GOLD IN PLANT: USING A PLANT SPECIES (*Funtumia elastica*) IN PROSPECTING FOR GOLD MINERALISATION AROUND IPERINDO, SOUTHWESTERN NIGERIA.

Jimoh M.T. [1]., Kolawole T. O.[2]., Jimoh M.A.[3] and Amos K. M.[1]

1. Department of Earth Sciences, Ladoke Akintola University of Technology, Ogbomosho.
2. Department of Geological Sciences, Osun State University, Oshogbo.
3. Department of Plant Biology, Osun State University, Oshogbo.

Correspondence author's e-mail address: mtjimoh@lautech.edu.ng

ABSTRACT

Iperindo gold deposit is one of the few primary gold mineralization deposits in Nigeria and the area is underlain by rocks of Precambrian basement complex. Despite previous studies on geology, petrology, mineralogy, petrochemistry, geophysics and geochemistry, no attempt has been made on biogeochemistry of plant present in this area using Scanning Electron Microscopy coupled with Energy Dispersive Spectroscopy (SEM-EDX). This work is therefore targeted at prospecting for gold using bark-scrapings of wild-native, deep rooted and perennial plant species known as Funtumia elastica. Rock units such as faulted migmatite gneiss, banded gneiss, granite gneiss, biotite-hornblende-gneiss, mica schist, quartzite/quartz schist and granite were identified. Eight representative samples of the tree bark were scraped to collect the soft outermost layer. The samples were air dried to prevent fungal and microorganism growth which can contaminate them. Laboratory preparation involved oven-drying at 105˚C for 24 hours. The dried samples were pulverised and sieved using ≥ 125 µm mesh size. The carbon coated samples were scanned at a magnification of ≥ 1000 times its original size to study the plant mineralogy and to infer gold mineralisation in underlying regolith or bedrock.

Surface morphology of the samples as revealed by SEM is homogeneous in composition. Two contrasting compositions are common to all the SEM images studied- an embedded grain clusters showing bright resolution within a matrix of dull resolution. EDX showed average concentration (wt %) of elements such as Ca (11.91), C (59.9), O (21.06), K (1.01), Si (0.14) and Te (6.03). Presence of Te which is associated with gold mineralisation indicates possibility of detecting gold in locations where Te is available.

Keywords: Iperindo, gold mineralisation, *Funtumia elastica*, surface morphology, matrix

INTRODUCTION

According to Korshunova and Charykova (2019), gold is characterized by a low abundance in upper crust 1.5 ppb especially in overburdened areas. In consequence of the high cost of low-concentration analysis, prospecting is often based on the use of elements associated with gold mineralization in primary haloes, such as Te, Bi, As, Ag, Cu and Sb..

Iperindo is a notable region located within the Precambrian basement complex of southwestern Nigeria. It is geographically bounded within latitude 07° 28′ to 07º 30′ North of the Equator and longitude 04˚ 48′ to 04º 51′ East of Greenwich Meridian. The study area is underlain by various lithologies such as migmatite gneiss, banded gneiss, granite gneiss, quartz schist, quartzite and granite. The area is known for its primary gold mineralization which is hosted in gold bearing (Auri-ferrous-quartz carbonate) veins localized by subsidiary fault hosted within biotite gneiss and mica schist (Elueze and Ogunniyi, 1985). The area has suffered from a lot of environmental degradation because of numerous abandoned mining pits and core drilling worked by artisanal miners whose activities at exploring for gold have not yielded any meaningful and tangible contribution to the nation and state treasury.

Nigeria as a whole and Osun state in particular are in need of boosting the development of vast mineral deposits for exploration and economic development. Newly discovered and reworking of hitherto exploited areas with gold mineralisation is highly required so as to widen the revenue generation base for all tiers of government. Many attempts have been made in the past at mapping the study area, such efforts include those of (Cooray, 1974; Hubbard, 1975) in which the geology of Iwo area was outlined on a scale of 1:250,000 with a view to account for new age data. The study showed that Ilesha area consists mainly of supracrustal sequences comprising of resistant quartzite, amphibolite and pelite, oligoclase granite gneiss and pegmatite that are associated with the schist.

