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The interaction of parent material and eolian debris on the formation of soils in the Silverbell Desert Biome of Arizona

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THE INTERACTION OF PARENT MATERIAL AND EOLIAN DEBRIS ON THE FORMATION OF SOILS IN THE SILVERBELL DESERT BIOME OF ARIZONA

by

Randi Helaine Rosenthal

A Thesis Submitted to the Faculty of the

DEPARTMENT OF SOIL AND WATER SCIENCE

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE

In the Graduate College

THE UNIVERSITY OF ARIZONA

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Date

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ABSTRACT

The objective of this study was to determine whether the properties of four soils of the Silverbell Desert Biome, located in sec 21, T. 11 S.,R. 9 E., Silverbell Peak quadrangle (U.S.G.S. 15-minute series) could be attributed solely to the parent material or alternately reflect the nature of contributions, if any, from eolian dust. The Anklam, Lajitas and Chimenea soils, classified as fine-loamy, mixed, thermic Lithic Haplargids and the Greyeagle (coarse-loamy, mixed, thermic, Lithic Torriorthent) soil formed an andesite, basalt, granite and basalt, respectively. They occur on gently sloping, stable terrain 20 km west of Marana and in the eastern portion of the Sonoran Desert in Pima County, Arizona. The four soils were studied through field descriptions, particle size analysis, mineralogical analyses of light and heavy sand fractions and clay mineral identification. Each soil has the same heavy mineral assemblage and similar clay mineralogy reflecting the eolian input that occurred in the Silverbell Desert Biome area. The Anklam, Lajitas and Greyeagle soils on the other hand have similar particle size distributions in the solum horizons reflecting the grain size of the bedrock. The Chimenea soil has a significantly coarser texture due to the influence of the granitic parent rock. The light mineral fraction of all four soils is directly affected by the parent material and is influenced much less, if at all by eolian activities due to the larger particle sizes. It is concluded that the genesis of soils was influenced by both the underlying rock and the input of eolian particulates.

CHAPTER 1

INTRODUCTION

Statement of the Problem

The Silverbell Desert Biome, part of the International Biome Program (IBP), was established in the early 1970's to be one of two main study areas that are representative of the Sonoran Desert. This program, supported by the National Science Foundation, established a number of such ecological study sites in various environments to attempt to quantify ecological processes with the emphasis on modeling. At the Silverbell site, a brief soils study was first completed by Hendricks (1972). His report identified the presence of several soils formed from different types of rocks located in very close proximity to each other. This pointed the way to the present study in which four soils formed from different parent rocks were compared to determine whether or not they formed primarily from material derived from the underlying rock or alternately from eolian particulate matter. The four soils represent different series and include the Anklam, Lajitas, Chimenea and Greyeagle formed on andesite, basalt, granite and basalt parent rock, respectively. These soils are classified as fine-loamy, mixed, thermic, Lithic Haplargids, except for the Greyeagle which is classified as a coarse-loamy, mixed, thermic Lithic Torriorthent.

It is well known that five factors affect soil formation: topography, vegetation, climate, time, and parent material (Jenny, 1941). The soils studied in this research occupy similar geomorphic surfaces at elevations averaging 671 to 695 meters above MSL. All four soils support the same sparse, typical Sonoran type vegetation. In addition, similar limitations on land use existed for all the soils studied. Because of the close proximity of the soils and the climate of the region, both past and present, all the soils were influenced in the same manner. Although a relative age difference exists among the four soils only one soil showed a significant age difference from the others.

Different types of parent material give rise to soils with diverse characters of texture and fertility. As weathering increases with time, the initial type of bedrock has less influence, and secondary factors such as drainage and debris blown into the area have a greater impact on soil genesis. Desert eolian debris, due to its chemical and grain size characteristics, is important in pedogenic processes of the soils in the Sonoran Desert.

The dominant emphasis of this thesis was to determine if selected soil characteristics of the four soils in the study area could be related to parent material, eolian dust, and/or their interaction. In order to accomplish the primary purpose of this study, the four soils were compared and contrasted. Information was obtained through detailed field descriptions, particle size analyses and mineralogical analyses.

Location of the Study Area

The soils involved in this research are located in the Silverbell Desert Biome Site (sec. 21,T.11 S.R.9E.) which is located 20 km west of Marana in the eastern portion of the Sonoran Desert in Pima County, Arizona (Fig. 1).

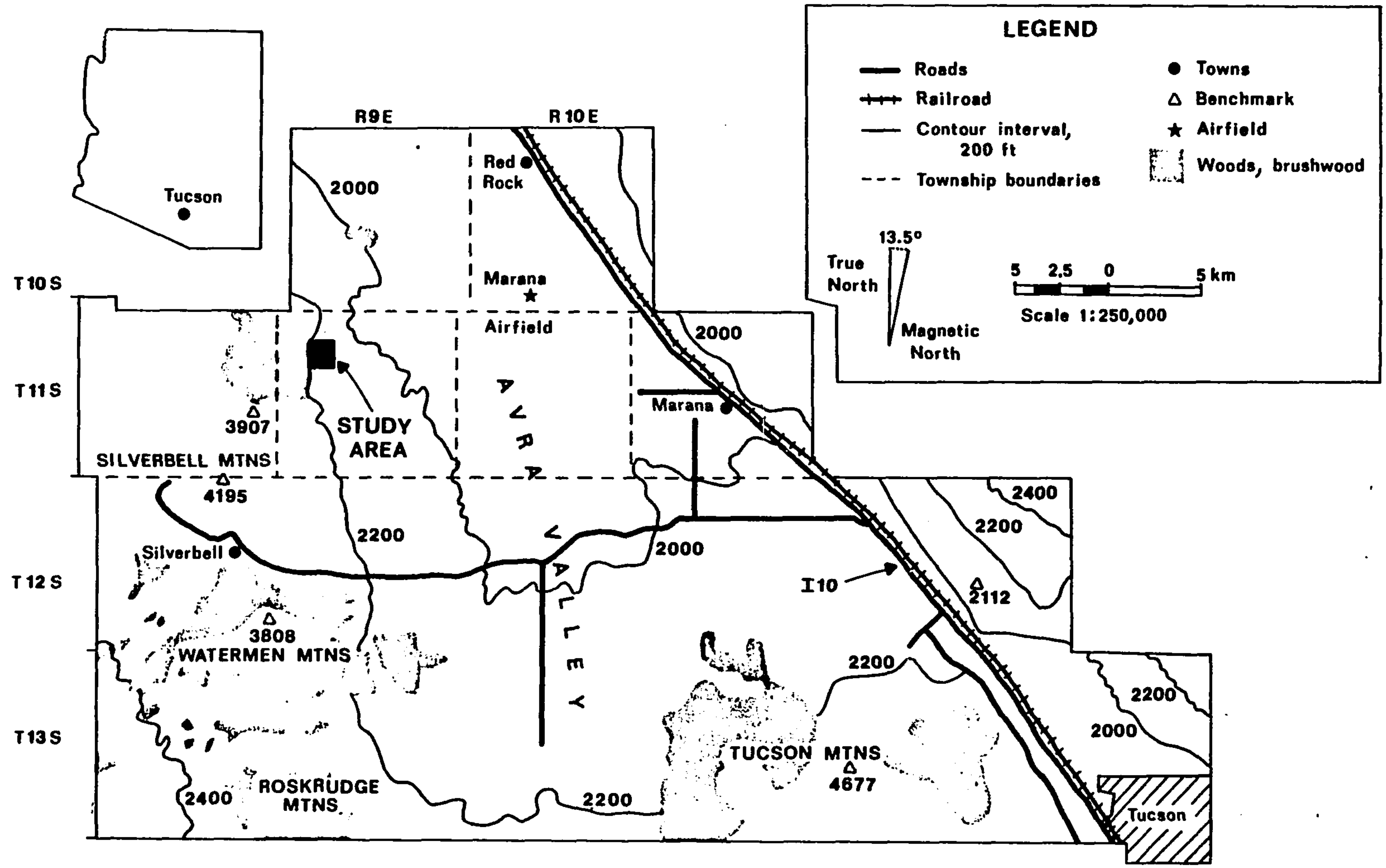

Fig. 1. Location of study area - Silverbell Desert Biome, Arizona.

Geological Setting of Parent Materials

The Silverbell Mountains, located 5 km to the southwest of the Silverbell Desert Biome, are the main topographical and geological feature found in the vicinity. This small but rugged mountain range rises abruptly above the alluvial plain and varies in elevation from 763 to 915 meters above MSL. This range contains the closest mapped geological units to the study region. The mapped units range in age from Precambrian to Recent (Kenyon, 1966). Rock units include chiefly Paleozoic and Mesozoic quartzarenite and arkoses and minor siltstone and limestone beds. Mesozoic and Tertiary igneous rocks occur as small stocks, dikes, or sills.

The primary parent materials of the four soils are highly diversified and their distinctiveness was a focal point of this study. The Anklam soil was formed from the weathering of a highly fractured subophitic andesite. Outcrops are found throughout the rolling hillslopes of the base of the mountain located in the study area. The subophitic andesite is medium grained and reddish-brown (10YR 4/4) in color (Fig. 2). The major mineralogical components include: 51% plagioclase, 32% augite, and 10% magnetite/ilmenite. Outcrops of this basic igneous rock showed little weathering on the exposed surfaces except for tiny cavities where minerals had been plucked out.

The bedrock beneath the Lajitas soil is a vesicular basalt (Fig. 3) in which the vesicles average 0.4 mm in size. This soil is located on a steep to very steep basaltic mountainslope. Although the slope contains numerous outcrops of the parent material, which are scattered throughout the area, the outcrops are concentrated towards the top of

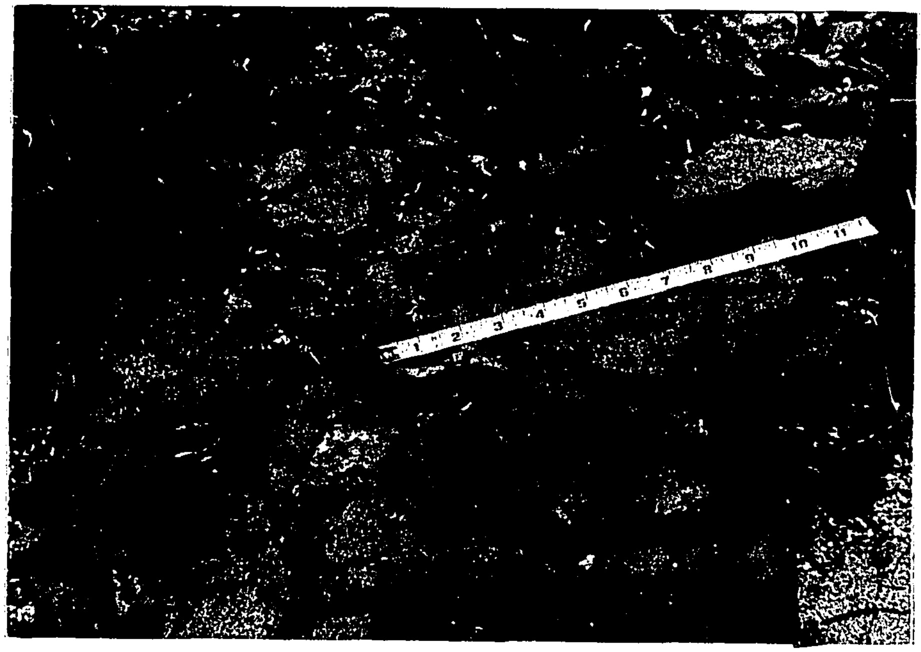

Fig. 2. The Anklam soil formed from a highly fractured subophitic andesite.

Fig. 3. The bedrock located under the Lajitas soil is a vesicular basalt.

the slope. This fine-grained basic igneous rock is medium dark gray (10YR 4/4) in color and shows moderate to heavy red iron oxide staining from weathering. The bedrock located at the upper elevations of the mountain exhibits more abundant vesicles. In addition, these vesicles are larger in size. They average 0.7 mm in diameter, but some vesicles reached a maximum diameter of 1.4 mm. Open vugs are visible where augite and plagioclase phenocrysts were once present. At lower elevations, the fine-grained basalt contains only a few small ellipsoidal to spherical empty cavities averaging 0.2 mm in diameter. This portion of the outcrop also displays less red iron oxide weathering. This vesicular basalt is composed of 65% groundmass, 18% plagioclase, 8% clinopyroxenes, and 10% accessory minerals of magnetite, ilmenite and hematite.

The parent material for the Chimenea soil is a perthitic granite (Fig. 4). Outcrops of this coarse-grained, acidic, igneous rock are not abundant in the study area. The average grain size perceptible to the naked eye is 1.5 mm. The dominant color of the least weathered portion of the bedrock is reddish-orange (10YR 6/8). Breakdown by weathering is readily visible on the feldspar grains. This bedrock was the most highly weathered of all four parent materials because of the ready susceptibility to chemical weathering of the biotite and to a lesser degree the plagioclase feldspar. Sixty-two percent of the bedrock is a perthitic feldspar accompanied by 21% quartz, 9% biotite and 7% plagioclase.

