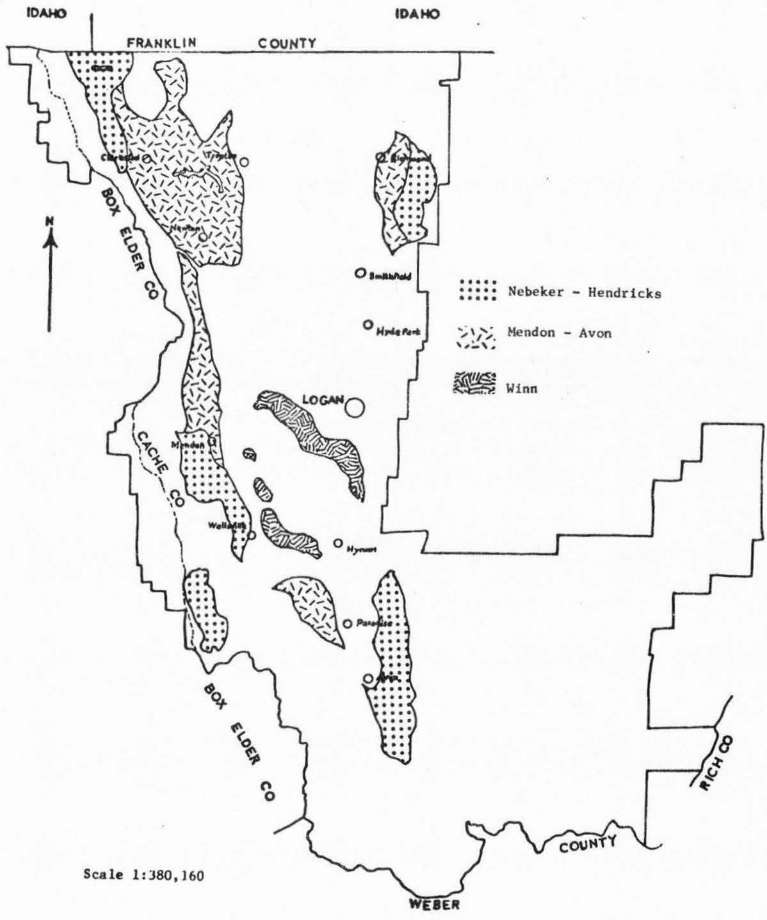


Figure 2. The general distribution of the soils under study in Cache County. (Adopted from Erickson et al., 1974.)

LITERATURE REVIEW

Systems of soil classification

The agricultural chemists (e.g. Liebig) and geologists were the early investigators of soils. Hilgard was one of the first who recognized "observable soil features as distinct from geological phenomenon" (Ablieter 1949, p. 184). The existence of a "systematic regularity and orderliness in the geographic distribution of soils" was first recognized by Dokuchaiev in Russia (Joffe,1936, p. 8). In fact almost all systems of soil classification represent in some form or another the idea of soil forming factors. After recognition of five soil forming factors (climate, vegetation, relief, time, and parent material) by Hilgard and Dokuchaiev, the construction of a soil classification based on individual soil formers or on a coordination of them carried out by many soil scientists; e.g., Glinka, Romann, Marbut, Shaw, and Desigmond (Jenny, 1941). Before the advent of the climatic concept in soil classification, the geologic nature of parent material was taken as the basis for soil classification; e.g., Polynov's system (Jenny, 1941). Thaer (1809-12) also introduced geologic classification of soils and terms such as granite soils and glacial soils (Buol, 1973). Shaw grouped the soils according to the several degrees of maturity and thus represented time "as the most prominent" factor (Jenny, 1961, p. 48). Marbut's geomorphological concept of soil is reflected in the influence of relief in his soil classification system (normal profile vs normal relief). In all studies vegetation is treated as a dependent variable rather than as soil forming factor (Jenny, 1941), but the terms such as "forest soils" show the vegetation concept of soil classification. The realization of the climatic element in soil formation led Lang (1920), Meyer (1926), Shostakovich (1932), Vilensky (1922) to group soils based on climatic information (Jenny 1941). An important change in the model of soil and therefore soil classification was brought into view by Sibirtzev's statement. The classification of soils and only one factor as the basis does not seem to be promising. The genetic soil classification should be based on the internal properties and characteristics of the soil itself. He emphasized climate as the more important soil forming factor and grouped the soils as zonal, azonal and interazonal. He then followed the principles of soil zonality and constructed a soil map of the world (Joffe, 1936). Joffe (1936, p. 62, 148) impressed by the Russian concept of soil classification believed that climatic factors which "are in the main responsible" for the formation of soils and differences in climate "leave their impression on the profile and by these one may differentiate the soil types and classify them."

The soils of the United States were not studied in any extensive manner until after the inauguration of the soil survey (1896). It attained its greatest development under the guidance of C. F. Marbut who published "Soils of the United States" in 1935 (Joffe, 1936). Marbut by placing emphasis upon the soil profile which is the reflection of the factors of soil formation introduced the "most major change in approach in American Soil Survey" (Simonson, 1952, p. 251).

The system of soil classification (based on zonality) was a natural consequence of the knowledge of that time. Although it made possible grouping and mapping of soils, however, lack of precision, proper definition of terms, and considering quantitative aspects of soil showed its inadequacy for the present time (Cline, 1961). Attempts have been made during the last 30 years to establish a more comprehensive system of soil classification. Soil Taxonomy, approved in 1965, is the result of these attempts. This system is the product of basic changes in soil definition. The soils in the old concept that was described by Marbut are considered as a continuum. In Soil Taxonomy soil is considered as a collection of bodies, that is the continuum has been divided into units (pedon and polypedon) that can be treated as a population (Cline, 1961) or in another word pedons are soil entities and polypedon soil individuals (Buol et al., 1973). The new system of soil classification is characterized by the more precise definitions and more emphasis on information about the quantitative compositions of soils. The more fundamental concept of the new system is the definition of pedon as the sampling unit. Kellogg (1963, p. 3) described the pedon as a "three-dimensional body on the surface of the earth that has area, shape and length. Each soil is one of these bodies and which has a range in profiles characteristics limited by our definitions." These bodies are "studied and classified into kinds of soil that are given names."

Soil mapping

"Soil mapping is simply the identification of different soils, the determination of their boundaries, and the delineation of those boundaries on a suitable base map," (Johnson, 1963, p. 31). Dokuchaiev by introducing the first scientific classification of soils developed the methods of soil mapping in the field and soil cartography in the laboratory (Buol, 1973). Before the use of aerial photographs in mapping soils, base maps were made by the plane-table traverse method. This was the only method for plotting soil boundaries. Replacement by aerial photographs resulted not only in more accurate base maps but also in "more accurate and detailed plotting of soil boundaries on the improved base maps," (Ableiter, 1949). Simonson (1952, p. 323) by comparing the early soil maps with modern ones stated that the early soil maps have, simple patterns with individual areas, limited numbers of soil units and smaller scale while the more detailed examination of land and greater number of soil units is represented in the modern maps. Recent advances in laboratory analysis and photogrametric interpretation along with more precise definitions of the soil characteristics provide more scientific approaches toward the precise identification of more detailed delineation of different soil types. At present time phases of the soil series are the most common units used in detailed soil maps. Soil association and undifferentiated soil groups are mostly used in low-intensity survey, (Johnson, 1963).

Soil phases are defined based on the differences in soil profile and external features such as slope, degree of erosion and stoniness (Simonson, 1952). Each kind of soil has a characteristic region of occurrence. It occurs as a number of separate bodies or segments of the continuum within a certain geographic region or regions (Simonson, 1959).