Agbor, (2014) studied the amphibolites around Zungeru with a view to unravel their chemical and mineralogical attributes, Elueze and Ogunniyi (1985) and Woakes *et.al*, (1989) investigated field occurrence, petrology and geochemistry of the Precambrian schist belt around Ilesha. In a similar manner, Bolarinwa and Adeleye (2015) and Abdulsalam, *et.al*, (2020) investigated the amphibolites around the Basement Complex of Iseyin-Oyan and Ilesha schist belts, In Odo and Iperindo gold mineralised area, the Pb-Pb systematics of the host granite gneiss, feldspar and pyrite were studied by Oyinloye (2006) so as to establish possible dates of emplacement, mineralisation, tectonic evolution and gold metallogenesis. Furthermore, Olomo, *et.al* (2018) examined the mineralisation potential around Iperindo using satellite remotely sensing and geophysical methods. The processed images revealed lineaments that trend mainly in NE-SW directions which is diagnostic of primary structures of potential targets for mineralisation in the area. Elsewhere outside Ilesha area, (Turner, 1983; Garba, 2000; Oke, *et.al*, 2014) investigated the field, mineralogy and geochemical attributes of gold bearing quartz veins and soils in parts of Maru schist belt, Northwestern Nigeria, the study revealed that gold bearing fluid could have been derived from fracturing, metamorphic dewatering, and crustal devolatilisation of sedimentary gabbroic protoliths emplaced in an orogenic setting.

Ability of many plants to take up gold from soils and accumulate them in their tissues makes it to reflect the concentration and distribution of nearby gold deposits hidden by complex regolith (Girling and Peterson 1980; Anderson *et.al,*1999; Anderson, 2005; Arhin, *et.al*, 2018). Gardea-Torresdey, *et.al* (2001) also noted that plants can uptake gold from soils as they are used as bio-indicators of gold deposits by mining companies.

Biogeochemistry is a prospecting method that relates the anomalous concentration of gold to the underlying regolith. When mineralization occurs, there is Au concentration which is higher than the background value (Anderson *et.al,* 2005). Therefore biogeochemistry is effectively used as a sampling survey when the soil provenance is unknown. This aspect of biogeochemistry has not been given research attention and no previous study has been reported on this subject matter around the study area in Nigeria. *Funtumia elastica*, the tree species which the bark samples were collected from is native to many West African countries such as Nigeria. It is a tropical tree that grows up to 30 m tall with a straight, cylindrical trunk and narrow tree crown. The epidermal layer is smooth with brown to dark colouration. Leaf shape is ovate; tree buttress is wide while its canopy is averagely about 20 x 9 cm. The tree has a tap root and branching fibrous roots which off shoot from the main tap root. The root system extends to about 20 m away from the buttress of the plant into the subsurface searching for nutrients, minerals and elements which are circulated to different parts of the tree. The height of this tree makes it easy for photosynthesis to occur which supplies necessary nutrient to the tree. The tree height and root system are advantageous because they supply nutrients and minerals far and wide to various parts of the tree. The deep tap root makes it easy to penetrate beyond the complex regolith into the weathered materials and hence uptake signatures of the underlying minerals which are hosted in various part of the tree (Chatuta and Direng, 2000; Anand and Paine, 2002; Dunn, 2007).

As noted by Mohammed and Abdullah (2018), Scanning electron microscopy (SEM) is a technique that reveals information about a particular sample such as surface or external morphology, texture, chemical composition, crystalline structure and orientation of material to be scanned available in the sample. Materials to be scanned is dried and homogenized before subjected to the beam of high energy electron. SEM is employed to carry out spot analysis on an area which is approximately 1 cm- 5 μm in width and it can magnify the original spot from about 20 times to 30,000 times the original size. It is also capable of performing analysis by selecting point location on the sample. It can also be employed in qualitative and quantitative determination of chemical composition of crystalline structures, plant structures, vegetation and soil samples.

This investigation which entails using SEM to study plant mineralogy is targeted at prospecting for gold mineralization around Iperindo using a deep rooted, tropical tree species known as *Funtumia elastica*.

Geology of the Study Area

Following the classification of Elueze (1984), the basement complex is made up of three litho-structural and petrological units which are an ancient complex of gneiss and migmatites, N-S trending schist belt and an intrusive suite of Pan-African granites and related rocks. Iperindo is an integral portion of Ilesha schist belt which in turns lies within the Precambrian basement complex of southwestern Nigeria. Various rock types around Iperindo fall within the respective petrological unit. Such rock units are migmatite gneiss, banded gneiss, granite gneiss, quartzite, quartz schist and granite. Field descriptions of the different rocks mapped in the study area are discussed below.

