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Geochemistry and Gold Mineralisation Potential of Ungwan Rimi and Environs, Part of Wamba 210 Sw/Kurra Sheet 189 Sw, North-Central, Nigeria

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ABSTRACT

The Ungwan Rimi area is located at the southern fringe of North-Central Nigeria and lies between (Lat. $8^{\circ}34'19''\text{E}$ $8^{\circ}38'29''\text{N}$ and long. $8^{\circ}58'00''\text{E}$, $9^{\circ}00'45''\text{N}$) near Wamba town. The area is underlain by Precambrian Basement Complex rocks. A total of 20 samples were collected. Eight (8) are rocks samples, while twelve (12) stream sediments samples. The samples were carried to the laboratory for XRF analysis. The plutonic bodies observed from the geochemical classification plots depict granite and granodiorite to diorite. The major elements variation diagrams show that, the rocks are essentially peraluminous, subalkaline, calc alkaline to tholeiitic series rocks. The granitic rocks as intrusions into pre-existing migmatite gneisses are magnesian, while the migmatite gneisses are generally ferroans in composition. The rocks are S-type which strongly implies being derived from sedimentary protoliths. The wide variation coexistence between the lithophile elements clearly suggest that, the rocks were possibly formed from fractional crystallization of melts derived from partial melting under the subduction related settings. The geochemical distribution patterns revealed the relative distribution of pathfinder elements (Sn, Co, Sc, Ni, Cd, V, Ta, Nb, W, Hf, Ba, Th, U, Pt, Sb) of gold in the area. Ungwan Rimi and environs were geochemically assessed using factor analysis and correlation coefficient so as to establish the possible gold occurrence. The factor analyses (Factor 1: Cl, S, Sc, Co, Ni, Y, Cd, Sn, Au; Factor 2: V, Ta, W, Sb, Nb; Factor 3: Ba, Hf, Th, U) and co-efficient of correlation (Au vs Sn, Nb vs Ta, Nb vs Ta, W vs Ta, Sb vs W) supported the possible association between the pathfinder elements of gold in the area. The enrichment map derived from the metal ratio values for both the rocks and stream sediments depicts areas of better promise in terms of gold potential in the area.

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INTRODUCTION

The increase in demand and rise in price of gold has led to intensive research of precious metals (including gold) all over the world. Gold in Nigeria usually occurs in alluvial and eluvial placers and primary veins from several parts of supracrustal (schist) belts in the northwest and southwest Nigeria (Garba, 1998). The widely known areas of gold are: Maru, Anka, Malele, Tsohon Birnin, Gwari-Kwaga, Gurmana, Bin Yauri, Okolom-Dogondaji and Iperindo areas, all associated with the schist belts of northwest and southwest Nigeria (Woakes and Bafor, 1982). It was believed that some areas have smaller occurrences of gold beyond the schist belts (North-central Nigeria included). Akintola *et al.*, 2012 elucidate that, majority of the viable economically mineral deposits e.g. gemstones and rare metals (gold) are mostly hosted in pegmatite. It was previously believed that the mineralized pegmatites are confined to a broad 400km long NW-SE trending belt stretching from

Wamba area in north-central Nigeria to Abeokuta area in the south-western Nigeria. Gold mineralization and occurrence in Nasarawa State is not well documented, thus records of previous mining from this part of the Region are scanty. However, few works have been done on Gold mineralization in Nasarawa state (Jatau *et al.*, 2018; Umar and Tanko 2020). Jatau, *et al.* (2013) worked on the preliminary stream sediment analysis of gold prospecting at Ragga and environs, North central Nigeria, and discovered the potential for gold mineralisation in the area. Umar and Tanko, (2020) carried out the geochemistry of stream sediments around the study area to determine the presence of gold and its associated elements like Pb, Eu, Yb, Re, Zr, Zn, Ru, etc. The result revealed the presence of traces of gold and some associated elements such as Zn, Cu, Ba, Pb, As etc. The investigation further shows the trend of mineralization in the NNE-SSE direction.

