



Relative Abundance of Minerals in Parent Rock and their Effects on Laterite Properties

Colonel V.O. Fagoyinbo, A.J. Adeola

Dept of Geology, Crawford University, Faith City, Ogun State, Nigeria

Abstract This paper seeks to determine relative abundance of minerals in parent rocks and the effect the minerals have on the engineering properties of laterites. The paper highlights how minerals are formed, the relationship between minerals and rocks, the formation of laterites and the factors affecting its formation. In addition, mineral composition of lateritic soils was discussed, how parent rock composition affects laterite formation and the effect of mineral abundance on engineering properties of laterites were also elucidated.

The chemical transformation to laterites occurs when water and oxygen interacts with minerals in the rock to create different chemical reactions and compounds through hydrolysis and oxidation. The minerals that remain after rocks are weathered include quartz, zircon as well as oxides of aluminium, iron, tin and titanium. Iron in laterites is present as goethite and hematite. Without the presence of these, there will not be iron in the laterite. The quantity of these minerals in the parent rocks greatly affects the engineering properties of the laterites. Specific gravity, to a large extent, determines engineering property of a soil and the specific gravity is affected by the presence and quantity of iron and aluminium in the parent rock. Therefore, relative abundance of minerals in the parent rocks affects the engineering properties of laterites.

Keywords minerals, parent rocks, laterite, hydrolysis, specific gravity, oxidation

Introduction

The whole earth is made up of rocks and minerals. The Earth is structured into 3 layers namely: the crust, the mantle and the core. The crust is the outer layer of the Earth and it is made of rocks and minerals. It is about 0.4% of the Earth mass and about 8 elements make up 98% of its crust. These elements are oxygen, silicon, aluminum, iron, calcium, sodium, potassium and magnesium [1]. All rocks are made of minerals. The minerals in a rock could range from 2 to many. A mineral is composed of the same substance throughout and there are about 3,000 minerals throughout the world. The minerals also are made of either a single or a combination of chemical elements. These minerals are sorted into 8 groups as follow:

1. Nature elements which are copper, silver, gold, nickel-iron, graphite and diamond.
2. Sulfides – Sphalerite, Chalcopyrite, Galena and Pyrite.
3. Halides – Halites, Fluorites.
4. Oxides and Hydroxides – Corundum, Hematite.
5. Nitrates, Carbonates, Borates – Calcite, Dolomite, Malachite.
6. Sulfates, Chromates, Molybdates, Tungstates – Celestite, Barite and Gypsum.
7. Phosphates, Arsenates, Vanadates – Apatite, Turquoise.
8. Silicates – Quarts, Almandine, Garnet, Topaz, Jadeite, Talc, Biotite, Micas.

The crust is made of rocks which also are composed of minerals. Do the rocks last forever? Not really! The rocks also break down through the process of weathering which is its breakdown by the action of rainwater, extremes of temperature or biological activities. These breakdowns are either in form of physical, chemical or biological weathering. Physical weathering is also known as mechanical weathering. It includes processes that fragment and disintegrate rocks into smaller pieces without changing the rocks mineral composition. It is caused



by cracks, fire, thawing and freezing of water in cracks, pressure release and water absorption by swelling clays. Chemical weathering is the alteration of the rock into new minerals. It generally occurs where water and minerals are in constant touch. Its agents are oxygen, air pollution, water, carbonic acid and strong acids. These combine with the minerals that made up the rocks to form clays, iron oxides and salts which are the end products of chemical weathering. Lastly, biological weathering is the disintegration of rocks as a result of action by living organism. Weathering rates are determined by water content, temperature, exposed surface area and the type of minerals within the rocks.

An intensive and long lasting weathering of rocks usually lead to the formation of laterites. This is especially common in tropical regions. Laterization could, therefore, be referred to as tropical weathering which is a prolonged process of chemical weathering. It is capable of producing a wide variety of laterite in term of thickness, grade, chemistry and ore mineralogy of the resulting soils. Laterites are formed from the leaching of parent rocks and mineralized proto ores leaving the more soluble ions, which are predominantly iron and aluminium. The mechanism of leaching involves acid dissolving the hot mineral lattice, followed by hydrolysis and precipitation of insoluble oxides and sulphates of iron, aluminum and silica under high temperature condition of a humid tropical monsoon climate. Repetition of wet and dry seasons, are essential in laterization. The reaction zone where rocks are in contact with water is progressively depleted of the easily leached ion of sodium, potassium, calcium and magnesium. The mineralogical and chemical composition of laterites are dependent on their parent rocks. They also determine their characteristics thereby dictating the suitability of the laterites as construction materials. Since their mineralogical and chemical composition determine their engineering suitability, there is need to pay attention to the quality of each mineral in laterite. The need to know the relative abundance of the various minerals in laterite is the basis for this paper.