Migmatite gneiss

Migmatite and other gneisses (banded, biotite and granite) are distinctly foliated as depicted by alternating layers of felsic and mafic minerals. Metamorphism and multiple phases of deformation have occurred in the gneiss-migmatite complex. Complex fold patterns as well as isoclinal fold with variable plunges showed that the migmatite and other gneisses have been affected by series of polycyclic deformational episodes. Migmatite gneisses are well exposed at the southwestern corner which is about 2 km west of Iperindo (Fig. 1). Generally, the major constituent minerals in the migmatite are quartz, plagioclase and alkali feldspar, biotite and muscovite (Fig. 2). Quartz assumed ribbon-like appearance due to shearing. In term of field occurrence, the rock body is mostly low lying with medium to coarse grained texture. Most locations with migmatite are compositionally, structurally and texturally similar, but in few cases, there are variations in some places. For example, the thickness of mafic bands in some locations is more than its felsic components and vice versa. The felsic bands are essentially composed of quartz, feldspar and some minor quantity of muscovite whereas the mafic bands are composed of equigranular biotite, muscovite, and plagioclase and alkali feldspar. In locations where the exposures are flat lying, migmatite gneisses are strongly foliated and jointed. Orientation of the joints is mostly along the foliation plane whereas a cross cutting main joint of about 10 m long run across the foliation. Pegmatite vein of about 40 cm thick runs parallel to the foliation plane. Strike and dip measurements of the foliation plane were taken as 058˚, 060°, 070°, 242˚ and 258˚ and 52˚E, 60˚E, $068°E, 070°E$ and 80˚E respectively.

Granite Gneiss

Granite gneiss mapped at the outskirt of Ipoole has undergone ductile deformation as a result of recrystallization of the constituent minerals. The outcrop is located in a community high school at Iperindo which is about 180 m away from the town's local Government. The granite gneiss has been crystallized deep in the earth's crust either during cooling of the magmatic melts under direct pressure or during the process of magma movement. The grains of the minerals particularly feldspar have been affected by the effect of heat and pressure making previously rounded grains to be flattened or compressed. The outcrop extends for about 62 m within the vicinity. Structures such as quartz vein and quartzo-feldspathic veins run parallel to the host rock. Quartz vein of about 20 cm thick has been affected by shearing. Granite gneiss occurs about 200 m north of Ipoole's palace whereas at the southern part, it is located about 500 m away from the township and to the east and west it spreads across the entire locality. It is noteworthy that in all occurrences, the rock unit is strongly foliated and well exposed but the exposure does not occur as a single body, it assumes boulder sized, dome-shaped pockets of different dimensions which has been transported down the hill. At Oke looyin, the exposure is fresh revealing medium sized to large crystals of pinkish alkali feldspar, whitish plagioclase and colorless to transparent quartz. The quartz has been stretched into ribbon in some portions of the outcrop, biotite and quartz defines the foliation. It is widely distributed in Oke Alasepe where the granite gneiss forms massive elongated body whereas in Odo Ijesha along Ilesha-Iperindo road, it occurs as well exposed outcrop, which dipped steeply down the hill into a seepage that could be a good source of spring water. At Odo Ijesha, strike and dip measurement of 36^0 and 70^0 W respectively were taken. Granite gneiss is made up of coarse-grained minerals such as quartz and feldspar which are compositionally similar to granite.

Quartzite

Quartzite comprising almost absolutely of quartz with a joint that runs across the foliation plane is found about 70 m south of granite gneiss. Assymetric fold occurs along the quartzite in a northward plunging, asymmetric recumbent fold. Quartz vein of about 20 cm thick runs as an intrusion parallel to the parent quartzite. In locality such as Odo-Ijesha, the rock units appear as a matrix supported conglomerate of different sizes and shapes (Fig. 3). At Ipoole and Omogbara, it appears massive and schistose respectively. In all locations, the quartzite is ferruginised, rutilated and garnet-bearing. Evidence of shearing in the quartz intrusion makes the quartz granulated, thereby reducing the size of quartz.

Quartzite exposure is about 101 m long around the palace square at Ipoole. Texture is medium to coarse grained as individual crystals can be identified with the naked eyes. Quartz is the most abundant constituent mineral in quartz. Minerals such as, muscovite, feldspar, garnet, rutile and sillimanite occur in accessory quantities. Quartzites are generally gritty to touch and due to tectonic deformation, the quartzite shows occurrence of multiple sets of joints on a mesoscopic scale. Some portions of the quartzite have been altered to kaolin which is greyish white, friable and fine grained in texture. The kaolin is rich in muscovite and feldspar. This milky white textural variety is commonly distributed in Odo Ijesha along Iperindo-Ipetu Ijesha road. The following strike measurements are taken at various localities of the study area 24^0, 32°, 28°and 180° while the dip measurements recorded are $54°SE$, $40,°E$ and $42°SW$ and 58^0 W.

