THE INFLUENCE OF PARENT MATERIAL (GRANITE AND SCHIST) ON PHYSICAL AND CHEMICAL PROPERTIES OF SOILS ON THE SYFERKUIL EXPERIMENTAL FARM

BY

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DECLARATION

I, Lebea Maribeng, declare that this mini-dissertation is my own work, except where specific literature and acknowledgement are made to the work of others. The information contained herein has not been conferred, published neither awarded for a degree nor diploma at any institution of higher learning.

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ABSTRACT

The influence of parent material on physical and chemical properties of soil was studied on granite and schist derived soils on the Syferkuil Experimental Farm, situated in the Mankweng area of the Limpopo Province of South Africa. A total of 49 samples of virgin soils were collected, where granite soils constituted 26 samples and schist soils 23. The study design that was used is cross-sectional. The samples were analysed for physical and chemical properties. The physical properties of granite and schist soils were determined as percentages coarse sand, percentages medium sand, percentages fine sand, percentages very fine sand, percentages silt and percentages clay, whilst the chemical properties were determined as concentrations (cmol (+) kg^{-1}) of Na, Mg, Ca, K ,ESP, CEC and P (mg kg^{-1}), as well as pH. Statistical analysis of the results was performed by application of the Unpaired Student's T Test, with the level of significance at $p<0.05$. The results showed that soils derived from granite had significantly higher coarse and medium sand fractions than schist soils; whereas schist soils were significantly higher in fine sand, very fine sand, silt and clay. The concentrations of Na, Ca, ESP and P, as well as CEC and pH in schist derived soils were higher than in granite derived soils although the differences were insignificant. However, significant differences occurred in K and Mg concentrations where schist derived soils had higher concentrations than granite derived soils. However, the concentrations of nutrient elements were found to be insufficient for proper production in agriculture. The sodium concentration was found to be low enough to not lead to sodic soil conditions. It was concluded that both granite and schist soils can be used for agriculture but require careful management because both soils indicated poor nutritional status.

1. INTRODUCTION

1.1 GENERAL

Geological parent materials, such as granite and schist, are the primary materials from which soils are formed. Granite is a type of igneous rock which forms deep in earth's crust as a result of cooling magma (Birot, 1950). Granite is light in colour and composed of large crystals of quartz, feldspars and mica (USDA, 1993).

Granite has coarse-grained minerals, mainly quartz which are rather resistant to weathering (Purves and Blyth, 1969). The coarse grained texture and resultant low CEC of soils developed on granite promotes leaching of cations such as potassium, magnesium and calcium. The leaching of essential cations (potassium, magnesium, calcium, sodium etc.) result in the soil colloids adsorbing hydrogen ions which results in low pH and causing acidity within such soils (Camps and Macia, 1996).

Smith (1990) showed the susceptibility of red soils developed on granite to crusting. Susceptibility of such soils to crusting can be stabilized as weathering intensifies, taking rainfall as a measure of weathering. Smith (1990) showed that increased rainfall leads to more advanced soil formation, thus leading to more stable soils which are less prone to erosion. However, the soils developed on granite and schist on the Syferkuil Experimental Farm are exposed to semi-arid climatic conditions, with a very low annual rainfall and this would lead to less advanced soil formation and thus less stable soils which are more prone to erosion (Smith, 1990).

Schist is a term that applies to any of several metamorphic rocks in which crystals of predominating minerals are aligned in parallel lines, forming a large number of close, well developed foliations (Bahnemann, 1973). Pressure and heat transform the original sedimentary rock into new forms and schist is formed (Venkatesh *et al*., 2001). Schist can be defined as a metamorphic rock, with medium sized grains.

Soils that develop on schist are generally characterised by instability of minerals (Dorr and Eschman, 1991). The mineralogical instability of schist causes it to weather readily. Schistose rocks break easily along lamination (foliation) of schistocity (Dorr and Eschman, 1991).

1.2 OBJECTIVES

The aim of this study was:

To study and compare the chemical and physical properties of soils formed on granite and schist on the Syferkuil Experimental Farm.

1.3 JUSTIFICATION OF RESEARCH OBJECTIVES

The widespread intensive cultivation on soils developed on granite and the consequential land degradation problems indicated the necessity for basic research of the characteristics of these soils. Such studies aid the development of appropriate management for soils developed on this parent material.

The nature of the parent material has a decisive effect on the properties of soils. Properties of the parent material that exert a profound influence on soil development include texture (physical property), mineralogical composition and chemical properties as well as the soil morphology.

Improving soil quality and productivity is a primary objective of soil science, hence, for the benefit of agriculture, is of vital need that research be conducted on land that is to be used for agricultural practices. Moreover, the chemical and physical properties within soils play a big role towards soil fertility and management.

There is a need for thorough investigations on chemical and physical factors affecting land forms and this can be achieved by first identifying the major factor of soil formation, which is the parent material, and secondly by identifying the characteristics (physical and chemical) of the soil developed on the parent materials.

1.4 GENERAL PROBLEM

There are very few publications of studies conducted on schist developed soils. In most of the reviewed works, it was found that the mineralogical basis of different schist rocks was mostly investigated. From the literature of soil and geological studies, it was only shown that schist soils are of better fertility than granite derived soils. A lot of work still needs to be conducted on schist derived soils, as well as on granite derived soils.

2. LITERATURE REVIEW

2.1 INTRODUCTION

Soil formation is influenced by four factors, which interact with the parent material to produce the soil profile during the soil formation process (Harlan *et al*, 1977). Climate, time, topography, organisms (both plants and animals) and the parent material interact amongst each other to develop a vertical section of the soil called a soil profile.

The soil profile begins at the surface and extends down to the (unconsolidated or consolidated) underlying material (Brady and Weil, 1998). A soil profile is made up of segments called horizons. As a major factor of soil formation, the parent material determines the mineralogical composition and contributes largely to the physical and chemical characteristics of a soil (USDA, 1994). It is important to research the chemical and physical composition of the soils in order to outline a full survey of soil nutrition. In this study, granite and schist parent materials were selected to be investigated.

Igneous rock such as granite is found scattered in most of the Limpopo areas, as well as neighbouring provinces such as Mpumalanga and Gauteng (Verster, 1990a). Most of the land in Syferkuil Farm is covered with sandy soils, underlain by granite parent material in most areas, as well as schist in a few areas. The scattered rocks of granite are found in other parts of Limpopo province such as Giyani, Timbavati and Pundmaria where they represent plutons which are younger than the surrounding rocks in which they were emplaced (Barton *et al.*, 1986).

Depending on various climatic conditions, temperature and rainfall, different schist rocks form (Duff, 1993). Each schist rock comprises of different chemical composition and minerals (David and Ming, 2001). The degree of nutrition in soils from each of these schist rocks will be different, depending on the type of the minerals comprising the rock in question, e.g. graphite schist, augite schist, chlorite schist, micas, tourmaline schist, gabbro schist, green stone schist, diorite schist, glaucophane schist, etc.

Munnik *et al.* (1984) attempted to quantify the soil site relationship and still very little research has been conducted in South Africa, especially on granite and schist derived soils. Verster (1990b) reported that typical granitic toposequences of soil occur only when both high densities of dolerite dykes and the more granitoid rock types are absent, and is exclusively associated with “unconsolidated” gneiss and granite. In areas where the more mafic types such as the ultra mafic schist dominate, reddish soils are dominant whilst shallow profiles are common (Verster, 1990b).

“Since the advent of pedological study, the search for a pattern in the distribution of soil on the land surface has been a key issue. According to other studies, the close relationship between soils and land forms as well as pedology and geomorphology is gradually being established” (Glassman *et al.,* 1980; Coventry, 1982; Verster, 1987). There is a need for studies to be conducted on schist and granite derived soils to implement viable soil management as well as good production on such soils (Walker *et al.,* 1968; Carter and Pearen, 1985; Verster, 1987).

2.2 GRANITE

Granite is an igneous rock and is formed from magma. Granite magma has many potential origins but it must intrude other rocks (Harvey and Robert, 1996). Most granite intrusions are emplaced at depth within the crust, usually greater than 1.5 km and up to 50 km depth within thick continental crust. Granite is a common and widely occurring type of intrusive, felsic, igneous rock (Harvey and Robert, 1996).

Granites are usually a white, black or buff colour and are medium to coarse grained, occasionally with some individual crystals larger than the ground mass forming a rock known as porphyry (Ovalles and Collins, 1986). Granites can be pink to dark gray or even black, depending on their chemistry and mineralogy (Harvey and Robert, 1996)

Outcrops of granite tend to form tors, rounded massifs, and terrains of rounded boulders cropping out of flat, sandy soils (Ovalles and Collins, 1986). Granites sometimes occur in circular depressions surrounded by a range of hills like the granite rocks in the Syferkuil Farm. The average density of granite is 2.75 $g{\cdot}cm^{-3}$ with a range of 1.74 $g{\cdot}cm^{-3}$ to 2.80 $g{\cdot}cm^{-3}$ (Harvey and Robert, 1996).

Granite primarily consists of orthoclase and plagioclase feldspars, quartz, hornblende, muscovite and/or biotite micas, and minor accessory minerals such as magnetite, garnet, zircon and apatite. Rarely, a pyroxene is present. Very rarely, iron-rich olivine, fayalite, occurs (Harvey and Robert, 1996). True granite according to modern petrologic convention contains both plagioclase and alkali feldspars. When a granitoid is devoid or nearly devoid of plagioclase the rock is referred to as alkali granite. When a granitoid contains <10% orthoclase it is called tonalite. Pyroxene and amphibole are common in tonalite.

A worldwide average proportion of the different chemical components in granites, in descending order by weight percent, is: SiO_2 (72.04 %), Al_2O_3 (14.42 %), K_2O (4.12 %), Na_2O (3.69 %), CaO (1.82 %), FeO (1.68 %), Fe_2O_3 (1.22 %), MgO (0.71%), TiO_2 (0.30 %), P_2O_5 (0.12 %), MnO (0.05 %), (Harvey and Robert, 1996).

Granitic rocks and their derived soils cover a large % of land in most African countries e.g. in Zimbabwe, South Africa, Swaziland, Nigeria (Purves and Blyth, 1969; Du Toit, 1954). Due to their wide distribution, a soil study will have important implications in the field of agriculture, ecology, engineering and conservation. The status of weatherable minerals of granitic rocks is such that a typical soil should at least consist of sandy loam at the surface, over sandy clay loam at lower depths (Purves and Blyth, 1969).

Verster (1990b) studied the geomorphology and soils derived from granite and showed the granitiod distribution in various areas near Kruger National Park, in Limpopo province. Generally, the geology of the Phalaborwa area where the study was conducted consists of granitoid rocks (gneiss, migmatite, granite) and greenstone belt rocks (predominantly amphibole and schist). Scattered rocks of granite were also identified in Giyani, and Letaba River, in Limpopo province (Barton *et al.,* 1986).

