Structural and Geochemical Evaluation of Gold Deposits around Angwan-Dasu, part of Share sheet 202 NW and Jebba sheet 181 SW, Southwestern Nigeria.

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Abstract

The occurrence of veined and disseminated gold in the mylonitized rocks including diorites, coarse grained granites, medium grained granites, and pegmatites around Angwan-Dasu area near Bode Saadu in Kwara State of Nigeria has been investigated to establish the gold mineralization pattern, distribution, and origin. Geochemical analyses of 16 whole rock samples for elemental composition using ICP-AES and ICP-MS for major and trace elements respectively show that the concentration of Au ranges from 0.0005ppm (crustal abundance) to 6.5314ppm (enrichment) which indicated anomalous concentration in diorites (up to 6.53ppm), porphyritic granitic (up to 6.07ppm), pegmatites (up to 1.14ppm) in the area. The Harker's plots indicated a major negative correlation between the major oxides against silica. The AFM diagram revealed an enrichment of alkali metals (Al_2O_3, Na_2O and K_2O) in all the rocks which plotted in the Cal-alkaline field. The plots of the protolith precursor show the rocks, except for pegmatites, plotting in the sedimentary/metasedimentary field. The chondrite-normalized plot displayed a general negative anomaly (depletion) in Eu concentration. Ore microscopy revealed the presence of gold mineralization in close association with sulphide ores that are disseminated within mylonitized rocks along the shear zones. This suggest that the auriferous hydrothermal fluid that precipitated gold and the associated sulphides was triggered by shearing and mylonitisation which accompanied the dynamo-thermal remobilization that took place during the waning stages of the Pan African orogeny.

Keywords: disseminated gold, mylonitized rocks, structural grains, ore microscopy

INTRODUCTION

Nigeria has abundant mineral deposits both solids and fluids. The mineral deposits are distributed fairly across each state in the country. According to the Nigeria Geological Survey Agency records, there are 44 major mineral deposits (Fig. 1) distributed across the country in over 450 locations (NGSA, 2008). The Nigerian schist belt is known to host varieties of minerals especially Gold. The gold creating ranges have been within the western portion of the basement complex where the schist belts are best created. Gold is found virtually everywhere in Nigeria particularly within the schist belts and alluvial deposits along streams and river channels. Due to the extensive use of gold in various sectors, it has led to an increase in its mining and some of these occurrences do not have proper research documentation.

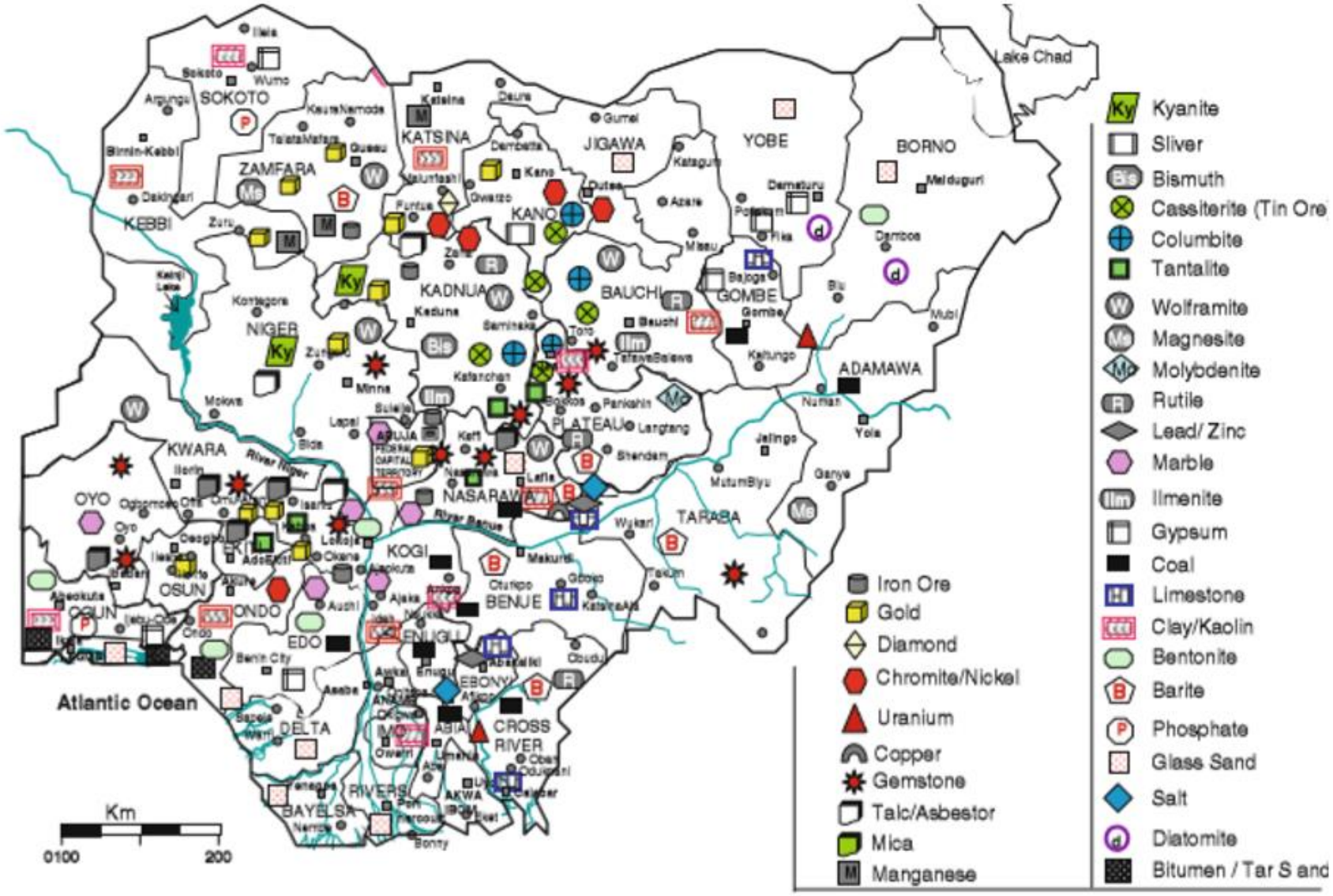


Figure 1: Map of Nigeria showing the distribution of solid minerals in each state (After NGSA, 2008).

GEOLOGICAL SETTING

The study area is located in Bode Saadu in Ifelodun Local Government Area of Kwara State. It extends from latitudes $8^0$55'00" N to $9^0$04'00" N and longitudes $4^0$37'00" E to $4^0$45'00" E covering part of the Share sheet 202 NW and Jebba sheet 181 SW. Prominent villages in the study area include Fala, Lasaki, Elelu, as well as Angwan-Dasu where a gold mine is currently being worked by a private industrialist. The study area which falls within the Basement Complex of Nigeria lies along transcurrent fault line of the Anka-Yauri-Iseyin schist belt (Obaje, 2009). The geochemical analyses done on Nigeria's basement rocks are the Major, Rare-Earth Elements, and Trace Element analyses. Despite the fact that geochemical studies have been and continue to be performed, other researchers have used and continue to use different geological methods in the investigation of gold mineralization in the Nigeria's basement complex. Danbatta and Ike (2001) deduced from the major and trace element geochemistry of metasediments (mica schists and quartzites) in the Kazuare Schist Belt that the protolith consists of shale-greywacke and clay deposits. Furthermore, Danbatta and Garba (2007) observed that the amphibolites in the Zuru Schist Belt had exceptionally low K_2O, high Al_2O_3, and low TiO_2, Niobium, Zirconium, Yttrium, Nickel, and Chromium concentrations, which are characteristic with island-arc or back arc settings.

