

Environmental and Affordable Housing Material - The Use of Bricks and Tiles in Reducing Housing Deficits in Developing Countries: A Case Study at Bongo District, Ghana

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ABSTRACT

Many factors such as inadequate mortgage finance, defective land tenure system, and high cost of land are speculated to influence the housing deficit in Ghana. Rarely do the housing deficit challenges include unavailability of construction materials as a factor. Evidence of clays used in building are common mostly in Great Britain, Italy, Japan and sparsely in developing countries and was used in building in ancient Ghana. Clay is considered as an eco- friendly building material available on earth. The abundance of intrusive rocks in Bongo District led to the exploration and evaluation of clay for bricks and tiles in Balungu and Apamtaga areas. Six pits were dug at these two areas for clay mineralogy studies. The predominant minerals found were quartz, kaolinite, smectite and those present but in trace amounts were dolomite, amphibolite, microcline, plagioclase and muscovite. The predominant minerals also vary in mineral compositions with respect to the characteristics of the underlying geology. The results showed over 50% quartz, 11.8 % kaolinite and 6.7% smectite clay minerals occur in most samples analysed. Additional investigation to aid in the determination of the clays suitability for bricks and tiles involved 85 auger drill holes that assessed the clay thickness at Balungu River catchment. An average clay thickness of 4.5 m was calculated from the 85 drill holes drilled over 382 m of core drilled. This drill activity identified 2840000 m² area with significant clay thickness of 4.5 m averagely. The product of the prospective clay area and the average thickness led to the estimation of clay volume of 12, 78000.00 m³. Using dimensions of standard solid bricks of 0.222 m × 0.106 m × 0.076 m, an equivalent of 0.00172 m³ 60000 bricks can be produced in a day. A total of 38 or 41 production years will be required to exhaust the discovered clay for bricks and tiles. The utilization of clay that are readily abundant in Ghana may significantly provide solutions to the Ghana's housing deficits and make housing affordable as the product will be cheap

Keywords: Bongo geology, Clay mineralogy, Bricks, Tiles, Exploration

INTRODUCTION

The local occupation in Bongo District is subsistence and livestock farming over a rocky land setting, fishing, art and craft and other trade related workers. This generally hampers farming. The consequence is the intense base of hill and alluvial plains

farming. The land sizes available for subsistence farming are restricted in addition to the infertile states of the soils. The rocky characteristics of Bongo landscape makes farming of any sort unattractive but other opportunities avail for the rock used as

construction material. The rocks can be used as dimension stones; cut into different ornamental stones for construction works when fresh. However, clays formed from the weathering of the rocks can be transformed into several clay products for construction industries (Kinuthia, 2016). For instance, bricks and tiles products, sanitary wares, crucibles for geochemical laboratory works, drill muds for mineral and water drilling etc., will depend on chemical composition of the clay formed. Harnessing clay deposit as a construction material depends on clay-type, its purity and colour. The identification of suitable clay, devoid of speculations and also the ability to serve the growing market without running out of products demand the understanding of the clay mineralogy, proper exploration and evaluation of Bongo clay deposits.

Inadequate knowledge of Bongo clay mineralogy and the unknown tonnage of the deposit are further worsened by real estate developers' preference of using cement blocks in the infrastructural development. The houses built by the government developers include the so-called affordable houses developed from imported and semi-imported constructional materials. These houses labelled affordable are indeed not affordable because of their high mortgage prices. To date the housing deficit in Ghana stands at over 2.0 million housing units (Owusu-Ansah, 2014). Successive governments in Ghana expound on the patronage in 'made in Ghana' goods. On the contrary, the use of solely natural materials in housing and infrastructure projects are uncommon nationwide particularly in the urban areas. Clay abounds in Ghana but apart from the local thatch houses, there are very few that uses bricks and tiles. It is unclear whether the statements by the successive governments are myth or reality.

The current scenario of climate change and high energy cost necessitates developing eco-friendly and low-cost variants of construction material to ensure economic interests do not undermine environmental concerns (Seyfang, 2009; Oti and Kinuthia, 2012). A perfect recommendation to ascertain economic interest whilst ensuring environmental sustainability is the use of clay for bricks and tiles. The ancient and modern men all used clay as a working material. It is easy to mix and flexible to mould. Churches, town halls and other monuments are only a few examples of the numerous buildings that can testify the long durability of clay bricks, roof tiles and pavers. Development of new techniques in transforming clay to bricks and tiles had boosted the performance of clay products to an outstanding level and made them perfectly suitable to innovative and future-oriented buildings (Kinuthis, 2016). It is revealing that clay bricks and roof tiles are essential components in the construction of low energy, passive and nearly-zero-energy houses or even plus-energy buildings (Oti and Kinuthia, 2012). Also, testimonies that ceramic roof tiles help recover clean water and are perfect products to provide good quality harvested water due to their hydrophobic coating has been confirmed by users of bricks and tiles product. Equally, special designed pavers from clay can be part of sustainable urban drainage systems filtering and cleaning rainwater through geotextile membranes and coarse graded aggregates. It is on these backdrops that this paper focuses on the potential of clay deposit at Bongo District and highlights on its value addition into bricks, tiles and clay paver products.