In the Makhwusi area (Limpopo province) the soils developed on granite were generally shallower and displayed poor a horizon development. The deeper soils only occurred in association with mafic rocks, interfluvial areas with low relief or alluvial deposits along drainage lines (Verster, 1990b).

In Houtboschrand, in the Limpopo province, the granitoid rocks which underlie the area consist mainly of tonalic gneiss, migmatite and amphibolite (Verster, 1990b) and as a result, the soils in Houtboschrand were generally loamy or clayey and red or dark. The yellowish sandy soils (Glenrosa series) were associated with crest and midslopes which occurred in localized areas where gneiss was dominant (Verster, 1990b). The Houtboschrand land is characterized by the occurrence of predominantly shallow, poorly developed yellowish to grayish sandy soils of the Glenrosa soil form (Verster, 1990b).

The largest single region of granite was discovered in the Southern part of Zimbabwe (former Rhodesia). It continues eastward in to former “Portuguese Territory”, southward in to former “Bechuana land” and across Limpopo in to “Transvaal”, where it stretches through to the lowveld of the eastern part of the former Transvaal Province and extends as a broken belt through Swaziland and Kwa-Zulu Natal (former Zululand and Natal) (Du Toit, 1954).

In the Cape Town area, granite extends the full length of the Peninsula and is almost throughout grey phorphyritic biotite granite with twinned crystals of white microcline-perthite (Cohen, 1874; Schwarz, 1913). In other parts of the Cape area e.g. Kalabas Kraal Station, soils were sandy resulting from coarser to medium grained biotite-muscovite granite (Cohen, 1874; Schwarz, 1913).

Soils derived from granite have fewer nutrient elements (Hamdan and Burnham, 1997). The mineralogical composition of soils derived from granite is greatly affected by the type of weathering (ARC, 1995). During some soil surveys, it was found (as a major possibility) that soils derived from granite were actually losing clay as a result of dispersion (Brady, 1984; Bohn *et al.* 1985). This loss of clay, in most cases, was due to other soil forming processes as well as normal erosion (Purves and Blyth, 1969). This weathering trend results in low base status within these granite soils.

Compared to schist, granite has less nutrient elements, as it is dominant in quartz (Birkeland, 1999), which makes it coarser. Elements such as iron, calcium, magnesium, potassium and sodium are easily leached (depending on rainfall) due to the low clay content found in such soils (Allen and Fanning, 1985; Moshia, 2004)). If the parent material is low in soluble ions, water moving through the soil removes the bases and substitutes them with hydrogen ions, making the soil acidic and unsuitable for agriculture practices (Price *et al.*, 1975). Granite varies in composition. It is mainly characterized by sand, which is porous and permeable, and results in poor nutrition (Streckeisen, 1967).

Barnes (1981) showed the residual effects on granite soil productivity of various treatments on grass leys, including level of nitrogen application, intensity of grazing and duration of ley, which were assessed in a series of three experiments by means of test crops of maize and measurement of soil chemical properties. Test crop yields increased with increasing grazing intensity and with an increase in the duration of the leys from two to four years. These increases appeared to be associated with increases in nitrogen supply and levels of nutrient bases in the surface soil. Overall, the experiments provide evidence that grazed nitrogen-fertilized leys facilitate the maintenance and improvement of the productivity of granite-derived sandy soils.

Olowolafe and Dung (2000), conducted a study to assess the nutritional state of soils (Entisols, Inceptisols, Alfisols and Ultisols) formed on biotite-granites on the Jos Plateau, Nigeria and recommended management practices for sustainable agricultural productivity of the soil. Analysis of the chemical properties showed that the soils have low to very low total N status, P deficiency and low to very low Ca as well as poor structure. Exchangeable K, Mg and micronutrients (Cu, Zn and B) deficiencies do occur but their deficiencies were not general (Olowolafe and Dung, 2000).

Johnson-Maynard *et al*. (1994) indicated that weathered granitic rock retains structural features of the hard rock, including joint fractures, but also has porosity generated as a result of weathering of primary minerals, clay formation, and root invasion. This study evaluated the physical and hydraulic properties of moderately and highly weathered granitic rock. Water retention data indicated that ~50% of the water held at saturation is drained at -100 cm head. Effective pore size distributions calculated from water retention data indicated that 25% of the total porosity was associated with pores >100 μm diameter (Johnson-Maynard *et al*., 1994)

Physical, chemical, and mineralogical properties of soils developed on granitic rocks under different climatic conditions in Portugal were studied, and the soils classified (Martins *et al*., 1995). Mean annual rainfall, the climate parameter best correlated with the variability of soil properties, was analyzed in terms of relationships with several soil properties (organic C content, soil pH, nature of the exchange complex, SiO_2: Al_2O_3 ratio, selective extractions of Fe and Al, P retention, content and nature of clay fraction). It was found that the amount of rainfall was corresponding to 800 and 1200 mm, and appeared to separate soil according to their characteristics. In wetter areas amorphous Al and P retention occurred in large amounts and were correlated with each other.

Vogel (1992) showed that, in granite soils, applied fertilizer nutrients and clay particles are lost through leaching. This further aggravates the already very low soil fertility status. Because of their high bulk densities (1.7 mg m^{-3}) and high penetration resistance (up to 3000 kPa), these granitic soils only have limited rooting depth (max. 500 mm). The high soil compaction also renders tillage difficult. This is worsened by the presence of *in situ* formed stone lines at shallow depths. Given their poor properties, these granitic soils require careful management and a minimum amount of cultivation.

2.3 SCHIST

Potassium is present in albite in low % and muscovite in low to medium levels. Microcline and biotite constitute medium to higher levels of potassium, while plagioclase and scapolite both show medium to higher levels of potassium availability. There is a higher % of potassium which is present in orthoclase (Mortimer and Roser, 1992; Glazner and Donald, 1979).

Magnesium is present in minerals like talc, chlorite, tremolite/actinolite hornblende and biotite in low %. The medium to high % of magnesium is present in minerals such as anthophyllite, almandite and biotite, augite and diopside (Mortimer and Roser, 1992; Glazner and Donald, 1979).

Sodium is present in minerals like albite, in low %, and in plagioclase in medium to high %. Other elements available in some of the mentioned minerals are aluminium, silicon and iron. These elements are present in various minerals with different % of availability (Mortimer and Roser, 1992; Glazner and Donald, 1979).

The term schist refers to the foliation of rock layers during rock formation. There are several aspects to be met for a rock to qualify as schist (Dipak-Dutta *et al.,* 1999). The structure of a schist rock resembles that of stratified rock but differs in that schist has:

1. “Crystalline and granulitic structure of minerals.”

2. “A striking want of continuity in the folia, which thicken out and die away, reappearing after an interval on the same or different plane.”

3. “A peculiar and a very characteristic welding of the folia into each other. The crystalline particles of one layer being so integrated with those layers above and below it that the whole tend to cohere as a tough, not easily effusive mass (Dipak-Dutta *et al.,* 1999).”

Schist breaks easily into thin layers parallel to the schistocity. It is commonly rich in quartz and contains some feldspar and carbonates (Norton and Franzmeier, 1978). Schist has the ability to release the nutrient elements due to its weatherable character. Consequently, soils that are derived from schist have a better nutrition value than granite formed soils.

The mineral composition of schist entails quartz in less density, compared to granite (Gosh and Tamgade, 1991). Other minerals found in schist are feldspars and mica, sometimes chlorite, garnet, hornblende, pyrite, tourmaline and other related minerals. All these characteristics are sufficient to indicate a greater difference between schistose rocks and ordinary stratified formation, in which the strata lie in continuous flat, parallel and more or easy separable layers.

The parent rock for schist is phyllite. Schist is a medium-grade metamorphic rock, so it has experienced more heat and pressure than both slate and phyllite. The main difference between phyllite and schist is that foliation is much more distinct due to the recrystallization of mica and chlorite mineral crystals. These larger crystals tend to reflect light very well, so schist usually has a higher luster than phyllite and slate (Gosh and Tamgade, 1991).

Samples of schist often contain some larger, unusual mineral crystals such as garnet and tourmaline, which are generally referred to as porphyroblasts. Such minerals can form as heat and pressure transform several different minerals into a new and distinct mineral, a process referred to as neomorphism. There is a variety of schists, each named for the dominant mineral that comprises that particular metamorphic rock specimen (Gosh and Tamgade, 1991).

Metamorphic rock such as schist, which is a relic of older greenstone belt within gneiss, occurs frequently in the northern area of the Limpopo province, especially in areas dominated by granite and gneiss parent materials (Du Toit, 1954). Schist and other metamorphic rocks such as amphibole, form red sandy clay loam soils of the Hutton, Shortlands, Glenrosa and Swartland soil forms in Limpopo province where it occurs. Such areas are undulating and lack distinctive catenary sequence of soils that are found in pure granite-gneiss area (Verster, 1990a). On the Syferkuil Experimental Farm schist derived soils were found to belong to the Hutton form, surrounded by Glenrosa and Shortlands soils.

Webb *et al.* (1991) showed results of research on soil-landscape relationships in a first-order catchment and a fifth-order catchment of the Waipori River, Australia. The soils were formed mainly from loess and loess−colluvium derived from schist, with limited inclusions of rock material from under lying schist bedrock. The tests were done on these soils and the results showed that all soils were acidic, strongly leached, and moderately weathered.

Camps and Macia (1996) showed that soils developed from base-rich parent material such as biotitic schist, generally had more abundant extractable Fe and Al, and other basic elements were expected to be present in high quantities than in soils developed from more acidic parent materials.

2.3.1 DIFFERENT SCHIST ROCKS AND THE MINERALS THEY PRODUCE

Graphite-schist is a name given to schistose bands, which probably represent what once were carbonaceous shales but are now phyllites or mica schists. They will have a black colour from graphite with which they are filled. The type of soil derived from graphite-schist will inherit the same properties of the same parent material unless disturbed by other environmental factors (Mortimer and Roser, 1992; Glazner and Donald, 1979).

Augite schist is a fine-grained aggregate of pale or dark green augite, with sometimes quartz. Certainly, the soil derived from this parent material will represent a fine to coarse textured variety of soil, with the coarse grains dominated by quartz (Mortimer and Roser, 1992; Glazner and Donald, 1979).

Chlorite schist is a scaly granular or granular schistose aggregate of some chloritic minerals, usually with quartz (Mortimer and Roser, 1992; Glazner and Donald, 1979).

Mica-schist is the common schistose rock. It represents a schistose aggregate of quartz and mica. Soil derived from this parent material range from basic to acidic, depending on the % of potassium, magnesium, iron and aluminium within the soil. The soil is mostly black. The characteristics of schist rock that is present in the Syferkuil Farm indicate the characteristics of mica schist (Mortimer and Roser, 1992; Glazner and Donald, 1979).