Chondrite normalized rare earth element signatures of samples indicate low grade post Archean terrigenous deposition of rocks derived from a possible mixture of granite-tonalities. Adekeye et al. (2015) asserted that the gold mineralization around Bishewa, Southwestern Nigeria, is structurally controlled, with emplacement consistent with the NE-SW and NW-SE fracture directions, and therefore could be linked to the Okolom and Ilesha gold fields, which, like the Bishewa gold mineralization, lack lithological preferences. Abdullahi and Alabi (2018) discovered a diverse spectrum of formations thought to be quartz vein harboring mineral deposits. Ajadi et al. (2018) provided a result that revealed that the gold present occurs as discrete primary ore in rocks and suggested a close association between the Au and Sulfide ores. He concluded that the Alagbede gold mineralization is not just a show, but a hydrothermal economic deposit hosted in the quartz veins that cut through the quartzitic portion of the curvilinear transcrustal fractures that are thought to be linked with the gold mineralization in Nigeria.

MATERIALS AND METHODS

Ten lithological groups were mapped in the study area (Fig. 2). These includes, Migmatite and Granite Gneisses, Quartzite and Quartz Schist, Coarse grained and medium grained Granites, Diorite, as the major rock types with Pegmatite, Aplite and Quartz Veins intruding into them. Two textural types of granites mapped in the are the porphyritic granite and the medium grained granite the diorites also consist of porphyritic diorites which alongside some pegmatites occur as mylonites at the northwestern part of the area hosting the gold minerals. The migmatite gneiss occurs as low-lying outcrops some of which are in boulders that are light to dark grey in colour it

occupies approximately 15% of the map and located at the extreme southwestern part of the map extending outwards from the map The intercalating bands are made of the felsic which is composed of feldspar ad quartz while the mafic ads are made up of dark minerals including biotite and amphibole which is supported by the thin section. The porphyritic granite occurs as a ridge covering more than 20km on land in the eastern part of the map. Though the outcrops are intrusive igneous rocks, they occur as a high exposed body as a result of uplifting and are intruded by aplite and quartzo-feldspathic veins.

The medium grained granite mapped in the area spans from the southern part of the map through the west up to the northern area where it is intruded into by mylonitized porphyritic diorite and schist. It occurs in boulders and low-lying exposures in some areas and as low ridge exposures with intrusions of quartzo-feldspathic veins and cross cutting joints. The diorite found in the study area occurs at the extreme northwestern part of the area extending outwards to the west of the location. In some areas it is found as porphyritic diorite with potassic feldspar as the phenocryst within a groundmass of mafic minerals and as a fine grained with quartzo-feldspathic veins intruding into it and as mylonites which hosts the gold that is being mined in Angwan-Dasu. Intruding virtually all the basement rock types in the area, the pegmatites and aplites in the area outcrops mostly as swamp. In Angwan-Dasu, it occurs as Tectonized Pegmatites which alongside with the mylonitized Diorite hosts the gold mineral. Unlike the pegmatite whose occurrence was almost 80%, aplite accounts for just 20% outcropping as small units within the porphyritic granite and diorite.

Field observations and structural geology

The dominant strike of foliation in Nigerian basement is N-S with variations between NW-SE and NE-SW (Oluyide 1988). The dominant strike direction of the foliation plane in the study area (Fig. 3) is NW-SE while the prominent join direction lies within the NE-SW. Cross-cutting joints were observed on the metasediments (Fig. 4) and on some of the medium grained granites (Fig. 5). Parallel joint sets were also observed on intruding quartz veins. A number of sinistral faults with displacements ranging from few centimeter up to 15cm (Fig. 6) were observed on the coarse-grained granitic rocks while dextral faults were observed on a medium granite biotite hornblende granite where the intruding quartzo-feldspathic vein was displaced by 3cm. Isoclinal and S-type folds (Fig. 7) were observed on some of the gneisses in the study area. Axes of folds in the study area are mainly trending in NNE-SSW which conforms with the conclusion of Olade (1978) that axis of fold in Nigerian Basement terrain generally trends in NNE-SSW direction.

Laboratory procedure

The main and minor elements in pulverized rock samples were determined using an inductively coupled plasma-atomic emission spectrometer (ICP-AES) for the major elements and an inductively coupled plasma-mass spectrometer (ICP-MS) for the trace elements. The raw rock samples (16) were air dried at room temperature before being crushed with a laboratory jaw crusher. The very fine-grained samples that resulted were subsequently crushed in a vibrating

Disc Mill. A mixer Mill was used for the final size reduction, mixing, and homogenization to 75m. 16 samples comprising of 4 Pegmatites,4 Porphyritic Diorites, 2 Medium Grained Biotite-Hornblende Granites, 2 Migmatite Gneisses, 1 Quartz Schist, 1 Granodiorite, 1 Medium Grained Biotite-Hornblende Alkali Granite and 1 Porphyritic Granite were then shipped off to MS Analytical Laboratories, Vancouver, Canada for major, trace and rare earth elements geochemistry. Samples suspected to host gold specks were polished and examined under the Reflected Light Microscope at the Department of Geology and Mineral Sciences, Kwara State University, Malete, to provide a clearer image and aid the identification of the ore minerals.

RESULTS AND DISCUSSION

Results

The rock types mapped in the study area have been categorized into two main groups which includes the igneous (medium grained granites, granodiorite, diorite, porphyritic diorite and pegmatites) and the metamorphic rocks (including the migmatite gneiss, granite gneiss and quartz schist). The chemical compositions in terms of major, trace and rare earth elements data for the 16 whole rock samples are presented in Tables 1, 2 and 3. The result shows that the rocks are silica saturated with values ranging between 51.25% – 74.25%.

Alumina variation diagram of $Al_2O_3/(Na_2O+K_2O)$ vs$Al_2O_3/(CaO+Na_2O+K_2O)$ (Shand 1943) was adapted which shows that the majority of the samples are peraluminous (Fig. 8), while those obtained from Medium Grained Alkali Granite and Granodiorite rocks are Peralkaline; this pattern is also recognized for older granites in Northern and Southwestern Nigeria basements because they contain a substantial quantity of alkalis and are Peraluminous, with corundum showing in the norm (Odeyemi, 1977; Olarewaju and Rahaman, 1982). Furthermore, granitic gneiss in the Jebba SW region (SW Nigeria) is Peraluminous (Okonkwo and Ganev, 2012). Rahaman et al., (1987) also noted that granitic rocks around the Oban Massif in Southeastern Nigeria are Peraluminous, while Okonkwo and Folorunsho (2013) noted that the foliated granitic gneisses of the Aderan area are calc-alkaline and peraluminous granites emplaced during the Pan-African orogeny, which differ from granitic rocks in Igbeti (SW Nigeria) (Rahaman et al., 1988), Ityowanye and Katsina-Ala areas (SE Nigeria) (Obiora, 2012) which are Metaluminous.

The total alkali (Na_2O+K_2O) versus SiO_2 (TAS) diagram of Cox et al. (1979) was adopted for the characterization and nomenclature of rocks (Fig. 9), which shows the gneisses lying within the granodiorite to granite field. Some of the pegmatites and diorites lie within the syeno-diorite to syenite fields, while the remaining rocks lie within the granitic field. Using the Tarney (1977) TiO_2 versus SiO_2 diagram, porphyritic granite and diorite plotted in the igneous field while the other rocks including the gneisses plotted in the sedimentary field. (Fig. 10). The Na_2O/Al_2O_3 versus K_2O/Al_2O_3 of Garrels and Mackenzie (1971) shows that most of the rocks plotted in the sedimentary/metasedimentary origin except for a pegmatite sample (Fig. 11) which plotted

within the igneous filed. The plotting in the sedimentary field indicates a fractionation pattern derived primarily from a sedimentary source with significant contamination from residual hornblende, clinopyroxene and garnet in a host source rock of igneous origin.

McCurry (1971), McCurry (1976), Ajibade *et al*. (1979), Adekoya (1998), Danbatta (2008), Danbatta (2010), have all established sedimentary/metasedimentary protolith for the younger metasediments in the Nigerian Basement Complex. Though, there are conflicting opinions on the development of gneisses, with most authors believing that gneisses are of igneous protolith, a couple of other researchers suggest that certain gneisses are formed through granitization of pre-existing metasediments. The chondrite normalized REE for the rocks exhibits remarkable parallelism. The distribution patterns of Rare Earth Elements (REE) are typically smooth, as evidenced by a reduction in REE values from light rare earth element (LREE) to heavy rare earth element (HREE) and a low Eu anomaly (Fig. 11). Except for Granodiorite which exhibits HREE depletion, LREE enrichment and a notable negative Eu anomaly.