Aim

The aim of this paper is to determine the relative abundance of minerals in lateritic soils.

Scope

To achieve this aim, the paper will cover the followings:

1. Formation of Minerals.
2. Minerals and Rocks.
3. Formation of Laterites.
4. Mineral Composition of Lateritic Soils.
5. Parent Rocks and Laterite Formation.
6. Effect of Mineral Abundance on Laterite Properties.

Formation of Minerals

Minerals are naturally occurring, inorganic, solid, crystalline substance which have fixed structure and chemical composition which is either fixed or which may vary within certain defined limits. They are the building blocks of rocks. Some minerals have definite fixed composition e.g quartz (SiO_2) and calcite (CaCO_3) while others exhibit a range of composition between two or more compounds called end members. For example, plagioclase feldspars have composition ranging between end members, anorthite ($\text{CaAl}_2\text{Si}_2\text{O}_8$) and albite ($\text{NaAlSi}_3\text{O}_8$). Its chemical formula is written as $(\text{Ca, Na}) (\text{Al, Si}) \text{AlSi}_2\text{O}_8$.

The physical properties that determine the characteristics of minerals are luster, colour, streak, hardness, cleavage, fracture and crystal form. Other properties are specific gravity, tenacity, taste, odour, feel and presence of striations. Minerals must be definable by chemical composition, have orderly atomic arrangement and mostly inorganic with a few exception. They are either found in shapeless form called massive or in special shapes as crystals. Minerals can be formed under a variety of conditions. These are cooling of molten materials, evaporation of liquid, cooling of liquids and growth in solid materials at high temperature and pressures. Other means are metamorphism, weathering, organic formation and precipitation from aqueous solutions. Most of the minerals that make up the Earth's crust formed from the cooling of magma which is derived from molten rock. Within the Earth's crust and below, rocks are molten into liquid form but as the magma rises up through the



crust, it cools and the minerals crystallize. Those that cool slowly form fine grained rocks while those that cool fast form coarse grained rocks. When the cooling is extremely fast, a glassy texture is formed. This means that no crystals formed. This implies that volcanic glass is not composed of minerals because the magma cools off too rapidly for minerals to form. However, over millions of years, the volcanic glass may crystallize into silicate minerals. There are man-made minerals known as synthetic minerals e.g industrial diamonds.

Minerals and Rocks

According to Nyamai, (2003) [1], minerals are the building blocks of rocks and over 3000 mineral species have been recognized. These can be subdivided into silicate and non-silicate minerals. Silicate minerals are those that have silicon in their chemical compounds while non-silicates do not have silicon in their composition. Silicate minerals form most of the rock forming minerals. These include quartz, feldspars, micas, amphiboles, pyroxenes, clays and carbonates. This is because silicates contain silicon and oxygen which are the two most abundant elements in the Earth's crust. The number of elements that form silicate minerals is comparatively few but because a variety of silicates can be formed, there are a great multiplicity of silicate minerals. The atomic structure of the silicate unit shows that for each silicon atom, there are four oxygen atoms. Any of the oxygen atom may, however, be replaced by another element to form different kinds of linkages. The different ways in which the tetrahedral silicate building blocks are linked together as well as the choice of cation to balance the negative charges are responsible for the variety of silicate minerals. Consequently, the tetrahedral can be linked into chains, sheets, rings and double chains in addition to its original single tetrahedral.

As minerals make up rocks, so do rocks make up the Earth's crust. Rocks are grouped into three namely; igneous rocks, metamorphic rocks and sedimentary rocks. Igneous rocks are formed by the cooling and crystallization of silicate melt called magma. The magma may be basaltic, andesitic or granitic. The magma temperature and its chemical composition determine the minerals that crystallize and the type of igneous rock formed.

Sedimentary rocks are products of the surface processes of the Earth. These include weathering, erosion, rain, stream flow, wind, wave action and ocean circulation. Weathering processes breakdown these rocks into small fragments, new minerals and dissolved portions of the rock. The new minerals are mainly clays while dissolved portions are those that dissolve in rivers and ocean water. All the sediments on the Earth's surface form from the accumulation of these weathered materials. When they solidify by cementation, sedimentary rocks are formed. Sedimentary rocks can be grouped into 2 divisions namely clastic sedimentary rocks and chemical/biological sedimentary rocks. Clastics consist of conglomerates, sandstones as well as mudstones and Shales. Chemical/biological sedimentary rocks consist of limestones/dolomites, evaporates and carbonaceous rocks. Metamorphic rocks are those whose original texture, composition and mineralogy have been changed by condition of high temperature and pressure that are beyond its original condition of formation. They are mostly encountered in the core zones of mountain belts, old continental shields and as basement rocks below the sediment veneer of stable continental platforms. Rocks are inter-convertible. Igneous can be converted to metamorphic when subjected to temperature and pressure or converted to sedimentary when it undergoes weathering, erosion and deposition. Sedimentary can be converted to metamorphic when subjected also to high temperature and pressure as well as chemical alteration. It can also be converted to igneous when it is subducted to a level where it becomes molten and later crystallize through cooling. Both igneous and metamorphic rocks can be converted to sedimentary rocks through weathering. However, when the weathering is total and does not allow cementation, the end product is soil.

