CHAPTER 3. SOIL HORIZONS, TAXONOMY AND MAPPING

HORIZON NOMENCLATURE

Nomenclature for soil horizons may be considered as being of two general kinds. In one, master horizons and subhorizons are indicated by symbols, such as A1 and B2, that are used to describe soils in the field. The other kind consists of named horizons, such as mollic epipedon and argillic horizon, that are definitive for various taxa in the classification of soils. Subsequent sections present these two kinds of horizons.

Diagnostic horizons

Five diagnostic horizons are used to classify soils in the study area. Two of these (the mollic epipedon and the ochric epipedon) are surface horizons. The other three (the argillic, calcic and petrocalcic horizons) are subsurface horizons. Only summary statements concerning diagnostic horizons are presented here. Full definitions may be found in Soil Taxonomy (Soil Survey Staff, 1975).

The mollic epipedon has at least 0.6 percent organic carbon; values (moist) and chromas are 3 or less. The thickness is one of the following after mixing the upper 18 cm of soil:

(1) The epipedon must be more than 25 cm thick if its texture is finer than loamy fine sand and the upper boundary of pedogenic lime that is present as filaments, soft coatings or soft nodules is deeper than 75 cm, and the base of the argillic horizon is deeper than 75 cm.

(2) In other soils that have a loamy or clayey epipedon, the thickness of the epipedon must be 18 cm or more and it must be more than 1/3 of the depth from the top of the epipedon to the shallowest of one of the features listed in No. 1 if that depth is less than 75 cm.

(3) In other soils the epipedon must be more than 25 cm thick if texture of the epipedon is as coarse as or coarser than loamy fine sand throughout its thickness.

The ochric epipedon is too light-colored, too thin, and/or has too little organic carbon for a mollic epipedon.

The argillic horizon contains illuvial silicate clay. If the eluvial horizon has not been truncated, the increase in clay to the argillic horizon is as follows:

Clay content of eluvial horizon	Minimum clay increase required for an argillic horizon
pct	pct or ratio
15	3
15-40	ratio of 1.2 or more
40	8

Various kinds of evidences for clay illuviation are required in different situations. In this semiarid region, the pertinent evidence is at least 1% of oriented clay as viewed in thin section. Argillic horizons in this area meet this requirement.

The calcic horizon is a horizon of secondary carbonate enrichment. It is at least 15 cm thick and has a $CaCO_3$ equivalent content of 15% or more unless the particle size class is sandy, sandy-skeletal, coarse-loamy, or loamy-skeletal with less than 18% clay. In these cases the 15% requirement for $CaCO_3$ equivalent is waived and the calcic horizon must have at least 5% (by volume) more soft powdery secondary $CaCO_3$ than an underlying horizon; it must also be at least 15 cm thick and have an upper boundary within 1 m of the surface of the soil.

The petrocalcic horizon is cemented by carbonates. Dry fragments do not slake in water. It is cemented or indurated and cannot be penetrated by spade or auger when dry. It is massive or platy, very hard or extremely hard when dry, and very firm or extremely firm when moist. Hydraulic conductivity is moderately slow to very slow. Laminar horizons are commonly present in the uppermost part of the horizon but are not required.

Horizons designated by symbol

Horizon designations follow the 1962 Supplement to the Soil Survey Manual (Soil Survey Staff, 1962) except for the K horizon nomenclature (Gile et al., 1965). New designations for soil horizons in a revised Soil Survey Manual were recently announced (Guthrie and Witty, 1982). See table 3 for approximate equivalents of horizon designations in this book and in the revised Soil Survey Manual.

The A horizon

The A1 horizon is at the soil surface if it has not been buried. Mineral particles in the A1 horizon have coatings of organic material, or the soil mass is darkened by organic particles. The A1 horizon is as dark as, or darker than, the underlying horizon.

The A2 horizon underlies an A1 horizon. Clay has been moved from the A2 horizon to deeper horizons by descending soil water. The A2 horizon is usually lighter colored than adjacent horizons. The color is largely that of the sand particles, which have been leached virtually free of clay.

The A3 horizon is transitional to an underlying B horizon, but is more like A than B.

The A1, A2, and A3 horizons may be further subdivided (e.g., A11).

The B horizon

The B notation designates materials that have been altered by pedogenesis (e.g., the illuviation of silicate clay). An A1 horizon or an A2 horizon, or both, occurs above the B horizon if the soil has been little affected or unaffected by erosion. The B horizon may be subdivided as follows.

Table 3. Approximate equivalents of horizon designations in this book and in the revised Soil Survey Manual

Horizon designations, this text		Horizon designations, revised Soil Survey Manual 1/	
Without vertical subdivision	with vertical subdivision	Without vertical subdivision	With vertical subdivision
A1	A11 A12	A	A1 A2
A2	A21 A22	E	E1 E2
A3		AB or EB	
B1t	B11t B12t	BAt	BAt1 BAt2
B2t	B21t B22t	Bt	Bt1 Bt2
B3t	B31t B32t B32tca	BCt	BCt1 BCt2 BCtk
C	C1 C2	C	C1 C2
If a K horizon is present			
K1	K11 K12	Bk	Bk1 Bk2
K2	K21 K22		Bk3 Bk4
K3	K31 K32		Bk5 Bk6
			Bk7

1/ Guthrie and Witty, 1982.

The B1 horizon is a transitional horizon between the A horizon and the B2 horizon, but is more like B than A.