Other types of schist that were discovered are: gabbro, greenstone, diorite, epidiorite, amphibolite and serpentine schist. More schist rocks can be named depending on the dominanting mineral within the schist rock (Mortimer and Roser, 1992; Glazner and Donald, 1979).

Tourmaline-schist is represented by a blackish, finely granular, quartzone rock bearing soil with the same characteristics. The soil formed on this parent material consists of needles of blackish colour, as a result of black tourmaline (Mortimer and Roser, 1992; Glazner and Donald, 1979).

3. MATERIALS AND METHODS

3.1 DESCRIPTION OF THE STUDY AREA

Soil samples were collected at randomly selected sites on the Syferkuil farm of the University of Limpopo. The farm is situated in the Mankweng area (Turfloop) in the Limpopo Province, South Africa (29.5 ^{0}N and 23.8 ^{0}E, 600 m above sea level). The farm consists mostly of savanna vegetation, characterized by continuous grass land mixed with several Acacia species. The farm is exposed to semi-arid climatic conditions with temperatures ranging between 14 ^{0}C during winter periods and 35^{0}C in summer, experiencing about 400mm of summer rainfall.

3.2 SOIL SAMPLING

Representative sites were identified for granite and schist parent materials respectively and the samples were collected on virgin soil of Hutton and Glenrosa soil forms. Five soil profiles were opened using a mechanical back-actor on soil that developed on granite parent material. Another five soil profiles were dug on an area of soils that developed on schist parent material. Each soil profile was sampled at 15 cm depth intervals, from the surface of the soil profile to the bottom where the hard rock begins.

Each soil sample was collected in a plastic sampling bag. From the selected sites, a total of 49 samples was taken from schist and granite derived soils. Twenty-six samples were collected from granite-derived soils and 23 from schist derived soils. All the soil samples were taken to the Soil Science Laboratory, at University of Limpopo, to be analysed.

3.3 SAMPLE PREPARATION

Soils were sieved to remove stones and gravel (>2mm diameter). Three types of sieving were adopted for sieving soil samples depending on the soil's physical characteristics of stones, concretions and plant debris contained.

3.3.1 Mechanical sieving

To break the soil peds, a mechanical sieve was used, where soils were passed through rubber rollers of the sieve. The soil passing through a 2 mm mesh sieve was collected in the outlet section of the sieve, and then transferred into a container. This type of sieving is suitable for the majority of advisory samples, but samples with large stones were sieved manually as the stones would tear and scar the rubber rollers. The rollers were at times adjusted or replaced to avoid excessive loss of soil during sieving. The area surrounding the sieve was cleaned regularly to avoid sample contamination (Byrne, 1979).

3.3.2 Manual roller sieving

The soils were rolled manually with a metal roller and sieved through a mechanically vibrating 2 mm mesh sieve. The method is much slower than the mechanical sieve and is usually reserved for soil survey samples, stony samples, and peat compost. As was the case during mechanical sieving, the sieved soils were transferred to a container.

3.3.3 Manual hand sieving

This method was used for soils without hard massive structure and with little or no stones, gravel or concretions. All the samples were thoroughly dried before sieving. It was extremely important to have total recovery of the soils being sieved, as it was the determining factor in the measurement of soil texture. The sieve that was used was a 2 mm mesh brass sieve of about 30 cm diameter.

3.4 CHEMICAL ANALYSIS

3.4.1 Phosphorus

Phosphorus extraction was done with the Bray 1 method and phosphorus determined by spectrophotometer. (Barnard *et al.*, 1990; Bray and Kurtz, 1945). This method estimates the relative bioavailability of inorganic ortho-phosphate (PO_4-P) in soils with acid to neutral pH, using an acid solution (hydrochloric) containing ammonium fluoride. The method is shown to be well correlated to crop response on neutral to acidic soils. This procedure is used as an index of available phosphorus in soils by extracting easily acid-soluble forms of phosphorus.

To 6.67g of soil in an extracting bottle, 50 ml Bray 1 solution was added. The bottle was sealed and the contents shaken on a reciprocating shaker for 60 seconds. Two drops of flocculent solution were added and the bottle re-shaken. The solution was filtered immediately through Whatman no 40 filter paper. After collecting the filtrate, 2 ml ammonium molybdate was added and the colour allowed developing for 10 minutes. The solution was transferred to a cuvet and the % transmittance was measured with a spectrophotometer.

3.4.2 Exchangeable cations

Exchangeable bases (Ca, Mg, K and Na) were extracted by 1mol dm^{-3} ammonium acetate of pH 7 and an atomic absorption spectrophotometer (AAS) was used for absorbance measurement (Barnard *et al.*, 1990; CSTPA, 1974).

Five grams of soil was weighed and placed in an extraction bottle and 50 ml NH_4OAc solution added where after it was shaken horizontally on a reciprocating shaker at 180 oscillations per minute for 15 minutes. The extract was filtered through Whatman no 40 filter paper and the filtrates were collected in 100 ml volumetric flasks but discarding the first a few drops. Five ml of lantanum chloride was added to the filtrate. The 100 ml volumetric flasks were filled to volume with H_2O. The AAS was then used to determine the absorbance of elements Ca, K, Mg and Na in the filtrate.

3.4.3 Cation exchange capacity

Twenty five grams of air dried soil was transferred to 800 ml beaker, 150ml LiCl solution added and the contents stirred and allowed to stand for one night. The mixture was thereafter transferred to a Buchner funnel (connected to suction pipe), fitted with Whatman 40 filter paper. The beaker and the soil on filter paper were rinsed with 50ml of LiCl solution until about 450 ml had been collected. Each added portion of solution was drained completely. The soil was kept wet to prevent cracking due to excessive drying, especially those with high clay content. The leachate was quantitatively transferred to a 500ml volumetric flask and made up to the mark with LiCl solution. The soil on the Buchner funnel was washed with about 150ml ethyl alcohol in three to four portions and each portion was allowed to drain completely before adding the next portion (making sure that soil was not allowed to crack). The soil and the filter paper were transferred to an 800ml beaker and 500 ml (0.25 mol dm^{-3}) $Ca\ (NO_3)_2$ was added. The contents were heated on a water bath at 80-90 degree C and intermittently stirred to break up the colloids (especially in clayey soils). After 30 minutes, the solution was filtered through a Whatman 40 filter paper, using a Buchner funnel. After filtration was complete, the CEC was determined in terms of the Li content of the calcium nitrate extract.

3.4.4 Soil pH

The soil pH was determined with a glass electrode using buffer solutions of pH 4 and pH 7 for calibration. Twenty grams of soil was weighed and placed in a beaker and 50 ml deionised water was added. The contents were stirred with a glass rod and allowed to stand for ten minutes, then stirred again and allowed to stand for another ten minutes. The pH was determined with the electrode positioned in the supernatant solution.

3.4.5 Particle size analysis

The hydrometer method was used to determine the particle size distribution of the soil where a total of 49 samples was tested, (CSTPA, 1974; McLean, 1982). Fifty grams of air-dry soil was weighed and transferred into a 250ml Erlenmeyer flask, using a funnel. One hundred ml of distilled water and 250ml of 10% Calgon (sodium hexametaphosphate) solution were added and the flask was sealed and shaken for 15 minutes. The stopper was removed and side of flask was washed with a jet from a wash bottle. The contents were transferred into a dispersion cup, and filled to 2/3 full with distilled water and stirred for 2 minutes. The sample was transferred into a Bouyoucos cylinder.

The hydrometer was carefully suspended (not dropped) into the suspension and distilled water was added to the mark, 1130ml for a 50.0 gram sample or 1205ml for a 100.0 gram sample. The hydrometer was removed. The base of the cylinder was held with one hand, the palm of the other hand placed over the open end to seal it, and inverted several times to mix the solution.

The cylinder was gently placed on the bench top, the hand removed and the time immediately noted to the nearest second. After 20 seconds, the hydrometer was carefully lowered into the suspension and it was steadied to suppress up and down movement and drifting. Readings at 40 seconds (top of meniscus) were recorded. The hydrometer was removed and the suspension temperature measured. A second hydrometer reading was taken and the temperature read after 5 hours. The first reading gives the (silt and clay) content and the second reading the clay content. The % silt and % clay in the samples was calculated from the readings and the % sand calculated by difference. Using the textural triangle, the textural class was determined.

A dispersed soil sample (100 g) was washed on 0,053 mm sieve, passing the silt and clay through the sieve via a funnel in to a 100ml cylinder and the sand was quantitatively transferred to an evaporating dish. The sand was dried at 105 ^{0}C for 24 hours to constant mass. The dried sand was thereafter transferred to a set of sieves arranged from top to bottom with decreasing mesh size of the following order: 0,5; 0,25; 0,106; 0,053 and pan (for collection of very fine sand). The mass of each sand fraction (coarse, medium, fine and very fine sand) was weighed and expressed as a % of the weight of the soil sample.

3.5 DATA ANALYSIS

Data was analysed using the statistical program GenStat (2003). The Student's unpaired t-test for two-samples was used with the significance obtained at the 5 % level ($P < 0.05$) (Snedecor and Cochran, 1980).

4. RESULTS AND DISCUSSIONS

4.1 PARTICLE SIZE DISTRIBUTION

The data for different particle size fractions of granite and schist derived soils are given in Appendices 1 and 2 respectively. The average particle size distributions of 49 soil samples for granite and schist derived soils are presented in Tables 4.1, 4.2, 4.3, 4.4, 4.5 and 4.6. The statistical data for the different particle size analysis of granite and schist derived soils is presented in Appendix 5.

Table 4.1. Percentage of coarse sand in granite and schist soils at various depths.

DEPTH (cm)	**COARSE SAND (%)**	
	GRANITE	**SCHIST**
0-15	20.1	7.6
15-30	17.1	4.8
30-45	14.1	6.4
45-60	11.14	11.3
60-75	18.0	3.2
75-90	11.9	0.1
90-105	N/A	1.4

The coarse sand contents of soils derived from granite were much higher than those of soils derived from schist (Table 4.1). The coarse sand content of granite soils ranged from 11.9-

39.9 %, whilst soils derived from schist had coarse content ranging from 3.9-12.4 %. Granite derived soils had an average of 14.8 % coarse sand, which was significantly higher than the 5 % of soils derived from schist (Appendix 5). Table 4.1 shows clearly that, in granite soils, the highest coarse sand content is found in the top 15 cm. There is a gradual decrease to a depth of 60 cm followed by a sharp increase in the 60-75 cm layer. The coarse sand content decreased sharply in the 75-90 cm layer. The coarse sand content in schist derived soil was generally lower than in granite derived soil except for 45-60 cm layer. A sharp decrease in underlying layers was found.