The Greyeagle soil is underlain by vesicular basalt (Fig. 5), which is brownish-gray (10YR 4/1) in color. This basalt is extremely fine grained and contains vesicles that are 1.0 mm in diameter. The

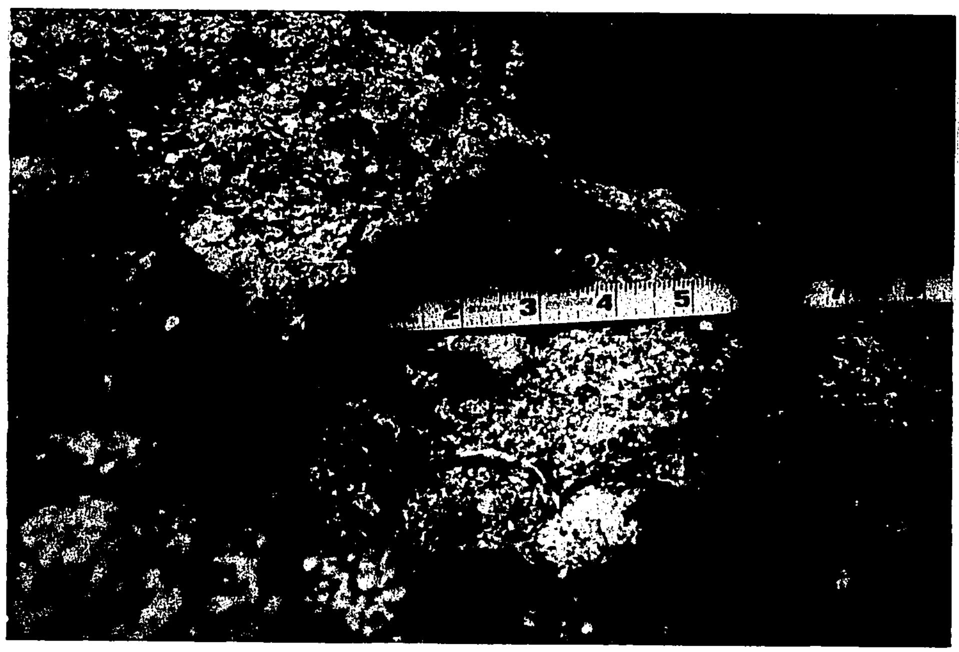

Fig. 4. A perthitic granite is the parent material on which the Chimenea soil formed.

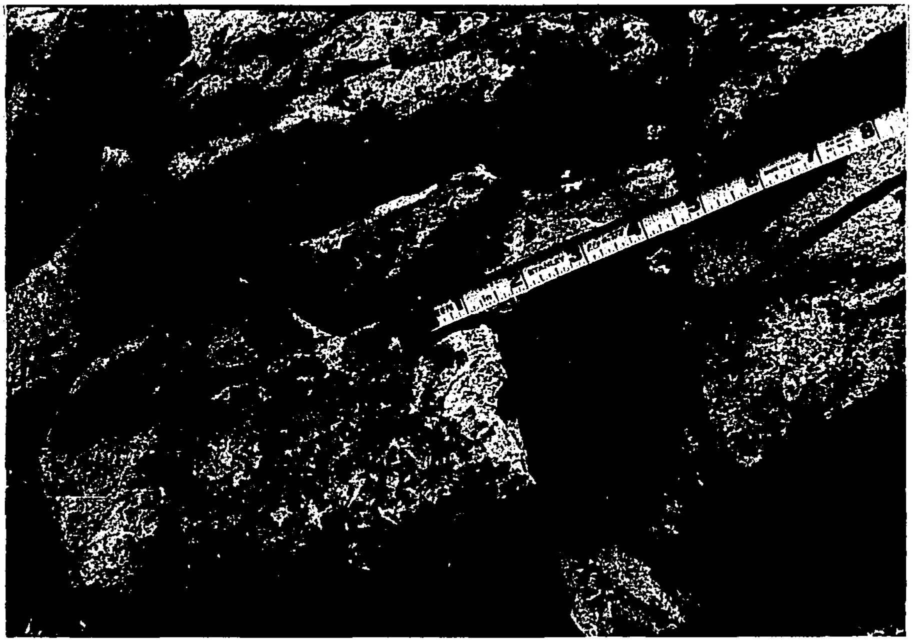

Fig. 5. The Greyeagle soil is underlain by vesicular basalt.

only sign of weathering is a slight reddish iron oxide staining. The groundmass makes up 81% of this rock. It also contains 8% plagioclase and 6% clinopyroxenes. Accessory minerals, which total 3%, includes magnetite, ilmenite and hematite. Because this soil is located at the edges of the Lajitas soil, the Greyeagle soil contains float from this unit. The pieces of float influenced the overall characteristics of the Greyeagle soil as it formed.

In addition to the bedrock from which the soils were directly derived, various types of float are scattered throughout all four soils. This diverse float thus had an impact on the pedogenic processes that occurred.

Soils formed on acidic igneous rocks, like granite, tend to exhibit a yellowish-brown color due to the low iron content of the minerals that comprise these types of rocks. The mineralogy not only affects the color, but directly impacts the pH and base saturation of the soil (Buol et al., 1973). Granites are comprised of approximately 25% quartz (Best, 1982). This quartz content may favor the development of acidic soils with low base saturations in a leaching environment. The size of the particles found in the soil profile can often be correlated to the type of parent material found below the soil unit (Nickling, 1983). The coarse-grained nature of granite produces a coarse loamy soil especially in the surface horizons. This textural class enhances permeability and thus the movement of water and cations through the profile. This movement aids in the formation of an acidic, low base saturated soil. Soils derived from these rocks are not only friable, but tend to be low in mineral nutrients (Buol et al., 1973). The clay found in these soils tends to be high in kaolinite (Birkeland, 1984).

Soils formed from the weathering of basic igneous parent material such as basalt or gabbro are rich in iron- and magnesium-bearing minerals. Therefore, the soils are generally dark reddish-brown in color and contain a high free iron content. This type of rock produces a soil with an alkaline pH and high base saturation. This type of geological rock is quartz-poor and therefore little sand appears in the profile of well weathered soils. These soils have large clay contents. The soils are mostly clay loams which have a low permeability (Buol et la., 1973). These ferromagesium enriched rocks break down to form smectite clays (Birkeland, 1984).

Vegetation and Land Use

The typical vegetation of the Silverbell Desert Biome is indicative of the rest of the Sonoran Desert. The vegetation exists as a sparse population throughout the study area. The natural vegetation where the Anklam soil is located is comprised of palo verde, cacti, whitethorn and triangle bursage. Because of the slope, moderately slow permeability, low available water holding capacity, and high gravel content, the Anklam soils are not used for farming. This soil could be crossed easily by livestock and its forage potential does exist all year round.

The dominant plant species inhibiting the Lajitas, Chimenea and Greyeagle soils include littleleaf palo verde, creosote bush, triangle bursage, white brittle bush, cacti and bush muhly. All three soils are unfit for farming due primarily to the slope of the terrain. These soils do provide forage all year round for livestock. Steepness, high surface gravel content, compounded by a large concentration of rock outcrops, limits the type of livestock which could utilize the area.

Climate

The climate of the Silverbell Desert Biome is semi-arid with mild winters and warm to hot summers. The climate in this region is influenced by four main factors: latitude, altitude, interfering mountain ranges, and remoteness from any large body of water. Typically, the long, hot season begins in April and ends in October. The average number of frost free days in the region is 220 to 290 days annually. Six months of the year, the maximum daily temperature exceeds 32°C, forty-one days a year the temperature exceeds 38°C. Diurnal temperature ranges are often great during a 24-hour period due to the small amount of smoke, moisture and clouds present in the atmosphere (Parker, 1977).

Rainfall is relatively low in the Sonoran Desert and in the vicinity of the study area amounts to approximately 25 to 30 cm per year. The majority of the rainfall (48%) is between July 1 and September 15. These summer rains are spontaneous in nature and tend not only to be short-lived, but also are accompanied by wind, thunder, and lightening. A secondary rainfall maximum (35%) occurs between December and March. The winter precipitation tends to be gentle, prolonged rain storms that provide the needed replenishment of ground water. The low rainfall is associated with extreme temperatures and result in low relative humidity (Parker, 1977).

Cloudless days are the norm in this desert. Surface winds are generally light, but occasionally localized dust storms may appear. Spring months have winds with sufficient velocity to damage trees, during these months, winds may reach a velocity of 30 to 45 kmph. Prevailing winds blow downslope from the southwest. The climate prevalent in Arizona today is not indicative of past climatic conditions (Parker, 1977).

Past climatic conditions had a much greater influence on soil formation. The climate of the paleoenvironment generally was colder with decreased evapotranspiration in which the more moist conditions led to a more rapid rate of weathering and soil formation. During the Pleistocene glaciation, glaciers were evident in the San Francisco Peaks near Flagstaff and in the White Mountains near Mount Baldy. As periods of glaciation enveloped the state, a wetter, moister climatic regime prevailed. The higher precipitation rate caused many shallow to deep lake basins in the western United States to be filled, such as Lake Cochise near Willcox, Arizona. Therefore, the kinds of plants and animals of the region were quite different. Evidence of this can be seen in fossils in packrat middens and by pollen stratigraphy (Hendricks, 1985). This fluctuation in moisture and temperature had an effect on the soils formed in the Silverbell Desert Biome. Soil of the same age experienced the same climatic conditions and went through similar chemical and physical rates of weathering. In addition, the soils in the area were exposed to the same rates of erosion and deposition patterns. The stability of the land surface has a marked effect on determining r\the rate of soil formation (Levine, 1985).

Soil Age

The exact age of the four soils studied is unknown. However, utilizing the degree of development of various diagnostic horizons, the age of the soils relative to each other can be estimated. Generally, the larger the number of horizons and the greater their thickness, the older and more mature the soil is (Jenny, 1941). Since the vegetation, climate, and topography are all similar for the soils that were studied, it can be assumed that the rate of weathering and thus the formation and magnitude of any soil's diagnostic horizon is based both on the parent material and on time. The classification of each soil studied in the project is given in Table 1.

The Anklam, Lajitas and Chimenea soils are classified in the same family (fine-loamy, mixed, thermic Lithic Haplargid). These soils all contain an argillic horizon that formed by clay translocation in the soil profile. The criterion for the argillic (Bt) horizon is that the horizon contains an "illuvial layer of lattice clays." This clay horizon is located below an eluvial horizon, but can be at the surface if the soil is truncated. The properties of an argillic horizon are described in detail in Soil Taxonomy (Soil Survey Staff, 1975), a United States government publication.

The development of an argillic horizon is a time-dependent slow process. The horizon's rate of formation depends in part upon the availability of clay and is directly related to eolian influx and weathering rates of various minerals to clay minerals. All three soils have a high gravel content on the surface which tends to increase the rate of clay accumulation from eolian debris. Gile (1975) discovered

Table 1. Characteristics of the soils studied.

Soil	Parent Rock	Slope(%)	Average Elevation(m)	Subgroup-Family
Anklam	Subophitic andesite	1-8	695	Fine-loamy, mixed, thermic Lithic Haplargid
Lajitas	Vesicular basalt	20-25	735	Fine-loamy, mixed, thermic Lithic Haplargid
Chimenea	Perthitic granite	1-5	671	Fine-loamy, mixed, thermic, Lithic Haplargid
Greyeagle	Vesicular basalt	3-8	683	Coarse-loamy, mixed, thermic, Lithic Haplargid

that clay accumulation is faster in gravelly material since there is less non-gravelly material between the clasts for fine eolian particles to infiltrate and accumulate. The presence of high amounts of calcium carbonate can inhibit the formation of an argillic horizon (Birkeland, 1984). None of the soils in this study have significant amounts of calcium carbonate. The percentage of clay found in each soil varies. The Anklam soil averages 25% clay and has a sandy clay loam texture. The Lajitas soil unit is also a sandy clay loam composed of 21% clay, but this soil may have a clay content that is as great as 35% (sandy clay). In these localized areas, the soil is also classified as having a sandy clay loam texture. The Chimenea soil averages 22% clay, but varies greatly in texture. It may exhibit a texture of sandy clay loam or sandy clay with up to 35% clay.

Gile et al. (1971) obtained radiocarbon dates of charcoal found in soil profiles in a semi-arid region of southern New Mexico. These soils have a distinct argillic horizon. Based upon their radiocarbon dates the formation of this clay horizon was estimated to be at least 5,000 years old. These scientists also believe that a wetter past climate preserved the argillic horizon. The wetter climate could support a greater vegetative cover and thus, less erosion occurred. With decreased erosional rates, the landscape was more stable and clay accumulation increased. Birkeland (1984) indicated that in Las Cruces, New Mexico, argillic horizons of similar clay content formed 5,000 to 10,000 years ago. The soils that the above authors discussed formed the alluvium and hence already contained clay. With the Anklam, Lajitas and Chimenea soils it was necessary to form clay by weathering and/or have eolian additions of clay before an argillic horizon could begin to form. Thus, these soils are undoubtedly considerably older than 5,000 to 10,000 years. The fourth soil unit in this study, the Greyeagle, is derived from a vesicular basalt similar to the parent material of the Lajitas series. The Greyeagle soil lacks any diagnostic subsurface horizons and is assumed to be the youngest soil studied.

Topography

Pima County lies within the Basin and Range province. The development of the Basin and Range features occurred during the Miocene. The progeny that formed these features began 13 million to 12 million years ago and ended between 10 to 6 million years ago (Hendricks, 1965). The modern topography consists of small, rugged ranges which strike northwesterly, and basins of broad alluvial outwash in between. Streams in the study biome are intermittent and drain radially from the ranges. The highest elevation in the Silverbell Desert Biome is 756 meters and is located in the northeast corner of the section. The lowest topographic levels are located in the southwest portion of the study area and reach a height of 671 meters. The average elevation of the Silverbell Desert Biome is between 671 and 695 meters (Fig. 6).

The Anklam soil is located on a rolling hillside at the base of the mountain. The soil unit is found on the northern boundary of the study site. The slope ranges from 1 to 8% (Hendricks, 1972). Average height of the terrain, which contains the Anklam soil unit, is 695 meters.

