Updates on the Geological Map of Paiko Sheet 185, North Central, Nigeria

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Abstract

Geological mapping of Paiko Sheet 185 was carried out on a scale of 1:100,000 to update the existing geological map of the area. Traverse as well as green line methods of mapping were employed. At each location, the lithology, color, texture, and nature of contact between lithologies and structures were noted and documented. Field observations show that the area is composed of migmatitic gneiss (66.15%), Porphyritic biotite granite (14.23%), medium-grained biotite granite (13.06%), sandstone (4.18%), tonalite (2.14%), ironstone (0.09%), Talcose rock (0.09%) and marble (0.06%). The modifications made to the existing map which was produced in 2009 and updated in 2015 include; the replacement of the alluvial lithology with the bedrock (migmatite) and the renaming of talc-tremolite-actinolite schist to Talcose rock due to the absence of schistosity. Other modifications include the removal of the Phyllite, mica schist interlayered with amphibolite in the northeastern part of the area because it is located on the adjacent Abuja Sheet; the inclusion of the Sakpe Formation around Lapai as well as harmonising of the marble occurring around Kwakuti as one unit. Structures such as folds, faults, joints, unconformities, exfoliations, strain-slip cleavage, trace fossils, bedding, and bedding planes were observed and recorded. The result of joint direction measurements shows that the principal joint direction is in the northwest-southeast. The economic geological resources within the area include gold, lead, zinc, marble, Talcose rock, rocks, laterite, clay, sand, and gravel.

Keywords: Geological mapping, Paiko Sheet, lithology, structures, geological resources

1.0 Introduction

Updating geological maps at time intervals is necessary to make the map more comprehensible. Some rocks and features that were not captured by earlier maps perhaps due to poor exposure might become visible as a result of natural processes (such as erosion and uplift) or anthropogenic activities (such as quarrying, mining, and construction). Geological mapping of Paiko Sheet 185 was carried out to update the existing map of the area. The geological map (Figure 1) of the area was produced by the Nigeria Geological Survey Agency (NGSA) in 2009 on a scale of 1:100,000 with a total of 11 lithologies. The map was modified by Ejepu & Umar in 2015 (Figure 2) with change in the names and colour of some lithologies. The changes in the name of some lithologies include Coarse Porphyritic Granite to Porphyritic Biotite and Biotite Hornblende Granite, Sandstone to Bida Sandstone, and Phyllite, Schist interlayered with amphibolitic to Phyllite Mica

Schist, Quartz Schist interlayered with amphibolite. The maps show that about 85 percent of the area is underlain by Basement Complex rocks while the remaining part is underlain by sedimentary rocks. The present study was carried out to update the existing geological maps of the area.

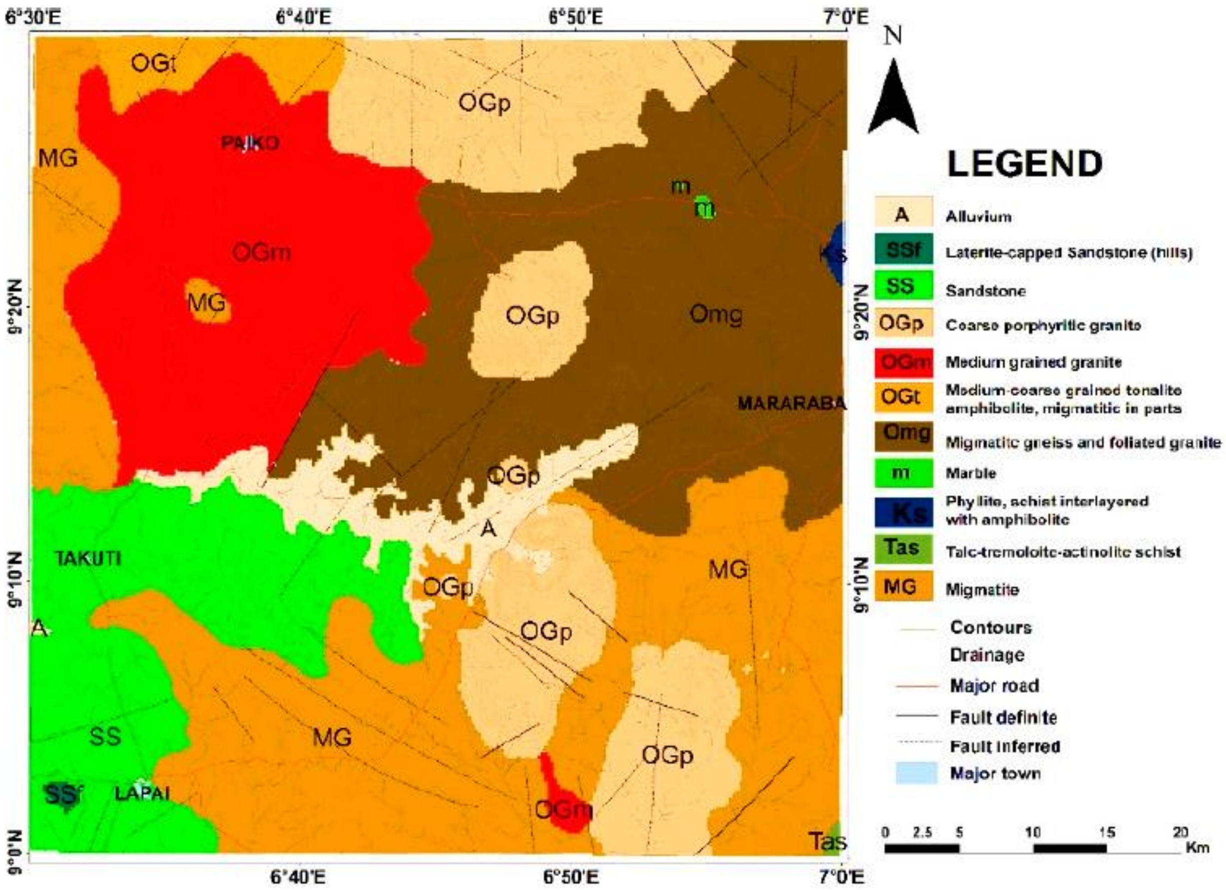

Figure 1: Geological map of Paiko Sheet 185 (NGSA, 2009)