Table 4.2. Percentage of medium sand in granite and schist soils at various depths.

	MEDIUM SAND (%)	
DEPTH (cm)	**GRANITE**	**SCHIST**
0-15	36.2	35.2
15-30	34.4	17.6
30-45	30.9	13.1
45-60	28.1	12.8
60-75	24.6	2.6
75-90	13.5	4.7
90-105	N/A	8.2

The medium sand fraction of granite derived soils was significantly higher than medium sand content of soil derived from schist (Appendix 5). In granite derived soil a gradual decrease of medium sand content, from topsoil to bottom, was found (Table 4.2). The topsoil (0-15 cm) of granite derived soil had a medium sand content of 36.2 %, followed by a gradual decrease down the profile, except at 60-75 cm and 75-90 cm depths where a sharp decrease was to 24.6 and 13.5 % respectively were found. The total average percent of medium sand fractions in granite soils was 25.6 and schist had a total average of 13.5 (Table 4.2).

A similar trend to this study was reported by Verster (1990b) where the medium sand content of granite derived soil showed a gradual decrease from the topsoil down the profile, especially in the upper foot slope profiles. The medium sand content of granite derived soils showed a different trend at midslope and lower slopes, however. The soil profiles of granite derived soils studied by Verster (1990b) in the North-East of Nelspruit were deeper than soil profiles of granite derived soils on the Syferkuil Experimental farm.

The medium sand fractions of schist derived soil had a high content in topsoil (0-15 cm), followed by a very sharp decrease in the 15-30 cm layer and a further gradual decrease to in the 30-45 cm and 45-60 cm layers. A sharp decrease to 2.6 % at 60-75 cm was found. Unexpectedly, increasing medium sand content was found at 75-90 cm and 90-105 cm layers respectively.

Table 4.3. Percentage of fine sand fraction in granite and schist soils at various depths.

DEPTH (cm)	FINE SAND (%)	
	GRANITE	**SCHIST**
0-15	16.4	22.2
15-30	22.2	24.5
30-45	20.8	25.8
45-60	22.9	21.6
60-75	18.2	19.4
75-90	6.9	17.4
90-105	N/A	20.1

The topsoil (0-15 cm) of granite derived soil showed a low fine sand content followed by fluctuating values in the 15-30 cm, 30-45 cm,45-60 cm and 60-75 cm layers, and a sharp decrease in the 75-90 cm layer (Table 4.3). Granite soils showed a total average of 15.4 % while schist had a total average of 21.6 %. The trend of fluctuating fine sand content on granite derived soil in the Syferkuil Experimental Farm was almost similar to the trend found on granite derived soil (on upper foot slope) in the north-east of Nelspruit (Mpumalanga Province), (Verster, 1990b).

The fine sand content in topsoil of schist derived soil was insignificantly higher than fine sand content of granite derived soil (Appendix 5). The fine sand content of schist derived soil was high in the topsoil layer (0-15 cm), and decreased gradually with depth, except where unexpected increase was found in the 30-45 cm and 90-105 cm layers (Table 4.3). The fine sand content of schist derived soil was significantly higher than the fine sand content of granite derived soil (Appendix 5).

Table 4.4. Percentage of very fine sand in granite and schist soils at various depths.

DEPTH (cm)	VERY FINE SAND (%)	
	GRANITE	**SCHIST**
0-15	8.8	15.4
15-30	7.9	21.3
30-45	9.0	22.0
45-60	12.9	18.2
60-75	6.8	26.6
75-90	1.7	26.3
90-105	N/A	23.8

The very fine sand content of granite derived soil was lower than the very fine sand content in schist derived soil (Table 4.4). The very fine sand content of granite derived soil was 8.8 % in the 0-15 cm layer, followed by a gradual decrease in the 15-30 cm, a gradual increase in the 30-45 cm and 45-90 cm layers, and a sharp decrease in the 60-75 and 75-90 cm layers respectively. A similar trend where fluctuation in very fine sand content of granite derived soil occurs was reported by Verster (1990b).

The very fine sand content of schist derived soil was significantly higher than the very fine sand in granite derived soil (Appendix 5). The very fine sand content of schist derived soil had a low value of 15.4 % in the topsoil (0-15 cm). A high increase to 21.3 % was found in the 15-30 cm layer in schist derived soil, followed by a small increase to 22.0 % in the 30-45 cm layer. A sudden decrease was found in the 45-60 cm layer and a high increase followed in the 60-75 cm layer, then a slight decrease at 75-90 cm and a gradual decrease in the 90-105 cm layer.

The fine sand, very fine sand and silt contents of schist derived soils are high, indicating poor soil physical conditions, especially susceptibility to crusting and compaction. Crusting leads to bare patches that do not recover in overgrazed areas and as a result, runoff and erosion are increased. Under irrigated and intensive dryland cultivation, crusting and compaction cause various problems, especially at 0-15 and 15-30 depths. South African observations have shown a problem of crusting and compaction, especially when fine sand, very fine sand and silt contents are > 50 % and clay is <35 %. The bare patches that do not recover as well as irrigation problems on crusting soils are found widespread in Limpopo Province.

In general, soils developed on schist found in the Syferkuil Experimental Farm had a higher content of fine sand, very fine sand, silt and clay, while soils derived on granite had a higher content of coarser soils particles. This indicates instability of minerals found in schist which causes schist to weather more easily than granite (Dorr and Eschman, 1991). Schist rocks break easily along lamination (foliation) of schistocity and result in more soil than with granite, thus schist consists of smaller minerals than granite, because it has more weatherable minerals. Granite has coarse-grained minerals, which are rather resistant to weathering (Purves and Blyth, 1969) and this results in coarser sand content in granite soils and leads to low silt and low clay content.

Table 4.5. Percentage of silt in granite and schist soils at various depths.

DEPTH (cm)	SILT (%)	
	GRANITE	**SCHIST**
0-15	12.5	14.0
15-30	12.7	22.8
30-45	16.5	23.6
45-60	14.7	27.8
60-75	8.6	32.2
75-90	3.9	32.6
90-105	N/A	26.5

The silt content in the granite derived soil showed a little increase in the 0-15 cm and 15-30 cm layers, and a high increase in the 30-45 cm layer (Table 4.5). However, a sharp decrease in the 45-60 cm, 60-75 cm and 75-90 cm layers was found. The total average of silt contents in granite soil was 9.9 % and the range was between 3.9-16.5 %. The silt content of granite derived soils is moderately high for South African soils and higher than the silt of granite soils reported by Verster (1990b). Verster (1990b) showed various silt contents of the granite derived soils found in the North-East of Nelspruit where the highest silt content at the topsoil (0-23 cm) and some of the sub-soils (23-35 cm) of the valley bottom was 10 %, and 9 % silt content was found in the topsoil layer (0-10 cm) of the midslope.

The silt content of schist derived soil was significantly higher than the silt content of soil derived from granite (Appendix 5). The silt content of schist derived soil increased with depth. The silt content of schist derived soil was 14.0 % at topsoil (0-15 cm), followed by a sharp increase to 22.8 % in the 15-30 cm layer and a gradual increase, except in the 90-105 layer where the silt content decreased to 26.5 % (Table 4.5). The silt content in schist derived soils, from 15 cm downward, is high for South African soils. The total average silt contents in schist derived soil was 25.6 %, and was significantly higher than silt content in granite derived soil. The 8.6 % and 3.9 % values found respectively at 60-75 and 75-90 depths were regarded as "normal" values, falling within the range of silt content reported by others on granite derived soils in South Africa.

The clay content of granite derived soil showed an increase in the 0-15 cm and 45-60 layers, except at 15-30 layer where the clay content was low (Table 4.6). Another decrease of clay content in granite derived soil was found at 60-75 depth and 75-90 layers. The clay content of granite derived soil found on Hutton on the Syferkuil Experimental Farm were very low compared to the clay content of granite derived soil studied in the Pretoria-Johannesburg area, in Hutton, Clovelly, Avalon, Longlands and Dundee soil forms, where the clay contents of the latter profiles ranged from 7-34%, however, the total clay content average was <15 % (Munnik *et al.*, 1991).

Table 4.6. Percentage of clay in granite and schist soils at various depths.

DEPTH (cm)	CLAY (%)	
	GRANITE (%)	**SCHIST (%)**
0-15	5.8	5.6
15-30	5.6	8.8
30-45	7.6	9.2
45-60	10.2	8.5
60-75	3.4	16.0
75-90	2.0	19.0
90-105	N/A	20.0

Verster (1990b) showed clay contents of granite derived soil (North-East of Nelspruit), which were low compared to the clay content of granite derived soil in the Pretoria-Johannesburg area and this applies to the granite soil on the Syferkuil Experimental Farm. The clay content of granite derived soil on the Syferkuil Experimental Farm could be associated with the clay content of granite derived soil in the Pretoria-Johannesburg area; however, exception is given to some profiles on Hutton and Longlands given by Verster (1990a) where high clay contents are found. Brady (1984) and Bohn *et al.* (1985) stated that the major possibility that the granite derived soil is losing clay could be as a result of dispersion.

The clay content of schist derived soil was low in the 0-15cm layer followed by an increase in the 15-30 and 30-45 layers respectively. A decrease was found in the 45-60 layer (Table 4.6). A large increase was found in the 60-75 layer, followed by a gradual increase in the 75-

90 and 90-105 cm layers respectively. The difference in clay content of granite and schist derived soils was significant (Appendix 5).

Table 4.7. The various soil depths in granite and schist derived soils.

SOILS	SOIL DEPTHS (cm)		SLOPE
	GRANITE	SCHIST	
PROFILE 1	75	45	MIDSLOPE
PROFILE 2	75	60	MIDSLOPE
PROFILE 3	60	75	MIDSLOPE
PROFILE 4	90	60	FOOT SLOPE
PROFILE 5	90	105	VALLEY BOTTOM

The soil profiles of schist derived soil were generally shallow compared to the soil profiles of granite derived soil; however, the exception is given to schist profile number 5, found at the Valley Bottom (105 cm) (Table 4.7). In comparison with the granite profiles on the Syferkuil Experimental Farm, the granite profiles studied in the North-East of Nelspruit were deeper, whereby the deepest profile found was 330 cm (Verster, 1990b). Munnik *et al.* (1991) showed the granite profile as deep as 165 cm, on Longlands soil form in the Pretoria-Johannesburg area. The shallow depths at Syferkuil Experimental Farm are due to the much lower rainfall experienced in the Syferkuil Experimental Farm than at Nelspruit and Johannesburg, leading to less deep weathering and shallower soils at Syferkuil Farm.