The highest elevation in the study area is occupied by the Lajitas soil. This mapped soil unit is moderately steep with 25 to 20 percent

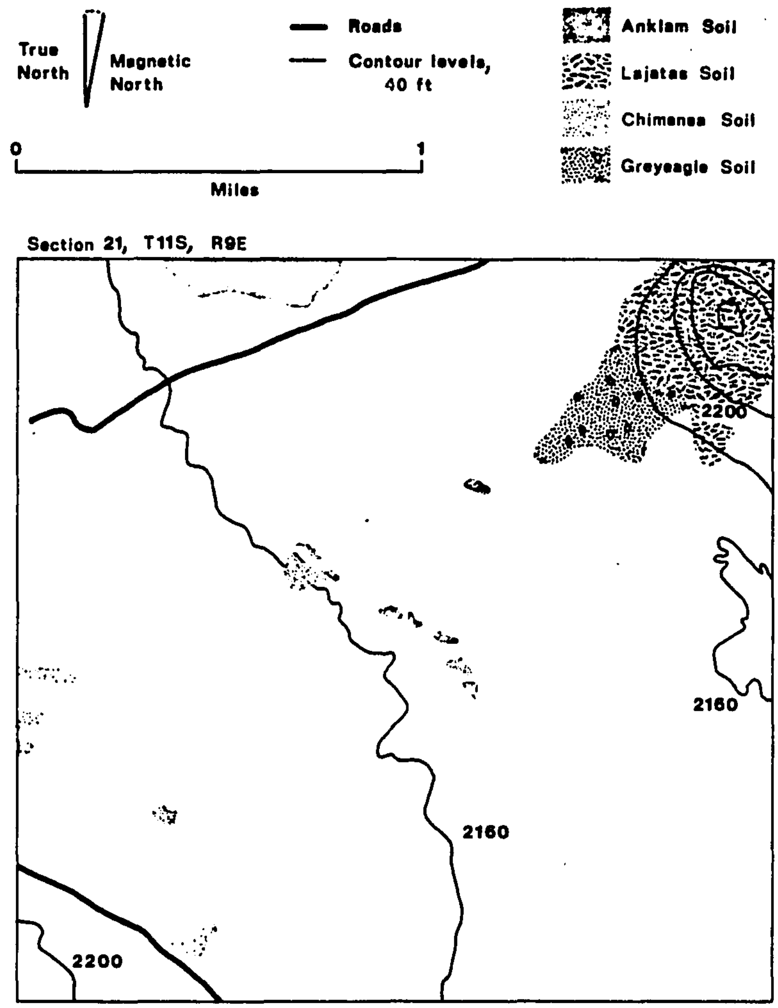

Fig. 6. A map of the topography and soils located in the Silverbell Desert Biome, Pima County, Arizona.

slope (Hendricks, 1972). The topographic levels for this site ranges between 756 to 714 meters.

The Chimenea soil is located near the channel of a small stream and occurs in the southwestern corner of the Biome at an elevation of approximately 671 meters. The slope of this soil series reaches a maximum of 5% (Hendricks, 1972).

The Greyeagle soil occurs on the same geomorphic surface as the Lajitas soil unit. It is located in the saddle of the mountain at an elevation of 683 meters; the saddle slope is 3 to 8% (Hendricks, 1972).

CHAPTER 2

BACKGROUND ON EOLIAN DEBRIS INFLUENCES ON SOIL FORMATION

The Silverbell Desert Biome is an ideal environment to compare the pedogenic processes that occur due to the influences of both parent material and eolian additions. Climatologically, the Silverbell Desert Biome is located in the subtropical high pressure belt. The unique conditions found in this area set up a system of circulating winds that have enough force to transport sediment along its path. The main force that drives the winds is the sun. The radiation from the sun and its interaction with the land's surface set the air in motion, thus forming winds (Lamb, 1972). The winds form due to the horizontal temperature variations produced across the earth's surface. This horizontal temperature gradient produces horizontal pressure differences which cause the air to sweep across the desert landscape. The force of this air system is enhanced in the atmosphere because the skies above the desert are usually clear except for the dust in the air. This phenomena is due to low water vapor content, the lack of cloud cover, and a large diurnal temperature gradient. The desert becomes very hot and all the available energy must be dissipated to the air or soil. The majority of this heat surplus is carried by turbulence into the atmosphere. This imbalance is eliminated usually at night and during the early morning hours; thus creating relatively light winds which have the potential to carry eolian debris. In addition, due to the lack of moisture and high heat content in the desert, the lower atmosphere over the desert is convectively very unstable. This instability leads not only to localized whirlwinds but also allows eolian particles to be transported from one place to another. Moreover, strong daytime convection of the desert produces a high momentum of fast moving air that is brought down and mixes with surface layers of air. Mid-afternoon winds are also sufficiently strong to transport sediment (Oke, 1978).

These various types of prevailing winds found in the atmosphere above the Silverbell Desert Biome move particles by either creep (rolling), saltation (bouncing), or suspension. The mode of the soil particle's movement is dependent on the individual size of each grain, the textural characteristics of the surface being eroded and the wind's velocity (Nickling, 1963). Once the particle is incorporated into the air, the eolian debris is deposited on the land's surface either due to interception by vegetation, or by impinging on some obstacle or by being washed to the earth's surface by rain and snow (Lamb, 1972).

Various types of airborne dust have been studied over the years. Wind blown debris from the Saharan Desert has been collected in specially devised dust traps in the Bahamas. In addition, the dust from the Saharan region has been identified in a variety of European countries ranging from Great Britain to Scandinavia. Often these dust clouds can be dense enough to effect the radiation associated with a particular region. Chemical analysis of dust found int he northern hemisphere has been correlated to Asia; while dust located over the southern hemisphere originates in Australia. The most extensive and persistent dust veils are comprised of tiny particles, about 1 um in diameter, and travel through the stratosphere. These veils are often the result of volcanic explosions. Studies have shown these particles can remain in the stratosphere 2 to 12 years before falling to the earth's surface. Particles not only enter the atmosphere from the earth's surface, but also research indicates dust from extraterrestrial sources is always present in the air. In the average year, it is believed one million tons of dust fall to the earth's landscape (Lamb, 1972).

The first research on eolian additions during soil formation was conducted by Darwin, Richtofen, and Udden (Geeley, 1985). Their projects were carried out in the mid-nineteenth century. They realized the soil particles at the surface will enter the wind when pressure against the dry soil particle exceeds the force of gravity. Since their research many studies have been conducted on the impact of eolian particles on soil properties. It should be noted that regardless of the type or location of the research executed, identification of wind blown sediments is not easy due to the fact that the amount and mineralogical composition of the dust would seriously change over time. The wind not only adds sediment to a soil profile, but it can have a profound effect on selectively removing sediments from an area. Early work on eolian movement of particles concentrated on the wind as an erosive agent which removed sediments from cultivated lands. These research projects, done in the late 1940's to early 1950's, also examined the landscape which remained behind after the wind scoured the land. Studies during this time period generally focused on regional transport of eolian matter. Syers et al. (1969) extensively studied the relationship between the diameter of the soil particle and the height above the surface that the sediment is transported. Fischer (1964) also looked at the parameters that effect the transportation and subsequent deposition of pyroclastic fragments.

In the late 1960's and early 1970's, in addition to exploring mechanics of transport, scientists inquired into the presence of unique minerals found in the soil profile. For example, Jackson and Rex (1978) looked for an explanation for the large quartz content found in Hawaiian soils derived from quartz poor basalts. The same type of projects were carried and developed in parts of Australia. During these years of research, many scientists investigated the origin of unusual dust found in the Bermuda-Bahamas region (Jackson et al., 1972). Their work led to the belief that the dust originated in the Sahara Desert. Projects in Israel continued to question the origin of eolian deposits (Goudie, 1978). Beginning around 1975, studies were determining the quantity of eolian debris transported. Jackson (1978) calculated the average amount of dust in the oceans. Others deduced the amount of dust falling on the earth's surface annually. Scientific work also probed what factors affect the size variation of dust falling in an area over time. Goudie (1978(investigated the long distance transport of dust and how it influences the geomorphology of a region. Moreover, he described the frequency of these storms and how much sediment is removed and added to the landscape. His study utilized data collected by other researchers. By compiling the work from various sources he was able to make generalized conclusions about certain global conditions induced by dust.

Some eolian debris located in soil profiles were dated to determine its age relative to the surrounding landscape. The research also started focusing on the wind's activities at higher altitudes and on a more global basis (Jackson et al., 1972). Scientists tried to not only identify the source of the particles, but also what geological era and paleoclimate were associated with the wind blown fragments. By oxygen isotope dating of quartz grains, Syers et al. (1969) demonstrated that eolian material not only just entered the soil profile but also influenced soil pedogenic processes. They correlated the origin of the fine silt fraction for a variety of locations around the world. In addition, they drew conclusions as to the geological era that deposition occurred. Work continues today to validate the existence of certain diagnostic horizons as being eolian in nature.

Muhs (1982) proved that silt enriched layers of certain California Channel Island soils were created by eolian products deposited in the profile. This project both sampled the soil profile, and the installed dust traps. Both soil and dust samples were analyzed by thin sections and scanning electron micrographs to determine the mineralogy of the samples. In addition, particle size analyses were conducted. Although the bedrock varied extensively through the study area, similarity in mineralogy existed for both the clay and silt fractions. Different types of analyses were used by Wilke et al. (1984) to prove that dust accumulated in Northern Nigeria during the dry season. This research project not only examined the mineralogy, but also concentrated on the total chemical nature of the dust. He focused on the amount of phosphorus, organic matter and trace elements present in the samples.

This thesis investigates the information derived from the analysis of particle size distribution, mineralogy , and soil characteristics in order to draw conclusions on whether or not the influence of eolian debris has occurred. If eolian particles are detected, their impact on pedogenic processes will be developed. Conclusions can be generated about eolian interaction with the soil profile since different types of parent material give rise to soils with various physical, chemical and fertility properties.

CHAPTER 3

METHODS

Field Sampling

Two types of field sampling techniques were utilized to collect the soil samples. The first type of samples were obtained from the various horizons (surface to bedrock) of a representative pedon of each soil. The pedon was described in detail, and the description included color, field texture, structure, consistency, depth of horizons, horizon boundaries, horizon designations, and reaction to dilute HCL acid.

The second type of sample included the A horizon only. These samples were randomly collected by transversing the area in a north-south and east-west direction. The soil locations were shown in Figure 6. The number of samples selected for each soil varied depending upon the areal extent of the particular soil. At all locations, a surface sample containing only the top two centimeters of the A horizon was collected. A second sample was collected of the remainder of the A horizon (below 2 cm).

Particle Size Analysis

All soil samples were passed through a "2 mm" sieve. A 20 gram subsample of the fine earth (< 2 mm) fraction was used for determining the particle size distribution analysis. This subsample was pretreated to remove carbonates with sodium acetate (pH = 5.0) and heating in a boiling water bath (Jackson, 1956). A second pretreatment with H_2O_2 removed the organic matter from each soil sample (Jackson, 1956). Once pretreatments were completed the samples were dispersed with 25 ml of

5N sodium pyrophosphate and 100 ml of distilled water. The soil solution was placed in a mixing cup to ensure proper dispersion. The fraction of the sample which ranged in size from 2.0 mm to 0.18 mm was separated from the remainder of the sample by a wet sieving technique. The 2.0 mm to 0.18 mm fraction was oven dried overnight at 105^{o}C, and then passed through a nest of sieves (0.5 ϕ intervals) in order to determine the distribution of particles found. The 0.18 mm and smaller fraction was placed in a 1200 ml fleaker which served as a sedimentation cylinder in which a representative clay (< .002 mm) sample was extracted with a 25 ml pipet following the appropriate settling time in which the silt would have settled at least 10 cm. The weight of extracted clay was determined gravimetrically with a correction made for the weight of the dispersing agent. The clay in the remainder of the sample was separated out by repeated centrifuging, dispersing, and sedimentation (Jackson, 1956). The 0.18 mm to 0.002 mm sized fraction was oven dried and analyzed with a Leeds and Northrup Microtrac particle size analyzer which further subdivided the finer sand and silt into 0.5 ϕ sized increments (Cooper et al., 1984). The particle size analysis procedure described enabled the percentage of sand and silt to be calculated as well as providing a particle size distribution at 0.5ϕ intervals from 2.0 to 0.002 mm.

Petrographic Thin Sections/Heavy Mineral Mount Preparation

Another randomly selected 20 gram subsample of the fine earth fraction (less than 2 mm) was used for the preparation of petrographic light mineral thin sections and heavy mineral mounts. These subsamples had the carbonates and organic matter removed utilizing the same technique as those employed in the particle size analysis. In addition, all the iron oxide coating on the grains was removed with bicarbonate-citrate buffer in order to enhance visual identification of the minerals with a petrographic microscope.

The heavy minerals were then separated from the light mineral fraction by utilizing 1,1,2,2,-Tetrabromethane (Carver, 1962). The heavy minerals were mounted in epoxy on a petrographic glass slide and covered with a cover slip (Leu and Druckman, 1982). The unconsolidated light minerals were mounted according to conventional petrographic techniques described in Allman and Lawerance (1972). Two thin sections of the light minerals and one heavy mineral mount were made for each sampled horizon.

Thin Section Analysis

Point counting techniques were employed to determine the percentages of various minerals found in the sand fraction of the soil horizons and the bedrock. The line method as outlined by Galehouse (1969) was utilized. Transects were made across the slide at 0.1 mm intervals and all the grains intersecting the horizontal cross hairs were counted. Between 500 and 600 soil grains from the very coarse sand to very fine sand size fraction (1000 um to 62 um) were counted. In addition, 500 to 600 counts were made on the bedrock thin sections to ascertain its mineralogy.

Heavy Mineral Analysis

The same point counting technique was used for the heavy mineral studies. The non-opaque and opaque minerals were both mounted on the petrographic slide. The very fine sand fraction (125 um to 62 um) only was used in this procedure. A total of 300 grains were counted per slide.

X-ray Diffraction Analysis of Clay

Subsamples of clay were saturated with either K^+ or Mg^{++}. These saturated samples were then treated in the manner outlined by Whittig (1965). Oriented mounts were produced by smearing a small amount of clay paste on glass slides (Theissen and Harward, 1962). The potassium saturated clays were air dried and heated at 105°C, 300°C and 500°C prior to analysis. The magnesium saturated clay mounts were exposed to 54% relative humidity and solvated with ethylene glycol, and with glycerol.