Weathering

Weathering is the breakdown of rocks, soil and minerals through contact with the earth's atmosphere, waters and biological organism. This is because rocks, minerals and soils normally change their structure in response to certain environmental forces. These forces include extreme weather, rain, ice, wind and biological activities. They promote the continuous breakdown, wearing away and loosening of rocks and soil. There are 3 main types of weathering namely physical, chemical and biological weathering. Physical weathering, also known as nonchemical weathering is the physical breakdown of rocks into smaller and smaller pieces. This may occur in



form of frost weathering, salt wedging, winds, water waves or rain. Chemical weathering occurs when rocks are worn away by chemical changes where natural chemical reactions within the rocks change its composition over time. These changes are gradual and they affect the mineralogy of the rocks thus weakening them and making them wear away or dissolve and, in some cases, disintegrate. This chemical transformation occur when water and oxygen interacts with minerals within the rocks to create different chemical reactions and compounds through processes such as hydrolysis and oxidation. Biological weathering, also known as organic weathering is the disintegration of rocks as a result of the action of living organism. Trees and other plants can wear away rocks through penetration of their roots into the rock cracks and joints. These roots get bigger thereby applying pressure on the rock making the cracks to grow bigger leading to split within the rocks. Microscopic organisms like algae, moss, lichens and bacteria can grow on rock surface to produce chemicals that have the potential of breaking down the outer layer of the rocks.

Formation of Laterites

Laterites are the products of intensive and long lasting tropical rock weathering which is intensified by high rainfall (Schellman, W.). The dominant process of laterite formation is the residual enrichment of iron and frequent enrichment of aluminum by removal of silica, alkalis and alkaline earths. The chemical alteration corresponds mineralogically with the formation of goethite, hematite, kaolinite and gibbsite. These minerals, together with relics of partially dissolved quartz, form the bulk of laterites. The transformation of rock into laterite proceeds gradually through the steady increase of iron and decrease of silica in laterite profiles above the parent rock.

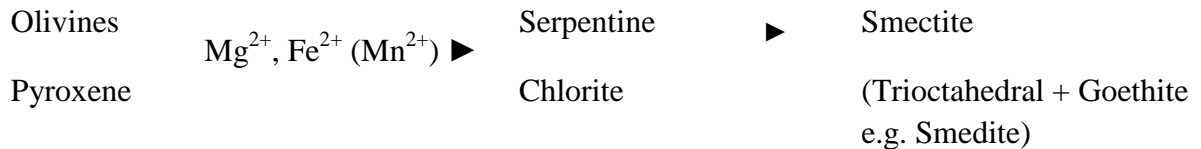
Aleva, 1994, quoted in Adebisi, et al, 2013 [3] stated that mineralogical composition of a parent rock is a pointer to the composition of soils development over it. Parent rock petrography reveals quartz and muscovite in quartz-schist and quartz while it reveals alkali feldspars and biotite in gneiss and granite. $\text{SiO}_2/\text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3$ indicate that soils from gneiss and granite fall into a class different from quartz schist. Adebisi, et al, 2013 [3] added further that kaolinite formed the dominant clay minerals in the soils with subordinate amount of illite (Kaolinite is between 52.3 – 75.5% while illite is between 2.3 – 17.6%). Smectite at 3.0m depth in soils over gneiss and granite contain 0.9 – 1.9%. This mode of formation and mineralogical composition of parent rocks caused variation in cohesion and compressibility characterization of lateritic soil. Clay is an important component of laterite soil, especially when assessed for civil engineering purposes. The field of clay properties is diverse and complex. Its study is therefore important especially in its descriptive form and its likely behavior. Its quantity in soil, therefore, goes a long way to determine the characteristics of the soil. Churchman and Lowe (2012) [4] stated that properties of soils relate to properties of clay, besides those arising from their particular mineralogical characterization. It was found that a combination of a specific surface area and total iron oxide content predicted clay content almost completely in a set of illitic soils. But explanations of the clay content of other soils from mineral properties were more complex and usually involve poorly crystalline and nanocrystalline phases. Oades and Water, 1991 [5] found out that the nature of aggregation with soil dominated by Kaolinites in close association with Fe and Al oxides differs from that in soils that are more illitic.