2.0 The study area

The Paiko Sheet 185 is located on latitude 9º00' to 9º30' and longitude 6º30' to 7º00' (Figure 3). The area covers about 3080.25 km². It is bounded to the north and south by Minna and Gulu sheets respectively and to the east and west by Abuja and Bida sheets respectively. The inhabitants are mainly farmers but mining activities are on the increase as the area plays host to a lot of economic minerals such as gold, lead-zinc, and marble among others in various locations. The major settlements include Paiko, Lapai, Pago, Lambata, Farin Doki, Baida, Kwakuti, and Baban Tsauni. The topography of the area is characterized by various landforms that include ridges, inselbergs, Batholiths, earth pillar and plains. The lowest point is 130m while the highest point is 600m above sea level and are all found in the southwest. The summit of the Kudan Batholith represents the highest point in the area. Averagely, the eastern half has higher relief than the western half. The average relief of the north-eastern portion is the highest of all followed by the south-eastern then the north-western portion while the least is the south-western portion. River Gurara which is located in the southeastern part of the area is the largest river draining the area with dozens of tributaries. The areas generally have a dendritic drainage pattern except for the areas around the Kudan batholith where a radial drainage pattern was observed. The majority of streams take their source from the highlands within the studied area; and the southern part generally has a better drainage system than northern part of the area. All streams and rivers are indirect tributaries of River Niger except River Gurara which empties its content directly into it somewhere around Dere close to Koton Karfe in Kogi State (outside the study area).

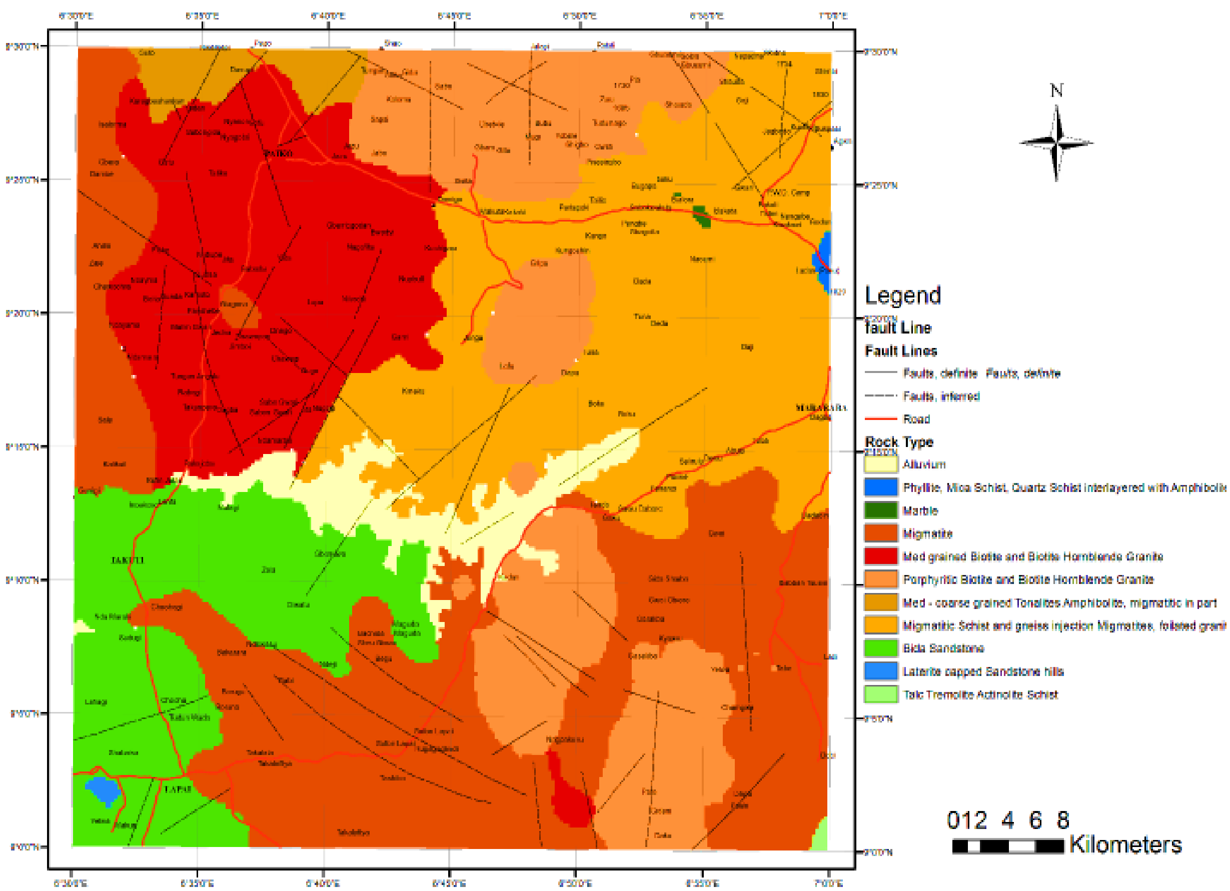

Figure 2: Modified Geological map of Paiko Sheet 185 (Ejepu & Umar, 2015)

The vegetation is of the Guinea Savannah type. The area is characterized by tropical shrubs as the major trees generally, but thicker forest exists in part of the southwestern portion (Sodugi and Kpaesan). Light forest also exists in the northwestern part (around Kwakuti). The climate of the area consists of two seasons (dry and wet). The dry season usually lasts between November and April while the wet season usually last between May and October. The total annual rainfall ranges between 1270mm to 1524mm (Ejepu & Omar, 2015). The maximum daytime temperature is about 35ºC in the months of March and April, while a minimum temperature of about 24ºC is usually recorded in the months of December and January. The dry season is marked by the influence of harmattan which is a result of North-East trade wind that blows across the Sahara which is often laden with red dust and lasts from the month of December to the month of February (Ejepu *et al.*, 2017).