The X-ray diffraction analysis was conducted on a Philips XRG-300 diffractometer which had a vertical goniometer and Cu K α- radiation. Background noise was reduced and Cu K β- radiation was eliminated by using a graphite, single crystal monochrometer and pulse height discrimination. Clay mineral identifications were obtained from information gathered from Griffin (1971), Brown (1961) and Whittig (1965).

Bedrock Bulk X-ray Analysis

Samples of bedrock was placed in a WC lined vial with a WC coated steel ball and crushed in a mixer-mill to produce a fine powder. The powder was then placed in the X-ray diffractometer. Characterization of the minerals in the bedrock was obtained through the same method as in the clay in identification.

CHAPTER 4

RESULTS

The samples obtained from sampling various depths of the A horizon were used to determine if each of the soils was uniform or highly varied throughout their delineations. The results of the microtrac particle size analyses (Appendix C), the light mineral analyses (Appendix D) and the heavy mineral analyses (Appendix E) indicate that the A horizons of each of the soils were horizontally uniform.

Soil Field Descriptions

The pedon descriptions of the Anklam, Lajitas, Chimenea, and Greyeagle soils as they appear in the Silverbell Desert Biome are given in Appendix A. This description includes information on horizon designations, horizon depths, color, texture, consistence, structure, pH and horizon boundaries.

Particle Size Analysis

The percentages of sand, silt and clay plus the textural class are given in Table 2. The Anklam, Lajitas and Chimenea soils all have argillic horizons, as confirmed by the increase in clay in the subsurface horizons. The most highly developed argillic horizon is in the Chimenea soil where the increase in clay was from 11% to 35%. The texture changes greatly from a loamy sand to a sandy clay. The Anklam soil increases from 10% clay (sandy loam) to 26% clay (sandy clay loam). The smallest accumulation of clay occurs in the Lajitas soil where the clay increases

Table 2. Percentages of sand, silt and clay.

Soil	Horizon	Sand	Silt	Clay	Texture
		------------	%	------------	
Anklam	A	59	23	10	sl
	Bt1	53	20	26	scl
	Bt2	59	16	24	scl
Lajitas	A	62	23	14	sl
	Bt1	55	22	21	scl
Chimenea	A	77	11	11	ls
	Bt1	61	14	23	scl
	Bt2	54	10	35	sc
	Bt3	61	9	29	scl
Greyeagle	A	55	30	13	sl
	C	49	35	16	l

only 7%. The Greyeagle has no argillic horizon present since the translocation of clay has been minimal.

Folk's (1974) statistical parameters of grain size distribution of the sand and silt (2.0 - .002 mm) separates are located in Table 3. The graphic mean represents the average size particle of the non-clay fraction found in each horizon. Based on this, the mean soil particle size for all four soils is a fine sand to very fine sand in size. The type of sorting in the soil horizons is determined by the inclusive graphic standard deviation. The degree of skewness is measured by the inclusive graphic skewness. All four soils are very poorly sorted and skewed to the fine side. The degree of kurtosis is also presented in Table 3, and varies from platykurtic to mesokurtic.

The particle size distribution of the non-clay (2.0 - .002 mm) of the Anklam soil horizons are shown on cumulative curves in Figure 7. This soil contains an argillic horizon and therefore classifies as an Argid. A noticeable difference exists between the portions of the slopes representing the sand size particles of the three lines which depict the individual horizons. The Lajitas soil (Fig. 8) is also classified as an Argid due to the presence of an argillic horizon. Yet, this soil shows a particle size distribution for each horizon that is similar in slope. The Chimenea soil (Fig. 9) also an Argid, shows that all four horizons have a unique particle size distribution. The Greyeagle soil (Fig. 10), an Entisol, lacks not only an argillic horizon but generally lacks horizon development. This is confirmed by the particle size distribution for the Greyeagle soil. The lines representing the horizons

Table 3. Folk's statistical parameters of grain size.

Soil	Horizon	Mz*	Tz**	SK_I***	K_G****
Anklam	A	2.8	2.9 very poorly sorted	.48 strongly fine-skewed	.86 platykurtic
	Bt1	3.3	2.9 very poorly sorted	.18 fine-skewed	.99 mesokurtic
	Bt2	3.9	3.1 very poorly sorted	.17 fine-skewed	1.10 mesokurtic
Lajitas	A	3.1	2.8 very poorly sorted	.11 fine-skewed	1.00 mesokurtic
	Bt1	3.7	2.9 very poorly sorted	.17 fine-skewed	.97 mesokurtic
Chimenea	A	1.9	2.8 very poorly sorted	.79 strongly fine-skewed	1.00 mesokurtic
	Bt1	1.9	2.5 very poorly sorted	.77 strongly fine-skewed	.83 platykurtic
	Bt2	2.4	2.7 very poorly sorted	.42 strongly fine-skewed	.83 platykurtic
	Bt3	2.2	2.5 very poorly sorted	.55 strongly fine skewed	.71 platykurtic
Greyeagle	A	3.6	3.0 very poorly sorted	.18 fine-skewed	.69 platykurtic
	C	3.6	3.0 very poorly sorted	.17 fine-skewed	.71 platykurtic

* Graphic mean
** Inclusive graphic standard deviation
*** Inclusive graphic skewness
**** Kurtosis

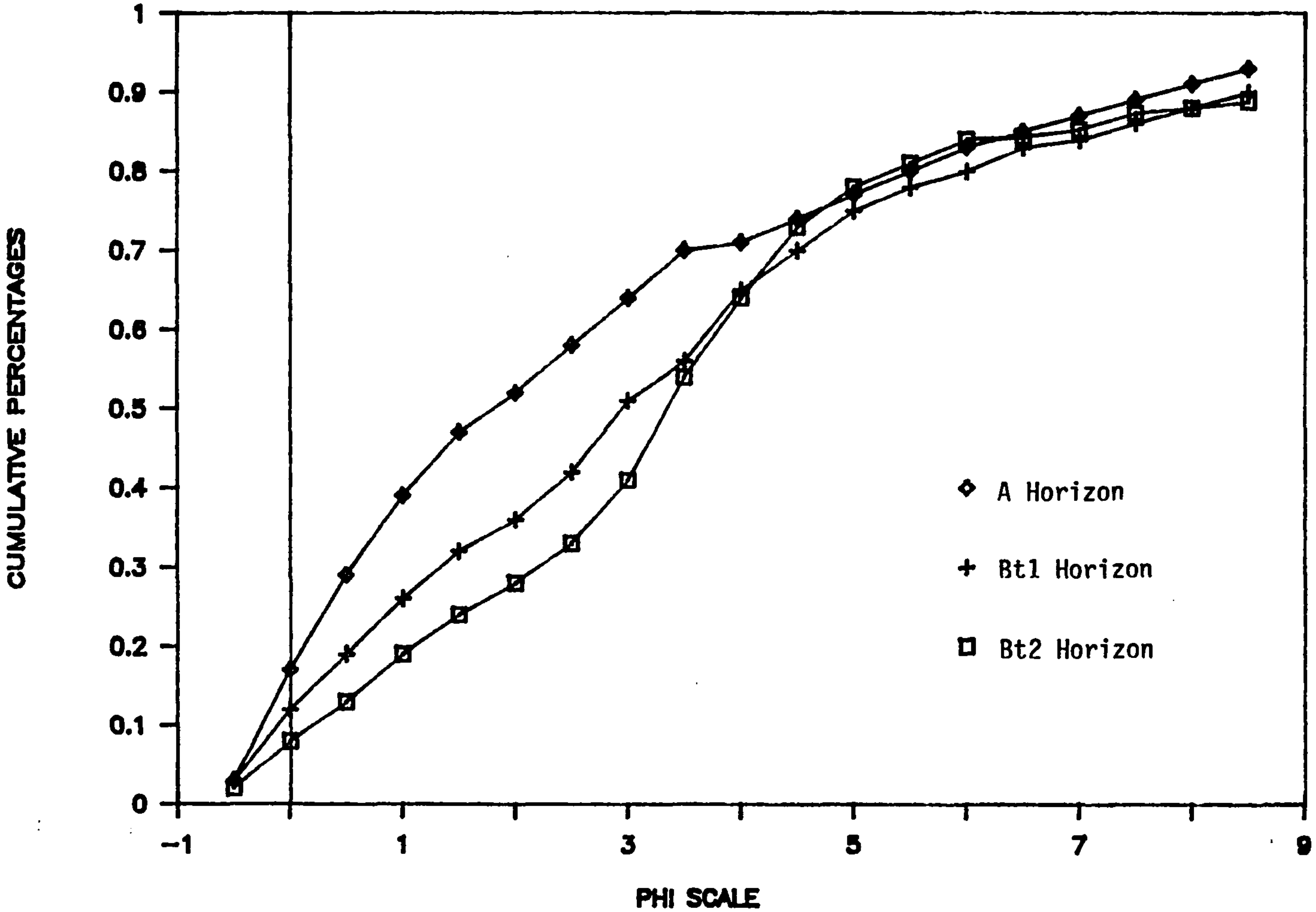

Fig. 7. Sand-silt particle size distribution of the Anklam soil.

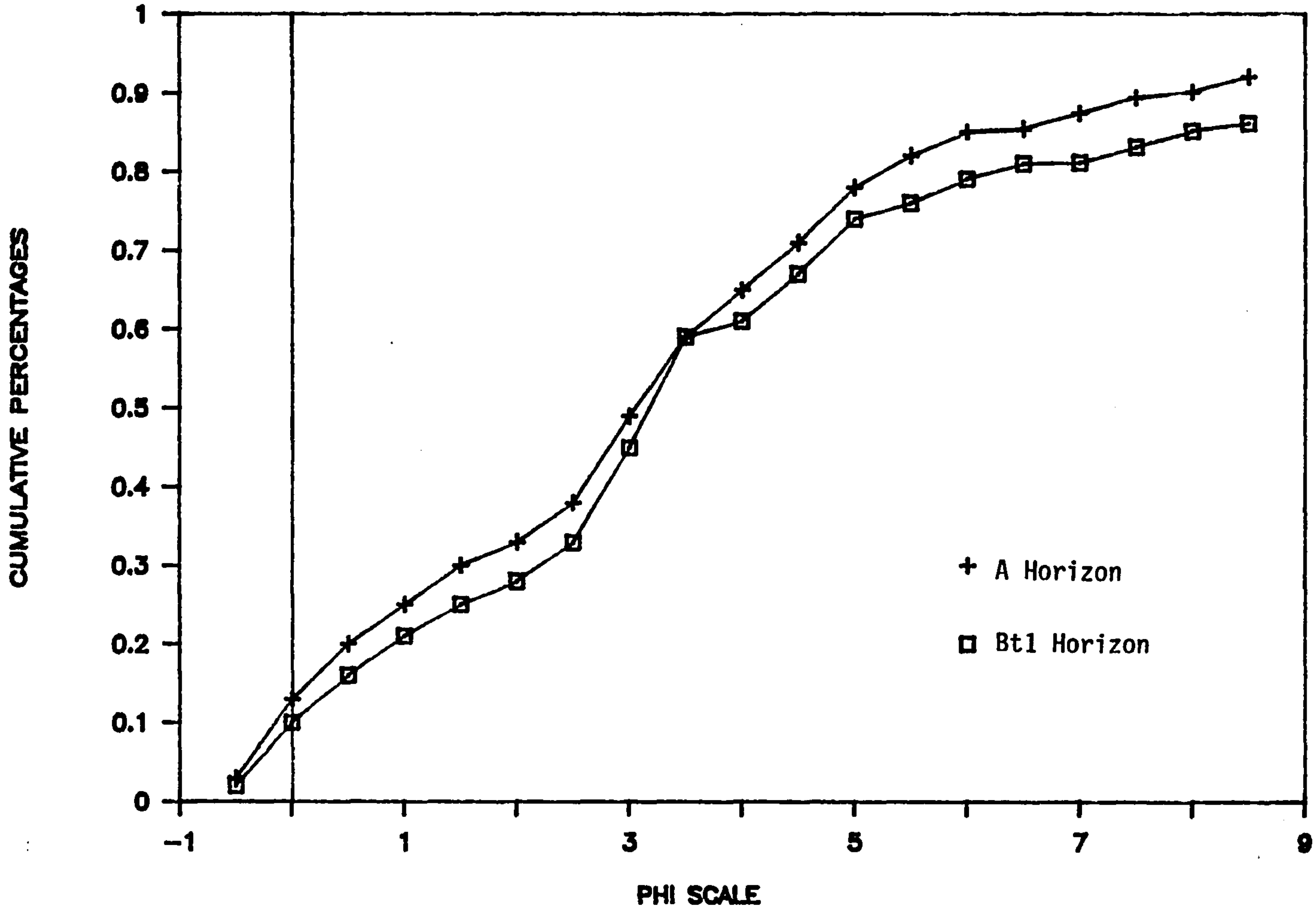

Fig. 8. Sand-silt particle size distribution of the Lajitas soil.