The process of weathering involves alteration of minerals as a result of factors different from their stages of formation. The alteration involves mainly primary minerals. The weathering involves reaction of minerals with water or an aqueous solution. However, there are exceptions where alteration of primary minerals occur without presence of water. Such activities take place in polar region through frost wedging or hot desert zones as a result of wind ablation [6]. One of the processes of soil formation is hydrolysis, which involves removing more soluble components selectively from the mineral. This leaves solid residue which differs in composition from the original mineral. The hydrolysis of silicates in water results in silicic acid and a base. Carroll, 1970 [7] and Chamley, 1989 [8] stated that because most aqueous solutions in which weathering takes place are acidic as a result of water being changed with dissolved CO_2 , giving rise to a continuous supply of carbonic acid, H_2CO_3 and H^+ ions, hydrogen ions are important weathering agents. Weathering can result in the alteration of the following minerals



a. Olivines, Pyroxenes and Amphiboles

Olivines are generally unstable and easily lose their Mg^{2+} , Fe^{2+} to give serpentine and later, smectite and goethite [9]. Olivines could give rise to smectite, kaolinite, halloysite as well as various oxides, hydroxides and oxyhydroxides of Fe, and possibly Mn [10]. Pyroxenes and amphiboles are slightly more stable than olivines. However they tend to breakdown in a similar manner to the olivines. In the process, they initially lose their divalent cations *e.g.* Mg, Ca and Fe. They result in chlorite, smectite and possibly, talc. If Ca is released in abundance, calcite may also be formed. Fine scale examination of the mineral grain revealed that amphiboles weathering led to a dioctahedralmorillonite and a trioctahedralsaponite (smectite). At the early stage of alteration, kaolinite-smectiteare simultaneously formed. With time, halloysite develop. Wilson, 2004 [11] gave the common pathway for this weathering process as follows:



b. Feldspars

Feldspars have been known to give rise to many different types of secondary minerals [4]. This encompasses the range of structural complexity from smectites to gibbsite and quartz. Allen and Hajek, 1989 [12] quoted many studies where smectites have been identified as products of alteration of feldspars. Carroll, 1970 [7] considered feldspars as the main source of micas. Kaolinites and halloysites were also often traced to feldspars as the source. Huang, 1989 [10] stated that feldspar, just the olivines, pyroxenes and amphiboles, dissolve probably at sides of excess energy such as area of dislocation.

c. Micas

Phyllosilicate micas can transform easily to phyllosilicate clay minerals in the solid state. These involve transformation such as exchange of the interlayer cations and reduction in the charge of the layers. Potassium ions occupy the interlayer regions of the common micas, biotite and muscovite. The replacement of the K^+ by hydrated cations such as Mg^{2+} or Ca^{2+} leads to a loss of strength of binding between adjacent layers, therefore, weakening the entire soil. The release of K^+ from micas is considered to occur by either layer weathering or edge weathering [13-14]. When it occurs through layer weathering, most of the K^+ in a particular interlayer is released virtually simultaneously. While in edge weathering, K^+ is released by diffusion from edges and fractures. Trioctahedral micas, such as biotite and phlogopite, weathers more readily than dioctahedral micas such as muscovite and illites. Plants can bring about the transformation of biotite to vermiculite through the extraction of K^+ from the mineral [15].

Transformation of micas in soils to expandable phase often occurs under acidic condition. Under low pit conditions where organic matter contents are high, especially under forests, micas may transform to smectites in soils as a result of acid leaching. The resulting smectites are generally rich in Al^{3+} and therefore beidellitic but may also be montmorillonitic. Alin and Peacor, 1987 [16], Banfield and Eggleton, 1988 [17] stated that kaoline minerals can form from micas early in the weathering process. This includes formation from biotite and muscovite. They emphasized that kaolinite can even form irregular intercalated layers between biotite layer.

d. Chlorites

Chlorites occur most commonly as trioctahedral minerals in parent materials for soils. They originate from low grade metamorphic rocks and as products of the early alteration of primary minerals containing Fe^{2+} and Mg^{2+} such as augite, hornblende, biotite and serpentine [4]. They are not common in soils mainly because of their low stability with regard to weathering. Chlorites dissolved typically leaving a solid residue of iron oxides and oxyhydroxides like goethite [18].



e. Serpentine

Serpentine rocks which are dominated by serpentines together with iron oxides and amphiboles, pyroxenes and talc are generally unstable in soils. Wildman, et al, 1968 [19], stated that the rock type in California, gave rise to unusually pure Fe-rich smectite in the fine clay fraction. The Mineralogical change was attributed to the loss of the more mobile elements such as Mg^{2+} and Si^{4+} as well as the relative enrichment of Fe^{2+} and Al^{3+} . Ducloux, et al, 1976 [20] stated that alteration of serpentine led to a trioctahedral chlorite which is normally regarded as a primary mineral and also to its alteration product. In Northwest Italy, the weathering products of serpentine were found to depend on drainage conditions.