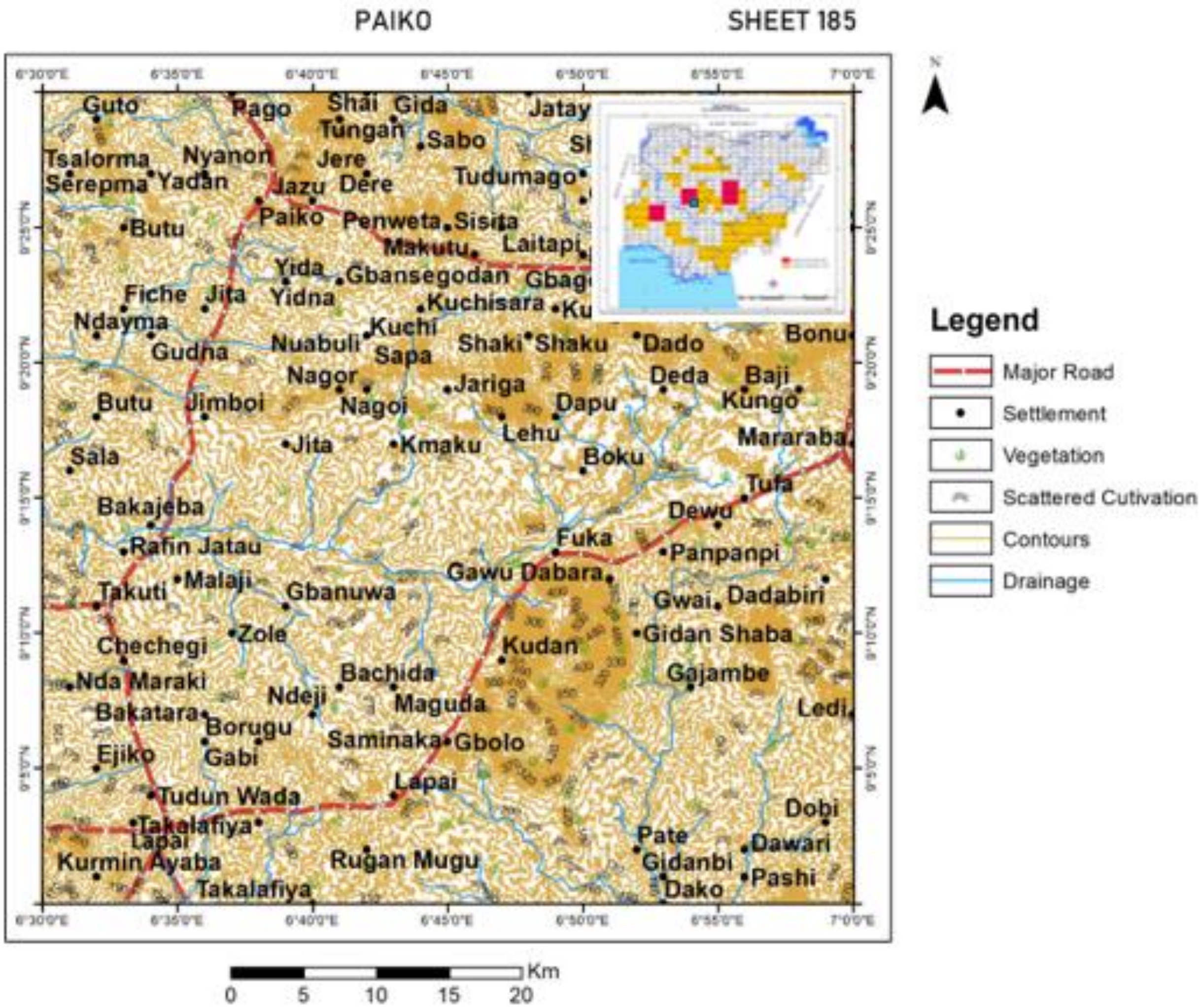

Figure 3: Location map of Paiko Sheet

3.0 Geology of the Area

Paiko Sheet 185 is part of the area covered by Russ (1957), and Truswell and Cope (1963) in their reconnaissance geological survey of part of Northern Nigeria. It forms part of the area studied for gold mineralization by Woakes and Bafor (1984). The geological map of the area was produced by NGSA in 2009 (Figure 1). The NGSA map recognized about eleven different lithologies in the area. These lithologies include Alluvium which can be found in the central part of the area; laterite-capped sandstone exist in the southwestern part of the area; Coarse-grained porphyritic granite is found in parts of the northern, northeastern and southeastern region of the area; Medium-coarse grained tonalite and amphibolite exist in part of the northwestern region of the area; migmatitic-gneiss and foliated granite is found in the north-eastern part of the area; Marble exists as small units in part of the north-eastern part of the area; Phyllite, mica schist interlayered with amphibolite are found at the end of the northeastern part of the area; Talc-tremolite-actinolite schist can be found at the end of southeastern part; and migmatite can be found in parts of the southern and northwestern part of the area. Migmatitic rocks dominated the area followed by granitic rocks that contain biotite and hornblende and then Sandstone Formation. The geology of the area shows that about 85% of the area is occupied by basement rocks and about 15% is occupied by sedimentary rocks according to Ejepu and Omar (2015).

