GEOLOGY OF NIGERIA

Nigeria lies approximately between latitudes 4°N and 15°N and Longitudes 3°E and 14°E, within the Pan African mobile belt in between the West African and Congo cratons (Fig.1). The Geology of Nigeria is dominated by three major rock types; the crystalline (igneous and metamorphic rocks) and sedimentary rocks both occurring approximately in equal proportions. The crystalline igneous and metamorphic rocks constitute the Precambrian-Palaeozoic basement complex which occur in the eastern region of the country and extend through the north central to the north eastern part of Nigeria. The Sedimentary Basins comprises of 7 inland basins namely the Niger Delta, the AnambraBasin, the Benue Trough, the Chad Basin, the Sokoto Basin, the Bida-Nupe Basin and the Dahomey Basin, all infill with sediments varying in age from the Cretaceous to recent.

BASEMENT COMPLEX

The Precambrian basement rocks in Nigeria consist of the migmatite gneissic –quartzite complex, the Schist belts (metasementary and metavolcanic rocks consisting of phyllites, schists, pelites, quartzites, marble, amphibolites) dated at Archean to Early Proterozoic (3500-2000 Ma). Intrusive into the pre-existing Basement rocks are the Pan-African granitoids (Older Granites) consisting of granites, granodiorites, syenites, monzonites, gabbros and charnockites batholiths. Also intrusive into the Basement are the igneous undeformed acid and basic dykes comprising of muscovite, tourmaline and beryl-bearing pegmatites, aplites and syenite dykes; basaltic, doleritic and lampropyric dykes).The Nigerian Basement have suffered 4 major thermo-tectonic episodes (orogenesis) namely: i. Liberian (Archaean) 2500Ma-2750± 25Maii. The Eburnean orogeny (Early Proterozoic), 2000Ma-2500Maiii. The Kibaran orogeny (Mid Proterozoic), 1100Ma - 2000Maiv. The Pan African Orogeny, 450Ma-750Ma.The Younger Granites ring complexes are centred around the Jos Plateau region and extends for a distance of about 1600km from northern Niger to Afu in central Nigeria with age trends ranging from 213 ± 7 Ma (at Dutse), 186 ± 15 Ma (at Zaranda) and 183 ± 7 Ma (at Ningi-Burra) to those in the southern extremity at 151 ± 4 Ma (Pankshin), 145 ± 4 Ma (Mada), and 141 ± 2 Ma (Afu). They were recognized as the major source of alluvial cassiterite deposits.

In addition, they are known to be associated with considerable amount of columbite, wolframite, scheelite and zinc mineralization.

MINERAL RESOURCES OF NIGERIA

Minerals resources are known to be associated with certain epochs/metallogenic provinces. Three economic metallogenic provinces/epochs are readily recognized in Nigeria; in the order of decreasing age are:

- Tin-tantalum (niobium in traces) pegmatites of probable Pan-African age in an E-W trending zone
- tin-niobium (with traces of tantalum and tungsten) greisens and granites of Mesozoic Younger granites of the Jos Plateau
- lead-zinc sulphide veins in Lower – Middle Cretaceous sediments of the Benue trough

Principal tectonic environments

In the Archaean, two principal tectonic environments can be distinguished; -

1). The high grade regions and 2). The greenstone belts.1). High grade zones: - Hosts mineral deposits such as Ni-Cu in amphibolites (e.g. Pikwe, Botswana); chromite in layered anorthositic complexes (e.g. Fiskenaessit, West Germany); chromite seams in dunite lenses (> 3800 Ma).

2). Greenstone belts: These belts are rich in mineral deposits associated with different rocks:

i) Ultramafic flows and intrusions: Cr, Ni, Cu

ii). Mafic to felsic volcanics: Au, Ag, Cu-Zn

iii). Sediments: Fe, Mn and Ba

iv). Granites and pegmatite: Li, Ta. Be, Sn, Mo, Bi

MINERAL COMMODITIES IN NIGERIA

Nigeria is endowed with about 34 solid minerals identified in 450 locations in the country. Some of these minerals include gold, iron ore, cassiterite, columbite, wolframite, pyrochlore, monazite, marble, coal, limestone, clays, barites, lead-zinc, etc. and occur in the different metallogenic provinces of Nigeria.Out of which Government has classified seven of these minerals as strategic minerals, which include bitumen, gold, coal, iron ore, limestone, lead/zinc ores, limestone and barites. Other minerals with good economic prospects are: tin, tantalite, niobium, gypsum, gemstones, kaolin etc.