In spite of these recent advances in finding precise defintions for differentiating among the different soils the delineation of the boundaries between soils is not as easy as one might assume. In fact in most cases the variability and complexity among the soils even within a small area are too high to permit an exact delineation of the boundaries. This problem is discussed in most literature dealing with soil mapping. Johnson (1963, p. 214) stated that, "we are for the most part unsuccessful in specifying the natural boundaries of the units." Buol (1973) believes that even with precise definition of soil taxa consistent mapping of corresponding soil bodies is difficult. Nygard and Itole (1949) discussed the problem and concluded that the mechanical limitation of map scale is the main limiting factor in proper mapping of taxonomic units. They also pointed out that soils occupy areas not the points where they are sampled or examined and the samples may not be the proper representative within a given soil area. Cline (1949, p. 88) while establishing basic principles of soil classification reminded: "it is impractical to attempt to deal with all these small units in any system of soil classification or in most practical problems involving use of the land. The range of properties of each is too narrow to be significant, their numbers are too great to allow individual treatment and the area represented is too small to serve as a practical land unit in most units." Kellogg (1963, p. 3) has stated that even on maps at scales of 1:20,000 the boundaries of a single mapping unit do not coincide exactly with that of an individual soil. He also has concluded that "at best the mapping units with single names are approximations of named soil individuals."

All the problems mentioned above make it impractical to make accurate soil maps without portions of the area including other soil bodies. Few studies have been done on the determination of the accuracy of soil maps prepared by different methods. Pomerening and Cline (1953) evaluated the accuracy of soil maps that had been prepared by various methods using aerial photograph interpretations. They indicated that maps prepared by using aerial photo interpretations alone are less accurate than soil maps prepared by using both field identification and delineation, and aerial photo interpretation. They also concluded that increasing complexity of the landscape greatly reduces the accuracy of aerial photo interpretation.

Previous work

Soils of Cache County have been surveyed and classified (Erickson et al., 1974). During this survey 84 soil series were recognized. The mapped area consists of 215 map units including series, complexes and associations. The soils have been classified at Order level as Mollisols (84.5 percent), Alfisols (5.96 percent), Inceptisols (3.58 percent), Entisols (2.38 percent), Vertisols (2.38 percent) and Aridisols (1.2 percent). In spite of the clear dominance of the Mollisol Order in the area, the classification of soils at lower categories (subgroup and family) as reported by Erickson, et al. (1974) show a great deal of variation among the soils of Cache County. The variations reflect a complex combination of the influences of the soil forming factors in the area. Among these factors the influence of climate and geology are perhaps the most responsible for the variations. Differences in elevation between the valley bottom (about 1,000 m) and the mountain peaks (about 3,000 m) has produced changes in climatic regimes mostly in precipitation and temperature. The nonuniform distribution of precipitation and temperature at different elevations of the county is one of the reasons related to the formation of the different soils in the area. Previous studies on the genesis of some of the soil series in the area by Al-taie (1958) on Manila soil series, Southard and Miller (1966) on four soils of Cache National Forest and Rooyani (1976) on McMurdie and Nebeker soil series have revealed that these soils reflect the influence of a wetter climatic condition than present (probably pliestocene or older).

The geology of Cache County reflects also the occurrence of many different types of events, among which the Laramide orogeny, Basin and Range faults and finally the Pleistocene glaciation and formation of the ancient Lake Bonneville are some important ones (Williams, 1948). These events are responsible for the formation of different landforms in the area. The geological history of the area also represents the existence of the different sequences of geologic depositional features. The mountainous areas of the County are mostly covered by paleozoic rock rocks-limestone, quartzite, sandstone, and dolomite are the dominant ones (Williams, 1948). The foothills are dominantly covered by Tertiary Salt Lake and Wasatch formation deposits. Tuff, tuffaceous sandstone and limestone, red sandstone and conglomarate are the main rocks of these deposits. The Lake Bonneville deposits almost covers the interior of Cache Valley (Williams, 1962). These deposits are mostly gravel, sand and fine-texture material. Alluvial fan, flood plain and delta deposits are also sources for the parent materials of the soils in this area. The various geologic deposits of the area are responsible for the development of different types of parent material which lead to the formation of different type of soils.

Such variations in climatic regimes and geologic deposits within a limited area (about 200,000 ha) not only create problems in field observation for detailed classification of soils but also produce different landforms that makes the aerial photo interpretation difficult. The combination of those two factors results in decreasing of accuracy of soil maps.

During this study the accuracy of mapping of five pachic or cumulic soils series was investigated. Increase in complexity of topography, increases the complexity of mapping these kinds of soils. Table 2 shows the general characteristics of parent material and elevation, for the soils under study (Erickson et al., 1974). Al-Amin (1974), during his study of the genesis of Mendon and Parley soil series in Cache County (Utah), concluded that Mendon soil series that had been mapped as Pachic Calcic Argixeroll are not pachic. He tested his statement by making thirty observations in three different locations. He concluded that 48 percent of the Mendon Pedons have an epipedon too thin to qualify as pachic. The Nebeker and the McMurdie soil series are mapped and classified by Erickson et al. (1974) as Pachic Argixeroll and Calcic Pachic Argixeroll respectively, but Rooyani (1976) who studied the genesis of these soils in Cache County has reported none of them as pachic.

Table 2. Parent materials, bedrocks and elevation of soils under study. (Erickson et al., 1974.)

Soil series	Parent material	Bedrock	Elevation (m)
Avon	Mixed lake sediment	Light-colored, tuffaceous sandstone and limestone	1402 -1554.5
Hendricks	Noncalcareous alluvium (old alluvial fans)	Sandstone and quartzite	1463 -1645.9
Mendon	Alluvium and colluvium (lake terraces)	Light-colored tuff, conglomerate, tuffaceous sandstone and limestone	1371 -1554.5
Nebeker	Noncalcareous alluvium	Sandstone quartzite and shale	1554.5-1737.4
Winn	Mixed alluvium	Limestone, sandstone and quartzite	1356.4-1493.5

METHODS AND PROCEDURES

Field Observation

Using the maps prepared by (Erickson,et al., 1974) as the base map with scale of 1:20,000, every significant delineation of map units of the selected soil series was studied in the field. The pedons were studied using auger, shovel, 0.2 N HCl, water and Munsell color book The pedons were selected in each delineation depending on different geomorphologic boundaries, slope, aspect and elevations. The number of pedons studied in each delineation differed depending on the general features of delineations and landscapes. Figure 3 shows the locations of sampling in each delineation. It was impossible to select the pedons by random sampling because of inherent variability of soils and because of the presence of different landscapes. In larger delineations where the soil seemed to be distributed uniformly, the pedons were selected randomly but in smaller delineations all pedons were selected subjectively. Attempts were made to select the pedons on transects with appropriate interval, depending on landforms and continuity of soils. Figure 4 shows a representative model of sampling in one of the delineations. In general, the pedons were selected subjectively and field observations determined the number of samples and type of sampling in each delineation. The total number of samples also could not be estimated prior to the field observation. The point is best described by Nygard-Hole (1949, P. 164): "The number of points of sampling needed cannot be fixed." Considering this point and problems such as: the time needed for proper sampling, obtaining permission from

