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Characteristics and Genesis of the Payson and Trenton Soils

Hakeem T. Saif
Utah State University

CHARACTERISTICS AND GENESIS OF THE PAYSON AND TRENTON SOILS

by

Hakeem T. Saif

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Hakeem T. Saif

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ABSTRACT

Characteristics and Genesis of the
Payson and Trenton Soils

by

Hakeem T. Saif, Master of Science
Utah State University, 1977

Major Professor: Alvin R. Southard
Department: Soil Science and Biometeorology

It is necessary to study the genesis of the Payson and Trenton polypedons in northern Utah to understand why the Payson polypedon is an Alfisol, while the Trenton polypedon is a Mollisol. Even though the soil-forming factors appear similar, the soils differ at the order level. Two pedons, one belonging to the Payson polypedons and the other belonging to the Trenton polypedon, have been described and sampled by genetic horizons. Both pedons have essentially the same climate, slope, age, elevation, and are developed on the parent material of Lake Bonneville sediments.

The differences in physical, chemical and mineralogical properties among the horizons in the same pedon and between the Payson and Trenton pedons is due to differences in deposition as alluvium or lacustrine sediments during different periods.

The high amount of exchangeable sodium in both pedons reflects the development of texture in natric horizons and helps the movement of fine clay and organic matter from the eluvial to the illuvial horizons.

The light color of the surface of the Payson pedon is related to high amounts of calcium carbonate in the A1 horizon, bleaching of soil particles within the structural units by sodium, and the presence of large amounts of light-colored minerals in the epipedon of the Payson soil.

(93 pages)

INTRODUCTION

Pedology

Although pedology began with a profile study of the soil body (Joffe, 1936), it was not recognized as an independent science for a long time. The first to publish a soil-forming factor equation was Dokuchaev in 1898, showing that a systematic regularity and orderliness existed in the geographic distribution of soils and realizing the existence of soil formers (Jenny, 1941, p. 17).

Hilgard (Jenny, 1961) recognized the existence of soil forming factors. He attributed the soil differences to climate and vegetation, but he did not summarize his observations in the form of an equation. Jenny, (1961) expressed the soil genesis equation and generalization of soil behavior related to genetic factors. Jenny's equations of 1941 and 1958 describe the relationship between soil properties and site factors.

$$S = f(cl, o, r, p, t, \ldots),$$

where S represents soil; cl, climate; o the organisms; r the relief; p, parent material; and t time.

Boul (1973, p. 3) provided a definition: "Soil genesis is that phase of soil science sometimes referred to as pedology when combined with soil classification activity that deals with factors and processes of soil formation." These factors are parent material, climate, biological activity, relief, and time. The greater the constant soil-forming factors, the greater the chance of finding a satisfactory correlation or similar soils. Cline (1961) stated that "With constant rates of processes, one may expect a soil to develop along a given course and to change mainly in degree of expression of properties rather than in kind, but with changes of soil itself, or of the environment, however, one may expect the rates of such processes to change relative one to another, and as a consequence, the course of soil formation may be expected to shift in time to produce new sets of properties we recognize as differences in kind rather than degree." Simonson (1959) emphasized the combination and the balance of many individual biological, chemical, and physical processes in the differentiation of soils, and indicated that soils of similar morphology may have travelled different ways.

Statement of the problem

The Payson polypedon is made up of somewhat poorly drained, alkaline soils, with fine-textured subsoils. Mean annual temperature is about 9.1°C, and its average precipitation is about 390 mm. The parent materials of the polypedon are reported to be lake sediments derived from limestone, sandstone, and shale. At an elevation of 1360 meters, the slope gradient is about 0 - 1 percent.

The Trenton polypedon is also composed of somewhat poorly drained, alkaline soils, with fine-textured subsoils. The slope, elevation, precipitation, and temperature are similar to the Payson polypedon. The parent material of these soils is also reported to be mixed lake sediments derived from limestone, sandstone, and quartzite.

The Payson polypedon under study is located between the city of Logan and the town of Benson near the Logan-Cache Airport, whereas the Trenton polypedon is located in the north-central part of Cache Valley, west of Richmond (Figure 1).

It is necessary to study the genesis of these two polypedons to understand (1) why the Payson polypedons is and Alfisol, while the Trenton polypedon is a Mollisol, and (2) even though the soil-forming factors appear similar, do the soils differ at the order level?

Objectives of this study

1. To verify the classificaiton of the polypedons
2. To establish the processes by which these two soils have evolved.

To accomplish these objectives, the following studies were conducted. To establish the presence or absence of argillic horizons, thin sections were examined with the polarizing microscope. Clay distribution, including that less than 0.2 micron effective diameter, was determined by using particle size distribution analysis. To verify the presence or absence of natric horizons, cation species and their distribution were established by chemical methods.

To establish the presence of light-colored minerals in sufficient quantity to preclude a mollic epipedons in the Payson polypedon, the very fine sand fractions were examined by x-ray diffration analysis. This also helped to establish the similarities and differences in parent materials for the two pedons.

LITERATURE REVIEW

Climate

Climate of the Cache area ranges from dry subhumid to moist subhumid. Precipitation increases with increases in elevation, with the average annual precipitation on the valley floor ranging from 356 to 432 mm.; most of this is snowfall during October through April, averaging 1524 to 2132 mm. Cache Valley's winters are cold, averaging 120 - 160 frost-free days on the valley floor. The temperature varies from less than -7°C in the winter to more than 38°C during the summer, accompanied by occasional thunderstorms. The growing season ranges from 114 to 150 days (Erickson, 1974). Tables 1 and 2 show climate data at Logan and Lewiston by Richardson (1977)*, where the Payson and Trenton polypedons are located, respectively.

Table 1. Average monthly temperature and precipitation during 1956 - 1975, USU Station in Logan, Utah (elevation 1373 meters).

JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
				Temperature (°C)								
-5.5	-1.8	-0.8	7.6	13.2	17.7	22.3	21.3	15.4	9.2	2.2	-3.6	8.1
				Precipitation (mm)								
42.9	26.4	35.8	41.4	34.3	40.9	11.2	20.3	32.2	37.1	36.3	30.2	389.9

*Richardson, E.A. 1977. Unpublished Climatological Data. Utah State University, Logan, Utah.

Table 2. Average monthly temperature and precipitation during 1924 - 1974, Lewiston Station, Utah (elevation 1366 meters).

JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
Temperature (°C)												
-6.2	-3.2	1.7	7.4	12.3	16.4	20.9	19.8	14.9	9.0	1.8	-4.2	7.6
Precipitation (mm)												
43.2	35.8	43.2	51.6	48.3	38.9	15.0	21.8	27.7	40.6	39.9	40.9	421.4

Geologic setting

Cache Valley is essentially Cache County and the drainage area surrounding it, lying at the northeast corner of the Great Basin in northen Utah. It was built during the growth of the great Laramide Mountains.

Structurally, Cache Valley is a graben, delineated by Basin and Range boundary faults, which are responsible for the major topographical features of Cache Valley. Although Cache Valley was created by down-faulting between mountain blocks that remained high (fault-valley), there is no evidence of erosion (Williams, 1958).

The valley is narrow and elongated, the bottom has a relatively smooth floor formed by the silt and clay deposits of Lake Bonneville, and is marked by a wide meander belt of the Bear River. The length of the valley is approximately 96 km., 56 km. in Utah and 40 km. in Idaho; the average width is about 16 km. (Young, 1939 and Williams, 1958).

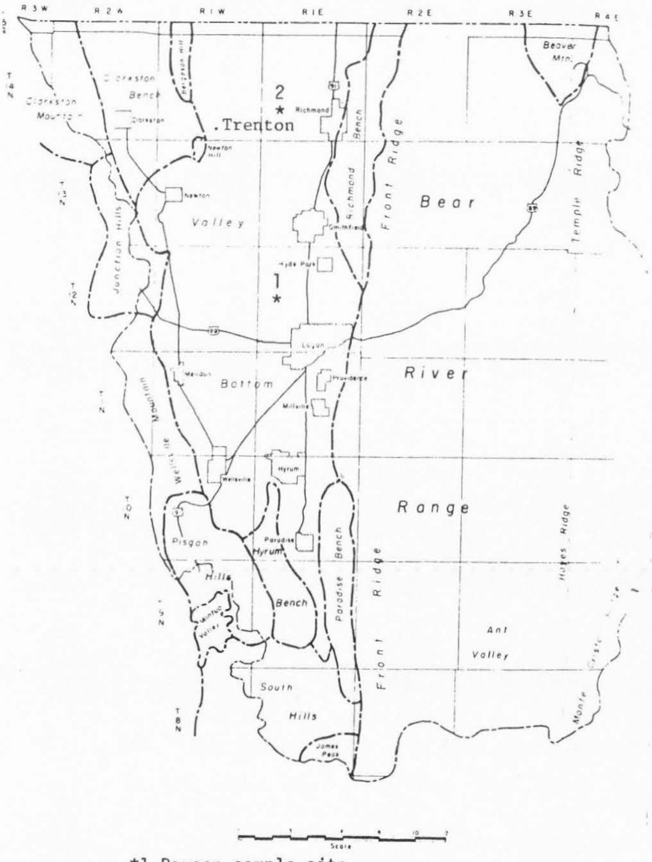
The major streams entering Cache Valley, the Bear and Logan Rivers, create V-shaped canyons.

Cache Valley is bordered on the east by the Bear River Range, on the northwest by the Malad Range, and on the southwest by the northern part of the Wasatch Range (Figure 1). The lowest part of Cache Valley, the west-central part, is about 1346 m. above sea level, while Mount Naomi is the highest, approximately 3040 m. (Williams, 1958). In general, the bottom of Cache Valley is covered by the Lake Bonneville group sediments; the foot hills formed by Tertiary rocks of the Salt Lake Formation; and the higher mountains bordering the valley composed of Paleozoic rocks (Williams, 1952).

During the Late Precambrian and early Cambrian, a thick sequence of metamorphosed, fine-grained Precambrian clastics were overlain by several thousand feet of quartzite. Then a thick section of carbonate occurred until the middle of the Ordovician, when the sea withdrew and deposited sediments across the area. In upper Ordovician time, the sea transgressed again. Other trangressions and regressions took place during the Paleozoic and into the Mesozoic (Maw, 1962). Paleozoic rocks were the source of most of these clastic materials that make up the Tertiary and Quaternary deposits in the valley (Williams, 1962).

As a result of the Laramide Orogeny, which began in the late Cretaceous time and lasted until the Eocene, the rocks in this region were folded and thrust faulted and eroded during the later Tertiary time (Williams, 1962 and Maw, 1968).

Tertiary deposits consist of two formations: 1) the Salt Lake formation of the Miocene and Pliocene ages, and 2) the Wasatch formation of the Paleocene and Eocene ages (Adamson et al., 1955). The Wasatch



*1 Payson sample site

*2 Trenton sample site

Figure 1. Physiological divisions of Cache County, showing the site location of studied soils (adapted from J. Williams, 1958).

formation consists of red conglomerate and sandstone derived from a Paleozoic source; its color indicates the warm humid climate of the subtropics which existed over the piedmont area (Williams, 1958). Later in the Tertiary, a large lake extended over much of northern Utah. This lake contained fresh water; no sodium chloride or calcium sulfate is found in the sediments; a high calcium carbonate content gives the light color to the Pliocene rocks. Conglomerates were deposited further away from the mountains, forming the Salt Lake formation (Maw, 1968). Williams (1962) classified the Salt Lake deposits into three members: 1) lower conglomerate unit, consisting of a white matrix of cobble and boulder conglomerate, exposed in the foothills near Wellsville and Mendon; 2) tuff unit, consisting of soft earthy-gray tuff, also containing a minor amount of pebble conglomerate, restricted to the Hyrum Bench; and 3) upper conglomerate and sandstone unit, consisting of rounded pebbles and cobbles in a matrix of calcium carbonate and tuffaceous sand.

After the deposition of the Salt Lake formation, subsequent faulting, tilting, and erosion created a varied topography; then later deposition of Lake Bonneville sediments occurred (Maw, 1968).

The Quarternary deposits (drift, alluvial fans, and terraces) consist of lacustrine sediments below the highest elevation of Lake Bonneville, 1565 m. (Williams, 1948 and Galloway, 1970).

Lake Bonneville grew in the northeast corner of the Basin and Range province which occupied northwestern Utah during the Pleistocene epoch, fed by streams from the Uinta and Wasatch mountains. Gilbert (1890) described some of the Lake features as deltas, shore embankments, and outlet channels. He also studied the major evidence left by the lake. The elevation of the lake shoreline is about 1565 m. above sea level and the greatest depth is about 320 m. It covered about 51,152 square kilometers. Previously, the Lake Bonneville basin was arid. After the first rise, yellow clay was deposited; whereas, after the second rise, white marl was deposited. These are separated by coarse deposits of gravel (Gilbert, 1890). Gilbert also concluded that the lake was created by glaciation and climatic changes, and the lacustrine epochs were epochs of relative cold. The four shoreline levels named by Gilbert, from oldest to youngest are:

1) Alpine formation, proposed by Hunt (1953), was considered the oldest deposits of Lake Bonneville exposed above the Provo shoreline and below the Bonneville shoreline, consisting of lacustrine gravel, sand, silt, and clay. The elevation extends to 1554 m. in southern Cache Valley (Williams, 1962).
2) Bonneville formation, younger than the Alpine formation, accumulated during the highest level of the lake, consisting almost completely of gravel. The elevation of the Bonneville shoreline is 1565 m., poorly exposed in southern Cache Valley (Williams, 1962).
3) Provo formation, consisting of boulders to fine sand, silt and clay, derived from Tertiary and Paleozoic rocks. The formation is extensively exposed in Cache Valley. Topographic expression and lithologic differences near the Provo shoreline are used to distinguish between the Provo and Bonneville formation (Maw, 1968). Most of the delta sediments were

deposited during this stage (Williams, 1962).