The B2 horizon is the most strongly expressed part of the B horizon. If the horizon is a Bt horizon, the B2t is the subhorizon of maximum clay content as compared to B1 and B3.

The B3 horizon is a transitional horizon between the B2 horizon and a horizon beneath B3.

The B1, B2, and B3 horizons may be further subdivided (e.g., B11).

The K horizon

The K horizon is defined in terms of volumes of K-fabric, in which fine-grained authigenic carbonate occurs as an essential continuous medium (Gile et al., 1965). The carbonate coats and commonly separates and cements skeletal pebbles, sand, and silt grains. The horizons are usually prominent and light colored, and many are white throughout. Consistence ranges from soft to extremely hard, but most K horizons are cemented to a noticeable degree and many are indurated. Materials with K-fabric occur in a variety of forms, such as laminar, nodular, cylindroidal, massive, blocky and platy.

The K1 horizon is transitional to an A or B horizon from an underlying K2 or K2m horizon and contains 50 percent or more of K-fabric. The K1 horizon may be transitional because of less hardness, less continuous induration, or a lesser volume of K-fabric than in the K2 horizon. Some K1 horizons consist of discrete, somewhat loose nodules or plates overlying a continuously indurated K2m horizon.

The K2 horizon is the most prominent, hardest, and whitest part of the K horizon and generally contains most of the authigenic carbonate. The K2 contains 90 percent or more of K-fabric. The K2 can be massive, blocky, platy, nodular, or cylindroidal, and is commonly composed of two or more of these macroscopic forms. Indurated K2 horizons are designated K2m. A distinctive subhorizon, the laminar horizon, occurs at the top of most K2m horizons. The laminar horizon is composed primarily of laminar carbonate with a small amount of included sand, silt, clay and organic matter. In some K2m horizons, several laminar horizons occur and in places are separated by nonlaminar, carbonate-cemented material.

The K3 horizon is transitional from a K2 or K2m horizon to an underlying Cca horizon, C horizon, paleosol, or bedrock, and contains 50 percent or more of K-fabric. The K3 horizon contains less carbonate, a smaller volume of K-fabric, or is not as hard or as light colored as the overlying K2 horizon. The K3 horizon is not continuously indurated, but can contain indurated nodules or agglomerations of skeletal grains. In the K3 horizon, carbonate content and volume of K-fabric commonly decrease with increasing depth. K3 horizons occur in most soils with K2 horizons.

The C horizon

The C notation designates horizons or materials, other than bedrock, that have been little affected by pedogenic processes. The C horizon is subdivided by using Arabic numerals (e.g., C1, C2).

Suffixes

Suffixes of lower case letters are used to indicate certain kinds of master horizons, as follows:

b - buried horizon

ca - accumulation of pedogenic carbonate that does not qualify as K horizon, defined earlier.

t - accumulation of pedogenic clay, most commonly used with B (e.g., Bt). The horizon has evidence of illuvial clay, in the form of clay bands and/or of clay accumulation throughout the horizon. In thin section the clay occurs as oriented coatings on sand grains. The Bt designation is not restricted to the argillic horizon but is used to designate accumulations of silicate clay that do not qualify as argillic horizons — horizons with clay bands, for example. If both the clay bands and material between the bands qualify as Bt, the horizon concerned is designated Bt (e.g., B21t). If only the clay bands qualify as Bt and they occupy <50% of the horizon, it is indicated by a dual designation in which the dominant fabric is given first (e.g., B21t&Bt); the symbol Bt refers to the clay bands.

Prefixes

Most of the sediments are of eolian origin, but some are of colluvial origin and a few deposits are of alluvial origin. Arabic numberals have been used as prefixes to distinguish the distinct colluvium of Birdwell age from sediments of eolian origin. However, Arabic numerals were not used to distinguish sediments that contain only small amounts of colluvium, such as sediments of Muleshoe age. Arabic numerals were also used to distinguish eolian sediments from the alluvium below gullies.

Discontinuities

Arabic numerals have been used as prefixes to denote distinct differences in origin of parent materials. Although eolian sediments are dominant, areas of colluvium and alluvium do occur in places.

EFFECT OF BURIED SOILS ON CLASSIFICATION OF LAND-SURFACE SOILS

Table 4 presents soils of the study area and their classification according to Soil Taxonomy (Soil Survey Staff, 1975). Series names are not available for most soils and these are given informal names or are named as variants. Soils SND-1, Alfisols and Entisols undifferentiated, and SND-2, Vertisols undifferentiated (table 4) are very minor in extent and were not examined in enough detail to classify them below the level of soil order.

Buried soils are common in arid and semiarid regions, and are also important in the soil and landscape history of the sandhills. In parts of the sandhills, buried soils with diagnostic horizons are overlain by young deposits that lack diagnostic horizons and that range widely in thickness (Chapter 2). Such young deposits underlain by buried soils are not uncommon elsewhere in arid and semiarid regions. Since some of the buried soils

Table 4. Soil classification and diagnostic horizons and features of soils in the study area[1/]

