DEGRADATION OF PEDOGENIC CALCRETES

IN WEST TEXAS

by

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CHAPTER I

INTRODUCTION

Soils are the parchment on which the earth records its most recent events. This fact is exaggerated in the case of many arid and semiarid regions of the world where the environment often forms a resistant crust in the subsoil known as calcrete.

Many studies have been conducted, detailing the formation of these pedogenic calcretes. With the exception of observations in several studies (Gile et al., 1966; Sehgal and Stoops, 1972; Reeves, 1976a; Klappa, 1983; McGrath, 1984; Sowers, 1985), few, if any, have directly investigated the degradation of carbonate-enriched soil horizons. Yet, this aspect could have immense importance in paleoclimate interpretations. An attempt has been made in this study to document the degradation of pedogenic calcretes and to investigate the relationship of its occurrence to climate, geomorphic surface stability, and soil properties. Specific objectives were to (1) determine the extent of "caprock" calcrete by excavating several deep pits along a transect between an outcrop (of the calcrete) on a nearby escarpment and another similar outcrop on a playa slope, (2) to study degradation features in the calcrete if present, (3) to determine associated physical, chemical, and mineralogical properties of the soils, including paleosols, overlying the calcrete, and (4) to study the extent of calcrete degradation in a more arid region in contrast to a semiarid region.

Detailed statistical analysis for the purpose of broad extrapolation was beyond the scope of this study. Yet, many of the observations noted in this study will certainly apply, at least in general, to calcretes which form in similar environments.

CHAPTER II

LITERATURE REVIEW

Introduction

The Cenozoic geology of the Southern High Plains may be divided into several surface formations. Some of these formations, such as the Blackwater Draw and Ogallala Formations, are essential to the discussion of pedogenic calcrete occurrence in the area, while others are useful locally as stratigraphic units, such as the Tahoka, Double Lakes, Tule, and Blanco Formations. The lacustrine Tahoka and Double Lakes Formations are often associated with playas, the prominent surface features of the region, while the bulk of the eolian upper mantle covering the Ogallala Formation comprises the Blackwater Draw Formation (Holiday, 1990). The surface sediments of the Trans-Pecos region, however, consist of eolian sand (Kelley, 1971) and valley alluvium (Beede, 1918). Yet, the soils of these two regions of West Texas exhibit properties of the larger general region, the southwestern United States. The most significant attribute of many of these soils is the light colored material in the subsoil, which, when indurated, is known as “calcrete” (Lamplugh, 1902). This is a feature primarily due to the semiarid to arid climate, which lacks the necessary precipitation to leach carbonates out of the soil profile.

The term “calcrete” has been accepted and used in the earth sciences since its introduction by G.W. Lamplugh at the beginning of the last century. The Glossary of Geology and Related Sciences (Weller, 1960) equates it with the more common colloquial term “caliche,” which he defines (on the usage of the term in Mexico and the southwestern U.S.) as, “gravel, sand, or desert debris cemented by porous calcium carbonate; also the calcium carbonate itself” (p. 42). This broad and somewhat vague

definition of caliche reflects its usage in the region when one considers the various meanings that have been applied to the term. This includes calcareous caprocks, “soil hardpans,” and earthy porous materials which occur at the surface or at shallow depths below the soil (Bretz and Horberg, 1949a).

The term “calcrete” will be used interchangeably in this work with the term “petrocalcic horizon” which is defined according to the current U.S. soil taxonomic system as: (1) a horizon that is cemented or indurated by carbonates, with or without silica or other cementing agents, (2) which because of its lateral continuity is impermeable to roots except along fractures, and (3) is equal to or greater than 10 cm or 1 cm if overlying bedrock (Soil Survey Staff, 1999).

In this brief survey of the literature, it is recognized that the subdivisions are arbitrary: i.e., the processes, mechanisms, and factors involved in calcrete formation, divided herein for convenience, are closely related. Many individual factors, both regional and local, are involved in the formation and degradation of calcretes, and to concentrate on one factor without recognizing the relationship to the other various factors is likely to lead to erroneous conclusions.

General Pedogenesis of Calcretes

Climate

The association of caliche with warm or hot, arid and semiarid regions has been well documented since the beginning of the last century (Blake, 1902; Johnson, 1901; Lamplugh, 1902). Such environments allow for the continual deposition of carbonates (primarily calcite), principally by pedological mechanisms (Nettleton and Peterson, 1983). Such is the case in Australia where 3.7 million km² or roughly 50% of the soils on the continent are associated with pedogenic carbonates chiefly in areas of

arid, semiarid and temperate climates (Fitzpatrick and Merry, 2000). Pan and Guo (2000) reported that soils in China (primarily in the arid and semiarid regions to the northwest) contain as much as 1/15 to 1/20 of the pedogenic carbonate world pool. Areas of southern Spain and northern Africa, the deserts of South America and Mexico, to name a few, have similar calcrete deposits (Reeves, 1976a; Goudie, 2002). The Southern High Plains, known as the Llano Estacado, as well as the desertic plains and basins of the Trans-Pecos region of Texas are no exception to this correlation of aridic/ustic soil moisture regimes to calcrete formation.

Gile et al. (1966) present one of the first consistent explanations for the accumulation of carbonates in both calcareous and noncalcareous sediments of the same age. Working with sediments of variable mineralogical composition in the New Mexico desert, they proposed that calcareous dust was the source of the carbonates instead of the sediments per se. Upon wetting, carbonates dissolve and precipitate in the soil as water evaporates. Using the concept that the net excess of precipitation over evapotranspiration represented the total moisture available to wet the soil during seasonal precipitation, Arkley (1963) related carbonate movement within soils to climatic data. The works of Arkley and Gile et al. were later supported by the use of tenable models within the framework of their contributions (McFadden et al., 1991). Royer (1999) suggests using climatic data only for a first order approximation of paleoprecipitation because of the complexities of near-surface environments (i.e., topography, vegetation, etc.) in a statistical evaluation of Arkley and others work. In more recent investigations, the use of carbonate isotopes and their relationship to paleoclimates has met with some success (Amundson et al., 1989; Buck and Monger, 1999).

Carbonates accumulate in soils when soluble cations, either from calcareous dust or minerals, are leached through the pedon to a depth limited by the amount of

precipitation in the environment (Price, 1940; Jenny, 1941). Carbon dioxide dissolves in the soil solution according to the equation:

where an increase in the concentration of CO_2 in the soil air and solution emitted from microflora and respiring roots drives the equation to the right (Birkeland, 1974; Buol et al., 1997). In humid regions, the precipitation largely outweighs evapotranspiration and carbonates are leached through the soil to groundwater (Nordt et al., 2000). In arid and semiarid environments, however, calcium carbonate dissolves from upper horizons according to the equation:

and precipitates in lower horizons according to the equation:

(Thorne and Seatz, 1955; Birkeland, 1974; Buol et al., 1997).

Harden et al. (1991) and Eghbal and Southard (1993), in their studies of soil chronosequences and stratigraphy, suggest that the reason for the deep location of calcic and petrocalcic horizons in soils of arid and semiarid environments of Quaternary age is climatic change. These intermittent cooler/wetter environments have leached carbonates deeper into soils (Reeves, 1970; Nordt et al., 2000) commonly below argillic horizons (Buol et al., 1997). Evidence for these periods of cooler temperatures and higher amounts of precipitation followed by warmer, drier climates, specifically in the Holocene, is further supported by the investigation of Polyak and Asmerom (2001) on alternating “clear and inclusion-rich” calcite couplets annual banding in stalagmites in caves of the Guadalupe Mountains.

The pedogenesis of carbonate-enriched horizons and specifically the degradation of the calcretes must be understood within the context of present and paleoclimates. Present mean annual precipitation is roughly 13 to 21 inches for the Southern High Plains and 8 to 13 inches for the Trans-Pecos Basin and Plains region, while average annual temperatures for both these areas are around 60°F (Garoojian, 2000).

Parent Material

There is some debate in the literature as to the source of the calcium carbonate (CaCO_3) in calcretes. According to Chitale (1986), several sources have been identified. Blank and Tynes (1965), James (1972), Read (1974), Arakel (1982), and Rabenhorst et al. (1991) report the cementation of CaCO_3 arising from the subaerial exposure of calcareous parent rocks such as limestone is a common source. In this mechanism, diagenesis of the parent material entails micritization and recrystallization, resulting in the calcrete.

Various sources have been proposed for the calcium needed for the formation of calcrete. Calcareous dust that has, through eolian processes, been deposited on surface horizons has been proposed as a source of calcium (Gile et al., 1966; Hay and Reeder, 1978; Gile and Grossman, 1979; Birkeland, 1999). This external source for calcium carbonate is further evidenced by the occurrence of petrocalcic horizons in non-calcareous soils (Brown, 1956; Gile et al., 1966; Gile and Grossman, 1979; Reeves, 1970; Naiman et al., 2000). Calcium, dissolved in rainwater, percolates into the soil and is deposited beneath the surface (Knox, 1977; Buol et al., 1997; Gardner, 1972; Machette, 1985). Bretz and Horberg (1949a), Jenny (1941), Cooke (1951), Flach et al. (1969), Sehgal and Stoops (1972), Reeves (1976a), and Gile et al. (1965) offer this source of CaCO_3 along with traditional pedogenic mechanisms (i.e., hydrolysis,

diagenesis, eluviation, and illuviation) that have acted upon primary calcium-rich minerals in their milieu forming the calcrete. Although more a mechanism than a source, dissolved calcium in soil solution and consequent deposition via capillary rise has also been reported (Mann and Horwitz, 1979; Goudie, 1973), but was not considered, to be widespread by Reeves (1976a) and Birkeland (1999).

The original parent material for the near-surface regolith on the High Plains is comprised largely of eolian sediments, which are ubiquitous in arid and semiarid environments. Weathering products of minerals in the parent rocks provide the source of calcium, and to a much lesser extent magnesium, which may be dissolved and reprecipitated lower in the soil through pedological mechanisms (McGrath, 1984).

Time Scale

Calcrete formation has been estimated by mathematical models based on soil forming factors (Goudie, 1973; Royer, 1999; Marion and Schlesinger, 1994). Goudie (1973) calculates the time necessary to develop a calcic horizon, with a thickness of C_t , based upon an infiltration of eolian material by means of the equation:

$$C_t = \frac{I}{C_g} \times \frac{D_{\text{CaCO}_3}}{C_{\text{CaCO}_3}}$$

where:

C_t = thickness formed in 10 thousand years (KA),

D_{CaCO_3} = percent CaCO_3 in the loess,

I = loess (gm^{-2} per year),

C_g = specific gravity of the caliche,

C_{CaCO_3} = calcium carbonate content of the caliche.

Thick indurated accumulations of caliche, such as the Ogallala caprock, is an indication of Tertiary as opposed to Quaternary formation (Goudie, 1973; Reeves, 1976a).

While correlating the percent of calcium carbonate with ages of local geomorphic surfaces and parent material, Ruhe (1965) proposed a calcium carbonate accumulation rate of approximately 1 percent per 1,000 years for specific caliches of south-central New Mexico (Reeves, 1976a).

Another method for determining the formation time of a particular soil, in this case a petrocalcic horizon, is by its relative stratigraphic position (Birkeland, 1974). The surface geology of the Llano Estacado (referred to by Roemer as the Steppen-Lande) and the Pecos region has been studied, albeit sporadically, since the 1840's by such investigators as William Kennedy and Ferdinand von Roemer, while acquiring knowledge of the general geology of Texas (Hill, 1887). The sediments of the Llano Estacado that contain calcretes or remnant fragments of past calcretes have long been identified with the Cenozoic Era. It is helpful, however, in the discussion of the Southern High Plains, to recognize two specific formations, the Blackwater Draw and the Ogallala Formations (Reeves, 1976b), to discuss the more specific time periods within the Cenozoic during which these formations were developing. Darton (1899), Sidwell (1943), Reeves (1970), Walker (1978), and Holiday (1990) place the extensive Ogallala Formation, the principal stratigraphic unit underlying the Blackwater Draw Formation, in the late Tertiary, probably in the late Miocene to early Pliocene. The upper stratum of this formation often contains the calcrete known as the Ogallala "caprock," and although strong variability in pedogenesis across the region that affected the induration of this calcrete is recognized, it probably took as much as several million years to form (Holiday, 1990). The surface formation, known as the Blackwater Draw, was deposited in a series of eolian depositional events, with long periods of stability in between, during the early to middle Pleistocene. The pedogenesis of the well-developed soils of the area (especially Paleustalfs and Paleustolls) began roughly

between 30 and 120 KA B.P (Holiday, 1990). Sediments in the Basin and Range province (Trans-Pecos region), specifically the Diablo Plateau, are derived from thick Quaternary and older bolson fills (Hawley et al., 1976).

Geomorphology

Horizons enriched with calcium carbonate are influenced by their geomorphological environments. Such factors as slope gradient, slope position, and slope aspect indirectly affect the formation and alteration of calcretes by directly influencing factors such as soil moisture regime, temperature, and erosion (Brown, 1956; Reeves, 1976a; Birkeland, 1999). It should be noted, however, that there exists complex mutual relationships between some of these factors (e.g., local relief) and the presence of these indurated horizons which also influence landscape evolution (Flach et al., 1969; Hall, 1983; Goudie, 1983).

Mineralogy and Chemistry

Carbonate

Goudie (1972) defines a calcrete, in part, as “terrestrial materials composed dominantly but not exclusively of calcium carbonate” (p. 449). This definition is reiterated by the work of Klappa (1983) and is germane to the discussion on the pedogenesis of calcrete on the Southern High Plains and the Trans-Pecos region of Texas.

Low amounts of magnesium occur in calcrete deposits, because magnesite (MgCO_3) is more soluble than calcite (CaCO_3) and, consequently, is preferentially leached from the soil under good drainage conditions (Goudie, 1972). There also exists a partitioning effect whereby the precipitation of CaCO_3 is favored over magnesite, magnesian

calcite $[\text{Ca}_{1-x}\text{Mg}_x(\text{CO}_3)]$, or dolomite $[\text{CaMg}(\text{CO}_3)_2]$ according to the equation:

$$\frac{\text{Mg}_c}{\text{Ca}_c} = D_{\text{Mg}} \left(\frac{\text{Mg}_s}{\text{Ca}_s} \right)$$

where:

Mg_c = the molar ratio of Mg in calcite,

Ca_c = the molar ratio of Ca in calcite,

D_{Mg} = the partitioning effect coefficient of Mg between calcite and solution,

Mg_s = the molar ratio of Mg in the equilibrium solution,

Ca_s = the molar ratio of Ca in the equilibrium solution,

(Doner and Lynn, 1989).

Neoformation of silica banding has been commonly reported in mature calcretes (Reeves, 1976a). McGrath (1984) noted an inverse relationship in increasing opal-CT content with palygorskite.

Sand, Silt, and Clay

The sand, silt, and clay fractions of indurated calcic horizons are derived, in part, from the composition of the original sediments in which the carbonates were deposited. Carbonates were deposited in the sand, sandy clay, silt, and gravelly sediments of the Ogallala Formation to form the caprock of the Llano Estacado (Darton, 1899; Bretz and Horberg, 1949b; Brown, 1956). It contains these gravel, sand, silt, and to some extent clay sediments, except where these sediments have been reworked by wind or undergone diagenesis. Clastic minerals within the Ogallala caprock are preeminently quartz, together with occurrences of orthoclase, microcline, epidote, zircon, tourmaline, and garnet, all of which are usually associated with the banding of the indurated caliche (Brown, 1956). The positioning of these sediments within

the calcrete is noteworthy. Brown (1956) reported the sand, silt, and gravel particulates were, by and large, not joining so that they “floated” in the calcium carbonate cement.

In general, the clay mineralogy of calcretes depends upon the lithology of the parent material, the age of the caliche, and its geographic position (Reeves, 1976a). Caliche deposits containing illite $[K_xAl_2(Si_{4-x}Al_x)O_{10}(OH)_2]$, chlorite $[\sim(R_{6-y-z}^{2+}R_y^{3+}\square_z)(Si_{4-x}R_x^{3+})O_{10}(OH)_8]$, kaolinite $[Al_2Si_2O_5(OH)_4]$, smectite $[M_{4+y}^{+}nH_2O)(R_{2-y}^{3+}R_y^{2+})(Si_{4-x}Al_x)O_{10}(OH)_2]$, palygorskite $[\sim(Mg_{5-y-z}R_y^{3+}\square_z)(Si_{8-x}R_x^{3+})O_{20}(OH)_2(OH_2)_4 \cdot R_{(x-y+2z)/2}^{2+}(H_2O)_4]$ and sepiolite $[\sim(Mg_{8-y-z}R_y^{3+}\square_z)(Si_{12-x}R_x^{3+})O_{30}(OH)_4(OH_2)_4 \cdot R_{(x-y+2z)/2}^{2+}(H_2O)_8]$, as well as mixed layered clays, have been reported in the United States (Vanden Heuvel, 1966; Reeves, 1976a; Watts, 1980; McGrath, 1984). Illite alteration into other phyllosilicates, such as pedogenic chlorite, hydroxy interlayered vermiculite, or even smectite, is known to occur in soils (Allen and Hajek, 1989), but is less common under arid and semiarid conditions. Diagenesis of clastic minerals in the calcrete may, however, under alkaline conditions and in the presence of soluble magnesium and silica (Bigham et al., 1980), form authigenic sepiolite and palygorskite (also known as attapulgite in older literature) (Halitim et al., 1983; Singer, 1989). These acicular minerals are postulated to have formed during the accumulation and consequent lithification of the calcrete (Vanden Heuvel, 1966). This is further evidenced by the work of Gardner (1972) on Mormon Mesa caliche in which the hypothesis of eluviation as a means of deposition seemed to be unlikely since kaolinite and montmorillonite, which were present in the parent material, was not enriched in the calcrete. The relative amount of palygorskite, however, did increase. Watts (1980) reported on the association of sepiolite with dolomite and maturity of the cal-

cretes in the Kalahari Desert, with dolomite and montmorillonite being responsible for the addition of magnesium, possibly by transformation.

Morphology

Macromorphology

Calcretes take many different forms and textures. In reviews of the literature, Reeves (1976a) and Goudie (1983) provide several morphologies of caliche including *birdseye* for algal structures in young caliches, *breccia-conglomerate* for the cementation of fractured nodules and other structures, *buckle cracks* for horizontal contraction cracks, *concretions* represented by roughly spherical, hardened, masses of calcite or silica within the matrix of calcium carbonate, *honeycomb* for the “honeycomb” type structure resulting from the movement of water and subsequent precipitation of calcium carbonate along roots and pores, *irregular masses*, *laminae* from the exposure of caliche to infiltrating water, *nodules* ranging from 25 mm to a 30 cm in diameter and discrete from their occurrence formation, *pipes* for solution conduits in caliche, *pisolites* for spherical to subspherical accretionary bodies over 2 mm in diameter, which form from concentric laminae of calcite, and are an indication of alternating periods of wetting and drying, and *plates* for (0.5 to 15 cm in diameter) “saucer-shaped” fragments to name a few. Pelletal calcrete has been reported in Kyle Canyon, Nevada as pellets suspended in the matrix of an indurated horizon which often differ mineralogically from the matrix (Sowers, 1985). Ooids and intraclasts of calcretes have been hypothesized to form from percolating water carrying dissolved CaCO_3 that, when limited by the depth of wetting (i.e., precipitation and temperature), precipitates the carbonate around grains in the matrix that act as nucleation centers either individually (ooids) or collectively (intraclasts) (Siesser, 1973). Arakel (1982) observed three

types of breccia formation in calcretes of Australia: (1) oriented, where breccia fragments are packed together; (2) reverse graded, where breccia fragments show reverse grading within the calcrete; and (3) clotted, where the fragments are suspended in the calcrete. Calcretes have been reported with teepee structures (pseudoanticlines) from the influence of biophysical and biochemical weathering (Klappa, 1980), as funnel-shaped structures, irregular aggregates, lenses, pseudo-ooids (Hay and Reeder, 1978), and bifurcating sheets (Knox, 1977).