Quartz schist

Quartz schist is almost indistinguishable from quartzite, in most cases, both lithologies are closely related or lie proximally to each other. In cases where they are discernible, quartz schist occurs as flat lying outcrop that is primarily dominated by 90 % quartz and accessories such as muscovite, feldspar, garnet, sillimanite and opaque minerals. It has undergone low grade metamorphism under low pressure and temperature condition which give it a slaty foliation. Strike and dip measurement recorded at Omogbara are 40° and dip $70°E$ respectively. Mica schist at Ipoole has been thoroughly weathered (Fig. 1). The schistose rock served as host rock for quartzite. It is a low lying located about 250 m away from Iperindo local government.

Granite

Medium to coarse grained granite occurs at Iperindo and Odo Ijesha. The outcrop along Ilesha-Iperindo road contains constituent minerals such alkali feldspar, quartz, plagioclase, biotite ± muscovite, opaques and accessory minerals. In addition to constituent minerals, it was observed that the granite particularly in this location is mylonitised. Occurrence of mylonite in this granite is an indication that Iperindo is a portion of shear zone which Ilesha-Ife schist belt is known for (Elueze, 1984). Mylonitisation is a product of tectonic deformation which affects the size, shape and arrangement of affected minerals in a particular direction. It is a boulder-sized, dome shaped outcrop which is about 5 m high and it extends to about 102 m. Granite at Odo Ijesha are confined within granite gneiss and quartzite (Fig. 1).

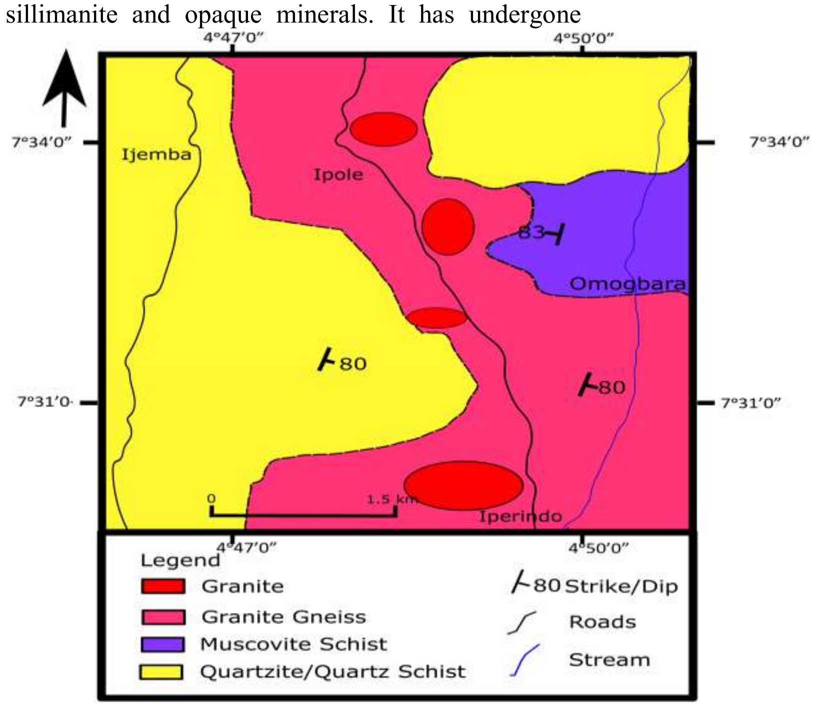

Fig. 1: Geological map of the study area

Fig. 2: (Top left) Gold-bearing quartzite at Omogbara (Top right) Recumbent fold in quartzite at Ipoole (Bottom left) Gold-bearing conglomeratic quartzite at Odo Ijesha (Bottom right) Quartzite intrusion in mica schist at Ipoole