Order	Suborder	Great group	Subgroup	Particle-size class[2/]	Series or variant
Entisols Lack diagnostic horizons unless they are buried	Psamments	Ustipsamments	Typic	Sandy	Tivoli. Lacks two or more continuous clay bands within 100 cm depth.
					Tivoli, thin variant #1. The same as Tivoli in upper part but has a buried argillic horizon with texture of loamy fine sand or coarser in some subhorizon between 50 and 100 cm depth.
			Alfic	Sandy	Circleback. Has two or more continuous clay bands within 100 cm depth and they are not those of a soil buried to depths greater than 50 cm.
	Fluvents	Ustifluvents	Typic	(Sandy, coarse-loamy)	Tivoli, thin variant #2. The same as Tivoli in upper part but has a buried argillic horizon with texture of loamy very fine sand or finer in some subhorizon between 50 and 100 cm depth.
Alfisols Argillic horizon	Ustalf	Haplustalfs	Psammentic	Sandy	Texico.
			Aridic	Coarse-loamy	Farwell.
					Farwell, thin variant. Like Farwell but there is no C horizon material between the argillic horizons of different ages; "PseudoPaleustalfs".
					Farwell, calcic variant. Has calcic horizon within 90 cm depth.
				Fine-loamy	Extee. Has calcic horizon within 90 cm depth.
					Keeney. Lacks calcic horizon within 90 cm depth.
(Alfisols and Entisols undifferentiated)					SND-1.
Mollisols Mollic epipedon	Ustolls	Argiustolls	Aridic	Fine-loamy	Newell, calcic variant. Has calcic horizon within 90 cm depth.
					Newell. Lacks calcic horizon within 90 cm depth.
				Sandy	Newell, sandy variant. Like Newell but is in a sandy family.
Inceptisols Ochric epipedon	Ochrepts	Ustochrepts Calcic or petrocalcic horizon	Aridic	Fine-loamy	Veal. Has calcic horizon within 90 cm depth.
				Sandy-skeletal	Veal, petrocalcic variant. Has petrocalcic horizon within 50 cm depth (is in shallow family).
(Vertisols undifferentiated)					SND-2.

1/ Diagnostic features listed are those important to the study area. See Soil Taxonomy (Soil Survey Staff, 1975) for a complete list. All soils are in the thermic temperature class. Mineralogical analyses indicate that some of the soils have siliceous mineralogy and that others have mixed mineralogy (see Sites 4-7, 22, 41, 43, and 53). Little data are available elsewhere for similar soils and eventually some of the series names may be changed, or mineralogy of some of the series may be changed (Earl Blakley, personal communication). Although further study is needed, it appears that all of the Entisols and many of the Psammentic Haplustalfs, coarse-loamy Aridic Haplustalfs and sandy Argiustolls have siliceous mineralogy. The fine-loamy Haplustalfs and Argiustolls probably have mixed mineralogy. The Ustochrepts have carbonatic mineralogy. Tivoli and Veal are established series. Circleback is a tentative series. Other names are informal.

2/ Particle-size class refers to the weighted average particle-size class of the control section, which refers to specific horizons and/or depths in the soil. For this area the control section for the Entisols extends from 25 to 100 cm depth; for the Alfisols and Mollisols, the control section is the upper 50 cm of the argillic horizon, or the whole argillic horizon if it is less than 50 cm thick; and for the Inceptisols, the control section is from 25 to 100 cm depth except for Veal, petrocalcic variant, in which the control section extends from the soil surface to the top of the petrocalcic horizon. As used in this report, Tivoli, thin variant #2 includes both the sandy and coarse-loamy particle-size classes.

are near the surface they must be considered in classification of land-surface soils, and for this reason Entisols may have buried diagnostic horizons (Soil Survey Staff, 1975, p. 179). Thickness limits for the young deposits are given in Soil Taxonomy (Soil Survey Staff, 1975, p. 2):

> A soil is considered to be a buried soil if there is a surface mantle of new material that is 50 cm or more thick or if there is a surface mantle between 30 and 50 cm thick and the thickness of the mantle is at least half that of the named diagnostic horizons that are preserved in the buried soil. A mantle that is <30 cm thick is not considered in the taxonomy but, if important to the use of the soil, is considered in establishing a phase. The soil that we classify in places where a mantle is present, therefore, has its upper boundary at the surface or <50 cm below the surface, depending on the thickness of its horizons.
>
> A surface mantle of new material as defined here is largely unaltered. It is usually finely stratified and overlies a horizon sequence that can be clearly identified as the solum of a buried soil in at least part of the pedon, as defined in the following chapter. The recognition of a surface mantle should not be based solely on studies of associated soils.

Thus, if the mantle of new material is more than 50 cm thick, or is 30 to 50 cm thick and is half or more the thickness of the buried diagnostic horizon, the upper boundary of the soil that we classify is at the land surface. In both cases the soils would be classified as Entisols because a surface mantle of new material, as defined, is excluded from the concept of diagnostic horizons.

Strata may or may not be present, in deposits of identical age; in practice, therefore, it is better and more consistent to simply use the absence of diagnostic horizons to identify the youthful mantle. Identification of its lower boundary was discussed in Chapter 2.

In the Grossarenic Paleustalfs, sandy epipedons >1 m thick overlie argillic horizons. Thus a basic decision in classification is whether thick sandy sediments constitute an epipedon that developed with the underlying argillic horizon, or are younger materials that have buried the argillic horizon. In the study area, sandy sediments of Muleshoe age have buried the argillic horizon as discussed in Chapter 2. But the provision for recognition of buried soils in Entisols is not always followed. In the vicinity of the study area, soils with 1 to 2 m of sandy sediments over buried argillic horizons have been classified as Grossarenic Paleustalfs (Earl Blakley, personal communication). Thus it should be recognized that some soils classified as Grossarenic Paleustalfs actually consist in part of buried soils. There is no doubt about the validity of thick A horizons and the Arenic and Grossarenic subgroups in some soils (e.g., North Carolina Paleudults, Gamble et al., 1970). But serious questions may be raised about the use of these subgroups in the Southern High Plains because the sandy sediments did not form with the underlying argillic horizon but instead are much younger sediments that bury it.