4.2 CEC AND ESP

4.2.1 CATION EXCHANGE CAPACITY

The CEC of granite derived soil increased from the topsoil to 30-45 layers, followed by a decrease down the profile (Figure 1). The low CEC in granite derived soil (below 60 cm) was due to the low clay content found in the deep layers of the soil. Munnik *et al.* (1991) showed the CEC of granite derived soil in the Pretoria-Johannesburg area where the granite derived soil generally had higher CEC than granite derived soil in the Syferkuil Experimental Farm.

The cation exchange capacity of schist derived soils was significantly higher than the cation exchange capacity of granite derived soils; however, both soils showed very low CEC values (Appendix 6). In both soils (granite and schist derived soils), the CEC was associated with the clay content found. The CEC of schist derived soils increased with depth except at 45-60 cm depth where CEC dropped. The CEC was high at 75-90 depth and was associated with high clay content (Figure 6).

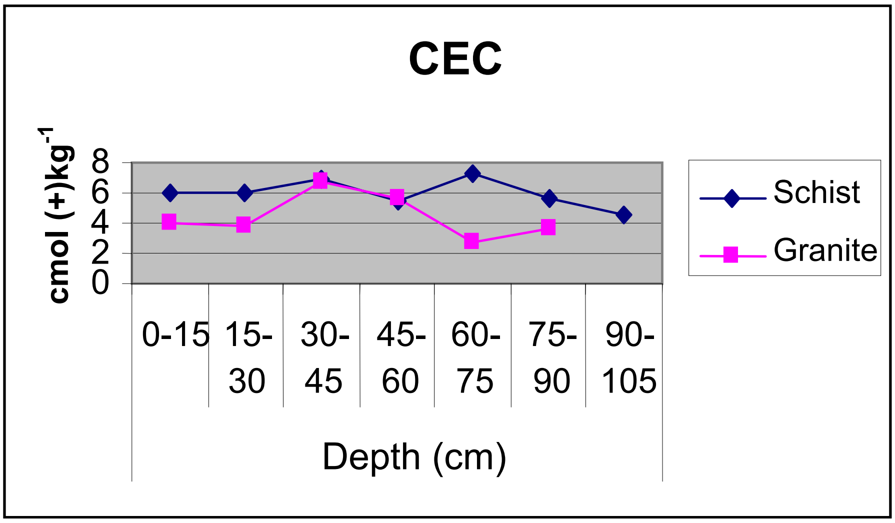

Figure 1. **Average CEC of granite and schist derived soils at different depths.**

4.2.2 EXCHANGEABLE SODIUM PERCENTAGE (ESP)

The exchangeable sodium percent (ESP) was generally low in both granite and schist derived soils (Appendix 3 and 4). The granite derived soils had high ESP values compared to schist derived soils. The granite derived soils had higher sodium contents than schist derived soils. The differences in CEC content were a factor to ESP values in both soils. The ESP values were extremely low (in both soils) to cause sodicity since the calculated values were far below a general threshold of 15 %.

4.3 EXCHANGEABLE CATIONS

The calcium concentration of granite derived soil showed low contents as well as a gradual decrease of concentrations with depth (Figure 2). However, the calcium concentrations in granite derived soil of the Syferkuil Experimental Farm were higher than the calcium concentrations of granite derived soils studied in the Pretoria-Johannesburg area (Munnik *et al.* 1991). Calcium is less soluble and more strongly adsorbed than the other cations. The Syferkuil Experimental Farm is a low rainfall area and the amount of rain found in this area is inefficient to leach calcium in to lower parts of the profile; thus result in high calcium concentration at 45-60 cm depth than in lower layers.

The calcium concentration of schist derived soil showed a gradual increase from topsoil to 60 cm layer (Figure 2). A high concentration of 4.65 cmol (+) kg^{-1} was found at 45-60 cm depth, followed by a sharp decrease to 2.21 at 60-75 cm depth and a gradual decrease below 60 cm depth. The calcium concentration of the schist derived soils was higher than the calcium concentration in the granite derived soils although the difference was insignificant (Appendix 6).

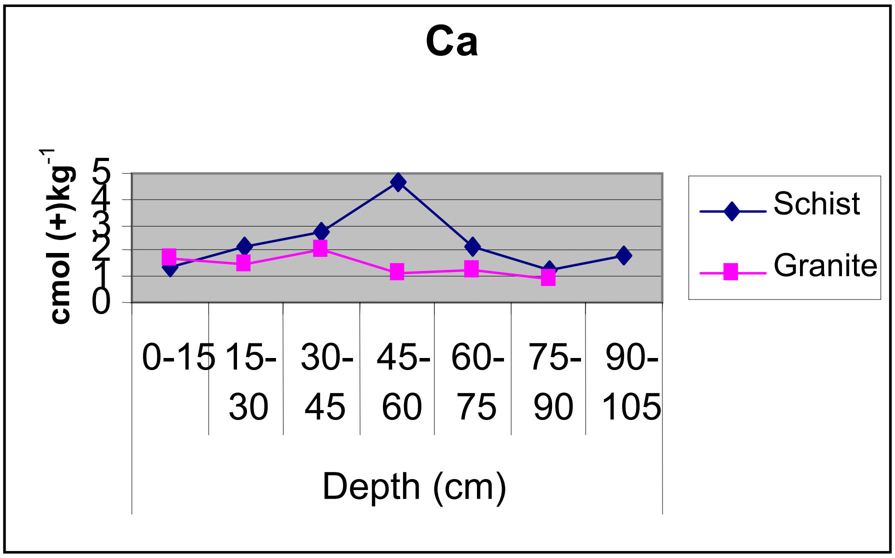

Figure 2 Average Ca concentration of granite and schist derived soils at different depths.

The magnesium concentration in granite derived soil gradually increased from topsoil to 45-60 cm layer and gradually decreased with depth (Figure 3). With the exception of the magnesium concentration at 45-60 depth (2.79 cmol (+) kg^{-1}), the magnesium concentrations of the granite derived soil were generally low and were associated with the low clay content found (Figure 3). The total average concentration of magnesium in schist derived soils were 2.37 cmol (+) kg^{-1}, and was significantly higher than 1.30 cmol (+) kg^{-1} of Mg in granite derived soils (Appendix 6).

Olowolafe and Dung (2000) showed magnesium deficiencies in biotite-granite derived soils in Jos-Plateus, Nigeria and the same trend is likely to occur in the Syferkuil Farm. Munnik *et al.* (1991) showed the relationship of magnesium concentrations with clay content in the granite derived soil of the Pretoria-Johannesburg area. The study was conducted on different soil forms (Hutton, Clovelly, Longlands, Cartref and Dundee) where, the magnesium concentrations in the granite derived soils of Pretoria-Johannesburg area were very low despite the high clay contents found. Moshia (2004) also found an increase of magnesium concentration with clay content in the topsoil of granite derived soils on the Syferkuil Experimental Farm.

The magnesium concentration in the schist derived soils was significantly higher than the magnesium concentration in the granite derived soils, especially at deep layers (Appendix 6). The high concentration of magnesium in schist soil was associated with the high clay content in deep layers of schist derived soil, and a high CEC value was expected.

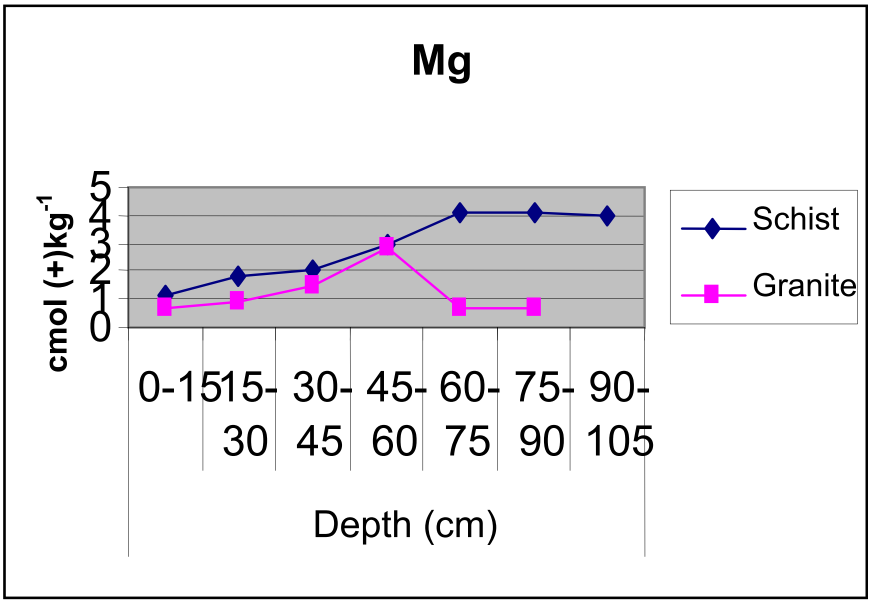

Figure 3. **Average Mg concentration of granite and schist derived soils at different depths.**

The potassium concentration in schist derived soils was significantly higher than the potassium concentration in granite derived soils (Appendix 6). The potassium concentration of granite derived soils was high in the topsoil (0-15 cm) and decreased with depth (Figure 4). There was a gradual decrease of potassium concentration in granite derived soil which was associated with the decrease in clay content. Olowolafe and Dung (2000) showed potassium deficiencies in biotite-granite derived soils in the Jos-Plateaus, Nigeria. However, the deficiency varied with profiles unlike the general potassium deficiency found on the Syferkuil Experimental Farm.

Potassium is naturally less soluble and more strongly adsorbed than sodium and is associated with the clay content found. The potassium concentration increased with depth in schist derived soils and decreased with depth in granite derived soils (Figure 4). The average concentration of potassium in schist derived soils was 0.22 cmol (+) kg^{-1} which was significantly higher than 0.13 cmol (+) kg^{-1} potassium in granite derived soils (Appendix 6).