4) Stansbury level, consisting of the youngest deposits, deposited during a shorter period than the Provo stage. These deposits are not well exposed in Cache Valley.

It is believed that Lake Bonneville began about 75,000 years ago, whereas the deposits of the Bonneville formation began about 25,000 years ago (Morrison, 1966). The different shoreline levels of Lake Bonneville are due to advances and retreats of glaciers in the Uinta and Wasatch mountains.

Since no significant geomorphic changes occurred in Cache Valley during the post-lake althithermal age of the Holocene (8000-4500 years ago), when the world's climate was much warmer and dryer than at the present, the waters of the lake withdrew to the lowest parts of its basin (Williams, 1956). Along the front of the mountains over Lake Bonneville seiments, poorly sorted alluvial fans were deposited. Then the streams cut the deltas and re-deposited the gravel and sand of the Provo formation in fans over the silt and clay of the Provo member at a lower elevation. The earliest sand deposits by the Bear River from the Provo delta were covered by lake sediments of silt and clay (Williams, 1962).

Payson and Trenton soils have developed on the parent material of the Lake Bonneville sediments. The Payson pedon has an elevation of 1356 m., whereas the elevation of the Trenton pedon is 1365 m. above sea level (Erickson et al., 1974). Both soils lie below the 1463 m. level of the Provo shoreline. The location of these two soils are shown in Figure 1 and 2. The silt and clay covered the land of

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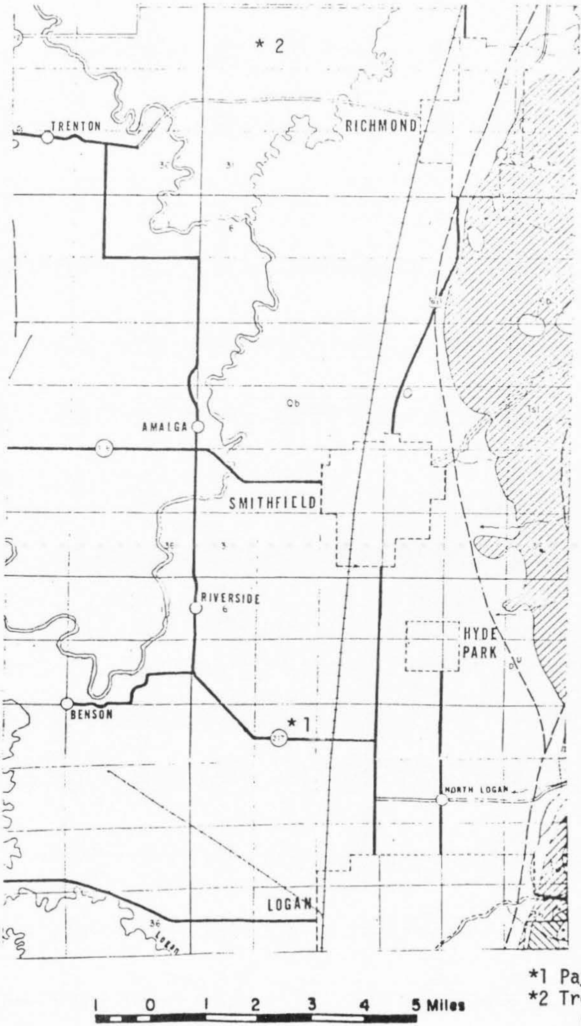

*1 Payson sample site
*2 Trenton sample site
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Cache Valley by settling from suspension in the lake water to the lake bottom. These sediments were derived from reworked sediments of the Bonneville formation (Williams, 1962).

Previous studies on soil genesis in arid and semi-arid rgions and evaluations of their soil forming factors

By observing the morphology and genesis of soils occurring in arid and semi-arid regions derived from highly calcareous parent materials, Harper (1957) concluded that the dispersion and accumulation of clay in the B horizon of Solonetz is due to a high exchangeable sodium percentage and a high pH value. Accumulation of clay in the B horizon of some calcareous soils is due to leached calcium carbonate at the time the B horizon was formed. Westin (1953) postulated that the Solonetzic soils of eastern South Dakota were developed from a saline-alkali parent material when the moisture regime was one of alternate ponding and desiccation, and changes in volume and consituents of the soil resulted from solonization. Soil development in the arid regions of south-central Washington was studied by Gilkeson (1957). He found a significant increase of exchangeable sodium in the lower horizons, and that most of the soil properties (texture, depth of solum, and the development of a lime zone) are related directly to the original deposition of the soil forming material.

The earlier and some recent studies emphasized the importance of climate as a factor in soil formation. Gilnka (1927) stated that "The law of the adaptability of soil types of the globe to definite natural (primarily climatic) conditions." Sibirtzev furthered the zonality principles, pointing out that "soils are distributed geographically on the surface of the earth in regional belts, each one having a definite set of soil formers, of which the climate is the most important one." Joffe (1936) reported that the soils of the world are classified due to the climatic factor, which is the most active soil former and responsible for soils formation. Kellogg (1941) stated that climate influenced the amount of various chemical elements and compounds in the soil over broad areas. Jenny (1941, p. 55) considered the formation of parent material as a function of climate. Gile (1968) reported that the wetter climate of the Pleistocene epoch and the greater vegetation cover and landscape stability were required for development of an argillic horizon and a strong horizon of carbonate accumulation in these highly calcareous parent materials. Climatic changes to warmer and drier, with increasing age of soil during recent time, appears to have been marked by the development of an A horizon and weak calcic horizons. Goddard (1973) pointed out that the formation and distribution of clay particles in the solum is influenced by the amount and distribution of rainfall (leachable water), the depth of leaching, and the natural drainage. Gelderman (1972) reported that in the Willamette group of northwestern Oregon more argillic horizons were produced during the late Pleistocene than in the present climate. The source of montmorillonite in these argillic horizons was related to the sediments in which the horizon was formed.

The resulting close relationship between the well developed soils and the parent material in arid and semi-arid lands is often neglected. Nikiforoff (1937) concluded that the rainfall in the desert region is a powerful factor and strong agent in the formation of parent materials. He suggested that the clay layer may be formed in place, postulating that the surface layer of the desert soils dries quickly after rain and protects the subsoil from loss of moisture, so the reaction is more complete in the moist subsoil. Gile (1966) concluded that the argillic horizons were formed in some desert soils of southern New Mexico and then destroyed. Evidence of former glaciation and lakes indicates that the Pleistocene epoch was wetter and cooler than the present climate, and the soils formed then tend to have thicker and stronger horizons than do soils recently formed.

The effects of age and parent materials on soil boundaries in an arid region were studied by Gile (1975). He reported that the major cause of difference in age was episodic sedimentation at various times and places, and that prominent changes in soils occur across the boundary between the Holocene and Pleistocene ages; whereas, the boundaries caused by changes in parent material are due to differences in amount of carbonate and coarse fragments. Molthan (1963) found that the texture and clay mineralogy differences between the two modal reddish prairie soils related to texture and chemical differences in parent materials. Jackson (1965) believed that the clay transformation in soil genesis during the Quaternary have been inherited as minerals from rocks of the entire geologic column and in part formed pedogenically. Boul (1965) concluded that the Zonal soils developed in arid and semi-arid regions are seldom, if ever, subjected to leaching of the entire profile. This results in the accumulation, at a shallow depth below the surface, of soluble and dispersible materials. Boul also concluded that the clay mineralogy in arid and semi-arid soils is probably more controlled by the parent material than by clay weathering during pedogenesis.

Jenny (1941, p. 45) defined parent material as the state of the soil system at the time zero of soil formation. The chemical, physical, and mineralogical properties of different soils developed in the Pre-Pleistocene were studied by Jarvis (1959), who found that the clay minerals were inherited directly from the parent material, with insufficient weathering to produce marked alteration of clay minerals. This was reflected in the translocation of the bases and clay minerals to lower horizons. Wilkinson (1954) reached similar conclusions when he studied some soils of Oklahoma. Thorp (1959) concluded that the accumualtion of clay in the B horizon of the Miami Series is due to translocation of clay from an eluvial horizon. The origin of the clay minerals was almost completely from parent material, but some illite was weathered to vermiculite, and both may be weathered to montmorillonite. Anderson (1975) studied the effect of parent material on genesis of the Borolls and Boralfs in a south-central New Mexico mountain. He found that Borolls and Boralfs are developed under similar soil forming factors except parent material; the parent material for Borolls is limestone, whereas for Boralfs it is sandstone. The presence of calcium carbonate in all soil horizons of Borolls prevents the development of an argillic horizon. Lepsch and Boul (1977) studied soil-landscape relationships in the Occidental Plateau of Sao Paulo State, Brazil. They concluded that kaolinite was the dominant clay mineralogy of the soils formed in unconsolidated deposits, because kaolinite is the most resistant mineral commonly present in the study area, while attapulgite and montmorillonite were inherited from the calcareous sandstone. Allison et al. (1949) studied inorganic colloid as a factor in retention of carbon during formation of humus. He suggested that the formation of mollic epipedons was most likely aided by the high amount of montmorillonite clay mineral which retained large amounts of organic matter. Smith (1968) concluded that clay formation in situ and translocation of fine clay (less than 0.2 micron) from the A horizon are responsible for the formation of argillic horizons in soils of arid and semi-arid regions. Nettleton (1975) studied the genesis of argillic horizons in the soils of desert areas in Nevada. He concluded that the translocation of salt, carbonate, and clay have been slower during the Holocene time than the Pleistocene. Accumulation of total Al_2O_3 and Fe_2O_3 in the argillic horizons is more direct evidence that clay translocation has occurred. Simonson (1959) reported that the various processes of addition, removal, and transformation may act to promote or retard the development of horizons, and, if they are operating at the same time in the same profile, may be in conflict to some degree.

Ballagh (1970) studied clay-rich horizons overlying limestone. He concluded that clay in a clay-rich horizon is primarily illuvial clay and is not residual material resulting from the dissolution of limestone. Chang Wang (1973) found that Hapludalfs and Fragiochrepts have similar lithologic discontinuities, and developed under similar soil systems, with the major differences due to the non-calcareous nature of parent material of the Fragiochrept.

Studies in northern Utah, on three profiles developed from sedimentary rock materials by Southard and Miller (1966), indicated that clay minerals are mostly inherited clays contained in the parent material and not clays formed by weathering of the primary minerals during altration of the sedimentary rock to soil. They also indicated that the clay involved has been less influenced by climate and time than by the parent rock. Douglas (1959) studied weathering products in the Payson soil series. He concluded that Payson soils were affected to varying degrees by stratification at the time of the deposition of the sediments which compose the parent material. He also concluded that the illite was the most prominent layer silicate in the clay fraction. Al-Taie (1958) studied the genesis of the Manila, Paradise, and Avon soil series associated with different levels of Lake Bonneville. He emphasized that montmorillonite is markedly the dominant clay mineral. He also concluded that the heterogeneity of the study area was responsible for the marked differences in clay types. Al-Amin (1975) studied the genesis of two soil series, Parleys and Mendon in Cache County, derived from different parent materials and developed under similar climatic, topographical, biological, and age conditions. He concluded that the measurable inherited properties of the soils are calcium carbonate, iron oxide, organic matter, and clay type. Most of these properties were shown to have a high degree of variability, which tends to support the idea that their differences are attibutable to their parent material.

Rooyani (1976) studied the genesis of the Nebeker and McMurdie soil series in Cache County. He reported that the Nebeker pedon was developed from a parent material rich in quartzite and sandstone with the matrix predominantly of shale, with characteristics very similar to the upper conglomerate member of the Salt Lake formation; the McMurdie pedon was formed from the material of the Salt Lake formation (older) deposited on the Lake Bonneville sediments (younger). Weak evidence of illuviation from field observations and laboratory analysis also support the belief that the McMurdie pedon was formed by deposition rather than the pedogenesis process.

Erickson (1968) classified the Payson soil series as Typic Natrustalfs, fine, mixed, mesic (an Alfisol). The Trenton soil series was classified by Erickson (1974) as Typic Natrixerolls, fine, mixed, mesic (a Mollisol). Both soils are alkaline, having a high amount of exchangeable sodium and a distinct calcic horizon. Parent material of these soils were derived from calcareous Lake Bonneville deposits.

METHODS AND PROCEDURES

Field procedures

Two pedons have been described and sampled by genetic horizon to determine the nature and arrangement of these horizons. One of the pedons belongs to the Payson polypedon and the other to the Trenton polypedon. Soil pedons were located on sites with gentle slopes (1 to 2 percent), and have the same elevation of 1360 meters (Figure 1), and developed on the parent material of Lake Bonneville sediments in Cache Valley in nothern Utah. The sites were obtained from topographic maps prepared by Erickson (1974).