The presence of hornblende in the protolith's felsic melts might explain the enrichment in light REE compared to heavy REE. This pattern is comparable to that of hornblende-biotite granitoids observed in the Itowanye and Katsina-Ala areas in Nigeria's southeast (Obiora, 2012). Olanrewaju (1988) documented comparable variance in Ado-Ekiti charnokitic rocks and granites. Light rare earth elements (LREE) are expected to be abundant in the gneisses owing to contamination from crustal sources. This is consistent with Rahaman et al (1988)'s results on gneisses in the Ile-Ife schist belt. The tendency of Eu to be incorporated preferentially into plagioclase over other minerals is often attributed to its enrichment or depletion (Weill and Drake, 1973). A low Eu anomaly in the rocks suggests that plagioclase feldspar was lost during fractionation (differential solubility during rock weathering). Negative Eu in gneisses was most likely caused by a low preferred concentration of plagioclase feldspar during protolith magma crystallization.

Ore microscopic study shows the presence of gold within the rocks which were concentrated along fractures in association with sulphides and were later remobilized and disseminated by dynamo-thermal deformation that mylonitized the host rocks at the waning stage of the Pan African event. Hand specimen samples produced photomicrographs that show the presence of the gold minerals (Figs.12-13) which are hosted within mylonitized coarse grained granites, diorites and pegmatites within the study area. The gold mineralization sometimes occurs in clusters while some are observed as disseminated specks. Polished sections were rubbed with immersion oil in order for the light to be reflected which aided the visibility of the minerals. As observed under the microscope, the gold mineralization occurs in association with sulphide minerals and galena. The clustered ores show alignment in a certain direction as shown by the dashes.

Discussion

The study area lies within the Anka-Yauri-Iseyin (AYI) transcurrent fault line of the Nigerian Basement Complex (Obaje, 2009) and has been largely affected by the transpressive forces leading to shearing, fracturing, mylonitization, and partial granitization of the underlying rocks. Petrographic study shows that the area is underlain by migmatite and granite gneisses, on which quartzite and quartz schist were infolded and later intruded by the Pan African Older Granite suites including porphyritic granite, medium grained granite, granodiorite, diorites, pegmatite, aplite and quartz veins. The migmatite occurs as low-lying outcrop extending outwards to the extreme southeastern part of the area with the granitic portion occurring within a few yards from the gneisses. The gneisses are strongly foliated with the presence of variety of folds indicating polyphase deformation and metamorphism. Migmatites outcrops as small units of relict xenolith and enclaves within the diorites in the extreme northwestern sector of the study area. The quartzite occurs as a ridge with an exposure on the earth road where thick foliations and bands defined by micaceous minerals were observed.

The schist within the area locally and progressively grades into phyllites towards the northern part. The coarse-grained granite occurs as a high rising ridge at Fala where it outcrops in association with other rock types as mylonites, extending from here to Angwan-Dasu where the ridge appears sheared and submerged. Unlike the coarse-grained granites, the medium grained granite outcrops discontinuously as low-lying ridge and in-situ boulders from Fanto to Bode Saadu where it terminates. The medium graine granite is dominated by alkali feldspar and also extends to the extreme northwestern part it appeared more mylonitized and together with other rocks, hosts the gold mineralization in the area. The pegmatite dominates over the aplite, and occurs as swamps, particularly around Fala where it occurs as impressive boulder outcrops of up to 24m above the surrounding country, and in the northwestern area as a mylonitized ridge. The aplite only outcrops within the coarse-grained granite and as minor bosses within the schists around Angwan-Dasu. The trend of dominant folds axes is NNE-SSW which consistent with the work of Olade (1978) within the Nigerian Basement terrain. The general trend of structural lineaments also show dominance in the NE/SW with subordinate and complimentary NW/SE minor joint directions obtained from the field data.

Petrographic observations reveal that the alkali elements in the metamorphic rocks have shown varied mobility during metamorphism, indicating low grade, greenschist facies, metamorphism for the schists and low to medium grade, greenschist to lower amphibolite facies, metamorphism for the gneisses. Most of the rock samples plot within the peraluminous field (Fig. 8), suggesting the likelihood of a continental origins with magma compositions derived from the crustal materials. Geochemical classification diagrams reveal a sedimentary/metasedimentary origin (Fig. 9) which were further supported by the chondrite normalized plots that shows a general low Eu value resulting from the hornblende remaining from the partial melting of sedimentary rocks during fractionation (Ajadi et al., 2018). This gives a possibility that the parent rock forming

material came from previously formed sedimentary or metamorphic rocks before being buried and melted.

The ore microscopy shows that the gold is disseminated along the shear zones of the mylonitized rocks giving the indication that the gold was precipitated under favorable rheological conditions during the Pan-African thermotectonic deformation and was partly remobilized and disseminated into the surrounding host rock by hydrothermal fluids emanating from metamorphic dewatering that accompanied the waning stage of the Pan African event. Anomalous concentration of Au that even visible in hand specimen of most of the mylonitized samples investigated confirmed the gold mineralization around Bode Saadu. There is higher concentration of target and pathfinder elements (Au, Pb, Cu, Ag and Zn) in places around Angwan-Dasu relative to Fala and Lasaki areas. The Au deposits can thus be said to be initially precipitated along structural lineament during compressive deformation that dominate the Pan African event during Neoproterozoic time and subsequently remobilized. This is consistent with the works of Adekeye *et al*, (2015) and Ajadi et al, (2018) on Au mineralization pattern around Bishewa area and Alagbede area respectively.

CONCLUSION

Field relationships and petrographic studies have shown that the major lithologies in the study area are the Migmatitic Gneiss (stromatic and ophthalmic migmatites), Metasediments (Quartzite and Quartz Schist), Diorite and Biotite and hornblende granites (porphyritic, coarse grained and medium grained varieties) while Pegmatites, Aplites and Quartz veins constitute the minor intrusives and outcrop mostly as veins and bosses. The major minerals mapped in the gneisses include quartz, plagioclase feldspar and biotite $\pm$ hornblende $\pm$ amphibole; the metasediments are dominated by quartz, muscovite $\pm$ biotite, sericite; while the granites are composed of quartz, microcline, muscovite, biotite ± amphibole, sericite and ore minerals. A geological map and cross section were produced, indicating the lithological distribution of rock underlying the study area. The dominant foliation trend is NNE-SSW which is in line with the general structural grains associated with the Pan African orogeny. The fold axial trace of most folds mapped in the area shows a NNE-SSW trends while dextral and sinistral faults were mapped on the migmatitic gneisses and metasedimentary rocks of the area.

The geochemical discrimination diagram shows that the gneissic rocks have sedimentary precursor while the pegmatites, porphyritic granites and diorites shows affinity for igneous origin. The rocks of the Bode Saadu area shows a low negative Eu anomaly on the chondrite normalized REE plot, which suggests a possible sedimentary origin for the Older Granite suites of the study area with possible igneous contribution. Most of the rock samples plot within the peraluminous, suggesting the likelihood of a continental origins with magma compositions derived from the crustal materials. The gold mineralization is initially precipitated along structural lineaments during compressive deformation that dominates the Pan African event during Neoproterozoic time and remobilized by subsequently metamorphic dewatering and

degassing during the waning stage of the Pan African event. Available ore microscopic evidence (Fig. 13) shows a close paragenetic mineral association including gold, pyrite, galena, chalcopyrite, sphalerite and bornite, suggesting that the gold and sulphide mineralization around Angwan-Dasu area are cogenetic.