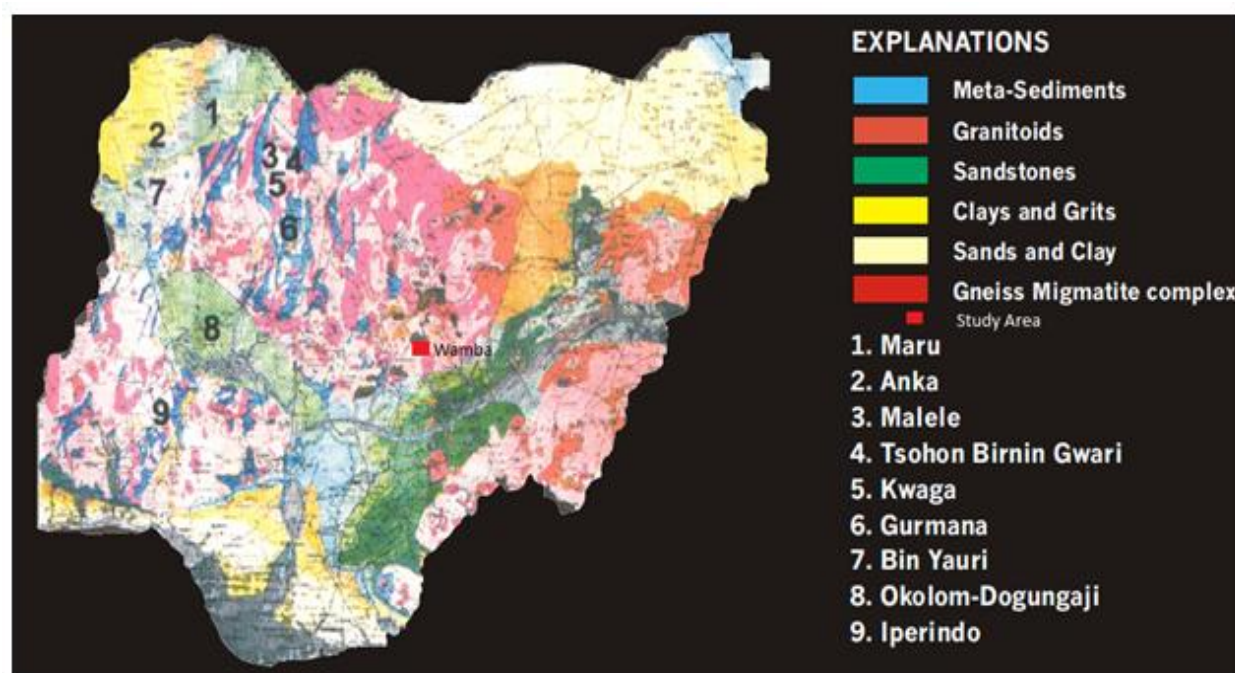


Figure 1.1 Geological map of Nigeria showing the major areas of gold mineralization (MMSD, 2010).

1.1 Regional Tectonic Setting

One of the major lithologic component of the underlying rocks that make up the geology of Nigeria is the basement complex. It consists of the Migmatite-Gneiss-Quartzite complex, the Schist Belts, the Older Granites, the Younger Granites and undeformed acidic and basic dykes. It also forms part of the Pan-African mobile belt that is found between the west African craton and Congo craton and it is south of Tuareg Shield (Black 1980). The Basement Complex rocks were intruded by the Mesozoic alkaline ring complexes and unconformably overlain by the sedimentary basins and younger sediments. It is believed that four orogenic episodes (polyphase) of deformation, metamorphism remobilization corresponding to Liberian (2700Ma), Eburnean (2100 Ma), Kibaran (1100Ma) and Pan African (600Ma) cycles has affected the basement complex of Nigeria. The first three were marked by intense formation of rock units and folding accompanied by regional metamorphisms which

were further followed by extensive migmatization. The Pan-African deformation was accompanied by a regional metamorphism, migmatization and extensive granitization and gneissification which produced granites and homogeneous gneisses (Abaa, 1983). It resulted from plate collision between the passive continental margin of the West African craton and the active Pharusian continental margin (Burke and Dewey, 1972. Dada, 2006). The collision led to the reactivation of the internal region of the belt. Emplacement of large volumes of granites from various orogenic and anorogenic events resulted in various mineral age in virtually all rock types of the basement. The imprint on the cratonic history of the basement is reflected by its widespread ages of 550 +/- 12100 Ma, However, the Pan-African Orogeny is believed to be the most extensive and in many locations overprints on earlier orogenies in most parts of Africa.