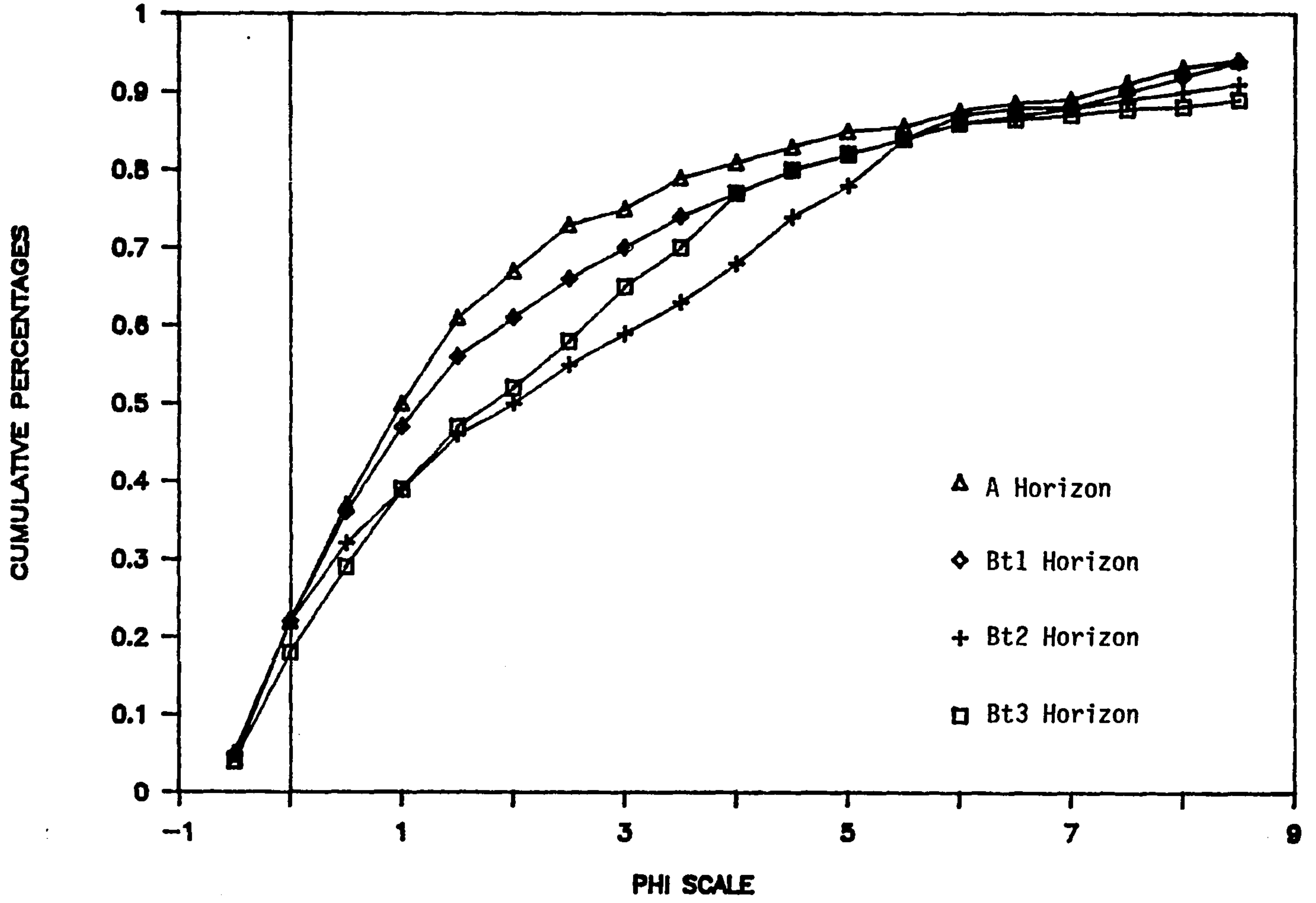

Fig. 9. Sand-silt particle size distribution of the Chimenea soil.

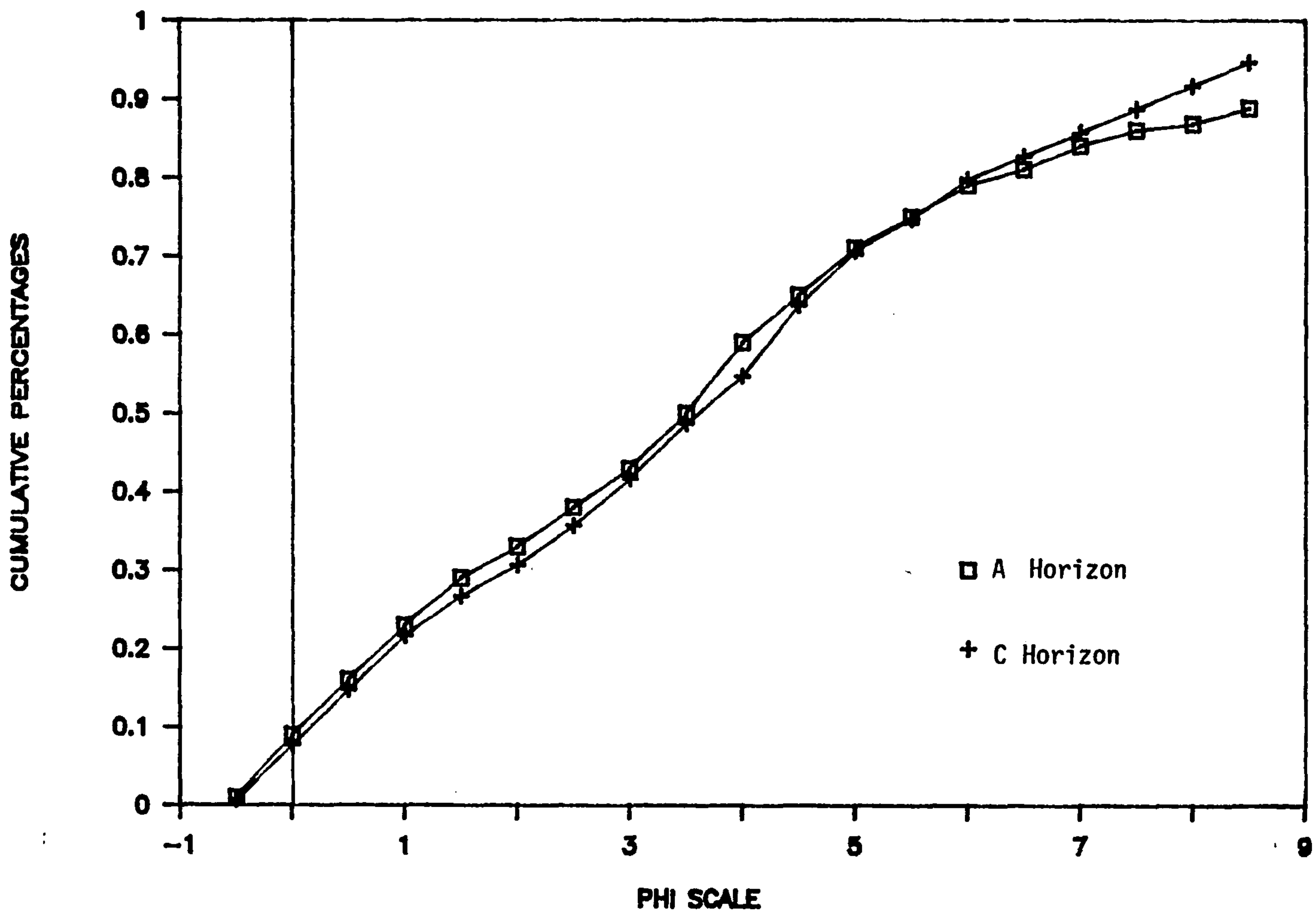

Fig. 10. Sand-silt particle size distribution of the Greyeagle soil.

have the same slope and show little difference in the particle size distribution of the sand and silt fractions.

Figure 11 compares the particle size distribution of the A horizon from each soil studied. This horizon is most affected by present day and recent eolian activity. The particle size distribution of Anklam, Lajitas, and Greyeagle soil resemble each other graphically. These soils have particle size distributions that do not vary significantly from each other reflecting a similar grain size in their parent rock. The Chimenea soil formed on the coarse grained granite, exhibits a significantly coarse-textured soil compared to the other three soils.

Light Mineral Fraction Analysis

Petrographic analyses of the sand fraction from all four soils showed the differences and similarities in the light mineral fraction (Table 4). Many of the minerals identified were unique to a particular soil and reflected the nature of the parent material. Significant differences can be identified in the minerals' relative abundance from soil to soil due to the vast difference in parent rock. Various amounts of weathering which is directly related to the ease of weathering of certain mineral types, on crystal faces is observed.

The sand of the Anklam soil is dominated by plagioclase, clino pyroxene, opaque minerals, and quartz with trace amounts of olivine. The major clinopyroxene observed was augite; smaller amounts of pigeonite also occurred. These minerals tend to exhibit good cleavage unless the grains are highly weathered. In localized areas the soil grains are not

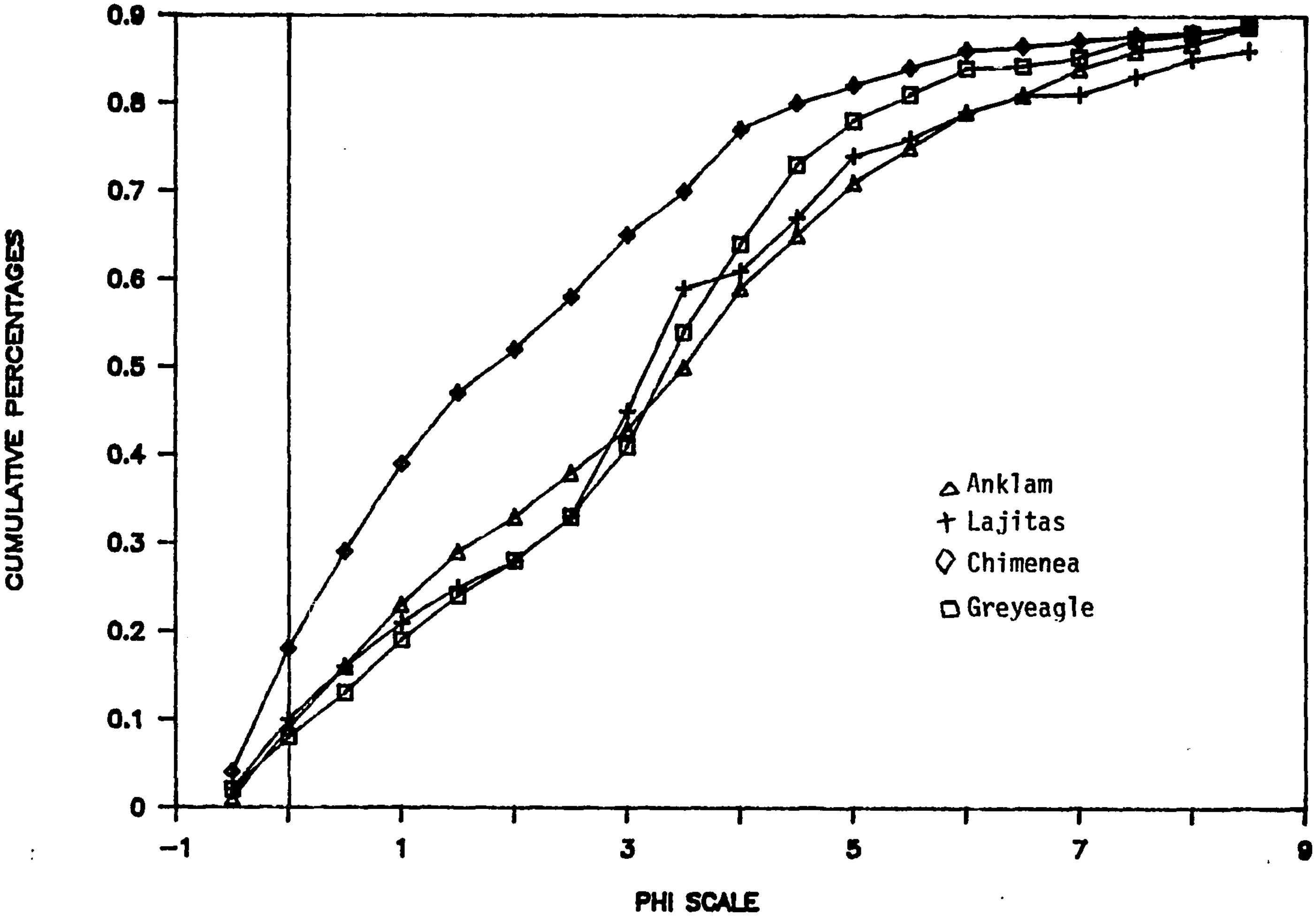

Fig. 11. Sand-silt particle size distribution of the A horizon from the Anklam, Lajitas, Chimenea and Greyeagle soil.

Table 4. Light minerals - results of point counts.

Soil	Horizon	Plagio-Clase	Clino-pyroxene	Opaques'	Rock groundmass fragments	Quartz	Perthite	Olivine	Mica
		--------------------	--------------------	--------------------	%	--------------------	--------------------	--------------------	--------------------
Anklam	A	19	32*	10	-	3	-	-	-
	Bt1	14	46*	14	-	3	-	-	-
	Bt2	14	54*	16	-	3	-	2	-
	R	51*	33*	10	-	-	-	5	-
Lajitas	A	2	8	4	60	3	-	-	-
	Bt1	3	8	3	67	6	-	-	-
	R	18	8	4	65	2	-	-	-
Chimenea	A	1	-	4	-	18*	52	-	4
	Bt1	2	-	4	-	21*	54	-	4
	Bt2	1	-	4	-	29*	56	-	3
	Bt3	2	-	14	-	25*	38	-	5
	R	7	-	2	-	21*	62	-	9
Greyeagle	A	2	5	2	66	11	-	-	-
	C	61	2	4	65	14	-	-	-
	B	8	6	3	68	-	-	-	-

* Statistically significant difference between soils ANOVA -> C.I. = 90%.

just comprised of individual clinopyroxene, but are a combination of interlocking clinopyroxene and plagioclase.

Oligoclase ($An_{21}Ab_{79}$) was determined to be the dominant plagioclase utilizing the Michel-Levy method. The majority of the minerals exist as lath shaped crystals.

Grey colored weathering products, albite twinning, and fractures are noticeable on many crystal faces. Some of the opaque minerals have weathered to hematite. Quartz grains display fractures along with evidence of small inclusions. The quartz grains do not exhibit any signs of weathering.