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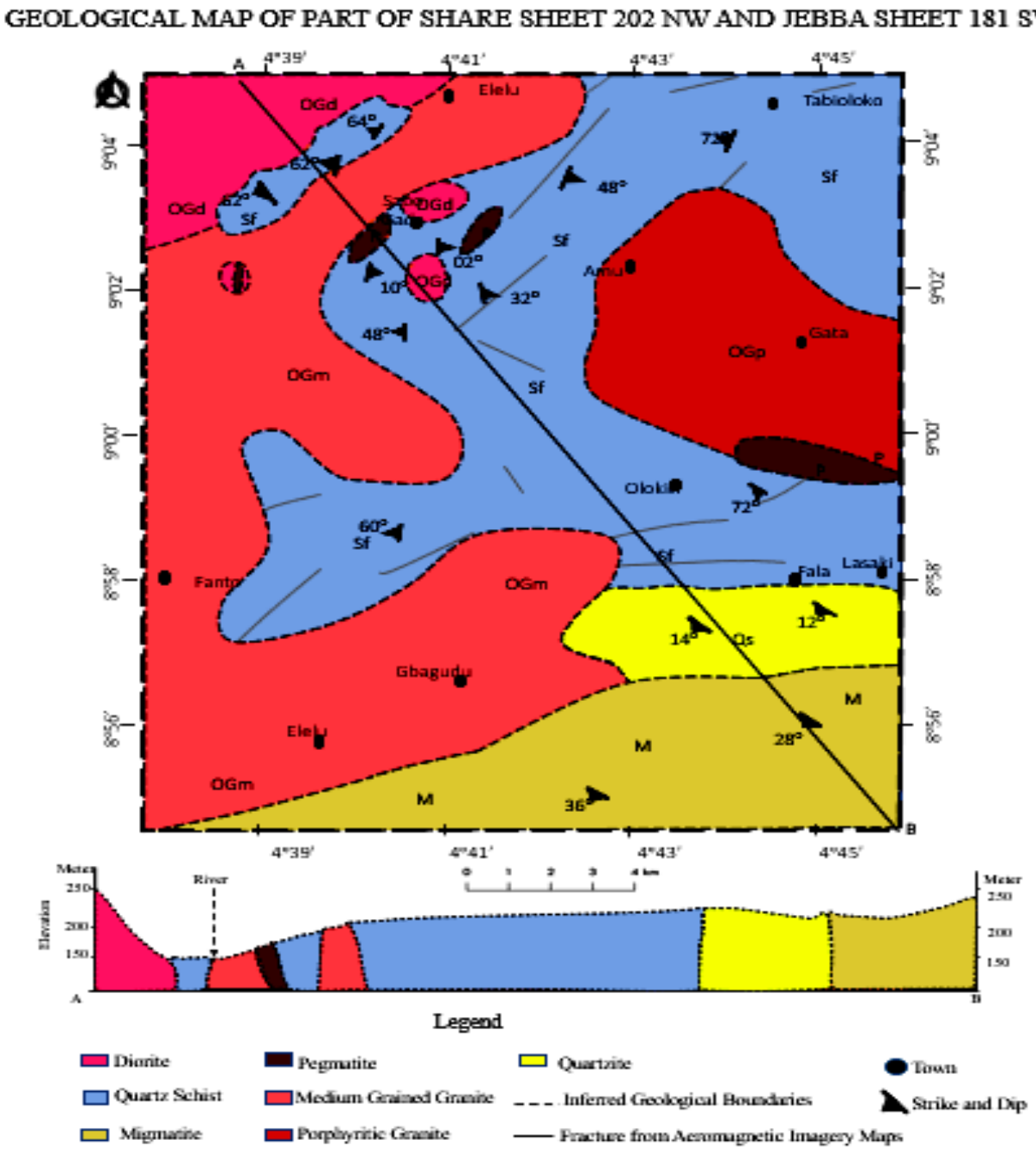


Figure 2: Geological map and cross section of the study area showing the lithologies

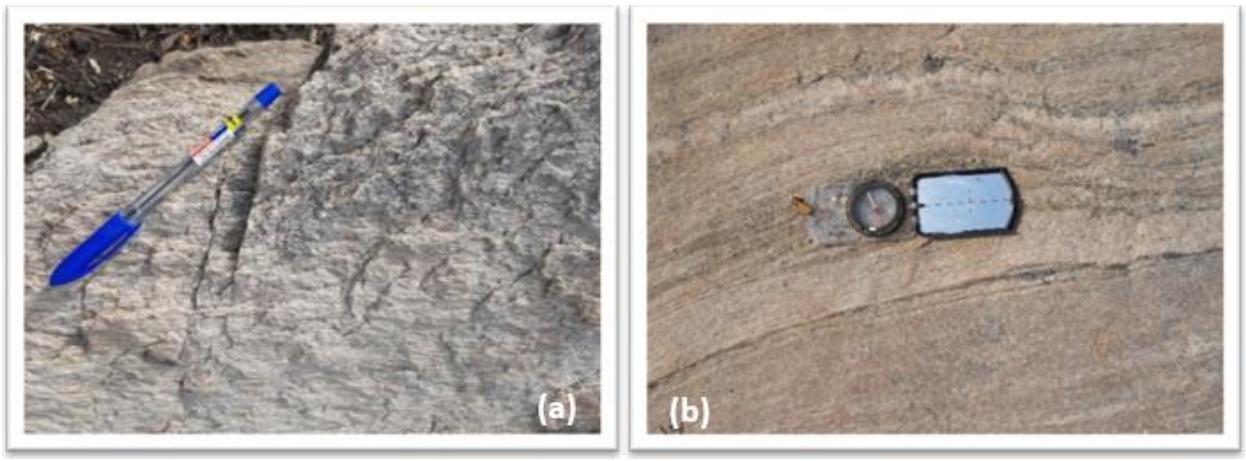


Figure 3: Photograph showing the foliation in (a) quartz schist, (b) granite gneiss



Figure 4: Photograph showing (a) Cross-cutting joints on a M-BHG (b) Joints cutting through a quartzo-feldspathic vein on a M-BHG

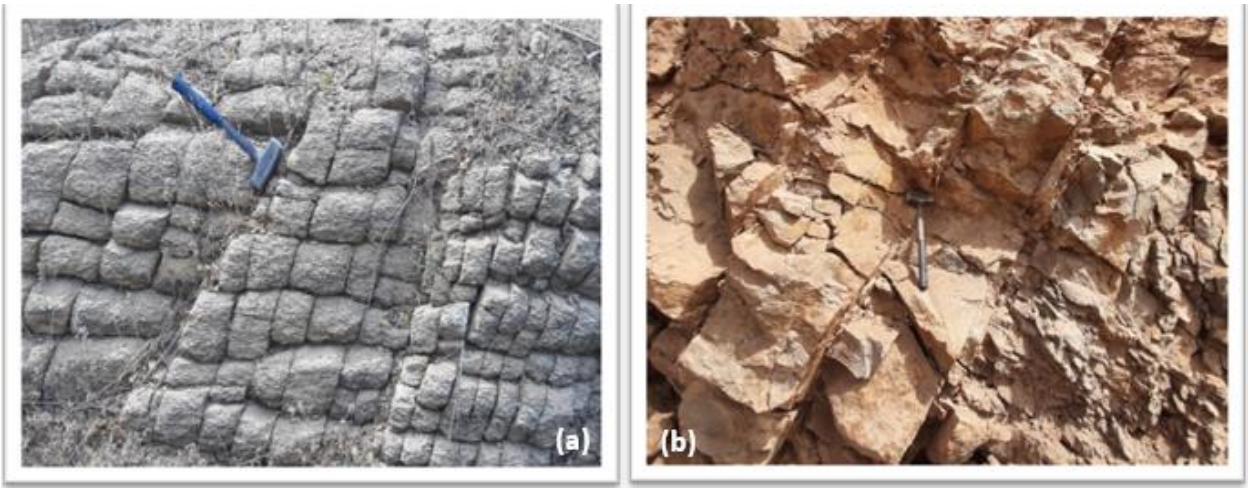


Figure 5: Photograph showing (a)Cross-cutting joint sets on a Quartz schist (b) Joint set on a tectonized pegmatite