The Ogallala caprock has various morphologies, including laminated, brecciated, chalky, pisolitic, containing concretionary nodules, cupped pebbles, geopetal pendants, teepee structures, and multiple stages of concretions (Bretz and Horberg, 1949a; McGrath, 1984; Chitale, 1986). In southern New Mexico, Gile et al. (1966) observed the laminar morphologies in the most developed calcretes and irregular gravelly, carbonate-plugged conglomerates in less mature horizons.

Micromorphology

Micromorphological properties of calcretes are as varied as their macromorphologies. Gile et al. (1965) proposed the term “K-fabric” as fine-grained authigenic carbonate that occurs as essentially a continuous medium. Knox (1977), reporting on calcretes of South Africa, described certain textural features such as leached particles, bridge and point-contact cement, uneven druses, tubules, irregular borings, acicular networks, and micritic and sparry fabrics. Microscopic laminations, nodules, pisolites, spherulites, coarse granular calcite, rounded calcite grains, needle-shaped calcite efflorescence, and microcrystalline calcite-lined vugs (neocalcitans) have also been reported (Sehgal and Stoops, 1972; Reeves, 1976a). Sehgal and Stoops (1972) observed four distinguishable types of nodules under the polarizing microscope: (1)

spongy nodules composed of microcrystalline calcite, (2) discrete compact nodules that are dense, irregular and large, (3) compact calcitic nodules surrounded by a halo of diffuse microcrystalline calcite, and (4) compound calcitic nodules that are compact with intruding sesquioxidic glaeboles or neosesquans. Oolitic textures and microscopic evidence for multiple varying climatic events (periods of precipitation and desiccation), such as calcite crystals forcing apart micritic clasts (known as grain brecciation by Goudie [1983]), are micromorphologic evidence for older, more mature caliches, whereas, drusy calcite is an indication of less mature, younger calcic horizons (Reeves, 1976a). Braithwaite (1983) suggests that the key feature of cements is the irregular pattern of distribution, representing subaerial variability.

McGrath (1984) noted cutans in all samples, especially calcitans, argillans, and silans, with the occasional occurrence of mangans and sesquans, indicative of older deposits on the Southern High Plains. He interpreted argillans as pedorelicts since many possessed a reddish color often associated with an older argillic horizon. Chitale (1986) observed spherical and elongated radial calcite with “organic” coatings in roughly a hexagonal shape in caprock specimens. Such biogenic structures suggest the former presence of roots. Banded travertine was observed in brecciated caprock in New Mexico (Bretz and Horberg, 1949a).

Models

Carbonate Formation

Probably the most used model for the formation of pedogenic carbonate accumulation in the literature was described by Gile et al. (1966) in their work in southern New Mexico and discussed later in the Desert Soil-Geomorphology Project report (Gile and Grossman, 1979) of work in the same area. The sequence is presented for

Figure 2.1. Stages of the morphogenetic sequence of carbonate deposition for gravelly and non-gravelly sediments. (After Gile et al., 1966.)

carbonate accumulation in two types of sediments: gravelly and non-gravelly (Figure 2.1; Table 2.1). In this system, there are four stages of accumulation and induration in each type of sediment corresponding to their geologic age where stage I is younger than II and so forth. Flach et al. (1969) provided further field evidence for the usefulness of this model.

Bachman and Machette (1977) proposed a similar, but less well known, sequence of carbonate accumulation in their study of calcretes in the southwestern U.S. that is composed of six morphogenetic sequence stages with the addition of textural and structural features (Table 2.1). The mechanism in this scheme, for the formation of stages I-III, is the deposition of carbonate by percolating soil solutions. Although, in stage IV, the horizon is plugged to downward moving solutions, carbonates are deposited in remaining pores and fractures so that the continued construction of the

Table 2.1. Sequences of carbonate accumulation. (After Gile et al., 1966; Bachman and Machette, 1977.)

Stage	Gile et al. (1966)		Bachman and Machette (1977)
	Gravelly Soils	Nongravelly Soils	
I	Thin, discontinuous pebble coatings.	Few filaments or faint coatings.	Filaments or faint coatings. Thin, discontinuous coatings on lower surface of pebbles.
II	Continuous pebble coatings, some interpebble fillings.	Few to common nodules.	Firm carbonate nodules few to common but isolated from one another. Matrix may include friable interstitial accumulations of carbonate. Pebble coatings continuous.
III	Many interpebble fillings.	Many nodules and internodular fillings.	Coalesced nodules in disseminated carbonate matrix.
IV	Laminar horizon overlying plugged horizon. (Thickened laminar and plugged horizons.)	(Increasing carbonate impregnation.) Laminar horizon overlying plugged horizon.	Platy, massive indurated matrix. Relict nodules may be visible in places. Plugged. May have weak incipient laminae in upper surface. Case hardening common on vertical exposures.
V			Platy to tabular, dense and firmly cemented. Well developed laminar layer on upper surface. May have scattered incipient pisoliths in laminar zone. Case hardening common.
VI			Massive, multilaminar and brecciated, with pisoliths common. Case hardening common.

horizon is at the expense of the preservation of overlying soil layers. That is to say, in this stage, deposition is upward. Stage V is realized by dense, indurated, platy to tabular structures and laminae. The most mature, developed, indurated caliche is defined by stage VI. It is characterized by a continuous, massive, multilaminar, well cemented horizon such as the Ogallala caprock (Bachman and Machette, 1977; Machette, 1985).

Sehgal and Stoops (1972) reported a three-stage profile development categorization based on soil microscopy helpful to their study of calcic horizons on an alluvial plain in India (Table 2.2). Their system is essentially identical to the one put forth by Gile et al. (1966), with the recognition that stage IV (calcretes) were not observed, probably due to a younger surface and pedoturbation, but possibly, by more pronounced biological activity (Sehgal and Stoops, 1972).

The pedodiagenetic model is offered by Klappa (1983), where it is recognized that pedogenic and diagenetic processes determine the morphology and composition of calcretes and that these processes cannot be entirely separated (Figure 2.2). Klappa (1983) writes:

Pedodiagenetic processes operate in an attempt to restore and maintain equilibrium. Treated simplistically, these processes lead to changes which involve additions, removals, translocations and transformations of materials. The driving mechanisms behind these changes, which are physical, chemical or biological in origin, may proceed independently or together. (p. 213)

In this model, six stages are presented (Table 2.2). Stages III-VI are roughly comparable to stages I-IV put forth by Gile et al. (1966) with an emphasis on micro-morphological interpretations and biological factors.

Watts (1980) also provided a model for calcrete formation in the Kalahari Desert, based on pedogenic and diagenetic processes with a particular emphasis on soil min-

Figure 2.2. The pedodiagenetic cycle. (After Klappa, 1983.)

eralogy. This is furthered by reports of clay coatings on accretionary grains and consequent replacement and cementation having played a major role in the formation of oolitic textures of calcretes (Hay and Reeder, 1978). Other models and classification schemes are presented in the literature (Reeves, 1970; Goudie, 1983; McFadden and Tinsley, 1985; Sowers, 1985; Rabenhorst et al., 1991; Marion and Schlesinger, 1994; Birkeland, 1999; Lal and Kimble, 2000) either for use in particular localities or in a survey of the literature utilizing morphological (macro and microscopic) or mineralogical criteria, biological, pedological, and diagenetic factors, and compartmentalized theoretical and mathematical equations, most of which may be generalized to those presented in this section or in the preceding section on climate.

Carbonate Degradation

With the exception of a few studies in the literature, very little direct attention has been given to the degradation of calcretes. Brown (1956) noted, however, exposed caliche being degraded on the Llano Estacado, while Knox (1977), in a study on caliche formation, outlined a dynamic environment of the continuous formation

Table 2.2. Sequences of carbonate accumulation. (After Sehgal and Stoops, 1972; Klappa, 1983.)

Stage	Sehgal and Stoops (1972)	Klappa (1983)
I	No specific horizon of calcite accumulation, the micrite crystals are found dispersed, with common neocalcitans and diffuse clustered calcitic nodules.	Preparation of host material: mechanical and biophysical disintegration, dissolution, etc.
II	Dominance of soft diffuse calcitic nodules; plasmic fabric moderately crystic.	Soil formation; unconsolidated sediment transformed in a soil primarily by biological and hydrological mechanisms.
III	Highly impregnated horizon with secondary carbonates; compact calcitic nodules; incipient spots of coarse-grained allotriomorphic granular calcite.	Accumulation of calcium carbonate; neocalcitans form; relic quartz and other mineral grains become progressively replaced by calcite.
IV		Profile development; formation of chalky horizon where precipitation and dissolution of carbonates occur concurrently.
V		Induration; diagenetic processes lead to fossilization and induration of the profile.
VI		Reworking; pedoturbation, dissolution, and reprecipitation forms recemented breccia-conglomeratic calcrete hardpan.

of fractures, breccias, and solution hollows. Watts (1980) and Klappa (1983), realizing the need for a broader approach in regards to pedogenic factors, offer, in their carbonate accumulation models, increased attention to cyclic pedodiagenetic processes. Disintegration of petrocalcic horizons has been observed in the Desert Project of southern New Mexico with mechanical, hydrological, and biological mechanisms given as explanations (Gile and Grossman, 1979). From their investigation of pa-

lygorskite and sepiolite deposits on the Southern High Plains. Bigham et al. (1980) reported that present soil conditions may be causing degradation of clay minerals preserved within the caprock.

CHAPTER III

MATERIALS AND METHODS

Field Studies

Field studies were conducted at two localities (Figures 3.1, 3.2, 3.3). Six pits were studied in native range near the eastern edge of the High Plains escarpment, overlooking Blanco Canyon, approximately 16.1 km (10 miles) southeast of Floydada. The pits were in northern Crosby County and are henceforth referred to as the Floydada site or pedons F1-F6. The second site was in an open caliche pit on the Diablo Plateau in Hudspeth Co., 13.2 km (8.2 miles) south of US 180/62, 300 m (981 ft) to the east of Ranch Road 1111. It is henceforth referred to as the Hudspeth site or Pedon H. At the Floydada site, six backhoe pits were excavated to approximately 300 cm, spaced approximately 45 m apart along a transect from the edge of the escarpment to a calcrete outcrop on a nearby playa slope, and labeled in sequential order beginning with the pit closest to the playa (F1). All profiles were described in detail according to the current U.S. soil taxonomy (Soil Survey Staff, 1999). Samples from horizons were selected for chemical, physical, and mineralogical analysis.

Laboratory Studies

Organic Carbon

Organic carbon (OC) was determined on selected samples using the procedure outlined by Prince (1955). Samples (0.40 to 0.80 g) were weighed in Erlenmeyer flasks. Ten ml of 0.4N chromic acid were added to each flask from a digital burette. The mixtures were gently boiled for 5 minutes and allowed to cool. After samples were brought to a ~250 ml volume, 4 ml of concentrated sulfuric acid (H_2SO_4) and

Figure 3.1. Location of sampling sites.

Figure 3.2. Floydada sampling site, looking northeast across Blanco Canyon. The area where pit F6 was sampled is in the foreground.

Figure 3.3. Hudspeth sampling site, approximately 100 m southeast of the sampling point. The prismatic blocks in the foreground are concrete.

three drops of orthophenanthroline indicator were added to flasks and titrated with ferrous ammonium sulfate $[\text{Fe}_2(\text{NH}_4)_2(\text{SO}_4)_3]$ solution to a reddish tinge end point.

Percent carbon was determined by the equation:

$$\frac{\frac{B - U'}{B} \times D \times N \times A \times 100}{W} = \%OC$$

where:

B = ml of $\text{Fe}(\text{NH}_4\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$ used for the blank,

U' = ml of $\text{Fe}(\text{NH}_4\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$ used for the sample,

D = ml of chromic acid,

N = normality of the chromic acid ($0.4N$),

A = meq weight of carbon (0.003g),

W = weight of sample (g).

Particle Size Distribution

Air-dried, 50 g samples were analyzed for particle size distribution using a modified Bouyoucos hydrometer method (Bouyoucos, 1951). The samples were corrected to a H_2O -free basis by heating a separate weighed sample to 105°C for 12 hours. The percentage of clay was determined by taking 2-hour and 6-hour hydrometer readings. Sand was estimated by taking 40-second readings and also, by drying, sieving, and weighing. (The 40-second readings were taken for comparison purposes only; the sieved sand weight was used to calculate texture.) Sand, silt, and clay percentages were multiplied by horizon thickness, summed, and divided by the depth of the respective profile to determine weighted averages for each pedon.

Sand Fractionation

Dried sands of selected samples were passed through a series of sieves (18, 35, 60, 110, and 325-mesh) using a mechanical shaker for approximately 15 minutes. Very fine, fine, and the combined total of very coarse, coarse, and medium sand fractions were collected and weighed.

pH Determination

Soil pH was determined from saturated pastes on all samples and prepared using the procedure outlined in the USDA Handbook No. 60 (U.S. Salinity Laboratory Staff, 1954). Determinations were made using a digital Beckman pHTM 40 pH meter.

Electrical Conductivity

Electrical conductivity of saturated pastes was determined following procedure 4b of the USDA Handbook No. 60 (U.S. Salinity Laboratory Staff, 1954).

Calcium Carbonate Equivalence

Calcium carbonate equivalence was determined for all samples following procedure 23c of the USDA Handbook No. 60 (U.S. Salinity Laboratory Staff, 1954) except that the end point (pH = 8.0) was determined using a digital Beckman pHTM 40 pH meter. Calculations were made according to the equation:

$$\% \text{CaCO}_3 = \frac{(A - B) \times 5}{W}$$

where:

A = meq HCl added,

B = meq NaOH used,

W = weight of sample.

Cation Exchange Capacity

Cation exchange capacity (CEC) was determined for selected samples using procedure 19 in the USDA Handbook No. 60 (U.S. Salinity Laboratory Staff, 1954), which was modified by the SampleTek Model 24VE programmable vacuum extractor instrumentation outlined in the Soil Survey Laboratory Methods Manual (National Soil Survey Center, 1996). The procedure for CEC determination is outlined below.

1. Exactly 1 g of ashless pulp was compacted to the bottom of the sample cylinder.
2. An aliquot of sample weighing 2.5 g (± 0.001) was placed overlying the compacted pulp.
3. Twenty ml of 1.0*N* sodium acetate were added to the sample cylinder and let to stand for 20 minutes, after which, 7 ml was rapidly extracted.
4. The upper reservoir cylinder was attached to the sample cylinder and approximately 45 ml were added and programmed to be extracted for 16 hours.
5. After extraction was complete, the extraction syringes were pulled down to remove excess sodium acetate, which was discarded.
6. The extraction syringes were reattached and steps 1-5 were repeated with 95% ethanol.
7. Steps 1-4 were repeated with 1.0*N* ammonium acetate, which had been adjusted to a pH of 7.0 with additions of acetic acid or ammonium hydroxide as needed.
8. Displaced Na^+ was determined on the final extraction solution by atomic absorption flame spectrometry.

Cation exchange capacity was calculated according to the equation:

$$\frac{A \times B}{W} \times 4.35 = \text{CEC (meq/100g)}$$

where:

A = displaced Na^+ in ppm,

B = volume of the extraction solution (L),

W = weight of sample used (g),

1.35 = 100 divided by the meq weight of Na (mg).

Clay Separation for X-ray Diffractometry

Calcium Carbonate Removal. Calcium carbonate was removed from samples selected for x-ray diffractometry (XRD) analysis by repeated addition and decantation of 10% sodium acetate (NaOAc) buffered at pH $\sim$ 5.0 until no reaction was observed when either fresh buffered solution or a small amount of the mixture was tested with 10% HCl. Final volume was reduced in beakers by flocculation and subsequent decantation.

Organic Matter Destruction. Samples were treated with 10% hydrogen peroxide (H_2O_2) by slow addition. The mixtures were allowed to react overnight. Samples were boiled until volume was sufficiently reduced. After samples had cooled to room temperature, this process was repeated with 20% H_2O_2 and again with 30% H_2O_2 . Samples were then flocculated in a 10% NaOAc solution.

Clay Separation. Reaction products and excess NaOAc solution were removed by repeated additions and decantations of deionized water until dispersion began. (Henceforth, H_2O will be understood to be deionized water unless specified otherwise.) Samples were transferred to 500-ml plastic bottles, treated with 15 ml of 5% sodium metaphosphate solution, and shaken on a reciprocating shaker for 1 hours. Suspensions were transferred to sedimentation cylinders and clay fractions were separated by use of a siphoning tube at a depth and time calculated according to Stoke's

Law:

$$V = \frac{2(\rho_s - \rho_l)gr^2}{9\eta}$$

where:

V = velocity (cm/sec),

ρ_s = solid density (g/cm³),

ρ_l = liquid density (g/cm³),

g = acceleration due to gravity (cm/sec²),

r = radius of particle (cm),

η = viscosity of liquid (g/cm sec).

Clay fractions were treated with 10% calcium chloride (CaCl₂) solution to flocculate the suspension and reduce the volume. The flocculated clay was treated with repeated additions and subsequent decantations of the supernatant solution until dispersion began.

Clay Orientation. Two separate samples from each suspension were saturated with calcium or potassium by washing three times, centrifuging, and decanting the supernatant liquid. Calcium-saturated clay samples were washed with a 1% glycerol solution and subjected to centrifugation and decantation until dispersion began. Potassium-saturated samples were treated in the same manner with H₂O instead of 1% glycerol. Samples were resuspended with either 1% glycerol or H₂O to make a thin suspension. Portions of the suspension were transferred via a dropping pipette to glass slides and air-dried overnight. Potassium treated slides were stored in a desiccator after drying. Calcium-glycerol slides were oven dried at 60°C overnight and placed in a desiccator. Potassium slides were analyzed at ambient temperature, after heating for 4 hours at 250°C. After the samples were x-rayed, they were heated for 4 hours at 550°C, cooled, and reanalyzed.

X-ray Diffraction of Clays

All selected samples were analyzed on a Phillips-Norelco x-ray diffractometer with Cu-K α radiation operating at 40 kV and 20 mA. Samples were scanned from 3 to 30°2 θ at a rate of 1° per minute and d-spacings were calculated with the Lab ViewTM software version 5.0 from National InstrumentsTM

X-ray Diffraction of Silt

Silt was separated from sand in selected samples (in which clay had already been removed for x-ray diffraction) by wet sieving through a 325-mesh screen. Silt was dried overnight at 105°C and powder mounts were prepared. Samples were analyzed on a Phillips-Norelco x-ray diffractometer with Cu-K α radiation operating at 40 kV and 20 mA and scanned from 15 to 32°2 θ at a rate of 1° per minute.

Micromorphology Analyses

Samples were selected for thin sections based upon their relative position in the profile and horizon morphology. Additionally, samples of some horizons on which mineralogy determinations were made were also selected. Fabric characteristics and micromorphological features were identified and described using a polarizing microscope in accordance with the terminology of Brewer (1964).

CHAPTER IV

RESULTS AND DISCUSSION

Field Studies

Tabular summaries of field profile descriptions are given in this section. Detailed descriptions are given in Appendix A. Soils were classified in accordance with the criteria set forth in the second edition of Soil Taxonomy (Soil Survey Staff, 1999).