MATERIALS AND METHODS

Location and Physiographic Setting

Bongo District is near the town of Bolgatanga in the Upper East Region. It is

799.6 km from Accra and 559.0 km from Kumasi (Figure 1). The area exhibits single rainy season. The monthly totals increase slowly from March and peak in August after which there is a sudden decrease after October (Kranjac-Bersaljevic et al. 1998). The average monthly rainfall is 986 mm per month. Temperatures are constantly high and averages at 28.6°C. Nonetheless monthly

averages range from 26.4°C at the peak of the rainy season in August to an extreme value of 32.1°C in April (Dickson and Benneh, 1995). As it is common for the tropics, diurnal temperature changes exceed monthly variations (Dickson and Benneh, 1995). The total evaporation of 2050 mm exceeds the annual rainfall more than two folds.



FIGURE 1. Location of Bongo District from Accra by road (Map data @ 2018 Google)
Geology

The Bongo areas forms part of the Bole-Navrongo-Nangodi Birimian Greenstone Belt of Ghana (Figure 2) with a general regional trend of northeast-southwest (Kesse, 1985). Underlying the District are metamorphosed lavas and pyroclastic suite of rocks intruded at places by granodiorites (Leube et al. 1990). According to Milési et al. (1989), three types of granitoids intrudes the country rocks in the area, thus, the Belt and Basin type granitoids, which intrudes the volcanic and the metasedimentary suit of rocks respectively. The third granitoid group

is very coarse grained with a large composition of potassium feldspars, it is identified only in the region and hence a type locality name of Bongo granitoid. The first two intrusive bodies are composed of hornblende, biotite, plagioclase feldspars and other accessory minerals in the case of the belt – type granitoid. The basin – type granitoids on other hand is composed largely of potassium feldspar, biotite, and muscovite together with some accessory minerals. These intrusive bodies are coarse to medium grained. However, the most prominent

outcrops in the area are the potassium rich granitoids thus, the ‘Bongo granitoids’. The general dominant mineralogical compositions of the rocks in the area are potassium and plagioclase feldspars. These rocks in the area have undergone varying degree of deformations characterized by shearing and jointing, their coarse nature also makes them porous. These deformational features together with the porous fabric property serve as conduits/channels ways for

water to readily infiltrate these rocks thereby facilitating chemical weathering. This process allows the mineralogical constituent, thus, the dominant relatively unstable minerals to rapidly undergo chemical alteration leading to the formation of large kaolinite and smectite type of clays. The kaolinite type of clay is a suitable raw material for ceramics and brick and tiles industries.