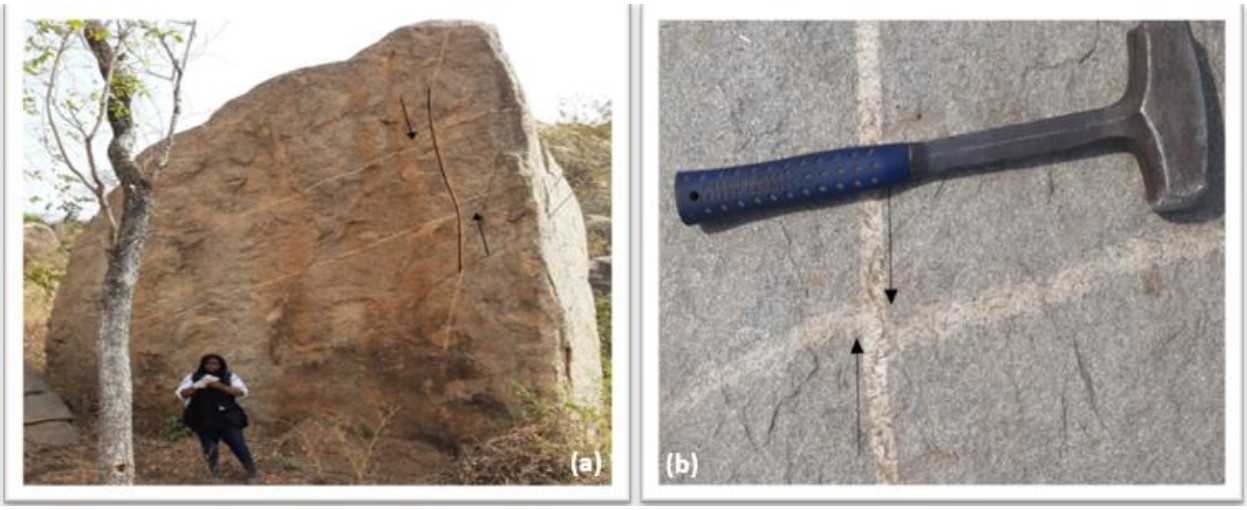


Figure 6: Photograph showing a (a) dextral fault on a coarse-grained granite (b) sinistral fault on a medium grained alkali granite

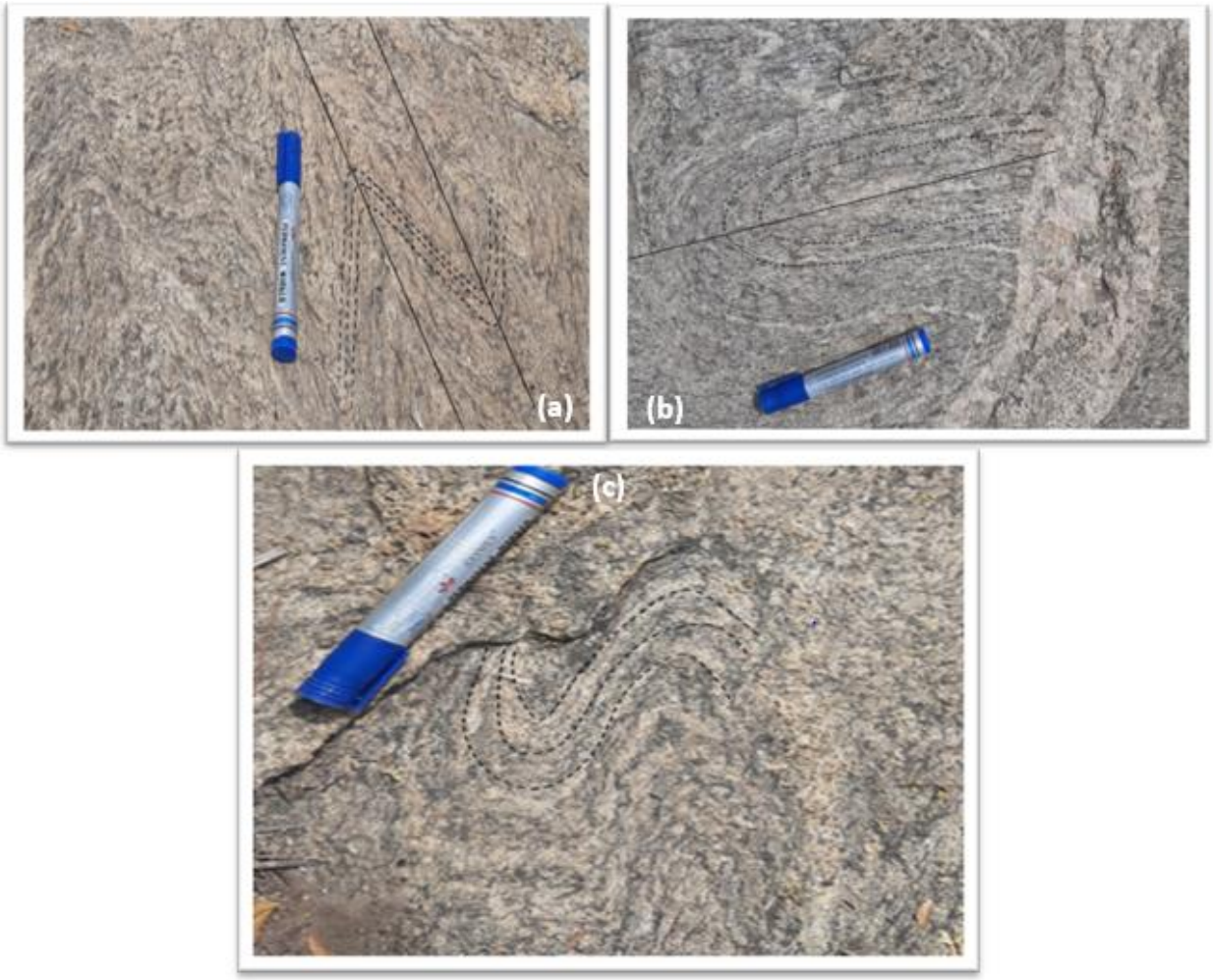


Figure 7: Sections of outcrops the migmatitic gneiss showing (a) anticlinal and synclinal chevron folds (b) isoclinal folds intruded by pegmatitic vein (c) Concentric S-fold pattern.