Another matter concerns suitability of the "Pale" great groups to classify thick, young sandy deposits underlain by buried argillic horizons. Much of the material and in some pedons the bulk of the material (the thick sandy deposits) in such "Grossarenic Paleustalfs" is actually less than about 4,000 years old, and possibly much less (see Muleshoe surface, Chapter 2). This youthful material does not fit the concept of the Paleustalfs, which are stated to be ". . . the thick reddish or red Ustalfs that are on old surfaces" (Soil Survey Staff, 1975).

A similar question may be raised about the use of Arenic subgroups in the Southern High Plains. These soils, which also contain buried diagnostic horizons, have an epipedon that is between 50 and 100 cm thick and that has texture of loamy fine sand or coarser. In other places (e.g., the Western states where buried soils are common) the rules for classification of Entisols have been followed. In these states buried soils, where overlain by a young mantle of appropriate thickness, are noted in the series description instead of using them to classify at the great group level (e.g., Arenic Haplustalfs). Thus young mantles 50 to 100 cm thick over buried argillic horizons are routinely classified as Entisols. This is illustrated by the Arizona Fluvents Estrella, Trix and Valencia. Materials overlying the buried soils consist of alluvium instead of eolian sediments, but the principle is the same; the buried soils are overlain by youthful sediments that lack diagnostic horizons.

On the basis of the foregoing it is suggested that the Arenic and Grossarenic subgroups not be used in the Southern High Plains. Instead, it is suggested that the rules in Soil Taxonomy, and the lead of other states, be followed for handling buried soils in Entisols. Then there would be an expected and natural gradation from thick Entisols to thin ones as the youthful deposits become thinner in various places. This would also avoid the logically tortuous transition in classification, Entisols - Arenic Haplustalfs - Grossarenic Paleustalfs, for sandy sediments having identical ages and differing only in thickness. In addition, the unfortunate conflict with true Arenic and Grossarenic subgroups would be avoided.

ENTISOLS

Two suborders of Entisols are present, Psamments and Fluvents (table 5).

Table 5. Diagnostic features for suborders and great groups of Entisols in the study area.

Suborder	Great Group
Psamments Texture is loamy fine sand or coarser in subhorizons between 25 and 100 cm, except for clay bands too few or too thin to be an argillic horizon (Soil Survey Staff, 1975).	Ustipsamments Ustic moisture regime
Fluvents Texture is loamy very fine sand or finer in some subhorizon between 25 and 100 cm depth, and organic carbon decreases irregularly with depth and/or is more than 0.2% at 125 cm depth.	Ustifluvents Ustic moisture regime

The Fluvents occur in two general ways in the study area. In the first, youthful eolian deposits, primarily of Muleshoe age, overlie wind-eroded and buried argillic horizons at 50 to 100 cm depth. If a buried argillic horizon occurs between depths of 50 and 100 cm, organic carbon tends to be higher in it than in overlying coarser-textured materials because of the close relation of organic carbon to clay. Thus organic carbon decreases irregularly with depth and these soils are Fluvents if texture is loamy very fine sand or finer in some subhorizon between 25 and 100 cm depth. Some of the buried argillic horizons are thin but others are very thick, and both the 30 to 50, and ≥50 cm depths, cited in the previous section, would apply. For convenience in this work, only the ≥50 cm depth was used (consideration could well be given to dropping the 30 to 50 cm criterion).

Muleshoe sediments range widely in thickness; figure 26 summarizes changes in soil classification with progressive thinning of young sandy sediments that lack a diagnostic horizon and that are underlain by a buried argillic horizon. As the young sandy deposit thins to less than 100, and then to less than 50 cm thickness, the soil changes are, in order, Psamment - Fluvent - Ustalf.