Within each study area, a number of auger borings were examined to be certain that the sites finally chosen would be as near to the model concept of the two soils as possible.

At each selected site, a pit was excavated with dimensions of 100 cm. wide, 200 cm. long, and 153 cm. deep. Detailed pedon descriptions were made for each soil according to the Soil Survey Staff (1951). The horizons were sampled from the bottom of the pit upward to avoid contamination.

Soil samples for chemical analysis were air dried and crushed to pass a 2 mm. sieve. Clods from each horizon were retained for thin sections studies and bulk density determination.

Laboratory procedures

The following procedures were used to determine the physical, chemical, and mineralogical characteristics for the two pedons.

Particle-size distribution. The pipette method of Kilmer and Alexander (1949) was used to determine the particle-size distribution. Organic matter and dissolved mineral matter were removed with hydrogen peroxide. Sodium metaphosphate was used as the dispersing agent. The sand fractions were separated by sieving, and the silt and clay fractions by pipette.

The Kittrick method (1963) was also used for selected horizons of each pedon to detemine the fine clay to total clay ratio.

Bulk density. Bulk density was determined by using the paraffin-coating method of Black (1965). Clods were oven dried, then coated with paraffin and suspended in water. Bulk density values were calculated by dividing the value of the dry weight to grams of water displaced.

Organic matter. The procedure used was that proposed by Black (1965). Potassium dichromate and concentrated sulfuric acid were used to oxidize the organic carbon, then the mixture was immediately swirled for 1 minute and allowed to stand for about 30 minutes, then filtered. Finally, the solution was titrated with ferrous sulfate. The organic matter was calculated by multiplying the organic carbon by the factor 1.7.

Calcium carbonate equivalent. The pressure manometric method, proposed by Williams (1948), was used to determine the calcium carbonate equivalent. The procedure is based on treating 2 grams of soil ground to -80 mesh, with 5 ml. of a 0.5N HCl. The percentage of calcium carbonate equivalent was determined by comparing the manometer reading to a curve prepared from standard samples of calcium carbonate, prepared by adding known amounts of calcium carbonate to carbonate-free soil.

Cation exchange capacity. Cation exchange capacity was determined by the centrifuge method, as described by Richards (1954). The soil was saturated with sodium by being treated and centrifuged with sodium acetate solution (pH 8.2). The soluble sodium acetate was removed by washing with ethanol (95 percent), then replacing the absorbed sodium from the sample by extracting with ammonium acetate solution (pH 7).

Extractable cations. Extractable bases--sodium, potassium, and magnesium--were extracted by washing the sample with ammonium acetate. The amount of cations in the extract was measured by using an atomic absorption spectrophotometer.

Water retention. Water retention at 15 atmospheres was determined by using the pressure membrane apparatus method proposed by Richards (1954). Samples were placed in retainer rings and allowed to absorb water overnight. The required pressure was applied after removing excess water. Moisture content was determined as percentage of oven dry weight.

Soil reaction. The pH value was measured by a glass electrode with a calomel reference electrode pH meter (Beckman Model H-2), using a saturated paste.

Total soluble salts. Measurements of total soluble salts were made on a saturated extract with electrical resistance, described by

Black (1965). The saturated soil paste was filtered (under a vacuum). The electrical conductivity of the extract was measured by a pipette conductivity cell using the conductivity bridge.

Available phosphorus. The modified method of Watanabe and Olson (1965) was used to determine available phosphorus. Carbon was added to the sample to obtain a clear filterate, then the aliquot was treated with ammonium molybdate, stannous chloride, and sodium bicarbonate. The transmittance of the solution was measured in the colorimeter 10 minutes after the addition of the stannous chloride and using 660mμ incident light. The available phosphorus in the ppm was then determined by plotting the percent transmittance against phosphorus concentration on single-cycle, semilog paper.

Free iron oxide. The dithionite-citrate extraction method as described by the Soil Survey Staff (1972) was used. The soil samples were treated with sodium dithionite and sodium citrate. The mixture were placed in the shaker overnight. After filtering, the amount of free iron oxide was measured by an atomic absorption spectrophotometer.

Micromorphology. Thin sections were prepared from undisturbed soil clods, using the modified procedure of Bourbeau (1947). Clods were oven dried and impregnated under vacuum with a mixture of one part castolite, two parts of styrene, an 0.5 percent by volume of hardener. The amount of resin was enough to cover the upper surface of the clods. The samples were left until the evolution of the air bubbles stopped, then allowed to harden slowly at room temperature to avoid cracking. The impregnated samples were cut and polished flat and smooth on one side, cleaned and cemented to a microscope slide, and ground to a thickness of about 30 mμ on a rotating lap with finer grades of grits.

Particle-size separation for X-ray diffraction analysis. The clay, less than 0.2 micron and 0.2-2 micron, silt, and sand fractions were separated following the procedure of the Kittrick and Hope (1963). Carbonates and soluble salts were removed using a sodium acetate solution and heating to 80°C for at least half an hour, then centrifuging. Organic matter was oxidized by adding hydrogen peroxide gradually, with anti-foam to contol frothing. Iron oxide coatings were removed by citrate buffer and dithionite. Saturated sodium chloride solution was added for adequate dispersion. Clay and silt fractions were separated by centrifuge, and sand fractions by sieving. Samples of clay fractions were satutated with magnesium by adding $MgCl_26H_2O$ solution. Each fraction of clay, silt, and very fine sand was examined by x-ray diffraction.

Differential thermal analysis. The differential thermal analysis method was described by Grim (1968). The selected clay size fraction sample was placed in one hole of a specimen holder, and an inert material (α-Al_2O_3) in the other hole. The thermocouples were arranged with one junction in the sample and the other junction in the inert material. The holder and thermocouples were placed in a furnace to control the rate of temperature increase. When the reactions occurred, a difference in temperature was recorded as a function of time, depending on whether the reaction was exothermic or endothermic.

FIELD MORPHOLOGY

Payson pedon

The Payson pedon is a somewhat poorly drained, alkaline soil with a fine-textured subsoil. These soils are derived from calcareous parent material of Lake Bonneville deposits. Elevation ranges from 1347 to 1372 meters and slopes from 0 to 1 percent. The Payson polypedon covers an area of about 482 hectares, which includes almost 0.2 percnet of the total area of Cache Valley. This pedon is located on the southwest corner of the Logan-Cache Airport, north of section 16, T. 12N., R. 1E.

A representative pedon is found in pasture areas exposed toward the west with a 1 percent slope (Figure 3 and 4).

Detailed descriptions of the pedon are as follows:

Horizon	Depth (cm)	Description
A1	0 - 8	Light brownish-gray (10 YR 6/2) silt clay loam, dark grayish brown (10 YR 4/2) moist; weak, fine granular structure; slightly hard, fiable, slightly sticky and slightly plastic; many fine roots; common fine medium, and coarse pores; moderately calcareous (pH 7.7 paste); clear smooth boundary.
A2	8 - 14	Light brownish-gray (10 YR 6/2) silt loam, grayish brown (10 YR 5/2) moist; moderate medium platy structure; slightly hard, friable, slightly sticky and slightly plastic; common fine and very fine roots; few fine pores; slightly calcareous (pH 8.2 paste) clear smooth boundary.

Figure 3. Profile of the Payson pedon


0
25
50
75
100
125

Figure 4. Landscape of the Payson pedon

Horizon	Depth (cm)	Description
B21t	14 - 24	Grayish-brown (10 YR 5/2) silt loam, very dark grayish brown (10 YR 3/2) moist; strong medium and coarse columnar structure; hard, firm, sticky and plastic; few fine and very fine roots; few fine pores; slightly calcareous (pH 8.1 paste); clear smooth boundary.
B22t	24 - 47	Light brownish-gray (10 YR 6/2) silty clay loam, dark grayish brown (10 YR 4/2) moist; moderate medium and coarse prismatic structure; very hard, very firm, very sticky and very plastic; few very fine roots; few fine pores; slightly calcareous (pH 8.8 paste); abrupt smooth boundary.
B3Ca	47 - 70	White (10 YR 8/2) silty clay, light gray (10 YR 7/2) moist; weak medium sub-angular blocky structure; very hard, firm, sticky and plastic; few fine pores; very strongly calcareous (pH 9.5 paste); clear smooth boundary.
Clca	70 - 91	Very pale brown (10 YR 7/3) silty clay loam, pale brown (10 YR 6/3) moist;many distinct yellow and brown mottles; weak medium sub-angular blocky structure; slightly hard, friable, sticky and plastic; few fine pores; very strongly calcareous (pH 9.2 paste); gradual smooth boundary.
C2ca	91 - 117	Brown (10 YR 6/3) sandy loam, brown (10 YR 5/3) moist; many distinct yellow and brown mottles; massive; slightly hard, friable, slightly sticky and slightly plastic; very strongly calcareous (pH 8.9 paste); gradual smooth boundary.
C3	117 - 153	Pale brown (10 YR 6/3) loam, brown (10 YR 5/3) moist; many distinct yellow and brown mottles; massive; slightly hard, friable, slightly sticky and slightly plastic; strongly calcareous (pH 8.6 paste).

The Payson pedon exhibits a pronounced horizon differentiation. There are distinct differentiations in color between the horizons. The color ranges from dark grayish-brown in the Al horizons, grayish-brown in the A2 horizon, very dark grayish brown in the B21t horizon, light gray in the B3ca, and pale brown in the C horizon.

There is strong evidence that the development of the rounded columnar type structure found in the B21t horizon resulted from the high amount of exchageable sodium. Other structures range from granular in the A1 horizon to blocky in the A2 and calcic horizons.

The A horizon is clearly eluviated and the B horizons contain more clay than either the A or C horizons. A sharp increase in sand and a decrease in clay percentage at the 91 - 153 cm. show that a discontinuity occurred during the deposition. Yellow and brown mottles at the depth of 70 - 153 cm. indicate that the soil is poorly drained and affected by a high water table. Texture changes in the C horizons and a loamy sand stata through the 91-153 cm.depths indicate stratification of the parent material. A strong and very strongly alkaline reaction is found throughout the calcareous horizons at the 47 - 153 cm. depths.

Trenton pedon

The Trenton (polypedon) soil is somewhat poorly drained, alkaline, and fine-textured. These soils were formed from Lake Bonneville deposits. They occur at elevations ranging from 1341 to 1433 meters and at slopes from 0 to 2 percent. They cover an area of about 6741 hectares, representing 3.6 percent of the total soil area in Cache Valley.

The pedon was taken in a cultivated wheat field, about four and one-half kilometers west of Richmond, 400 meters south and 400 meters west of the center of section 20, T. 14 N., R. 1E. The exposure was toward the west, on a 1 percent slope and at an elevation of about 1355 meters (Figures 5, 6, and 7).

Detailed descriptions of the pedon follow:

Horizon	Depth (cm)	Description
AP1	0 - 8	Grayish-brown (10 YR 5/2) silty clay loam, very dark grayish brown (10 YR 3/2) moist; weak fine granular structure; soft, friable, sticky and plastic; common fine and medium roots; few fine pores; non-calcareous (pH 7.8 paste); abrupt smooth boundary.
AP2	8 - 22	Grayish-brown (10 YR 5/2) silty clay loam, very dark grayish brown (10 YR 3/2) moist; moderate medium angular blocky structure; hard, firm, sticky and plastic; common fine and medium roots; few fine pores; non-calcareous (pH 7.7. paste); clear smooth boundary.
B21t	22 - 43	Grayish brown (10 YR 5/2) silty clay, very dark grayish-brown (10 YR 3/2) moist; moderate coarse and medium prismatic structure; very hard, very firm, very sticky and very plastic; common fine roots, few fine and coarse pores; slightly calcareous (pH 7.8 paste); gradual wavy boundary.
B22t	43 - 71	Pale brown (10 YR 6/3) silty clay, dark brown (10 YR 4/3) moist; moderate coarse and medium prismatic structure; very hard, very firm, very sticky and very plastic; few fine roots; few fine pores; strongly calcareous (pH 8.2 paste); clear wavy boundary.
B31ca	71 - 86	Very pale brown (10 YR 7/3) silty clay, brown (10 YR 5/3) moist; weak medium prismatic structure; very hard, very firm, very sticky and very plastic; very strongly calcareous (pH 8.3 paste); clear wavy boundary.

Figure 5. Profile of the Trenton pedon


0
25
50
75
100
125

FIgure 6. Landscape of the Trenton pedon

Figure 7. Cracks on the surface of the Trenton polypedon

Horizon	Depth (cm)	Description
B32ca	86 - 98	Pinkish-gray (7.5 YR 7/2) silty clay, brown (7.5 YR 5/2) moist; weak medium prismatic structure; very hard, very firm, very sticky and very plastic; very strongly calcareous (pH 8.4 paste); gradual smooth boundary.
Clca	98 - 127	Pink (7.5 YR 7/4) silty clay, brown (7.5 YR 5/4) moist; common medium distinct brown and black mottles; massive very hard, very firm, very sticky and very plastic; very strongly calcareous (pH 8.3 paste); diffuse smooth boundary.
C2	127 - 153	Pink (7.5 YR 7/4) silty clay, brown (7.5 YR 5/4) moist; common medium distinct brown and black mottles; massive; very hard, very firm, very sticky and very plastic; very strongly calcareous (pH 8.2 paste).