Mineral Resources Classification

1. Metallic Mineral Resources

2. Non-metallic Mineral Resource

3. Fuel Mineral Resource

1. Metallic mineral resources are minerals resources that contain metal in raw form, their appearances have metallic shine and they can be melted to obtain new products. Examples of metallic mineral resource include Gold, Silver, Copper, Tin, Iron, Lead, Zinc, Nickel, Chromium, and Aluminium.

2. Non-metallic mineral resources are minerals that do not contain extractable metals in their chemical composition; they include sand, stone, gravel, clay, gypsum halite, and Uranium.

3. Fuel mineral resource include coal, crude oil (petroleum) and natural gas.

MINERAL OCCURRENCES (in federation states of Nigeria)

.1 Tantalite Cross River, Ekiti, Kogi, Kwara, Nasarawa

2 Kaolin Akwa Ibom, Anambra, Bauchi, Bayelsa, Ekiti, Imo, Katsina, Kebbi, Kogi, Ogun, Ondo, Plateau, Rivers

3 Mica Ekiti, Kogi, Kwara, Nasarawa, Oyo

4 Baryte Benue, Cross River, Nasarawa, Plateau, Taraba, Zamfara

5 Coal Abia, Adamawa, Anambra, Bauchi, Benue, Cross River, Delta, Ebonyi, Edo, Enugu, Gombe, Imo, Kogi, Nasarawa, Plateau

6 Rutile Bauchi, Cross River, Kaduna, Plateau

7 Ta l c Ekiti, Kaduna, Kogi, Niger

8 Bismuth Kaduna

9 Gypsum Adamawa, Edo, Gombe, Ogun, Sokoto, Yobe

10 Feldspar Bauchi, Borno, FCT, Kaduna, Kogi,

11 Gold FCT, Kaduna, Kano, Katsina, Kebbi, Kogi, Kwara, Niger, Osun, Zamfara

12 Clay In all the states of the federation

13 Silver Ebonyi, Kano

14 Ilmenite Bauchi, Cross River, Kaduna, Plateau

15 Limestone Benue, Cross River, Ebonyi, Edo, Gombe, Kogi, Ogun, Sokoto

16 Columbite Bauchi, Cross River Kaduna, Kano, Kwara, Nasarawa, Plateau

17 Cassiterite Bauchi, Cross River, Kaduna, Kano, Kwara, Nasarawa, Plateau

18 Diatomite Borno, Yobe

19 Silica sand Delta, Jigawa, Kano, Lagos, Ondo, Rivers

20 Fluorite Bauchi, Ebonyi, Plateau, Taraba

21 Bitumen Edo, Lagos, Ondo, Ogun

22 Lead Cross River, Ebonyi, FCT, Plateau, zamfara

23 Zinc Cross River, Ebonyi, FCT, Plateau, Zamfara

24 Benonite Borno, Edo, Kogi, Ogun, Ondo

25 Kyanite Kaduna, Niger

26 Iron ore Enugu, FCT, Kaduna, Kogi, Nasarawa, Zamfara

27 Lithium Kaduna, Nasarawa, Niger, Zamfara

28 Magnesite Adamawa, Zamfara

29 Wolframite Bauchi, Kaduna, Kano, Kwara, Nasarawa, Niger, Zamfara7

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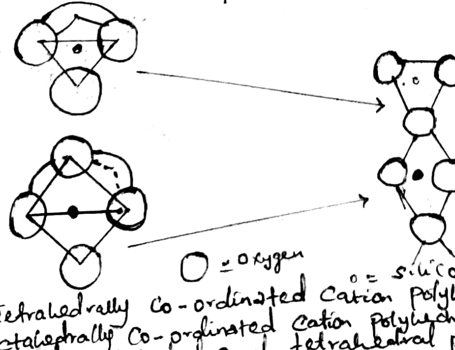
CLAY MINERALS AND THEIR DISTINCT PROPERTIES

Clay minerals are a diverse group of hydrous layer alumino silicates that constitutes the greater part of the phyllosilicate family of minerals. They are commonly defined by geologists as hydrous layer aluminosilicates with a particle size <2μm, while engineers and soil scientists define clay as any mineral particle <4μm. However clay minerals are commonly >2μm, or even 4μm in at least one dimension. Their small size and large ratio of surface area to volume gives clay minerals a set of unique properties, including high cation exchange capacities, catalytic properties, and plastic behaviour when moist.