Floydada Site

Pedon F1 (Table 4.1), classified as a fine, mixed, active,¹ thermic Aridic Calcistoll, had a cambic horizon from 24 to 48 cm, a calcic horizon from 48 to 212 cm and a buried argillic horizon from 102 to 138 cm. The particle size control section extended from 25 to 100 cm. The primary parent material for this pedon was eolian sediments typical of the Blackwater Draw Formation. Some slope colluvium has probably been intermixed with the eolian sediments. The pedon was well drained with a slightly sloping (1.53%) surface slope. The depth to which this pit was dug was limited by the degree of cementation and the occurrence of common medium and coarse petrocalcic fragments in the Bkb horizon.

Pedon F2 (Table 4.1; Figures 4.1 and 4.2) was classified as a fine-loamy, mixed, active, thermic Aridic Paleustoll, had an argillic horizon from 11 to 96 cm and a calcic horizon from 96 to 300 cm. The particle size control section extended from 11 to 61 cm. The primary parent material for this pedon was eolian sediments typical of the

¹Activity classes are based on cation exchange capacity/non-carbonate clay ratios. These ratios were low when compared to those obtained from similar soils in the area, as discussed later under "Laboratory Studies." Most of the soils in the area are classified as "superactive."

Table 4.1. Profile Descriptions for the Floydada and Hudspeth sites.

Horizon	Depth (cm)	Color		Texture†	Structure†	Dry Consistency‡	Effervescence¶	Boundary#	CaCO ₃ Distribution††	Roots/ Pores††
		Dry	Moist							
A	0-8	10YR 4/2	10YR 3/2	l	—— Pedon F1 ——					
Bw1	8-24	7.5YR 4/2	7.5YR 3/2	cl	1 m sbk 2 m pr/ 1 m sbk	vh vh	esl es	cs cw	0 m ma	3 f.m 2 f.m
Bw2	24-48	7.5YR 5/4	7.5YR 4/4	cl	1 m pr/ 1 m sbk	h	ev	cw	1 f.m ma; 0 pf	2 f.m
Bk1	48-71	7.5YR 6/4	7.5YR 5/4	sicl	1 m sbk	m	ev	gw	3 f.m,c ma; 1 pf	1 f.m
Bk2	71-102	5YR 6/4	5YR 5/4	sicl	1 m sbk	w	ev	cw	2 f.m,c ma; 1 pf	1 f.m
Btkb	102-138	5YR 6/4 5YR 8/4	5YR 5/4 5YR 7/4	cl	1 m sbk	m	ev	cw	2 f.m,c ma; 1 vc pf	1 f.m
Bkb	138-212+	5YR 7/6	5YR 6/6	grcl	ma	vs	ev		2 m,c pf	
A	0-11	7.5YR 4/3	7.5YR 3/3	l	—— Pedon F2 ——					
Bt	11-32	7.5YR 4/3	7.5YR 3/3	c	2 m sbk 2 m pr/ 2 m sbk	vh vh		cs cw		3 f.m 2 f.m
Btk1	32-51	7.5YR 4/3	7.5YR 3/3	c	2 m pr/ 2 m sbk	vh	es	gw	2 fi,tr	1 f
Btk2	51-74	7.5YR 5/4	7.5YR 4/4	cl	2 m pr/ 2 m sbk	vh	ev	cw	3 fi,tr	1 f
Btk3	74-96	5YR 5/6	5YR 4/6	cl	1 m pr/ 2 m sbk	vh	ev	cw	2 fi,tr, 2 f.m ma	1 f
Bk1	96-142	7.5YR 8/6	7.5YR 7/6	sicl	ma	w	ev	gw	cm	2 kr
Bk2	142-167	7.5YR 8/4	7.5YR 7/4	sicl	1 m sbk	m	ev	gw	4 m,c ma	2 kr
B'tk1	167-220	7.5YR 6/6 7.5YR 8/4	7.5YR 5/6 7.5YR 8/4	cl	1 m sbk	w	ev	gw	3 f.m,c ma	2 kr
B'tk2	220-252	7.5YR 6/6	7.5YR 5/6	cl	1 m sbk	w	ev	cw	2 f.m ma	2 kr
Bk	252-300+	7.5YR 8/3 7.5YR 6/6	7.5YR 8/3 7.5YR 5/6		ma	m	ev		3 m,c ma; 1 pf	2 kr

Table 4.1. Continued.

Horizon	Depth (cm)	Color		Texture†	Structure†	Consistence‡	Effervescence¶	Boundary#	CaCO ₃ Distribution††	Roots/ Pores††
		Dry	Moist							
A	0-12	10YR 4/2	10YR 3/2	l	2 m sbk	vh		cs		3 f.m
Bt1	12-31	7.5YR 4/2	7.5YR 3/2	cl	2 m pr/ 2 m sbk	vh		cw		2 f.m
Bt2	31-51	7.5YR 4/3	7.5YR 3/3	c	2 m pr/ 2 m abk	vh		cw		2 f.m
Bt3	51-70	7.5YR 4/4	7.5YR 3/4	cl	1 m pr/ 2 m abk,sbk	vh	esl	aw		1 f
Btk1	70-89	5YR 4/4	5YR 3/4	cl	1 m pr/ 2 m sbk	vh	es	cw	2 fi.tr	1 f
Btk2	89-103	5YR 4/4	5YR 3/4	cl	1 m pr/ 2 m sbk	vh	ev	aw	3 fi.tr	1 f
Bk1	103-132	7.5YR 7/4	7.5YR 6/4	cl	ma	m	ev	gw	cm	0 f
Bk2	132-151	7.5YR 7/6	7.5YR 6/6	cl	ma	m	ev	gw	cm	0 f
B'tk1	151-197	7.5YR 6/6	7.5YR 5/6	cl	1 m sbk	w/m	ev	gw	4 m,c ma	1 kr
B'tk2	197-234	7.5YR 6/6	7.5YR 5/6	cl	1 m sbk	m	ev	gw	3 m,c ma	1 kr
B'tk3	234-280+	5YR 8/3	5YR 8/3	cl	1 m sbk	m	ev		3 m,c ma	1 kr
		5YR 8/2	5YR 8/2	cl						
-----Pedon F4-----										
A	0-13	7.5YR 4/2	7.5YR 3/2	l	2 m sbk	vh		cs		
Bt1	13-26	7.5YR 4/2	7.5YR 3/2	cl	2 m pr/ 2 m sbk	vh		cs		
Bt2	26-40	7.5YR 4/3	7.5YR 3/3	cl	2 m pr/ 2 m abk,sbk	vh		cw		
Bt3	40-62	7.5YR 5/3	7.5YR 4/3	c	2 m pr/ 2 m abk	vh	esl	cw		
Btk1	62-85	7.5YR 5/4	7.5YR 4/4	cl	1 m pr/ 2 m abk	vh	ev	gw	2 fi.tr	
Btk2	85-106	7.5YR 5/4	7.5YR 4/4	cl	1 m pr/ 1 m sbk	h	ev	aw	3 fi.tr	—

Table 4.1. Continued.

Horizon	Depth (cm)	Color		Texture†	Structure†	Dry Consistence‡	Effervescence¶	Boundary#	CaCO ₃ Distribution††	Roots/ Pores††
		Dry	Moist							
Bk1	106-148	7.5YR 8/4	7.5YR 7/4	cl	ma	m	ev	gw	cm	
Bk2	148-188	5YR 7/6	5YR 6/6	c	1 m sbk	m	ev	ci	3 m,c ma	
Btkb1	188-220	2.5YR 5/6	2.5YR 4/6	cl	1 m sbk	vh	ev/esl	gw	3 m,c ma	
Btkb2	220-268	2.5YR 6/6	2.5YR 5/6	cl	ma	vh	es/esl	gw	3 m,c ma,to	
		2.5YR 8/6	2.5YR 7/6							
Btkb3	268-280	2.5YR 5/6	2.5YR 4/6	scl	ma	vh	es/esl	cw		
Btkb4	280-310+	2.5YR 5/6	2.5YR 4/6	scl	ma	vh			0 pf	2 f,c kr
----- Pedon F5 -----										
A	0-14	10YR 4/2	10YR 3/2	l	2 m sbk	vh		cs		3 f,m
Bt1	14-33	10YR 4/2	10YR 3/2	cl	2 m pr/ 2 m sbk	vh		gs		2 f,m
Bt2	33-51	7.5YR 4/2	7.5YR 3/2	cl	2 m pr/ 2 m sbk	vh	esl	aw		2 f,m
Btk1	51-66	7.5YR 4/3	7.5YR 3/3	cl	2 m pr/ 2 m sbk	vh	ev	cw	2 fi,tr	2 f,m
Btk2	66-84	7.5YR 5/3	7.5YR 4/3	c	1 m pr/ 2 m sbk	vh	ev	cw	3 fi,tr	1 f,m
Bk1	84-103	7.5YR 8/1	7.5YR 7/1	cl	1 m sbk	vh	ev	gw	3 f,m ma	1 f,m
		7.5YR 6/6	7.5YR 5/6							
Bk2	103-146	7.5YR 8/3	7.5YR 7/3	cl	1 m sbk	vh	ev	gw	2 f,m ma	1 f,m
		7.5YR 6/6	7.5YR 5/6							
Bk3	146-191	7.5YR 7/4	7.5YR 6/4	sicl	ma	m	ev	ci	cm	1 f
		7.5YR 8/2	7.5YR 8/2							
Bk4(Upper)	191-220	7.5YR 6/6	7.5YR 5/6	sicl	1 m sbk	w	ev		3 f,m,c ma	
		7.5YR 8/2	7.5YR 8/2							
Bk4(Lower)	220-250	7.5YR 6/6	7.5YR 5/6	c	1 m sbk	w	ev	ci	3 f,m,c ma	
		7.5YR 8/3	7.5YR 7/3							
Bk5(Upper)	250-291	5YR 6/6	5YR 5/6	---	1 m sbk	w	ev		2 pf	
		5YR 8/3	5YR 8/3							
Bk5(Lower)	291-315+	5YR 6/6	5YR 5/6		1 m sbk	w	ev		2 pf	2 f,c kr
		5YR 8/3	5YR 8/3							

Table 4.1. Continued.

Horizon	Depth (cm)	Color		Texture†	Structure†	Dry Consistence‡	Effervescence¶	Boundary#	CaCO ₃ Distribution††	Roots/ Pores††
		Dry	Moist							
A	0-12	10YR 4/2	10YR 3/2	cl	2 m sbk	vh	esl	cs		3 f,m
Bt1	12-25	10YR 3/2	10YR 2/2	c	1 m pr/ 2 m sbk	vh	ev	cs		2 f,m
Bt2	25-48	10YR 4/2	10YR 3/2	c	2 m pr/ 2 m abk	vh	ev	aw		2 f,m
Btk1	48-80	10YR 4/2	10YR 3/2	c	1 m pr/3 m abk	vh	ev	cw	3 f,lr	1 f
Btk2	80-98	10YR 4/2 7.5YR 8/3 7.5YR 4/4	10YR 3/2 7.5YR 7/3 7.5YR 3/4	c	2 m abk,sbk	vh	ev	cw	2 f,lr; 1 f,m ma	0 f,m
Bk1	98-128	7.5YR 7/6 7.5YR 8/4	7.5YR 6/6 7.5YR 7/4	cl	1 m sbk	m	ev	gw	3 f,m,c ma; 1 m,c pf	0 f,m
Bk2	128-150	7.5YR 5/6 7.5YR 8/4	7.5YR 4/6 7.5YR 7/4	cl	1 m sbk	m	ev	gw	3 f,m,c ma; 2 m,c pf	0 f,m
Bk3	150-165+	7.5YR 8/3 7.5YR 5/6	7.5YR 8/3 7.5YR 4/6	cl		m	ev			
Pedon H										
A	0-5	10YR 5/3	10YR 4/3	fsl	1 c pl	slh	es	as		
Bk1	5-28	10YR 5/3	10YR 4/3	l	1 m pr/ 1 m sbk	slh	cs	gs		
Bk2	28-43	10YR 5/4	10YR 4/4	l	1 m sbk	h	cs	cw		
Bk3	43-53	10YR 5/4 10YR 8/2	10YR 4/4 10YR 8/2	—	1 m sbk		es	aw	3 fr,ma	
Bk4	53-99				ma		cs	gw	cm	
Bk5	99-168+				ma		cs		cm	

†)=loam,c=clay,si=silty,s=sand,f=fine,gr=gravelly; †1=weak, 2=moderate,m=medium,c=coarse,pr=prismatic,abk=angular blocky, sbk=subangular blocky,pl=platy,ma=massive; §h=slightly hard,h=hard,vh=very hard,el=extremely hard,w=weakly cemented,m=moderately cemented, s=strongly cemented,vs=very strongly cemented; ¶cs=slightly effervescent, es=strongly effervescent,ev=violently effervescent; #a=abrupt,c=clear,g=gradual, s=smooth,w=wavy,l=irregular; ††0=very few, 1=few, 2=common, 3=many,l=very many,f=fine,m=medium,c=coarse,vc=very coarse,f=fibers,tr=threads, to=tongues,ma=masses,cm=continuous matrix of calcium carbonate,kr=krotovinas

Figure 4.1. Upper part of Pedon F2 profile.

Figure 4.2. Lower part of Pedon F2 profile. Knife is on fragmented petrocalcic horizon

Blackwater Draw Formation. The pedon was well drained with a nearly level (0.62%) surface slope. A few calcrete fragments occurred in the Bk horizon.

Pedon F3 (Table 4.1; Figure 4.3), classified as a fine, mixed, active, thermic Aridic Paleustoll, had an argillic horizon from 31 to 103 cm and a calcic horizon from 103 to 280 cm. The particle size control section extended from 31 to 81 cm. The primary parent material for this pedon was eolian sediments typical of the Blackwater Draw Formation. The pedon was well drained with a nearly level (0.03%) surface slope. The structure in the pedon followed a somewhat typical distribution in the upper 150 cm: a moderately well-developed argillic horizon grading into a series of structureless calcic horizons. The increased development in the grade of the structure of the B'tk1, B'tk2, and B'tk3 horizons indicates that these horizons were not formed concurrently with the land-surface soil and may be buried horizons.

Pedon F4 (Table 4.1; Figure 4.4) was classified as a fine, mixed, active, thermic Aridic Paleustoll. It had an argillic horizon from 26 to 106 cm, and a calcic horizon from 106 to 268 cm. The particle size control section extended from 26 to 76 cm. The primary parent material was eolian sediments typical of the Blackwater Draw Formation. The pedon was well drained with a nearly level (0.24%) surface slope and very few calcrete fragments were present in the Btkb4 horizon. Root distribution was not determined in the field.

Pedon F5 (Table 4.1; Figure 4.5) was classified as a fine-loamy, mixed, active, thermic Aridic Paleustoll, had an argillic horizon from 33 to 84, and a calcic horizon from 84 to 315 cm. The particle size control section extended from 33 to 83 cm. The primary parent material for this pedon was eolian sediments typical of the Blackwater Draw Formation. The pedon was well drained with a nearly level (0.87%) surface slope. The Bk5 horizon had common calcrete fragments.

Figure 4.3. Profile of Pedon F3.

Figure 4.4. Profile of Pedon F4.

Figure 4.5. Profile of Pedon F5. A krotovina is between 20 and 40 cm to the left of the tape.

Pedon F6 (Table 4.1; Figure 4.6) was classified as a fine mixed, active, thermic Aridic Paleustoll. It had an argillic horizon from 12 to 98 cm and a calcic horizon from 98 to 165 cm. The particle size control section extended from 12 to 62 cm. The primary parent material for this pedon was eolian sediments typical of the Blackwater Draw Formation. The pedon was well drained with a slightly sloping (1.80%) surface slope. The depth of this pit was limited by the strongly cemented calcrete fragments in the Bk3 horizon.

In general, color hues for these pedons became increasingly redder with depth; the maximum redness was expressed at 2.5 YR in the Btkb horizons of pedon F1. The anomalies were pedons F2 and F3 which exhibited two sequences of increasing redness: from 0 to 96 cm and 96 to 300 cm in pedon F2, and from 0 to 103 cm and 103 to 280 cm in pedon F3. Krotovinas were common to few in pedons F2 to F5, ranged in size from 8 to 25 cm in diameter, and occurred at shallower depths in pedons F2 and F3 (96-151 cm) than in F4 and F5 (280-291 cm). Effervescence for the Floydada site pedons maintained a uniform pattern of noneffervescence in the upper part of the profile to violent effervescence in the lower part, except for pedon F4. This pedon followed the pattern for the upper 190 cm at which depth the matrix was mixed slightly and violently effervescent to 280 cm after which the bulk of the matrix was noneffervescent. Visible CaCO_3 distribution increased with depth for most pedons. The exception was pedon F4 where there was a decrease in the Btkb horizons. Carbonate morphology included films, threads, masses, tongues, and strongly indurated rounded nodules many of which were believed to be remnant calcrete fragments. Slopes were related to the depth of free carbonates in the profiles, and a strong correlation ($r^2 = 0.95$) was observed.

Figure 4.6. Profile of Pedon F6.

Figure 1.7 illustrates the diagnostic subsurface horizons for the Floydada site as well as relative elevation and distance. Several points are noteworthy. First, the relative elevations of the calcic horizons follow the relative elevation distribution of the surface very closely. This is significant in two ways. It suggests an association between the present local topography and pedogenesis for the upper part of the current calcic horizons. The processes that formed the upper portion of the calcic horizons are probably associated with most of the surface mantle. The thickness of the current steadily forming soil unit within the profile may be considered to be from the surface to some depth within the calcic horizon. Furthermore, since the parent material for the soil is of eolian origin, the upper profile must have been deposited slowly and evenly across the pedons. It may be inferred, therefore, that the soil on which the upper mantle was deposited was developed enough to withstand the erosional processes that may have preceded these depositional events. The stability of the soil may be because of several reasons such as well developed structure and large amounts of carbonate.

Second, since it is assumed that the climatic environment since the deposition of the surface mantle reflects the latest pedogenic climate, both the stability of the soil and the presence of argillic horizons (although not in every profile), specifically the evidence of clay eluviation, represents a wetter soil moisture regime than during the time of deposition.

Third, the relative distribution of calcrete fragments through the transect may be correlated with the present surface slopes. At the steepest slopes of pedons F1 (closest to the playa) and F6 (closest to the escarpment), the remnant calcrete fragments were closest to the surface. Calcrete fragments in pedons F2 and F5, which are somewhat less sloping, occurred much farther down into the profile (>250 cm) and

only very few fragments were present under the most level surface slopes at pedons F3 and F4. The interaction between surface slope and water movement within the profile is the most probable explanation for this phenomenon. Water that infiltrates the soil will percolate deeper on more level surfaces than sloping ones, resulting in soil on these nearly level surfaces with potential for greater carbonate degradation through pedodiagenetic processes. From one aspect, the greater than 1% slopes of pedons F1 and F6 preserved some of the original properties of the soil on which the upper mantle was deposited. Furthermore, the convex nature of the topography along this transect and the distribution of these calcrete fragments, strongly suggests a continuous indurated matrix in the past.

Fourth, the presence of the thickest argillic horizons with the most level slopes of pedons F3 and F4, supports the conclusions based on the distribution of calcrete fragments. The greater water percolation through these soils (due to their nearly level slope) has exacerbated the translocation of clay yielding a thicker, better developed argillic horizon than in case of steeper slopes.

Hudspeth Site

Pedon H (Table 4.1; Figure 4.8) was classified as a coarse-loamy, carbonatic, thermic Typic Haplocalcid, had an ochric epipedon from 0 to 25 cm, and a calcic horizon from 43 to 53 cm. The particle size control section extended from 25 to 100 cm. The primary parent material for this pedon was locally-derived, eolian sediments and possibly limestone residuum since the solum overlaid limestone bedrock. The pedon was well drained with a nearly level (0-1%) surface slope.