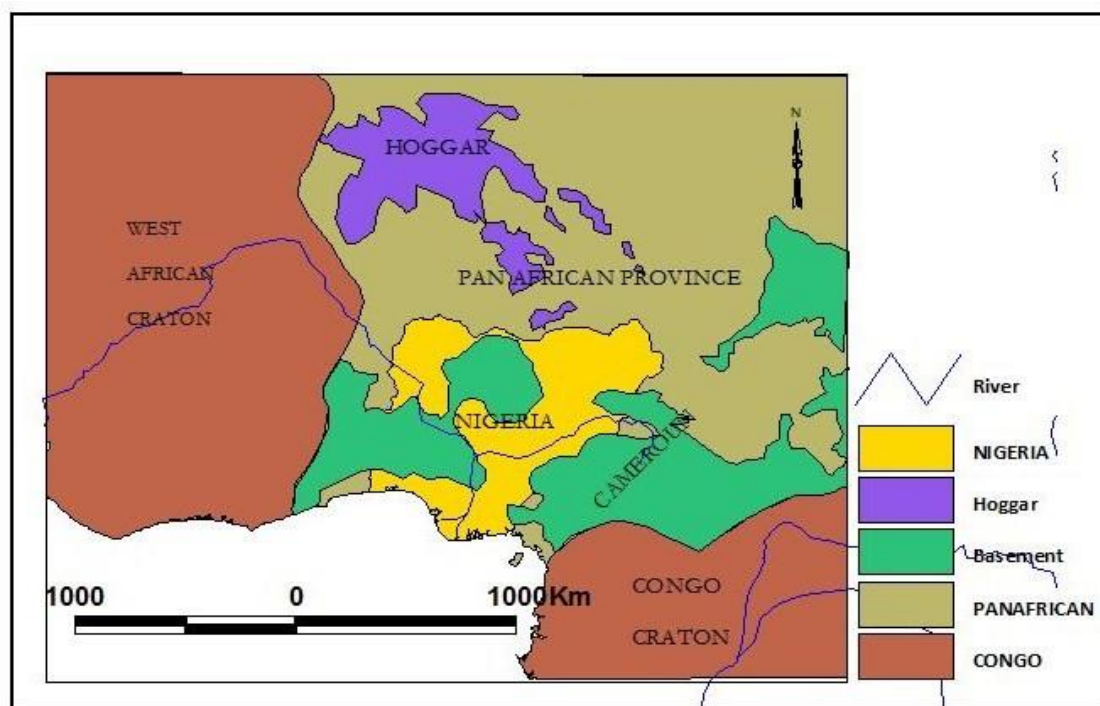


Figure 1.2: Generalized geological map of Pan-African belt east of West-Africa (Turner, 1983).

2. METHODOLOGY

Systematic operations were carried out in order to carefully achieve the aim and objectives of this research work, which entail desk study, literature review, field work, laboratory analyses, interpretation and discussion of the data obtained. The mapping exercise was carried out in two phases. The first phase was basically for reconnaissance survey so as to derive familiarity with the area or terrain. This phase involves only little collection of samples, access roads and routes were identified. The second phase covers detailed mapping and collection of samples where systematic studies were carried out. A total of eight (8) rock samples and twelve (12) stream sediments were collected and analysed (XRF Analytical technique) at Nigerian Geological Research Laboratory (NGRL) Kaduna, for their major and trace elements. Factor analysis uncovers inter-correlations within datasets and allows for mutually correlated associations to be grouped. This method was employed to exposed elements that behave similarly in a geochemical environment and could serve as a pointer to associations in the mineralization (Chork and Salminen *et al.* 1993). Metal Ratio examines the abundance or concentration of metal at each sampling point relative to their background concentrations per metal in a sample (Nishida *et*

al., 1982; Chonet *al.*, 1985; Fakayode and Olu-Owolabi, 2003). Metal ratio less than 1.0 has not attained levels of metal enrichment, elements with metal ratio 1.0 are regarded as areas with optimal enrichment and areas with value greater than 1.0 were locations with enhanced metal concentration.

3. RESULTS AND DISCUSSION

3.1 Geology of the Study Area

The detailed geological mapping carried out revealed five major lithological units underlying the area which are namely: biotite granite, medium grained biotite granite, medium grained biotite gneiss, biotite schist and fine grained migmatite gneiss. The host rocks are unevenly distributed and were intruded by pegmatitic and quartzo-feldspathic veins. The medium grained biotite granite occurs relatively lesser in the area, followed by biotite granite and subsequently the fine grained migmatite gneiss, then the biotite schist and lastly the medium grained biotite gneiss which essentially occurs as the largest unit in the area (Figure 3.1). The rocks are accompanied with multiple structural elements such as foliation, lineation, faults, xenoliths and folds respectively. The field work shows that the structural elements are probably as a result of tensional forces and metamorphic deformations of the rocks.

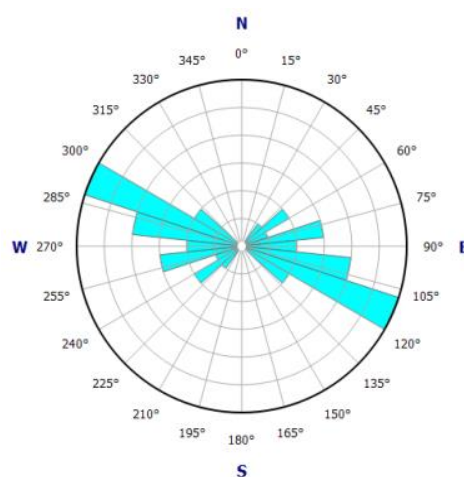


Plate 3.1: Photograph of the field occurrence of biotite granite (N08°37'36.5'' and E09°00'43.6'') and Rose diagram of fractures and veins in biotite granite depicting the dominant trend of WNW-ESE (n=40).