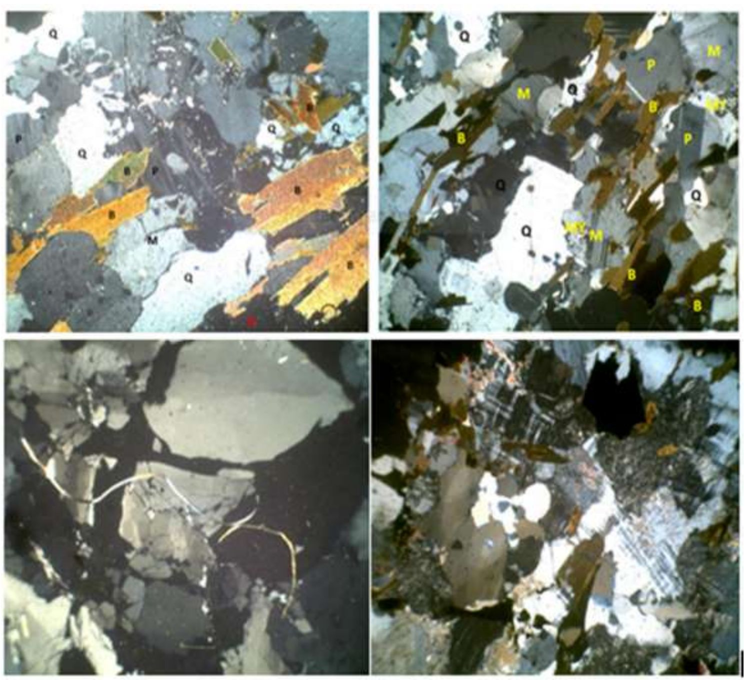

Fig. 3: Photomicrograph of gold related lithology; (Top left) Granite gneiss (Top right) Biotite gneiss (Bottom left) Sillimanite-bearing quartzite (Bottom right) Granite

METHODOLOGY

Geological Mapping

Geological mapping on a scale of 1:50,000 was undertaken in order to study the field occurrence and structural relationship among various rocks types in Iperindo and its environs. The topographical map was gridded into equal portions before the reconnaissance survey was conducted. Field equipment and tools like topographical map, Global Positioning System (GPS), compass-clinometer, digital camera, permanent marker, geological hammer, magnifying lens, chisel, shovel, digger, cutlass, paper tapes, sample bags, cellophane bags, measuring tapes, and field note book were used for various data collection purposes.

Collection of Bark Samples

The species of the tree bark that was sampled is *Funtumia elastica*. The tree species was specifically chosen because of its unique characteristics such as cylindrical tree trunk which extends to about 30 m above the ground. The tree's epidermal layer (bark) is soft, smooth and succulent for scraping to occur (Adekunle and Ikumapayi, 2006). The tree root penetrates more than 20 m into the regolith, offshoots of tender and fibrous roots extend from the tap root provides additional strength for its nutrient uptake thereby increasing the rate at which aqueous solution containing various minerals and element are up taken into the tree trunk. The minerals and nutrients taken up by the root of this plant is used up for the growth of the plant while gold cannot be absorbed rather it is adsorbed and secreted through the bark of the plant as a waste product.

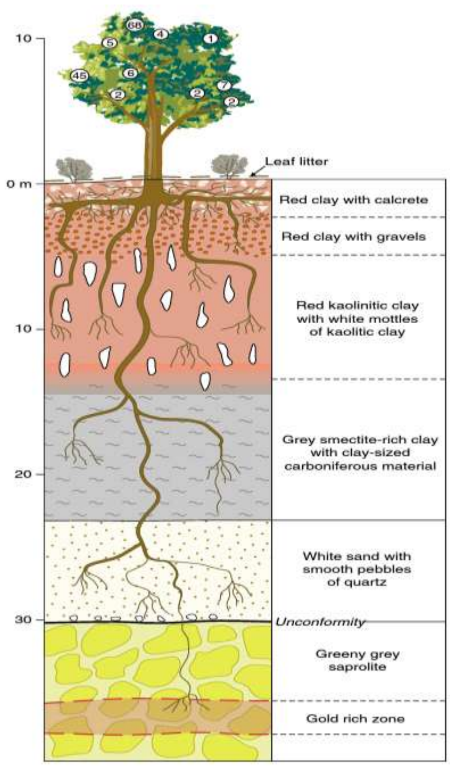

Fig. 4: Schematic diagram of Funtumia elastica root system through regolith at Iperindo (modified after Lintern, et al, 2013).

Procedures involved in Bark Sample Preparation

Eight bark samples were collected at different locations during mapping. Each sample was bookmarked to its respective location and lithology. Materials such as cutlass, polythene bag, pestle and agate mortar, methylated spirit, cotton wool and electric oven were used for sample collection and preparation. The outermost part of the tree barks were scraped with a sharp cutlass. The scrapings were collected and packed in labelled polythene bag. To prevent moisture and growth of microorganism, the samples were air dried in the laboratory for few days. The samples were thereafter heated for 24 hours in an oven at 105°C. They were pulverized and packed for determinative mineralogy using Scanning Electron Microscope coupled to Energy Dispersive X-Ray (SEM-EDX).

RESULTS AND DISCUSSION

Morphological characteristics of the bark samples

Generally, the morphology of the bark samples is characteristically spongy in appearance, irregular in shape and typically non-crystalline.