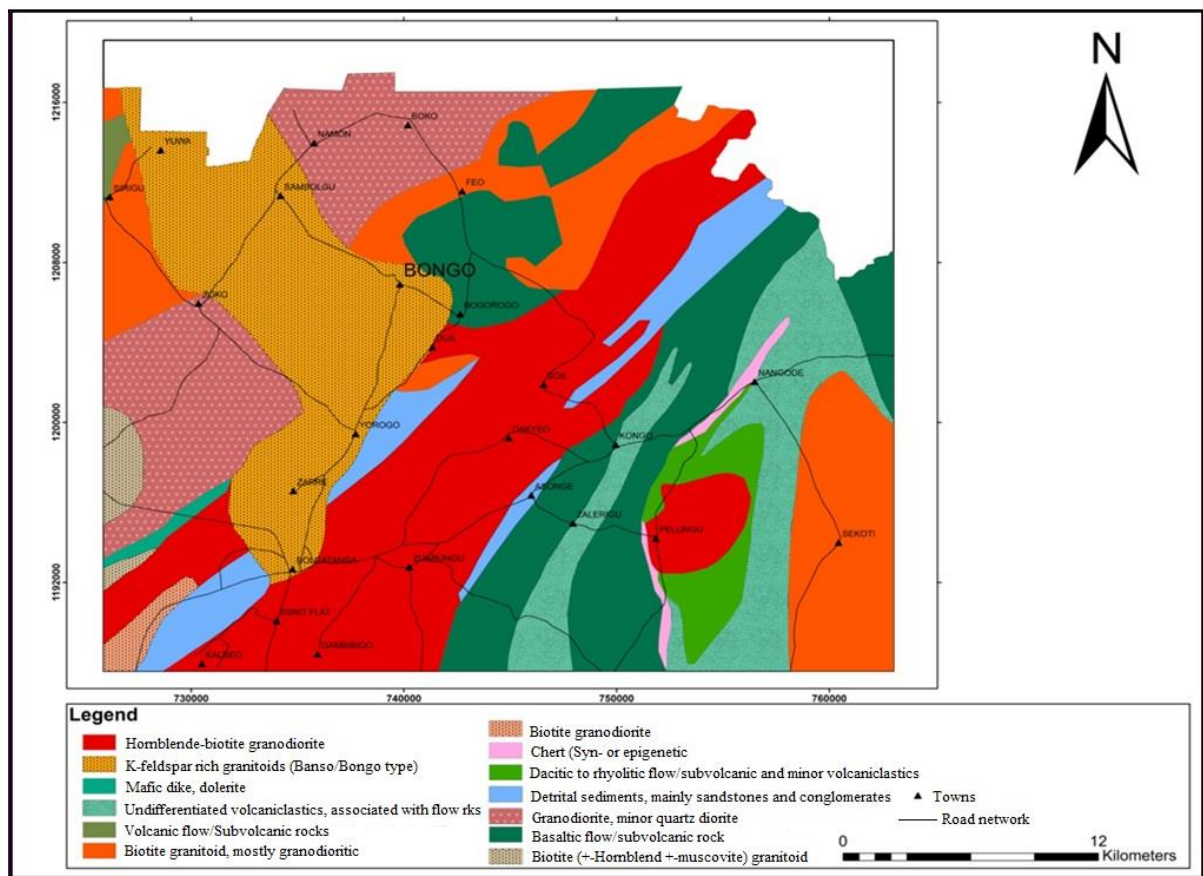


FIGURE 2. Geology of Bongo and its surrounding areas (Modified after Ghana Geological Survey Authority, 2010)

Assessment of clay deposits

Assessment of any clay deposit is a process that requires the following operations: (a) Field observation, including the description of surface outcrops, test pitting, results of

auger drilling and geological diagnosis. Information on clay deposit based on clay thickness and true section thickness (that includes the clay and overburden thickness) with quantified volume of overburden is

useful in establishing the life of business. Macroscopic description of target clay materials that specifies properties such as mineralogy, colour, variability and spatial homogeneity is important in clay exploration and evaluation. The development of clays from different rock types suggest the need to examine the particle sizes of the extracted clays so that the fraction of materials expected to be the beneficiated product can be assessed.

The discovered clay deposit reserve should be calculated to help manage the production and also establish the life of the brick and tile factory. The required data for brick and tiles as well as fine ceramics industry is metric tonnes for clay raw materials but can be expressed also from bricks in cubic metres. This involves bulk density calculations as well as prior knowledge of specific volumes of brick types to estimate quantity of bricks to be moulded in a day throughout the life of the factory. The bulk density of plastic clays including bentonites varies between 2.0 and 1.7 g cm⁻³ and residual kaolin derived from granitoids range between 2.2-1.5 g cm⁻³ but often found around 1.8 g cm⁻³. However, it is recommended (for the calculation of their reserves) to determine this value on actual samples. Such extended information on the qualities of available clay raw materials improves the quantification of reserves. The variability of the raw clay materials in the field requires prior homogenization for efficient clay production. This means that raw materials must be blended through programmed stockpiling. All these are necessities for modern bricks and tiles factories that produce construction products to close the housing deficit gaps particularly in the developing countries.

Field Methods

Geological field mapping was conducted to outline the granitic terrains because the feldspars in the granites generally weather to

clay. Streams and rivers draining the granitic terrains were tested for their potential for hosting clay deposit.

Six pits with 1.0 m x 1.0 m dimension were dug at the catchment areas of Balungu River and a stream at Atampaga. The planned depths of the pit excavation were 3 m but most of them, particularly at Balungu River basin were stopped at 1.8 m, though in clay zones before the 3 m depth. The Atampaga pits from the surface upper soil to the bedrock measured averagely about 1.5 m, of which the clay zone was only 0.3 m. Pit profile information of the sub horizontal layers were recorded. This included the upper soil and clay zone thicknesses as well as the depth to the bedrock and the bedrock type. Pit location environments were also described. Sixteen samples in all with 8 samples each coming from Balungu and Apamtaga. The north face of the pits were chipped randomly within the clay zone. These samples were sun dried at a field camp where they were sieved to < 125 µm size fraction after 24 hour sun drying. 100 g weight materials were collected from the sieved materials using 'precision riffle splitter'. The 100 g weight portion was labelled using sequential unique numbering system different from the field numbers used. The labelled samples were sent to ALS Geochemical laboratory in Kumasi for clay mineralogy studies.