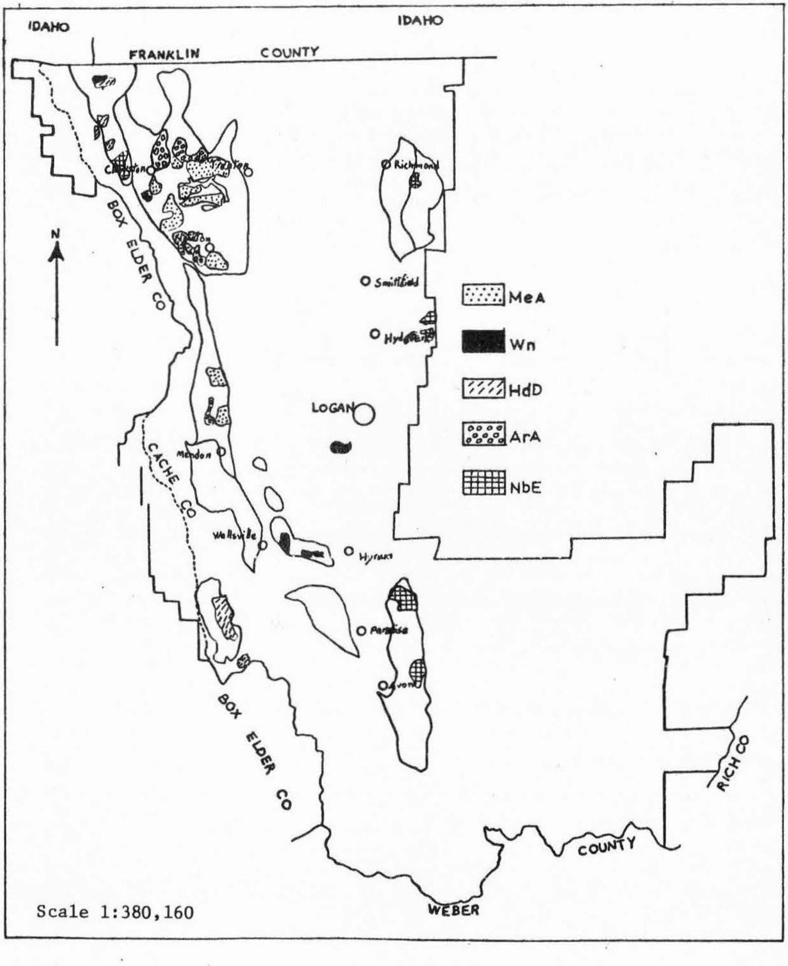


Figure 3. Approximate sampling locations.

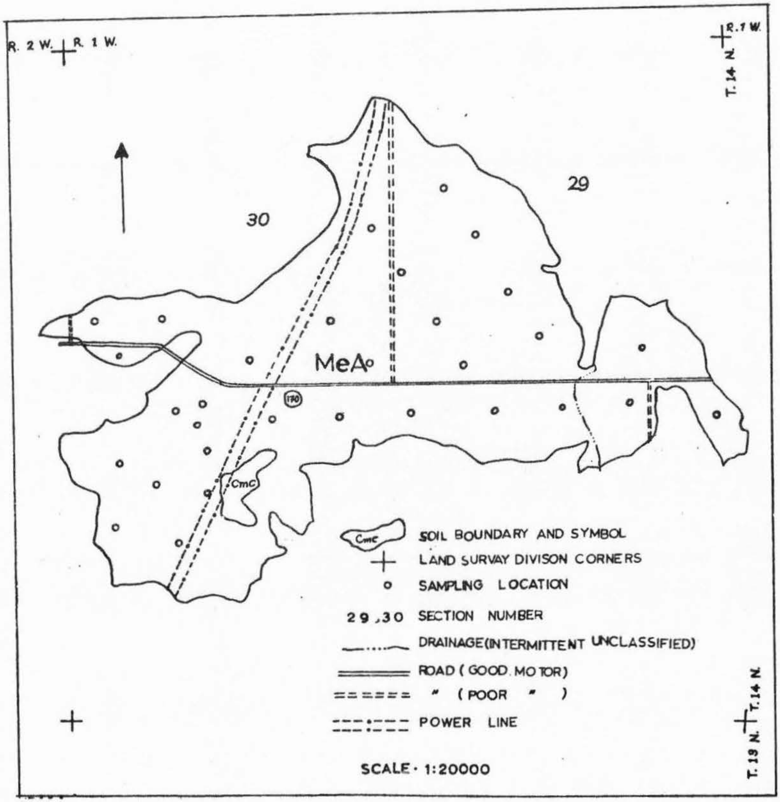


Figure 4. Representative sampling of one delineation of Mendon map unit.

landowners and access to the delineations to be studied, number of personnel, expenses and finally the level of the study, it was suggested that the data of about 400 samples is sufficient for the purpose of the study. This number of samples was split for five soils under study proportional to the area occupied by them as follows:

Mendon	(MeA)	174	Samples
Nebeker	(NbE)	81	Samples
Avon	(ArA)	61	Samples
Hendricks	(HdD)	42	Samples
Winn	(Wn)	41	Samples

All pedons were described for thickness of horizons, color (moist), texture, structure, reaction, and their approximate locations were marked on the maps.

Analysis

After collecting the required data from the field sampling, the pedon descriptions were analyzed in order to determine: (1) the thickness of the mollic epipedon in each sample based on the field observations. For this purpose the definitions of the pachic* or cumulic and mollic epipedon as reported in Soil Taxonomy (Soil Survey Staff 1973) were employed, (2) the number of samples in each map unit whose descriptions fit within the range in characteristics of the respective pedons of the map units reported by Erickson et al. (1974),

*The area of the pedon is considered one square meter.

(3) The number of samples that fit the descriptions of the inclusions of the map units.

The data obtained from these analyses were interpreted statistically.

Statistical interpretations

As mentioned earlier, few statistical studies have been carried out to determine the accuracy of soil mapping. The reasons have been discussed in previous pages. To show the magnitude of the problems in this kind of study, some figures are presented: The total mapped area in Cache County consists of 2.1×10^9 m^2 or pedons.* The total pachic and cumulic soils in the mapped area consits of 4.85×10^8 and 22.6×10^7 pedons, respectively. The total (four pachic and one cumulic) soils under study consist of 8.17×10^7 and 9.27×10^6 pedons, respectively. No defined and (generally) accepted idea is present to demonstrate where the boundaries are between pedons with different characteristics. During this study about 400 samples were described in the field using an auger with a diameter of 8.5 cm. The actual area that has been studied, therefore, is only 2.27 m^2. This small area has been considered to be the representative of an area about 9.09×10^7 m^2 (the area under study). This is the reason why 25 percent inclusions are permitted in each map unit. In other words because of the problems involved we can always expect that each map unit may include up to 25 percent of soils with characteristics different from the named soil of the map unit. Thus for the purpose of this study a

*The area of the pedon is considered one square meter.

75 percent accuracy of the pachic (cumulic) soils in Cache County was based on the assumption that 75 percent of the pedons in each delineation belong to the named soil (Figure 5). Using the Chi square method, the hypothesis was rejected whenever the observed values showed statistically that less than 75 percent of the pedons belong to the named series.

Figure 5. Diagram of desirable maximum amounts of inclusions in a mapping unit. Prepared by James Carley soil scientist (1972). (Ref. SCS Memo. 66-pp. 12-14.)

RESULTS AND DISCUSSIONS

The results from the field observations for each map unit under study are presented first, followed by the statistical interpretations.

Mendon, 0-3 percent slope (MeA)

The distribution of samples taken from MeA map unit in map sheets prepared by Erickson et al. (1974) are presented in Table 3 and the results are summarized in Table 4. Avon, Collinston, Wheelon and Crookston soil series are reported as inclusions for Mendon. The inclusions as identified in the field during this study are Collinston (11.43 percent) and Avon (3.43 percent). The Collinston series have been classified as Typic Calcixerolls by Erickson et al. (1974). These soils are in the same family as Mendon (fine-silty, mixed, mesic). Collinston differs from Mendon in: (1) lack of argillic horizon and (2) lack of thick mollic epipedon. The mollic epipedon in Collinston has a depth of about 39 centimeters which is not deep enough to qualify for pachic. The Avon soil series are very similar to the Mendon. The only difference that can be helpful in distinguishing the two soils under field condition is the finer texture of Avon.