Descriptive Mineralogy of the bark samples

Tree species which is underlain by mylonitised granite and bark sample (L3BT1) was collected at a location close to Ilesha-Iperindo road. Back Scattered Electron Image (BSEI) revealed two contrasting composition comprising the matrix or groundmass showing dark resolution whereas the embedded structure was brightly resolved. Texturally, the embedded structure is coarse grained whereas the matrix is fine grained. The crystal of the embedded structure is fully developed forming euhedral habit. Resolution in SEM is a function of atomic number of the elements constituting the crystal lattice of the sample under investigation. Dark resolution of the matrix showed that the constituent elements are of low atomic numbers, whereas the bright resolution of the embedded structure is composed of elements with high atomic numbers. The matrix and the embedded structure are homogeneous in texture but the shape is irregular (Fig. 5). **S**ample L12BT4 which developed over quartzite is compositionally similar to L3BT1 as it also revealed two contrasting compositions, the matrix or ground mass showed dark resolution whereas the embedded structure has a bright resolution. In term of texture, the sample formed a subhedral habit as the grain boundaries between the groundmass and embedded structure were not clearly defined or fully formed. The embedded structure is coarser in texture than the matrix. It was also observed that there is abundant distribution of the brightly resolved embedded structure over the poorly resolved matrix. From the distribution of the brightly resolved structure, it can be deduced that this sample developed over quartzite is dominated by element of higher atomic number and patches of element with low atomic number. The embedded structure has a boulder-sized appearance while the matrix occurs as irregularly shaped patches.

Sample L20BT7 which was collected on species developed over granite gneiss revealed two contrasting compositions similar to the locations previously described. The matrix and embedded structures did not form clearly developed and distinct boundaries which made them to display spongy appearance (Fig. 5). The texture is medium to coarsely grained showing interwoven distribution of both light and dark resolutions. At the top of the image to the left there is an occurrence of an isolated dark patches and to the middle the structures are interlocked with dominance of lighter patches and to the right side at the bottom of the image there is a bit light and dark composition. It can be deduced from this BSEI that the resolution has both element of high and low atomic number almost in equal proposition. They are also irregular in shape. Sample L40BT10 which was underlain by quartzite revealed two contrasting compositions, the groundmass shows dark resolution whereas the embedded structure has bright resolution. In this BSEI, there is homogeneous distribution of the embedded structure it has a cloudy distribution over the ground mass. Both matrix and embedded structure are fine grained in texture, they are anhedral in form because the matrix-embedded structure boundaries have been obliterated. However irregular patches of brightly resolved structures are widely distributed within the matrix. The sample contained the highest proportion of these brightly resolved structures.