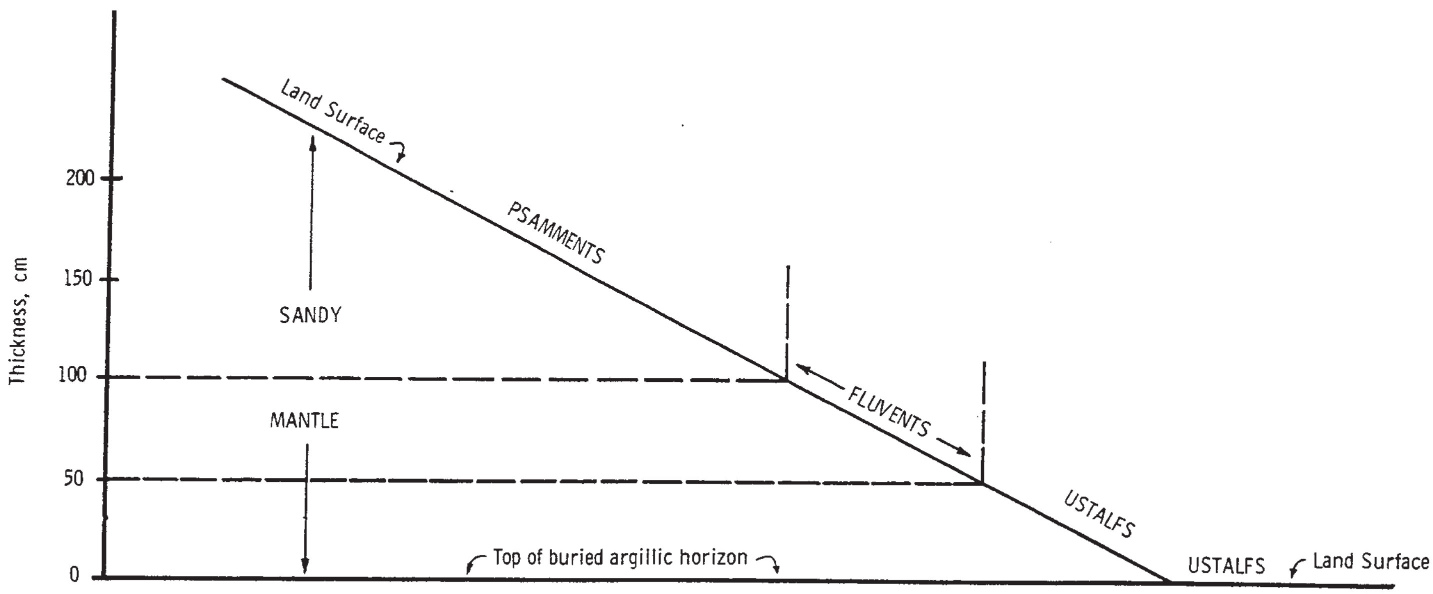

Figure 26. Diagram illustrating the suborder transition from Psamments to Ustalfs with the thinning of young sandy sediments that lack a diagnostic horizon.

The second way that Fluvents occur in the study area consists of deposits of gully-derived alluvium that overlie buried soils. Most of the alluvium is less than about four decades old; commonly the A horizons of the buried soils have been preserved (see Site 37). However, in most places the alluvium is less than 50 cm thick, in which case the buried soil is classified as the land-surface soil as discussed earlier (a phase could be used if desired, as cited in the previous section).

Typic Ustipsamments and Alfic Ustipsamments are the dominant Entisols in thick deposits. The Alfic Ustipsamments have clay bands, or lamellae, but they are too thin or too few to meet the requirements of the argillic horizon (Soil Survey Staff, 1975). Since the word lamellae is plural, the interpretation is that more than one is required for the Alfic Ustipsamments. In this study, therefore, soils designated Alfic Ustipsamments have two or more clay bands that are continuous enough to meet the requirements of the polypedon (>1 m^2; Soil Survey Staff, 1975). The clay bands are diagnostic for the Alfic Ustipsamments if they are within 1.5 m of the soil surface (Soil Survey Staff, 1975, p. 207). However, horizons with clay bands are not one of the formally defined diagnostic horizons (Soil Survey Staff, 1975, p. 14-47), and a mantle of new material above a soil with clay bands would not be distinguished for classification purposes in Soil Taxonomy. But in this study, horizons with clay bands are considered to be diagnostic for the purpose of recognizing buried soils with clay bands. Soil with clay bands are classified as Alfic Ustipsamments if the soils are at the land surface or if they are buried by a mantle of new material >50 cm thick.

ALFISOLS

Alfisols have argillic horizons (Soil Survey Staff, 1975). As discussed in Chapter 2, the transition between Entisols and Alfisols is marked, first, by the development of discontinuous clay bands, in Muleshoe sediments; second, by the formation of continuous bands and sporadic development of the argillic horizon and the Alfisols, in Longview sediments; and, third, by continuous occurrence of the argillic horizon and the Alfisols at stable sites in Birdwell sediments. All of the Alfisols, even the oldest ones, are Haplustalfs because the argillic horizons do not meet the requirements of Paleustalfs as discussed later.

The Ustalfs are the mostly reddish Alfisols of warm subhumid to semiarid regions (Soil Survey Staff, 1975). In the study area, the Ustalfs are in a semiarid region that borders and is transitional to Aridisols in drier areas to the west. Thus, the Ustalfs are in Aridic subgroups (Soil Survey Staff, 1975) except for soils that have argillic horizons with sandy control sections; these are the Psammentic Haplustalfs (table 1).

Paleustalfs are the thick reddish or red Ustalfs of old surfaces (Soil Survey Staff, 1975). Soils of this area that would qualify as Paleustalfs must have both of these characteristics (Soil Survey Staff, 1975):

(1) a clay distribution such that the percentage of clay does not decrease from its maximum amount by as much as 20 percent of that maximum throughout a depth of 1.5 m from the soil surface . . . and

(2) one of more of the following in the argillic horizon:

(a) a hue redder than 10YR and chroma that is more than 4 in the matrix of at least the lower part;
(b) a hue that is 7.5YR or redder and a value, moist, that is less than 4 and a value, dry, that is less than 5 throughout the major part; or
(c) common coarse mottles that have a hue of 7.5YR or redder or chroma more than 5, or both . . .

Some Ustalfs of the study area meet color requirements of 2(a) but do not meet other requirements for the Paleustalfs. First, some soils have abundant carbonate at shallow depths; when carbonate clay is treated as silt, as it must be (Soil Survey Staff, 1975; Guy D. Smith, personal communication, January 1981), the clay decrease requirement is not met. Second, other soils have little or no carbonate but clay decreases too much with depth. Third, some Haplustalfs that at first glance might appear to qualify as Paleustalfs actually consist of buried soils that are overlain by much younger (Holocene) sediments in which an argillic horizon has formed. Such soils were not intended to be classified as Paleustalfs (Guy D. Smith, personal communication, January 1981). In this situation no C horizon material occurs between the argillic horizons of different ages (see Site 43).