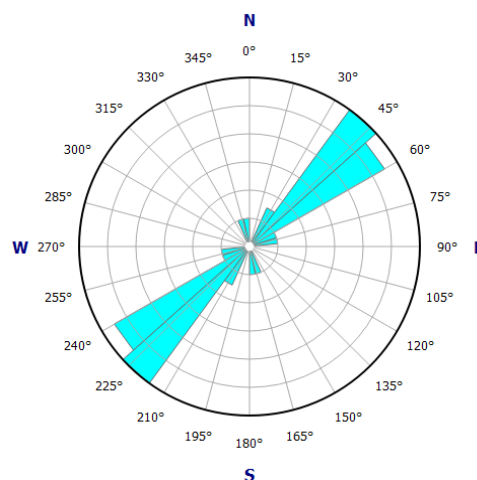


Figure 3.2: Photograph of the field occurrence of medium grained granite ($N08^{\circ}58'57.3''$ and $E08^{\circ}36'8.6''$) and Rose diagram of fractures in medium grained biotite granite displaying the dominant trend of NNE-SSW ($n=45$).

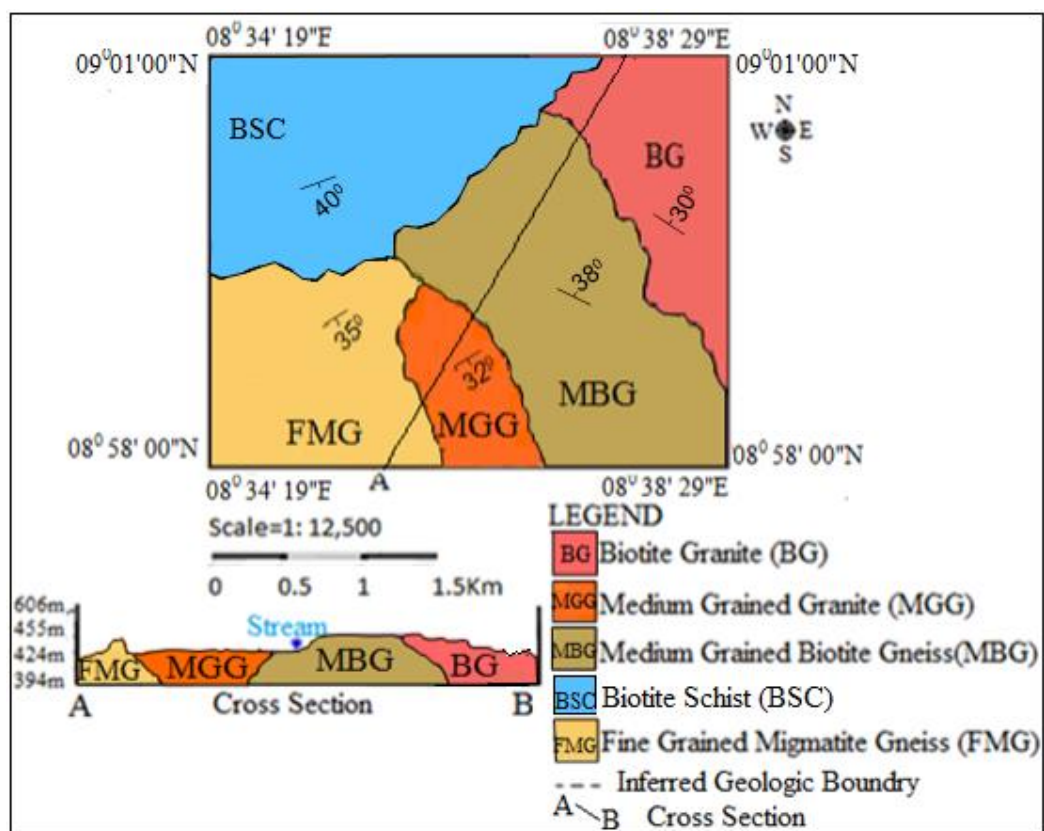


Figure 3.1: Geological map of the study area.

4. GEOCHEMISTRY

Geochemical assessment of rocks and stream sediments were carried out in order to examine the major and trace element variations. This is to uncover the geochemical attributes, relationships and tectonic environment (evolution) as well as the possible gold mineralisation potential.