f. Volcanic Parent Material

Volcanic materials are outstanding because they usually contain glass which is a fast weathering source of Si^{4+} and Al^{3+} . They can also contain other weatherable minerals depending on their origin, nature and composition. Volcanic materials may originate from effective eruption forming lavas or explosive eruption. These eruptions generate fragmental, unconsolidated deposits called pyroclastic materials that may be distributed widely by the wind. Volcanic materials therefore may be basaltic, rhyolitic and andesitic. Basaltic eruptions are rich in Fe and Mg, rhyolitic eruptions, have abundant Si rich glass, comparatively low in Al but may contain minor amounts of mafic minerals, including biotite and feldspars. Andesitic eruption are intermediate in composition between basaltic and rhyolitic eruptions. The hydration and breakdown of glass results in fluxes of some elements from glasses into interstitial pore waters. This is also accompanied by very rapid precipitation of secondary minerals from such solution as well as replacement of glass by new minerals [21].

Mineral Composition of Lateritic Soils

The mineralogical and chemical compositions of laterites are dependent on their parent rock. Laterite consists mainly of quartz, zircon and oxides of aluminum, iron, tin and titanium. These are the minerals that remain during the course of weathering. Quartz is the most abundant relic mineral from the parent rock because of its resistance to weathering. The main host minerals for nickel and cobalt can be either iron oxides, clay minerals or manganese oxides. Iron oxides are derived from mafic igneous rocks and other iron – rich rocks. Bauxites are derived from granite igneous rocks and other rocks poor in iron. Nickel laterites occur in zones of the earth which experienced prolonged tropical weathering of ultramafic rocks which contains ferro-magnesian minerals like olivine, pyroxene and amphiboles.

The type of laterite, the chemical component, the engineering characteristics and the minerals available in it depends largely on the parent rock. Also, the relative abundance of the minerals contained in lateritic soils is controlled mainly by the types and quantity of minerals that make up the parent rock. In addition, laterites reflect past weathering conditions. Hydrogeologically, the types and qualities of minerals in laterites greatly affect its capability in serving as an aquifer. Laterites with very high percentage of clay minerals will tend towards an aquitard while those with higher percentage of silt and sand will serve as an aquifer.

Ultramafic rocks are mostly rich in Nickel – Cobalt. When such rocks weather into laterites, the deposits becomes an important source of Nickel. Ni – Cobalt laterites are supergene deposits of Ni plus or minus Co which are formed from the pervasive chemical and mechanical weathering of ultramafic rocks. The formation of secondary concentration of Ni and Co that is significant enough as an economic resource depends on protolithology that is primarily enriched in Ni. Lelong, et al, 1976 [22], stated that ultramafic rocks can contain as much as 0.3 percent Ni. These rocks occur within Ophiolite Complexes as Harzburgite and Dunite. They could also occur within pegmatites and layered complexes as peridotites and dunites. The extreme weathering removes almost all elements except the least soluble ones from the protolith. The enrichment of Ni in the weathering profile is controlled by several interplaying factors such as parent rock, climate, chemical composition, rate of chemical weathering, drainage and tectonics [23-24]. From the above, the mineral composition of the parent rocks determines to a large extent, the relative abundance of minerals in laterites.

Mutembei, et al, 2014 [25] analyzed iron enrichment on lateritic soil in selected regions of Kenya. The result of elemental analysis showed that raw laterites contain 28 – 31% by mass iron. However, after heat treatment, the level of iron content had increased to 55 – 64%. Its X-ray diffraction indicated that iron in the raw laterites was



present predominantly on goethite and hematite. This implies that without the presence of goethite or hematite in the parent rock, there may not be iron in the laterite.

Adebisi, et al, 2013 [3] discovered that the relationship between plasticity index and Fe_2O_3 reveals that the forms of iron oxide that reduces the plasticity of laterite soil, the mode of formation and mineralogical composition of parent rocks caused variation in cohesion and compressibility characteristics of laterite soils. He added that since the mineralogical composition of gneiss is close to granite gneiss as compared to quartz schist, the iron oxide content in soils derived from quartz schist is far below those in soils derived from granite and gneiss. They concluded that through Silica – sesquioxide molar ratios, laterization in the horizon of soil developed over gneiss decreases with depth while it increases with depth in the horizon of soils developed over quartz schist and granite. In addition, granite derived soils tend to have less cohesive strength than gneiss derived soils and quartz – schist derived soils. This resulted from the fact that both gneiss and quartz schist are of metamorphic origin while granite is igneous. Because gneiss and granite are similar in mineralogical composition, the soils developed over them have higher variation.