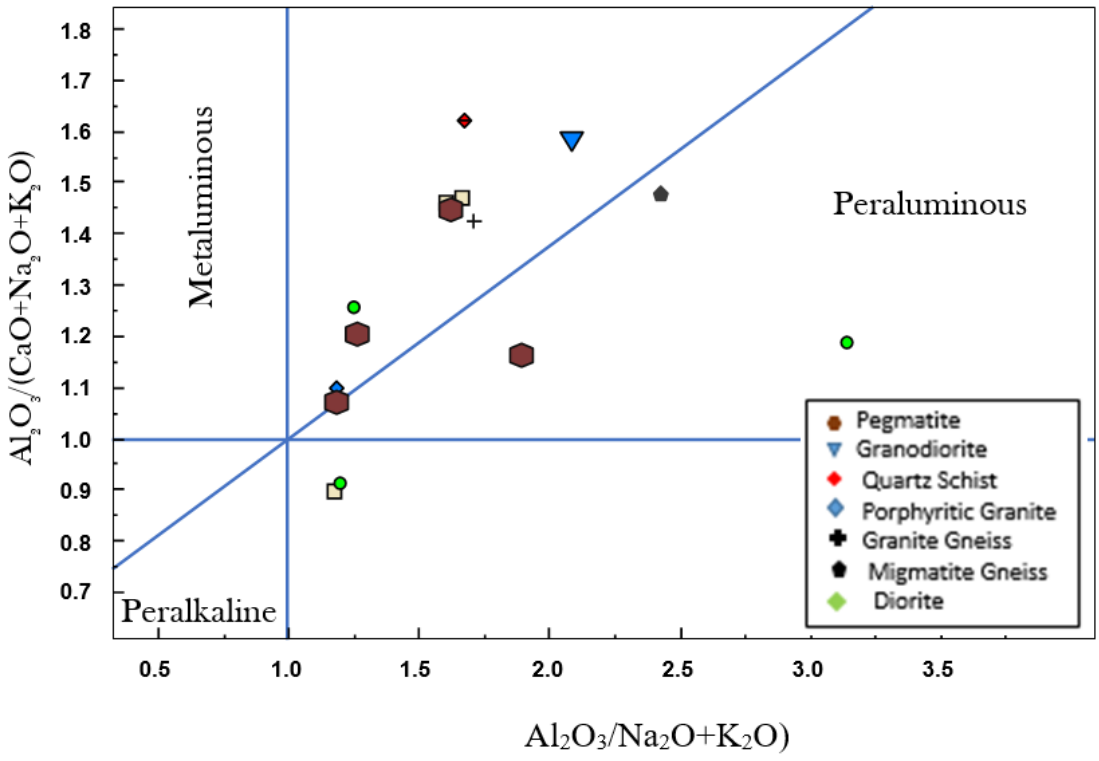


Figure 8: Shand's (1943) binary plot of alumina to alkalis [$Al_2O_3/(Na_2O+K_2O)$] vs alumina to lime and alkalis [$Al_2O_3/(CaO+Na_2O+K_2O)$] demonstrating chemical categorization of the rock.

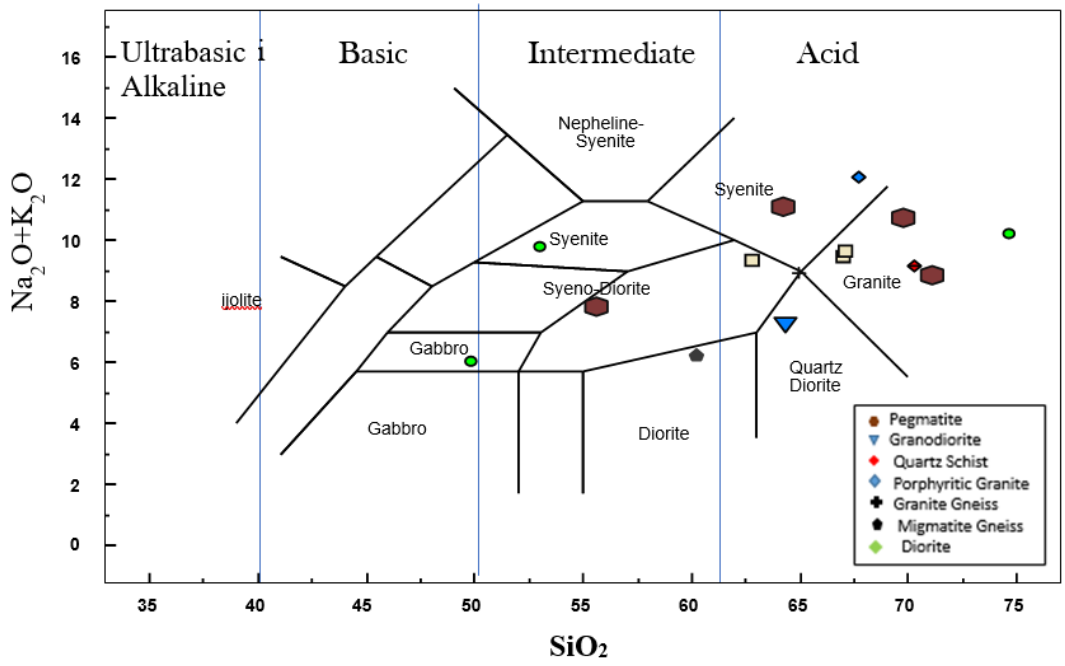


Figure 9: Cox et al., 1979 bivariate discriminating plot of SiO_2 vs Na_2O+K_2O demonstrating chemical categorization and nomenclature of igneous and metamorphic rocks.

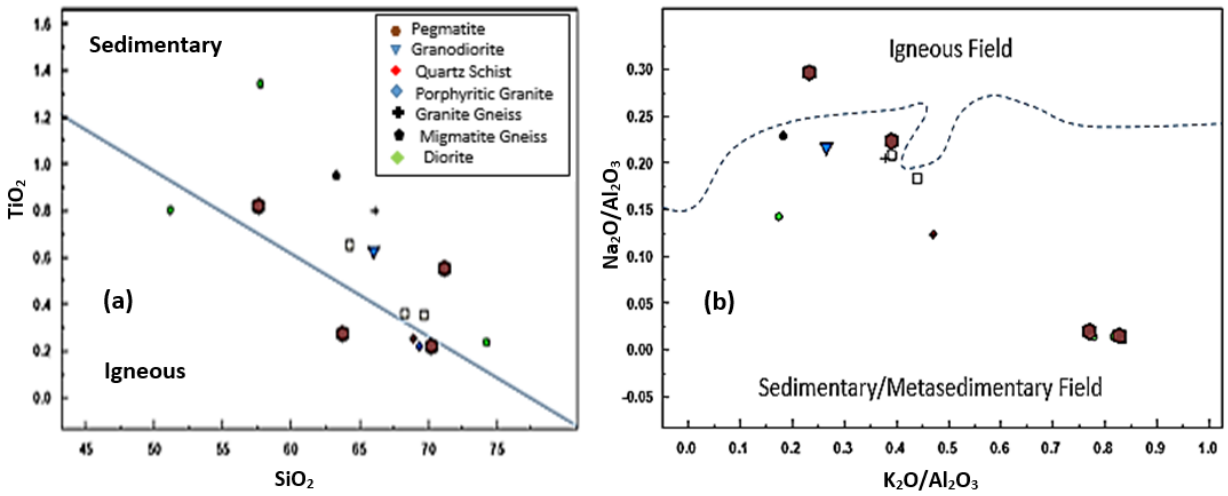


Figure 10: (a) Bivariate (TiO_2 versus SiO_2) discrimination diagram of Tarney, 1977 indicating Igneous and Sedimentary fields (b) Na_2O/Al_2O_3 versus K_2O/Al_2O_3 plot of Igneous and Metasedimentary rocks of Agwan-Dasu area (Adapted from Garrels and Mackenzie, 1971).