4.1 Major Elements

Harker Variation Diagrams

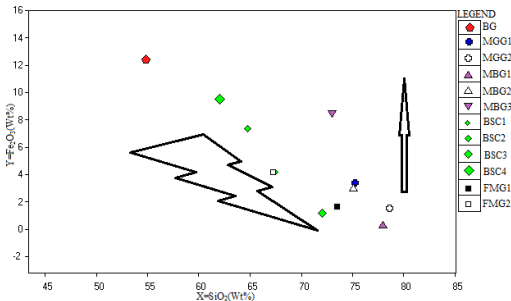


Figure 4.1: Plot of MnOvsSiO₂.

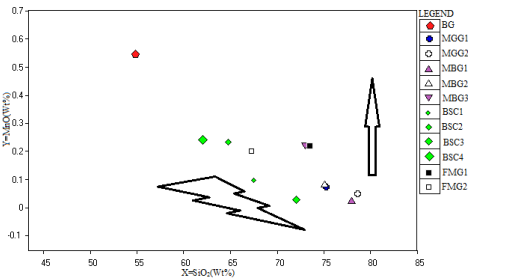


Figure 4.2: Plot of Fe₂O₃vsSiO₂

4.2 Rock Classification and Other Geochemical Components of Rocks in the area

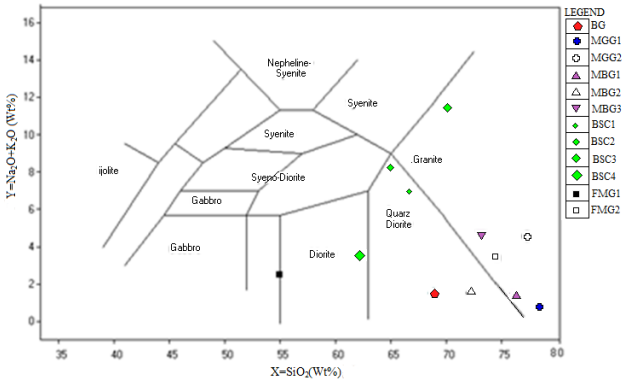


Figure 4.3: The chemical classification and nomenclature of plutonic rocks using the total alkalis versus silica(TAS) diagram, after Cox-Bell-Pank,(1979).

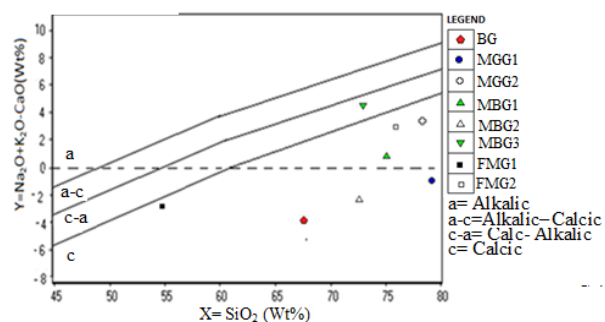
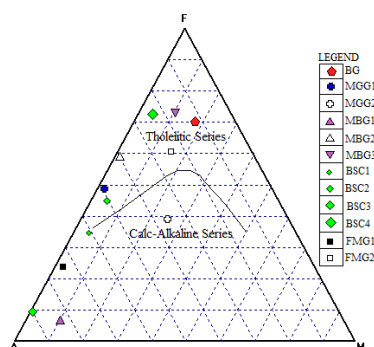
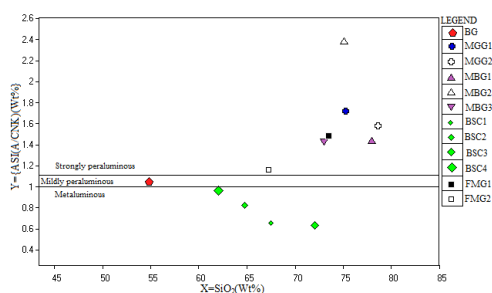
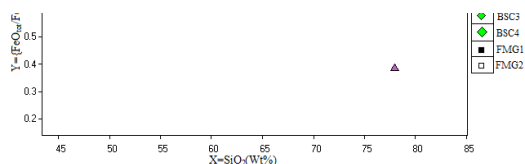
Figure 4.4: Bivariate plot of $\text{Na}_2\text{O} + \text{K}_2\text{O} - \text{CaO}$ vs SiO_2 after Frost *et al.*, (2001).

Figure 4.5: AFM diagram showing a typical tholeiitic and the calc-alkaline trends after Irving and Baragar, (1971)

Figure 4.6: Plot of molecular ratio $\text{Al}_2\text{O}_3 / (\text{Na}_2\text{O} + \text{K}_2\text{O} + \text{CaO})$ vs SiO_2 after Chappel and White, (1974).Figure 4.7: $\text{FeO}_{\text{tot}} / (\text{FeO}_{\text{tot}} + \text{MgO})$ vs $\text{SiO}_2 \text{ (Wt\%)}$ plot after Frost *et al.*, (2001).