The present-day environment and parent material for the soil at site H differs considerably from that at the Floydada site. At the Hudspeth site, the soil moisture

Figure 4.8. Profile of the Hudspeth site. Limestone bedrock is seen in the lower half of the section.

regime was aridic and the parent material consisted mostly of local eolian sediments with a possible contribution from limestone residuum. Pedogenesis was probably slower in this environment and the limestone may have been an important source of calcium. Yet, at this site, as well as the Floydada site, evidence suggests that the series of Bk horizons were formerly (especially in the lower part) calcretes. Today, they lack the lateral continuity defining a petrocalcic horizon. This suggests even more aridic conditions at the time of formation.

Other Examples

Three other sites are shown in Figures 4.9, 4.10, 4.11, and 4.12, which show typical degrading calcrete and calcic horizons on the Southern High Plains. As indurated and thick as the Floydada site escarpment is (Figure 4.9), approximately 45 m to the west (Pedon F6), only fragments remain. At the “Gentry” pit (Figures 4.10 and 4.11), rounded carbonate nodules, believed to be remnants of calcrete, occur in two parallel layers indicating two possible periods of deposition or major change in the paleoclimate. The degradation of calcretes in various stages is portrayed in a caliche pit north of Floydada on TX 207 (Figure 4.12).

Laboratory Studies

Results of the laboratory analyses for the Floydada and Hudspeth sites are in Table 4.2.

Organic Carbon

Organic carbon percentages followed a typical distribution for the area (Table 4.2). Percentages ranged from 1.7 to 1.0 in the A horizons of the Floydada pedons and was 0.4 in the upper horizon of the Hudspeth pedon. All profiles followed a similar trend

Figure 4.9. Exposure of the caprock escarpment, 45 m east of pedon F6, Floydada site.

Figure 4.10. The “Gentry Pit,” on the northeast corner of the intersection between FM 1294 and I 27, approximately 8 miles north of Lubbock.

Figure 4.11. Lower part of the profile at the “Gentry Pit,” Lubbock Co.

Figure 4.12. Profile of a soil exposed in a caliche pit in Floyd Co., 6.8 miles north of the junction of US 62 and TX 207.

Table 4.2. Laboratory Results for the Floydada and Hudspeeth sites.

Horizon	Sieve		Hyd	Sand Mf	Ft	VF _s	Silt _f	Clay		Textural Class-#	pH	Electrical Conduc- tivity††	Organic Carbon	Calcium Carbonate Equivalence	Cation Exchange Capacity††	
	NI	NI						2hr	6hr							
Pedon F1																
A	52	46	-	-	-	-	24	29	24	scl	7.2	0.95	1.7	2.5	16.1	
Bw1	51	42	-	-	-	-	18	35	31	scl	7.3	0.80	1.1	17.2		
Bw2	40	47	4	31	65	-	28	35	32	cl	7.7	0.70	0.8	32.2	13.1	
Bk1	33	50	-	-	-	-	35	36	32	cl	7.9	0.30	0.5	59.8		
Bk2	36	31	< 1	23	77	-	23	47	41	c	7.9	0.35		46.9	10.4	
Btkb	40	32	-	-	-	-	23	43	37	cl	8.0	0.35		27.2		
Bkb	57	49	-	-	-	-	23	28	20	sl	8.3	0.35		90.6		
Pedon F2																
A	59	47	-	-	-	-	19	27	22	scl	7.2		1.1	0.6	14.3	
Bt	53	42	-	-	-	-	18	35	29	scl	7.4	-	0.9	0.8		
Btk1	49	41	-	-	-	-	16	38	35	sc	7.7		0.8	5.5		
Btk2	48	39	-	-	-	-	17	40	35	sc	7.9		0.5	7.2	15.9	
Btk3	48	38	-	-	-	-	17	39	35	scl	7.9			9.4		
Bk1	27	27	-	-	-	-	29	55	44	c	8.1			64.2		
Bk2	25	17	< 1	23	77	-	29	63	46	c	8.2			69.5	7.9	
B'tk1	34	25	-	-	-	-	22	55	44	c	8.2			49.0		
B'tk2	42	31	-	-	-	-	22	47	36	cl	8.3			42.7		
Bk			3	29	69	-					8.4			45.4		
Pedon F3																
A	52	45	-	-	-	-	26	28	22	scl	7.3	0.75	1.0	0.5	14.5	
Bt1	56	47	-	-	-	-	20	29	24	scl	7.2		0.9	0.7		
Bt2	47	36	-	-	-	-	16	39	37	sc	7.3	0.6	0.8	3.7	17.3	
Bt3	44	34	-	-	-	-	17	43	39	cl	7.4		0.5	5.4		
Btk1	46	38	-	-	-	-	15	41	39	sc	7.5		0.4	5.5		
Btk2	44	34	3	50	47	-	17	41	39	cl	7.8		0.4	7.1	16.4	

Table 4.2. Continued.

Horizon	Sieve Hyd		Sand M ϕ	F ϕ		Silt ϕ	Clay		Textural Class #	pH	Electrical Conduc- tivity $\ddagger$	Organic Carbon	Calcium Carbonate Equivalence		Cation Exchange Capacity $\ddagger\ddagger$
	26	18		20	10		2hr	6hr					%	%	
Bk1	26	18		20		20	66	54	c	8.2			27.4		
Bk2	30	19		17		17	65	53	c	8.4	0.6		57.1		
B'tk1	33	23		16		16	59	51	c	8.2			46.6		10.9
B'tk2	47	36		17		17	46	36	sc	8.1			58.8		
B'tk3	40	26		19		19	51	41	c	8.2			37		
Pedon F4															
A	50	43		26		26	26	24	scl	7.2		1.1	0.7		14.6
Bt1	52	45		22		22	31	26	scl	7.0		1	0.9		
Bt2	49	36		16		16	37	35	scl	7.2		0.7	3.1		
Bt3	45	36		18		18	39	37	sc	7.3		0.6	3.8		18.3
Btk1	47	38		16		16	39	37	sc	7.8		0.4	9.2		
Btk2	49	38		16		16	37	35	scl	8.1		0.4	5.9		
Bk1	27	18		20		20	65	53	c	8.0			70.2		
Bk2	28	19	<1	13	87	23	59	49	c	8.1			46.7		12.9
Btkb1	41	31		23		23	46	36	cl	8.2			60.6		
Btkb2	47	39		20		20	40	33	scl	8.2			38.2		
Btkb3	67	60	<1	6	94	6	31	27	scl	8.0			10.2		9.8
Btkb4	69	61		2		2	32	29	scl	8.0			17.3		
Pedon F5															
A	61	51		18		18	25	21	scl	7.1		1	0.7		12.7
Bt1	61	49		14		14	30	25	scl	7.0		0.7	3.1		
Bt2	56	47		17		17	31	27	scl	7.0		0.4	4.6		15.1
Btk1	62	43		7		7	34	31	scl	7.4		0.6	6.3		
Btk2	45	36		19		19	40	36	cl	7.6		0.4	10.6		
Bk1	37	28	<1	27	73	19	50	44	c	7.7			34.9		14.5
Bk2	37	29		20		20	50	43	c	8.0			49.9		
Bk3	26	17		25		25	61	49	c	8.1			72.9		

Table 4.2. Continued.

Horizon	Sieve Hyd		Sand M $\ddagger$	F $\ddagger$		VF $\S$	Silt ¶	Clay		Textural Class#	pH	Electrical Conduc- tivity¶¶	Organic Carbon	Calcium Carbonate Equivalence	Cation Exchange Capacity¶¶
	27	19		23	77			2hr	6hr						
Bk4(Upper)	27	19	-	-	-	-	21	62	52	c	8.1			49.5	
Bk4(Lower)	35	27	<1	23	77		19	56	46	c	8.0			41.8	12.6
Bk5(Upper)			-								8.1			63.1	
Bk5(Lower)											8.4			88.9	
Pedon F6															
A	54	43	-	-	-		17	32	29	sc1	7.5		1.2	2.4	16.3
Bt1	42	34					20	43	38	cl	7.4		0.8	4.8	
Bt2	42	30					18	42	40	cl	7.6		0.5	6.6	16.9
Btk1	43	36					19	40	38	cl	7.9		0.3	5.3	
Btk2	46	38	-				18	43	36	sc	7.8		0.2	5.3	
Bk1	30	22	-				22	58	48	c	8.0			56.9	
Bk2	-	-	<1	17	83		-				8.0			43.2	12.2
Bk3	-	-	-								7.9			67.3	
Pedon H															
A	73	65					17	11	10	sl	8.0	0.7	0.4	9.8	9.7
Bk1	65						17	23	18	sl	7.7	0.75	0.4	17.5	
Bk2	59	52	<1	16	84		21	23	20	sc1	7.8	0.75	0.5	20.5	12.5
Bk3	71	67					17	17	12	sl	7.9	0.9	0.4	52.7	
Bk4	86	85	-				6	8	8	ls	7.9	2.4		78.4	
Bk5	74	70	2	45	53		10	19	16	sl	8.0	9		80.2	5.8

†medium; ‡fine; §very fine; ¶6hr; #l=loam,s=sandy,c=clay,si=silty,f=fine; ††mmho/cm; ††meq/100g

of decreasing organic carbon with depth. Those at the Floydada site are sufficiently high for mollic epipedons.

Particle Size Distribution

Particle size distributions are shown in Figures 4.13-4.19. The weighted averages for the sand, silt, and clay percentages for pedon F1 were 15.9, 24.5, and 29.6, respectively. Textures for the upper profile followed a typical distribution of increasing clay content with depth. Below approximately 90 cm within the profile, there was a steady decrease in clay and increase in the amount of sand. For pedon F6, which had the most comparable slope to pedon F1, sand, silt, and clay percentages averaged 41.1, 19.3, and 39.6, respectively. Pedons F1 and F6 followed a similar trend for the same depths; clay percentages immediately increased in the subsoil, followed by a gradual decline and terminated by a slight increase. Clay percentages (especially in the upper parts of the profiles) tended to have narrower ranges among the horizons in the pedons on the relatively steeper slopes than in the pedons at less sloping sites.

Ranges for the clay percentages of pedons F2 and F5 tended to be wider than those of pedons F1 and F6. The weighted averages for the sand, silt, and clay percentages, respectively, were 39.2, 22.2, and 38.6 for pedon F2 and 40.2, 19.2, and 40.6 for pedon F5. Clay increased through both profiles and the texture became gradually finer. Sand percentages decreased with depth above 160 cm, at which point they increased gradually.

Figures 4.15 and 4.16 depict somewhat abrupt changes in particle size distribution as a function of depth. Weighted averages for the sand, silt, and clay percentages, respectively, were 40.6, 17.9, and 41.5 for pedon F3 and 41.5, 17.9, and 37.6 for pedon F4. These pedons on nearly level slopes also had wider clay ranges than either of

Figure 4.13. Particle size distribution for Pedon F1.

Figure 4.14. Particle size distribution for Pedon F2.

Figure 4.15. Particle size distribution for Pedon F3.

Figure 4.16. Particle size distribution for Pedon F4.

Figure 4.17. Particle size distribution for Pedon F5.

Figure 4.18. Particle size distribution for Pedon F6.

Figure 4.19. Particle size distribution for Pedon H.

those pedons on steeper surfaces. Clay distribution within these profiles followed a pattern of incremental increases with depth to approximately 120 cm. Below this point, it followed a pattern of incremental decreases that mirrored the upper part of the profiles.

The particle size distribution of the pedon at the Hudspeth site (Figure 4.19) was remarkably uniform throughout the depth of the pedon. Weighted averages for sand, silt, and clay percentages were 71.5, 11.5, and 14.0, respectively, and showed little variation from their mean. There was a slight increase in clay in the Bk1 and Bk2 horizons followed by a general decrease through the next three horizons. Textures were much coarser than those at the Floydada site.

Overall, the samples analyzed in this study contained high CaCO_3 percentages in the lower part of the pedons. Undoubtedly, the high clay percentages are due, to a considerable extent, to clay-size carbonate particles.

pH Determination

Soil reaction for the Floydada pedons (Table 4.2) was consistent with the pattern of increasing average pH according to the carbonate distribution of the profile. Arithmetic average pH of the A horizons was 7.25 and increased with depth, reaching approximately 8.2 in the Bk horizons. Soil reaction for the Bt horizons ranged from 7.0 to 7.6 and had a mean of 7.25. In the Btk, Btkb and Bw horizons it ranged from 7.3 to 8.3 and averaged 7.95. Average pH of the Bk and Bkb horizons was 8.1 and ranged from 7.7 to 8.4.

All of the layers in the Hudspeth profile were calcareous (Table 4.2). The surface horizon had a pH of 8.0: which dropped to 7.7 in the Bk1 horizon, and increased back to 8.0 at the Bk5 horizon. This pattern indicates a current environment suitable for

retention of carbonates in the upper horizons. Calcareous sediments are probably still being deposited on the surface giving a relatively high pH for the A horizon.

Electrical Conductivity

Electrical conductivity was determined only on selected horizons (Table 4.2) of pedons F1 and F3 from the Floydada site. The EC values for pedon F1 decreased from the surface to the Bk1 horizon, increased in the Bk2 horizon, and remained at 0.35 mmho/cm throughout the rest of the profile. This was consistent with the samples analyzed from pedon F3. The EC values for the Hudspeth site followed a reverse pattern from pedon F1, beginning from the surface horizon at 0.7 mmho/cm and ending at the Bk5 horizon at 9.0 mmho/cm. This moderately saline horizon may have been caused from percolating water carrying salts more soluble than gypsum from localized (perhaps from the Salt Basin 35 to 50 km to the east) surface-deposited saline sediments.

Calcium Carbonate Equivalence

Calcium carbonate equivalence (CCE) for the Floydada site showed consistent distribution with surface slope (Table 4.2). Regression analysis between the surface slope of each Floydada pedon, the midpoint depth of each horizon with increasing calcium carbonate, and the percent calcium carbonate determined in those horizons revealed a strong correlation ($P < 0.001$). The simplest 3-dimensional sigmoidal/linear curve with the equation:

$$Y = \beta_0 + \frac{\beta_1}{1 + e^{-\frac{\beta_2 X_1 + \beta_3 X_2}{\beta_4}}} + \beta_4 X_2,$$

where:

$$Y = \text{CCE},$$

Figure 4.20. CCE as a function of horizon midpoint depth and surface slope.

X_1 = Depth to midpoint of the horizon (cm),

X_2 = Surface slope of the pedon (%),

$\beta_0, \dots, \beta_4$ = parameters determined by the least squares curve,

was used for the regression model (Figure 4.20).

The model was reasoned a priori to statistical evaluation by recognizing the dynamic interaction of several dominant factors influencing the process of calcium carbonate enrichment and subsequent dissolution: (1) soil moisture and its interaction with depth, (2) calcite solubility, (3) the asymptotic effect of a percentage, and (4) the gradual grading of the surface slopes along with its interaction with CCE and depth as a fixed relationship. The sigmoidal relationship between CCE and horizon depth in semiarid to arid environments may be observed by measuring the percentage of carbonates through the profile. In the upper horizons, precipitation has leached

carbonates leaving them non-calcareous in soils on more stable landscape positions. There is usually an increase in the percentage of carbonates until the “current” depth of wetting is reached. Below this point, a sudden decrease in carbonates may be expected as well as another sigmoidal relationship between depth and CCE if buried soils, that have undergone the same process over geologic time, are present.

This is illustrated at the Floydada site. Pedons F2, F3, F4, and F5 have been subjected to the most amount of weathering due to their more level slopes compared to pedons F1 and F6, and thus, have a greater wetting depth. Calcium carbonate equivalence for these horizons are consequently more gradually related to depth than F1 and F6. This hypothesis is supported by the explanations given in the “Field Studies” section of this chapter.

Cation Exchange Capacity

In general, cation exchange capacity (CEC) of the soils at the Floydada site all followed a similar sequence of increasing value through the Bt horizons succeeded by a decrease in the Btk and Bk horizons (Table 4.2).¹ The reason for this distribution lies in the effect of CaCO_3 on CEC. Cation exchange capacity is a property of colloid-size organic matter, amount of silicate clay and the mineralogy of the clay. Therefore, since soils at the Floydada site have undergone pronounced pedogenesis to contain higher amounts of clay in the subsoil than in overlying horizons, this first increase in CEC is expected. The content of non-silicate clay-sized CaCO_3 explains the decrease at subsequent depths. Pedons F1 and F6 departed from this sequence with slightly

¹Cation exchange capacity values were lower than those obtained in studies of soils of similar composition (Allen et al., 1972; Weindorf, 1997) and results of numerous analyses (Soil Survey Staff, unpublished data).

higher 'CEC' values in the surface horizons. This was probably due to an increase in organic matter.

Cation exchange capacity values at the Hudspeth site followed a similar pattern of increase and subsequent decrease as those at the Floydada site. The lower surface CEC at this site compared to the Floydada site, however, was indirectly due to the aridic moisture regime that both limits overall vegetation and contributes higher percentages of CaCO_3 to the clay fraction.

Mineralogy

Clay. Mineralogical analysis of clays was determined by calcium saturated, glycerol solvated slides of the clay fraction from selected horizons and confirmed by potassium saturation and heat treatments. X-ray diffraction (XRD) patterns for all selected samples are indexed in Appendix B and summarized in Table 4.3.

Analyses revealed a remarkably uniform clay mineralogy among horizons, both at the Floydada and Hudspeth sites. Moreover, little variation was apparent among the Floydada pedons. The mineralogy was dominated by illite, kaolinite, quartz, and feldspars. The latter two usually tend to be concentrated in the coarse clay fractions. Smectite was identified at the Floydada and Hudspeth sites on Ca-glycerol slides after correcting the x-ray diffractometer for a false peak that occurred between 4.4 and $5.4^\circ 2\theta$ (as shown in Appendix B figures). Sepiolite and palygorskite were identified in the Bk5 horizon at the Hudspeth site.

At the Hudspeth site, the asymmetrical broad illite peak at $\sim 8.84^\circ 2\theta$ ($10.00 \text{ \AA}$) in the Ca-saturated, glycerol solvated slides of horizons A and Bk2 suggest some illite-smectite (I/S) interstratification. This I/S interstratification is common in soils of arid and semiarid regions.

Table 1.3. Clay mineralogy of selected samples.

Horizon	Depth (cm)	Smectite†	Illite†	Kaolinite†	Sepiolite†	Palygorskite†
—————Pedon F1—————						
A	0-8	XXX	XX	XX	—	—
Bw2	21-18	XX	XX	XX	—	—
Bk2	71-102	XXX	XX	XX	—	—
—————Pedon F2—————						
A	0-11	XX	XX	X	—	—
Btk2	51-74	XX	XX	X	—	—
Bk2	142-167	XXX	XX	X	—	—
Bk‡	252-300	XXXX	XX	X	—	—
—————Pedon F3—————						
A	0-12	XX	XXX	X	—	—
Bt2	31-51	XX	XX	X	—	—
Btk2	89-103	XX	XX	X	—	—
B'tk1	151-197	XXX	XX	X	—	—
—————Pedon F4—————						
A	0-13	XX	XX	XX	—	—
Bt3	40-62	XXXX	XX	XX	—	—
Bk2	148-188	XXX	XX	XX	—	—
Btkb3	268-280	XXXX	XX	X	—	—
—————Pedon F5—————						
A	0-14	X	XX	X	—	—
Bt2	33-51	XXX	XX	X	—	—
Bk1	84-103	XXX	XX	XX	—	—
Bk4(Lower)	220-250	X	XX	XX	—	—
—————Pedon F6—————						
A	0-12	XX	XX	XX	—	—
Bt2	25-48	XXX	XX	XX	—	—
Bk2	128-150	XX	XX	XX	—	—
Bk3‡	150-165	X	XX	X	—	—
—————Pedon H—————						
A	0-5	XXX	X	X	—	—
Bk2	28-43	X	X	X	—	—
Bk5	99-168	XXX	X	X	XX	X

†XXXX=dominant,XXX=major,XX=minor,X=trace; ‡calcrete fragment

The direct implications of sepiolite and palygorskite occurrence at the Hudspeth site are unclear. The pedogenic origin of these acicular clay minerals, however, may indicate a past calcrete. Palygorskite is a relatively common component of calcretes in West Texas and New Mexico (McGrath, 1984). This would suggest that at least the lower part of the profile was a continuously indurated carbonate horizon that has since undergone degradation.