4.0 Method of Study

The traversing method was utilized mainly for the field mapping exercise along with green line mapping methods also called exposure mapping used for mapping very large exposures (Barnes and Lisle, 2004). Roads (main road, minor road, main path, and minor roads), road cuts, and river channels were utilized to locate outcrops. Materials used include compass/clinometers that were used for measuring strikes and dips of rocks and structures, hand lens for field examination of mineral and textural composition, geological hammer for sampling, and pen and field notebook for the recording of field observations. Others include a topographic map that was used as a base map, a rucksack for carrying samples, a camera for taking photographs of important features, and a Global Positioning System (GPS) for recording coordinates. Since the area cut across both basement complex and sedimentary terrain, the expected rock types were igneous, metamorphic, and sedimentary rocks. Igneous rocks were studied using a checklist proposed by Thorpe and Brown (1985) while metamorphic rocks were studied using the criteria proposed for mappable units by Fry (1984). Sedimentary rock studies were achieved using the broad scheme developed by Tucker (1982). Results from the geological field exercise were used to prepare a geological map, and cross profiles and the measurement taken for joint directions were used to prepare a rosette diagram to determine the principal joint direction of the area with the aid of ArcGIS 10.5 and Surfer 13 software. Appropriate map symbols were used for ease of comprehension.

5.0 Results and Discussion

5.1 Petrography

5.1.1 Migmatitic-Gneisses

Migmatitc-gneiss are the dominant rock types in the northeastern and southern parts of the Paiko Sheet. It is also exposed at the end of the northwestern part of the sheet. The rocks comprise migmatites and gneisses coexisting together without any particular order. The most notable of the gneiss is exposed in the ENE (around Dagigbe) part of the area as shown in Plate I and it is located on latitude 9º21'43.1" and longitude 6º59'55.3". The trend of the outcrop is 328ºNW. The outcrop was poorly exposed by a road cut. Bandings (alternation of light and dark-colored minerals) were observed on the outcrop and boulders. The dark-colored minerals predominate as their layers are usually thicker than the light-colored minerals. It is generally hard signifying slight to no weathering. The migmatite-gneisses were intruded in parts by granitic rocks. Plate II shows a very fine-grained migmatitic rock located (latitude 9º08'37.2" and longitude 6º32'58.3") at the contact between Basement Complex and Bida Basin. The rock appeared to have been affected by shear force due to the very fine-grained nature of the grain sizes. The rock is exposed along a stream that flows southwest takes its source around Achitupa and Kpaesan hills. They are generally low-lying. Bida Sandstone unconformably overly the magmatic rock at the southern-western part of the exposure. Observations from hand specimens show that the migmatite–gneissic rocks from Paiko Sheet 185 are generally dark in color and composed of Biotite, quartz, plagioclase feldspar, and accessory minerals. They are mostly medium to coarse-grained except those that exist at the Basement Complex-Bida Basin contact within the southwestern part of the sheet. They occupy more than 60% of the rocks in the area. It is dominated by dark-colored minerals.

5.1.2 Porphyritic Biotite and Biotite Hornblende Granite

This is the major rock type occupying part of the north-eastern Paiko Sheet and also forms part of the rocks underlying the southern portion. The outcrops within these areas also exist in various igneous landforms. The notable igneous landforms in this area are Gbagbanpi Ridge, Shaku Ridge and Bodna – Sekiape ridge, Kudan Ridge (the most prominent of all with a length of more than 18km, breadth of more than 10km and a peak of about 600m above sea level) and Dawaki hills in the south; and Pita laccoliths and Gbodna hill in the northern part of the area. They are porphyritic in texture and dark in appearance. It is dark colored and the major mineral composition includes biotite, quartz, and feldspar. Accessory minerals are also present. Field relationship shows that they intruded into the Migmatite-Gneiss.

Plate I: Foliated gneiss (9º21'43.1"; 6º59'55.3")

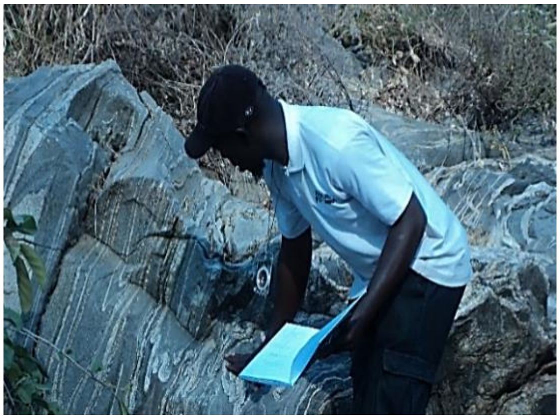

Plate II: Ptygmatitic folded migmatite (09°08'37.2", 006°32'58.3")

5.1.3 Medium Grained Biotite and Biotite Hornblende Granite

This rock type dominates the north-western part of the Paiko Sheet. A very small portion of it exists in the southeastern part of the sheet. The outcrops within this area exist in various igneous landforms. Notable among these igneous landforms is the Paiko Laccolith. It is medium grained and consist of biotite and biotite-hornblende granite. It is dark in appearance and Biotite mica is the dominant mineral followed by feldspar, quartz, and then accessory minerals. Field relationship shows that they intruded into the Migmatite-Gneiss.

5.1.4 Medium - Coarse Grained Tonalite and Amphibolite

These rocks underlay part of the extreme north-western portion of the Paiko Sheet. This set of rocks was found only in this region. The tonalite is an intermediate rock composed mainly of plagioclase feldspar with less amount of quartz and alkali feldspar with medium to coarse-grained texture. It is greyish in color. The amphibolite contains amphibole and plagioclase feldspar with some accessory minerals. It has a coarse-grained texture and is greenish in appearance. However, tonalite is dominant over amphibolite.