MOLLISOLS

Mollisols do not occur on ridges because of runoff and because of low percentage of clay (and consequent relatively low organic carbon) in the soils. Mollisols occur only in depressions, primarily where the bordering ridges contribute runoff and thick sandy deposits are absent. These factors contribute to denser vegetation, high organic carbon and a mollic epipedon. Surficial horizons of other soils in the depressions are not quite dark enough and/or have chroma too high for a mollic epipedon. All of the Mollisols are Argiustolls. Texture of the Bt horizons is not suitable for the Paleustolls, which must have argillic horizons with one or more of the following (Soil Survey Staff, 1975):

1. A vertical clay distribution such that the clay content does not decrease by 20 percent of the maximum clay content within 1.5 m of the soil surface, and the argillic horizon has one or both of these:

    a. A hue redder than 10YR and chroma higher than 4 in the matrix; or
    b. Common coarse mottles that have a hue of 7.5YR or redder or chroma higher than 5; or

2. A particle-size class in the upper part that is clayey and an increase of at least 20 percent clay (absolute) within a vertical distance of 7.5 cm or of 15 percent clay (absolute) within 2.5 cm at the upper boundary.

In some soils of depressions, organic carbon, chroma and value requirements of the mollic epipedon are easily met (e.g., Pedons 33d, 50). But in other soils, although organic carbon is sufficient, the epipedon is barely mollic or is ochric, depending upon chroma, value and depth to carbonates (see Sites 34, 35, 48, and 49 for illustration). These factors can cause complex soil occurrence at the highest level of classification (soil order): Mollisols - Alfisols - Inceptisols.

INCEPTISOLS

Minor areas of Inceptisols occur in large blowouts in the southern part of the study area. Ustochrepts occur side by side with Haplustalfs, the only difference being that the argillic horizon has been wind-truncated in the Ustochrepts but not in the Haplustalfs (Sites 51, 52). The calcic or petrocalcic horizon remains, however, and in this area is diagnostic for the Ustochrepts. Consideration could well be given to adding two new subgroups to the Ustochrepts: Calcic Ustochrepts, which would have a calcic horizon, and Petrocalcic Ustochrepts, which would have a petrocalcic horizon.

SOIL MAP

Conventions and mapping units

The study area was first explored with a hydraulic power probe to a depth of about 1.25 m, and in places with a hand auger and extensions to depths up to 7 m. Sites were then selected for detailed study and trenching; some of the trenches were later expanded to obtain additional information.

The soil map (fig. 27, tables 6, 7) has eleven mapping units. The mapping units consist of (1) soils belonging to one or more dominant series or variants (termed "dominant soils"), which occupy more than 10 percent of the map unit and are capitalized in the table of mapping unit composition, and (2) lesser proportions of other soils (termed "inclusions"), each of which occupy 10 percent or less of the mapping unit. Percentages of dominant soils are estimated to be within ± 10 percent of the figure given. The designation "variant" and a modifier have been used as a handle to designate soils that differ in an indicated characteristic from a soil defined at the series level (e.g., Newell, calcic variant, has a calcic horizon within 90 cm depth).

The mapping units are designated as texture phases, as variants, and as soil complexes. Texture phases (e.g., Tivoli fine sand) indicate the average texture of the surface layer (as used here, the upper 15 cm). In soil complexes, the dominant soils occur in such intricate patterns that they cannot be mapped separately at a scale of 1:15,840. Soils are not considered complexes if the dominant soil occupies at least 50 percent of a mapping unit and no other component occupies more than 10 percent of the unit.

Figure 27. Soil map of the study area. A = Tivoli fine sand. B = Tivoli variants. C = Circleback complex. D = Texico - Circleback complex. E = Texico fine sand. F = Texico - Farwell complex. G = Farwell variant. H = Texico complex. I = Keeney complex. J = Newell - Extee complex. K = Extee - Veal complex.

Table 6. Composition of mapping units A - E [1/]

Series or variant	Subgroup	Particle-size family	Percentage of mapping unit
Unit A, Tivoli fine sand			
TIVOLI	TYPIC USTIPSAMMENTS	SANDY	80
Circleback	Alfic Ustipsamments	Sandy	10
Texico	Psammentic Haplustalfs	Sandy	5
Other inclusions (Tivoli, thin variants #1 and 2, Farwell; Keeney)			5
Unit B, Tivoli variants			
TIVOLI, THIN VARIANT #2	TYPIC USTIFLUVENTS	(SANDY, COARSE-LOAMY)	45
TIVOLI, THIN VARIANT #1	TYPIC USTIPSAMMENTS	SANDY	30
Circleback	Alfic Ustipsamments	Sandy	10
Texico	Psammentic Haplustalfs	Sandy	10
Other inclusions (Farwell,Keeney)			5
Unit C, Circleback complex			
CIRCLEBACK	ALFIC USTIPSAMMENTS	SANDY	35
TIVOLI	TYPIC USTIPSAMMENTS	SANDY	30
TEXICO	PSAMMENTIC HAPLUSTALFS	SANDY	25
Newell, sandy variant	Aridic Argiustolls	Sandy	5
Other inclusions (Farwell, Keeney, Tivoli, thin variant #1)			5
Unit D, Texico - Circleback complex			
TEXICO	PSAMMENTIC HAPLUSTALFS	SANDY	45
CIRCLEBACK	ALFIC USTIPSAMMENTS	SANDY	40
Tivoli, thin variant #1	Typic Ustipsamments	Sandy	5
Tivoli	Typic Ustipsamments	Sandy	10
Unit E, Texico fine sand			
TEXICO	PSAMMENTIC HAPLUSTALFS	SANDY	75
Farwell	Aridic Haplustalfs	Coarse-loamy	10
Circleback	Alfic Ustipsamments	Sandy	10
Other inclusions (Keeney, SND-1)			5

1/ Tivoli is an established series. Circleback is a tentative series. Other names are informal.