Follow up down hole investigations were carried out also to establish the depths and volumes of clay deposit in the study area. The clay-rich areas based on clay thicknesses were subjected to auger drilling. Apamtaga pits were shallow, and had a measured average clay thickness of 0.3 m. This terrain did not show potential of underlying clay deposit; hence no auger drilling survey was conducted in the area. Conversely, Balungu area where the excavated pits ended in clay zone merited this investigation, so 85 drill holes were marked out for drilling on 500 m

x 100 m grid. This was followed on by close infill drilling at the significant clay thickness sites at 250 m x 50 m intervals. The drilled-out materials were logged with respect to depth. 1 kg weight samples were collected at every 1 m drill. Information about the 1 m sample materials was recorded. The protocol used in the field to map out the suitable clay materials and also blend appropriately the raw clay materials for future brick production included visually logging the augured materials as clayey, silty clay, sandy clay, clayey silt etc. A total of 382.5 m of auger drilling was obtained from the 85 drill holes. The total area coverage and the average clay thickness were computed from the drill holes information. The tonnage of the clay deposit was also calculated using specific density value of 2.6 g cm^{-3} for kaolin derived from granitoids and the products of average grade and the clay potential area.

RESULTS AND DISCUSSIONS

Results

The results of the field geological mapping presented in Figure 2 shows granitic intrusive dominance among the rock types in the north-western parts of the district. From Figure 2 the intrusive bodies have considerable textures ranging from fine to coarse grain with some granitoids depicting porphyritic textural features. Also from the hand specimen the mineral compositions seem to range from hornblende, biotite, and potash and K-feldspar-rich granitoids. The variable mineral compositions of the granitoids play significant role in the formation of different clays at the end of the weathering processes. This is demonstrated in the clay mineralogy results obtained from pit samples and presented in Figures 3 & 4 and Tables 1 - 3. Table 1 represents the chemical composition of clay minerals in the Bongo area whilst Figure 3, Table 2 and Figure 4, Table 3

provide clay mineralogy results for Atampaga and Balungu.

The clay mineralogy results with sample identification numbers DPBS 001A, DPBS 001B and DPBS002A at Atampaga, contains no smectite clay mineral. But majority of the samples such as DPBS 002B to DPBS 002C. DPBS 003 samples have ~5-7% smectite, with trace number of amphiboles (Table 2 and Figure 3). Though no Atterberg limit test was performed on the clay to know the plasticity index but it is known that smectite clay mineral produces high plasticity clay (Azonon et al. 2010). For the purpose of evaluating clays for bricks and tiles, the smectite clays may require suitable mix or blend with other clay minerals. This result from the clay mineralogy at Apamtaga made the clays there unsuitable for the intended purpose for bricks and roofing tiles. In addition, the clay thickness was shallow; up to 0.3 m thick averagely meaning very large areas underlain by clay was required, which was not available. The overall examination of the samples collected from the clay zones; identified some clay minerals with silica or quartz. It recognized the dominance of silica in all samples with an average fine quartz percentage of 57.5. Feldspar, a potential mineral that weathers to clay was found in the form of plagioclase and microcline and is present in minor amounts in all the samples. Minor amount of kaolinite was also seen in all the collected samples analysed. As seen in Table 2 and Figure 3 the only sample where muscovite was not detected was sample with identification number DPBS 002A. Smectite was not also detected in DPBS 001 and DPBS 002A. However, the smectite clay content increases from the results obtained at Balungu area was different as the two pits excavated presented two varying outcomes. No smectite were found at BAL001 area whilst samples from BAL002 terrain contained varying amount of smectite (Table

3 and Figure 4). Quartz dominance in the samples was observed in BAL 001 samples particularly in BAL 001D. That same sample has the highest chemical composition of kaolinite (~32%). Similar to Apamtaga area the feldspars are preserved in the form of microcline and plagioclase and are present in minor amounts in all BAL samples (Table 3 and Figure 4). The inconsistent nature of

chemical compositions in the samples may be an attribute of mosaic of different rock types across the landscape. The fractionation of the minerals in the underlying rocks presents the minerals in the overburden units above it. This probably explains the differences in chemical compositions between BAL 002 and BAL 003 (Table 3 and Figure 4).