5.1.5 Talcose rock

This rock is exposed at the end of the southeastern part of the study area. It is located around latitude 9º02'11.7" and longitude 6º31'25.8". The rock is talc-rich and massive without foliation. It is poorly exposed and is overlain by lateritic soil (that shows a coarsening upward sequence) but good exposure exists where artisanal mining is active. The artisanal miners were mining for ceramic industries. It was weathered to varying degrees ranging from slightly weathered to highly weathered rock (Plate III). The rock is soapy to the touch. The fresh sample is greyish in color. This type of rock is also called steatite or soap rock or talc schist (if it is foliated). It is fine-grained, massive, and opaque. The outcrop cut across Paiko, Abuja, Gulu, and Kuje sheets.

Plate III: Talcose rock displaying a different degree of weathering around Dobi (9º02'11.7"; 6º31'25.8").

5.1.6 Marble

This is exposed in the ENE part of the Paiko Sheet and it is located on latitude 9º23'53.1" and longitude 6º54'46.4". The trend of the exposure is 349ºNNW. In the southern part, the deposit is overlain by thick clay which is more than 10m in some places. The clay is overlain by a thicker layer of laterite deposited. In the northern part, the marble deposit is overlain by laterite directly. Two varieties of marble exist namely; the grey and coarse-grained variety, and the white and fine-grained variety. They have interlocking textures. Artisanal mining activities by the surrounding villagers are rampant in the area. There is the presence of a quarry company (Kaffo Mines) mining the marble deposit in addition to artisanal mining activities.

5.1.7 Schist

This rock types exist around latitude 9º29'38.1" and longitude 6º37'13.4" in the north-western part of the study area. The schist is poorly exposed by Shelter Clay company mining activities in the area. Shelter Clay company mines lateritic clay for bricks production in Pago (along Suleja-Minna Road). Close to this mine is artisanal gold mining sites with better exposure of the rock although it is highly weathered (Plate IV). It was observed that some pits were dug along a vein composed mainly of about 5m thick quartzite. The schistose structure was found preserved in part of the overlying lateritic clayey soil, especially on the desiccation cracks within the Shelter Clay mine suggesting that the bedrock (schist) is the source of the soil in the area (Plate V).

Plate IV: Highly Weathered Schist within a mining site in Pago (9º30';

Plate V: Desiccation exhibited by clayey soil (9º29'59.55"; 6º32'58.3")

5.7.8 Quartzite

This rock was exposed in the northwestern portion of the sheet. It was poorly exposed, low lying, and occupies very little portion compared to other rocks in its surrounding. It is located on latitude 9º29'58.1" and longitude 6º37'07.2". Mining activity appeared to have taken place as lots of broken pieces were seen on and around the exposure. They also occur in the form of veins that cut across some of the artisanal gold mines nearby. They occur sporadically within this neighborhood and appear to be the host for gold being mined in this area. They are greyish in color and predominantly made of quartz grains with some accessory minerals.

5.1.9 Claystone with Sandstone Intercalation

These are found in the southwestern part of the Paiko Sheet. The outcrop is located around latitude 9º02'11.7" and longitude 6º31'25.8". The rocks are thought to be part of the Bida Formation of the Bida Basin. This is because of similar features such as very high quartz content and the presence of trace fossils described by Obaje (2009). The average strike/dip of beds is 104°/19°. This outcrop is about 190m thick above ground level. The bedding planes separating the beds of these rocks are made up of ironstone. These bedding planes are usually fractured (Plate VIa) while some have ripples mark-like structures (Plate VIb).

a

b

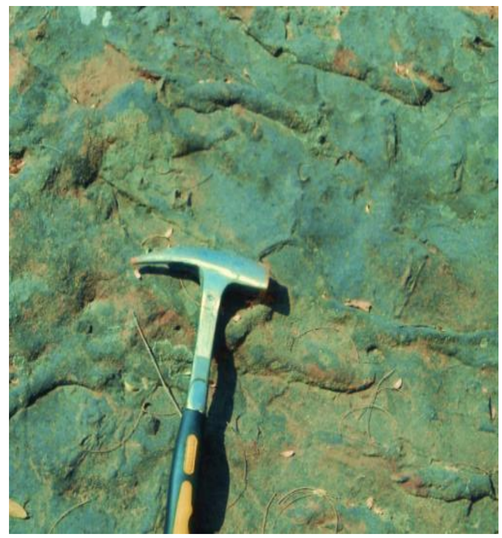

Plate VIa: Fractured bedding plane (9º02'01.2"; 6º31'46.7")

Plate VIb: Ripple marks like-structure observed on some bedding planes (9º02'49.6";

From the litho-logs shown in Figure 4, Mudstone with fine-grain sandstone interbeds directly overlain the basement rock. These (Mudstone with fine-grain Sandstones interbed) was in turn overlain by Conglomeratic Sandstone. Immediately above the Conglomeratic Sandstone is obscured by ironstone rubbles (they are poorly exposed). Above this point is arkosic pebbly Sandstone beds with Mudstone intercalations believed to be correlatable to Doko Member of the Bida Formation. Overlying these (arkosic pebbly Sandstone beds) is a poorly exposed bed covered by ironstone rubbles which are overlain by a very thick bed of whitish Claystone (about 60m thick) with cross-laminated fine grain Sandstone interbeds (This is thought to be the lateral correlate-able to Jima Member of Bida Formation). Overlaying this is Ironstone.