Table 7. Composition of mapping units F - K[1/]

Series or variant	Subgroup	Particle-size family	Percentage of mapping unit
Unit F, Texico - Farwell complex			
TEXICO	PSAMMENTIC HAPLUSTALFS	SANDY	.60
FARWELL	ARIDIC HAPLUSTALFS	COARSE-LOAMY	.30
Other inclusions (Keeney, Tivoli, Circleback)			.10
Unit G, Farwell variant			
FARWELL, THIN VARIANT	ARIDIC HAPLUSTALFS	COARSE-LOAMY	.95
Farwell	Aridic Haplustalfs	Coarse-loamy	5
Unit H, Texico complex			
TEXICO	PSAMMENTIC HAPLUSTALFS	SANDY	.60
KEENEY	ARIDIC HAPLUSTALFS	FINE-LOAMY	.20
Newell	Aridic Argiustolls	Fine-loamy	.10
Farwell	Aridic Haplustalfs	Coarse-loamy	.10
Unit I, Keeney complex			
KEENEY	ARIDIC HAPLUSTALFS	FINE-LOAMY	.65
NEWELL	ARIDIC ARGIUSTOLLS	FINE-LOAMY	.25
Farwell	Aridic Haplustalfs	Coarse-loamy	.10
Unit J, Newell - Extee complex			
NEWELL, CALCIC VARIANT	ARIDIC ARGIUSTOLLS	FINE-LOAMY	.35
NEWELL	ARIDIC ARGIUSTOLLS	FINE-LOAMY	.30
EXTEE	ARIDIC HAPLUSTALFS	FINE-LOAMY	.30
Other inclusions (Farwell, SND-2)			5
Unit K, Extee - Veal complex			
EXTEE	ARIDIC HAPLUSTALFS	FINE-LOAMY	.40
VEAL	ARIDIC USTOCHREPTS	FINE-LOAMY	.35
Newell, calcic variant	Aridic Argiustolls	Fine-loamy	.10
Other inclusions (Farwell, calcic variant, Keeney, Veal, petrocalcic variant			.15

1/ Tivoli and Veal are established series. Circleback is a tentative series. Other names are informal.

Table 8 gives areas of soil mapping units and individual soils. The Psammentic Haplustalf, Texico, is the most extensive soil in the study area. Although some soils are only of minor extent, their repeated occurrence in specific landscape positions indicates that their total area in all similar sandhills would be considerably greater, and underlines the significance of even these soils of lesser extent as components of the sandhill terrain.

It is of interest to compare the soil map of this study with that of the Bailey County Soil Survey (Girdner et al., 1963, sheet 18). The survey was completed before the new soil classification system (Soil Survey Staff, 1975) was adopted, thus soil classification differs from the system presently in use. It should also be stressed that the survey was made on a much smaller scale and that the mapping units covered a much larger area than mapping units of this study. Nevertheless, the comparison does illustrate the kinds of soils found in a detailed examination of parts of some mapping units in the survey.

Table 9 presents a comparison of mapping units and dominant soils from the Bailey County survey and from this study. Six mapping units of the survey cross the study area. Although no mapping unit inclusions were listed for units Sh and Tv (Girdner et al., 1963), these units showed the greatest contrast between soils indicated to be present in the survey and soils actually found. The part of mapping unit Tv (Tivoli fine sand) that crosses the study area actually contains only about 30 percent of Tivoli soils. The comparison indicates that some mapping units in the Bailey County survey should be reexamined, and that more soils should be added to descriptions of some of the mapping units.

Organization of mapping unit descriptions

Information in the mapping units is arranged as outlined below.

Table of mapping unit composition. This table lists the soils present in the mapping units (see also tables 6, 7), and approximate percentages of the soils.

Location, landscape, soil occurrence, vegetation.

Typical pedon(s), properties and ranges. This section locates information on typical pedons, properties and ranges of characteristics of dominant soils.

Study site(s). This section presents information about study sites that occur in the mapping unit and in some instances in an adjacent unit if the study trench crosses a mapping unit boundary.

The individual study sites are designated in several ways, depending upon the number of studied areas at a given location. Each site is designated first of all by number (e.g., Site 8). Most sites consist of more than one part; the components are designated a, b, c, etc. In some instances a component part was further subdivided and designated by a dash and number following the letter (e.g., Site 8c-2). The pedon that was actually described and/or sampled is designated Pedon 8c-2, for the purpose of specific reference to the small volume of soil containing the horizons that were sampled (Glossary).