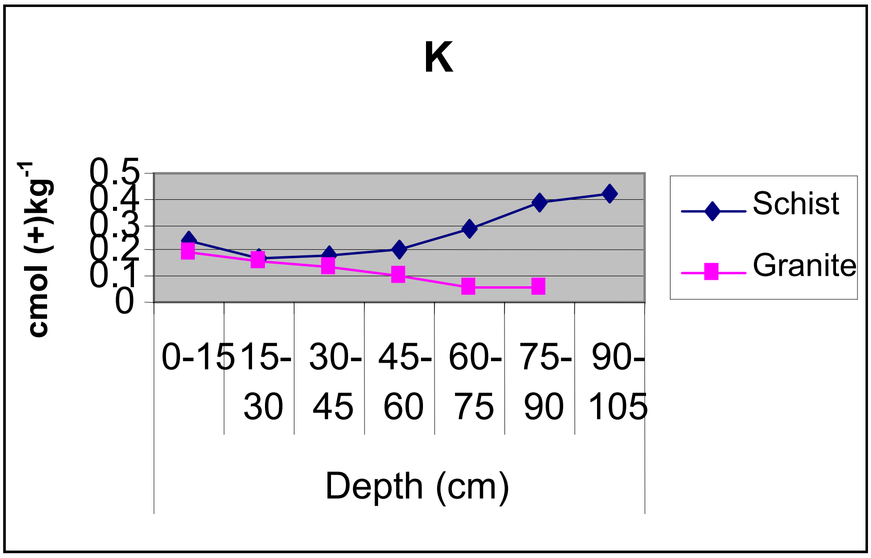

Figure 4. **Average K concentration of granite and schist derived soils at different depths.**

Differences in sodium concentration between granite and schist derived soil were insignificant (Appendix 6). There was also very little variation with depth. A noticeable variation between granite and schist derived soils occurred at 45-60 cm where schist soil had 0.044 cmol (+) kg^{-1} concentration and the granite derived soil had 0.062 cmol (+) kg^{-1}

(Figure 5). The sodium concentration in the granite derived soil of the Syferkuil Experimental Farm was moderately high compared to the sodium concentrations of granite derived soils in the Pretoria-Johannesburg area (Munnik *et al.,*1991).However, the concentration differences between granite and schist soils were statistically insignificant. The average sodium concentration in schist soils was 0.051 cmol (+) kg^{-1}, while granite soils recorded 0.049 cmol (+) kg^{-1} Na on average (Figure 5).

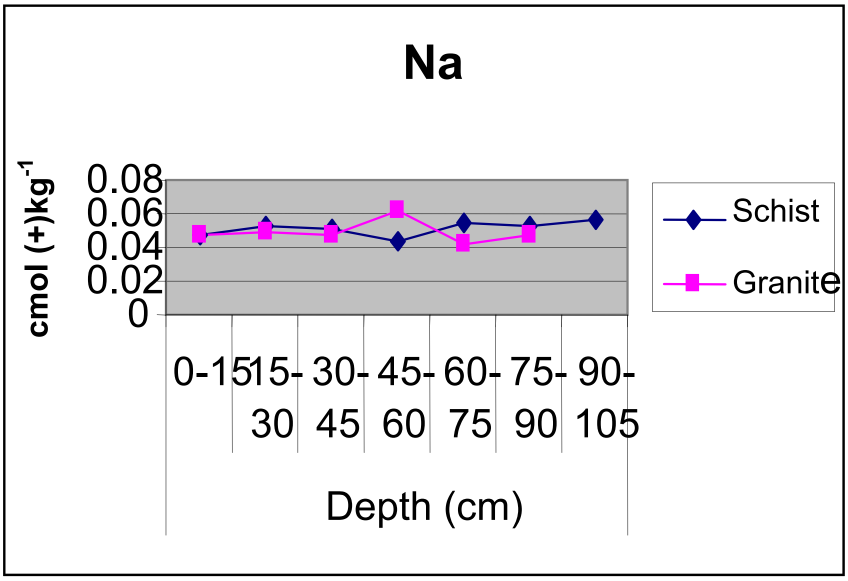

Figure 5.**Average Na concentration of granite and schist derived soils at different depths.**

4.4 PHOSPHORUS

The phosphorus concentration in schist derived soils was insignificantly higher than the phosphorus concentration in granite derived soils (Appendix 6). The phosphorus concentration in granite derived soil showed a decrease from 3.98 mg kg^{-1} in the 0-15 cm layer to 2.1 mg kg^{-1} in the 15-30 cm layer, followed by an increase to 3.7 mg kg^{-1}, after which the phosphorus concentration decreased gradually with depth (Figure 6). In schist derived soils, there was a gradual and fluctuating decrease of phosphorus concentration with depth.

The highest phosphorus concentration in schist derived soil was 6.4 mg kg^{-1} in the 30-45 layer (Figure 6).

The phosphorus concentrations of granite and schist derived soils were generally low, especially in the topsoil, which is normal, considering the fact that the soil samples were collected on a virgin land. Olowolafe and Dung (2000) showed a deficiency of phosphorus in biotite-granite derived soil in Jos-Plateau, Nigeria and is associated to the low levels of phosphorus found in granite derived soil on the Syferkuil Experimental Farm.

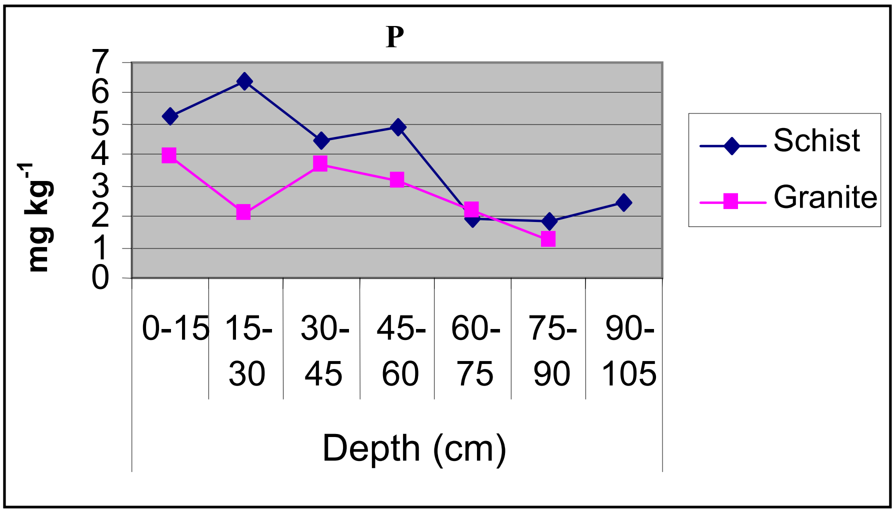

Figure 6. **Average P concentration of granite and schist derived soils at different depths.**

4.5 pH

4.5.1 GRANITE DERIVED SOILS

At all subsoil depths (below 15 cm), there was almost no difference in pH values between profiles (Figure 7). There was also a very small difference with depth. A substantial difference was only found in topsoil (0-15 cm). The pH values of granite derived soil ranged from 4.82 and 6.07. All of the pH values in granite derived soil were below pH 5, except at profile 4 where pH 6.07 was found.

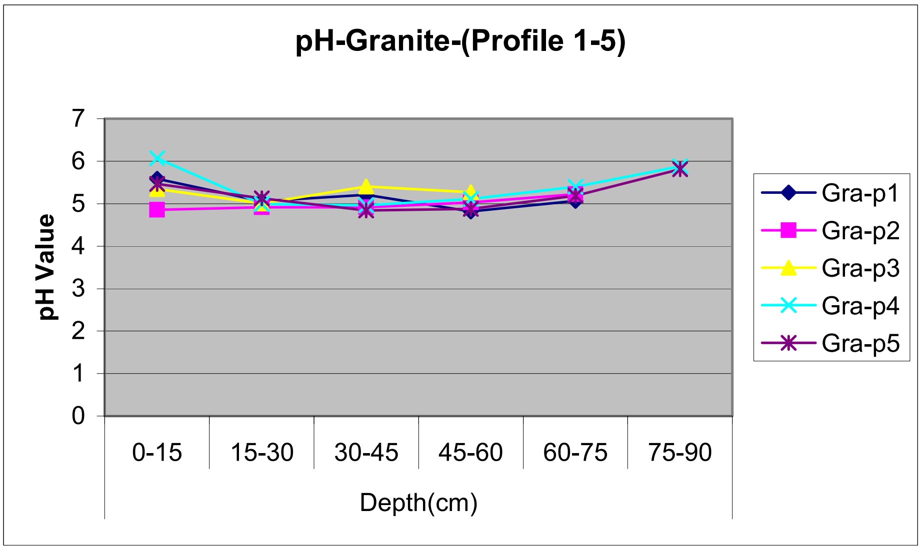

Figure 7. The pH values of 5 granite derived soil profiles at different depths.

4.5.2 SCHIST DERIVED SOILS

The pH values found in schist derived soils were unexpected since the values of the topsoils varied little whilst the differences between profiles at 30-45 and 45-60 depths were very large (Figure 8). There was an unusual situation with pH values in schist derived soils, normally the highest variations are found in topsoil. The pH of schist derived soil ranged from 5.17 and 6.9 (Appendix 3). The overall average pH value of schist derived soil was 5.75.

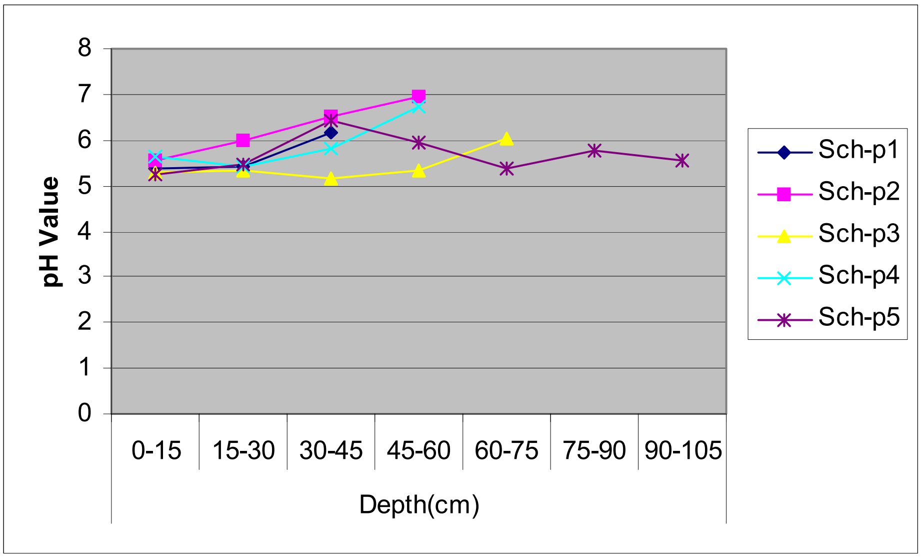

Figure 8. The pH values of 5 schist soil profiles at different depths.

5. CONCLUSION AND RECOMMENDATIONS

The fine sand, very fine sand and silt content in schist derived soils were high for South African soils. Verster (1990b) showed low values of silt content on granite derived soils found in the north-east of Nelspruit. The status of granite and schist derived soils on the Syferkuil Experimental Farm indicates poor physical conditions and susceptibility to crusting and compaction. The problem of crusting in such soils leads to bare patches that do not recover, especially in overgrazed areas, and as a result, increased runoff and erosion will be experienced.

Given the percentage fine sand, very fine sand and silt in granite and schist derived soils on the Syferkuil Experimental Farm, decreased infiltration and lower emergence rate are expected. The granite and schist derived soils on the Syferkuil Experimental Farm showed poor structure, indicating fragile and unconsolidated peds, especially in the 0-15 cm and 15-30 cm layers. In some profiles of both granite and schist derived soils, 30-45 cm layers were affected.