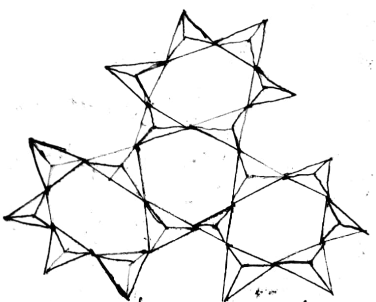
Clay minerals are the major constituent of fine-grained sediments and rocks (mudrocks, shales, claystones, clayey siltstones, clayey oozes, and argillites). They are an important constituent of soils, lake, estuarine, delta and the ocean sediments that cover most of Earth's surface.

Clay structure and chemistry

Clay can be envisaged as comprising sheets of tetrahedra and sheets of octahedra. The general formula for the tetrahedron is T_2O_5, where T is mainly Si^{4+}, but Al^{3+} frequently (and Fe^{3+} less frequently). The octahedral sheet comprises two planes of close packed oxygen ions with cations occupying the resulting octahedral sites between the two planes. The cations are most commonly Al^{3+}, Fe^{3+} and Mg^{2+}, but the cations of other transition elements can occur. The composite layer formed by linking one tetrahedral and one octahedral sheet is known as 1:1 layer. In such layers, the upper most unshared plane of anions in the octahedral sheet consists entirely of OH groups. A composite layer of one octahedral layer sandwiched between two tetrahedral layers (both with the tetrahedra pointing towards the octahedral layer) is known as a 2:1 layer. 2:1 clays of the mica and chlorite families have multiple polytypes defined by differences in stacking parallel to the C axis. If the 1:1 or 2:1 layer charge is ~~neutralized by interlayer materials.~~ electrostatically neutral (due to substitution of trivalent cations for Si^{4+} or of divalent for trivalent cations) the layer charge is neutralized by interlayer materials. These can be cations (commonly K^+, Na^+ or NH_4^+), hydrated cations (most common Mg^{2+}, Ca^{2+}, or Na^+) or single sheets of hydroxide octahedral groups ($Al(OH)_3$ or $Mg(OH)_2$. These categories approximately coincide with the illite, smectite, and chlorite-vermiculite families of clays. It is evident that the different types of interlayer cation will have a direct effect upon the thickness of the clay unit cell in the 001 dimension...



(a) Tetrahedrally co-ordinated cation polyhedrons;
(b) octahedrally co-ordinated cation polyhedrons;
(c) linked octahedral and tetrahedral polyhedrons



Hexagonal arrangement of edge-linked tetrahedra

CLASSIFICATION

Clays are normally classified according to their layer type, with layer charge used to define subdivisions. Because of their fine particle size, clay minerals are not easily identified by optical methods, though the distinctive chemistry and sometimes habit or morphology of most allows identification by X-ray analysis in electron microscope studies.

Typical values for cation exchange capacities

Kaolinite	3 - 18
Halloysite	5 - 40
Chlorite	10 - 40
Illite	10 - 40
Montmorillonite	60 - 150
Vermiculite	100 - 215

Clays (~~kaolinite~~) (Serpentine and kaolinite) (1:1)

~~The se~~ Berthierine, $(Fe, Mg)_{3-x}(Fe_3, Al)_x(Si_{2-x}Al_x)O_5(OH)_4$, is the Fe(II)-rich member of the serpentine subgroup most commonly encountered in unmetamorphosed sedimentary rocks and odinite is its Fe(II) rich counterpart found (so far) in Eocene and younger sediments. Chemically, the kandite minerals are alumina octahedra and silica ~~octahedra~~ tetrahedra with occasional substitution of Fe^{3+} for Al^{3+}. Of the kandite group, kaolinite is by far the most abundant clay. ~~kao~~ kaolinite and both halloysites are single-layer structures whereas dickite and nacrite are double layer polytypes i.e the repeat distance along the direction perpendicular to (001) is 14Å, not 7Å.