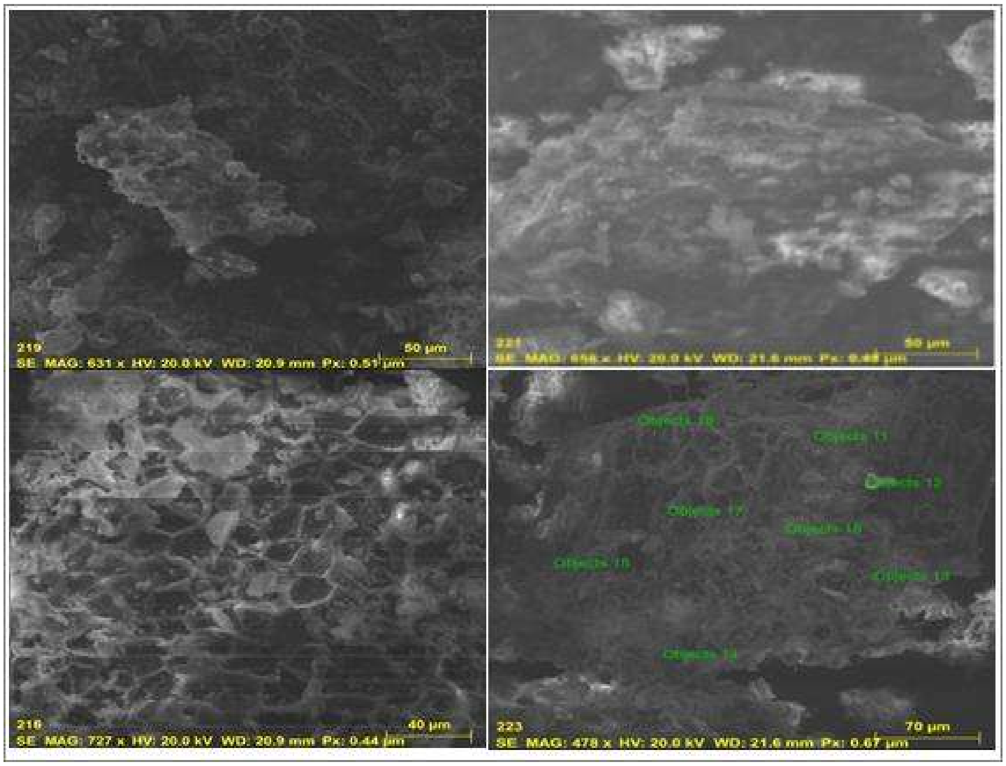

Fig. 5: Back Scattered Electron Image of *Funtumia elastica* bark on mylonitised granite at Iperindo Top left: (L3BT1), Top right: (L12BT4), Bottom left: (L20BT7), Bottom right: (L40BT10)

Samples L12BT4 and L40BT10 are compositionally similar to L3BT1. However, bark samples of the tree were developed over quartzite. In term of texture, the sample formed a subhedral habit as the grain boundaries between the groundmass and embedded structure were not clearly defined or fully formed. The embedded structure is coarser in texture than the matrix. The embedded structure has a bouldery appearance while the matrix occurs as irregularly shaped patches.

Sample L20BT7 was developed over granite gneiss. The matrix and embedded structures did not form clearly developed and distinct boundaries which made them to display spongy appearance. The texture is medium to coarsely grained showing interwoven distribution of both light and dark resolutions. At the top of the image to the left there is an occurrence of an isolated dark patches and to the middle the structures are interlocked with dominance of lighter patches and to the right side at the bottom of the image there is a bit light and dark composition.

Mineral Chemistry

Composition of elements obtained by EDX from various locations is presented in Table. 1. Generally, elements such as C, K, Ca, O and Te were detected in the bark samples. It is evident that Te display bright resolution in BSEI due to its high atomic number. Te which is a trace element is sometimes found in its native state, but quite often is found with gold than uncombined form. The mineral chemistry of L12BT4, L3BT1, L40BT10, L40BT11 and L40BT12 were shown in Figs. 6 and 7. Elements such as C, K, Ca, O and Te have percentage weight that ranged from 32.65-75.90%, 0.37-2.45%, 0.56-38.28%, 8.44-30.86%, and 0.79-20.08 respectively (Table 1).

The mineral chemistry of L20BT7 was shown in Fig. 7. Elements such as C, K, Ca, and O were also observed. However, from Table 1 and Fig. 7, it is observed that there is no occurrence of Tellurium in the sample.

Table 1: Composition of Elements obtained by EDX at Different Locations

	Concentration (wt %)								
Element	**L3BT1**	**L20BT7**	**L12BT4**	**L40BT10**	**L40BT11**	**L40BT12**	Average	Minimum	Maximum
C	75.9	74.48	56.4	71.09	32.65	71.8	63.72	32.65	75.90
O	21.18	23.75	30.86	24.73	8.44	23.02	22.00	8.44	30.86
Ca	1.76	0.56	7.04	2.28	38.28	2.08	8.67	0.56	38.28
Te	0.79	-	3.25	1.11	20.08	0.95	5.24	0.79	20.08
K	0.37	1.2	2.45	0.79	0.54	0.69	1.01	0.37	2.45