In the Trenton polypedon, cultivation has mixed the horizons AP1 ans AP2 with B21t. The dry and moist color and thickness of these horizons meets the requirements for the mollic epipedon. The development of a prismatic structure and the increase of the clay content from the A to the B horizons is sufficient to meet the clay requirements of argillic horizons. Field observations show that cracks 5 cm. wide and 69 cm. deep developed in this soil (Figure 7) because of the high amount of exchangeable sodium and clay content throughtout the pedon.

The calcareous nature and the lighter color of the lower horizons indicate the presence of a calcic horizon in the lower part of the B horizon and the upper part of the C horizon.

The presence of black and brown mottles in the lower horizons emphasizes that this soil is affected by a seasonal high water table and is poorly drained. Differences in color and the calcium carbonate content indicate that there was a difference in deposition.

RESULTS AND DISCUSSION

Physical properties

Particle size distribution. Distribution of clay, silt, and sand particles in the Payson pedon is presented in Table 3 and Figure 8. The data show that the increase in clay at the 14 - 24 cm. depth is not sufficient to meet the requirements for an argillic horizon, but the reaults of the carbonate-free clay distribution data (Table 4) do indicate that the clay at the 14 - 24 cm. depth compared to that at the 8 - 14 cm. depth increases more than 1.2 times. The maximum clay percentage occurs at the 24 - 47 cm. depth. The fine clay/total clay ratio of selected horizons, as shown in Table 4 and Figure 10, indicates one important difference between the illuvial and eluvial horizon, that of differential movement of different size clay particles. The difference is due to translocation of fine clay (more mobile in the illuviation process than is the coarse clay) to an argillic horizon. The fine clay to total clay ratio at the 14 - 24 cm. depth is 0.13 more than at the 8 - 14 cm. depth. In other words, the ratio of fine clay to total clay is greater in the argillic horizon than in the overlying eluvial horizon by more than one-third, thereby meeting the diagnostic feature necessary to be termed an argillic horizon. Also, the fine clay/total clay ratio is 0.2 more at the 24 - 47 cm. depth than at the 8 - 14 cm. depth.

The data in Table 3 show that the clay distribution through the

Table 3. Selected physical properties of the Payson and Trenton pedons.

Horizon	Depth (cm)	Very coarse sand % (2-1mm)	Coarse sand % (1-0.5mm)	Medium sand % (0.5-0.25mm)	Fine sand % (0.25-0.1 mm)	Very fine sand % (0.1-0.05mm)	Total sand % (2-0.5mm)	Total silt % (.05-0.002mm)	Total clay* % (<.002mm)	H_2O retention (15 bar) (%)	Bulk density (g/cm^3)
Payson											
A1	0 - 8	1.8	1.0	0.5	2.5	3.9	9.8	57.0	33.2	12.5	1.5[illegible]
A2	8 - 14	0	0.1	0.1	1.2	4.6	6.0	68.6	[illegible]	11.3	[illegible]
B21t	14 - 24	0	0.1	0.1	1.1	4.3	5.5	68.3	26.2	11.8	1.52
B22t	24 - 47	0	0	0.1	1.0	3.9	5.0	55.5	39.5	18.4	1.[illegible]
B3ca	47 - 70	0	0.1	0	1.1	5.2	6.5	47.5	46.0	18.3	1.5[illegible]
C1ca	70 - 91	0.2	0.4	0.2	2.5	10.3	13.7	57.2	29.1	14.6	1.62
C2ca	91 - 117	0	0.1	0.5	12.0	21.4	33.9	53.7	12.4	7.9	1.66
C3	117 - 153	0	0.6	1.6	17.9	21.8	41.9	45.9	12.2	7.4	1.67
Trenton											
AP1	0 - 8	0	0.1	0.1	2.5	5.1	7.9	60.9	31.2	12.3	1.5[illegible]
AP2	8 - 22	0.1	0.1	0.1	2.5	5.1	8.0	59.5	32.5	13.5	1.55
B21t	22 - 43	0	0.1	0.1	1.4	4.1	6.2	45.1	48.7	19.1	1.70
B22t	43 - 71	0	0	0	1.2	2.4	3.6	47.9	48.5	18.7	1.71
B31ca	71 - 86	0	0	0	0.5	1.0	1.5	47.4	51.1	19.1	1.72
B32ca	86 - 98	0	0	0	0.1	0.2	0.3	43.7	56.0	19.4	1.61
C1ca	98 - 127	0	0	0	0	0.1	0.2	42.1	57.7	21.5	1.5[illegible]
C2	127 - 153	0	0	0	0.1	0.1	0.2	42.6	57.2	23.3	1.6[illegible]

* Analysis by pipette method

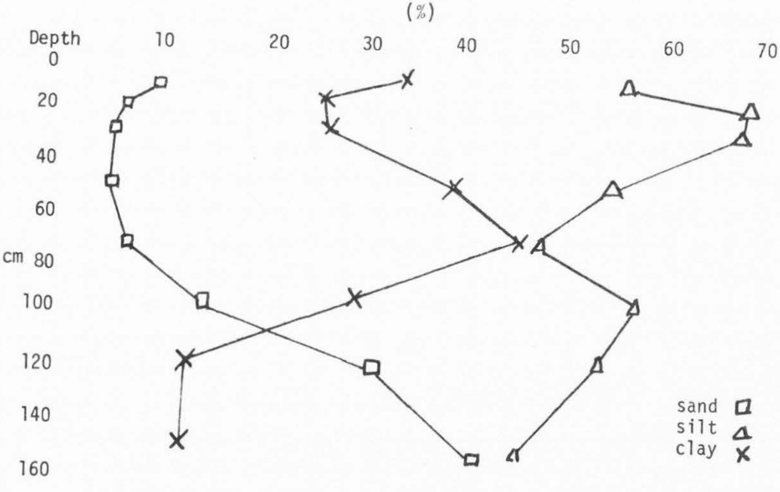

Figure 8. Particle size distribution for the Payson pedon with depth.

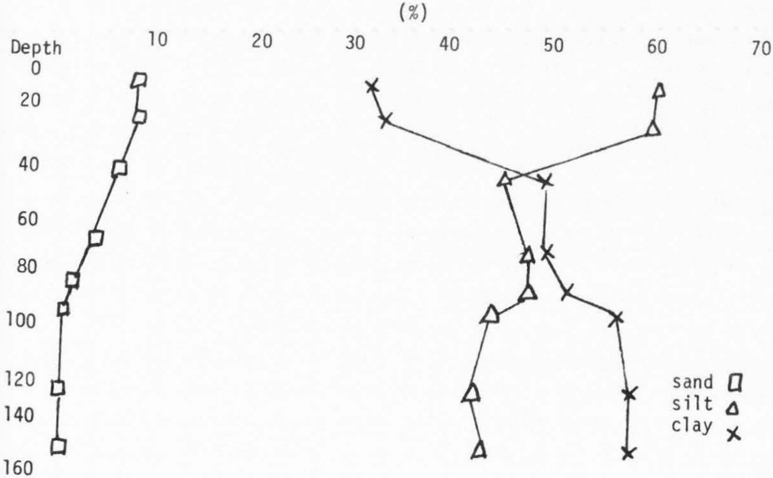

Figure 9. Particle size distribution for the Trenton pedon with depth.

upper 8 - 70 cm. which reflects the impact of pedongenic processes which contribute to the translocation of the clay from eluvial to illuvial horizons. A sharp increase in sand at the 91 - 153 cm. depth is due to a discontinuity in deposition; the increase in sand fractions at this horizon is probably related to the wave action of Lake Bonneville (At Provo still stand wave action eroded materials from the beach, which were then deposited as sediment on the valley floor).

The higher sand and clay and lower silt percentage at the 0 - 8 cm. depth compared to the percentage of the same size fractions at the 8 - 14 cm. depth suggest that the upper horizon was probably from a different deposit than the underlying horizon. The upper horizon (0 - 8 cm. depth) may have been formed by flood-plain sediment of the Bear River, mixed with wind-blown deposits during recent time (Holocene).

There is a marked difference in particle size distribution between the Payson and Trenton pedons. Data in Tables 3 and 4 and Figure 9 show that the clay percentage increases with depth in the Trenton pedon. The abrupt increase in clay content in the Trenton pedon is at 22 cm.; the increase in clay percentage at this depth probably results from translocation of fine clay from the eluvial horizons above, by weathering in place, or by deposition as alluvial or lacustrine sediments. The increasing amounts of clay at the 22 - 71 cm. depth is sufficient to meet the requirements for an argillic horizon. The difference in clay percentage between the 22 - 43 cm. and 8 - 22 cm. depth is more than 16 percent, and the ratio of fine clay to total clay at the 22 - 43 cm. depth increases 0.18 over that at the 8 - 22 cm. depth. The high amount of clay percentage

Table 4. Particle-size distribution* of the Payson and Trenton pedons.

Depth (cm)	Total Fraction			Coarse sand (1-0.5)	Particle diameter (mm)								
	Sand (2-.05)	Silt (.05-.002)	Clay (.002)		Medium sand (.5-.25)	Fine sand (.25-.10)	Very Fine sand (.10-.05)	Coarse silt (.05-.02)	Medium silt (.02-.005)	Fine silt (.005 .002)	Coarse clay (.002-	Fine clay (.002)	Fine/Total clay/clay ratio
Payson													
0 - 8	(not analyzed by x-ray)												
8 - 14	10.44	68.93	20.64	0.00	1.65	1.54	7.25	28.04	33.39	7.50	13.2	7.52	0.35
14 - 24	8.36	66.28	25.36	0.00	0.66	1.04	6.66	27.66	32.81	6.81	12.87	12.49	0.49
24 - 47	9.56	54.47	35.67	0.00	0.60	1.21	7.75	20.46	27.56	6.54	15.91	20.06	0.56
91 - 117	54.92	37.28	7.79	0.00	1.28	14.34	39.30	21.96	13.55	1.77	6.19	1.60	0.21
Trenton													
0 - 8	(not analzyed by x-ray)												
8 - 22	9.48	62.19	28.33	0.00	2.12	3.23	4.13	20.63	26.80	14.76	15.57	12.76	0.45
22 - 43	7.85	49.78	42.00	0.00	0.81	1.62	5.78	15.47	19.90	14.41	15.56	26.44	0.63
43 - 71	4.36	43.67	51.98	0.00	0.49	0.87	3.00	10.55	21.28	11.84	18.68	33.30	0.64
71 - 127	2.29	41.58	56.3	0.00	0.00	0.51	1.78	2.73	23.61	15.24	25.06	31.07	0.55

*Calculations based on separation by x-ray analysis

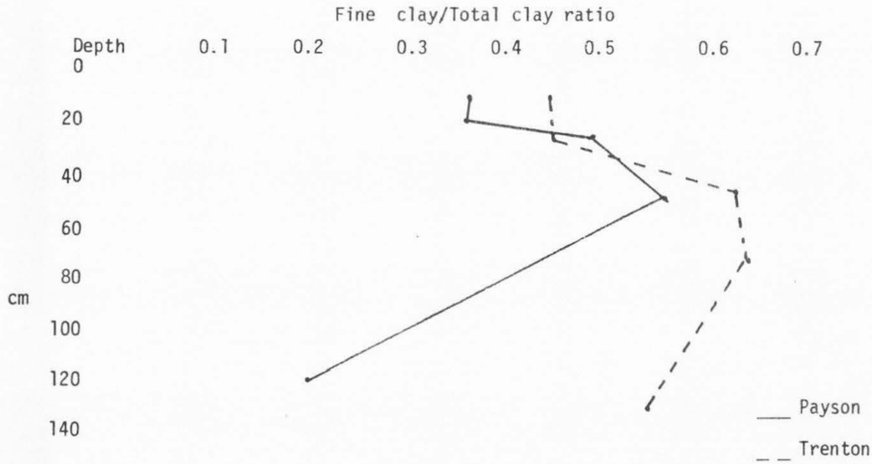

Figure 10. Fine clay/Total clay ration with depth.