The misclassified soils are those that are similar to the descriptions of Mendon except for the thickness of the mollic epipedon. They differ from the Collinston soils in the lack of abrupt change in color value between the epipedon and the layer beneath it. The samples in this category should be classified as Calcic Argixerolls.

Table 3. Distribution of samples taken from MeA map unit in map sheets.

Sheet No.	No of samples	No. of MeA samples	No. of other samples
32	21	12	9
20	26	13	13
15	60	26	34
19	27	18	9
16	16	8	8
8	12	5	7
7	6	3	3
28	7	1	6
Total	175	86	89

Table 4. Summary of results for MeA map unit.

Category	No. of samples	Percentage
MeA (Mendon map unit)	86	49.14%
Inclusions:		
1. Avon	6	2.43%
2. Collinston	20	11.43%
Misclassified	49	28 %
Not classified	14	8 %
Total	175	100 %

The "not classified" soils are those that are neither MeA nor the reported inclusions. "Not classified" samples can be grouped in two categories: (1) those that have gravelly textures in the surface layers and (2) those that have a very dark chroma and value to a depth of about 120 centimeters. The first group of soils were mapped on sheet No. 15 and the second group on sheet No. 7.

The thickness of the mollic epipedons of samples of MeA map units including inclusions, misclassified and "not classified" are presented in Table 5. The calculated average thickness of the (pachic) mollic epipedon for 86 pedons of MeA is 64.3 centimeters and the average thickness of 165 samples (pachic or not pachic) is calculated as 49.6 centimeters. The other 10 samples are excluded because of very thick

Table 5. The thickness of mollic epipedons in samples from MeA map unit.

No.	Thickness (cm)	No.	Thickness (cm)	No.	Thickness (cm)	No.	Thickness (cm)
1	30.5	26	20.0	51	71.0*	76	46.0
2	30.5	27	20.0	52	20.0	77	46.0
3	48.0	28	38.0	53	20.0	78	15.0
4	48.0	29	38.0	54	25.5	79	51.0*
5	89.0*	30	38.0	55	25.5	80	51.0*
6	89.0*	31	38.0	56	25.5	81	66.0*
7	61.0*	32	20.0	57	25.5	82	66.0*
8	61.0*	33	20.0	58	71.0*	83	66.0*
9	61.0*	34	20.0	59	71.0*	84	66.0*
10	61.0*	35	20.0	60	71.0*	85	61.0*
11	66.0*	36	25.5	61	40.5	86	61.0*
12	66.0*	37	25.5	62	40.5	87	61.0*
13	66.0*	38	56.0*	63	40.5	88	61.0*
14	35.5	39	56.0*	64	25.5	89	43.0
15	35.5	40	35.5	65	35.5	90	43.0
16	35.5	41	71.0*	66	35.5	91	38.0
17	40.5	42	71.0*	67	38.0	92	38.0
18	40.5	43	71.0*	68	38.0	93	71.0*
19	76.0*	44	71.0*	69	38.0	94	71.0*
20	76.0*	45	71.0*	70	51.0*	95	71.0*
21	61.0*	46	71.0*	71	51.0*	96	51.0*
22	20.0	47	51.0*	72	51.0*	97	51.0*
23	71.0*	48	51.0*	73	51.0*	98	51.0*
24	46.0	49	51.0*	74	51.0*	99	51.0*
25	35.5	50	71.0*	75	51.0*	100	51.0*

* Samples with epipedon thicker than 50 centimeters (pachic).

Table 5. (Continued)

No.	Thickness (cm)	No.	Thickness (cm)	No.	Thickness (cm)
101	30.5	126	63.5*	151	122.0*
102	15.0	127	63.5*	152	30.5
103	61.0*	128	20.0	153	30.5
104	61.0*	129	73.5*	154	35.5
105	35.5	130	25.5	155	63.5*
106	35.5	131	76.0*	156	91.5*
107	33.0	132	20.0	157	91.5*
108	33.0	133	20.0	158	25.5
109	33.0	134	20.0	159	66.0*
110	76.0*	135	25.5	160	66.0*
111	76.0*	136	25.5	161	66.0*
112	63.5*	137	30.5	162	66.0*
113	63.5*	138	30.5	163	73.5*
114	61.0*	139	56.0*	164	73.5*
115	61.0*	140	56.0*	165	73.5*
116	56.0*	141	56.0*	166	114.0+
117	56.0*	142	56.0*	167	114.0+
118	53.0*	143	30.5	168	114.0+
119	53.0*	144	30.5	169	122.0+
120	51.0*	145	51.0*	170	101.5+
121	51.0*	146	81.0*	171	101.5+
122	30.5	147	81.0*	172	101.5+
123	30.5	148	35.5	173	127.0+
124	43.0	149	35.5	174	127.0+
125	43.0	150	61.0*	175	101.5+

*Samples with epipedon thicker than 50 centimeters (pachic).
+Samples with a very thick mollic epipedon.

mollic epipedons. The calculated median for the thickness of 175 samples (pachic or not pachic) is 88th item on the array. Counting down the frequencies in Table 6 we find the 88th item to be 51. Thus the median; (M) = 51.0 centimeters considering the data of Table 6, there is only one absolute mode, 51.0 centimeters, since this value occurs 19 times and no other value occurs that frequently. Figure 6 shows the frequency histogram plotted from Table 7.

The data obtained from field observations are interpreted statistically and the summary is presented in Table 6. According to these results the data showed that less than 75 percent of the samples taken from MeA map unit have the characteristics required for the Mendon series. In fact only 49 percent of the samples with confidence interval of 42-56 percent have the required characteristics of Mendon.

HO: proportion of Mendon = .75

HA: proportion of Mendon ≠ .75

Reject HO: if $\chi^2 > \chi^2_{(k-1)(1-\alpha)}$ where $\begin{cases} k = 2 \\ \alpha = 0.05 \end{cases}$

$\chi^2 = 62.40$

$\chi^2_{(1)(0.95)} = 3.84$

Since the calculated chi-square value is more than the critical value we reject the hypothesis that MeA proportion is equal to 75. By inspection this proportion is significantly less than 75 percent.

The confidence interval for above proportion is as follows:

$$\hat{p} \pm Z_{\frac{\alpha}{2}} \sqrt{\frac{\hat{p}\hat{q}}{n}}$$

$\hat{p} = \frac{86}{175} = .4914$ where $\begin{cases} \alpha = 0.05 \\ \text{The table value for } Z_{\frac{0.05}{2}} = 1.96 \end{cases}$

$\hat{q} = 1 - .4914 = .5086$

Table 6. Frequency distribution for data of Table 5. (MeA)

Epipedon thickness (cm)	Frequency
15	2
20	12
25.5	11
30.5	11
33.0	3
35.5	12
38.0	9
40.5	5
43.0	4
46.0	3
48.0	2
51.0	19
53.0	2
56.0	8
61.0	14
63.5	5
66.0	11
71.0	15
73.5	4
76.0	5
81.0	2
89.0	2
91.5	2
101.5	4
114.0	3
122.0	2
127.0	2
Total	175

Table 7. Frequency distribution (using class intervals) for data of Table 5. (MeA)

Epipedon thickness (cm)	Frequency in specified class interval
$10 < x \leq 20$	15
$20 < x \leq 30$	11
$30 < x \leq 40$	35
$40 < x \leq 50$	14
$50 < x \leq 60$	29
$60 < x \leq 70$	30
$70 < x \leq 80$	24
$80 < x \leq 90$	4
$90 < x \leq 100$	2
$100 < x \leq$	11
Total	175

Table 8. The summary of chi-square (goodness of fit) analysis for Mendon.