Silt. X-ray diffraction patterns for selected horizons are indexed in Appendix C. Analysis of silt fractions revealed a remarkable uniformity in mineralogy within and among pedons at the Floydada and Hudspeth sites. Mineralogy consisted of quartz (which was easily distinguished at 4.25 and 3.31 Å) and both plagioclases and K-feldspars. The latter two were distinguished from each other on the basis of the plagioclase peak at $27.98^{\circ}2\theta$ (3.19 Å) and the K-feldspar peak at $27.57^{\circ}2\theta$ (3.21 Å).

Although the stability of plagioclases depends upon the species, K-feldspars are generally considered to be more resistant than plagioclases and, therefore, commonly occur in greater amounts (Allen and Hajek, 1989). This appeared to be the case at the Floydada site, where the relative intensity of the K-feldspar peak was always greater than the plagioclase. In contrast, this did not apply at the Hudspeth site. The plagioclase peak dwarfed K-feldspar in horizons Bk2 and Bk5 of the pedon. This deviation suggests that the K-feldspars may be a source of potassium for the illitization of smectite.

Micromorphology

Selected horizons were studied for micromorphological properties including the general fabric of the horizon. Features that indicated degradation, especially in the lower horizons, were noted.

Floydada site. The Bt horizons in all pedons showed that appreciable clay illuviation has occurred (Figures 4.21 and 4.22). Grain argillans with sharp outer boundaries were common. Channel argillans with diffuse boundaries within the matrix were much less common. The fabric in most horizons were classified as mo-skelsepic (Brewer, 1964). Sufficient oriented clay to justify the argillic horizon designation was present.

Pedon F1 was described as having a cambic horizon (versus argillic horizons in the other pedons) and was verified by the lack of oriented clay. Calcic (Bk) horizon thin sections were all described as having crystic fabric (Figure 4.23). Some Btk horizons also had a crystic fabric, but most had some parts with a mo-skelsepic fabric. Such areas may be due to (1) an argillic horizon that has not been engulfed by CaCO_3 during a recalcification process, or (2) dissolution of the carbonates, permitting translocation of clay into the carbonate-dominated matrix (Figure 4.24).

Many of the thin sections with a crystic fabric showed evidence of partial quartz and feldspar dissolution. The remaining part of the primary mineral often was surrounded by sparitic calcite as contrasted to micrite in the matrix. Domains of sparite in the micrite suggest occupancy of former voids. Sparite also lined the walls of channels of calcrete fragments and completely filled some apparent former channels.

Hudspeth site. The upper part of the Bk (Bk1 and Bk2) horizon was characterized by in-skelsepic fabric (Brewer, 1964). Oriented aggregates of clay were scattered widely in the matrix (Figure 4.25). Very thin oriented clay argillans were associated with a few sand grains.

Crystic fabrics were present in the Bk3 and Bk4 horizons. Thin silicate clay concentrations occurred as concentric rings in some small aggregates (ooids?) in the Bk horizon.

Figure 4.21. Photomicrograph of Pedon F4, Bt2 horizon.

Figure 4.22. Photomicrograph of Pedon F4, Btk1 horizon.

Figure 4.23. Photomicrograph of Pedon F2, Bk1 horizon.

Figure 4.24. Photomicrograph of Pedon F6, Bk2 horizon.

Figure 4.25. Photomicrograph of Pedon H, Bk2 horizon.

None of the lower Bk horizons were designated as a petrocalcic horizon in the field because of lack of lateral continuity. Many fragments of the calcrete are still in place, however. A thin section containing the upper surface of one of the fragments (Bk4 horizon) showed pronounced indentations and occasional channels suggesting ongoing dissolution.

CHAPTER V

SUMMARY AND CONCLUSIONS

Six pedons (F1-F6) were sampled on the eastern edge of the Southern High Plains in northern Crosby County (Floydada site) and one (H) on the Diablo Plateau of the Trans-Pecos region in Hudspeth County (Hudspeth site). The six pits of the Floydada site were dug along a transect of approximately 300 m in length.

Standard field descriptions and laboratory analyses were conducted on selected samples. The analyses included organic carbon, particle size distribution, pH, electrical conductivity, calcium carbonate equivalence, cation exchange capacity, clay and silt mineralogy by x-ray diffractometry, and micromorphology.

The pits excavated at the Floydada site were on a slightly convex surface. Pedons F1 and F6 at the two ends of the transect, were somewhat more sloping than those at the other pits. When these slopes were related to the depth of free carbonates in the profiles, a strong correlation ($r^2 = 0.95$) was observed. Floydada pedons were classified as: fine mixed, active, thermic Aridic Calciustoll for the F1 pedon; fine-loamy, mixed, active, thermic Aridic Paleustolls for pedons F2 and F5; fine, mixed, active, thermic, Aridic Paleustolls for pedons F3, F4, and F6. Pedon H was classified as a coarse-loamy, carbonatic, thermic Typic Haplocalcid.

Results of laboratory analyses were mostly as expected. Percent organic carbon was sufficiently high for a mollic epipedon in pedons F1 through F6 and decreased with depth. Organic carbon was too low for a mollic epipedon at the Hudspeth site. Particle size analyses revealed narrower sand, silt, and clay variation with depth within pedons F1 and F6 than in F3 and F4, probably because of surface slope. Soil reaction for both sites followed the carbonate distribution of the profiles, i.e.,

increasing slightly with increasing CaCO_3 equivalence. The deepest horizon sampled at the Hudspeth site was moderately saline, whereas the overlying horizons were non-saline. Surface slope showed a strong correlation with the fixed relationship of CaCO_3 equivalence and horizon midpoint depth ($P < 0.001$).

Clay mineralogy of the samples in this study were generally high in smectite and illite. Kaolinite was present in most samples as a minor or trace component. The patterns of the Hudspeth site showed more evidence of illite-smectite (I/S) interstratification than any of the Floydada samples. Moreover, the Bk5 horizon contained sepiolite and palygorskite, whereas neither mineral was detected in the Floydada samples. Micromorphological analysis of selected samples showed evidence of a calcrete that has undergone considerable degradation (e.g., angular pedorelicts with crystic fabrics scattered in a matrix with skel-mosepic fabric). Moreover, solution channels were common in some of the calcrete fragments.

Several conclusions can be made from the data. (1) Calcrete degradation has, in fact, occurred in the areas studied in West Texas (the Southern High Plains and the Trans-Pecos). (2) This degradation suggests a broad movement in geologic history of the border between the ustic and the aridic moisture regimes in the Pleistocene Epoch. (3) Because of the dynamics of surface hydrology, calcretes are more likely to be preserved in soils on gentle slopes than in nearly level areas.

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APPENDIX A
DETAILED PROFILE DESCRIPTIONS

Pedon F1

Location. Crosby County, Texas. From the intersection of U.S. Hwy 62 and State Route 193, 4.8 km (3.0 mi) east, then 1.8 km (3.0 mi) north, then 2.4 km (1.5 mi) east, then 3.7 km (2.3 mi) southeast on ranch road. Latitude: 33 degrees 49 minutes 21.7 seconds north; Longitude: 101 degrees 16 minutes 11.7 seconds west.

Landform. Nearly level upland.

Pedon. Well drained, 1-2% slope in native rangeland at an elevation of about 945 m (3100 ft).

Parent Material. Eolian sediments.

Soil Moisture. An ustic moisture regime bordering on aridic.

Vegetation. Native vegetation is dominantly blue grama, buffalograss, and three-awn.

Classification. Fine, mixed, active, thermic Aridic Calcistoll

Description.

- A- 0 to 8 cm; very dark grayish brown (10YR 3/2) moist, dark grayish brown (10YR 4/2) dry, loam; weak medium subangular blocky structure; very hard; many medium and fine roots; slightly effervescent; clear smooth boundary.
- Bw1- 8 to 24 cm; dark brown (7.5YR 3/2) moist, brown (7.5YR 4/2) dry, clay loam; moderate medium prismatic structure parting to weak medium subangular blocky structure; very hard; common medium and fine roots; very few medium carbonate masses; strongly effervescent; clear wavy boundary.
- Bw2- 24 to 48 cm; brown (7.5YR 4/4) moist, brown (7.5YR 5/4) dry, clay loam; weak medium prismatic structure parting to weak medium subangular blocky structure; hard; common medium and fine roots; few medium and fine carbonate masses; very few petrocalcic fragments; violently effervescent; clear wavy boundary.
- Bk1- 48 to 71 cm; brown (7.5YR 5/4) moist, light brown (7.5YR 6/4) dry, silty clay loam; weak medium subangular blocky structure; moderately cemented; few medium and fine roots; many coarse, medium, and fine carbonate masses; few petrocalcic fragments; violently effervescent; gradual wavy boundary.

- Bk2- 71 to 102 cm: reddish brown (5YR 5/4) moist, light reddish brown (5YR 6/4) dry, silty clay loam; weak medium subangular blocky structure; weakly cemented; few medium and fine roots; common coarse, medium, and fine carbonate masses; few petrocalcic fragments; violently effervescent; clear wavy boundary.
- Btkb- 102 to 138 cm: reddish brown (5YR 5/4) and pink (5YR 7/4) moist, light reddish brown (5YR 6/4) and pink (5YR 8/4) dry, clay loam; weak medium subangular blocky structure; moderately cemented; few medium and fine roots; common coarse, medium, and fine carbonate masses; few petrocalcic horizon fragments (up to 12 cm in diameter); violently effervescent; clear wavy boundary.
- Bkb- 138 to 212+ cm: reddish yellow (5YR 6/6) moist, reddish yellow (5YR 7/6) dry, gravelly clay loam; massive; very strongly cemented; common medium and coarse petrocalcic fragments (up to 45 cm in diameter); violently effervescent.

Pedon F2

Location. Crosby County, Texas. From the intersection of U.S. Hwy 62 and State Route 193. 1.8 km (3.0 mi) east, then 4.8 km (3.0 mi) north, then 2.4 km (1.5 mi) east, then 3.7 km (2.3 mi) southeast on ranch road. Latitude: 33 degrees 19 minutes 22.5 seconds north; Longitude: 101 degrees 16 minutes 10.4 seconds west.

Landform. Nearly level upland.

Pedon. Well drained, 0-1% slope in native rangeland at an elevation of about 945 m (3100 ft).

Parent Material. Eolian sediments.

Soil Moisture. An ustic moisture regime bordering on aridic.

Vegetation. Native vegetation is dominantly blue grama, buffalograss, and three-awn.

Classification. Fine-loamy, mixed, active, thermic Aridic Paleustoll.

Description.

- A- 0 to 11 cm; dark brown (7.5YR 3/3) moist, brown (7.5YR 4/3) dry, loam; weak medium subangular blocky structure; very hard; many medium and fine roots; clear smooth boundary.
- Bt- 11 to 32 cm; dark brown (7.5YR 3/3) moist, brown (7.5YR 4/3) dry, clay; moderate medium prismatic structure parting to moderate medium subangular blocky structure; very hard; common medium and fine roots; clear wavy boundary.
- Btk1- 32 to 51 cm; dark brown (7.5YR 3/3) moist, brown (7.5YR 4/3) dry, clay; moderate medium prismatic structure parting to moderate medium subangular blocky structure; very hard; few fine roots; common carbonate films and threads; strongly effervescent; gradual wavy boundary.
- Btk2- 51 to 74 cm; brown (7.5YR 4/4) moist, brown (7.5YR 5/4) dry, clay loam; moderate medium prismatic structure parting to moderate medium subangular blocky structure; very hard; few fine roots; many carbonate films and threads; violently effervescent; clear wavy boundary.
- Btk3- 74 to 96 cm; yellowish red (5YR 4/6) moist, yellowish red (5YR 5/6) dry, clay loam; weak medium prismatic structure parting to moderate medium subangular blocky structure; very hard; few fine roots; common carbonate films and threads and common, medium, and fine carbonate masses; violently effervescent; clear wavy boundary.

- Bk1- 96 to 112 cm; reddish yellow (7.5YR 7/6) moist, reddish yellow (7.5YR 8/6) dry, silty clay loam; massive; weakly cemented; continuous matrix of calcium carbonate; common krotovinas ranging in size from 8-25 cm in diameter; violently effervescent; gradual wavy boundary.
- Bk2- 112 to 167 cm; pink (7.5YR 7/4) moist, pink (7.5YR 8/1) dry, silty clay loam; weak medium subangular blocky structure; moderately cemented; very many coarse and medium carbonate masses; common krotovinas ranging in size from 8-25 cm in diameter; violently effervescent; gradual wavy boundary.
- B'tk1- 167 to 220 cm; strong brown (7.5YR 5/6) and pink (7.5YR 8/1) moist, reddish yellow (7.5YR 6/6) and pink (7.5YR 8/1) dry, clay loam; weak medium subangular blocky structure; weakly cemented; many coarse, medium, and fine carbonate masses; common krotovinas ranging in size from 8-25 cm in diameter; violently effervescent; gradual wavy boundary.
- B'tk2- 220 to 252 cm; strong brown (7.5YR 5/6) and pink (7.5YR 8/4) moist, reddish yellow (7.5YR 6/6) and pink (7.5YR 8/4) dry, clay loam; weak medium subangular blocky structure; weakly cemented; common medium and fine carbonate masses; common krotovinas ranging in size from 8-25 cm in diameter; violently effervescent; clear wavy boundary.
- Bk- 252 to 300+ cm; pink (7.5YR 8/3) and strong brown (7.5YR 5/6) moist, pink (7.5YR 8/3) and reddish yellow (7.5YR 6/6) dry; massive; moderately cemented; many coarse and medium carbonate masses; 10% randomly occurring petrocalcic fragments; common krotovinas ranging in size from 8-25 cm in diameter; violently effervescent.

Pedon F3

Location. Crosby County, Texas. From the intersection of U.S. Hwy 62 and State Route 193, 1.8 km (3.0 mi) east, then 4.8 km (3.0 mi) north, then 2.1 km (1.5 mi) east, then 3.7 km (2.3 mi) southeast on ranch road. Latitude: 33 degrees 19 minutes 23.3 seconds north; Longitude: 101 degrees 16 minutes 39.0 seconds west.

Landform. Nearly level upland.

Pedon. Well drained. 0-1% slope in native rangeland at an elevation of about 945 m (3100 ft).

Parent Material. Eolian sediments.

Soil Moisture. An ustic moisture regime bordering on aridic.

Vegetation. Native vegetation is dominantly blue grama, buffalograss, and three-awn.

Classification. Fine, mixed, active, thermic Aridic Paleustoll

Description.

- A- 0 to 12 cm; very dark grayish brown (10YR 3/2) moist, dark grayish brown (10YR 4/2) dry, loam; moderate medium subangular blocky structure; very hard; many medium and fine roots; clear smooth boundary.
- Bt1- 12 to 31 cm; dark brown (7.5YR 3/2) moist, brown (7.5YR 4/2) dry, clay loam; moderate medium prismatic structure parting to moderate medium subangular blocky structure; very hard; common medium and fine roots; clear wavy boundary.
- Bt2- 31 to 51 cm; dark brown (7.5YR 3/3) moist, brown (7.5YR 4/4) dry, clay; moderate medium prismatic structure parting to moderate medium angular blocky structure; very hard; common medium and fine roots; clear wavy boundary.
- Bt3- 51 to 70 cm; dark brown (7.5YR 3/4) moist, brown (7.5YR 4/1) dry, clay loam; weak medium prismatic structure parting to moderate medium angular and subangular blocky structure; very hard; few fine roots; slightly effervescent; abrupt wavy boundary.
- Btk1- 70 to 89 cm; dark reddish brown (5YR 3/4) moist, reddish brown (5YR 4/4) dry, clay loam; weak medium prismatic structure parting to moderate medium subangular blocky structure; very hard; few fine roots; common carbonate films and threads; strongly effervescent; clear wavy boundary.

- Btk2- 89 to 103 cm: dark reddish brown (5YR 3/4) moist, reddish brown (5YR 4/4) dry, clay loam; weak medium prismatic structure parting to moderate medium subangular blocky structure; very hard; few fine roots; many carbonate films and threads; violently effervescent; abrupt wavy boundary.
- Bk1- 103 to 132 cm: light brown (7.5YR 6/1) moist, pink (7.5YR 7/4) dry, clay loam; massive; moderately cemented; very few fine roots; continuous matrix of calcium carbonate; violently effervescent; gradual wavy boundary.
- Bk2- 132 to 151 cm; reddish yellow (7.5YR 6/6) moist, reddish yellow (7.5YR 7/6) dry, clay loam; massive; moderately cemented; very few fine roots; continuous matrix of calcium carbonate; violently effervescent; gradual wavy boundary.
- B'tk1- 151 to 197 cm: strong brown (7.5YR 5/6) and pink (7.5YR 7/4) moist, reddish yellow (7.5YR 6/6) and pink (7.5YR 8/4) dry, clay loam; weak medium subangular blocky structure; weakly cemented, grading into moderately cemented; very many coarse and medium carbonate masses; few krotovinas of varying ages ranging in size from 10-25 cm in diameter; violently effervescent; gradual wavy boundary.
- B'tk2- 197 to 234 cm; strong brown (7.5YR 5/6) and pink (7.5YR 8/3) moist, reddish yellow (7.5YR 6/6) and pink (7.5YR 8/3) dry, clay loam; weak medium subangular blocky structure; moderately cemented; many coarse and medium carbonate masses; few krotovinas of varying ages ranging in size from 10-25 cm in diameter; violently effervescent, gradual wavy boundary.
- B'tk3- 234 to 280+ cm; pinkish white (7.5YR 8/2) and strong brown (7.5YR 5/6) moist, pinkish white (7.5YR 8/2) and reddish yellow (7.5YR 6/6) dry, clay loam; weak medium subangular blocky structure; moderately cemented; many coarse and medium carbonate masses; few krotovinas of varying ages ranging in size from 10-25 cm in diameter; violently effervescent.

Pedon F4

Location. Crosby County, Texas. From the intersection of U.S. Hwy 62 and State Route 193, 1.8 km (3.0 mi) east, then 1.8 km (3.0 mi) north, then 2.1 km (1.5 mi) east, then 3.7 km (2.3 mi) southeast on ranch road. Latitude: 33 degrees 49 minutes 21.1 seconds north; Longitude: 101 degrees 16 minutes 37.5 seconds west.

Landform. Nearly level upland.

Pedon. Well drained, 0-1% slope in native rangeland at an elevation of about 915 m (3100 ft).

Parent Material. Eolian sediments.

Soil Moisture. An ustic moisture regime bordering on aridic.

Vegetation. Native vegetation is dominantly blue grama, buffalograss, and three-awn.

Classification. Fine, mixed, active, thermic Aridic Paleustoll

Description.