Table 8. Areas of mapping units and individual soils

Map symbol	Mapping unit name	Acres	Percent of total
A	Tivoli fine sand	109	15.5
B	Tivoli variants	104	14.8
C	Circleback complex	66	9.4
D	Texico-Circleback complex	52	7.5
E	Texico fine sand	159	22.7
F	Texico-Farwell complex	84	12.0
G	Farwell variant	8	1.1
H	Texico complex	36	5.2
I	Keeney complex	9	1.3
J	Newell - Extee complex	44	6.2
K	Extee - Veal complex	30	4.3
	Total	701	100%

Individual soil	Acres	Percent of total
Circleback	81	11.5
Extee	25	3.6
Farwell	46	6.6
Farwell, thin variant	8	1.1
Keeney	13	1.8
Newell	19	2.7
Newell, calcic variant	18	2.6
Newell, sandy variant	3	0.4
Texico	247	35.2
Tivoli	112	16.0
Tivoli, thin variant #1	47	6.7
Tivoli, thin variant #2	34	4.9
Veal	11	1.6
Other inclusions (Circleback; Farwell; Farwell, calcic variant; Keeney; SND-1; SND-2; Tivoli; Tivoli, thin variants #1 and 2; Veal, petrocalcic variant)	37	5.3
Total	701	100%

Table 9. Comparison of mapping units and dominant soils of the Bailey County Soil Survey[1/] and this study

Bailey County Soil Survey		This study[2/]	
Mapping unit symbol	Dominant soil	Mapping unit symbol	Dominant soil(s)
AfA	Amarillo	G	Farwell, thin variant
AfB	Amarillo	F	Farwell Texico
Br	Brownfield	A,B,C	Circleback Tivoli Tivoli, thin variants
MkB	Mansker	K	Extee Veal
Sh	Springer	Mostly E,F; also smaller areas of B,I,J, and H	Texico Farwell Keeney Tivoli, thin variants Newell Newell, calcic variant
Tv	Tivoli	Mostly A,B,C,D, and E; also smaller areas of F,H, and I	Tivoli Tivoli, thin variants Circleback Texico Farwell Keeney Newell

1/ Girdner et al. (1963)

2/ Dominant mapping unit(s) and soil(s) that occur in indicated mapping unit of the County survey, left column, as the unit crosses the area of this study.

Abbreviations in tables of soil characteristics follow the Soil Survey Staff (1951) except for terms indicating effervescence with HCl (e = slight effervescence, es = strong effervescence; nc = noncalcareous). Intermediate hue designations indicate the closest hue, e.g., 8YR indicates that the hue is between 7.5YR and 10YR, but closer to 7.5YR than 10YR.

In Chapters 5-9 the soils are presented by increasing age of a dominant geomorphic surface. All of the mapping units contain more than one surface and age of sediment, and this must be kept in mind in assessing the chrono-morphologic relationships of soils in the units.

LABORATORY METHODS

Laboratory determinations at Sites 3b, 4-7, 18c-4, 21, 22, 41, 43, and 53 were made by the National Soil Survey Laboratory. The NSSL methods of analyses (referenced in the Appendix) have been presented (Soil Conservation Service, 1972). Organic carbon determinations by the Soil and Water Testing Laboratory, New Mexico State University, were made by the Walkley-Black method. Particle size analyses of Pedon 27a were made by the Soil and Water Testing Laboratory at New Mexico State University, using the pipette method. Samples for thin sections were impregnated according to the method described by Gile (1967); the thin sections were made commercially by the National Petrographic Service Co., Houston, Texas.

Laboratory investigations at the Texas Tech University Laboratory centered primarily on particle size analyses. The analyses were undertaken to document these aspects of the study: the initial development of the argillic horizon, because of its genetic significance and because its presence distinguishes soils of the study area at the highest level of soil classification (Entisols vs. Alfisols); the character of silicate clay distribution for the wide variety of morphological expression, landscape position, and degree of landscape stability in the study area; the striking textural sequence on sides of Birdwell dunes and in adjacent depressions; and the postulated additions of sediment from dustfall during times considered to be fairly stable (i.e., between major erosive episodes).

Table 10 summarizes methods of particle-size analysis used for the various pedons. Particle-size analyses at the Texas Tech Laboratory were made by hydrometer method as follows.1/ Because the Bouyoucos method (Bouyoucos, 1962) overestimates the clay fraction (Gee and Bauder, 1979), the Simplified Day procedure was used in the initial investigations (table 10). Later it was found that a modified Bouyoucos procedure, in which a 6-hour reading instead of a 2-hour reading was taken for clay, gave results very similar to the Simplified Day method. Since the 6-hour clay reading was considerably faster, it was used during the remainder of the particle-size investigations (table 10).

Particle-size determinations for Pedon 15; for selected horizons of Pedons 47 and 50; for the caliche pit exposure south of the sandhills; and for horizons in Roosevelt sediments (see Roosevelt sediments, Chapter 3) were made by the Soil and Water Testing Laboratory at New Mexico State University, also using Bouyoucos procedure with a 6-hour reading for clay.

1/ This section written by B. L. Allen, Texas Tech University.

Table 10. Methods used for particle-size analyses

Pipette procedure	Hydrometer procedure: Simplified Day method	Hydrometer procedure: Modified Bouyoucos method (6-hour reading for clay)
Pedon nos. 3b, 4-7, 18c-4, 21, 27a, 41, 43, 53	Pedon nos. 27b-1, 28, 29, 31b, 33a, 35b, 36a, 37b, 38a, 42, 44a, 45a, 46, 55b	Pedon nos. 3g, 15, 25b, 32b, 32c, 33b, 33c, 33d, 34a, 34c, 39b, 47-50, 51a, 51b, 52a, 52b, 55a; pedons in table 2a