Classification	Observed	Expected	$\frac{(O-E)^2}{E}$
Mendon	$O_1 = 86$	$E_1 = 175\ (\frac{75}{100}) = 131.25$	$\frac{(86 - 131.25)^2}{131.25} = 15.60$
Not Mendon	$O_2 = 89$	$E_2 = 175 - 131.25 = 43.75$	$\frac{(89 - 43.75)^2}{43.75} = 46.80$
Total	175	175	$\chi^2 = \Sigma\frac{(O-E)^2}{E} = 62.40$

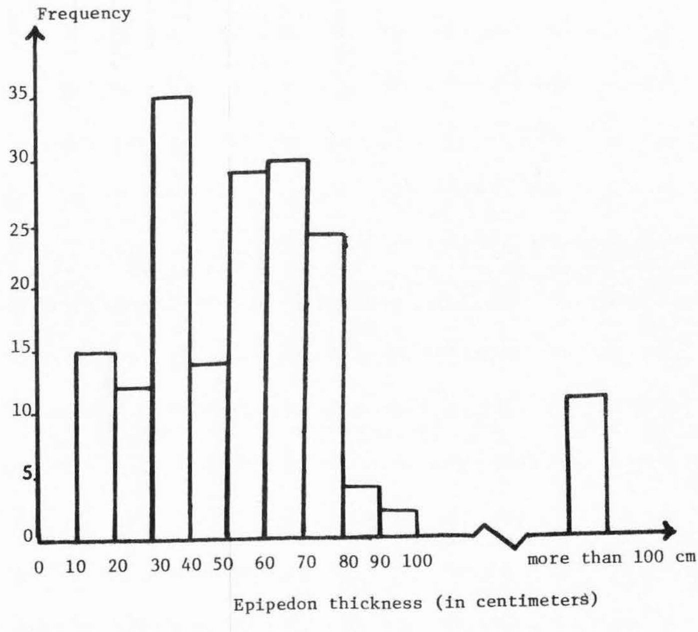


Figure 6. Frequency histogram plotted from Table 7. (MeA)

$$0.4014 \pm 1.96 \sqrt{\frac{(.4914)(.5086)}{175}}$$

$$\boxed{.42 < \hat{p} < .56}$$

Therefore the proportion of Mendon is somewhere between 0.42 and 0.56 with 0.95 confidence.

Nebeker 10-25 percent slope (NbE)

The distribution of samples taken from NbE map unit are presented in Table 9. The results obtained from NbE map unit are presented in Table 10, Hendricks, and Sterling soil series are reported by Erickson et al. (1974) as inclusions with Nebeker. According to the data of Table 10, no inclusions were identified in all 81 samples of NbE map unit and the thickness of only 12 samples was less than 50 centimeters. These 12 samples are in the category of misclassified pedons. Most of the misclassified samples of NbE pedon were identified in sheet No. 26. the suggested classification name for these pedons is Typic Argixerolls.

The summary of statistical interpretation of data obtained from field observation is presented in Table 11. According to these results the data showed that more than 75 percent of the samples taken from NbE map unit have the characteristics required for Nebeker series. In fact 85 percent of the samples with confidence interval of 77-93 percent have the required characteristics of Nebeker.

Table 9. Distribution of samples taken from NbE map unit in map sheets.

Sheet No.	No. of samples	No. of NbE samples	No. of other samples
51	19	17	2
26	24	16	8
57	13	13	0
7	9	9	0
18	16	14	2
Total	81	69	12

Table 10. Summary of results for NbE map unit.

Category	No. of samples	Percentage
NbE (Nebeker map unit)	69	85.2%
Inclusion	0	0 %
Misclassified	12	14.8%
Not classified	0	0 %
Total	81	100 %

Table 11. The summary of chi-square (goodness of fit) analysis for Nebeker.

Classification	Observed	Expected	$\frac{(O-E)^2}{E}$
Nebeker	$O_1 = 69$	$E_1 = 81(\frac{75}{100}) = 60.75$	1.12
Not Nebeker	$O_2 = 12$	$E_2 = 81 - 60.75 = 20.25$	3.36
Total	81	81	$\chi^2 = \Sigma\frac{(O-E)^2}{E} = 4.48$

HO: proportion of Nebeker = .75

HA: proportion of Nebeker $\neq$ .75

Reject if $\chi^2 > \chi^2_{(k-1)(1-\alpha)}$ where $\{ \begin{matrix} k = 2 \\ \alpha = 0.05 \end{matrix}$

$\chi^2 = 4.48$

$\chi^2_{(1)(.95)} = 3.84$

Since the calculated chi-square value is more than critical value we reject the hypothesis of NbE proportion is equal 75. By inspection this proportion is about 85 percent.

The confidence interval for above propoetion is as follows:

$\hat{p} \pm Z_{\frac{\alpha}{2}} \sqrt{\frac{\hat{p}\hat{q}}{n}}$ where $\{ \begin{matrix} \alpha = 0.05 \\ \text{The table value for } Z_{\frac{0.05}{2}} = 1.96 \end{matrix}$

$\hat{p} = \frac{69}{81} = .85$

$\hat{q} = 1 - .85 = .15$

$0.85 \pm 1.96 \sqrt{\frac{(.85)(.15)}{81}}$ $\boxed{.77 < \hat{p} < .93}$

Therefore with .95 confidence the proportion of Nebeker is somewhere between .77 and .93.

Avon 0-3 percent slope (ArA).

The distribution of samples taken from ArA map unit are presented in Table 12. The results obtained from ArA map unit are presented in Table 13. Mendon, Wheelon and Collinston soil series are reported by Erickson et al. (1974) as inclusions for Avon. According to the data of Table 13 no inclusion was identified in all 61 samples of ArA map unit and the thickness of only five samples was less than 50 centimeters. These five samples are in the category of misclassified pedons. All of the five misclassified samples of ArA pedon were identified in sheet No. 7. The suggested classification name for these pedons is Calcic Argixerolls. The thickness of the epipedon of 43 samples of Avon series is presented in Table 14. According to this Table the average thickness of the pachic epipedons for 47 samples of ArA, is calculated as 72.63 centimeters and the average thickness of the epipedons for 52 samples (including both pachic and not pachic pedons) is calculated as 69.5 centimeters. The other nine samples are excluded because of a very thick mollic epipedon.

The calculated median (M) for the thickness of 61 samples (all samples pachic or not pachic) is 31st observation in the array. Counting down the frequencies in Table 15, we find the 31st item to be 68.5. Thus M = 68.5 centimeters. Considering the data of Table 15 we see there is only one absolute mode, 68.5 centimeters, since this value occurs 16 times and no other value occurs that frequently. Figure 7 shows the frequency Histogram plotted from Table 16.

The data obtained from field observations are interpreted statistically and the summary is presented in Table 17. According to

Table 12. Distribution of samples taken from ArA map unit in map sheets.

Sheet No.	No. of samples	No. of ArA samples	No. of other samples
7	37	32	5
19	3	3	0
20	3	3	0
28	1	1	0
32	7	7	0
8	7	7	0
15	3	3	0
Total	61	56	5

Table 13. Summary of results for ArA map unit.

Category	No. of samples	Percentage
ArA (Avon map unit)	56	91.8%
Inclusions	0	0 %
Missclassified	5	8.2%
Not classified	0	0 %
Total	61	100 %

Table 14. The thickness of mollic epipedons in samples from ArA map unit.