- A- 0 to 13 cm; dark brown (7.5YR 3/2) moist, brown (7.5YR 4/2) dry, loam; moderate medium subangular blocky structure; very hard; clear smooth boundary.
- Bt1- 13 to 26 cm; dark brown (7.5YR 3/2) moist, brown (7.5YR 4/2) dry, clay loam; moderate medium prismatic structure parting to moderate medium subangular blocky structure; very hard; clear smooth boundary.
- Bt2- 26 to 40 cm; dark brown (7.5YR 3/3) moist, brown (7.5YR 4/3) dry, clay; moderate medium prismatic structure parting to moderate medium angular and subangular blocky structure; very hard; clear wavy boundary.
- Bt3- 40 to 62 cm; brown (7.5YR 4/3) moist, brown (7.5Yr 5/3) dry, clay; moderate medium prismatic structure parting to moderate medium angular blocky structure; very hard; slightly effervescent; clear wavy boundary.
- Btk1- 62 to 85 cm; brown (7.5YR 4/4) moist, brown (7.5YR 5/4) dry, clay loam; weak medium prismatic structure parting to moderate medium angular blocky structure; very hard; common carbonate films and threads; violently effervescent; gradual wavy boundary.
- Btk2- 85 to 106 cm; brown (7.5YR 4/4) moist, brown (7.5YR 5/4) dry, clay loam; weak medium prismatic structure parting to weak medium subangular blocky

structure: hard; many carbonate films and threads; violently effervescent; abrupt wavy boundary.

Bk1- 106 to 148 cm; pink (7.5YR 7/4) moist, pink (7.5YR 8/4) dry, clay loam; massive; moderately cemented; continuous matrix of calcium carbonate; violently effervescent; gradual wavy boundary.

Bk2- 148 to 188 cm; reddish yellow (5YR 6/6) moist, reddish yellow (5YR 7/6) dry, clay; weak medium subangular blocky structure; moderately cemented, many coarse and medium carbonate masses; violently effervescent; clear irregular boundary.

Btkb1- 188 to 220 cm; dark red (2.5YR 4/6) moist, red (2.5YR 5/6) dry, clay loam; weak medium subangular blocky structure; very hard; many coarse and medium carbonate masses; calcium carbonate makes up 80% of matrix; mixed violently and slightly effervescent; gradual wavy boundary.

Btkb2- 220 to 268 cm; yellowish red (2.5YR 5/6) and light red (2.5YR 7/6) moist, red (2.5YR 6/6) and light red (2.5YR 7/6) dry, clay loam; massive; very hard; 40% coarse masses and tongues of calcium carbonate; mixed violently and slightly effervescent; gradual wavy boundary.

Btkb3- 268 to 280 cm; dark red (2.5YR 4/6) moist, red (2.5YR 5/6) dry, sandy clay loam; massive; very hard; 25% carbonate nodules; mixed violently and slightly effervescent; clear wavy boundary

Btkb4- 280 to 310+ cm; dark red (2.5YR 4/6) moist, red (2.5YR 5/6) dry, sandy clay loam; massive; very hard 10% medium carbonate masses; interior of peds non-calcareous; common coarse and fine krotovinas; very few petrocalcic fragments.

Pedon F5

Location. Crosby County, Texas. From the intersection of U.S. Hwy 62 and State Route 193, 4.8 km (3.0 mi) east, then 1.8 km (3.0 mi) north, then 2.1 km (1.5 mi) east, then 3.7 km (2.3 mi) southeast on ranch road. Latitude: 33 degrees 49 minutes 25.1 seconds north; Longitude: 101 degrees 16 minutes 35.8 seconds west.

Landform. Nearly level upland.

Pedon. Well drained, 0-1% slope in native rangeland at an elevation of about 945 m (3100 ft).

Parent Material. Eolian sediments.

Soil Moisture. An ustic moisture regime bordering on aridic.

Vegetation. Native vegetation is dominantly blue grama, buffalograss, and three-awn.

Classification. Fine-loamy, mixed, active, thermic Aridic Paleustoll

Description.

- A- 0 to 14 cm; very dark grayish brown (10YR 3/2) moist, dark grayish brown (10YR 4/2) dry, loam; moderate medium subangular blocky structure; very hard; many medium and fine roots; clear smooth boundary.
- Bt1- 14 to 33 cm; very dark grayish brown (10YR 3/2) moist, brown (7.5YR 4/2) dry, clay loam; moderate medium prismatic structure parting to moderate medium subangular blocky structure; very hard; common medium and fine roots; gradual smooth boundary.
- Bt2- 33 to 51 cm; dark brown (7.5YR 3/2) moist, brown (7.5YR 4/2) dry, clay loam; moderate medium prismatic structure parting to moderate medium subangular blocky structure; very hard; common medium and fine roots; slightly effervescent; abrupt wavy boundary.
- Btk1- 51 to 66 cm; dark brown (7.5YR 3/3) moist, brown (7.5YR 4/3) dry, clay loam; moderate medium prismatic structure parting to moderate medium subangular blocky structure; very hard; common medium and fine roots; common carbonate films and threads; violently effervescent; clear wavy boundary.
- Btk2- 66 to 84 cm; brown (7.5YR 4/3) moist, brown (7.5YR 5/3) dry, clay; weak medium prismatic structure parting to moderate medium subangular blocky structure; very hard; few medium and fine roots; many carbonate films and threads; violently effervescent; clear wavy boundary.

- Bk1- 81 to 103 cm: light gray (7.5YR 7/1) and strong brown (7.5YR 5/6) moist, white (7.5YR 8/1) and reddish yellow (7.5YR 6/6) dry. clay loam; weak medium subangular blocky structure; very hard; few medium and fine roots; many medium and fine carbonate masses; violently effervescent; gradual wavy boundary.
- Bk2- 103 to 116 cm: strong brown (7.5YR 5/6) and pink (7.5YR 7/3) moist, reddish yellow (7.5YR 6/6) and pink (7.5YR 8/3) dry. clay loam; weak medium subangular blocky structure; very hard; few medium and fine roots; common medium and fine carbonate masses; violently effervescent; gradual wavy boundary.
- Bk3- 146 to 191 cm; light brown (7.5YR 6/4) and pinkish white (7.5YR 8/2) moist, pink (7.5YR 7/1) and pinkish white (7.5YR 8/2) dry. silty clay loam; massive; moderately cemented; few fine roots; continuous matrix of calcium carbonate; violently effervescent; clear irregular boundary.
- Bk4(Upper)¹- 191 to 220 cm; strong brown (7.5YR 5/6) and pinkish white (7.5YR 8/2) moist, reddish yellow (7.5YR 6/6) and pinkish white (7.5YR 8/2) dry. silty clay loam; weak medium subangular blocky structure; weakly cemented; many coarse, medium, and fine carbonate masses; violently effervescent.
- Bk4(Lower)[†]- 220 to 250 cm: strong brown (7.5YR 5/6) and pink (7.5YR 7/3) moist, reddish yellow (7.5YR 6/6) and pink (7.5YR 8/3) dry, clay; weak medium subangular blocky structure; weakly cemented; many coarse, medium, and fine carbonate masses; violently effervescent; clear irregular boundary.
- Bk5(Upper)[†]- 250 to 291 cm; pink (5YR 8/3) and yellowish red (5YR 5/6) moist, pink (5YR 8/3) and reddish yellow (5YR 6/6) dry; weak medium subangular blocky structure; weakly cemented; common coarse weathered petrocalcic fragments; violently effervescent.
- Bk5(Lower)[†]- 291 to 315+ cm; pink (5YR 8/3) and yellowish red (5YR 5/6) moist, pink (5YR 8/3) and reddish yellow (5YR 6/6) dry; weak medium subangular blocky structure; weakly cemented; violently effervescent.

¹The upper and lower designations were given primarily for the purpose of analyses because of the thickness of these horizons rather than because of any morphological differences within the layer.

Pedon F6

Location. Crosby County, Texas. From the intersection of U.S. Hwy 62 and State Route 193, 1.8 km (3.0 mi) east, then 4.8 km (3.0 mi) north, then 2.4 km (1.5 mi) east, then 3.7 km (2.3 mi) southeast on ranch road. Latitude: 33 degrees 19 minutes 25.7 seconds north; Longitude: 101 degrees 16 minutes 31.6 seconds west.

Landform. Nearly level upland.

Pedon. Well drained, 1-2% slope in native rangeland at an elevation of about 945 m (3100 ft).

Parent Material. Eolian sediments.

Soil Moisture. An ustic moisture regime bordering on aridic.

Vegetation. Native vegetation is dominantly blue grama, buffalograss, and three-awn.

Classification. Fine, mixed, active, thermic Aridic Paleustoll

Description.

- A- 0 to 12 cm; very dark grayish brown (10YR 3/2) moist, dark grayish brown (10YR 4/2) dry, clay loam; moderate medium subangular blocky structure; very hard; many medium and fine roots; slightly effervescent; clear smooth boundary.
- Bt1- 12 to 25 cm; very dark brown (10YR 2/2) moist, very dark grayish brown (10YR 3/2) dry, clay; weak medium prismatic structure parting to moderate medium subangular blocky structure; very hard; common medium and fine roots; violently effervescent; clear smooth boundary.
- Bt2- 25 to 48 cm; very dark grayish brown (10YR 3/2) moist, dark grayish brown (10YR 4/2) dry, clay; moderate medium prismatic structure parting to moderate medium subangular blocky structure; very hard; common medium and fine roots; violently effervescent; abrupt wavy boundary.
- Btk1- 48 to 80 cm; very dark grayish brown (10YR 3/2) moist, dark grayish brown (10YR 4/2) dry, clay; weak medium prismatic structure parting to strong medium subangular blocky structure; very hard; few fine roots; many carbonate films and threads; violently effervescent; clear wavy boundary.
- Btk2- 80 to 98 cm; very dark grayish brown (10YR 3/2), dark brown (7.5YR 3/4), and pink (7.5YR 7/3) moist, dark grayish brown (10YR 4/2), brown (7.5YR 4/1), and pink (7.5YR 8/3) dry, clay; weak medium angular and subangular blocky

structure; very hard; very few medium and fine roots; many carbonate films and threads, and few medium and fine carbonate masses; violently effervescent; clear wavy boundary.

Bk1- 98 to 128 cm: reddish yellow (7.5YR 6/6) and pink (7.5YR 7/4) moist, reddish yellow (7.5YR 7/6) and pink (7.5YR 8/4) dry, clay loam; weak medium subangular blocky structure; moderately cemented; very few medium and fine roots; carbonates disseminated throughout and many coarse, medium, and fine masses; erratic occurrence of coarse and medium petrocalcic fragments; violently effervescent; gradual wavy boundary.

Bk2- 128 to 150 cm; strong brown (7.5YR 4/6) and pink (7.5YR 7/4) moist, strong brown (7.5YR 5/6) and pink (7.5YR 8/4) dry, clay loam; weak medium subangular blocky structure; moderately cemented; very few medium and fine roots; carbonates disseminated throughout and many coarse, medium, and fine masses; common petrocalcic nodules scattered throughout the matrix; violently effervescent; gradual wavy boundary.

Bk3- 150 to 165+ cm: pink (7.5YR 8/3) and pink (7.5YR 7/4) moist, pink (7.5YR 8/3) and pink (7.5YR 8/4) dry, clay loam; structureless; moderately cemented; violently effervescent.

Pedon H

Location. Hudspeth County, Texas. From the intersection of U.S. Hwy 82/180 and Ranch Road 1111, 13.2 km (8.2 mi) south on RR 1111, then 300 m (984 ft) east. Latitude: 31 degrees 38 minutes 28.1 seconds north; Longitude: 105 degrees 22 minutes 1.8 seconds west.

Landform. Nearly level backslope.

Pedon. Well drained, 0-1% slope in native rangeland at an elevation of about 1280 m (4200 ft).

Parent Material. Limestone residuum and eolian sediments.

Soil Moisture. An aridic moisture regime.

Vegetation. Native vegetation is dominated by creosotebush.

Classification. Coarse-loamy, carbonatic, thermic Typic Haplocalcid.

Description.

- A- 0-5 cm; brown (10YR 4/3) moist, brown (10YR 5/3) dry, fine sandy loam; weak coarse platy structure; slightly hard; strongly effervescent; abrupt smooth boundary.
- Bk1- 5-28 cm; brown (10YR 4/3) moist, brown (10YR 5/3) dry, loam; weak medium prismatic structure parting to weak medium subangular blocky structure; slightly hard; strongly effervescent; gradual smooth boundary.
- Bk2- 28-43 cm; dark yellowish brown (10YR 4/4) moist, yellowish brown (10YR 5/4) dry, loam; weak medium subangular blocky structure; hard; strongly effervescent; clear wavy boundary.
- Bk3- 43-53 cm; dark yellowish brown (10YR 4/4) moist, yellowish brown (10YR 5/1) dry; weak medium subangular blocky structure; many masses and threads of very pale brown (10YR 8/2) moist, white (10YR 8/1) dry secondary calcium carbonate; strongly effervescent; abrupt wavy boundary.
- Bk4- 53-99 cm; layer of secondary calcium carbonate; massive; strongly effervescent; gradual wavy boundary.
- Bk5- 99-168+ cm; layer of secondary calcium carbonate; massive; strongly effervescent.

APPENDIX B
X-RAY DIFFRACTION PATTERNS OF SELECTED
CLAY SAMPLES

Figure B.1. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F1, A horizon.

Table B.1. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F1, A horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.42	8.84	10.00	179	72	Illite
2	6.20	12.39	7.14	112	45	Kaolinite
3	8.91	17.81	4.98	80	32	Illite
4	12.43	24.86	3.58	113	45	Quartz
5	13.34	26.68	3.34	250	100	Kaolinite

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.2. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon F1, A horizon.

Table B.2. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon F1, A horizon.

$n^{\dagger}$	θ	2θ	d (Å)	$I_{n^{\dagger}}^P$	$I_r^P \S$	Mineral
1	4.47	8.94	9.89	178	100	Illite
2	6.22	12.44	7.11	66	37	Kaolinite
3	8.92	17.84	4.97	45	25	Illite
4	12.53	25.06	3.55	62	35	Kaolinite
5	13.41	26.81	3.33	163	92	Quartz

$\dagger$ peak number; $\ddagger$ net peak intensity;

$\S$ relative peak intensity

Figure B.3. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon F1, A horizon.

Table B.3. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon F1, A horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.42	8.83	10.01	620	100	Illite
2	8.89	17.78	4.99	127	20	Illite
3	10.41	20.82	4.27	56	9	Quartz
4	13.35	26.70	3.34	428	69	Quartz
5	13.71	27.42	3.25	76	12	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.4. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F1, Bw2 horizon.

Table B.4. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F1, Bw2 horizon.

n [†]	θ	2θ	d (Å)	I_n^P [‡]	I_r^P [§]	Mineral
1	4.43	8.86	9.98	200	79	Illite
2	6.19	12.38	7.15	142	56	Kaolinite
3	8.92	17.84	4.97	95	38	Illite
4	12.47	24.94	3.57	152	60	Kaolinite
5	13.41	26.81	3.33	253	100	Quartz

[†]peak number; [‡]net peak intensity;

[§]relative peak intensity

Figure B.5. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon F1, Bw2 horizon.

Table B.5. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon F1, Bw2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.49	8.98	9.85	164	100	Illite
2	6.22	12.44	7.11	61	37	Kaolinite
3	8.94	17.88	4.96	36	22	Illite
4	12.50	24.99	3.56	57	35	Kaolinite
5	13.42	26.84	3.32	140	85	Quartz
6	13.77	27.54	3.24	48	29	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.6. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon F1, Bw2 horizon.

Table B.6. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon F1, Bw2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.41	8.82	10.03	514	100	Illite
2	8.86	17.72	5.01	118	23	Illite
3	10.40	20.80	4.27	42	8	Quartz
4	13.32	26.63	3.35	383	75	Quartz
5	13.73	27.47	3.25	92	18	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.7. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F1, Bk2 horizon.

Table B.7. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F1, Bk2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.45	8.89	9.94	203	90	Illite
2	6.16	12.33	7.18	174	77	Kaolinite
3	8.91	17.81	4.98	81	36	Illite
4	12.48	24.96	3.57	170	76	Kaolinite
5	13.36	26.71	3.34	225	100	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.8. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon F1, Bk2 horizon.

Table B.8. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon F1, Bk2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.51	9.01	9.81	233	100	Illite
2	6.28	12.56	7.05	63	27	Kaolinite
3	8.94	17.88	4.96	62	27	Illite
4	12.54	25.08	3.55	67	29	Kaolinite
5	13.38	26.76	3.33	133	57	Illite
6	13.81	27.63	3.23	38	16	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.9. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon F1, Bk2 horizon.

Table B.9. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon F1, Bk2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.42	8.83	10.01	588	100	Illite
2	8.87	17.73	5.00	133	23	Illite
3	13.34	26.68	3.34	387	66	Quartz
4	13.65	27.30	3.27	74	13	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.10. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F2, A horizon.

Table B.10. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F2, A horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.45	8.89	9.94	213	72	Illite
2	6.18	12.36	7.16	153	52	Kaolinite
3	8.86	17.73	5.00	89	30	Illite
4	10.46	20.93	4.24	51	17	Quartz
5	12.50	24.99	3.56	138	47	Kaolinite
6	13.34	26.68	3.34	294	100	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.11. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon F2, A horizon.

Table B.11. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon F2, A horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.49	8.98	9.85	202	100	Illite
2	6.23	12.46	7.10	72	36	Kaolinite
3	8.92	17.84	4.97	48	24	Illite
4	12.54	25.08	3.55	58	29	Kaolinite
5	13.41	26.81	3.33	186	92	Quartz
6	13.85	27.69	3.22	40	20	Feldspars
7	14.22	28.44	3.14	77	38	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.12. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon F2, A horizon.

Table B.12. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon F2, A horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.40	8.80	10.05	587	100	Illite
2	8.82	17.63	5.03	115	20	Illite
3	10.38	20.77	4.28	55	9	Quartz
4	13.28	26.55	3.36	439	75	Quartz
5	13.63	27.27	3.27	82	14	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.13. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F2, Btk2 horizon.

Table B.13. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F2, Btk2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.47	8.94	9.89	165	49	Illite
2	6.21	12.41	7.13	166	50	Kaolinite
3	8.94	17.88	4.96	98	29	Illite
4	10.46	20.93	4.24	74	22	Quartz
5	12.51	25.01	3.56	144	43	Kaolinite
6	13.36	26.71	3.34	335	100	Quartz
7	13.77	27.54	3.24	70	21	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.14. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon F2, Btk2 horizon.

Table B.14. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon F2, Btk2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.51	9.01	9.81	284	100	Illite
2	6.23	12.46	7.10	96	34	Kaolinite
3	8.96	17.91	4.95	60	21	Illite
4	12.54	25.08	3.55	78	27	Kaolinite
5	13.45	26.89	3.32	249	88	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.15. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon F2, Btk2 horizon.

Table B.15. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon F2, Btk2 horizon.

$n^{\dagger}$	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.43	8.85	9.99	820	100	Illite
2	8.87	17.73	5.00	195	24	Illite
3	10.40	20.80	4.27	66	8	Quartz
4	13.33	26.65	3.34	698	85	Quartz
5	13.69	27.38	3.26	85	10	Feldspars

$\dagger$ peak number; $\ddagger$ net peak intensity;

$\S$ relative peak intensity

Figure B.16. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F2, Bk2 horizon.