TABLE 1. Chemical mineralogical composition of the Bongo area

Mineral types	Chemical composition
Dolomite	$\text{CaMg}(\text{CO}_3)_2$
Amphibole	$\text{Ca}_2(\text{Mg}_{4.5-2.5}\text{Fe}_{0.5-2.5})(\text{Si}_8\text{O}_{22})(\text{OH})_2$
Kaolinite	$\text{Al}_2(\text{Si}_2\text{O}_5)(\text{OH})_4$
Microcline	$\text{K}(\text{AlSi}_3\text{O}_8)$
Muscovite	$\text{KAl}_2(\text{AlSi}_3\text{O}_{10})(\text{OH})_2$
Plagioclase	$(\text{Na,Ca})(\text{Si,Al})_4\text{O}_8$
Quartz	SiO_2
Smectite	$(\text{Na,Ca})_{0.3}(\text{Al,Mg})_2\text{Si}_2\text{O}_{10}(\text{OH})_{2.n}(\text{H}_2\text{O})$

TABLE 2. Clay mineral weight (Wt. %) identified in DPBS samples

Mineralogy	DPBS 001A	DPBS 001B	DPBS 002A	DPBS 002B	DPBS 002C	DPBS 003A	DPBS 003B	DPBS 003C
Dolomite	0.2	0.2	0.0	0.5	0.2	0.4	0.0	0.1
Amphibolite	-	0.2	-	-	-	-	-	-
Kaolinite	11.5	10	12.4	10.6	10.3	10.7	11.6	17.5
Microcline	6.7	10.2	7.6	11.5	9.4	9	10.2	7.5
Muscovite	6.1	6.7	0	5.8	5.6	6.4	7.5	6.8
Plagioclase	16.2	15.9	11.2	10.5	9.3	14.8	11.6	4
Quartz	59.4	56.8	68.8	54.7	56.1	54	52.2	58.1
Smectite	0	0	0	6.5	9.3	4.8	6.9	6.4

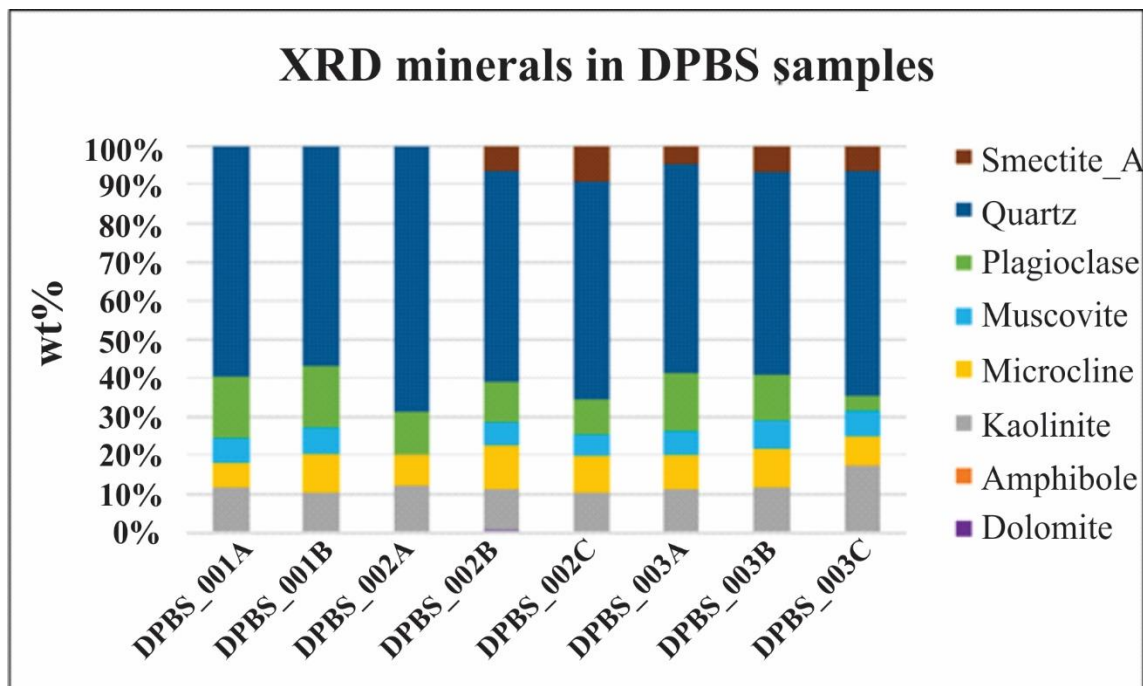


FIGURE 3. Presentation of Wt. % of clay minerals in DPBS samples

TABLE 3. Proportion of clay mineral weight (wt. %) in Balungu samples (BAL)