No.	Thickness (cm)	No.	Thickness (cm)	No.	Thickness (cm)
1	68.5	21	51.0	41	127.0
2	68.5	22	68.5	42	101.5
3	68.5	23	68.5	43	101.5
4	68.5	24	68.5	44	63.5
5	68.5	25	53.0	45	63.5
6	68.5	26	53.0	46	58.0
7	68.5	27	68.5	47	58.0
8	68.5	28	68.5	48	58.0
9	68.5	29	76.0	49	58.0
10	63.5	30	76.0	50	58.0
11	63.5	31	76.0	51	114.0
12	63.5	32	46.0*	52	114.0
13	58.5	33	46.0*	53	101.5+
14	30.5*	34	46.0*	54	101.5+
15	30.5*	35	68.5	55	101.5+
16	63.5	36	68.5	56	101.5+
17	63.5	37	81.0	57	101.5+
18	63.5	38	81.0	58	101.5+
19	51.0	39	127.0	59	101.5+
20	51.0	40	127.0	60	101.5+
				61	101.5+

*Samples with epipedon less than 50 centimeters (not pachic).
+Samples with a very thick mollic epipedon.

Table 15. Frequency distribution for data of Table 14. (ArA)

Epipedon thickness (cm)	Frequency
30.5	2
46.0	3
51.0	3
53.0	2
58.0	5
58.5	1
63.5	8
68.5	16
76.0	3
81.0	2
101.5	2
114.0	2
127.0	3
101.5+	9
Total	61

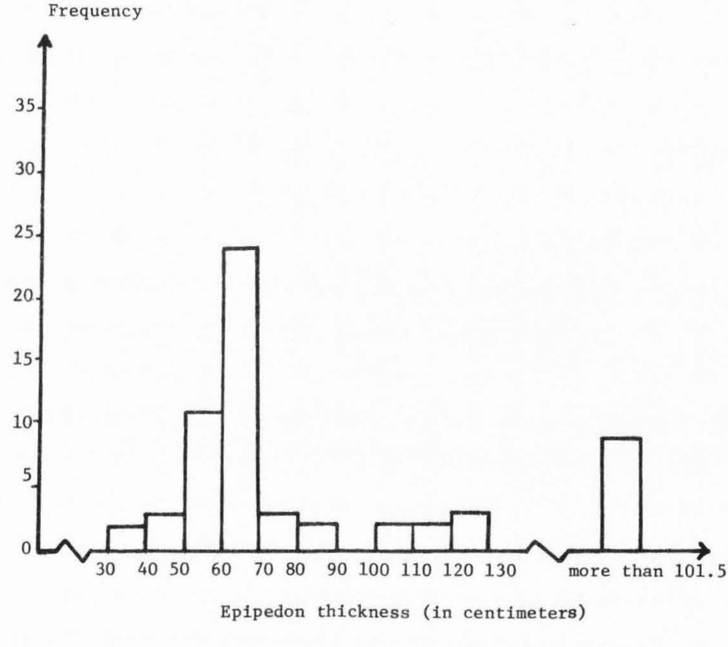


Figure 7. Frequency histogram plotted from Table 16. (ArA)

Table 16 . Frequency distribution (using class intervals) for data of Table 15. (ArA)

Epipedon thickness (cm)	Frequency (specified class interval)
30 $< x \leq$ 40	2
40 $< x \leq$ 50	3
50 $< x \leq$ 60	11
60 $< x \leq$ 70	24
70 $< x \leq$ 80	3
80 $< x \leq$ 90	2
90 $< x \leq$ 100	0
100 $< x \leq$ 110	2
110 $< x \leq$ 120	2
120 $< x \leq$ 130	3
101.5 $< x$	9
Total	61

Table 17. The summary of chi-square (goodness of fit) for Avon.

Classification	Observed	Expected	$\frac{(O-E)^2}{E}$
Avon	$O_1 = 56$	$E_1 = 45.75$	2.296
Not Avon	$O_2 = 5$	$E_2 = 15.25$	6.889
Total	61	61	$\chi^2 = \Sigma \frac{(O-E)^2}{E} = 9.185$

These results the data showed that more than 75 percent of the samples taken from ArA map unit have the characteristics required for Avon series. In fact 92 percent of the samples with confidence interval of 85-99 percent have the required characteristics of Avon.

HO: proportion of Avon = .75

HA: proportion of Avon ≠ .75

$\chi^2 = 9.185$

$\chi^2_{(1)(.95)} = 3.84$

Since the calculated chi-square value is more than critical value we reject the hypothesis of ArA proportion is equal 75. By inspection this proportion is about 92 percent.

The confidence interval for above proportion is as follows:

$\hat{p} \pm Z_{\frac{\alpha}{2}} \quad \frac{\hat{p}\hat{q}}{n}$ where $\{ \alpha = 0.05$; The table value for $Z_{\frac{0.05}{2}} = 1.96$

$\hat{p} = \frac{56}{61} = .92$

$\hat{q} = 1 - .92 = 0.08$

$.92 \pm 1.96 \sqrt{\frac{(.92)(0.08)}{61}}$ $\boxed{.85 < \hat{p} < .99}$

Hendricks 10-20 percent slope (HdD)

The distribution of the samples taken from Hendricks map unit are presented in Table 18 and the results are summarized in Table 19. Nebeker, Crowshaw, Ricks and Sterling soil series are reported by Erickson et al. (1974) as inclusions for Hendricks. According to these data only 19 samples (45.2 percent) of the total 42 samples have characteristics similar to the descriptive pedon of the map unit. Two samples (4.8 percent) have characteristics similar to the Nebeker soil series. These two are in inclusion category. The only difference between the Nebeker and Hendricks soils series as reported by Erickson et al., is the higher clay content in argillic horizon of the Nebeker soil. The other characteristics including color, depth of argillic horizon, and surface texture are very close together. In most cases the two soils have apparently developed in the same geologic and geographic locations. Sixteen and seven-tenths percent of samples have characteristics very similar to the HdD except for the thickness of the mollic epipedon. These samples are in the misclassified category. It is suggested that soils in this category be classifed as Typic Argixerolls.

Thirty-three and three tenths percent of samples have characteristics different from the HdD. These soils are in not-classified category. These soils occurred mostly in sheets 55, 49 and 6. Some of these soils have gravelly subsoil and some are strongly calcareous in the solum. Four of these pedons should be classified as Xerothents but the other 10 are Mollisols.

Table 18. Distribution of samples taken from HdD map unit in map sheets.

Sheet No.	No of samples	No. of HdD samples	No. of other samples
6	10	5	5
1	7	2	5
55	9	6	3
49	16	6	10
Total	42	19	23

Table 19. Summary of results for HdD map unit.

Category	No. of samples	Percentage
HdD (Hendricks map unit)	19	45.2%
Inclusions:		
Nebeker	2	4.8%
Misclassified	7	16.7%
Not classified	14	33.3%
Total	42	100 %

The statistical interpretation of the data obtained from field observation and the summary is presented in Table 20. According to these results the data showed that less than 75 percent of the samples taken from HdD map unit have not the characteristics required for Hendricks series. In fact only 45 percent of the samples with confidence interval of 30-60 percent have the required characteristics of Hendricks.

Table 20. The summary of chi-square (goodenss of fit) analysis for Hendricks.

Classification	Obs.	Exp,	$\frac{(O-E)^2}{E}$
Hendricks	$O_1 = 19$	$E_1 = 31.5$	4.96
Not Hendricks	$O_2 = 23$	$E_2 = 10.5$	14.88
Total	42	42	$\chi^2 = \Sigma\frac{(O-E)^2}{E} = 19.84$

HO: proportion of Hendricks = .75

HA: proportion of Hendricks $\neq$ .75

Reject HO: if $\chi^2 > \chi^2_{(k-1)(1-\alpha)}$ where $\{ K = 2, \alpha = 0.05$

$\chi^2 = 19.84$

$\chi^2_{(1)(.95)} = 3.84$

Since the calculated chi-square value is more than critical value we reject the hypothesis of HdD proportion is equal 75. By inspection this proportion is about 45 percent. The confidence interval for above portion is as follows:

$$\hat{p} \pm A_{\frac{\alpha}{2}} \quad \frac{\hat{p}\hat{q}}{n}$$

$$\hat{p} = \frac{19}{42} = .45$$

$$\hat{q} = 1 - .45 = .55$$

$$.45 \pm 19.6 \sqrt{\frac{(.45)(.55)}{42}} \quad \text{where } \begin{cases} \alpha = 0.05 \\ \text{The table value for } Z_{\frac{0.05}{2}} = 1.96 \end{cases}$$

$$\boxed{.30 < \hat{p} < .60}$$

Therefore the proportion of Hendricks is somewhere between 0.30 and 0.60 with 0.95 confidence.