5.1.10 Ironstone

This rock is underlain by claystone in the southwestern part of the Paiko sheet. The outcrop forms part of the *earth pillar* and it is located around latitude 9º02'11.7" and longitude 6º31'25.8". It comprises oolitic ironstone and pisolitic ironstone. The oolitic ironstone overlies claystone while

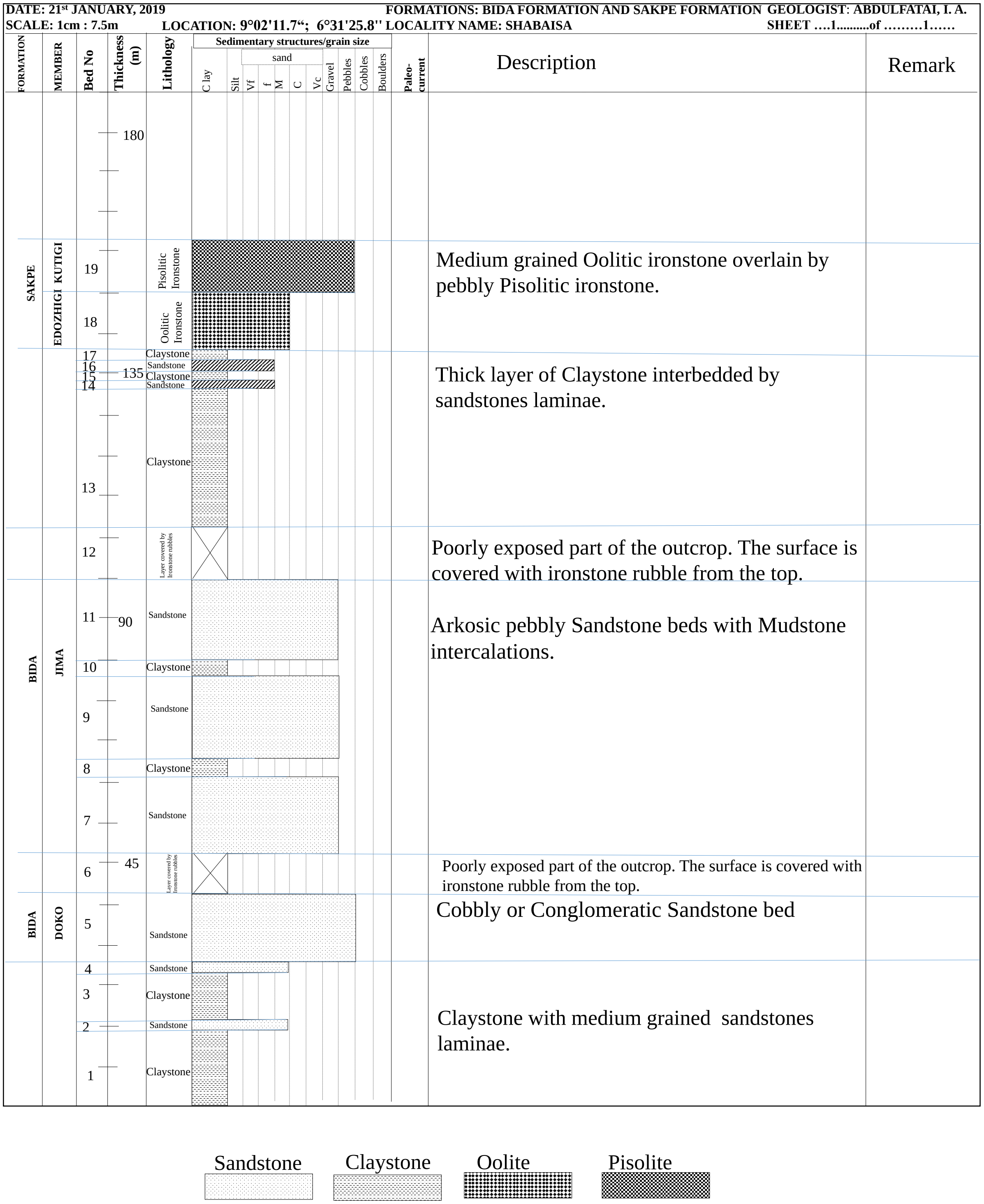

Figure 4: Lithologic section of Claystone with sandstone intercalations overlain by ironstone at Lapai (9º02'11.7"; 6º31'25.8").

it was overlain by the pisolitic ironstone at the top. A lot of animal burrows (trace fossils) were observed on the ironstone but were more on the oolitic ironstone. They have a total thickness of about 20m. They are reddish brown in color and the oolite generally has a finer texture than the pisolite. This exposure is correlatable to Sakpe Ironstone Formation as the features observed were similar to it.

5.2 Geological Structures

Minor folds were the only type of fold observed during the fieldwork exercise. They were observed to be more on migmatitc rocks than other rock types. Ptygmatitc fold (Plate II) was dominant on the migmatitic rocks. The antiformal closures are commonly in the northeastern direction while synformal closures are in the southwestern direction. Fractures including both joints and faults were encountered during the geological field mapping exercise. Joints (Plate VII) make up a larger percentage of the fractures encountered in the field. Joint direction values obtained from the field were used to construct a rosette diagram (Figure 5). The rosette diagram shows that the principal joint direction is in the northwest-southeast. Outcrops were highly jointed with many cross cuttings one another, particularly in the north-western part of the study area resulting in joint sets and joint densities in some cases. The southwestern part of the area recorded the lowest joint count. Faults mainly strike-slip faults were encountered. The amount of displacement ranges from a few centimeters to several meters. Both dextral (Plate VIII) and sinistral faults were encountered. Dip-slip faults (normal faults) were observed along a stream channel close to Lefu (around the middle part of the studied area). There is an existence of a mini waterfall at the faulted point.

Veins (Plate IX) observed in the field were majorly made-up quartz. Aplite veins were also noticed in some rocks. Some of these veins appear to have been either fold or emplaced in areas where fractures previously existed. Some veins were found to cross-cut one another. The thickness ranges from about 1cm to several meters. Pegmatitic veins were also noticed on some outcrops. Exfoliation which is also referred to as onion skin weathering was found on the granitic rocks found within the area. The intensity varies from one granitic rock to another but is generally more intense in coarse-grained granitic rocks with thicker blocks.