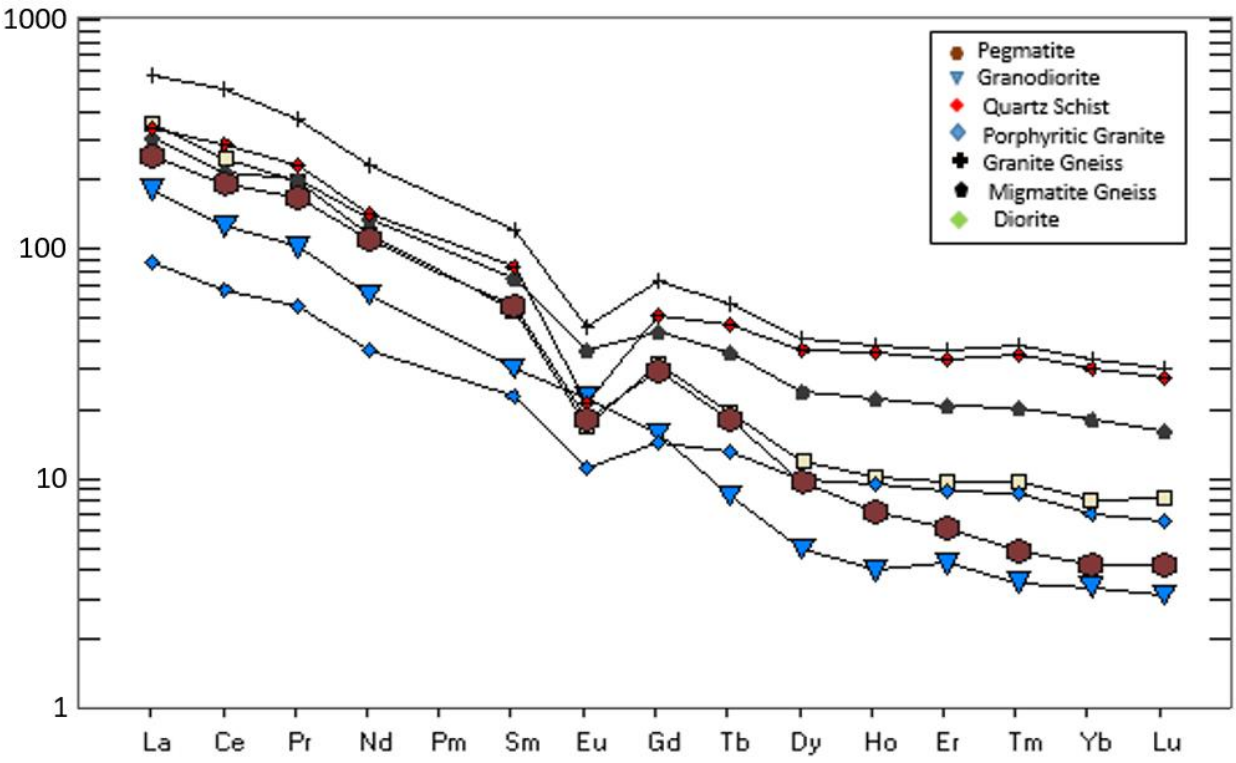


Figure 11: Chondrite normalized diagram exhibiting the rare earth elements (REE) fractionation pattern of rocks around Agwan-Dasu (After Nakamura, 1974)

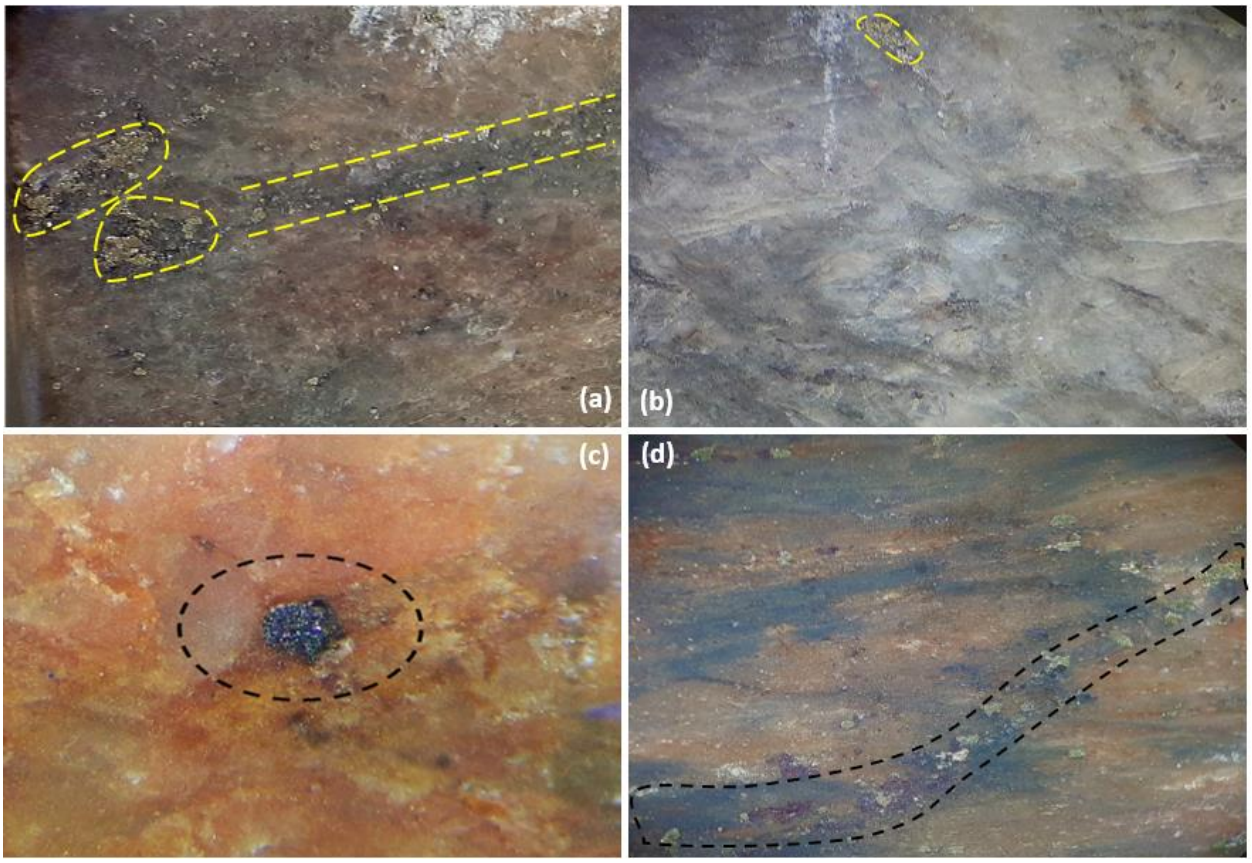


Figure 12: Photomicrograph of mylonitized pegmatites showing gold specks (a) as disseminated nuggets and fracture-filling in association with sulphides (b) as isolate nuggets (c) as blind gold in sulphides (d) as fracture-filling in association with galena in mylonitized diorite.