Winn (Wn)

Table 21 represents the distribution of 41 samples taken from Wn map unit in map sheets prepared by Erickson et al. (1974). Table 22 shows the analysis of the data obtained from the field observation. Provo (gravelly loam) and Kirkham soil series are reported by Erickson et al. (1974) as inclusions for Winn. According to this Table among 41 samples taken from the Sn map unit 28 samples (68.3 percent) have characteristics that fit with the respresentative pedon as described by Erickson et al. (1974).

Seven samples (17.1 percent) were identified as misclassified whose characteristics are very similar to the representative pedon except for the thickness of the mollic epipedon which is less than 50 centimeters. All of the misclassified samples were identified in sheet No. 15. The suggested classification name for these pedons is Typic Haplaquolls fine-loamy, mixed (calcareous), mesic.

Table 21. Distribution of samples taken from Wn map unit in map sheets.

Sheet No.	No. of samples	No. of Wn samples	No. of other samples
33	15	8	7
1	4	4	0
43	4	4	0
42	18	12	6
Total	41	28	13

Table 22. Summary of results for Wn map unit.

Category	No. of samples	Percentage
Wn (Winn map unit)	28	68.3%
Inclusions:		
Kirkham series	6	14.6%
Misclassified	7	17.1%
Not classified	0	0 %
Total	41	100 %

Six samples (14.6 percent) were also identified as inclusions of Wn map unit. These pedons are characterized by (1) shallow epipedon (not thicker than 25 centimeters), (2) strongly calcareous epipedon, (3) a slight increase in clay content in 8 horizons. The characteristics of these inclusions are very similar to Kirkham series which have been classified Fluvaquentic Haplustolls fine-silty, mixed, mesic by Erickson et al. (1974).

The data in Table 23 shows the thickness of the epipedon for 41 samples from Wn map unit. The average thickness of the epipedons for 35 samples (including both pachic and not pachic pedon) is calculated as 80.5 centimeters. The other six samples are excluded because of very thick mollic epipedon. The calculated median (M) for the thickness of 41 samples (all samples) is 21st observation in the array. Counting down the frequencies in Table 24 we find the 21st item to be 86.9. Thus M = 86.0 centimeters. Considering the data of Tables 24 there are only one absolute mode, 46.0 centimeters, since this value occurs seven times and no other value occurs that frequently. Figure 8 shows the frequency histogram plotted from Table 25.

The data obtained from field observations are interpreted statistically and the summary is presented in Table 26. According to these results the data showed that about 75 percent of the samples taken from Wn map unit have the characteristics required for Winn series. In fact 68 percent of the samples with confidence interval of 54-82 percent have the required characteristics of Winn.

Table 23. The thickness of mollic epipedon in samples from Wn map unit.

No.	Thickness (cm)	No.	Thickness (cm)
1	46.0	22	140.0+
2	46.0	23	140.0+
3	46.0	24	91.5*
4	89.0*	25	91.5*
5	86.0*	26	86.0*
6	86.0*	27	86.0*
7	91.5*	28	46.0
8	101.5*	29	46.0
9	56.0*	30	46.0
10	89.0*	31	46.0
11	63.5*	32	30.5
12	63.5*	33	30.5
13	63.5*	34	30.5
14	89.0*	35	20.0
15	89.0*	36	20.0
16	89.0*	37	20.0
17	89.0*	38	101.5+
18	56.0*	39	101.5+
19	56.0*	40	101.5+
20	56.0*	41	101.5+
21	101.5*		

*Samples with epipedon more than 50 centimeters (pachic).
+Samples with a very thick mollic epipedon.

Table 24. Frequency distribution for data of Table 23. (Wn)

Epipedon thickness (cm)	Frequency
20.0	3
30.5	3
46.0	7
56.0	4
63.5	3
86.0	4
89.0	6
91.5	3
101.5	2
101.5+	4
140.0+	2
Total	41

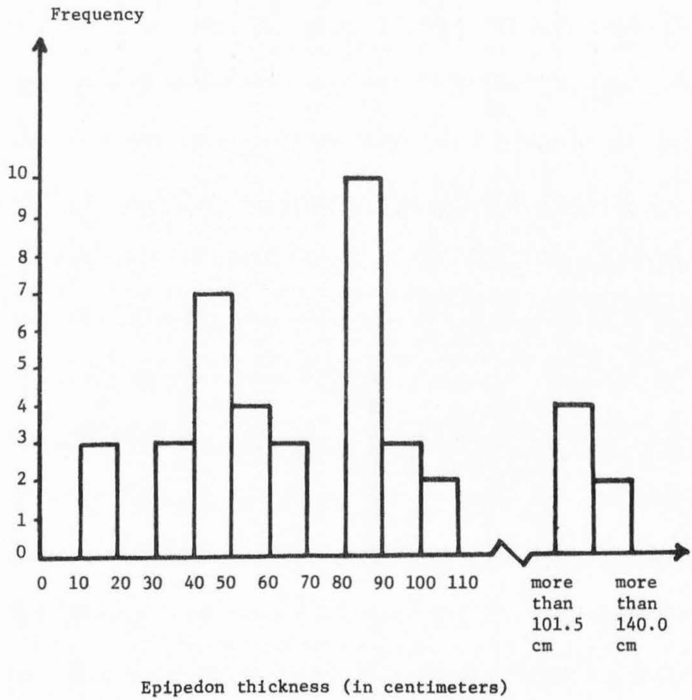


Figure 8. Frequency histogram plotted from Table 25. (Wn)

Table 25. Frequency distribution (using class interval) for data of Table 23. (Wn)

Epipedon thickness (cm)	Frequency in specified class intervals
$10 < x \leq 20$	3
$20 < x \leq 30$	0
$30 < x \leq 40$	3
$40 < x \leq 50$	7
$50 < x \leq 60$	4
$60 < x \leq 70$	3
$70 < x \leq 80$	0
$80 < x \leq 90$	10
$90 < x \leq 100$	3
$100 < x \leq 110$	2
$101.5 < x$	4
$140.0 < x$	2
Total	41

Table 26. The summary of Chi-square (goodness of fit) analysis for Winn.

Classification	Observed	Expected	$\frac{(O-E)^2}{E}$
Winn	$28 = O_1$	$30.75 = E_1$	.246
Not Winn	$13 = O_2$	$10.25 = E_2$	.738
Total	41	41	$\chi^2 = \Sigma \frac{(O-E)^2}{E} = 0.984$

HO: proportion of Winn = .75

HA: proportion of Winn ≠ .75

Reject 40 if $\chi^2 > \chi^2_{(k-1)(1-\alpha)}$ where $\begin{cases} k = 2 \\ \alpha = 0.05 \end{cases}$

$\chi^2 = 0.984$

$\chi^2_{(1)(.95)} = 3.84$

Since the calculated chi-square value is less than critical value we fail to reject the hypothesis of Wn proportion is equal 75. By inspection this proportion is about 68 percent.