Parent Rocks and Laterite Formation

The relative abundance of minerals in the Earth's Crust is governed by the relative abundance of elements in these units. There are more than 3000 known minerals in the Earth's crust, out of which only 20 are very common. 9 of these twenty minerals constitute 95% of the crust. These are silicate minerals and they are also called the rock forming minerals. These rocks forming minerals can be grouped into mafic and felsic minerals. These names are based on the principal rock types they occur mainly in. The mafic minerals contain relatively heavier minerals than Felsic minerals. Chemical weathering changes the materials that make up rocks and soils. These materials are mostly minerals. When carbon dioxide from the air combines with water, carbonic acid is produced. This is a weak acid but can dissolve rocks. This continues over a long period and it results into soil. Depending on the region, the soil may be laterite.

The condition for the soil to be laterite is that there must be alternate dry and wet season, heavy rainfall and high temperature. Laterites are formed mainly as a weathering product of basalt. It may also be formed from the weathering of sandstones, clay, limestones, schist, gneisses, migmatites, granites, gabbros or peridotites. It occurs through leaching of the disintegrated rocks leaving the more insoluble ions. These ions are predominantly iron and aluminum. The mineralogical and chemical compositions of laterites depend on the parent rocks. It consists mainly of quartz, zircon and oxides of titanium, iron, tin, aluminum and manganese. These are the residuals that remain after weathering has taken place. However, quartz is the most abundant because of its high resistance to weathering. According to Whittington and Muir (2000) [26] laterites vary significantly, depending on their location, climate and depth. It was stated that chemical weathering losses are estimated from measurement of immobile element enrichment in the weathered material. Elements that are immobile during chemical weathering become enriched as other elements are removed by dissolution. The greater the mass lost through dissolution, the greater the relative enrichment of the immobile elements that are left behind.

Tzu – Hsing (2014) [27] investigated the role of parent material on weathering process on physical, chemical and composition of the laterite formed. They studied five lateritic soils formed from different parent materials in Taiwan. They confirmed that the physical, chemical and mineralogical composition of the parent rock strongly affects the nature of soils formed and that the greatest difference among the lateritic soils is their iron oxide content. The Tamshin and Tungwei lateritic soils were found to have magnetic iron oxides which are magnetite and maghemite formed from parent materials that are andesite and basalt, respectively, which are igneous rocks. The Pingchen and Loupi have stronger weathering process than those of Tamshin and Tungwei. In addition, lateritic soils from Pingchen and Loupi contain identical iron oxides like goethite and less hematite. In laterite, derived from Soka parent rock, the major iron oxide is lepidocrolite. Pingchen and Loupi possessed the same clay minerals including kaolinite, micas, gibbsite, vermiculite and minor mixed layer chlorite. Lateritic soils from Soka contain large amount of quartz, micas and mixed layer clay minerals. The clay minerals in Tamshin and Tungwei are not conspicuous. Only montmorillonite is detected in Tungwei soils. They therefore concluded that parent material play very important role in the chemical composition and characteristics of lateritic soils.



Rare earth elements (REE) are considered to be relatively unaffected by weathering. However, Kogel, et,al (2006) [28] stated that some lateritic REE deposits show sign of mobilization and deposition. Residual concentration of REE minerals, like monazite, is possible in laterite. Differences in REE distribution in different lateritic deposits may result from differences in parent rocks.

Mash and Anderson (2011) [29] stated that Nickel – Cobalt laterites are a supergene enrichment of Nickel and Cobalt formed from pervasive chemical and mechanical weathering of ultramafic rocks. It is from the ultramafic rocks that the laterite profile develops. The weathering progresses from the development of saprolite layers on the bedrock, to clay alteration of the saprolite then to oxide alteration of the clay and hydrous Mg – silicate, the limonite layer and concludes with the hematite alteration of the oxides capping to the profiles with ferricrete.

Effects of Mineral Abundance on Laterite Properties

Tuncer (1976) [30] stated that five major factors influence the formation of soils and they are parent rocks, climate, topography, vegetation and time. He explained further that the properties are features of the parent material from which the soil is formed. The soil minerals occurring in the soil mass apparently have direct influence on the size, shape and arrangement of the soil aggregates. The occurrence of kaolinite content decreases with continued weathering while the sesquioxides of iron and aluminum increases. The developments of all these minerals are dependent on their presence in the parent material or the presence of the compounds/minerals forming them. Oxides of iron and aluminum are very active as building agents increases the strength of the soil making it a good material for engineering works.

According to Alexander and Cady, Primary feldspars are reduced to kaolinite and primary ferromagnesian minerals are converted to sesquioxides. When weathering proceeds further, the kaolinite is converted to gibbsite. Lateritic soil with higher specific gravity implies that the soil contains higher specific gravity minerals. The more weathered a soil is, the higher the percentage of minerals with high specific gravity. The higher the specific gravity, the better the laterite as a sub grade or sub base material, minerals with high specific gravity can only be found in large quantity if the parent rock contains ferromagnesian minerals. The parent rock therefore, has a lot to do with the engineering properties of the laterite formed.