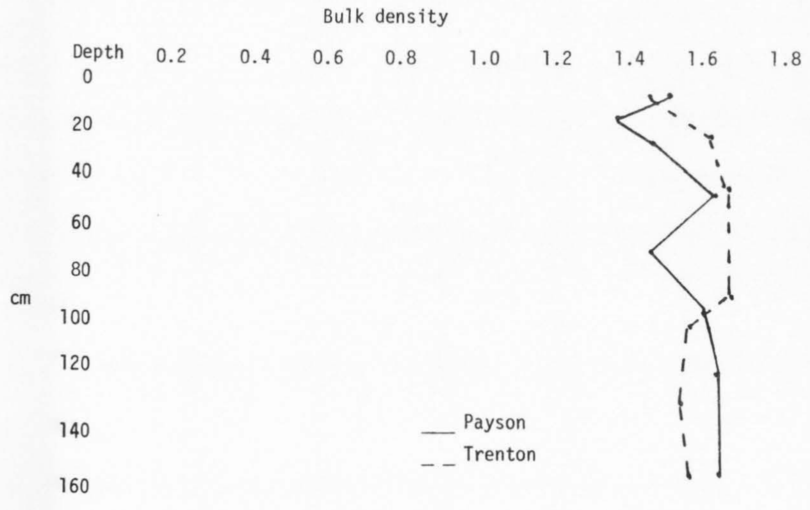

Figure 11. Soil bulk density changes with depth.

in lower horizons suggests that this change is probably due to different depositions by Lake Bonneville during different periods. Weak evidence of illuviation, as indicated by micromorphology studies, suggests the deposition rather than pedogeneis processes. It suggests the possibility of secondary clay formation in place within the argillic horizon in both pedons, in addition to clay translocated from the upper horizons, and the occurrence of different deposits. "Highly alkaline conditions during pedogenesis would be conducive to the solubilization of silica and alumina translocation into zones of higher electrolyte content, which may combine with soluble consitituents thereby forming secondary clay mineral (Whittig, 1959)."

Formation of the argillic horizons and translocation of clay in both pedons suggest that the illuviation of clay could have occurred since Lake Bonneville drained during the Holocene.

Bulk density. The values of the bulk density are presented in Table 3 and Figure 11. The Payson pedon has a maximum bulk density value at the 91 - 153 cm. depth. This may be attributed to a high sand percentage, compaction, and lack of root activity. The relatively higher bulk density at the 0 - 8 cm. depth than at the 8 - 14 cm. depth is probably due to a smaller amount of organic matter; as mentioned previously, the soil of the 0 - 8 cm. depth is probably formed from flood plain sediments and wind-blown deposits during the Holocene. Thus the surface 8 cm. differs from the underlying horizon, which probably formed during the Pleistocene. This difference in deposition may cause the difference in bulk density.

The lowest bulk density value in the Trenton pedon is at the 0 - 22 cm. depth, probably due to higher content of organic matter and more activity of macro-organisms than in the underlying horizons. The maximum bulk density is at the 22 - 86 cm. depth. The increasing bulk density in the argillic horizons of the Payson and Trenton pedons could be ascribed to the filling of pores by illuviation. The slightly higher bulk density of the Payson pedon at the 91 - 153 cm. depth compares with the Trenton at the same depth. This is probably attributed to the nature of materials deposited by Lake Bonneville as a higher amount of sand and lower amount of organic matter in the Payson than in the Trenton pedon.

The lower bulk density in the surface horizons probably reflects the larger quantity of roots and more activity of macro-organisms in the surface horizons than in the lower horizons.

Water retention. Data for water retention at 15 bar is shown in Table 3 and Figure 12. The results indicate that the maximum values of water retention at 15 bar in the Payson pedon occur at the 24 - 76 cm. depth, and the lowest values occur in the C horizons, at the 91 - 153 cm. depth. In the Trenton pedon, the values of water retention at 15 bar increase with the depth. The highest values are in the C horizon, at the 98 - 153 cm. depth; the lowest values occur in the surface horizons at the 0 - 22 cm. depth.

It is very obvious that the clay in the Trenton pedon increases with the depth: the maximum amount is in the C horizon. However, in the Payson pedon, the maximum amount of clay is in the B22t horizon. This

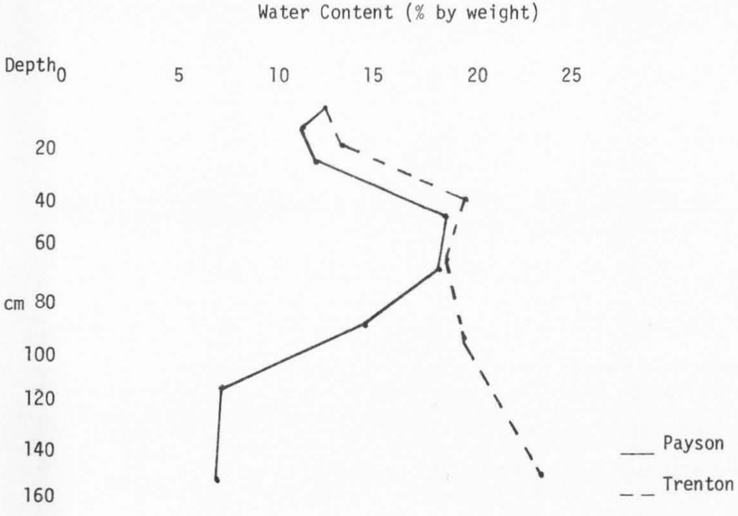

Figure 12. Distribution of water content with depth measured at 15 bar tension.

suggests that the amount of water held in these soils is a function of the specific surface and largely controlled by soil texture. The retention of water is also influenced by the type of clay mineral, soil structure, organic matter, and bulk density.

Chemical properties

Soil reaction, soluble salts, and calcium carbonate. Table 5 represents the data for pH, ECe, and $CaCO_3$ equivalent. In the Payson pedon, the pH values range from pH 7.7 at the 0 - 8 cm. depth to pH 9.5 at the 47 - 70 cm. depth. These high values are considered typical in arid and semi-arid soils. The pH values of the Trenton pedon are slightly lower than those of the Payson pedon, ranging from pH 7.7 at the 8 - 22 cm. depth to pH 8.4 at the 86 - 98 cm. depth. High values of soil reaction, at the 24 - 153 cm. depth of the Payson pedon and at the 43 - 153 cm. depth of the Trenton pedon, reflect the presence of a high amount of exchangeable sodium.

The soluble salt content throughout the Payson pedon is relatively low. There is slight increase in the electrical conductivity at the 47 - 91 cm. depth, with the maximum value 2.6 mmhos per cm. at the 47 - 70 cm. depth. The data for the Trenton pedon also show a slight increase in soluble salts at the 71 - 98 cm. depth, but also indicates a higher electrical conductivity at the 98 - 153 cm. depth. The maximum value is 9.8 mmhos per cm. for the sample from the 127 - 153 cm. depth. The higher amount of soluble salts in the lower horizons than the upper horizons, in both pedons, is due to differences in deposition of Lake

Table 5. Chemical Properties of the Payson and Trenton pedons.

Horizon	Depth (cm)	Organic matter (%)	pH (paste)	Electrical conductivity (ECe) mmhos/cm	Extractable cations Ca	Mg	K	Na	Exchangeable sodium percent (ESP)	CEC (me/100 g soil)	Calculated CEC (me/100 g clay)	$CaCO_3$ equiv. (%)	Extractable Na (H_2O-Sol me/100 g)
					(NH_4OAC, me/100 g)								
Payson													
A1	0 - 8	2.6	7.7	1.4	9.2	8.2	1.7	1.0	4	19.6	42.8	14.8	0.2
A2	8 - 14	3.3	8.2	1.0	8.2	7.8	1.5	1.4	6	18.5	45.7	1.3	[illegible]
B21t	14 - 24	1.6	8.1	1.1	3.6	6.1	2.0	3.9	23	15.0	49.7	0.2	0.4
B22t	24 - 47	0.6	8.8	1.7	*	11.7	2.1	11.3	48	21.2	50.6	3.3	1.1
B3ca	47 - 70	0.2	9.5	2.6		9.1	.5	7.0	50	10.7	22.3	56.4	1.6
C1ca	70 - 91	0.1	9.2	1.9		9.6	.5	7.2	50	12.1	40.9	49.8	1.1
C2ca	91 - 117	0.1	8.9	1.7		6.9	.5	4.2	39	9.2	73.4	38.5	1.0
C3	117 - 153	0.1	8.8	1.5		7.7	.5	4.3	40	9.5	76.9	29.8	.5
Trenton													
AP1	0 - 8	1.8	7.8	1.2	12.9	2.3	2.7	1.1	5	19.6	51.2	0.5	0.2
AP2	8 - 22	1.9	7.7	1.1	14.3	2.5	2.2	1.0	4	19.6	42.6	0.5	0.2
B21t	22 - 43	0.9	7.8	0.7	15.4	6.5	2.2	1.9	6	25.5	48.5	2.2	0.3
B22t	43 - 71	0.6	8.2	1.2	13.4	8.5	1.7	3.8	12	26.6	52.3	18.2	0.6
B31ca	71 - 86	0.5	8.3	2.0	7.6	9.3	1.7	6.2	21	23.4	43.8	27.8	1.2
B32ca	86 - 98	0.4	8.4	3.5	5.7	9.9	1.9	8.5	27	23.4	40.4	[illegible]	2.3
C1ca	98 - 127	0.4	8.3	6.0	4.6	11.5	2.2	10.0	26	23.9	39.7	30.0	3.9
C2	127 - 153	0.4	8.2	9.8	4.1	11.6	2.2	14.7	32	25.5	43.3	27.2	6.6

* See table 6

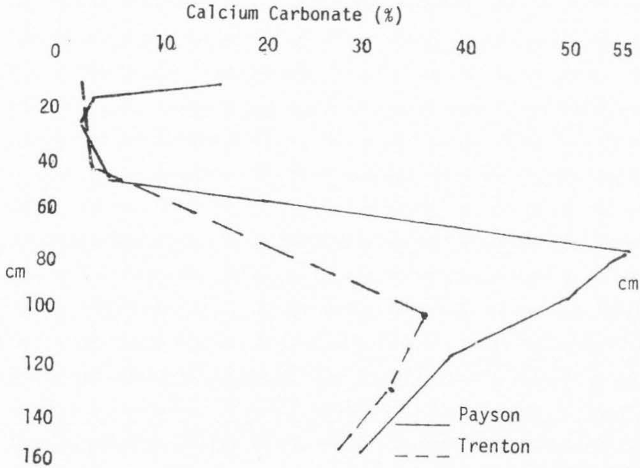

Figure 13. Distribution of calcium carbonate equivalent with depth

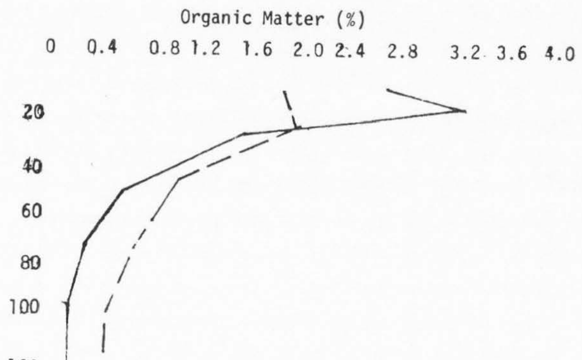

Figure 14. Distribution of organic matter with depth

Bonneville sediments during different periods or the effect of leaching salts from the upper to the lower horizons.

The distribution of calcium carbonate in both pedons is shown in Table 5 and Figure 13. The values of calcium carbonate in the Payson pedon range from 0.2 to 56.4 percent. A carbonate-rich layer exists between depths of 47 and 153 cm. The maximum value of calcium carbonate is found at the 47 - 70 cm. depth. The values at 47 - 117 cm. depth are sufficiently high for this layer to qualify as a calcic horizon because "The horizon is considered a calcic horizon if the $CaCO_3$ equivalent of a layer 15 cm. or more thick exceeds 15 percent by weight and the layer has at least 5 percent more $CaCO_3$ equivalent than the underlying layer (Soil Survey Staff, 1975)." The higher value of $CaCO_3$ equivalent at the 0 - 8 cm. depth than at underlying horizons suggests that the surface horizon was formed from different deposition of floodplain sediments and wind-blown deposits rich in alkaline earth carbonates during the present (Holocene) time. Thus, the time and amount of leaching water since that deposition is not enough to leach carbonates from the surface horizons to an underlying horizon.

Distribution of calcium carbonate in the Trenton pedon ranges from 0.5 to 35.3 percent. The minimum percentage is found in the surface horizons at the 0 - 43 cm. depth, whereas the maximum value is found at the 86 - 98 cm. depth, decreasing below this zone. The amount of calcium carbonate equivalent in the 71 - 127 cm. depth is sufficiently high to qualify as a calcic horizon.

The high amount of calcium carbonate content in the lower horizons of both pedons suggests that there is an eluviation of carbonate in highly calcareous parent materials, probably bicarbonate from the upper horizons of both pedons. The leaching probably took place since Lake Bonneville drained. Calcium carbonate equivalent in both pedons is leached to about the same depth. This suggests that if moisture is the same in both pedons, the age may be the same.

Organic matter. The distribution of organic matter in both pedons is reported in Table 5 and Figure 14. The distribution of organic matter in the Payson pedon indicates more organic matter at the 8 - 14 cm. than at the 0 - 8 cm. depth. This suggests that the 0 - 8 cm. depth was deposited during the Bonneville formation in the Pleistocene epoch as discussed previously. Therefore, the present A2 horizon has been an A1 horizon covered by the recent deposits. The other possibility is the presence of high amount of exchangeable sodium reacting with water to produce sodium hydroxide which dissolved the organic matter, which was moved to the underlying horizons during the processes of illuviation. The amount of organic matter and the thickness of surface horizons in the Payson pedon are sufficient to meet the requirements for a mollic epipedon, but the color is not dark enough. The reason for the light color is probably due to the high amount of calcium carbonate (14.8 percent) "because finely divided lime act as a white pigment (Soil Survey Staff, 1975)." The other possibilities are the bleaching of soil particles within the structural unit in the A2 horizon, and the presence of a sufficient quantity of light-colored minerals such as quartz and calcite in the A1 and A2 horizons that precluded the dark color required for a mollic epipedon.