Mineralogy	DPBS 001A	DPBS 001B	DPBS 001C	DPBS 001D	DPBS 002	DPBS 003A	DPBS 003B	DPBS 003C
Dolomite	1	0.5	0.6	0.0	0.2	0.0	1	0.0
Amphibolite	-	-	-	-	2	3	3.8	2.7
Kaolinite	8.5	11.7	14.1	31.8	12.6	7.9	8.7	10.6
Microcline	10.5	14	13.9	12.4	11.7	12.5	9.8	9.7
Muscovite	-	4.5	5.7	-	-	5.2	3.4	5
Plagioclase	9.5	6.2	8.4	8.5	9.9	16.1	13.5	13.4
Quartz	70.3	63.1	57.1	47.3	43.7	43.5	30.5	30
Smectite_A	-	-	-	-	-	8.4	19.5	18.5
Smectite_B	-	-	-	-	19.9	3.3	9.6	10.2

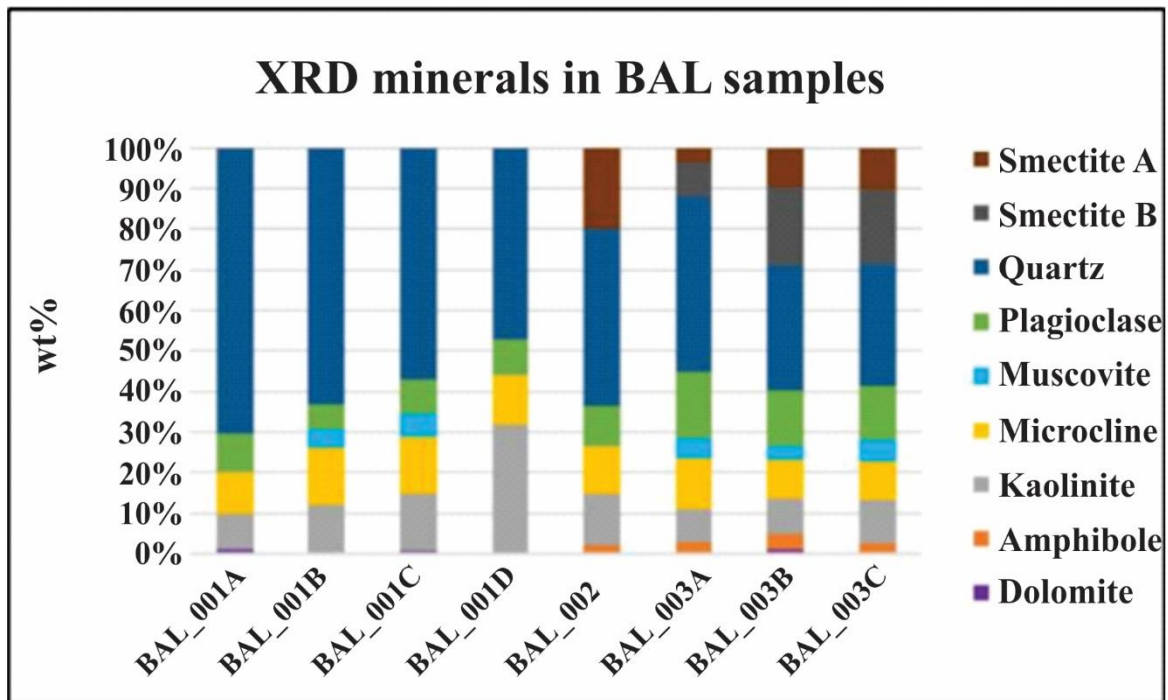


FIGURE 4. Wt. % proportions of clay minerals in BAL samples

DISCUSSIONS

Granitic outcrops seem to dominate the study area. This makes it not surprising despite the predominance of quartz in clay samples analysed (Figures 3 & 4). The rocks in the area as identified by Milési et al. (1989) consist of three types of granitoids in terms of mineralogical compositions. These are mica-rich, potash-rich and some belt-type granitoid varieties. From Figures 2 and 3 smectite and kaolinite type of clays coexist in the study area. The smectite clays may have relationship with the belt-type granitoids intruding the metavolcanic suite of rocks whilst the kaolinite probably may belong to the metasedimentary rocks intruded by basin-type and potash-rich granitoid areas. The belt-type granitoids intruding the metavolcanic rocks will weather to smectite and montmorillonite clays. These types of clays have expansive features that may affect bricks and tiles produce from them. Smectite clays are considered as expansive clay