South African observations have shown a problem of crusting and compaction, especially in areas where (fine sand + very fine sand + silt) contents are > 50 % and clay is < 35 %. The soil on the Syferkuil Experimental Farm is experiencing a trend of clay contents which is < 35 %. For the granite derived soils the percent (fine sand + very fine sand + silt) are < 50 % but for schist derived soils the % (fine sand + very fine sand + silt) are > 50% at all soil depths. This indicates the vulnerability of the schist derived soils to crusting and compaction.

The laboratory analysis showed variable nutritional status in both soils where schist soils dominated in nutrients element and had a higher pH values than granite soils. Both parent materials were exposed to the same climatic conditions but have proven through this experiment to be different in their evolution. Given long periods and different climatic conditions, more differences (physically and chemically) are expected.

Generally, both granite and schist derived soils showed poor nutritional status, especially granite derived soils. The CEC in the granite derived soils was very low compared to the CEC in the schist derived soils and this (CEC trends) was associated with the different clay contents in both soils. Munnik *et al.* (1991) showed the CEC of granite derived soil in the Pretoria-Johannesburg area where the granite derived soil generally had higher CEC compared to the granite derived soil in the Syferkuil Experimental Farm. The sodium values were generally low in both soils and these values were a proof enough that sodicity is not a problem in the granite and schist derived soils on the Syferkuil Experimental Farm.

The magnesium, potassium and calcium concentrations in granite and schist soils were also associated with the clay contents found. The magnesium and potassium concentrations in schist derived soils were higher than those in granite derived soil and a significant difference occurred in deep layers (60-75 cm and 75-90 cm) where clay contents in granite and schist soils were significantly different. The calcium concentrations of schist derived soils was high in the 30-45 cm layer and low in below 45 cm layer and this clearly indicates the insufficiency of rain to leach calcium in deep layers of the profiles. This trend is important to indicate water shortage on the Syferkuil Experimental Farm.

The phosphorus concentrations in granite and schist derived soils were, as expected, very low, considering that the tests were done on virgin soils. For cultivation purposes on granite and schist soils, phosphorus supplements are highly recommended.

The increasing attention being paid to the irrigation of granite soils highlights the need for the studies on these soils. Such studies will help to ascertain the effects of cultivation on such soils, especially in view of the possibility of increased clay loss due to increased water movement.

It was proven through this study that soils developing on granite and schist differed in their chemical and physical characteristics, though they were exposed to similar environmental conditions. This variation of properties in granite and schist soils, should serve as an awareness call for the agricultural sector that a close look at soils is relevant for better managerial skills in order to practice sound sustainable agriculture.

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APPENDIX 1

THE PARTICLE SIZE DISTRIBUTION OF FIVE GRANITE DERIVED SOILS

Granite	**Sand**							
	0-15 cm							
		Coarse	**Medium**	**Fine**	**Very fine**	**Total %**	**Silt %**	**Clay %**
Profiles	Profile 1	11.9	32.4	14.7	15.0	74.1	15.9	10
	Profile 2	17.4	41.4	21.4	8.8	89	5	6
	Profile 3	15.6	41.4	15.3	7.9	80.2	13.8	6
	Profile 4	39.9	23.7	11.2	4.1	79	18.0	2
	Profile 5	15.8	41.9	19.4	8.2	85.2	9.8	5
Sum		100.6	180.8	82.0	44.1	407.4	62.6	29
Average		20.1	36.2	16.4	8.8	81.5	12.5	5.8

Granite	**Sand**							
	15-30 cm							
		Coarse	**Medium**	**Fine**	**Very fine**	**Total %**	**Silt %**	**Clay %**
Profiles	Profile 1	20.9	305	18.0	7.3	76.7	17.3	6
	Profile 2	10.1	39.1	24.0	10.1	83.3	8.7	8
	Profile 3	19.7	44.4	16.8	4.3	85.2	10.8	4
	Profile 4	27.1	20.1	24.4	9.8	81.3	14.7	4
	Profile 5	7.8	38.2	27.8	8.3	82.2	11.8	6
Sum		85.5	172.2	111.0	39.8	408.7	63.3	28
Average		17.1	34.4	22.2	7.9	81.7	12.7	5.6

Granite	**Sand**							
	30-45 cm							
		Coarse	**Medium**	**Fine**	**Very fine**	**Total %**	**Silt %**	**Clay %**
Profiles	Profile 1	11.8	34.9	19.2	12.3	78.2	15.8	6
	Profile 2	12.2	39	21.1	7.2	79.6	14.4	6
	Profile 3	6.6	19.2	12.4	13.8	52	29.3	18
	Profile 4	35.7	17.3	22.2	8.5	83.7	12.3	4
	Profile 5	4.1	44.3	29.1	7.9	85.5	10.5	4
Sum		70.39	154.76	103.98	49.85	378.98	82.32	38
Average		14.1	30.9	20.8	9.9	75.8	16.5	7.6

Granite	**Sand**							
	45-60 cm							
		Coarse	**Medium**	**Fine**	**Very fine**	**Total %**	**Silt %**	**Clay %**
Profiles	Profile 1	12.6	39	17.4	14	83.1	9.9	6
	Profile 2	11.4	37.2	23.3	9.5	81.3	10.7	8
	Profile 3	1.1	8.1	25.4	18.2	51.7	27.3	21
	Profile 4	27.5	24.2	20.3	10.3	82.4	11.6	6
	Profile 5	3.1	32.2	28.3	12.3	75.9	14.1	10
Sum		55.6	140.7	114.7	64.3	374.3	73.7	51
Average		11.14	28.1	22.9	12.9	74.9	14.7	10.2

Granite	**Sand**							
	60-75 cm							
		Coarse	**Medium**	**Fine**	**Very fine**	**Total %**	**Silt %**	**Clay %**
Profiles	Profile 1	19.2	34.9	22.5	9.4	86	12	2
	Profile 2	33.3	35.2	15.9	6.8	91.3	4.7	4
	Profile 3	**	**	**	**	**	**	**
	Profile 4	31.4	17.8	23.3	7.7	80.2	13.0	5
	Profile 5	6.2	35.2	29.1	10.1	80.6	13.4	6
Sum		90.1	123.2	90.9	34.0	338.1	43.1	17
Average		18.0	24.6	18.2	6.8	67.6	8.6	3.4

Granite	**Sand**							
	75-90 cm							
		Coarse	**Medium**	**Fine**	**Very fine**	**Total %**	**Silt %**	**Clay %**
Profiles	Profile 1	**	**	**	**	**	**	**
	Profile 2	**	**	**	**	**	**	**
	Profile 3	**	**	**	**	**	**	**
	Profile 4	38.8	19.3	21	4.9	83.9	12.0	4
	Profile 5	20.9	48.4	13.4	3.8	86.6	7.4	6
Sum		59.8	67.6	34.4	8.7	170.6	19.4	10
Average		11.9	13.5	6.9	1.7	34.1	3.9	2

**** = the profile(s) did not reach the corresponding depth(s) and therefore, no values/concentrations were determined.**

APPENDIX 2

THE PARTICLE SIZE DISTRIBUTION OF FIVE SCHIST DERIVED SOIL

Schist	**Sand**							
	0-15 cm							
		Coarse	**Medium**	**Fine**	**Very fine**	**Total %**	**Silt %**	**Clay %**
Profiles	Profile 1	5.8	43.4	23.5	14.3	86.9	9.1	4
	Profile 2	8.4	42.9	18.9	12.3	82.6	13.4	4
	Profile 3	3.9	45.9	20.1	14.2	84.2	11.8	4
	Profile 4	7.3	31.4	22.4	16.2	77.7	16.3	6
	Profile 5	12.4	12.2	26.1	19.9	70.5	19.5	10
Sum		37.8	175.9	111	76.9	401.9	70.1	28
Average		7.6	35.2	22.2	15.4	80.4	14.0	5.6

Schist	**Sand**							
	15-30 cm							
		Coarse	**Medium**	**Fine**	**Very fine**	**Total %**	**Silt %**	**Clay %**
Profiles	Profile 1	1.1	25.8	28.7	16.3	71.9	24.1	4
	Profile 2	6	18.3	23.2	24.7	72.2	16.9	10
	Profile 3	2	19.5	19.4	23.2	64.1	25.9	10
	Profile 4	11.4	17.1	25.3	18.3	72.2	19.9	8
	Profile 5	3.7	7.3	25.8	23.8	60.7	27.3	12
Sum		24.2	88.1	122.4	106.4	341.2	114.2	44
Average		4.8	17.6	24.5	21.3	68.2	22.8	8.8

Schist	**Sand**							
	30-45 cm							
		Coarse	**Medium**	**Fine**	**Very fine**	**Total %**	**Silt %**	**Clay %**
Profiles	Profile 1	6.4	14.8	31.5	21.0	73.7	20.3	6
	Profile 2	6.6	23	28.8	19.8	78.2	15.8	6
	Profile 3	1.2	9.2	22.4	27.1	59.9	28.2	12
	Profile 4	16.6	10.2	28.1	15.7	70.6	23.4	6
	Profile 5	1.3	8.1	18.1	26.48	53.94	30.06	16
Sum		32.0	65.3	128.9	110.2	336.3	117.8	46
Average		6.4	13.1	25.8	22.0	67.3	23.6	9.2

Schist	**Sand**							
	45-60 cm							
		Coarse	**Medium**	**Fine**	**Very fine**	**Total %**	**Silt %**	**Clay %**
Profiles	Profile 1	**	**	**	**	**	**	**
	Profile 2	11.5	31.5	22.2	10.0	75.2	20.8	4
	Profile 3	3.4	2.6	18.1	29.1	53.3	37	10
	Profile 4	28.6	13.8	24.7	9.1	76.3	21.7	2
	Profile 5	1.5	3.3	21.2	24.4	50.4	31.6	18
Sum		45.1	51.2	86.3	72.7	255.2	111.1	34
Average		11.3	12.8	21.6	18.2	63.8	27.8	8.5

Schist	**Sand**							
	60-75 cm							
		Coarse	**Medium**	**Fine**	**Very fine**	**Total %**	**Silt %**	**Clay %**
Profiles	Profile 1	**	**	**	**	**	**	**
	Profile 2	**	**	**	**	**	**	**
	Profile 3	5.8	1.31	20.4	26.2	53.6	32.4	14
	Profile 4	**	**	**	**	**	**	**
	Profile 5	0.7	3.9	18.5	27.0	50	32	18
Sum		6.5	5.2	38.8	53.2	103.6	64.4	32
Average		3.2	2.6	19.4	26.6	51.8	32.2	16

Schist	**Sand**							
	75-90 cm							
		Coarse	**Medium**	**Fine**	**Very fine**	**Total %**	**Silt %**	**Clay %**
Profiles	Profile 1	**	**	**	**	**	**	**
	Profile 2	**	**	**	**	**	**	**
	Profile 3	**	**	**	**	**	**	**
	Profile 4	**	**	**	**	**	**	**
	Profile 5	0.1	4.7	17.4	26.3	48.4	326	19
Sum		0.1	4.7	17.4	26.3	48.4	32.6	19
Average		0.1	4.7	17.4	26.3	48.4	32.6	19

Schist	**Sand**							
	90-105 cm							
		Coarse	**Medium**	**Fine**	**Very fine**	**Total %**	**Silt %**	**Clay %**
Profiles	Profile 1	**	**	**	**	**	**	**
	Profile 2	**	**	**	**	**	**	**
	Profile 3	**	**	**	**	**	**	**
	Profile 4	**	**	**	**	**	**	**
	Profile 5	1.4	8.2	20.1	23.8	53.6	26.5	20
Sum		1.4	8.2	20.1	23.8	53.6	26.5	20
Average		1.4	8.2	20.1	23.8	53.6	26.5	20

APPENDIX 3
SUMMARY OF SELECTED CHEMICAL PROPERTIES OF GRANITE DERIVED SOIL.