Trace fossils such as animal burrows and paths were observed on the sedimentary rocks (sandstones and ironstones) located in the southwestern part of the study area. A lot of burrows were observed on the mottled colored sandstone exposed by the road cut between Takuti and Lapai (N09°08'32.3"; 006°32'54.5") especially in the finer-grained portion of the exposure around the basement complex – sedimentary terrain contact. Some of the observed burrows appeared vertical in outline. This area had migmatic rock unconformably overlain by Sandstone in one part and mudstone in the other part around Achitupa village (Plate X and XI). The sedimentary rocks exist in beds separated by bedding planes.

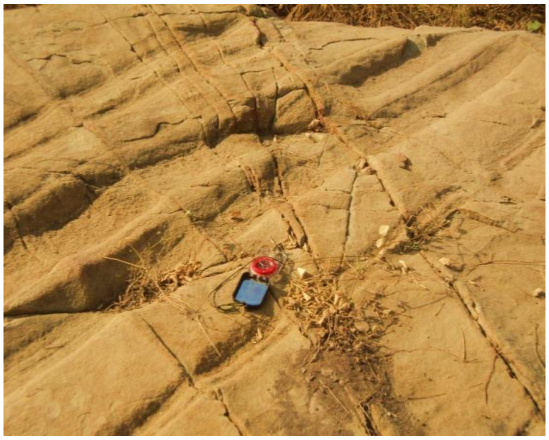

Plate VII: Cross cutting sets of joints [09°29'10", 006°36'16.2"].

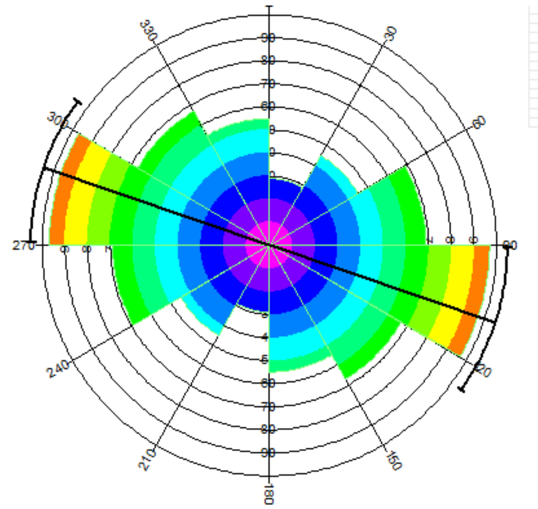

Figure 5: Rosette diagram of measured joint direction within Paiko Sheet

Plate VIII: Dextral fault [09°25'56", 006°37'54.3"].

Plate IX: Cross cutting veins [09°23'42.3", 006°55'37.2"].

Plate X: Clast supported conglomerate) overlaying basement complex [09°08'37.0", 006°32'55.4"].

Plate XI: Mudstone overlaying a basement rock [09°08'39.0", 006°32'58.6"].

5.3 Economic Geology

Quarrying and mining activities are common in villages within the study area. This is because these villages are either rich in economic minerals or other geological resources that are economical. These activities are very common among the host communities although some companies are also involved. This has generated employment and sources of income for many people within these areas and beyond. These minerals or geological resources include the Marble deposit that exists around Tunga Gade and Pibata villages although the deposit is popularly called Kwakuti Marble. Talc deposits exist around Gangare village located after Dobi in Gwagwalada Area Council, Federal Capital Territory, Abuja. The mining activity is carried out by artisanal miners from the host locality for ceramic industries.

The medium-scale and artisanal gold mining activities are prevalent in the southeastern part of the studied area, particularly the Dadabiri and Baban-Tsauni areas. Southwestern part is also witnessing gold mining activities around Saminaka. Other areas of gold mining include Pago, Ebbah, and Butu in the northern half of the study area. Sulphide ores also exist in the southeastern portion of the area especially Dadabiri and Baban-Tsauni localities. Prominent among them are galena, sphalerite, pyrite, and chalcopyrite. Active mining of lead (galena) and zinc (sphalerite) is going on in the area.

Rocks quarrying exist within the studied area due to the presence of various massive intrusions that are well-exposed. They quarry these rocks into a finished product such as dimension stones, chippings, and dust for various construction purposes. Deposits of laterite exist in many locations within the sheet but prominent among them are Wabe, Tungan Gade, and Gangare (all in the northwestern part of the area). They are exploited for subgrade in road construction and are also useful in other construction activities. Mining of sand and gravel is not restricted to any part of the sheet as it cut across the entire area. The mining activities are dominated by artisanal miners. Their activities are mostly restricted to areas around streams or rivers and their flood plains. These materials (sand and gravel) are mainly used for construction purposes. Lateritic clay deposit in Pago is being mined by Shelter Clay Company for the production of bricks. The southern part of the Kwakuti marble deposit is overlain by approximately 10 meters of thick clay although mining activity was not observed on this occurrence. The clay is overlain by lateritic soil about 15 meters thick.

5.4 Updates on the Map of Paiko Sheet 185

The updated map is shown in Figure 6. The following updates were made to the previous map of the Paiko Sheet by the NGSA (2009):