The bedrock that underlies the Anklam soil is classified as a subophitic andesite. Its main constituents are similar in appearance to those found in the soil horizon. Oligoclase is the main plagioclase mineral identified. The crystals exhibit twinning and are lath shaped but not well terminated. They tend not to be highly weathered except for a slight gray weathering product on a few crystals. This basic igneous rock has randomly oriented euhedral clinopyroxene crystals that enclose, either partially or wholly, laths of plagioclase (Best, 1982). The rest of the parent rock consists of opaque minerals and olivine that has been replaced by iron oxides and serpentine.

The sand from the Lajitas soil has a similar mineralogy to the Anklam containing: plagioclase, clinopyroxene crystals that enclose, either partially or wholly, laths of plagioclase (Best, 1982). The rest of the parent rock consists of opaque minerals and olivine that has been replaced by iron oxides and serpentine.

The sand from the Lajitas soil has a similar mineralogy to the Anklam containing: plagioclase, clinopyroxene, opaques, hematite, and quartz. The clinopyroxene of this soil is predominantly augite with minor amounts of pigeonite. The euhedral mineral is fractured and subangular or tabular in nature. Only one dominant cleavage is readily visible. Lath shaped plagioclase display some twinning and are chiefly oligoclase in composition. Opaque minerals are angular to subangular. Some of the opaques show hematite weathering on the edges. Quartz is either subangular or elongated. Not all of the quartz grains have fractures, inclusions, or show signs of weathering.

Some of the soil particles are fragments of groundmass. The exact composition of the groundmass can not be determined because it is so fine grained. The constituents of the groundmass which could be identified are small plagioclase laths, interconnecting with various opaques.

The parent material from which the Lajitas soil is formed from is a vesicular tholeiitic basalt. The bedrock is holocrystalline with intergranular phenocrysts. The subhedral or euhedral phenocrysts are plagioclase of clinopyroxene, and are arranged in a glomeroporphyritic texture. Groundmass is composed of small plagioclase laths, opaques, and hematite accompanied by trace amounts of clinopyroxene and quartz. Plagioclase occurs as slender laths embedded in the groundmass. It is composed chiefly of oligoclase with minor amounts of andesine. Fractures and weathering products do exist on the phenocrysts along with replacement by hematite on crystal surfaces. The clinopyroxene is highly cracked and iron oxide weathering is visible. Rounded or angular opaque minerals are evenly distributed throughout the rock. Hematite is associated with edges of the crystal. Opaques and hematite have completely weathered whole crystals of clinopyroxene and thus become a replacement mineral.

The predominate type of mineral from the Chimenea soil horizons is a perthitic feldspar. These grains are rounded or subangular nd elongated with various degrees of sericite weathering and fracturing. The majority of the perthite grains have opaques or quartz inclusions. The subangular quartz soil particles have round, clear inclusions. s The biotite is extremely fine grained. They are rectangular in shape with shredded edges.

The bedrock underlying the Chimenea soil is a perthitic granite. The granite is hyidiomorphic in texture. The perthite is a combination of microcline and albite. It is subhedral perthite with good cleavage present. Patches of sericite and other grey weathering products are seen on crystal faces. The quartz shows no evidence of weathering and is not cracked or fractured. Quartz fills the pores and acts like veins and inclusions within the perthite. Primary biotite in many places has been replaced by secondary mica, clays, hematite, and iron oxides. Euhedral plagioclase shows visible signs of weathering and twinning on crystal faces. The plagioclase is oligoclase ($An_{21}Ab_{79}$) in composition. Angular and euhedral opaques are observed in the granite.

The Greyeagle sand contains fragments of basaltic groundmass. The groundmass is a very fine matrix which makes detailed identification of the exact mineralogy impossible. Generally, the groundmass is composed of plagioclase laths and opaque minerals accompanied by patches of hematite weathering. Angular quartz grains display quartz overgrowths.

Original quartz boundaries are rugged, while the overgrowths have smooth edges. Many quartz grains are highly physically abraded and fractures. Plagioclase laths exhibit visible twinning and zoning. Clinopyroxene have one strong cleavage visible. They are highly weathered with ragged edges with no cleavage and iron oxide inclusions.

The parent material from which the Greyeagle soil is derived from is a vescicular theoliitic basalt. The rock is holocrystalline with phenocrysts of plagioclase and clinopyroxene embedded in a fine matrix. These phenocrysts are arranged in a glomeroporphyritic texture. Groundmass is comprised of tiny plagioclase laths, opaques, clinopyroxene and trace amounts of hematite. Only partial terminations are present on the laths. Laths are grouped together and intergrown with clinopyroxene. Most of the grains display twinning, fracturing, and various degrees of weathering. The clinopyroxene is highly weathered and fractured. Many grains are totally weathered away with only visible boundary remnants remaining. Empty pore spaces exists due to the weathering and removing of clinopyroxene. The majority of crystal faces have poor or no cleavage and inclusions of iron oxide. The mineral faces are rimmed with hematite and magnetite.

Heavy Mineral Analysis

Heavy minerals from fine sand (125 um to 62 um) were studied from all four soils to ascertain the differences and similarities (Table 5). Although the soils are derived from a variety of parent rocks, each soil contains the same assemblage of heavy minerals. The heavy minerals observed include: zircon, rutile, epidotee-clinozoisite-zoisite,

Table 5. Heavy minerals - results of point counts.

Soil	Horizon	Ziron	Rutile	E-C-Z[1]	Sphene	Opaques[2]	Leuc-oxene	Biotite	Basalt hornblende	Hnd	Hematite	Hypers-thene
		%										
Anklam	A	9	6	18	11	3*	4	3	5	25*	-	-
	Bt1	8	4	19	12	2*	3	3	6	25*	-	-
	Bt2	3	11	17	20	3*	4	2	1	24*	-	-
Lajitas	A	8	6	30	-	11	9	<1	2	9	3	3
	Bt1	7	7	31	-	16	7	<1	3	9	2	2
Chimenea	A	8	5	29	6	28[3]	-	<1	3	17	-	<1
	Bt1	5	4	26	5	22	-	1	3	16	-	<1
	Bt2	5	4	11	8	4	-	-	1	5	-	-
	Bt3	6	11	14	5	26	-	-	<1	3	-	-
Greyeagle	A	6	4	18	14	18[4]	4	<1	2	8	1	2
	C	5	9	19	15	14	4	<1	3	10	2	4

* statistically significant difference between soils ANOVA -> C.I. = 9%

1 Epidote - clinozoisite - zoisite
2 Magnetite and ilmenite
3 Magnetite, ilmenite, pyrite, leucoxene and hematite
4 Magnetite, ilmenite and pyrite
- Not detected

sphene, a variety of opaques, biotite, basaltic hornblende, hornblende, and hypersthene. The Anklam soil has a significantly greater amount of hornblende compared to the other soils. In addition, this soil has smaller quantities of opaques. The remainder of the heavy minerals do not differ significantly in abundance. The overall appearance of the heavy minerals does not change from soil to soil. Generally, the heavy fraction shows minimal amounts of chemical and physical weathering.

Zircon which is the same from soil to soil, is the most diversified of all the minerals identified in the soils and occurs in a wide variety of sizes and shapes. Some grains are unaltered with visible crystal faces (chiefly terminations). Others exist with terminations that are highly rounded and crystal faces have been altered. Several zircon crystals are pale in color, some exhibit strong bifrengence. The dominant colors observed are pink, blue, green and yellow.

The yellowish-red rutile has various degrees of iron oxides covering the crystal faces. Rutile tends to be subangular and elongated with visible striations. The epidote-clinozoisite-zoisite minerals exhibits weathering and iron oxides on the crystal faces. These grains are rounded or irregularly shaped.

Sphene is irregularly shaped and slightly rounded to subangular. The majority of the sphene is highly fractured with jagged, frayed edges. Iron oxides also exists on the grains.

Magnetite, ilmenite, pyrite, leucoxene, and hematite comprise the opaques that appeared in the soil profile. The opaques are rounded to subangular in shape. Torn pieces of biotite flakes are present in small quantities.

The basaltic hornblende is brownish-green and displays some weathering on the grains. Some of the basaltic hornblende occurs only as torn pieces and not complete crystals.

Typical hornblende grains are greenish-brown and slightly pleochroic to yellowish-green. Smaller sized hornblende is more rounded in shape. A larger portion of the hornblende has edges that are jagged and highly weathered. All crystals display fractures throughout their faces. The majority of the hypersthene has crystal faces covered with iron oxide.

Clay Mineralogy

The results of the X-ray diffraction analysis are given in Table 6 for all four soils studied. The X-ray diffractograms upon which the data of Table 6 are based on are on file in the Department of Soil and Water Science, University of Arizona. The clay mineral composition for the bedrock that is located under the soils appears in Appendix B.

The Anklam soil clay is dominated by montmorillonite in all three horizons. Small amounts of mica and koalinite are also detected throughout the profile. Trace amounts of quartz and feldspar are distributed in the clay in all the horizons of the Anklam soil. The Bt2 horizon which is 14 cm to 22 cm below the surface has slightly higher quantities of clay size quartz and feldspar than the other two horizons.

The Lajitas soil has a large diversity of clay minerals although montmorillonite prevails. Both Arizona, A and Btl, have small amounts of mica, koalinite, and an interstratified clay present. The interstratified clay is a combination of layers of mica and montmorillonite.

Table 6. Clay minerals identified in soil profiles.

Soil	Horizon	Mont.	Mica	Verm.	Chl.	Koal.	Mixed layer	Quartz	Feld.
Anklam	A	5	2	0	0	2	0	1	1*
	Bt1	5	2	0	0	2	0	1	1
	Bt2	5	2	0	0	2	0	2	2
Lajitas	A	5	2	0	0	2	2	1	1
	Bt1	5	2	0	0	2	2	2	0
Chimenea	A	4-2	3-2*	2-1	1*	3*-2*	0	2	2*-1
	Bt1	4*-2	3-2*	2-1	1*	4-2	0	2-1	1
	Bt2	4*-2	3	2	0	4	0	2	2
	Bt3	4*-2	3	2	0	4	0	1	1
Greyeagle	A	5	1*	0	0	1*	0	1	1*
	C	5	1*	0	0	1*	0	1	2*

5 = predominant
4 = abundant
3 = moderate
2 = small
1 = trace
0 = none or not detected

The top 5 cm (A horizon) of the Lajitas soil unitcontains trace amounts of quartz and feldspar. The Btl horizon, 5 cm to 18 cm, has small quantities of quartz, but no feldspar was detected.

The Chimenea soil does not have one dominant clay, although montmorillonite is dominant in certain areas except where the major component of the clay is koalinite. The regions which have a large amount of koalinite also have significant quantities of mica. The portion of the soil with a high montmorillonite concentrations also has small to trace quantities of mica, vermiculite, koalinite, and quartz. The quantities vary for these minerals depending on the exact location of the sample. Trace amounts of chlorite and feldspar are found in the Chimenea soil. The quantities of chlorite and feldspar vary with each sample locale. Certain sample sites do not have any chlorite detected. In addition, throughout the whole profile no interstratified clay was identified.

The Greyeagle soil is dominated by montmorillonite in both the A and C horizons. The A horizon has trace amounts of mica, koalinite, quartz and feldspar. The lower C horizon is comprised of trace quantities of mica, koalinite and quartz; plus this horizon has slightly larger amounts of feldspar than the A horizon.

CHAPTER 5

SUMMARY AND CONCLUSIONS

All four of the soils studied indicate to varying degrees that their genesis is influenced by both parent material and eolian debris. The mineral composition of the sand and silt sized particles, clay mineralogy, and also the particle size distribution have been affected by both factors during their formation. The scope of this project cannot determine the exact percentages of the minerals that are removed by the wind and carried to another location or have accumulated following eolian deposition.

The Anklam, Lajitas and Greyeagle soils have similar particle size distribution in their A horizon. All three soils are derived from bedrock that is fine grained. The fine grains from the three soils are the appropriate size to be readily carried by wind currents. The grains, which are normally associated with eolian movement, could have been mixed together by the wind and then deposited back onto the soils. Eolian particulates can also be brought in from outside; particularly from alluvial soils. Wind currents in the Silverbell Desert Biome Site are strong enough during part of the year to move smaller particles to another location. Therefore, all three soils would be expected to contain similar sized particles regardless of the original grain size of the parent material. On the other hand, the Chimenea soil formed from a very coarse grained granite. These coarser fragments are larger in size than the average eolian particle carried under suspension. The coarser soil grains of the Chimenea soil are believed not to have been involved in eolian processes. This soil has a significantly coarser texture than the other three soils studied. The Chimenea particle-size distribution is attributed largely to the parent material.

The light mineral fraction of the soils is indicative of their respective parent rocks. The soil particles from all four soils contain the same mineralogy (both in composition and appearance) as the rocks from which they formed from. In addition, the majority of the grains of the light mineral fraction tends to be too large to have been transported by suspension. Therefore, any mixing that did occur among the soils was minor.

The composition of the heavy minerals of the fine sand of all four soils is very similar. Generally the relative abundance of each type of mineral does not change from soil to soil. The exception being the Anklam soil which shows significantly less opaques and significantly more hornblende. These minerals which are smaller in size are believed to have been transported, mixed and redeposited by the wind's activity. Heavy minerals are resistant to weathering and would persist in the soil profile over the time of soil formation. The Anklam, Lajitas, and Greyeagle all were derived from basic igneous rocks. Basic igneous rocks usually do not have biotite, sphene, and hornblende in their heavy mineral assemblage. Hypersthene and basaltic hornblende are not associated with granites but is present in the Chimenea soil, a product of acid igneous weathering, as well as in the other three soils. The clay mineralogy of the Anklam, Lajitas, and Greyeagle soils is dominated by montmorillinite (Table 6). Montmorillinite formation is favored by arid climatic regimes since the quantity of precipitation is a major factor in the formation of particular clay mineral species. Montmorillinite formation is also favored to form in soils formed from andesites and basalts. The Chimenea soil is also dominated by montmorillinite and is formed under the influence of the climate in the Silverbell Desert Biome. This dominance by montmorillinite is not only a result of climate, but also could be due to the input of eolian particulates. Koalinite is more abundant in the northern areas of the Chimenea soil as seen in the diffractograms from these sample locales. These areas of the Chimenea soil containing more koalinite were probably influenced to a greater degree by their parent material than from the input of eolian particulates.