because they are prone to large volume changes (i.e. swelling and shrinking). The swelling and shrinking features in this type of clays have direct relationship to changes in water content (Bain, 1971). Clay materials with a high content of expansive minerals can form deep cracks in drier seasons or years; such clays with smectite clay minerals, including montmorillonite have the most dramatic shrink-swell capacity. From Figures 3 and 4, two types of residual clays are recognized to occur in the investigated area and the sources are likely to be related to the underlying geology. The physiochemical properties of the two clays vary. For example, smectite is made up of phyllosilicate minerals. This determines its industrial and chemical usages however; natural smectite clay has three sub divisions, which determines its functions in its industrial and chemical usages (Odom, 1984). These are, Na smectite, Ca – Mg smectite and Fuller's or acid earth type. The three types are directly used in foundry, oil well drilling as well as

civil engineering to control water movement among other usage. The Fuller's or acid earth type of smectite has largely been used commercially in the preparation of animal litter trays, oil and grease absorbents and for decolorizing oil and fats (Odom, 1984). The range of uses and industrial need of smectite group of clays is due to the unique physiochemical properties smectite mineralogy exhibits through their (i) structural characteristics due to chemical factors (ii) extreme small crystal size (iii) variation in the internal chemical composition (iv) large surface area that is chemically active and (v) variations in types of exchangeable ions and surface charge. With a large spectrum of possible usage of the smectite type of clay, its presence as the second dominant clay mineral makes the deposit a potential raw material for a possible clay factory in the catchment. The structure, chemical composition, exchangeable ion type and small crystal size of smectite clays provides that several unique properties. This includes a large chemically active surface area, a high cation exchange capacity, inter-lamellar surfaces that depict unusual hydration characteristics, and sometimes the ability to interfere strongly with the flow behaviour of liquids. This clay-type has major industrial and chemical uses. They can be used in foundry, oil well drilling, and iron ore and feed pelletizing industries. Similarly, they can be used in civil engineering to impede water movement. Brick-products produced from the smectite clay can be used to construct structures in waterlogged areas. With the changing climate resulting in flooding, bricks from clay will be useful as a constructing product as this can avert strongly the flow behaviour of water that destroys people's properties because the cement blocks are unable to withstand the increasing flood waters. Significant volumes of clays (kaolinite and smectite) are used for various purposes in the manufacturing of

many industrial, chemical and consumer products (Odom, 1984). It thus appears from the clay mineralogy in Bongo area that varied clay products could be chained out for different industries to be setup to improve the district as well as the national economy.

The revelation of locating and identifying the correct clay deposit for bricks and tiles development in the area was presented in Tables 2 and 3. From Table 2, the dominant mineral in the DPBS samples is quartz with an amount >50. Feldspar was found in the form of plagioclase and microcline and is present in minor amounts in all the samples. Minor amount of kaolinite and muscovite were also observed across all the DPBS samples. Specific samples such as DPBS 002A was the only sample where muscovite was not detected. Also, no smectite was detected in DPBS 001 and DPBS 002A. However, the smectite clay content was recognized to increase from samples with identification numbers DPBS 002B and DPBS 002C. DPBS 003 samples have ~5-7% smectite (Table 2 and Figure 2). Trace amount of amphibole was observed in DPBS 001B only (Table 2). It appeared most clay in DPBS area contain some smectite that will expand and contract rapidly at a change in climate. This will not make the clay suitable for bricks and tiles intended for the housing construction sector. Though the smectite clay can be used for another purpose but are unsuitable as a construction material in real estate where there is 1.7 million housing deficit.

Also as seen in Table 3, variable proportions of minerals were recorded at Balungu area. This reflects the lithological settings of the area. The underlying rock unit is metavolcanic but has been intruded at places by Belt-Type granitoids and much younger intrusive rich in potash and microcline. The predominance of quartz in most of the