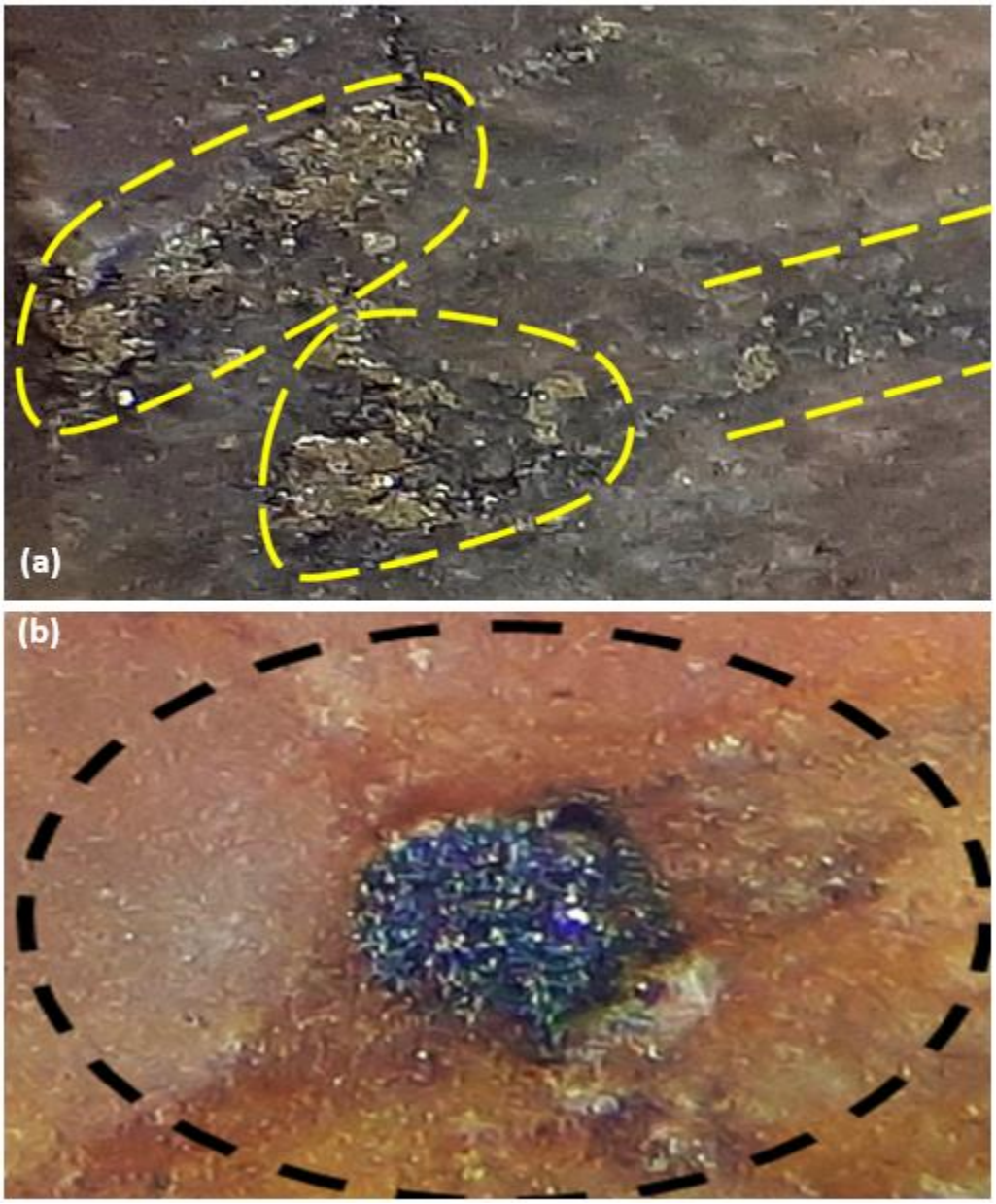


Figure 13: Photomicrograph of mylonitized pegmatites showing (a) disseminated specks of gold associated with sulphides (b) blind gold mineralization in sulphides

Table 1: Major Elements Composition of some selected whole rock samples

Element	OGm 1	OGm 2	OGm 3	OGg	OGd 1	OGd 2	OGd 3	OGd 4	OGp	P 1	P 2	P 3	P 4	GG	Sf	M
SiO_2	68.34	69.75	64.25	66.03	74.36	74.25	51.25	57.80	69.35	70.27	71.17	63.74	57.62	66.16	68.96	63.34
BaO	0.12	0.17	0.12	0.23	0.10	0.10	0.09	0.17	0.08	0.09	0.54	0.42	0.21	0.13	0.10	0.10
TiO	0.36	0.35	0.65	0.62	0.23	0.23	0.8	1.34	0.22	0.22	0.55	0.2	0.82	0.80	0.25	0.95
Al_2O_3	16.05	16.09	11.3	15.42	12.73	12.71	19.38	12.74	14.68	12.79	11.21	17.88	15.32	15.50	15.02	15.84
Fe_2O_3	2.81	2.97	6.07	4.53	0.99	0.97	5.51	10.35	2.09	2.44	3.57	2.06	6.65	3.61	1.85	5.65
MnO	0.05	0.06	0.08	0.06	0.01	0.01	0.12	0.15	0.03	0.03	0.03	0.08	0.17	0.0	0.03	0.10
MgO	0.53	0.56	0.96	1.45	0.05	0.05	3.34	1.2	0.35	0.44	0.12	0.65	2.75	0.87	0.77	2.34
CaO	1.31	1.03	3.06	2.38	0.04	0.05	10.22	3.45	1.11	1.19	0.47	1.38	5.12	1.86	0.34	4.21
Na_2O	3.34	2.93	0.13	3.3	0.15	0.15	2.74	0.15	0.25	0.19	0.22	3.99	4.52	3.16	1.85	3.63
K_2O	6.28	7.08	9.43	4.20	9.85	9.94	3.41	10.44	12.12	10.60	8.65	7.01	3.58	5.88	7.09	2.90
P_2O_5	0.1	0.12	0.30	0.21	0.07	0.07	0.30	0.39	0.10	0.08	0.51	0.06	0.37	0.31	0.03	0.41
Cr_2O_3	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
SrO	0.03	0.03	0.07	0.05	0.01	0.01	0.04	0.09	0.02	0.03	0.04	0.14	0.18	0.02	0.01	0.04
LOI	0.29	0.45	2.48	0.47	0.74	0.65	3.93	2.61	0.76	1.11	1.37	0.74	0.82	0.59	2.33	1.29
Total	99.61	101.61	98.93	98.86	99.31	99.19	101.14	101.40	101.16	99.47	98.45	98.42	98.13	98.94	98.64	100.8

Table 2: Trace Element Composition of some selected whole rock samples

Element	OGm	OGm	OGm	Ogg	GG	M	Sf	OGd	OGd	OGd	OGP	P	P	P	P
Ba	1028.9	1507.9	1160.3	2072.5	1130.7	952.9	958.5	898.3	788.3	1511.3	757.5	843.3	4951.6	3789.8	1950.4
Cs	4.8	1.55	1.18	2.93	2.77	2.78	6.05	1	1.05	1.53	1	0.82	1.03	4.45	1.48
Ga	22.6	21.5	17.2	22.5	23.6	23.1	21.2	19.5	19.5	20	19.5	18.1	18.5	20	18.9
Hf	8.2	9.8	10	5.8	23.4	12.	8.2	4.9	10.5	10.	3.4	4.8	3.3	5.9	7.6
Nb	22.5	19.3	18.7	10	46.8	22	24.9	7.9	20.5	39.3	14.5	7.1	136.2	20.8	14
Rb	229.4	285.9	128.1	141.3	262.1	112.1	260.2	150.4	89.9	161.1	202	8	161.4	224.2	66.5
Sr	220.6	265.9	613.1	433.9	193.1	356.4	73.7	103.4	309.7	788.2	149.9	296.8	393.9	1233.8	1662.6
Ta	1.4	1.3	1	1	2.4	1.4	2	0.9	2.1	1.4	1.1	1.2	1.3	2.1	1.1
Th	52.06	86.3	24.88	6.08	6.36	26.84	37.77	48.57	23.7	28.04	15.86	60.22	34.4	9.01	7.48
U	4.51	4.48	1.35	0.96	4.25	2.25	4.32	1.59	6.88	2.08	1.82	2.04	1.69	3.45	1.06
V	22	21	37	46	19	70	20	13	124	87	14	20	41	22	98
W	1	1	2	1	1	1	1	5	2	13	5	4	5	1	1
Zr	299	342	402	222	853	428	250	10	341	420	102	150	102	210	309
Ag	0.01	0.01	0.01	0.01	0.01	0.01	0.01	2.29	0.12	0.03	2.14	0.46	0.59	0.01	0.01
As	0.1	0.1	0.5	0.1	0.1	0.2	0.1	1.7	0.1	0.1	1.3	1.3	0.9	0.1	0.6
Au	0.0005	0.0066	0.0005	0.0005	0.0005	0.0128	0.0008	6.5314	0.301	0.0027	6.0658	0.5952	1.1374	0.0005	0.0012
Bi	0.01	0.05	0.38	0.03	0.03	0.02	0.04	0.05	0.03	0.16	0.06	0.12	0.02	0.07	0.110
Cd	0.01	0.03	0.01	0.03	0.03	0.03	0.04	0.02	0.01	0.08	0.04	0.03	0.01	0.02	0.002
Cu	0.2	12	3.2	15.6	7.5	5.7	24.2	19	2.4	27.2	20.7	21.7	14.6	5.2	7.5
Hg	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Mo	0.05	0.57	0.32	0.13	0.39	0.26	0.24	4.24	12.51	0.4	21.33	36.72	11.85	0.32	0.35
Ni	0.2	3.9	3.6	13.6	5.9	3.3	11.9	3.6	1.8	32.3	4.4	3.6	2.3	2.2	5.7
Pb	0.2	8.2	17.3	7.3	2.8	12.9	2.2	15.5	22.8	13.5	14.2	36.8	19.6	6.1	19
Sb	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.3	0.1	0.05	0.42	0.3	0.13	0.05	0.05
Se	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.9	0.2	0.2	0.7	0.2	0.3	0.2	0.2
Tl	0.02	0.63	0.42	0.02	0.59	0.37	0.52	0.1	0.08	0.02	0.78	0.14	0.15	0.5	0.03
Zn	1	89	21	26	91	61	94	20	12	68	94	18	19	67	22