Table B.16. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F2, Bk2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.46	8.93	9.91	94	31	Illite
2	6.21	12.43	7.12	194	64	Kaolinite
3	8.92	17.84	4.97	104	34	Illite
4	12.46	24.93	3.57	177	59	Kaolinite
5	13.39	26.78	3.33	219	73	Quartz
6	13.82	27.64	3.23	30	10	Feldspar

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.17. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon F2, Bk2 horizon.

Table B.17. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon F2, Bk2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.48	8.96	9.87	157	100	Illite
2	6.25	12.49	7.09	70	45	Kaolinite
3	8.95	17.89	4.96	56	36	Illite
4	12.51	25.03	3.56	54	34	Kaolinite
5	13.42	26.84	3.32	145	92	Quartz
6	14.24	28.48	3.13	66	42	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.18. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon F2, Bk2 horizon.

Table B.18. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon F2, Bk2 horizon.

n [†]	θ	2θ	d (Å)	I _n [‡]	I _r [§]	Mineral
1	4.41	8.82	10.03	505	100	Illite
2	8.86	17.72	5.01	116	23	Illite
3	10.37	20.73	4.28	56	11	Quartz
4	13.37	26.73	3.33	362	72	Quartz
5	13.72	27.43	3.25	72	14	Feldspars

[†]peak number; [‡]net peak intensity;

[§]relative peak intensity

Figure B.19. X-ray diffraction pattern of Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F2, Bk horizon, petrocalcic fragments.

Table B.19. Peak identification of Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F2, Bk horizon, petrocalcic fragments.

$n^{\dagger}$	θ	2θ	d (Å)	$I_n^P{}^{\ddagger}$	$I_r^P{}^{\S}$	Mineral
1	4.38	8.77	10.09	108	64	Illite
2	6.18	12.37	7.16	140	82	Kaolinite
3	8.90	17.80	4.98	53	31	Illite
4	12.43	24.87	3.58	116	68	Kaolinite
5	13.32	26.63	3.35	170	100	Quartz

† peak number; ‡ net peak intensity;

§ relative peak intensity

Figure B.20. X-ray diffraction pattern of K-saturated, heated at 250°C, clay fraction, Pedon F2, Bk horizon, petrocalcic fragments.

Table B.20. Peak identification of K-saturated, heated at 250°C, clay fraction, Pedon F2, Bk horizon, petrocalcic fragments.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.40	8.79	10.06	382	100	Illite
2	6.16	12.33	7.18	128	34	Kaolinite
3	8.84	17.68	5.02	95	25	Illite
4	12.46	24.91	3.57	148	39	Kaolinite
5	13.36	26.73	3.34	334	87	Quartz
6	14.18	28.36	3.15	129	34	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.21. X-ray diffraction pattern of K-saturated, heated at 550°C, clay fraction, Pedon F2, Bk horizon, petrocalcic fragments.

Table B.21. Peak identification of K-saturated, heated at 550°C, clay fraction, Pedon F2, Bk horizon, petrocalcic fragments.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.43	8.86	9.98	604	100	Illite
2	8.91	17.81	4.98	172	28	Illite
3	13.36	26.71	3.34	421	70	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.22. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F3, A horizon.

Table B.22. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F3, A horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.43	8.87	9.97	285	77	Illite
2	6.18	12.35	7.17	171	46	Kaolinite
3	8.90	17.80	4.98	107	29	Illite
4	10.43	20.85	4.26	85	23	Quartz
5	12.46	24.92	3.57	93	25	Kaolinite
6	13.35	26.70	3.34	370	100	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.23. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon F3, A horizon.

Table B.23. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon F3, A horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.46	8.92	9.92	347	98	Illite
2	6.18	12.35	7.17	84	24	Kaolinite
3	8.88	17.77	4.99	93	26	Illite
4	10.45	20.90	4.25	84	24	Quartz
5	12.48	24.97	3.57	95	27	Kaolinite
6	13.35	26.70	3.34	353	100	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.24. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon F3, A horizon.

Table B.24. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon F3, A horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.45	8.89	9.94	328	90	Illite
2	8.91	17.83	4.98	99	27	Illite
3	10.44	20.88	4.26	82	22	Quartz
4	13.34	26.68	3.34	365	100	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.25. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F3, Bt2 horizon.

Table B.25. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F3, Bt2 horizon.

$n^{\dagger}$	θ	2θ	d (Å)	$I_n^{\dagger}$	$I_r^{\S}$	Mineral
1	4.45	8.90	9.94	310	79	Illite
2	6.18	12.35	7.17	162	42	Kaolinite
3	8.88	17.77	4.99	81	21	Illite
4	10.44	20.88	4.25	66	17	Quartz
5	12.45	24.90	3.58	140	36	Kaolinite
6	13.37	26.73	3.33	390	100	Quartz

† peak number; ‡ net peak intensity;

§ relative peak intensity

Figure B.26. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon F3, Bt2 horizon.

Table B.26. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon F3, Bt2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.46	8.92	9.92	378	100	Illite
2	6.20	12.40	7.14	164	43	Kaolinite
3	8.89	17.78	4.99	101	27	Illite
4	12.47	24.93	3.57	110	29	Kaolinite
5	13.38	26.77	3.33	350	93	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.27. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon F3, Bt2 horizon.

Table B.27. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon F3, Bt2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.46	8.91	9.92	363	100	Illite
2	8.92	17.84	4.97	108	30	Illite
3	10.44	20.88	4.26	58	16	Quartz
4	13.38	26.76	3.33	351	97	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.28. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F3, Btk2 horizon.

Table B.28. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F3, Btk2 horizon.

$n^{\dagger}$	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.46	8.93	9.91	155	45	Illite
2	6.18	12.36	7.16	175	51	Kaolinite
3	8.83	17.66	5.02	98	29	Illite
4	10.41	20.83	4.27	64	19	Quartz
5	12.44	24.88	3.58	179	52	Kaolinite
6	13.37	26.74	3.33	250	73	Quartz

$\dagger$ peak number; $\ddagger$ net peak intensity;

$\S$ relative peak intensity

Figure B.29. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon F3, Btk2 horizon.

Table B.29. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon F3, Btk2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.44	8.88	9.96	185	100	Illite
2	6.21	12.43	7.12	75	41	Kaolinite
3	8.93	17.86	4.97	52	28	Illite
4	12.49	24.98	3.57	53	29	Kaolinite
5	13.38	26.76	3.33	167	90	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.30. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon F3, Btk2 horizon.

Table B.30. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon F3, Btk2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.43	8.87	9.97	670	100	Illite
2	8.88	17.77	4.99	180	27	Illite
3	13.36	26.72	3.34	437	65	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.31. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F3, B'tk1 horizon.

Table B.31. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F3, B'tk1 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.47	8.94	9.89	110	36	Illite
2	6.21	12.43	7.12	160	53	Kaolinite
3	8.88	17.76	4.99	73	24	Illite
4	12.46	24.93	3.57	143	47	Kaolinite
5	13.38	26.76	3.33	230	76	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.32. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon F3, B'tk1 horizon.

Table B.32. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon F3, B'tk1 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.48	8.96	9.87	140	100	Illite
2	6.28	12.56	7.05	54	39	Kaolinite
3	8.93	17.86	4.97	41	29	Illite
4	12.50	24.99	3.56	38	27	Kaolinite
5	13.42	26.84	3.32	128	91	Quartz
6	14.22	28.44	3.14	76	54	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.33. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon F3, B'tk1 horizon.

Table B.33. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon F3, B'tk1 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.42	8.83	10.01	562	100	Illite
2	5.26	10.52	8.41	114	20	Unidentified
3	8.86	17.72	5.01	110	20	Illite
5	13.39	26.78	3.33	364	65	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.34. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F4, A horizon.

Table B.34. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F4, A horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.46	8.91	9.92	111	25	Illite
2	6.21	12.43	7.12	175	39	Kaolinite
3	8.89	17.78	4.99	88	20	Illite
4	10.45	20.89	4.25	97	22	Quartz
5	12.48	24.96	3.57	152	34	Kaolinite
6	13.35	26.69	3.34	444	100	Quartz
7	13.70	27.39	3.26	48	11	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.35. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon F4, A horizon.

Table B.35. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon F4, A horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.48	8.96	9.87	177	87	Illite
2	6.27	12.54	7.06	65	32	Kaolinite
3	8.95	17.89	4.96	50	25	Illite
4	10.50	20.99	4.23	38	19	Quartz
5	12.56	25.11	3.55	41	20	Kaolinite
6	13.37	26.74	3.33	204	100	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.36. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon F4, A horizon.

Table B.36. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon F4, A horizon.

n†	θ	2θ	d (Å)	$I_n^P‡$	$I_r^P§$	Mineral
1	4.41	8.82	10.03	525	84	Illite
2	8.88	17.75	5.00	130	21	Illite
3	10.41	20.82	4.27	112	18	Quartz
4	13.30	26.60	3.35	625	100	Quartz
5	13.73	27.47	3.25	72	12	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.37. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F4, Bt3 horizon.

Table B.37. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F4, Bt3 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.44	8.88	9.96	208	36	Illite
2	6.15	12.29	7.20	273	47	Kaolinite
3	8.88	17.76	4.99	198	34	Illite
4	10.43	20.86	4.26	99	17	Quartz
5	12.44	24.88	3.58	251	44	Kaolinite
6	13.32	26.64	3.35	576	100	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.38. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon F4, Bt3 horizon.

Table B.38. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon F4, Bt3 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.50	8.99	9.83	216	100	Illite
2	6.25	12.49	7.09	84	39	Kaolinite
3	8.96	17.93	4.95	54	25	Illite
4	10.50	20.99	4.23	37	17	Quartz
5	12.54	25.08	3.55	73	34	Kaolinite
6	13.41	26.83	3.32	202	94	Quartz
7	13.80	27.59	3.23	47	22	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.39. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon F4, Bt3 horizon.

Table B.39. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon F4, Bt3 horizon.

n†	θ	2θ	d (Å)	$I_n^P‡$	$I_r^P§$	Mineral
1	4.42	8.84	10.00	696	100	Illite
2	8.87	17.74	5.00	175	25	Illite
3	10.41	20.81	4.27	62	9	Quartz
4	13.40	26.79	3.33	621	89	Quartz
5	13.73	27.46	3.25	116	17	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.40. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F4, Bk2 horizon.

Table B.40. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F4, Bk2 horizon.

$n^{\dagger}$	θ	2θ	d (Å)	$I_n^P{}^{\ddagger}$	$I_r^P{}^{\S}$	Mineral
1	4.40	8.79	10.06	76	32	Illite
2	6.17	12.34	7.17	111	46	Kaolinite
3	8.89	17.78	4.99	83	35	Illite
4	10.42	20.84	4.26	51	21	Quartz
5	12.45	24.89	3.58	167	70	Kaolinite
6	13.32	26.64	3.35	239	100	Quartz

† peak number; ‡ net peak intensity;

§ relative peak intensity

Figure B.41. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon F4, Bk2 horizon.

Table B.41. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon F4, Bk2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.46	8.91	9.92	111	78	Illite
2	6.27	12.54	7.06	40	28	Kaolinite
3	8.95	17.89	4.96	49	34	Illite
4	12.53	25.06	3.55	62	43	Kaolinite
5	13.46	26.93	3.31	83	58	Quartz
6	14.23	28.46	3.14	143	100	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.42. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon F4, Bk2 horizon.

Table B.42. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon F4, Bk2 horizon.

n [†]	θ	2θ	d (Å)	I_n^P [‡]	I_r^P [§]	Mineral
1	4.41	8.82	10.03	365	100	Illite
2	8.89	17.78	4.99	85	23	Illite
3	13.37	26.73	3.33	285	78	Quartz
4	13.72	27.43	3.25	58	16	Feldspars

[†]peak number; [‡]net peak intensity;
[§]relative peak intensity

Figure B.43. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F4, Btkb3 horizon.

Table B.43. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F4, Btkb3 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.50	8.99	9.83	85	45	Illite
2	6.16	12.33	7.18	104	55	Kaolinite
3	8.91	17.83	4.98	65	34	Illite
4	12.43	24.86	3.58	99	52	Kaolinite
5	13.35	26.69	3.34	189	100	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.44. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon F4, Btkb3 horizon.

Table B.44. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon F4, Btkb3 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.46	8.91	9.92	117	100	Illite
2	6.23	12.46	7.10	51	44	Kaolinite
3	8.97	17.94	4.94	35	30	Illite
4	12.51	25.01	3.56	33	28	Kaolinite
5	13.41	26.83	3.32	103	88	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.45. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon F4, Btkb3 horizon.

Table B.45. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon F4, Btkb3 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.41	8.82	10.03	514	100	Illite
2	8.80	17.60	5.04	119	23	Illite
3	13.34	26.68	3.34	337	66	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.46. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F5, A horizon.

Table B.46. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F5, A horizon.

n†	θ	2θ	d (Å)	$I_n^{\dagger\dagger}$	$I_r^{\dagger\dagger}$	Mineral
1	4.46	8.93	9.91	266	70	Illite
2	6.24	12.48	7.09	147	39	Kaolinite
3	8.96	17.91	4.95	83	22	Illite
4	10.45	20.89	4.25	68	18	Quartz
5	12.49	24.98	3.57	114	30	Kaolinite
6	13.39	26.78	3.33	379	100	Quartz

†peak number; ††net peak intensity;

§relative peak intensity

Figure B.47. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon F5, A horizon.

Table B.47. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon F5, A horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.47	8.94	9.89	369	94	Illite
2	6.22	12.44	7.11	134	34	Kaolinite
3	8.92	17.84	4.97	132	34	Illite
4	10.46	20.91	4.25	48	12	Quartz
5	12.48	24.96	3.57	96	25	Kaolinite
6	13.39	26.78	3.33	391	100	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.48. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon F5, A horizon.

Table B.48. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon F5, A horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.47	8.94	9.89	397	100	Illite
2	8.94	17.88	4.96	107	27	Illite
3	10.44	20.88	4.26	61	15	Quartz
4	13.36	26.71	3.34	370	93	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.49. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F5, Bt2 horizon.

Table B.49. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F5, Bt2 horizon.

n [†]	θ	2θ	d (Å)	$I_{n\ddagger}^P$	$I_r^P\S$	Mineral
1	4.43	8.86	9.98	181	32	Illite
2	6.17	12.34	7.17	234	41	Kaolinite
3	8.86	17.71	5.01	140	25	Illite
4	10.42	20.84	4.26	172	30	Quartz
5	12.43	24.86	3.58	217	38	Kaolinite
6	13.32	26.64	3.35	571	100	Quartz

[†]peak number; [‡]net peak intensity;

[§]relative peak intensity

Figure B.50. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon F5, Bt2 horizon.

Table B.50. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon F5, Bt2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.50	8.99	9.83	155	100	Illite
2	6.26	12.51	7.08	69	45	Kaolinite
3	8.96	17.93	4.95	45	29	Illite
4	10.55	21.09	4.21	33	21	Quartz
5	12.51	25.01	3.56	44	28	Kaolinite
6	13.37	26.74	3.33	149	96	Quartz
7	13.81	27.61	3.23	29	19	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.51. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon F5, Bt2 horizon.

Table B.51. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon F5, Bt2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.43	8.85	9.99	649	100	Illite
2	8.87	17.73	5.00	147	23	Illite
3	10.39	20.78	4.27	86	13	Quartz
4	13.28	26.57	3.36	487	75	Quartz
5	13.69	27.38	3.26	138	21	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.52. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F5, Bk1 horizon.

Table B.52. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F5, Bk1 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.45	8.89	9.94	120	38	Illite
2	6.19	12.38	7.15	200	63	Kaolinite
3	8.91	17.83	4.98	102	32	Illite
4	12.46	24.93	3.57	163	52	Kaolinite
5	13.36	26.71	3.34	316	100	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.53. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon F5, Bk1 horizon.

Table B.53. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon F5, Bk1 horizon.

n [†]	θ	2θ	d (Å)	I_n^P [‡]	I_r^P [§]	Mineral
1	4.46	8.93	9.91	191	100	Illite
2	6.25	12.49	7.09	82	43	Kaolinite
3	8.94	17.88	4.96	63	33	Illite
4	12.55	25.09	3.55	52	27	Kaolinite
5	13.38	26.76	3.33	147	77	Quartz

[†]peak number; [‡]net peak intensity;

[§]relative peak intensity

Figure B.54. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon F5, Bk1 horizon.

Table B.54. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon F5, Bk1 horizon.

n†	θ	2θ	d (Å)	$I_{n\ddagger}^P$	$I_r^P\S$	Mineral
1	4.40	8.80	10.05	750	100	Illite
2	8.88	17.77	4.99	213	28	Illite
3	10.43	20.85	4.26	73	10	Quartz
4	13.41	26.82	3.32	526	70	Quartz
5	13.73	27.47	3.25	97	13	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.55. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F5, Bk4(Lower)horizon.

Table B.55. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F5, Bk4(Lower)horizon.

n [†]	θ	2θ	d (Å)	I_n^P [‡]	I_r^P [§]	Mineral
1	4.44	8.88	9.95	339	69	Illite
2	6.20	12.40	7.14	208	42	Kaolinite
3	8.90	17.80	4.98	180	37	Illite
4	10.45	20.90	4.25	80	16	Quartz
5	12.48	24.95	3.57	195	40	Kaolinite
6	13.34	26.68	3.34	490	100	Quartz
7	13.75	27.50	3.24	139	28	Feldspars
8	14.17	28.33	3.15	74	15	Feldspars

[†]peak number; [‡]net peak intensity;

[§]relative peak intensity

Figure B.56. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon F5, Bk4(Lower)horizon.

Table B.56. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon F5, Bk4(Lower)horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.49	8.98	9.85	155	94	Illite
2	6.23	12.46	7.10	48	29	Kaolinite
3	8.92	17.84	4.97	48	29	Illite
4	10.53	21.06	4.22	28	17	Quartz
5	12.51	25.01	3.56	45	27	Kaolinite
6	13.39	26.78	3.33	165	100	Quartz
7	13.81	27.61	3.23	36	22	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.57. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon F5, Bk4(Lower)horizon.

Table B.57. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon F5, Bk4(Lower)horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.44	8.88	9.95	693	100	Illite
2	8.88	17.77	4.99	198	29	Illite
3	10.43	20.85	4.26	90	13	Quartz
4	13.31	26.62	3.35	602	87	Quartz
5	13.74	27.48	3.25	140	20	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.58. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F6, A horizon.

Table B.58. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F6, A horizon.

n [†]	θ	2θ	d (Å)	I_n^P [‡]	I_r^P [§]	Mineral
1	4.44	8.88	9.95	307	67	Illite
2	6.21	12.42	7.13	158	34	Kaolinite
3	8.93	17.87	4.96	97	21	Illite
4	10.44	20.88	4.25	68	15	Quartz
5	12.48	24.95	3.57	140	30	Kaolinite
6	13.36	26.72	3.34	460	100	Quartz

[†]peak number; [‡]net peak intensity;

[§]relative peak intensity

Figure B.59. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon F6, A horizon.

Table B.59. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon F6, A horizon.

$n^{\dagger}$	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.44	8.88	9.95	360	100	Illite
2	6.19	12.38	7.15	136	38	Kaolinite
3	8.89	17.78	4.99	82	23	Illite
4	10.46	20.92	4.25	71	20	Quartz
5	12.50	25.00	3.56	90	25	Kaolinite
6	13.36	26.72	3.34	359	100	Quartz

$\dagger$ peak number; $\ddagger$ net peak intensity;

$\S$ relative peak intensity

Figure B.60. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon F6, A horizon.