The Trenton epipedon has sufficient amounts of organic matter, dark color, and adequate thickness (0 - 43 cm.) to qualify as a mollic epipedon; the mollic epipedon in the Trenton pedon includes the AP and the B21t horizons.

Field observations indicate that the roots in the Trenton pedon extend to 71 cm. depth, whereas in the Payson pedon they extend to 47 cm. depth, suggesting that the high amount of calcium carbonate equivalent (56.4 percent) at the 47 - 70 cm. depth may create a carbon dioxide toxicity and drought at this depth preventing root activity.

<u>Free iron oxide and available phosphorus</u>. The data for free iron oxide and available phosphorus are given in Appendixes B and C.

<u>Cation exchange capacity</u>. Table 5 and Figure 17 represent the data of cation exchange capacity for both pedons. The results of cation exchange capacity determination in the Payson pedon indicate that the maximum value is 21.2 me/100 grams soil at the 24 - 47 cm. depth, and the minimum value is 9.2 me/100 grams soil at the 91 - 117 cm. depth. The data show that cation exchange capacities of the Trenton pedon are higher than those in the Payson pedon. This may be explained by higher amounts of clay in the Trenton pedon and the indication of more montmorillonite by x-ray diffraction.

The relatively high cation exchange capacities at the 0 - 14 cm. depth of the Payson pedon is clearly influenced by organic matter content. The increases in cation exchange capacities of some horizons in both pedons would be expected on the basis of increasing clay content and clay type. The lowest values of cation exchange capacity at the 91 - 153 cm. depth in the Payson pedon reflects the lower clay contents.

Calculated cation exchange capacities as shown in Table 5 are calculated based on me/100 grams clay. The values for the Payson pedon in the upper 47 cm. range between 42.8 and 50.6 me/100 grams clay which suggests that a mixture of illite, montmorillonite, and kaolinite clay minerals are present. The calculated values of the Trenton pedon in the upper 71 cm. range between 48.5 and 52.3 me/100 grams clay which also suggests that the mixture of illite, montmorillonite, and kaolinite clay minerals are present and the montmorillonite type is dominant, as shown by the results from x-ray analysis.

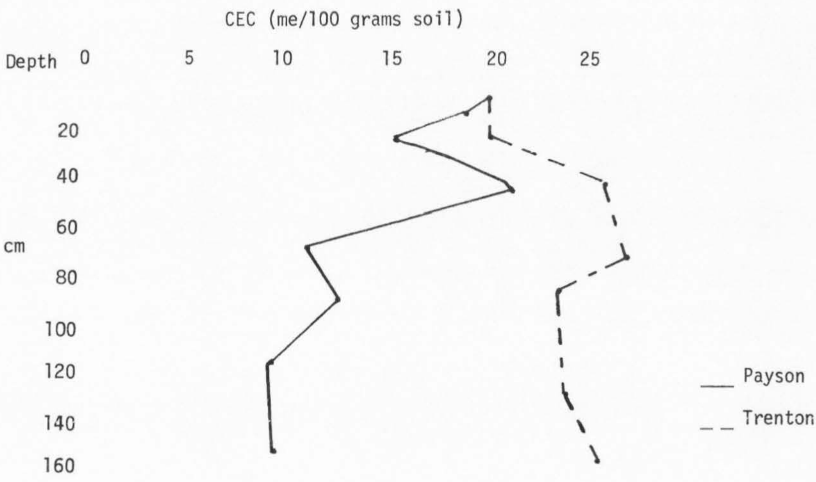

Figure 15. Distribution of cation exchange capacity with depth.

Extractable cations and exchangeable sodium percentage (ESP)

The predominant extractable cations, as shown in Table 5, are calcium, magnesium, and sdoium. The maximum extractable calcium in the Payson pedon is 9.2 me/100 grams soil in the 0 - 8 cm. depth. This value tends to decrease with depth. In the Trenton pedon the extractable calcium value at the 0 - 8 cm. depth is 13.9 me/100 grams soil and increases with depth. It reaches the maximum of 15.4 me/100 grams soil at the 22 - 43 cm. depth and then decreases with greater depth. The concentration of extractable calcium near the surface suggests that it is probably related to residue from plants, wind blown deposits, and high water table.

Extractable magnesium exceeds calcium in the lower horizons and generally increases with depth in the Trenton pedon. The maximum value is 11.6 me/100 grams soil at the 98 - 153 cm. depth; whereas the least value is 2.3 me/100 grams soil at the 0 - 8 cm. depth. The distribution of extractable magnesium in the Payson pedon is different from that of the Trenton pedon. The maximum value is 11.7 me/100 grams soil at the 24 - 47 cm. depth and the minimum value is 6.1 me/100 grams soil at the 14 - 24 cm. depth. These differences in the distribution are possibly related to different deposition or different degrees of weathering. The high amount of extractable magnesium in both pedons can be explained by the presence of dolomite, as identified by x-ray analysis, which dissolves in ammonium acetate. The values of extractable cations, potassium, magnesium, and sodium at the 24 - 153 cm. depth in the Payson pedon exceed the values of cation exchange capacities, therefore, the values for clacium by this method have little meaning. It was necessary to use the ($BaCl_2$-TEA) method in place of ammonium acetate to prevent the

Table 6. Extractable cations* at the 24 - 153 cm. depth of the Payson pedon

Depth	$BaCl_2$-TEA				
	Ca	Mg	K	Na	CEC
	(me/100 g)		(NH_4OAC, me/100 g)		(me/100 g)
24 - 47	2.0	4.6	2.1	10.9	21.7
47 - 70	2.0	2.1	0.5	8.9	10.5
70 - 91	2.6	2.6	0.5	7.6	12.1
91 - 117	1.1	3.0	0.5	4.6	9.3
117 - 153	1.6	3.9	0.5	3.6	9.9

* Analysis of Mg and Ca ions were determined after extraction with $BaCl_2$-TEA method rather than with NH_4OAC, which dissolves alkaline earth carbonates.

dissolution of dolomite and give a more meaningful set of values for magnesium and calcium as shown in Table 6. Data in Table 6 indicate lower amounts of extractable magnesium by using ($BaCl_2$-TEA) as the extracting medium than that using the ammonium acetate method. The presence of chlorite, identified by x-ray analysis later, also increases the amount of extractable magnesium by weathering. Riecken (1943) reported that with the increasing alkalinity of the soil, a greater amount of Mg ions than Ca ions are absorbed by the soil colloids. THis indicates that there is a greater affinity for Mg^{+2} ions than Ca^{+2} ions by the Na-clay at a higher pH.

The presence of extractable sodium is relatively high in both pedons, ranging from 1 me/100 grams soil at the 0 - 8 cm. depth to 11.3 me/100 grams soil at the 24 -47 cm. depth in the Payson pedon, and 1 me/100 grams at the 0 - 22 cm. depth to 14.7 me/100 grams soil at the 127 - 153 cm. depth in the Trenton pedon. The data in Table 5 also show that the sodium is the predominant water-soluble cation. The maximum values are 1.6 me/100 grams soil at the 47 - 70 cm. depth of the Payson pedon, and 6.6 me/100 grams soil at the 127 - 153 cm. depth of the Trenton pedon. Magnesium is the second most abundant of these three cations.

The exchangeable sodium percentage in the Payson is higher than in the Trenton pedon, as shown in Table 5 and Figure 19. The extractable sodium percentage in the Trenton pedon ranges between 4 percent at the 0 - 43 cm. depth to the maximum of 32 percent at the 127 - 153 cm. depth; in the Payson pedon, the lowest value is 4 percent at the 0 - 8 cm. depth, and the greatest value is 50 percent at the 47 - 91 cm. depth. It is suggested that the increase in sodium percentage with depth is due to continued leaching which results in the removal of exchangeable sodium from the surface and its concentration in the lower horizons. Whittig (1959) noted that exchangeable sodium does play a vital role in the development of sharply delineated textural B horizons. The presence of considerable soluble sodium and free carbonate in the lower horizons (the presence of natric and calcic horizons) suggests that the exchangeable sodium was higher in concentration near the surface during the deposition of the sediments than is presently indicated. Under alkaline conditions, calcium and magnesium will exist largely as relatively insoluble carbonate. Removal of sodium from the exchange complex will allow its replacement by calcium and magnesium ions.

Extractable potassium was greater at the 0 - 47 cm. depth than the 47 - 153 cm. depth in the Payson pedon, and higher at the 0 - 8 cm. depth than the 43 - 98 cm. depth in the Trenton pedon. This can be explained by several possible mechanisms. Recycling the potassium through the plant occurs as the roots absorb potassium from lower horizons and add it to the surface by sloughing leaves. Another explanation is that wind transported the potassium salts from the Great Salt Lake Desert. Such dust high in illite would contain large amount of potassium (Hart and Southard, 1973).

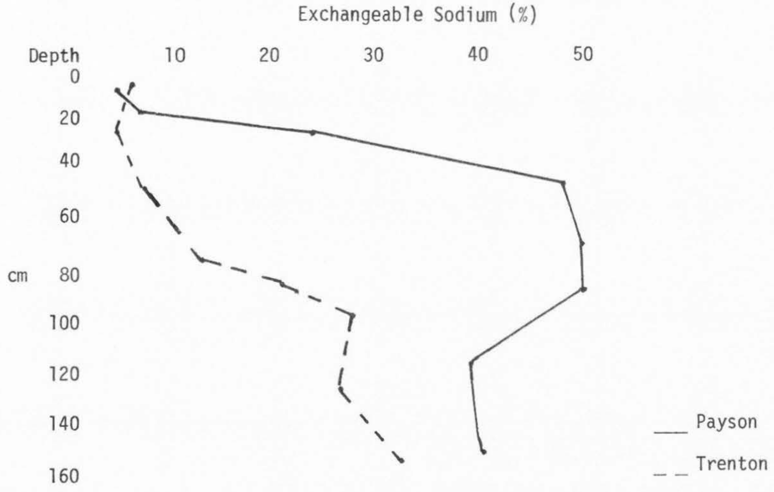

Figure 16. Distribution of exchangeable sodium with depth.

Mineralogical composition

X-ray analysis

Payson. Although the x-ray diffraction patterns of the fine clay fractions (less than 0.2 micron) show the similarity in composition throughout the pedon, only a slighly higher peak of illite (d=10 Å) appears at the 8 - 47 cm. depth when compared with the 91 - 117 cm. depth. Montmorillonite (d=14 Å, shifts to d=17 Å by saturating with ethylene glycol and heating to 60°C) is the dominant mineral at the 91 - 117 cm. depth with minor amounts of other minerals. Kaolinite (d=7.2 Å) and quartz (d=3.32 Å) are present in small amounts throughout the pedon. The kaolinite peak increases slightly for the 8 - 14 cm. depth. This mineral is often confused with kaolinite in x-ray patterns, especially since the 14 Å peak of chlorite is not pronounced. However, the third order (d=4.9 Å) peak indicates the presence of chlorite. When heated to 575°C, the kaolinite peak (d=7.2 Å) disappears because at this temperature kaolinite tends to lose its crystaline character; whereas, chlorite at this temperature in only partially dehydrated, causing an increased intensity of the 14 Å reflection. The intensity of the 10 Å peak also increases after heating to 575°C. Evaluation of the patterns before and after heating indicates there is some montmorillonite mixed with chlorite, because montmorillonite shows a complete collapse in its 10 Å peak when heated to remove water from its interlayer (Figure 17). Feldspars are absent in the fine clay fractions.

The coarse clay fractions (0.2 - 2 micron)are dominated by quartz at the 14 - 47 cm. depth, but less quartz occurs at the 8 - 14 cm. and 91 - 117 cm. depths. Montmorillonite is the most abundant clay mineral at 91 - 117 cm. depth, as it was for the fine clay fractions. Kaolinite is well crystallized (sharp differaction patterns) and shows a slight increase in peak intensity with the increase in depth. The relative intensity of illite and chlorite is about the same abundance throughout the pedon. Feldspars in the form of microcline and albite (d=3.25 and 3.18 Å) are present in the coarse clay fractions in trace amounts.

The x-ray data from the fine and coarse silt fractions at the 8 - 47 cm. depth show that quartz is more evident and that there is a considerable amount of feldspar and illite, and less kaolinite, chlorite, and montmorillonite. In the 91 - 117 cm. depth samples, the quartz and dolomite are the most abundant minerals. Kaolinite, illite, and feldspar are also present in considerable amounts.

Quartz is the most abundant in the fine sand fractions throughout the pedon, whereas dolomite and quartz are the most abundant at the 91 - 117 cm. depth, decreasing upward. A considerable amount of feldspar, in the form of microcline and albite, are present in the 8 - 24 cm. depth sample, decreasing with depth.