4.3 Tectonic Classification and Origin of UngwanRimi Rocks

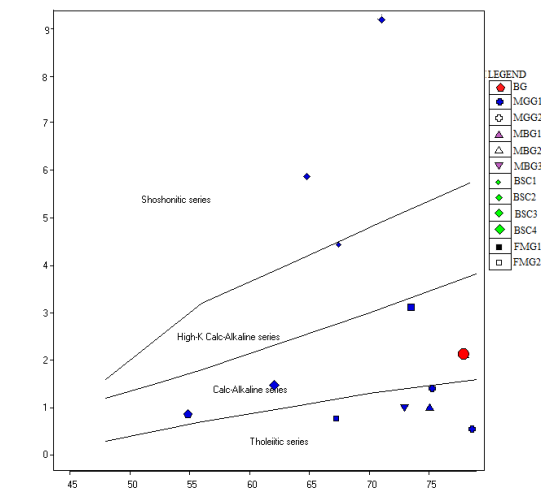


Figure 4.8: Plot of K₂O vs SiO₂ after Rickwood.,(1989).

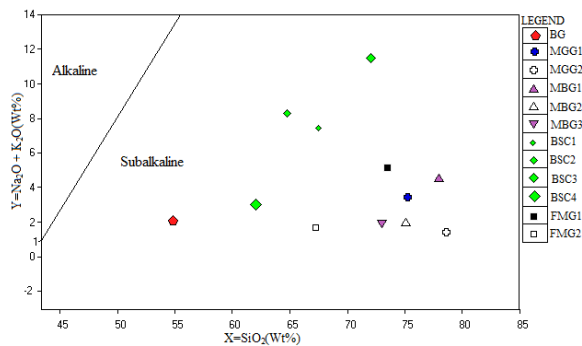


Figure 4.9: Plot of Na₂O + K₂O vs SiO₂ after MacDonald., (1968).

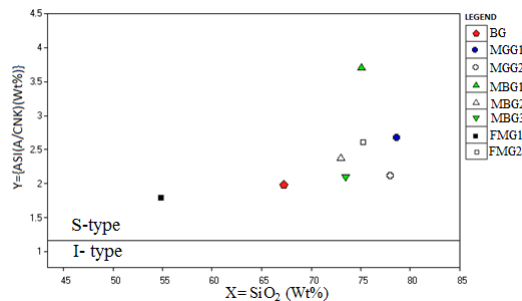


Figure 4.10: Plot of A/CNK vs SiO₂(Wt%) discrimination diagram after Tarney,(1976) illustrating the sedimentary protolith origin of rocks in the study area

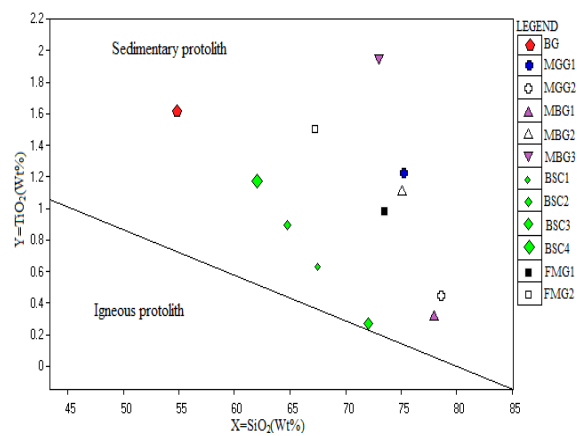


Figure 4.11: Plots of TiO_2 vs SiO_2 after(Chappel and White,1974).

4.4 Trace Elements

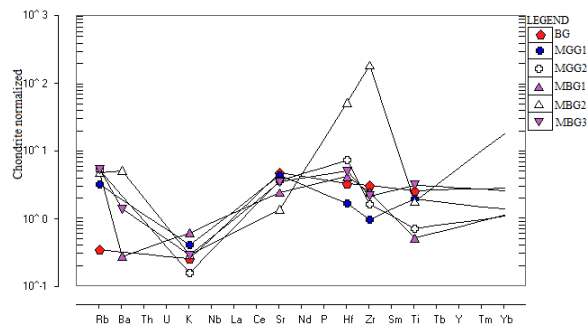


Figure 4.12: the spider plots of granitic rocks in the areaafterTaylor & McLennan (1985)