Tuncer (1976) [30] found out that cohesion varies in accordance with varying kaolinite content which implies that cohesion increases with increasing clay content. On the other hand, he stated that internal friction tends to increase with increasing amount of sesquioxides as a result of formation of large water, stable soil aggregate with the binding action of sesquioxides. He added that the engineering properties of soil, like natural dry density, void ratio and specific gravity are closely related to the minerals present in the soils. Since the minerals present in the soil are dependent on those present in the parent rock, the engineering products of lateritic soils are greatly dependent on the parent rocks.

Conclusion

Minerals are formed by chemical elements. Minerals are aggregated together to form rocks and most of the rock forming minerals are silicates. A variety of silicates can be formed. There is, therefore, a great multiplicity of silicate minerals in the earth's crust. Rocks weather over time when subjected to conditions differ from when they were formed. Chemical weathering is one of the 3 major types of weathering and it occurs when chemical changes occur due to its natural chemical reaction within the rocks leading to changes in its composition over time. These chemical transformation occurs when water and oxygen interacts with mineral in the rock to create different chemical reactions and compounds through processes such as hydrolysis and oxidation. Laterites are the products of intensive and long lasting tropical weathering of rocks. Lateritic formation leads to residual enrichment of iron and aluminum by the removal of silica, alkalis and alkaline earths. Clay is an important component of lateritic soil, especially when assessed for civil engineering purposes. Weathering can result in the alteration of olivines, pyroxenes and amphiboles.

Olivines give rise to smectite, kaolinite and halloysite and other oxides of hydroxide as well as oxyhydroxides of Fe. Pyroxenes and amphiboles could give rise to chlorite and Smectite. In some cases, talc may be formed. Also, weathering can cause feldspar to give rise to secondary minerals such as smectites, gibbsite and quartz



Micas, also can be weathered into phyllosilicates. This lead to loss of strength of layer binding as a result of replacement of K^+ by Mg^{2+} and Ca^{2+} . This release of K^+ occur either by layer or edge weathering. Chlorites and serpentines are also weathered into solid residue of iron oxides and iron rich smectites respectively. Volcanic parent materials break down into fluxes of some elements from fluxes of some elements from glass into interstitial pore waters.

Lateritic soils consist mainly of quartz, zircon and oxides of aluminum, iron, tin and titanium. These are the mineral that remain after the course of weathering because they are more resistant than others. The type of laterite, the chemical component, the engineering characteristics and the minerals available in it, depend on the parent rock. Iron in the raw laterite was present predominately as goethite and hematite. This implies that without the presence of goethite and hematite in the parent rock, there will not be iron in the laterite.

Elements that are immobile during chemical weathering becomes enriched as other elements are removed by dissolution. The greater the mass lost through dissolution, the greater the relative enrichment of the immobile element left behind. Iron content forms a major difference in soils formed and these iron content affects the specific gravity of the soil which in turn contribute immensely to the engineering property of the soil.

Oxides of iron and aluminum are very active binding agent, increase in the amount of these binding agent increases the strength of the soil, making it a good material for engineering purposes. The developments of these minerals are dependent on their presence in the primary mineral within the parent rock. The abundance of mineral in the parent rock, therefore, greatly affects the engineering properties of the lateritic soil. The presence of Fe and Al in a soil determines its specific gravity, which is a determining factor in the engineering property of the soil. Without the presence of Fe or Al in the parent rock, they will not be found in the soil. Cohesion varies in accordance with varying kaolinite content which implies that cohesion increases with increasing clay content. Internal friction increases with increasing sesquioxides. The amount of kaolinite and sesquioxides are governed by their presence in the parent rock. This further proves that the abundance of mineral in a parent rock have determining effect on the properties of lateritic soils.