Trenton. The mineralogical composition of the various selected horizons of the Trenton pedon are quite different from the Payson pedon. There is also a distinct difference within the pedon itself. Weak, broad x-ray diffraction peaks appear for the fine clay (less than 0.2 micron) at the 9 - 22 cm. depth, but after being heated to 575°C, a considerable peak of illite appears (Figure 18). The low crystallinity indicated by the above phenomena is probably due to a large amount of amorphous clay, which is not detectable by x-ray diffraction. Montmorillonite dominates the fine fractions throughout the pedon, with some chlorite in the samples of the 43 - 71 cm. depths. Montmorillonite is identified by its shift from 14 Å to 17 Å peak when heated to 60°C and saturated with ethylene glycol; chlorite was identified by the presence of a 14 Å peak after moderate heating and treating with glycol and the presence of a 4.95 Å peak and a 7.13 Å peak (Figure 18). The 7.13 Å reflection dissappears on heating to 575°C, indicating the existence of some kaolinite. The x-ray diffraction pattern of the sample from the 98 - 127 cm. depth shows a dominant 12.98 Å peak (Figure 18). This suggests that the montmoillonite has some interlayering with the illite. Calcite (d=3.04 Å) and quartz are also present in the fine clay fractions.

Table 7. Mineral estimates from x-ray diffraction from selected horizons of the Payson and Trenton pedons.

Depth	Size Fraction (micron)	Quartz	Feldspar	Dolomite	Calcite	Illite	Montmorill-onite	Chlorite	Kaolinite	Amorphous Material
Payson										
8 - 14	<0.2	++				++	+	+	+	
	0.2 - 2	++	tr			++	tr	+	+	
	2 - 20	++++	++			++	tr	+	+	
	50 - 100	++++	++	tr		tr				
14 - 24	<0.2	+				++	+	+	tr	
	0.2 - 2	+++	tr			++	+	tr	++	
	2 - 20	++++	+++			++	tr	+	+	
	50 - 100	++++	++	tr		tr				
24 - 47	<0.2	++				++	+	+	tr	
	0.2 - 2	+++	tr			++	+	+	++	
	2 - 20	++++	++			++	tr	+	+	
	50 - 100	++++	+	+++		tr				
91 - 117	<0.2	+				+	++++		tr	
	0.2 - 2	++		tr		++	++++	+	++	
	2 - 20	++++	++	++++		+++	+	++	++	
	50 - 100	++++	+	++++		tr				
Trenton										
8 - 22	<0.2					tr				++++
	0.2 - 2	++++		tr		++	++	+	++	
	2 - 20	++++	tr			+++	+	++	++	
	50 - 100	++++	+++	+	tr	tr				
22 - 43	<0.2	+			tr	+	+++		tr	
	0.2 - 2	+++	+	tr		+++	+++	+	++	
	2 - 20	++++	+	tr		+++	+	++	++	
	50 - 100	++++	++							
43 - 71	<0.2	++				+	++++	+	tr	
	0.2 - 2	+++	tr			+++	++++	++	++	
	2 - 20	++++	tr	tr		++	tr	++	+++	
	50 - 100	++++	+++	+		tr				
98 - 127	<0.2	++			tr	+	++++		+	
	0.2 - 2	+++		tr	tr	+++	++++	++	++	
	2 - 20	++++	+	++		++	+	+++	+	
	50 - 100	++++	++	+++		tr				

Explanation

1. The x-ray apparatus was used with a copper Kα radiation and a nickle filter, having a current of 18 ma. at the 35 Kv., scanning speed used 2θ/min., and the beginning value was 4°.

2. Trace = less than 1cm. peak height
   Low = 1 to 2 cm. peak height
   Medium = 2 to 4 cm. peak height
   High = 4 to 8 cm. peak height
   Dominant= more than 8 cm. peak height

* Dominant=++++; High=+++; Medium=++; Low=+; Trace=tr (detectable)

Coarse clay fractions are dominated by montmorillonite mixed with chlorite. Quartz is also abundant. Illite and kaolinite are the two other minerals present in appreciable amounts, and there is a small amount of calcite at the 98 - 127 cm. depth.

Illite and quartz are the most abundant minerals in the silt fractions, which also contain kaolinite and chlorite-montmorillonite. The very fine sand fractions are predominantly quartz throughout the pedon; feldspar is also common in the 8 - 22 cm. and 98 - 127 cm. samples. Dolomite is abundant at the 98 - 127 cm. depth, and absent at the 22 - 43 cm. depth. The formation of the mollic epipedon in the Trenton polypedon was most likely aided by the high amount of montmorillonite clay mineral which retained large amounts of organic matter.

The chlorite in both pedons is probably derived from the weathering of mica (Jackson, 1956). Quartz dominates in fine fractions and is most abundant in the coarse fraction. Kaolinite exists in considerable amounts, which is common for soils in an advanced stage of weathering. This suggests that the clay-size material probably originated from the erosion of highly weathered mountain areas. The presence of high exchangeable sodium percentage in the present environment perhaps causes the weathering to proceed at a more rapid rate than would be expected. Southard and Miller (1966) emphasized the importance of inherited clays in explaining the kind of clay minerals found in many moderately to well developed soils formed from sedimentary rocks.

Jackson (1948) related the rate of weathering to the enviornment

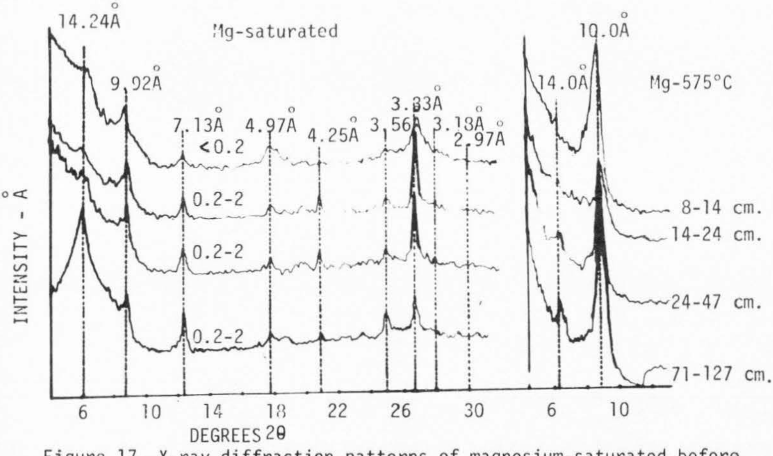

Figure 17. X-ray diffraction patterns of magnesium-saturated before and after heating (575°C) for the Payson pedon.

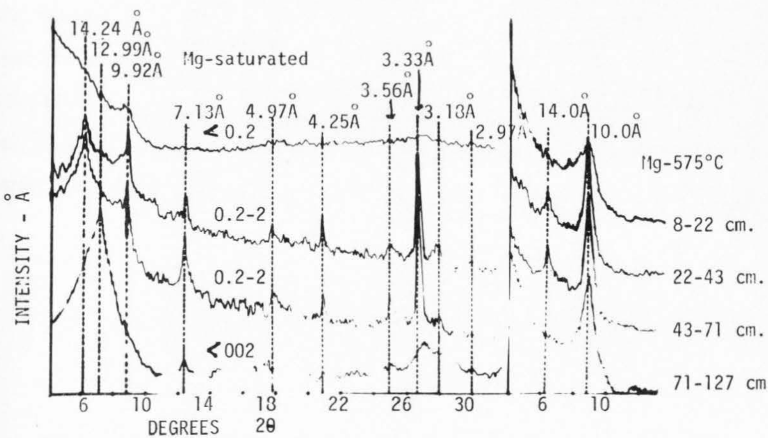

Figure 18. X-ray diffraction patterns of magnesium-saturated before and after heating (575°C) for the Payson pedon.

and time. Although Jackson allowed the advanced weathering stage in recent sediments because of inheritance, this concept received generally little emphasis, especially with regard to moderately and well developed soils (Southard and Miller, 1966). Grim (1968, p. 518) postulated that two factors influence weathering conditions: 1) the kind of alkali metal or alkaline earth metal, since potassium leads to the formation of illite and magnesium to the formation of montmorillonite, and 2) the presence of this alkaline earth in the environment of alteration and the length of time. Carbonate retard the alteration of the primary silicate until the carbonate and calcium are removed from the enviornment.

Na-rich feldspar as albite, which were identified by x-ray diffraction in both pedons, are considered a source of high amounts of extractable sodium. Riecken (1943) suggested that the presence of Mg^{+2} ions in high proportions in many soils which have natric horizons is due to parent material. The parent materials probably have large amounts of $MgCO_3$, which could provide ample amount of Mg^{+2} ions for the exchangeable complex. He also suggested that these soils are in an advanced weathering stage; therefore, the secondary and primary minerals may be supplying more Mg^{+2} ions than Ca^{+2} ions.

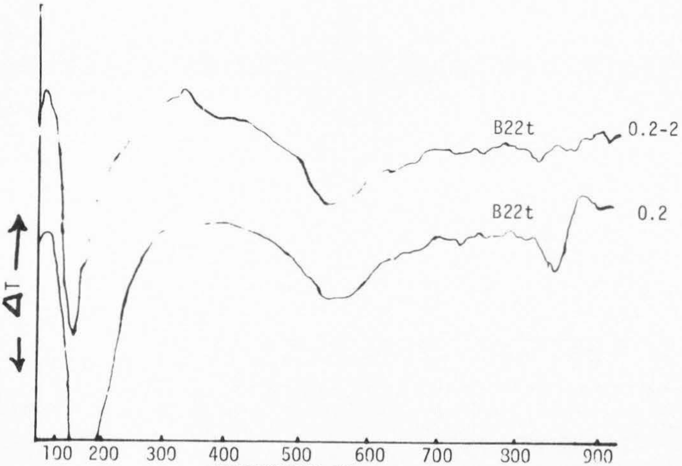

Figure 19. DTA curves of clay size fractions in argillic horizons of the Payson pedon.

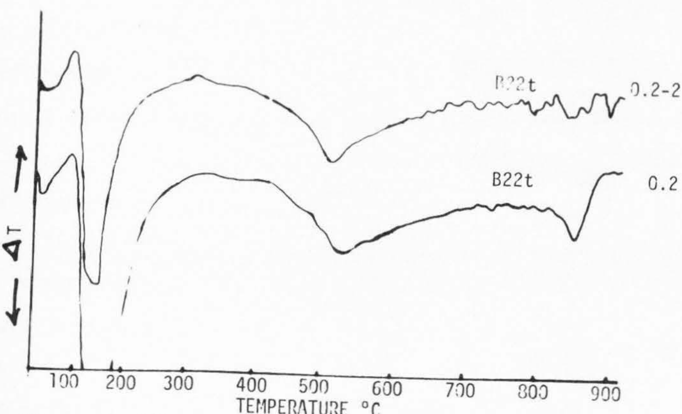

Figure 20. DTA curves of clay size particles in argillic horizons of the Trenton pedon.

Differential thermal analysis

Differential thermal curves, Figure 19 and 20, show that the Payson clays at the 24 - 47 cm. depth and the Trenton clays at the 43 - 71 cm. depth have similar peaks. The endotherms at 600 - 700°C are indications of the presence of montmorillonite. The endotherm loops between 600 and 700°C suggest more montmorillonite in the Trenton than in the Payson pedon. The endotherm at the 150° and 500 - 600°C are typical for illite. Kaolinite and chlorite minerals produce an endothermic peak at 550°C. Another important endothermic peak in the differential thermal analysis of clay minerals is the 150°C, the absorbed water reaction. The area of this peak is a function of specific surface, which indicates that the endothermic peak at 150°C in the 0.2 micron is larger than in the 0.2 - 2 micron; also the area of the 150°C peak decreases from montmorillonite to illite and from illite to kaolinite (Martin, 1953). No exothermic peak occurred at 575°C, which is diagnostic of quartz. No explanation is offered for the lack of a peak in DTA which x-ray diffraction analysis shows a peak for quartz.