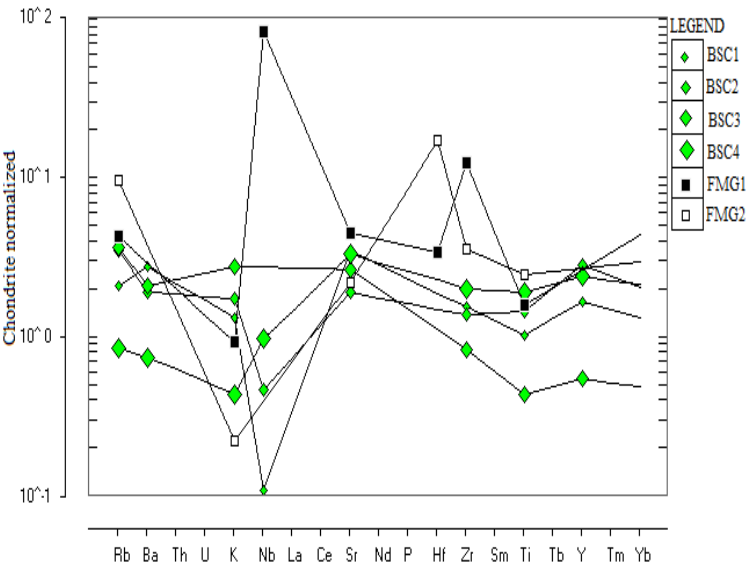


Figure 4.13: Spider Plot of migmatite gneisses normalized to average crustal composition after area after Taylor & McLennan (1985).

5. ELEMENTS ASSOCIATION

Before deciding to use a pathfinder element, the reason for common association of the pathfinder to a range of geochemical environments in which the associations occur is to be examined. The

pathfinder element may be more easily detected than the element being sought and has to be consistent in relationship to mineralisation which are now tied to the gold mineralisation.

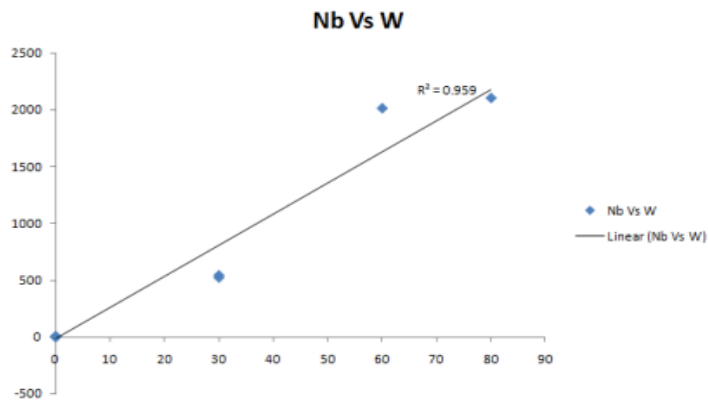


Figure 5.1: The scatter plot displaying the positive correlation existence between, Nbvs W (associates of gold).

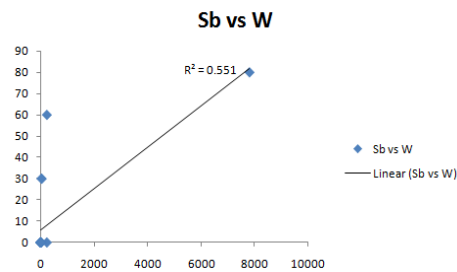


Figure 5.2: The scatter plot describing the positive correlation existence between Sb vs W (associates of gold).

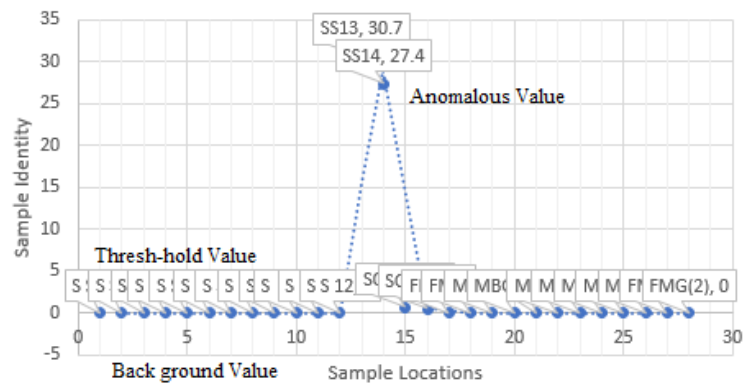


Figure 5.3: Anomalous cocentration of Au in the study area

6. STATISTICAL EVALUATIONS

6.1 Factor Analyses

The factor analysis revealed three major groups of inter-related elements.