samples at this terrain may be an attribute from the widespread intrusive bodies in the area. Sample BAL_001 contain predominantly quartz minerals. BAL_001D was recognized to be rich in kaolinite (~32%) as compared to other DPBS samples. Feldspars were found in the form of microcline and plagioclase in the samples and were present in minor amounts across all BAL samples. BAL 002 and BAL 003 contain minor amount of smectite. Meanwhile, BAL 003 show increase in smectite content and these were conspicuous with BAL samples with subscripts A to C. Unlike DPBS where trace amounts of amphibole were found in only DPBS 001B, in the BAL samples trace amounts of dolomite, muscovite and amphibole were detected in all samples (Table 3 and Figure 3). From Figures 2 and 3 it is indicative that the overburden at the terrain where the BAL samples were collected have more kaolinite-rich-clay materials and some minor smectite units compared to samples from DPBS areas. The clay mineralogy obtained from the test pits excavated at the two study areas constrained the locations where the systematic clay exploration for brick and tiles factory had to be conducted. As seen in Figures 3 and 4, no pure clay was found in the area. Impure clays containing mixture of clay (i.e. kaolinite and smectite) and multiple non-clay minerals including quartz and iron characterized the area. The BAL area characterized by kaolinite +/- smectite rich overburden tested by auguring 85 holes defined prospective clay area of about 2840000 m². The resultant clay thickness obtained from the 85 auger drill holes was 4.5 m (table 4). The product of the prospective clay area and the average thickness led to the estimation of clay volume of 12, 78000.00 m³.

In working out the mass of clay to help calculate the tonnage, the relationship

between volume and density was employed. The relationships were as expressed in the formulae:

$$\text{Density of Clay} = \frac{\text{mass of clay}}{\text{volume of clay}} = \frac{m_c}{v_c}$$

And using the specific gravity of wet clay of 2.6, the clay tonnage was calculated as 7,384,000,000 metric tons or 7384 Mt. Most solid bricks have standard dimensions of 0.222 m × 0.106 m × 0.076 m. This by volume is 0.00172 m³. This implies that the discovered clay if used to make brick and tiles can contribute in reducing Ghana's housing deficit, which is pin at over 1.7 million houses. Currently the Ghanaian affordable housing demand is mounting steep day by day but this is not parallel to real estate sector growth in the country. Costs of houses termed affordable really, are not cheap. This may be an attribute of high cost of materials used. Apart from cost reduction in the building industry, clay bricks have the ability to "self-regulate" temperatures. This makes it superior to alternate lightweight building systems such as cement blocks and sand-Crete especially in the savannah regions. Property developers and architects need to consider not only the short-term costs of construction, but the long-term costs in terms of impact on the environment, energy efficiency, maintenance, operation and the lifespan of the building itself. Additionally, once laid, face brick withstands fire, rain, hail and intense heat – remaining beautiful indefinitely without maintenance – no initial painting, and no on-going repainting and replastering. Clay bricks are entirely natural, contain no pollutants or allergens and are resistant to ants, borer and termites. They are also recyclable or reusable, and can be returned to the earth at the end of their useful life. Clay bricks are truly sustainable and are trusted to create environmentally responsible living and workspaces for today's generation and beyond. Clay bricks have been used as the building material of choice in the rural

communities since our ancestors but not the burnt form. The long-life span and durability afforded by clay brick ensures that clay brick homes last for generations, while also instilling a sense of place, worth, comfort and security in the lives of our people. Considering the long-term performance, occupancy comfort, colour-fastness and life cycle value to enjoy from living in a clay brick house, it should be the preferred building material in the developing countries. These are some of the advantages the clay bricks bring into modern construction industry in addition to its decorative and aesthetic features. Clay brick stands out as a pillar of value and would be able to reduce the housing deficit which is in the range of 1.7 million houses.

The composition of clay determines its usage for building industry or as an additive to ceramics and drilling muds and in the production of plastics and paper. The reported clay deposits by Ghana Geological Survey do not give any accounts of clays in Bongo District. However, by virtue of the underlying geology there exist the possibilities of having abundant clay deposits from the weathering of the feldspar-rich granitoids extensively outcropping and underlying the district. The analysis of the XRD results has shown the presence of clay smectite and kaolinite clays in Bongo District.

CONCLUSION

The weathered materials from the granitoids were rich in clay minerals suitable for bricks and tiles production. Mineralogy of clays at the two sites appeared suitable for the manufacturing of bricks and tiles because blends can be obtained using different proportions of the clays for specific purpose. The silica mineral makes up $> 50\%$ of the clayey soils with the remainder containing kaolinite, smectite, microcline and others. Blends of these clay minerals make up the 78000.00 m^3 , equivalent to 7384 Mt of clay deposit discovered from the exploration survey where 85 drill holes drilled intersected average clay thickness of 4.5 m. The standard solid brick size used realized 60.000 bricks can be produced daily for 42 years; working continuously for 300 days a year and 38 years for 360 days. Conversely, if the plant is shut down for 10 days for maintenance in a year, the production life of the discovered clay will be 41 years. In conclusion harnessing the discovered clay deposit into bricks and tiles will reduce the material cost of building houses and will ultimately bring down cost of building house. This will significantly reduce the housing deficit challenges and also improve the local economies as jobs will be created in the local communities.

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