The Anklam, Lajitas and Greyeagle soils all formed from basic igneous rocks; while the Chimenea is derived from an acidic igneous rock. The basic igneous rocks differ chemically from each other. Even though bast differences exist between the four parent materials studied, similarities are noted in all soils studied. All four soils have the same heavy mineral suite regardless of the parent rock. The clay fraction from the soil in the Silverbell Desert Biome is dominated by montmorillinite, although the Chimenea soil is higher in koalinite and mica. The Anklam, Lajitas and Greyeagle have similar particle size distributions.

The eolian influences have made all four soils similar even though the parent rocks were different. The wind currents in the vicinity of the Silverbell Desert Biome site have mixed the grains from all the soils as well as brought in material from other areas and thus allowed some of their physical characteristics to become similar. The scope of this project did not encompass the quantity of eolian debris, the exact mineralogical composition, or the origin of the eolian dust brought into the Silverbell Desert Biome. Further research could investigate and evaluate these topics. By setting up dust traps in the research area the quantity of sediment transported under today's wind currents could be defined. Dust traps would also enable the mineralogical composition of the eolian debris to be obtained. Any dust collected would only be indicative of the modern dust and not necessarily reflect the composition of the dust accumulated in the past. Through the use of oxygen isotope dating of various grains particularly quartz, the origin of the dust might be identified.

APPENDIX A

PEDON DESCRIPTIONS

ANKLAM SOIL: A representative pedon is located 280 feet south and 1800 feet eact of the southwest corner of the site. Fine-loamy, mixed, thermic-Lithic Haplargid.

A 0-2 cm - Brown (7.5YR5/4) gravelly sandy loam, dark brown (7.5YR3/4) moist; weak medium platy structures; soft, friable, slightly sticky, slightly plastic; few very fine and fine roots; common fine and very fine vesicular pores; mildly aklakine (pH 7.5); abrupt smooth boundary.

Bt1 2-4 cm - Yellowish red (5YR4/6) gravelly sandy clay loam, dark reddish brown (5YR3/4) moist; weak fine and medium subangular blocky structure; slightly hard, firm, sticky, plastic; few fine roots; clay dilms of gravels; mildly alkaline (pH 7.5); cleaer wavy boundary.

Bt2 14-22 cm - Dark yellowish red (5YR3/6) very gravelly sandy clay loam, dark reddish brown (5YR3/4) moist; structureless massive; slightly hard, firm, sticky, plastic; few fine and medium roots; clay films on gravels; mildly alkaline (pH 7.5)' abrupt irregular boundary.

R 22-30 cm - subophitic andesite.

LAJITAS SOIL: A representative pedon is found 520 feet south and 800 feet west of the northeast corner of the site. Fine-loamy, mixed, thermic - Lithic Haplargid.

A 0-5 cm - Reddish yellow (7.5YR8/4) gravelly sandy loam, dark brown (7.5YR3/3) moist; weak medium platy structure; soft, friable, slightly sticky, slightly plastic; few medium and fine roots; neutral (pH 7.0); clear wavy boundary.

Bt1 5-18 cm - Yellowish red (5YR4/6) gravelly sandy clay loam, dark reddish brown (5YR3/4) moist; weak medium subangular blocky structure; soft, friable, slightly sticky, slightly plastic; few medium and fine roots; neutral (pH 7.2); abrupt wavy boundary.

R 18-30 cm - Vesicular basalt.

CHIMENEA SOIL: A representative pedon is found 480 feet north and 1240 feet each of the southwest corner of the site. Fine-loamy, mixed, thermic - Lithic Haplargid.

A 0-5 cm - Reddish yellow (7.5YR6/6) gravelly sandy loam, light brown (7.5YR6/4) moist; weak medium subangular blocky structure; slsightly hard, soft, slightly sticky, slightly plastic; few fine roots; neutral (pH 6.6); abrupt smooth boundary.

Bt1 5-15 cm - Yellowish red (5YR4/8) gravelly sandy clay loam, dark reddish brown (5YR3/4) moist; moderate medium subangular blocky structure; slightly hard, friable, sticky, plastic; few medium and fine roots; mildly alkaline (pH 7.5); clear wavy boundary.

Bt2 15-25 - Yellowish red (5YR4/8) gravelly sandy clay, dark yellowish red (5YR3/6) moist; moderate medium subangular blocky structure; hard, friable, sticky, plastic; few medium and fine roots; mildly alkaline (pH 7.8); clear wavy boundary.

Bt3 25-30 cm - Yellowish red (5YR4/8) very gravelly sandy clay loam, dark yellowish red (5YR3/6) moist; moderate medium subangular blocky structure; hard, friable, sticky, plastic; few medium and fine roots; mildly alkaline (pH 7.9); abrupt wavy boundary.

R 30-40 cm - Perthitic granite.

GREYEAGLE SOIL: A pedon representative of the Greyeagle soil is located 1200 feet south and 1200 feet west of the northeast corner of the site. Coarse-loamy, mixed, thermic-Lithic Torriorthent.

A 0-7 cm - Brown (7.5YR5/3) gravelly sandy loam, dark brown (5YR3/3) moist; weak medium subangular blocky structure; soft, friable, sllightly sticky, slightly plastic; few fine roots; mildly alkaline (pH 7.4); gradual smooth boundary.

C 7-20 cm - Brown (7.5YR5/3) gravelly sandy loam, dark brown (5YR3/3) moist; structureless massive; soft, friable, slightly sticky, slightly plastic; few fine roots; mildly alkaline (pH 7.6); clear wavy boundary.

R 20-30 cm - Vesicular basalt.

APPENDIX B

MINERALS, IDENTIFIED WITH X-RAY DIFFRACTION FROM PARENT MATERIAL

Anklam-Subophitic andesite

plagioclase	4
quartz	2
pyroxene	2
muscorite	1
biotite	1
olivine	1
koalinite	1

Lajitas - Vesicular basalt

plagioclase	5
pyroxene	2^+

Chimenea - Perthic granite

plagioclase	4
quartz	3
orthoclase	2
hematite	1^+
muscorite	1
biotite	1

Greyeagle - Vesicular basalt

plagioclase	4
pyroxene	3
hematite	2
geothite	1
koalinite	1

Lehmans - Llapilli breccia

plagioclase	4
orthoclase	3
quartz	2
biotite	1
geothite	1

5 = predominant	2 = small
4 = abundant	1 = trace
3 = moderate	0 = none or not detected

APPENDIX C

SAND SIEVE ANALYSIS

1 = A horizon
2 = Bt1 horizon
3 = Bt2 horizon
4 = Bt3 horizon
5 - C horizon

A = 0-2 cm of A horizon
B = Below 2 cm A horizon

Sample location	Particle size interval (ϕ) -0.5	0.0	0.5	1.0	1.5	2.0	2.5
Anklam				%			
1-A*	5	11	14	17	19	18	15
1-B*	6	13	15	15	18	17	14
2-A	8	15	16	16	16	14	11
2-B	10	23	18	16	14	10	9
3-A	17	19	20	19	13	13	-
3-B	11	20	18	15	15	11	11
4-A	10	16	17	17	15	13	13
4-B	9	18	17	16	15	13	12
5-A	3	10	14	18	20	17	17
5-B	5	16	19	19	18	14	10
6-A	7	19	17	19	16	12	17
7-1*	8	20	17	17	14	10	15
7-2*	6	25	20	17	13	9	10
7-3*	9	26	16	18	16	13	12
Lajitas							
1-A	18	22	16	13	11	9	10
1-B	13	21	16	15	13	10	11
2-A	13	19	17	15	13	11	12
2-B	10	25	17	13	10	8	8
3-A	15	21	17	12	12	10	13
4-A	9	15	14	14	15	15	18
4-B	15	22	14	11	12	12	14
5-A	13	22	18	15	13	9	13
5-B	15	25	17	15	11	9	9
6-A	12	23	18	15	12	11	10
6-B	15	26	19	12	10	8	9
7-A	13	13	21	18	15	11	9
7-B	8	20	18	17	15	10	11
8-A	12	22	17	14	13	11	12
8-B	17	19	16	14	12	11	11

Sample location	Particle size interval (ϕ) -0.5	0.0	0.5	1.0	1.5	2.0	2.5
Anklam	------------------	------------------	------------------	%	------------------	------------------	------------------
9-A	14	19	16	14	12	13	11
9-B	14	25	18	13	11	9	10
10-A	9	21	18	15	14	11	11
10-B	12	24	16	14	13	11	10
11-1	6	23	18	15	12	10	15
11-2	7	26	19	15	14	11	9
Chimenea							
1-A	18	24	13	12	12	11	10
1-B	22	27	16	11	9	8	7
2-A	7	25	19	16	13	9	10
2-B	13	23	18	14	13	10	10
3-A	9	23	18	15	13	8	12
3-B	11	21	18	15	14	11	9
4-1	20	22	19	12	8	6	6
4-2	8	32	18	13	12	7	9
4-3	8	26	21	17	14	7	8
4-4	5	24	21	18	15	8	9
Greyeagle							
1-A	9	15	15	14	13	11	14
2-B	11	23	20	16	12	9	8
3-A	10	18	16	15	14	13	14
3-B	8	18	18	16	15	12	13
4-A	11	15	19	16	14	11	10
4-B	8	15	26	17	14	13	9
5-A	9	21	18	17	14	10	10
5-B	24	31	18	12	7	4	4
6-A	12	19	18	16	13	11	12
6-B	6	6	19	17	15	13	14
7-1	3	20	20	19	15	9	13
7-2	2	20	21	19	15	10	13

APPENDIX D

MICROTRAC DATA

1 = A horizon
2 = Bt1 horizon
3 = Bt2 horizon
4 = Bt3 horizon
5 - C horizon

A = 0-2 cm of A horizon
B = Below 2 cm A horizon

Sample location	176	125	88	62	44	31	22	16	11	7.8	5.5	3.9	2.8
	Particle size interval ( )												
Anklam	%												
1-A*	10.5	18.3	20.8	15.2	9.3	5.4	5.6	3.5	1.4	3.2	2.1	2.0	2.1
1-B*	10.7	17.7	11.3	15.8	11.2	5.6	5.4	2.8	3.2	3.9	3.8	3.0	4.9
2-A	10.5	18.4	18.6	15.8	15.5	5.7	4.3	2.4	2.2	4.1	.0	.0	2.1
2-B	10.7	14.7	10.7	16.3	9.3	6.5	6.9	6.6	3.5	3.8	4.7	2.2	5.6
3-A	7.1	16.0	21.1	5.8	11.4	12.0	4.1	5.9	4.5	3.2	3.2	2.2	2.8
3-B	9.0	15.8	21.1	6.1	11.5	9.8	5.3	7.8	0.8	2.0	4.3	2.7	3.1
4-A	8.5	14.9	20.2	8.9	7.3	13.4	4.4	3.4	6.2	1.0	3.8	4.7	2.8
4-B	9.2	15.8	17.8	12.1	14.3	7.8	2.8	6.9	1.4	2.9	3.7	2.1	2.7
5-A	6.7	11.5	20.2	16.3	12.3	8.6	5.0	5.1	3.5	2.0	2.8	3.0	2.4
5-B	7.7	17.2	18.0	8.1	10.3	7.8	5.3	2.8	3.1	0.7	5.0	5.2	3.2
6-A	10.7	16.2	14.6	17.4	12.4	7.4	6.4	4.1	3.6	2.5	1.4	1.3	1.3
7-1*	8.6	13.9	20.7	16.4	13.8	8.7	4.5	5.3	0.4	1.8	2.8	1.2	1.2
7-2*	12.2	16.1	9.5	16.2	10.1	8.9	4.8	3.2	5.0	2.7	3.4	4.1	3.2
7-3*	9.7	14.7	16.8	3.7	7.5	7.7	7.0	8.8	4.4	4.4	5.4	4.7	4.5
Lajitas													
1-A	12.9	14.1	17.4	14.6	13.7	9.5	0.7	6.8	1.1	0.3	4.0	2.6	1.6
1-B	9.6	13.2	13.7	17.3	16.2	9.2	2.1	5.1	2.8	2.3	2.7	1.9	3.5
2-A	6.4	11.4	13.8	16.8	14.0	10.0	5.0	6.1	3.1	2.8	4.4	2.7	2.9
2-B	8.2	15.7	11.4	12.7	13.4	8.0	5.2	4.9	6.7	3.0	3.2	3.4	3.2
3-A	9.3	16.8	7.2	15.1	17.1	6.3	5.2	6.5	1.7	3.1	4.2	3.4	3.4
4-A	6.3	10.0	17.0	11.6	13.6	10.4	3.7	6.6	4.4	4.8	4.1	3.7	3.3
4-B	8.1	12.2	13.0	13.7	10.8	8.9	7.3	7.2	4.1	1.4	5.1	4.8	2.9
5-A	6.7	11.5	20.2	16.3	12.3	8.6	5.0	5.1	3.5	2.0	2.8	3.0	2.4
5-B	10.2	14.1	14.8	16.3	11.5	8.4	4.7	7.3	2.7	2.5	3.1	1.2	2.6
6-A	10.7	16.2	14.6	17.4	12.4	7.4	6.4	4.1	3.6	2.5	1.4	1.3	1.3
6-B	7.4	12.3	9.4	12.0	14.9	5.6	7.7	8.3	2.6	5.4	5.3	4.2	4.2
7-A	8.7	15.7	10.7	16.2	15.6	8.3	5.4	7.3	1.3	2.1	3.9	1.7	2.6
7-B	12.2	16.1	9.5	16.2	10.1	8.9	4.8	3.2	5.0	2.7	3.4	4.1	3.2
8-A	9.0	16.3	7.1	11.9	13.3	6.6	7.1	8.2	2.9	3.4	5.6	4.0	4.0
8-B	4.4	16.3	14.6	12.3	11.0	9.3	4.9	7.4	4.1	5.8	6.4	3.2	5.8