Micromorphology

Thin sections were prepared from selected horizons of the Payson and Trenton pedons and observed through the microscope in order to determine if movement of clay from eluvial to illuvial horizons had occurred. The Soil Survey Staff (1975) explain the movement of clay as follows:

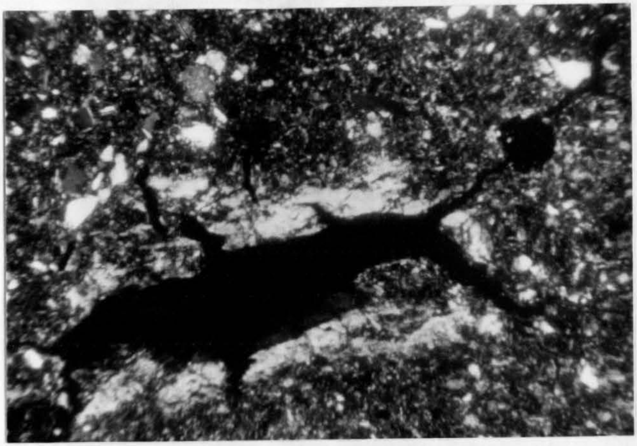

Figure 21. Thin section of a clay skin on a ped surface (crossed polarizers) from the B22t horizon of the Payson pedon. Height of seciton 0.03 mm. (Average actual width pore size=0.2 mm., and photo is 100x)

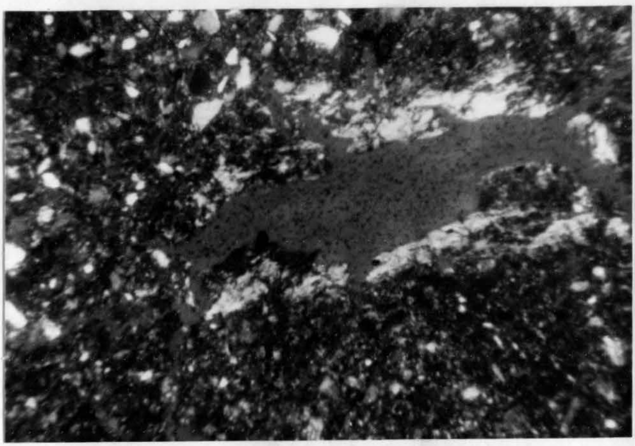

Figure 22. Thin section of a clay skin on a ped surface (partial polarizers) from the B22t horizon of the Payson pedon. Height of section 0.03 mm. (Average actual width of pore= 0.2mm, and photo is 100x)

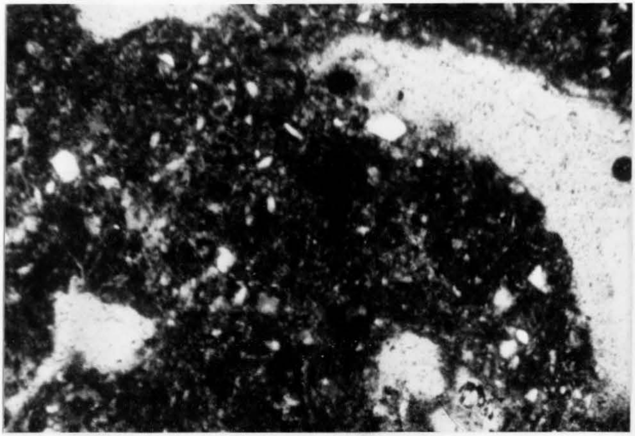

Figure 23. Thin section of a ped surface (plain light) from the A2 horizon of the Payson pedon. Height of section 0.03mm. (Average actual width of pore=0.4, and photo is 100x)

> The clay moves with percolating water in non-capillary voids and is stopped by capillary withdrawal; the clay is then believed to be deposited on the walls of the non-capillary voids and faces of beds, at a time when the water left by evaporation or is withdrawn by roots. (p.)
>
> (Soil Survey Staff, 1975)

The most reasonable explanation of the clay movement is the presence of very fine, negative-charged clay that tends to disperse. The high concentration of sodium ions in both pedon likely increases dispersion of clay fractions and helps the clay move with percolating water. By studying thin sections under crossed and partial polarizars, a number of oriented layers could be seen along the pore walls in the B2t horizon of the Payson pedon (Figures 21 and 22). The maximum amount of clay orientation was observed in samples of the B22t horizon which occurs at a depth of 24 - 47 cm. These observations are considered to be evidence for clay illuviation in this profile. No evidence of clay orientation was observed in samples from the 8 - 14 cm. or the 70 - 91 cm. depths (Figure 23). As a result of pedoturbation, the Trenton pedon shows poor orientation of clay. The high carbonate and salinity concentration tends to keep the clay flocculated and retards clay illuviation, thereby preventing good clay orientation; clay shrinking and swelling in the Trenton pedon (Figure 7) also leaves new planes of weakness continually upon new wetting-drying cycles. Thus, clay skins that formed on the surfaces of the peds may later be located in the interior of an altered ped. The fine texture and montmorillonite clay type reduce the leaching and favor shrinking and swelling, which perhaps induce the destruction of clay films and consequently the lack of a good clay orientation. The more distinct clay orientation in the Payson B2t horizon is probably due to larger amount of sodium ions, less carbonates, and a coarser texture (which allows less shrinking and swelling) in the Payson than in the Trenton B2t horizon.

Soil classification

Payson. The amount of organic matter, thickness, and base saturation of the surface horizons in the Payson polypedon are sufficient to meet the requirement for a mollic epipedon, but the dry and moist color values are more than 5.5 and 3.5 respectively at 0 - 14 cm. depth; therefore, the epipedon is not mollic.

The ratio of clay at 14 - 47 cm. to that at the 8 - 14 cm.depth is more than 1.2. The ratio of fine clay to total clay at the 14 - 47 cm. depth is greater than that at the 8 - 14 cm. depth by about one-third (Table 4). The presence of significant amount of oriented clays is shown in Figures 21 and 22. All these properties emphasize the presence of an argillic horizon. The results in Table 5 show that the exchangeable sodium is more than 15 percent, so the argillic horizon is considered as a natric horizon. Calcium carbonate at 47 - 117 cm. is sufficiently high to qualify as a calcic horizon (Table 5). The textural class of the control section at the 24 - 47 cm. is fine because it has more than 35 percent clay (Tables 3 and 4).

The mineralogy class of the pedon is mixed because all clay minerals have less than 40 percent of any one mineral (Table 9). It has an ustic moisture regime, because of a fluctuating seasonal water table and mesic temperature regime because the annual mean soil temperature is about 9.1 °C (air temperature +1°C).

According to these properties, the Payson pedon is classified as a member of a fine, mixed, mesic family of Typic Natrustalfs.

Trenton. The epipedon has a color value less than 5.5 when dry and 3.5 when moist, and chorma less than 3.5 when moist to the 43 cm. depth. Average organic matter content is more than 1 percent. Base saturation is more than 50 percent (Table 5); all characteristics above are enough to meet the requirement for a mollic epipedon.

The ratio of clay at the 22 - 71 cm. to that at the 8 - 22 cm. depth is more than 1.2 (Table 4). The fine clay to total clay ratio is also a higher actual value at 22 -71 cm. than at 8 - 22 cm. depth. These characteristics meet the requirement of the argillic horizon. The argillic horizon is also considered to be a natric horizon because the amount of exchangeable sodium is more than 15 percent at the 71 - 153 cm. depth. The value of calcium carbonate at the 71 - 127 cm. depth is sufficiently high to qualify as a calcic horizon. The textural class of the control section at the 22 - 71 cm. depth is fine because it has more than 35 percent clay (Table 3). The mineralogy classifies as montmorillonite because it is the most abundant mineral in the clay fraction. (Erickson et al. (1974) classified clay mineralogy at family level of Trenton soil series as mixed.) It has an xeric moisture regime and a mesic temperature regime. The mean annual soil temperature is about 8.6°C and the average annual precipitation is about 421 mm.

According to these properties, the Trenton pedon is classified as a member of a fine, montmorillonite, mesic, family of Typic Natrixerolls.

SUMMARY AND CONCLUSIONS

Soils of the Payson and Trenton polypedons in Cache Valley, Utah, were studied to establish the processes by which these two soils have evolved and to verify the classification of the polypedons. The purpose of the study was to investigate the genesis of these two polypedons to understand why the Payson polypedon is an Alfidol, while the Trenton polypeodn is a Mollisol. Even though the soil-forming factors appear simialr, the soils differ at the order level. Two pedons, one belonging to the Payson polypedon and the other belonging to the Trenton polypedon, have been described and sampled by genetic horizon to determine the nature and arrangment of these horizons. Both pedons are presumed to have the same climate, slope (1 to 2 percent), age, and elevation (1360 meters) above sea level, and developed on a parent material of Lake Bonneville sediments.

The Payson polypedon is a somewhat poorly drained, alkaline soil, with a fine-textured subsoil. There are distinct differentiations in color between horizons. A strong evidence of the development of the rounded columnar structure found in the B21t horizon, because this soil is influenced by a high amount of exchangeable sodium (enough to qualify as a natric horizon). High values of calcium carbonate equivalent at 47 - 117 cm. meet the requirement for a calcic horizon.

The Trenton polypedon is also a somewhat poorly drained, alkaline, and fine textured soil. The color and thickness of the epipedon meets the requirement for mollic epipedon. Increasing clay percentage in the subsoil horizons, high amount of exchangeable sodium, and prismatic structure indicate the presence of a natric horizon. The amount of calcium carbonate at the 71 - 127 cm. depth indicates the presence of a calcic horizon. Wide and deep cracks found in the Trenton pedon indicate presence of clays with high shrink-swell potential.

Some differences in physical, chemical, and mineralogical properties between the Payson and Trenton peodns are clear. Two depositional discontinuities appear in the Payson pedon, the upper 8 cm. differ from underlying horizons by the presence of very coarse and coarse sand, higher sand, clay, and calcium carboante and less silt content. This evidence indicates that the upper horizon probably formed by flood-plain sediments of the Bear River, mixed with wind-blown deposits during recent time (Holocene). The other discontinuity, a sharp increase in sand and a decrease in clay, appears at the 91 - 153 cm. depth; the increase in the sand fractions in these horizons is probably related to the wave action of Lake Bonneville, which eroded the material from the beach areas and deposited it as sediments on the valley floor. The clay distribution through the upper 8 - 70 cm. depth in the Payson pedon reflects the impact of pedogenic processes which contribute to the translocation of clay from eluvial to illuvial horizons. The abrupt increase in clay content at the 22 cm. in the Trenton pedon and weak evidence of illuviation as indicated by micromorphology studies suggest that this is due to different deposits as alluvium or lacustrine sediments during different periods.

The high amount of exchangeable sodium in both pedons reflects the development of natric horizons by increased dispersion of the clay fractions and enhances the movement of fine clay from eluvial to illuvial horizons. The illuviation evidence is more clearly expressed in the Payson than in the Trenton pedon, because the fine texture and montmorillonite clay in the Trenton favor shrinking and swelling in addition to high carbonate and salinity which enhances the soil flocculation, thereby retarding clay eluviation and preventing good clay orientation. The high exchangeable sodium also enhances the translocation of organic matter to lower horizons.

X-ray analysis indicates a mixture of illite, montmorillonite, kaolinite, and chlorite clay minerals in both pedons, but the montmorillonite clay type is the dominant clay mineral in the Trenton pedon.

The light color of the epipedon of the Payson pedon is due to high amounts of calcium carbonate (14.8 percent) in the A1 horizon, the bleaching of soil particles within the structural unit by sodium hydroxide and the presence of a sufficient quantity of light-color minerals, such as quartz and calcite, in the A1 and A2 horizons.

The Payson pedon is classified as a member of a fine, mixed, mesic family of Typic Natrustalfs and the Trenton pedon as a member of a fine, montmorillonite, mesic family of Typic Natrixerolls.

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APPENDIXES

Appendix A

Extractable cations (H_2O - Sol me/100 g) in the Payson and Trenton pedons.

	Depth (cm)	Extractable cation Mg (H_2O - Sol me/100 g)	K	Nc
Payson				
	0 - 8	0.2	0.1	0.2
	8 - 14	0.1	0.1	0.2
	14 - 24	0.1	0.1	0.4
	24 - 47	0.1	0.1	1.1
	47 - 70	0.1	0.1	1.6
	70 - 91	0.1	0.1	1.1
	91 - 117	0.1	0.1	1.0
	117 - 153	0.1	0.1	.5
Trenton				
	0 - 8	0.1	0.1	0.2
	8 - 22	0.1	0.1	0.2
	22 - 43	0.1	0.1	0.3
	43 - 71	0.1	0.1	0.6
	71 - 86	0.1	0.1	1.2
	86 - 98	0.2	0.1	2.3
	98 - 127	0.4	0.1	3.9
	127 - 153	1.0	0.1	6.6

Appendix B

Free iron oxide contents of the Payson and Trenton pedons.

	Depth (cm)	Free iron oxide (ppm)
Payson		
	0 - 8	3450
	8 - 14	5100
	14 - 24	4750
	24 - 47	5000
	47 - 70	1360
	70 - 91	2940
	91 - 117	3300
	117 - 153	3600
Trenton		
	0 - 8	5550
	8 - 22	5320
	22 - 43	6300
	43 - 71	5700
	71 - 86	4790
	86 - 98	4970
	98 - 127	6130
	127 - 153	7400

Appendix C

Available Phosporus in the Payson and Trenton pedons.

Depth (cm)	Avavilable phosphorus (ppm)
Payson	
0 - 8	29
8 - 14	23
14 - 24	16
24 - 47	13
47 - 70	24
70 - 91	17
91 - 117	10
117 - 153	11
Trenton	
0 - 8	10
8 - 22	11
22 - 43	4
43 - 71	3
71 - 86	4
86 - 98	6
98 - 127	8
127 - 153	9

VITA

Hakeem Thamir Saif

Candidate for the Degree of

Master of Science

Thesis: Characteristics and Genesis of the Payson and Trenton pedons.

Major Filed: Soil Genesis and Classification

Biographical Information:

Personal Data: Born at Amara, Iraq, September 3, 1943; son of Thamir Saif and N. Laabey; married Faiza Zeki in 1973; two children: Farrah and Senan.

Education: Attended elementary school in Kalat Salih, Amara; graduated from Al-Markazia High School in Baghdad in 1961; received the Bachelor of Science degree in Soil and Field Crops in 1966 from Baghdad University, Baghdad; completed the requirements for the Master of Science degree at Utah State University in 1977.

Professional Experience:

Worked as Agriculture Engineer in Soil Survey Department, State Organization for Soils and Land Reclamation, Baghdad, Iraq, 1966 - 1975.