References

- [1]. Rocksforkid.com. www.Madehow.com/volume-3/sand.html. Accessed 31 Jan 2017.
- [2]. Nyamai, C.M (2003) Materials of the Earth, Lecture note. Nairobi University press page 110.
- [3]. Adebisi, N.O., Adeyemi, G.O, Oluwafemi, O.S, and Songca, S.P. (2013). Important properties of clay content of lateritic soils for engineering project. Journal of Geography and Geology, Vol 5, (2).
- [4]. Churchman, G. J. and Lowe, D.J 2012 Alteration, formation and occurrence of minerals in soils. In Huang, P. M, Li, Y, Sommer, M. E. (editors). Handbook of soil sciences, 2nd edition, Vol 1: properties and Processes. CRC Press (Taylor & Franais), Boca Raton, FL pp. 20.1 – 20.72
- [5]. Oades, J.M and Waters, A.G, 1991. Aggregate hierarchy in soils. Australian Journal of soil research 29:815 – 828
- [6]. Shoji, S, Nauzyo, M and Takashi, T, 2006. Factors of soil formatin on climate. As exemplified by volcanic ash soils Pp 131 – 149. In Certinia, Scalengher R (edition)
- [7]. Carroll, D, 1970. Weathering monographs in Geoscience. Plenum press, New York.
- [8]. Chamley, H, 1989. Claysedimatology. Springer – Velog, Berlin.
- [9]. Loughman, F.C, 1969. Chemical weathering of the silicate minerals. Elsevier, New York.
- [10]. Huang, P.M, 1989. Reldpoers, Olivines, Pyroxenes and amphibole, Pp 975 – 1050 In Dixon J.B and Weed S.B, edition).
- [11]. Wilson, M. J. (2004). Weathering of the primary rock-forming minerals: processes, products and rates. *Clay Minerals*, 39(3), 233-266.
- [12]. Allen, B.L and Hajek, B.F, 1989, Mineral occurrence in soil environments. Pp. 199 – 278. In Dixon J.B, and S.B Weed (edition). Mineral in soil Environments. 2nd Edition. Soil Science Society of America, Madison, Wisconsin.
- [13]. Jackson, M. L., Hseung, Y., Corey, R. B., Evans, E. J., & Heuvel, R. C. (1952). Weathering sequence of clay-size minerals in soils and sediments. *Soil Science Society of America Journal*, 16(1), 3-6.



- [14]. Mortland, M. M. (1958). Kinetics of potassium release from biotite. *Soil Science Society of America Journal*, 22(6), 503-508.
- [15]. Jackson, M. L. (1959). Frequency distribution of clay minerals in major great soil groups as related to the factors of soil formation. *Clays and Clay Minerals*, 6, 133-143.
- [16]. Alin, J.H and Peacor, D.R, 1987. Kaolinization of biotite _TEM data and implication for an alteration mechanism. *American mineralogist*. 72:353-356.
- [17]. Banfield, J.F and Eggleton, R.A, 1988, A transmission electron microscoppr study of biotic weathering, clays and clay minerals. 36:46 – 70.
- [18]. Bain, D. C. (1977). The weathering of ferruginous chlorite in a podzol from Argyllshire, Scotland. *Geoderma*, 17(3), 193-208.
- [19]. Wildman, W. E., Jackson, M. L., & Whittig, L. D. (1968). Serpentinite rock dissolution as a function of carbon dioxide pressure in aqueous solution. *American Mineralogist*, 53(7-8), 1252.
- [20]. Ducloux, J., Meunier, A., & Velde, B. (1976). Smectite, chlorite and a regular interlayered chlorite-vermiculite in soils developed on a small serpentinite body, Massif Central, France. *Clay Minerals*, 11(2), 121-135.
- [21]. Daux, v, Croviser, J.L, Hemond, C, and Petit, J.C 1994. Geochemical evolution of basaltic rocks subjected is weathering: Fate of the major element, rare earth element and thorium, *Geochemicalet'cosmochemicalActa* 58:4941 -4954.
- [22]. Lelong, F., Tardy, Y., Grandin G., Trescases J.J., and Boulange, B., 1976, Pedogenesis, chemical weathering and processes of formation of some supergene ore deposits, in Wolf K. H., ed., *Handbook of stratabound and stratiform ore deposits—I—Principles and general studies—Vol. 3—Supergene and surficial ore deposits; texture and fabrics: Amsterdam, Elsevier*, p. 93–133.
- [23]. Ogura, Y., 1986, *Mineralogical studies on the profiles of nickeliferous laterite deposits in the Southwestern Pacific Area: Geological Survey of India Memoir* 120, p. VI-1–VI-12
- [24]. Gleeson, S.A., Butt, C.R.M., and Elias, M., 2003, Nickel laterites, a review: *SEG Newsletter*, v. 54, p. 11–18.
- [25]. Mutembei, P.K, Nafirati T.M, Jackson, W.M 2014, Iron enrichment in laterite soil from selected region in Kenya using magnetic separation. *IOSR Journal of Engineering* Vol 4 (03) pp 42 – 48.
- [26]. Whittington, B.I and Mvir, D.2000. Pressure acid leaching of Nichel Laterite: A Review. *Mineral Processing as Extractive Metalling Review*. 21(6)
- [27]. Tzu – Hsing, K (2014). Nature and properties of lateritic soils derived from different parent materials in Taiwan. *The Scientific World Tunnel* Vol (2014).
- [28]. Kogel, J.E, Trivedi, N.C, Barker, J.M and Krukowski, S.T (2006) *Industrial minerals and rocks; commodities, markets and uses*. Society for mining and metalling and Exploretim, INC
- [29]. Marsh E and Anderson, E (2011).Ni-Co laterite. A depril model. US Dept of Interior, USGS, Open File Report.
- [30]. Tuncer, E. R. (1976). Engineering behavior and classification of lateritic soils in relation to soil genesis.