The confidence interval for above proportion is as follows:

$\hat{p} \pm Z_{\frac{\alpha}{2}} \sqrt{\frac{\hat{p}\hat{q}}{n}}$

$\hat{p} = \frac{28}{41} = .683$ 0.825

$\hat{q} = 1 - .683 = .317$ 0.541

$.683 \pm 1.96 \sqrt{\frac{(.683)(.317)}{41}}$ where $\begin{cases} \alpha = 0.05 \\ \text{The table value for } Z_{\frac{\alpha}{2}} = 1.96 \end{cases}$

$0.541 < \hat{P} < 0.825$

SUMMARY AND CONCLUSION

The accuracy of certain map units in Cache County was studied through field investigations and statistical interpretation. The soil maps that were used as the basis for this study have been prepared by Erickson et al. (1974) at the scale of 1:20,000.

Among the 215 map units that were recognized in Cache County five map units which include almost 52.3 percent of the pachic and cumulic soils in the survey area were selected for this study. These are: Mendon (0-3 percent slope), Nebeker (10-25 percent slope), Avon (0-3 percent slope), Hendricks (10-20 percent slope) and Winn. These 5 soils cover large areas when compared to other soil series and they are distributed throughout the county. All these map units have been recognized as pachic and cumulic soils by Erickson et al. (1974). The thickness of the epipedon was therefore selected as the principal criterion for determination of the accuracy of the map units.

About 400 samples from the major delineations (40: 16 for Mendon, 7 for Nebeker, 9 for Avon, 5 for Hendricks and 4 for Winn) of these map units were studied in field. Color, thickness of epipedon, lime, and texture for each sample was described in the field and the necessary data were collected and interpreted statistically in order to find: (1) the accuracy of each map unit, (2) the inclusions, misclassified and not classified pedons and their proportion, and (3) the estimated thickness of the epipedons.

Statistical interpretations were conducted by using the chi-square method. The hypothesis for the accuracy of the map units was established based on the expectation that 75 percent of the pedons have been mapped accurately. The hypothesis was therefore rejected whenever the observed values showed statistically that less than 75 percent of the studied pedons were not mapped accurately.

The results and interpretations of the collected data showed:

1. Statistically only 42-56 percent of the samples taken from Mendon map unit (MeA) had the characteristics required for Mendon series. This value is less than 75 which is the critical value for the map units by definition. It was concluded therefore that with the available data the Mendon series have not been mapped correctly. The MeA delineations in areas under study usually occur in areas with little variation in topography. This is especially true in delineations which include most of the inclusions and misclassified pedons (for example sheet No. 15). Since the climatic condititions for these delineations should not be highly variable, it is apparently the influence of the parent material which causes the variation in soil properties within these delineations. The difference in lime content (a property of parent material) and variation in depth to the lime zone is probably the reason for the poor accuracy in the MeA map unit. Since the direct influence of lime content can not be detected through aerial photo interpretations it appears to be very difficult to delineate accurately the boundaries between soils with varying depths to lime concentrations. The data also revealed that the average

thickness of the epipedon for all Mendon samples is 49.6 centimeters. The median and mode are both 51 centimeters. These values suggest that the thickness of the epipedon of the Mendon is generally somewhere around 50 centimeters which is the critical value for pachic epipedon. Any slight and geographically limited differences in topography, moisture regime or lime content of parent material can produce a change in color sufficient to lower the epipedon thickness to less than the 50 centimeters necessary for pachic and therefore changes the classification name of the map unit at the Subgroup level. If a lower value is considered for the pachic epipedon (about 48 centimeters) which apparently does not influence the practical use of the soil then the accuracy of MeA map unit will increase to more than 75 percent. The misclassified pedons of the Mendon series had mostly characteristics required for Calcic Argixerolls at the Subgroup level. The occurrence of these pedons and pachic pedons were such that a complex map unit may not be used, while an undifferentiated group may be suggested for the mapping of Mendon soils. We may generalize these statements to other map units of Mendon (MeB and MeC) because in these cases the variations in slopes will probably also decrease the accuracy of mapping by increasing the variability of epipedon thickness.

2. Among the samples taken from Nebeker series, 77-93 percent had characteristics which fit the requirements of the representative pedon of the series. According to the present data the Nebeker series (NbE map unit) was mapped correctly. Field observation showed that the pachic epipedons of the Nebeker pedons were not formed as a result of deposition of materials from higher elevations while the formation in

place may be responsible for the thickening of the epipedon. The misclassified pedons of this map unit have characteristics similar to the representative pedon except for the thickness. These pedons should be named Typic Argixerolls. These pedons were mapped mostly in sheet No. 26 but their proportion is too small to permit them to be delineated separately from the pachic pedons.

3. Statistical interpretation showed that the 85-99 percent of the samples taken from Avon series (ArA) had the characteristics required for the ArA map unit. According to the present data these values suggest that the Avon series were mapped correctly. The average thickness of the epipedon is 69.5 centimeters with the median and mode of 68.5 centimeters. The misclassified pedons as recognized in ArA map unit occurred mostly in sheet No. 7. As reasoned earlier the depth of the epipedon in this area is not enough to qualify for pachic, it is therefore suggested that these pedons be classified as Calcic Argixerolls. The thickness of the epipedon in other areas for Avon was much deeper than 50 centimeters. Particularly field observation showed that the thickness of epipedons in ArA map units increases whenever the delineation were surrounded by areas of higher elevations. This suggest that the thickening of the mollic epipedon is probably the result of the accumulation of the materials from the surrounding hills, or the epipedon may be classified as cumulic rather than pachic at the subgroup level in most cases. Since the topographic feature of the area is one of the major factors determining the thickness of the epipedon in ArA delineations, it is possible in some cases to put the boundary between the cumulic and misclassified

soils of ArA pedons. Field observation also revealed that in the samples under study the surface layers (A and B, horizon) responded to HCl slightly, moderately and in some cases strongly. While these layers as described by Erickson et al. (1974) were neutral or slightly calcareous. The difference can be attributed to the variations in relief or over wash from calcareous materials of surrounding areas.

4. The results from Hendricks samples (HdD) shows the existence of many variations between the studied pedons. Only 30-60 percent of the samples had characteristics required for the map unit. These values are less than the critical value for the map units (75 percent). It is therefore concluded that HdD map unit has been mapped incorrectly. The not classified pedons for this series include almost 33 percent of the samples under study. There are many variations among these pedons especially in sheets No. 49 and 55. Topographic features (thickness of epipedon) and difference in parent material (calcareous solum) are factors responsible for these variations. The not classified pedon inclusions in HdD were similar to the misclassified pedon inclusions of Nebeker. The misclassified pedons that had a lower proportion compared to not classified pedons should be classed as Typic Argixeroll; because of very low proportions (16 percent) they may not be delineated from other soils. It is suggested that further study both field observation and laboratory analysis are necessary in order to differentiate the different pedons that are mapped as HdD.

5. The results from the samples taken from Winn series (Wn map unit) showed that 54-68 percent of the samples had characteristics similar to the representative pedon of the series. The statistical analysis did not reveal strictly whether the pedons were mapped correctly or not. Analyzing of more samples in future may narrow the interval bounds and permit a more precise interpretation. The misclassified pedons were mostly found in sheet No. 15. Lack of strong overwash of material because of low surrounding topography did not allow the formation of Cumulic soils in the misclassified pedons of this map sheet.

It is generally concluded that in Cache County the influence of different geologic depositions and variations in topography are two major factors responsible for poor accuracy in mapping the Mendon and Hendricks series. Under these conditions more observations are required in order to meet the 75 percent standard of accuracy for mapping phases of a series in a second order survey. Otherwise the soils should be mapped as complexes, associations, or undifferentiated units as the situation dictates. Therefore in research, if for any reason it is necessary to locate the model pedon in areas mapped as Mendon, or Hendrick; extra care should be used in selecting the pedons.

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