Granite		CONCENTRATION OF ELEMENTS (cmol (+) kg^{-1}) Profile 1						
		Na	Mg	K	Ca	P (mg/kg)	CEC	pH
Depth (cm)	0-15	0.0513	0.621	2.06	4.02	6.1	6.3	5.59
	15-30	0.0404	0.803	0.145	1.85	4.4	4.4	5.06
	30-45	0.0406	0.857	0.0851	2.01	13.8	10.7	5.21
	45-60	0.0571	0.692	0.0799	1.63	5.7	3.9	4.82
	60-75	0.043	0.633	0.0689	1.64	3.9	2.1	5.07
Granite		Profile 2						
		Na	Mg	K	Ca	P	CEC	pH
Depth (cm)	0-15	0.0387	0.349	0.206	0.696	7.3	3.6	4.86
	15-30	0.0439	0.504	0.142	0.912	1.5	4.3	4.92
	30-45	0.0508	0.77	0.19	1.38	4.8	4.2	4.92
	45-60	0.0578	0.84	0.0946	1.48	1.4	5.1	5.03
	60-75	0.0495	0.925	0.0961	1.62	2.9	2.3	5.23
Granite		Profile 3						
		Na	Mg	K	Ca	P	CEC	pH
Depth (cm)	0-15	0.043	1.13	0.307	1.67	1.6	3.7	5.35
	15-30	0.0452	1.68	0.355	2.49	1.71	2.8	5.01
	30-45	0.0435	4.43	0.238	4.22	23.3	8.9	5.41
	45-60	0.0839	0.872	0.191	0.527	3.5	6.3	5.27
Granite		Profile 4						
		Na	Mg	K	Ca	P	CEC	pH
Depth (cm)	0-15	0.0583	0.631	0.143	0.809	0.5	2.6	6.07
	15-30	0.0657	0.807	0.0754	0.891	1.9	2.9	4.99
	30-45	0.0543	0.915	0.0618	1.51	9.3	4.8	4.96
	45-60	0.0495	0.915	0.0538	0.891	2	5.7	5.11
	60-75	0.0365	0.794	0.0402	0.633	1.1	2.9	5.4
	75-90	0.0426	0.802	0.0515	0.619	1.29	3.2	5.88
Granite		Profile 5						
		Na	Mg	K	Ca	P	CEC	pH
Depth (cm)	0-15	0.0487	0.626	0.0999	0.605	4.43	3.4	5.47
	15-30	0.0482	0.742	0.0861	1.17	0.93	4.4	5.13
	30-45	0.0469	0.365	0.0818	0.985	0.68	4.6	4.84
	45-60	0.0491	0.455	0.0689	1.17	3.72	7.4	4.88
	60-75	0.0409	0.495	0.0443	1.05	0.89	3.8	5.19
	75-90	0.0534	0.503	0.0551	1.24	1.32	4.2	5.81

SUMMARY OF AVERAGE SELECTED CHEMICAL PROPERTIES OF GRANITE DERIVED SOIL

Granite		**Concentration in (cmol (+) kg^{-1})**						
		Na	**Mg**	**K**	**Ca**	**P (mg/kg)**	**CEC**	**ESP**
Depth (cm)	0-15	0.0483	0.671	0.194	1.68	3.9	3.92	1.23
	15-30	0.0487	0.894	0.161	1.46	2.1	3.76	1.30
	30-45	0.0474	1.45	0.132	2.02	3.7	6.64	0.71
	45-60	0.0622	2.79	0.105	1.13	2.9	5.68	1.10
	60-75	0.0426	0.712	0.0626	1.23	2.2	2.78	1.53
	75-90	0.0474	0.653	0.0533	0.93	1.23	3.7	1.28
Sum		0.249	6.52	0.653	7.52	14.8	26.5	7.15
Average		0.0496	1.3	0.131	1.5	2.9	4.41	1.19

APPENDIX 4
SUMMARY OF SELECTED CHEMICAL PROPERTIES OF SCHIST DERIVED SOIL.

Schist	CONCENTRATION OF ELEMENTS (cmol (+) kg^{-1})							
	Profile 1							
		Na	Mg	K	Ca	P(mg/kg)	CEC	pH
Depth (cm)	0-15	0.0543	0.944	0.14	1.43	3.9	4.7	5.38
	15-30	0.0465	1.31	0.0974	2.11	5.2	5.1	5.41
	30-45	0.0582	1.72	0.107	3.19	9.6	11.0	6.16
Schist		Profile 2						
		Na	Mg	K	Ca	P	CEC	pH
Depth (cm)	0-15	0.0437	0.886	0.227	1.74	7.2	6.4	5.54
	15-30	0.0513	1.27	0.138	2.25	1.7	11.7	6.01
	30-45	0.0443	1.41	0.113	2.79	3.5	7.2	6.5
	45-60	0.0591	12.2	0.149	7.28	4.5	6.8	6.95
Schist		Profile 3						
		Na	Mg	K	Ca	P	CEC	pH
Depth (cm)	0-15	0.0417	0.979	1.67	0.76	4.7	6.0	5.3
	15-30	0.0561	2.27	0.126	2.11	2.9	5.3	5.35
	30-45	0.05	1.96	0.113	1.66	3.8	6.6	5.17
	45-60	0.0622	2.39	0.136	1.94	2.9	5.9	5.32
	60-75	0.057	3.73	0.19	2.59	19.7	7.0	6.04
Schist		Profile 4						
		Na	Mg	K	Ca	P	CEC	pH
Depth (cm)	0-15	0.0552	1.33	0.167	1.67	7.5	4.7	5.63
	15-30	0.0509	1.72	0.126	2.72	2.3	5.0	5.41
	30-45	0.0409	1.84	0.213	3.88	4.4	5.1	5.83
	45-60	0.0461	2.59	0.182	7.24	6.2	4.6	6.72
Schist		Profile 5						
		Na	Mg	K	Ca	P	CEC	pH
Depth (cm)	0-15	0.0461	1.56	0.479	1	2.9	8.5	5.25
	15-30	0.06	2.59	0.382	1.52	2.4	3.1	5.48
	30-45	0.0591	3.5	0.359	1.86	1.1	4.5	6.41
	45-60	0.0539	4.754	142.3	2.12	6	4.8	5.94
	60-75	0.0508	4.5	0.364	1.84	6.6	7.4	5.39
	75-90	0.0517	4.06	0.384	1.8	2.9	5.7	5.75
	90-105	0.0565	3.97	0.418	1.83	1.2	4.5	5.56

SUMMARY OF AVERAGE CHEMICAL PROPERTIES OF SCHIST DERIVED SOIL

Schist	Average concentrations (cmol (+) kg^{-1})							
		Na	**Mg**	**K**	**Ca**	**P (mg kg^{-1})**	**CEC**	**ESP (%)**
Depth	0-15	0.0474	1.142	0.237	1.32	5.2	6.06	0.684
	15-30	0.0530	1.83	0.175	2.14	6.4	6.04	0.660
	30-45	0.0504	2.1	71.24	2.68	2.3	6.88	0.880
	45-60	0.0443	2.97	0.183	4.65	4.9	5.53	0.911
	60-75	0.0539	4.12	0.285	2.21	4.3	7.20	0.749
	75-90	0.0526	4.055	0.0551	1.24	1.9	5.70	0.923
	90-105	0.0565	3.97	0.42	1.83	2.5	4.50	0.126
Sum		0.3580	16.6	1.56	16.1	27.5	36.6	4.93
Average		0.0513	2.37	0.223	2.29	3.9	5.23	0.705

APPENDIX 5

STATISTICAL DATA FOR PHYSICAL PROPERTIES OF GRANITE AND SCHIST DERIVED SOILS.

Sample	**Size**	**Mean**	**SD**	**SEM**	**Probability**
Coarse Sand %					< 0.001
Granite	6	15.40 a	3.568	1.457	
Schist	7	4.97 b	3.830	1.448	
Medium Sand %					0.022
Granite	6	27.97 a	8.215	3.354	
Schist	7	13.45 b	10.89	4.116	
Fine Sand %					0.175
Granite	6	17.89 a	5.924	2.418	
Schist	7	21.56 a	2.913	1.101	
Very Fine Sand %					< 0.001
Granite	6	8.033 a	3.719	1.518	
Schist	7	21.94 b	4.121	1.558	
Silt %					0.013
Granite	6	13.66 a	8.137	3.322	
Schist	7	25.63 b	6.365	2.406	
Clay %					0.019
Granite	6	5.483 a	2.456	1.003	
Schist	7	12.44 b	5.758	2.176	

SD is the standard deviation of each mean
SEM is the standard error of each mean

APPENDIX 6

STATISTICAL DATA FOR CHEMICAL PROPERTIES OF GRANITE AND SCHIST DERIVED SOILS.

Sample	**Size**	**Mean**	**SD**	**SEM**	**Probability**
Na					0.549
Granite	7	0.05120 a	0.004124	0.001559	
Schist	6	0.04935 a	0.006581	0.002687	
Mg					0.016
Granite	7	2.881 a	1.214	0.4590	
Schist	6	1.194 b	0.8380	0.3421	
K					0.006
Granite	7	0.2706 a	0.09807	0.03707	
Schist	6	0.1178 b	0.05521	0.02254	
Ca					0.095
Granite	7	2.296 a	1.155	0.4366	
Schist	6	1.409 a	0.3969	0.1620	
P					0.195
Granite	7	3.890 a	1.804	0.6819	
Schist	6	2.730 a	1.057	0.4315	
CEC					0.035
Granite	7	5.987 a	0.8925	0.3373	
Schist	6	4.413 b	1.443	0.5890	

SD is the standard deviation of each mean
SEM is the standard error of each mean