Table B.60. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon F6, A horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.44	8.88	9.96	375	100	Illite
2	8.91	17.81	4.98	122	33	Illite
3	10.44	20.88	4.26	56	15	Quartz
4	13.39	26.78	3.33	345	92	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.61. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F6, Bt2 horizon.

Table B.61. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F6, Bt2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.42	8.83	10.01	281	85	Illite
2	6.18	12.37	7.16	149	45	Kaolinite
3	8.89	17.78	4.99	102	31	Illite
4	10.41	20.82	4.27	49	15	Quartz
5	12.43	24.87	3.58	147	44	Kaolinite
6	13.31	26.62	3.35	332	100	Quartz
7	13.73	27.45	3.25	82	25	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.62. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon F6, Bt2 horizon.

Table B.62. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon F6, Bt2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.50	8.99	9.83	211	100	Illite
2	6.26	12.53	7.07	78	37	Kaolinite
3	8.93	17.86	4.97	59	28	Illite
4	12.48	24.96	3.57	69	33	Kaolinite
5	13.41	26.83	3.32	184	87	Quartz
6	14.24	28.48	3.13	71	34	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.63. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon F6, Bt2 horizon.

Table B.63. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon F6, Bt2 horizon.

n [†]	θ	2θ	d (Å)	I_n^P [‡]	I_r^P [§]	Mineral
1	4.43	8.85	9.99	671	100	Illite
2	8.93	17.87	4.96	142	21	Illite
3	10.46	20.92	4.25	78	12	Quartz
4	13.34	26.68	3.34	560	83	Quartz
5	14.33	28.65	3.12	111	17	Feldspars

[†]peak number; [‡]net peak intensity;

[§]relative peak intensity

Figure B.64. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F6, Bk2 horizon.

Table B.64. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F6, Bk2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.41	8.82	10.03	416	100	Illite
2	6.14	12.28	7.21	177	43	Kaolinite
3	8.88	17.75	5.00	132	32	Illite
4	10.44	20.88	4.25	40	10	Quartz
5	12.47	24.93	3.57	126	30	Kaolinite
6	13.33	26.65	3.34	334	80	Quartz
7	13.73	27.47	3.25	98	24	Feldspars
8	14.17	28.33	3.15	193	46	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.65. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon F6, Bk2 horizon.

Table B.65. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon F6, Bk2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.51	9.03	9.80	146	100	Illite
2	6.26	12.53	7.07	72	49	Kaolinite
3	8.96	17.93	4.95	64	44	Illite
4	12.49	24.98	3.57	59	40	Kaolinite
5	13.43	26.86	3.32	123	84	Quartz
6	13.79	27.58	3.23	37	25	Feldspars
7	14.22	28.44	3.14	61	42	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.66. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon F6, Bk2 horizon.

Table B.66. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon F6, Bk2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.43	8.85	9.99	695	100	Illite
2	8.85	17.70	5.01	178	26	Illite
3	13.34	26.68	3.34	518	75	Quartz
4	13.72	27.43	3.25	97	14	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.67. X-ray diffraction pattern of Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F6, Bk3 horizon, petrocalcic fragments.

Table B.67. Peak identification of Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon F6, Bk3 horizon, petrocalcic fragments.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.44	8.88	9.95	258	93	Illite
2	6.18	12.37	7.16	143	52	Kaolinite
3	8.88	17.75	5.00	90	33	Illite
4	12.46	24.92	3.57	122	44	Kaolinite
5	13.34	26.68	3.34	276	100	Quartz
6	13.74	27.48	3.25	98	36	Feldspars
7	14.21	28.42	3.14	57	21	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.68. X-ray diffraction pattern of K-saturated, heated at 250°C, clay fraction, Pedon F6, Bk3 horizon, petrocalcic fragments.

Table B.68. Peak identification of K-saturated, heated at 250°C, clay fraction, Pedon F6, Bk3 horizon, petrocalcic fragments.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.51	9.03	9.80	105	100	Illite
2	6.26	12.51	7.08	43	41	Kaolinite
3	8.91	17.83	4.98	37	35	Illite
4	12.56	25.11	3.55	40	38	Kaolinite
5	13.45	26.89	3.32	95	90	Quartz
6	13.79	27.58	3.23	51	49	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.69. X-ray diffraction pattern of K-saturated, heated at 550°C, clay fraction, Pedon F6, Bk3 horizon, petrocalcic fragments.

Table B.69. Peak identification of K-saturated, heated at 550°C, clay fraction, Pedon F6, Bk3 horizon, petrocalcic fragments.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.50	8.99	9.83	454	100	Illite
2	8.95	17.89	4.96	89	20	Illite
3	13.41	26.81	3.33	282	62	Quartz
4	13.81	27.61	3.23	96	21	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.70. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon H, A horizon.

Table B.70. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon H, A horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.42	8.84	10.00	166	69	Illite
2	6.17	12.34	7.17	177	74	Kaolinite
3	8.87	17.74	5.00	67	28	Illite
4	10.42	20.84	4.26	64	27	Quartz
5	12.44	24.88	3.58	148	62	Kaolinite
6	13.31	26.61	3.35	240	100	Quartz
7	13.71	27.43	3.25	62	26	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.71. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon H, A horizon.

Table B.71. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon H, A horizon.

n [†]	θ	2θ	d (Å)	I_n^P [‡]	I_r^P [§]	Mineral
1	4.37	8.74	10.11	73	100	Illite
2	6.25	12.49	7.09	43	59	Kaolinite
3	9.00	17.99	4.93	27	37	Illite
4	12.58	25.16	3.54	30	41	Kaolinite
5	13.37	26.74	3.33	59	81	Quartz

[†]peak number; [‡]net peak intensity;

[§]relative peak intensity

Figure B.72. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon H, A horizon.

Table B.72. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon H, A horizon.

$n^{\dagger}$	θ	2θ	d (Å)	$I_n^{\dagger\dagger}$	$I_r^{\dagger\dagger}$	Mineral
1	4.46	8.91	9.92	301	100	Illite
2	8.97	17.94	4.94	63	21	Illite
3	10.52	21.04	4.22	46	15	Quartz
4	13.41	26.83	3.32	192	64	Quartz
5	13.90	27.79	3.21	73	24	Feldspars

$\dagger$ peak number; $\dagger\dagger$ net peak intensity;

$\S$ relative peak intensity

Figure B.73. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon H, Bk2 horizon.

Table B.73. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon H, Bk2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.42	8.83	10.01	151	68	Illite
2	6.16	12.32	7.19	120	54	Kaolinite
3	8.82	17.63	5.03	66	30	Illite
4	12.43	24.85	3.58	93	42	Kaolinite
5	13.30	26.60	3.35	222	100	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.74. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon H, Bk2 horizon.

Table B.74. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon H, Bk2 horizon.

n†	θ	2θ	d (Å)	$I_n^{\dagger\dagger}$	$I_r^{\dagger\dagger}\S$	Mineral
1	4.48	8.96	9.87	110	100	Illite
2	6.29	12.58	7.04	40	36	Kaolinite
3	8.94	17.88	4.96	28	25	Illite
4	12.46	24.91	3.57	33	30	Kaolinite
5	13.41	26.83	3.32	78	71	Quartz

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.75. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon H, Bk2 horizon.

Table B.75. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon H, Bk2 horizon.

$n^{\dagger}$	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.44	8.88	9.96	430	100	Illite
2	8.88	17.76	4.99	88	20	Illite
3	10.47	20.94	4.24	63	15	Quartz
4	13.36	26.71	3.34	322	75	Quartz

$\dagger$ peak number; $\ddagger$ net peak intensity;

$\S$ relative peak intensity

Figure B.76. X-ray diffraction pattern of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon H, Bk5 horizon.

Table B.76. Peak identification of the Ca-saturated, glycerol solvated, ambient temperature, clay fraction, Pedon H, Bk5 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	3.50	7.00	12.63	88	37	Sepiolite
2	4.08	8.15	10.85	51	22	Palygorskite
3	6.17	12.33	7.18	113	48	Kaolinite
4	9.90	19.80	4.48	52	22	Palygorskite
5	12.46	24.92	3.57	99	42	Kaolinite
6	13.30	26.60	3.35	79	34	Quartz
7	14.13	28.25	3.16	235	100	Feldspars
8	14.71	29.42	3.04	60	26	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.77. X-ray diffraction pattern of the K-saturated, heated at 250°C, clay fraction, Pedon H, Bk5 horizon.

Table B.77. Peak identification of the K-saturated, heated at 250°C, clay fraction, Pedon H, Bk5 horizon.

n†	θ	2θ	d (Å)	$I_n^\dagger$	$I_r^\S$	Mineral
1	3.81	7.61	11.62	310	79	Sepiolite
2	4.12	8.24	10.73	392	100	Palygorskite
3	6.18	12.36	7.16	63	16	Kaolinite
4	6.91	13.81	6.41	54	14	Palygorskite
5	8.87	17.74	5.00	63	16	Illite
6	12.49	24.98	3.57	64	16	Kaolinite
7	13.35	26.69	3.34	172	44	Quartz
8	14.16	28.33	3.15	278	71	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

Figure B.78. X-ray diffraction pattern of the K-saturated, heated at 550°C, clay fraction, Pedon H, Bk5 horizon.

Table B.78. Peak identification of the K-saturated, heated at 550°C, clay fraction, Pedon H, Bk5 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	4.43	8.86	9.98	256	100	Illite
2	8.91	17.81	4.98	71	28	Illite
3	13.36	26.73	3.34	116	45	Quartz
4	14.14	28.28	3.16	254	99	Feldspars

†peak number; ‡net peak intensity;

§relative peak intensity

APPENDIX C
X-RAY DIFFRACTION PATTERNS OF SELECTED
SILT SAMPLES

Figure C.1. X-ray diffraction pattern of the silt fraction Pedon F1, Bw2 horizon.

Table C.1. Peak identification of the silt fraction, Pedon F1, Bw2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	10.44	20.88	4.25	2437	22	Quartz
2	11.01	22.02	4.04	91	1	Plagioclase
3	11.79	23.58	3.77	167	2	Plagioclase
4	12.10	24.20	3.68	85	1	Plagioclase
5	12.86	25.72	3.46	81	1	K-Feldspar
6	13.33	26.67	3.34	10923	100	Quartz
7	13.56	27.12	3.29	134	1	K-Feldspar
8	13.78	27.57	3.24	420	4	K-Feldspar
9	13.99	27.98	3.19	273	2	Plagioclase
10	14.94	29.88	2.99	55	1	K-Feldspar
11	15.06	30.12	2.97	49	0	Plagioclase
12	15.27	30.53	2.93	15	0	Plagioclase
13	15.40	30.80	2.90	77	1	K-Feldspar
14	15.62	31.23	2.86	40	0	Plagioclase

†peak number; ‡net peak intensity;

§relative peak intensity

Figure C.2. X-ray diffraction pattern of the silt fraction Pedon F2, Bk2 horizon.

Table C.2. Peak identification of the silt fraction, Pedon F2, Bk2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	10.44	20.88	4.25	1868	19	Quartz
2	11.03	22.07	4.03	74	1	Plagioclase
3	11.63	23.25	3.83	31	0	K-Feldspar
4	11.82	23.63	3.76	103	1	Plagioclase
5	12.13	24.25	3.67	92	1	Plagioclase
6	12.78	25.55	3.49	32	0	K-Feldspar
7	12.84	25.68	3.47	42	0	K-Feldspar
8	13.33	26.67	3.34	9918	100	Quartz
9	13.56	27.12	3.29	21	0	K-Feldspar
10	13.73	27.47	3.25	1056	11	K-Feldspar
11	13.97	27.93	3.19	429	4	Plagioclase
12	14.93	29.87	2.99	49	0	K-Feldspar
13	15.13	30.25	2.95	40	0	Plagioclase
14	15.39	30.78	2.90	324	3	K-Feldspar

†peak number; ‡net peak intensity;

§relative peak intensity

Figure C.3. X-ray diffraction pattern of the silt fraction of Pedon F2, Bk horizon, petrocalcic fragments.

Table C.3. Peak identification of the silt fraction of Pedon F2, Bk horizon, petrocalcic fragments.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	10.04	20.08	4.42	52	1	Kaolinite
2	10.27	20.53	4.33	146	3	Kaolinite
3	10.46	20.92	4.25	993	18	Quartz
4	11.43	22.87	3.89	254	5	K-Feldspar
5	11.81	23.62	3.77	86	2	Plagioclase
6	12.49	24.98	3.56	211	4	Kaolinite
7	12.98	25.95	3.43	422	8	K-Feldspar
8	13.36	26.72	3.34	5486	100	Quartz
9	13.48	26.95	3.31	138	3	K-Feldspar
10	13.77	27.53	3.24	478	9	K-Feldspar
11	14.00	28.00	3.19	166	3	Plagioclase
12	14.43	28.85	3.09	446	8	Plagioclase
13	15.83	31.65	2.83	337	6	Plagioclase

†peak number; ‡net peak intensity;

§relative peak intensity

Figure C.4. X-ray diffraction pattern of the silt fraction Pedon F3, Btk2 horizon.

Table C.4. Peak identification of the silt fraction, Pedon F3, Btk2 horizon.

$n^{\dagger}$	θ	2θ	d (Å)	$I_n^{\dagger}$	$I_r^{\S}$	Mineral
1	10.49	20.98	4.23	2624	20	Quartz
2	11.06	22.12	4.02	81	1	Plagioclase
3	11.62	23.23	3.83	56	0	K-Feldspar
4	11.83	23.67	3.76	165	1	Plagioclase
5	12.16	24.32	3.66	43	0	Plagioclase
6	12.88	25.77	3.46	120	1	K-Feldspar
7	13.38	26.77	3.33	13451	100	Quartz
8	13.79	27.58	3.23	399	3	K-Feldspar
9	14.02	28.03	3.18	310	2	Plagioclase
10	14.99	29.98	2.98	49	0	Plagioclase
11	15.30	30.60	2.92	42	0	Plagioclase
12	15.43	30.87	2.90	46	0	K-Feldspar

$\dagger$ peak number; $\ddagger$ net peak intensity;

$\S$ relative peak intensity

Figure C.5. X-ray diffraction pattern of the silt fraction Pedon F3, B'tk1 horizon.

Table C.5. Peak identification of the silt fraction, Pedon F3, B'tk1 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	10.47	20.93	4.24	2341	22	Quartz
2	11.07	22.13	4.02	81	1	Plagioclase
3	11.58	23.17	3.84	45	0	K-Feldspar
4	11.83	23.65	3.76	132	1	Plagioclase
5	12.14	24.28	3.67	115	1	Plagioclase
6	12.85	25.70	3.47	144	1	K-Feldspar
7	13.37	26.73	3.33	10806	100	Quartz
8	13.78	27.57	3.24	413	4	K-Feldspar
9	13.99	27.98	3.19	285	3	Plagioclase
10	14.13	28.27	3.16	40	0	Plagioclase
11	15.00	30.00	2.98	86	1	K-Feldspar
12	15.29	30.58	2.92	64	1	Plagioclase
13	15.44	30.88	2.90	66	1	K-Feldspar
14	15.68	31.37	2.85	44	0	Plagioclase

†peak number; ‡net peak intensity;

§relative peak intensity

Figure C.6. X-ray diffraction pattern of the silt fraction Pedon F4, Bk2 horizon.

Table C.6. Peak identification of the silt fraction, Pedon F4, Bk2 horizon.

n†	θ	2θ	d (Å)	$I_n^\dagger$	$I_r^\S$	Mineral
1	10.43	20.87	4.26	1875	21	Quartz
2	11.02	22.03	4.03	141	2	Plagioclase
3	11.44	22.88	3.89	81	1	K-Feldspar
4	11.79	23.58	3.77	125	1	Plagioclase
5	12.20	24.40	3.65	76	1	Plagioclase
6	12.80	25.60	3.48	121	1	K-Feldspar
7	13.33	26.65	3.34	8963	100	Quartz
8	13.74	27.48	3.25	628	7	K-Feldspar
9	13.98	27.97	3.19	233	3	Plagioclase
10	14.13	28.25	3.16	102	1	Plagioclase
11	14.39	28.78	3.10	40	0	Plagioclase
12	14.93	29.85	2.99	62	1	K-Feldspar
13	15.13	30.25	2.95	37	0	Plagioclase
14	15.24	30.48	2.93	82	1	Plagioclase
15	15.46	30.92	2.89	118	1	K-Feldspar

†peak number; ‡net peak intensity;

§relative peak intensity

Figure C.7. X-ray diffraction pattern of the silt fraction Pedon F4, Btkb3 horizon.

Table C.7. Peak identification of the silt fraction, Pedon F4, Btkb3 horizon.

n†	θ	2θ	d (Å)	I_n^P ‡	I_r^P §	Mineral
1	10.44	20.88	4.25	1788	18	Quartz
2	11.02	22.03	4.03	113	1	Plagioclase
3	11.50	23.00	3.87	34	0	K-Feldspar
4	11.77	23.53	3.78	136	1	Plagioclase
5	12.16	24.32	3.66	215	2	Plagioclase
6	12.78	25.57	3.48	54	1	K-Feldspar
7	13.32	26.63	3.35	9773	100	Quartz
8	13.73	27.45	3.25	456	5	K-Feldspar
9	13.85	27.70	3.22	27	0	Plagioclase
10	13.97	27.93	3.19	323	3	Plagioclase
11	14.13	28.25	3.16	41	0	Plagioclase
12	14.95	29.90	2.99	63	1	K-Feldspar
13	15.07	30.13	2.97	34	0	Plagioclase
14	15.27	30.53	2.93	50	1	Plagioclase
15	15.38	30.75	2.91	55	1	K-Feldspar

†peak number; ‡net peak intensity;

§relative peak intensity

Figure C.8. X-ray diffraction pattern of the silt fraction Pedon H, Bk2 horizon.

Table C.8. Peak identification of the silt fraction, Pedon H, Bk2 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	9.94	19.88	4.47	45	1	Kaolinite
2	10.49	20.98	4.23	946	21	Quartz
3	11.08	22.15	4.01	151	3	Plagioclase
4	11.48	22.95	3.87	51	1	K-Feldspar
5	11.86	23.72	3.75	165	4	Plagioclase
6	12.18	24.37	3.65	97	2	Plagioclase
7	12.90	25.80	3.45	84	2	K-Feldspar
8	13.39	26.78	3.33	4489	100	Quartz
9	13.83	27.67	3.22	173	4	K-Feldspar
10	13.96	27.92	3.20	471	10	Plagioclase
11	15.00	30.00	2.98	58	1	Plagioclase
12	15.27	30.53	2.93	53	1	Plagioclase
13	15.48	30.97	2.89	81	2	K-Feldspar

†peak number; ‡net peak intensity;

§relative peak intensity

Figure C.9. X-ray diffraction pattern of the silt fraction Pedon H, Bk5 horizon.

Table C.9. Peak identification of the silt fraction, Pedon H, Bk5 horizon.

n†	θ	2θ	d (Å)	$I_n^P \ddagger$	$I_r^P \S$	Mineral
1	9.95	19.89	4.46	50	1	Kaolinite
2	10.48	20.96	4.24	709	19	Quartz
3	11.07	22.14	4.01	59	2	Plagioclase
4	11.51	23.03	3.86	34	1	K-Feldspar
5	11.88	23.76	3.74	117	3	Plagioclase
6	12.16	24.31	3.66	49	1	Plagioclase
7	12.87	25.74	3.46	53	1	K-Feldspar
8	13.36	26.73	3.34	3696	100	Quartz
9	13.94	27.88	3.20	154	4	Plagioclase
10	14.04	28.08	3.18	109	3	Plagioclase
11	14.17	28.34	3.15	376	10	Plagioclase

†peak number; ‡net peak intensity;

§relative peak intensity

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