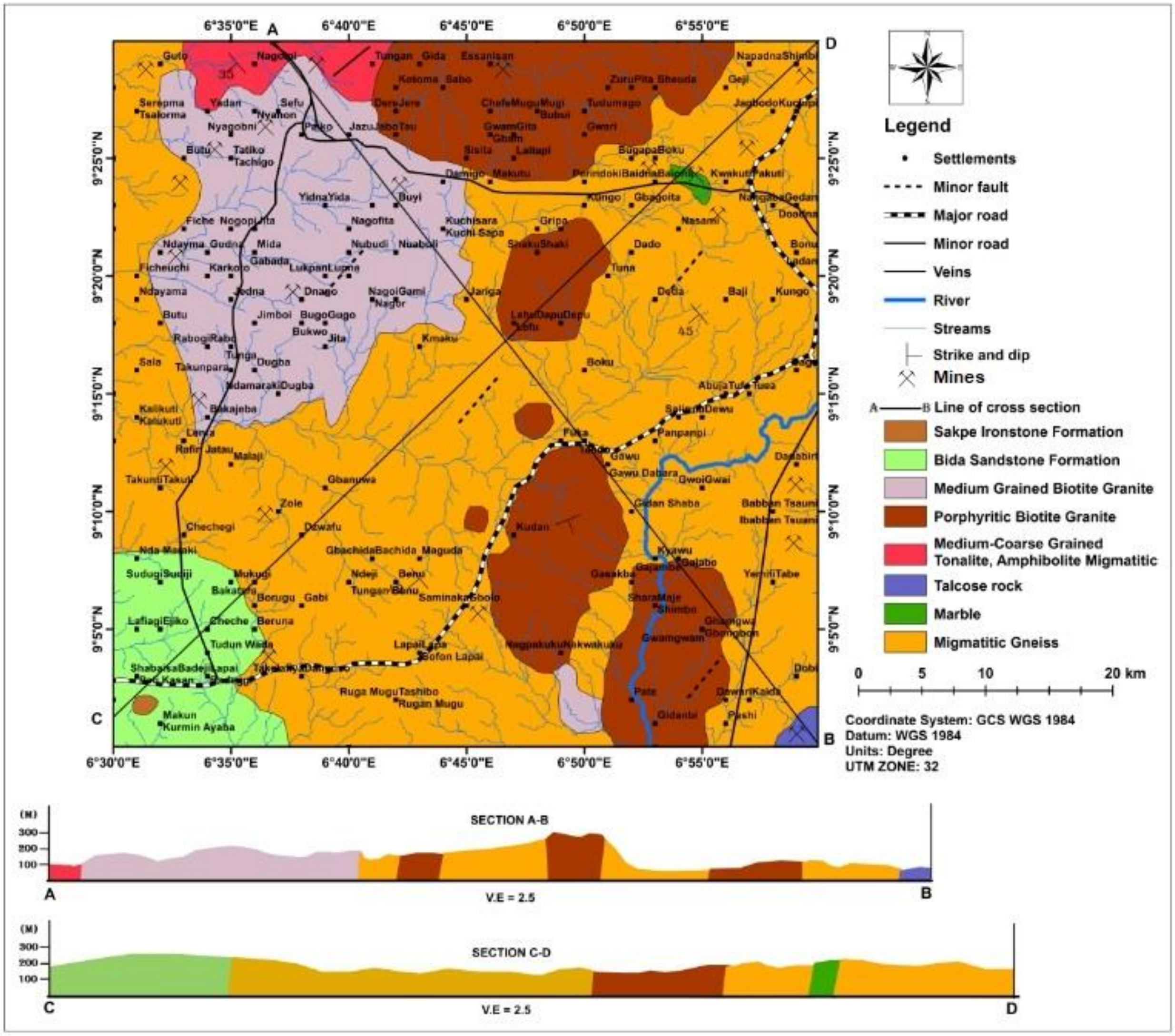

Figure 6: Updated geological map Paiko sheet 185 with cross section of progressive changes in the geology of Paiko sheet from the Northwest to the Southeast (i.e., A-B) and cross section of progressive changes in the geology of Paiko sheet from the Northeast to the Southwest (C-D).

1. Phyllite-Mica-Schist, and Quartz-Schist interlayered with Amphibolite was removed from the map because they are in Abuja Sheet which is east of Paiko Sheet. Although; the rocks were close to the boundary of the Paiko Sheet, they must have been included in the previous map due to a lack of good exposure around the boundary of the Paiko Sheet with the Abuja Sheet. However, recent construction activities of Minna-Suleja Road have exposed the actual rock in this area which is gneissic (Plate I).
2. Migmatitic Schist and Gneiss injection Migmatites, foliated granite was made part of Migmatite-gneiss because the schist in this area is not significant enough to be included in a map. And also, the term foliated granite could be termed as gneiss.

3. Migmatite was also made part of Migmatite-Gneiss. This is because of the occurrence of gneiss (though in little amount) in the part colored migmatite.
4. Alluvial deposit part of the previous map was removed and replaced with the actual bedrock underlying this deposit which is migmatite.
5. Lateritic-capped Sandstone was replaced with Claystone with Sandstone intercalation which is thought to be lateral correlation of Bida Formation because it unconformably overlies the Basement complex with similar characteristics. Overlying these is ironstone which is thought to be lateral correlation of the Sakpe Ironstone Formation because of the similarity in features.
6. Talc-Actinolite-Tremolite Schist was replaced with Talcose rock which is the general name for a talc-rich deposit because the schistose structure was not observed on the outcrop.
7. Harmonization of marble lithology as one unit against the two discrete units recorded in the previous maps. This is because geological contact or different lithology was not observed between the two units.
8. The locality referred to as Mararaba in the earlier maps was corrected to Lambata in the updated map.

Conclusion

Paiko Sheet 185 is underlain by Basement rocks (approximately 95%) and Sedimentary rocks of the Bida Basin (approximately 5%). A total of eight modifications were made to the updated map including seven lithological modifications and one locality correction. The new map shows that there are eight different major rock types underlying the study area against 11 lithologies suggested by the earlier maps. There are however two rock types (schist and quartzite) that were not represented on the map because of their small sizes. The principal joint direction is in the Northwestern direction. Geological resources (such as gold, marble, lead, zinc, laterite, sand, and gravel) that can be economically exploited abound within the sheet. Petrologists especially Sedimentologists need to carry out more research to unravel the reason for the thick clay deposit within the sedimentary section of the Paiko sheet as Bida Formation is popularly known to be made up of mainly sandstones. Petrologists and Mineralogists need to carry out more research to unravel the evolution of Kwakuti Marble. This is because the closest sedimentary basin which is the Bida Basin which is about 40 kilometers away from the Marble deposit. There is a need to determine the protolith to adequately understand the history of the rock.

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