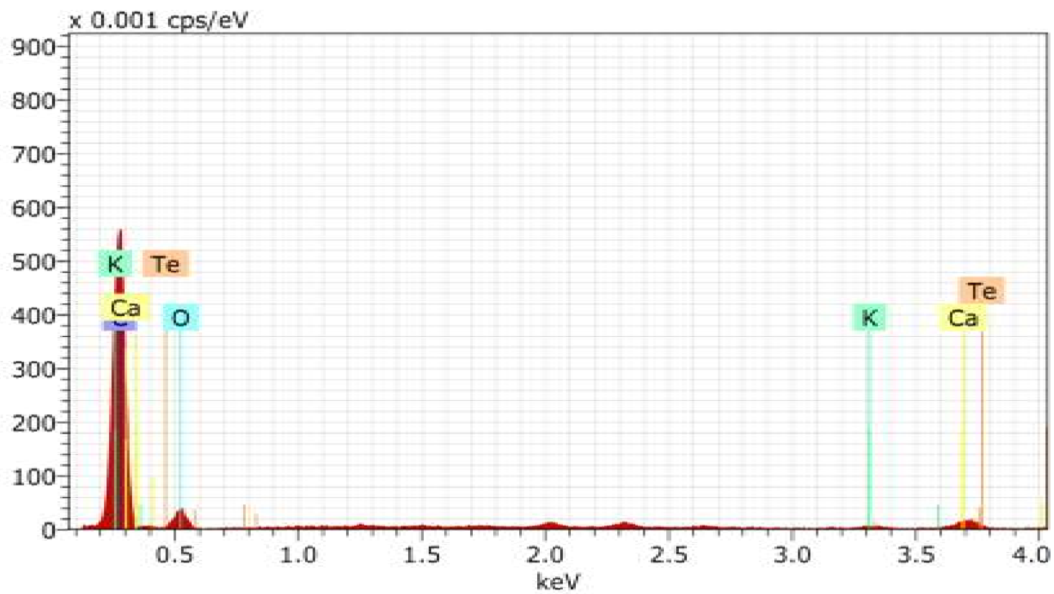

Fig. 6: Energy Dispersive Spectrogram (EDX) of L3BT1

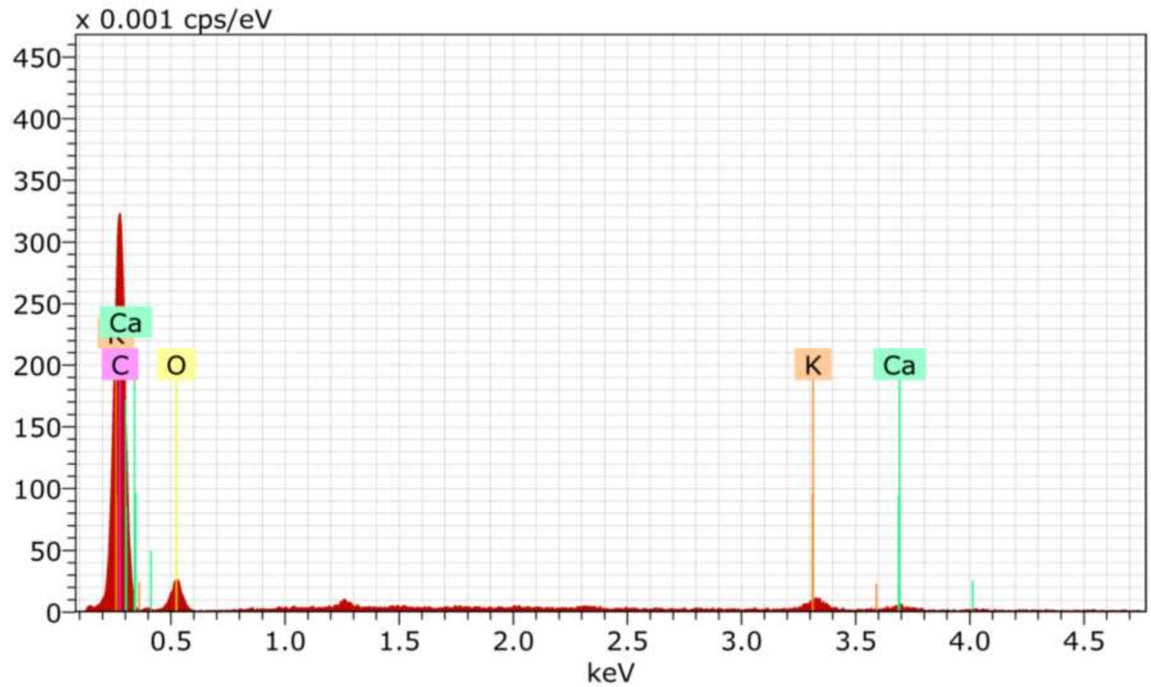

Fig. 7: Energy dispersive spectrogram of L20BT7

Discussion

Tellurium is known to have some valences (+2, and +6) and to change its geochemical behavior with the difference of the redox conditions. Tellurium is occasionally found native, but is more often found as the telluride of gold (calaverite) and combined with other metals. From the EDX result, the occurrence of Te is confirmed in L12BT4 and L40BT10 whereas in L20BT7 it was absent. This could be an indication that the presence of Te is as a result of absorption of Te from the surrounding mineralised area. This is because Te has been established to be associated with gold mineralisation.

Conclusion

This study investigates the provenance of gold mineralisation in plant of Iperindo and its environs. Although, the target fell short of its set objective in that gold was not directly detected. But Te occurrence which is closely associated with gold was determined using SEM-EDX technique.

It is recommended that geochemistry of the plant and the soil should be carried out to unveil the occurrence of gold in plant of the study area.

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