Clays (Talc and Pyrophyllite (2:1)

Ideal talc $(Mg_3Si_4O_{10}(OH)_2)$ and pyrophyllite $(Al_2Si_4O_{10}(OH)_2)$ are 2:1 clays with no substitution in either sheet and hence no layer charge or interlayer cations. However, minor substitution is common.

Clays (Smectite) (2:1)

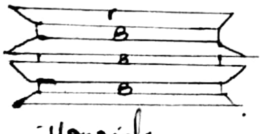
The 2:1 clays with the lowest interlayer charge are the smectites. This group have the capacity to expand and contract with the addition or loss (through ~~heating~~ heating) of water and some organic molecules. It is this property that is used to identify smectites by glycol or glycerol solvation and heat treatments in XRD studies. This swelling is believed to be due to the greater attraction of the interlayer cations to water than to the weakly charged layer. Montmorillonite is a predominantly dioctahedral smectite with the charge primarily in the octahedral sheet $(R^+(Al_3Mg_{.33})Si_4O_{10}(OH)_2$ while beidellite $(R^+Al_2(Si_{3.67}Al_{.33})O_{10}(OH)_2)$ and nontronite $(R^+Fe(III)_2(Si_{3.67}Al_{.33})O_{10}(OH)_2)$ are dioctahedral with the charge mainly in the tetrahedral sheet (where R = mono or divalent interlayer cations).

Clays (Chlorite) (2:1)

Chlorite consists of a 2:1 layer with a negative charge $[(R^{2+}, R^{2+})_3(Si_{4-x}R^{2+}_y)O_{10}OH_2]^-$ that is balanced by a positively charged interlayer octahedral sheet $[(R^{2+}, R^{2+}, R^{3+})_3(OH)_6]^+$. R is most commonly Mg, Fe(II), with Mg-rich chlorite (clinochlore) generally being metamorphic (high temperature) or associated with aeolian and sabkha sediments, while Fe-rich chlorite (chamosite) is typically diagenetic (low temperature).

Isomorphous substitution : Al for Si in 2:1 layer

Linkage between sheets : brucite linkage + secondary valence



$d = 14A^\circ$

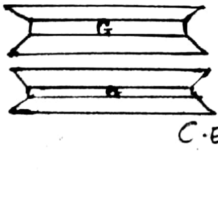
$$[(Mg)_3(Si\ Al)_{3\cdot3\cdot5}\ O_{10}(OH)_2]^{-0.5\ to\ -1.0}\ [(Mg\,Al)_3(OH)_5]^{+0.6\ to\ 1.0}$$

C.E.C = 10 → 40m . eq/100gm

Montmorillonoids

Isomorphous substitution : Mg for Al, 1 in 6

linkage between sheets : Exchange ion + SECONDARY VALENCE



d Variable (Generally 16 TO 18A° DAMP)

$$[Al_{1.7}\ Mg_{0.3}^{-0.3}) (Si_4)\ O_{10}(OH)_2]^{-0.3}\ (M)^{+0.3}$$

C.E.C = 100m eq./100gm

Clays (Vermiculite) (2:1)

The second group of clays with exchangeable cations is vermiculite. Vermiculite has a talc-like structure in which some Fe^{3+} has been substituted for Mg^{2+} and some Al^{3+} for Si^{4+}, with the resulting charge balanced by hydrated interlayer cations, most commonly Mg^{2+}. The layer charge typically ranges from 0.6 to 0.9. Vermiculite is distinguished from s smectite by XRD after saturating with $MgCl_2$ and solvation with glycerol. This results in expansion ~~to this rule~~ of the interlayer to 14.5Å rather than ~~the~~ 18Å characteristic of smectite (though there may be exceptions to this rule). Vermiculite is much less often encountered in sedimentary rocks than is smectite, probably because it is most commonly a soil-formed clay, while coarsely crystalline vermiculite deposits are formed from alteration of igneous rocks.

Clays (mica and illite) (2:1)

Substitution of one Al^{3+} for one Si^{4+} results in a layer charge of 1, which in true mica is balanced by one monovalent interlayer cation (denoted R). In mica the cation is usually K^+, less often Na^+ or Ca^{2+} and rarely NH_4^+. The term claygrade mica is sometimes used to describe mica which has been weathered resulting in loss of interlayer cations or formation of expandable smectite by layers.