Sample location	Particle size interval ( )												
	176	125	88	62	44	31	22	16	11	7.8	5.5	3.9	2.8
<u>Anklam</u>							%						
9-A	12.7	20.7	12.3	15.4	14.1	6.7	2.9	6.1	0.4	0.3	3.6	2.7	1.5
9-B	7.3	14.1	11.8	15.0	13.3	5.3	7.3	5.4	2.9	4.6	4.4	3.7	4.2
10-A	12.5	19.3	15.1	7.4	9.6	6.5	7.3	6.2	2.2	2.4	3.5	4.5	2.8
10-B	12.1	22.5	13.2	6.4	9.1	7.9	4.9	4.3	5.8	1.7	3.9	4.7	3.6
11-1	10.7	18.7	21.3	10.5	9.8	11.0	3.5	4.5	2.4	0.2	2.5	2.4	1.9
11-2	11.1	17.4	17.2	9.8	9.4	11.7	6.8	5.1	0.7	3.1	2.5	1.1	3.4
<u>Chimenea</u>													
1-A	6.7	11.1	19.3	17.4	9.1	6.3	5.5	4.4	2.8	4.6	4.0	3.3	4.9
1-B	4.4	8.6	12.9	13.6	11.4	8.7	4.5	7.7	4.4	4.4	6.9	5.4	6.5
2-A	10.6	12.5	18.6	16.3	13.0	10.3	0.3	5.4	3.8	0.9	2.9	2.9	1.9
2-B	8.7	13.0	15.7	16.7	14.4	6.9	5.4	5.8	1.1	3.4	2.9	2.4	2.8
3-A	9.8	13.6	16.8	16.3	12.4	8.2	3.7	7.1	0.9	0.4	4.6	3.4	2.2
3-B	10.6	11.3	10.4	19.1	12.1	7.0	5.6	6.4	2.6	4.9	4.0	1.1	4.5
4-1	16.7	19.0	13.0	19.5	8.5	4.7	5.6	4.2	1.4	1.7	1.9	0.9	2.4
4-2	13.3	10.1	12.5	14.6	16.0	10.4	1.7	7.8	3.1	0.0	3.5	3.2	3.2
4-3	9.0	12.5	11.5	10.0	9.9	5.4	7.1	7.6	2.8	4.4	7.1	4.9	7.2
4-4	10.7	10.3	16.1	10.4	7.5	6.9	2.6	6.8	6.0	1.9	7.1	7.9	5.2
<u>Greyeagle</u>													
1-A	5.5	11.1	15.6	12.1	11.4	10.8	7.8	7.4	4.4	2.1	4.0	3.8	3.4
2-A	7.1	14.5	12.4	13.2	16.3	10.0	6.2	3.5	3.6	2.4	2.9	3.0	2.5
3-A	8.1	14.6	14.2	11.8	13.8	9.0	6.3	7.7	1.8	1.6	3.5	3.4	3.4
3-B	6.5	11.6	18.1	12.0	10.9	10.2	5.4	8.3	2.1	1.7	4.5	4.2	3.8
4-A	10.0	13.0	11.7	13.9	14.9	13.3	5.4	5.3	2.5	2.2	2.7	2.0	2.5
4-B	1.3	5.4	8.1	13.4	17.0	12.2	4.8	6.2	5.8	5.1	5.0	4.8	5.2
5-A	4.6	11.2	11.7	15.7	17.6	12.2	5.4	7.0	2.5	1.4	4.3	3.1	2.8
5-B	1.9	5.9	9.6	13.1	13.6	13.0	7.7	8.7	4.2	5.1	6.2	4.5	5.7
6-A	6.3	10.6	10.9	14.7	12.7	10.5	7.8	6.8	4.2	3.3	4.1	3.8	3.7
6-B	3.0	9.4	10.5	11.4	14.0	10.9	5.5	8.8	4.1	4.7	5.9	4.5	6.8
7-1	7.1	8.2	12.5	15.9	11.6	10.0	7.6	6.7	3.9	6.1	4.2	1.5	4.2
7-5	4.8	8.7	11.2	10.5	14.4	11.3	6.3	8.5	5.5	4.5	4.9	4.5	4.1

APPENDIX E

LIGHT MINERALS - RESULTS OF POINT COUNTS

1 = A horizon
2 = Bt1 horizon
3 = Bt2 horizon
4 = Bt3 horizon
5 - C horizon

A = 0-2 cm of A horizon
B = Below 2 cm A horizon
R = Bedrock

Sample location	Plagio-clase	Clino-pyroxene	Opaques	Groundmass fragments	Quartz	Perthite	Olivine	Mica
Anklam				%				
1-A*	25	40	11		4			
1-B*	17	39	10		1			
2-A	14	34	11		4			
2-B	23	51	11		4			
3-A	22	43	15		8			
3-B	16	45	12		4			
4-A	18	52	11		3			
4-B	11	41	20		6			
5-A	26	45	8		<1			
5-B	21	55	15		3			
6-A	21	53	11		2			
7-1*	8	41	11		0			
7-2*	16	48	48		4			
7-3*	14	53	13		3		2	
R*	51	55	10		0		6	
Lajitas								
1-A	1	9	4	78	2			
1-B	3	5	3	70	8			
2-A	2	2	5	56	6			
2-B	<1	10	3	72	<1			
3-A	2	13	4	50	2			
4-A	1	5	3	56	3			
4-B	<1	7	2	53	4			
5-A	8	9	2	82	4			
5-B	<1	4	4	66	3			
6-A	8	7	6	59	5			
6-B	3	8	5	72	4			
7-A	1	6	1	75	5			
8-A	2	6	2	74	2			
8-B	1	6	4	57	9			
9-A	2	11	4	52	4			

Sample location	Plagio-clase	Clino-pyroxene	Opaques	Groundmass fragments	Quaartz	Perthite	Opivine	Mica
Anklam				%				
9-B	3	7	3	61	7			
10-A	4	10	5	64	3			
10-B	3	8	2	68	5			
11-1	2	8	4	60	3			
11-2	3	8	3	67	6			
R	18	8	4	65	2			
Chimenea								
1-A	1		5		13	53		5
1-B	<1		4		24	60		4
2-A	<1		3		16	56		4
2-B	3		3		16	55		3
3-A	2		3		20	15		5
3-B	3		4		17	60		2
4-1	1		4		18	52		4
4-2	2		4		21	54		4
4-3	1		4		29	56		3
4-4	2		14		25	38		5
R	7		2	64	21	42		9
Greyeagle								
1-A	3	6	3	75	10			
2-A	2	3	2	57	15			
3-A	1	2	2	63	18			
3-B	1	9	3	68	12			
4-A	<1	6	5	60	9			
4-B	<1	4	3	68	11			
5-A	<1	9	3	64	17			
5-B	1	6	2	78	10			
6-A	1	2	2	83	7			
6-B	<1	3	6	60	13			
7-1	2	5	2	66	11			
7-5	<1	2	4	65	14			
R	8	6	30	58	-			

APPENDIX F

HEAVY MINERAL COMPOSITION OF THE FINE SAND (125-62 UM) RESULTS OF POINT COUNTING

1 = A horizon
2 = Btl horizon
3 = Bt2 horizon
4 = Bt3 horizon
5 - C horizon

A = 0-2 cm of A horizon
B = Below 2 cm A horizon

a = Epidote-clinzoisite-zoisite
b = Magnetite and ilmenite

Sample location	Zircon	Rutite	E-C-Z[a]	Sphene	Opaques[b]	Leu-coxene	Biotite	Basalt hnd	Hnd	Hema-tite	Hyper-stene
Anklam						%					
1-A*	13	6	10	11	3	3	1	9	25		
1-B*	8	3	11	5	3	3	4	11	32		
2-A*	16	5	13	9	2	2	2	6	26		
2-B*	12	3	11	13	3	3	3	6	24		
3-A*	7	3	19	6	3	3	3	5	29		
3-B*	8	2	20	7	1	3	4	3	28		
4-A*	6	5	18	14	3	2	1	4	33		
4-B*	4	3	20	9	2	4	2	5	30		
5-A*	8	7	22	8	3	3	3	6	29		
5-B*	10	6	19	7	8	3	4	3	21		
6-A	7	7	17	10	6	4	3	5	14		
7-1	9	6	18	11	3	4	3	6	25		
7-2	8	4	19	12	2	3	3	6	25		
7-3	3	11	17	20	3	4	2	1	24		
Lajitas											
1-A	8	9	48		19	3	1	1	10	4	5
1-B	5	3	32		20	7	<1	2	9	2	6
2-A	6	4	30		13	6	<1	2	8	2	6
2-B	8	9	28		21	7	<1	<1	6	3	2
3-A	5	5	23		16	14	3	3	11	1	1
4-A	7	2	25		18	10	1	3	8	1	3
4-B	8	7	20		19	6	<1	4	7	2	4
5-A	11	8	21		23	11	<1	2	3	4	3
5-B	9	10	17		14	10	1	3	5	<1	3
6-A	11	9	20		14	11	1	2	12	<1	1
6-B	11	14	25		14	8	2	3	9	1	<1
7-A	7	5	28		13	8	<1	3	8	2	2
8-A	9	10	32		11	4	1	2	8	<1	2
8-B	10	13	37		15	9	<1	3	7	2	2
9-A	9	5	39		16	11	2	3	16	4	2

Sample location	Zircon	Rutite	E-C-Z[a]	Sphene	Opaques[b]	Leu-coxene	Biotite	Basalt hnd	Hnd	Hema-tite	Hyper-stene
Lajitas					%						
9-B	8	3	40		15	10	<1	4	15	3	2
10-A	8	6	36		14	8	1	6	14	3	<1
10-B	8	7	35		14	9	2	5	8	3	<1
11-1	8	6	30		11	9	1	2	9	3	3
11-2	7	7	31		16	7	1	3	9	2	2
Chimenea											
1-A	8	4	23	6	22		3	5	18		3
1-B	7	5	30	4	8[A]		2	3	19		2
2-A	10	10	29	3	17		<1	3	18		3
3-A	4	4	25	2	24		1	3	15		1
3-B	6	6	28	6	23		<1	3	12		4
4-A	5	12	24	5	25		<1	<1	14		<1
4-B	6	15	32	8	29		2	2	18		<1
5-A	5	13	12	9	28		<1	6	5		2
5-B	6	14	14	7	25		<1	1	13		3
6-A	8	14	25	6	20		1	4	17		<1
7-1	8	5	29	6	28		4	3	16		<1
7-2	5	4	26	5	22		1	3	5		0
7-3	5	4	11	8	4		0	1	3		0
7-4	6	11	14	5	26		0	<1	1		3
Greyeagle											
1-A	6	4	26	10	20[B]	1	1	11	1	3	1
2-A	6	3	19	11	20	5	<1	9	2	1	5
3-A	6	3	21	7	23	4	1	11	3	5	4
3-B	9	4	20	11	17	3	<1	9	4	4	3
4-A	6	3	28	17	19	2	<1	11	6	3	2
4-B	5	4	17	21	16	3	1	10	4	2	3
5-A	3	6	17	17	20	4	3	9	3	3	4
5-B	5	4	21	10	13	3	2	11	5	4	2
6-A	6	3	21	13	14	2	<1	8	2	3	3
6-B	6	7	20	15	20	3	2	4	12	1	4
7-1	6	4	18	14	18	4	<1	2	8	1	2
7-5	5	9	19	16	17	4	<1	3	10	2	4

APPENDIX G

PERCENTAGE SAND, SILT AND CLAY

	Sand	Silt	Clay	Texture
	----------------------	%	----------------------	
Anklam				
1-A*	72	20	7	Sl
1-B*	65	22	13	Sl
2-A	63	17	16	Sl
2-B	67	17	18	Sl
3-A	65	17	13	Sl
3-B	68	19	13	Sl
4-A	66	22	--	Sl
4-B	63	25	9	Sl
5-A	74	14	18	Sl
5-B	73	16	5	Sl
6-A	66	21	15	Sl
7-1*	59	23	10	SCl
7-2*	53	20	26	SCl
7-3*	59	16	24	SCl
Lajitas				
1-A	74	17	5	Sl
1-B	65	22	9	Sl
2-A	64	23	9	Sl
2-B	63	20	13	Sl
3-A	49	39	9	l
4-A	52	28	7	Sl
4-B	56	27	10	Sl
5-A	64	20	8	Sl
5-B	63	19	10	Sl
6-A	53	23	23	SCl
6-B	51	18	31	SCl
7-A	73	16	12	Sl
7-B	64	19	16	Sl
8-A	62	31	5	Sl
8-B	54	36	7	Sl
9-A	70	18	10	Sl
9-B	65	26	9	Sl
10-A	72	18	9	Sl
10-B	77	12	11	lS
11-1	62	23	14	Sl
11-2	55	22	21	SCl

1 = A horizon
2 = Bt horizon
3 = Bt2 horizon
4 = Bt3 horizon
5 = C horizon

A = 0-2 cm of a horizon
B = below 2 cm of a horizon

	Sand	Silt	Clay	Texture
	%			
Chimenea				
1-A	67	21	13	S
1-B	65	21	13	S
2-A	66	19	9	S
2-B	58	20	13	S
3-A	65	19	13	S
3-B	65	16	15	S
4-1	77	11	11	S
4-2	61	14	23	SC
4-3	54	10	37	SC
4-4	61	9	29	SC
Greyeagle				
1-A	45	37	10	l
2-A	63	29	9	Sl
3-A	54	33	10	Sl
3-B	56	31	8	Sl
4-A	56	35	6	Sl
4-B	46	41	8	l
5-A	55	35	7	Sl
5-B	59	26	14	Sl
6-A	54	35	8	Sl
6-B	52	37	10	Sl
7-1	55	30	13	Sl
7-5	49	35	16	l

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