These groups are:

- (i) Factor 1: Cl, S, Sc, Co, Ni, Y, Cd, Sn, Au;
- (ii) Factor 2: V, Ta, W, Sb, Nb;
- (iii) Factor 3: Ba, Hf, Th, U

Table 1: R-mode factor analysis of rocks and stream sediments prospect of the area

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
Vanadium	0.430	0.674	0.091	0.324	-0.102	-0.165	-0.343
Chromium	0.417	0.393	-0.164	0.128	-0.052	-0.607	-0.347
Copper	-0.804	0.130	0.325	0.351	-0.136	-0.162	-0.042
Zinc	-0.164	0.442	-0.476	0.476	0.151	-0.076	0.166
Gallium	-0.215	-0.434	0.181	0.443	0.276	0.484	-0.267
Rubidium	-0.154	-0.168	-0.190	0.644	0.239	-0.052	-0.339
Strontium	-0.244	0.200	-0.456	0.288	0.313	0.449	-0.165
Lead	-0.393	-0.373	0.455	0.416	0.094	0.054	0.097
Tantalum	-0.268	0.936	-0.040	-0.087	0.000	0.092	0.080
Wolfram	-0.322	0.897	-0.186	-0.008	0.030	0.030	0.117
Barium	-0.180	0.050	0.789	0.131	0.397	-0.231	0.065
Arsenic	0.117	-0.298	-0.035	-0.313	-0.746	-0.028	0.103
Antimony	-0.209	0.690	-0.480	0.303	0.066	-0.042	0.233
Niobium	-0.268	0.930	-0.131	-0.033	0.043	0.084	0.110
Hafnium	-0.194	-0.012	0.735	0.282	0.150	-0.240	0.019
Zirconium	-0.024	-0.046	0.412	0.468	0.105	-0.076	0.606
Thorium	-0.300	0.497	0.601	-0.409	0.064	0.106	-0.151
Uranium	-0.330	0.449	0.721	-0.317	0.141	0.074	-0.126
Platinum	-0.203	0.532	0.405	-0.460	0.058	0.244	-0.107
Chlorine	0.837	-0.026	-0.065	-0.208	0.446	-0.029	0.037
Sulphur	0.847	0.048	0.027	-0.068	0.303	-0.092	-0.008
Scandium	0.843	0.199	0.200	0.195	-0.200	0.094	-0.040
Cobalt	0.937	0.113	0.105	0.020	0.138	0.050	0.061
Nickel	0.937	0.069	0.047	-0.060	0.206	0.068	0.043
Yttrium	0.964	0.133	0.132	0.063	0.085	0.038	0.029
Silver	0.394	-0.166	-0.213	-0.396	0.682	-0.063	0.140
Cadmium	0.610	0.190	0.255	0.296	-0.293	0.275	0.099
Tin	0.745	0.222	0.275	0.311	-0.314	0.216	0.048
Gold	0.808	0.230	0.247	0.270	-0.283	0.058	-0.056
Eigen Value	8.481	5.306	3.837	2.839	2.205	1.238	1.054
Eigen Value	29.244	18.295	13.23	9.791	7.605	4.27	3.635
Cumulative %	29.244	47.539	60.769	70.56	78.164	82.434	86.07

	V	Cr	Cu	Zn	Ga	Rb	Sr	Pb	Ta	W	Ba	As	Sb	Nb	Hf	Zr	Th	U	Pt	Cl	S	Sc	Co	Ni	Y	Ag	Cd	Sn	Au
V	1																												
Cr	0.643	1																											
Cu	-0.045	-0.171	1																										
Zn	0.0333	0.160	0.149	1																									
Rb	0.062	0.080	0.249	0.291	0.532	1																							
Sr	0.010	-0.068	0.096	0.356	0.302	0.188	1																						
Pb	-0.270	-0.364	0.518	-0.007	0.486	0.194	-0.068	1																					
Ta	0.428	0.168	0.272	0.398	-0.341	-0.142	0.244	-0.290	1																				
As	-0.224	-0.113	-0.175	-0.438	-0.143	-0.293	-0.433	-0.227	-0.236	-0.244	-0.328	1																	
Nb	0.418	0.174	0.251	0.483	-0.318	-0.099	0.311	-0.321	0.985	0.984	0.002	-0.261	0.807	1															
Zr	-0.080	-0.120	0.315	0.074	0.166	0.148	-0.152	0.414	-0.044	-0.055	0.444**	-0.172	0.000	-0.041	0.326	1													
Ag	-0.1680	0.032	-0.628	-0.107	-0.094	-0.073	-0.052	-0.265	-0.197	-0.183	-0.038	-0.242	-0.125	-0.170	-0.198	-0.152	-0.145	-0.153	-0.084	0.693	0.498	-0.041	0.487	0.489	0.376	1			
Sn	0.563	0.276	-0.367	-0.069	-0.113	-0.086	-0.200	-0.133	-0.006	-0.100	-0.036	0.096	-0.068	-0.037	0.049	0.168	-0.079	-0.084	-0.045	0.381*	0.512	0.790	0.721	0.618	0.774	-0.101	0.955	1	
Au	0.644	0.413	-0.422	-0.066	-0.122	-0.102	-0.229	-0.195	-0.037	-0.113	-0.041	0.150	-0.077	-0.053	0.025	0.163	-0.089	-0.095	-0.051	0.466	0.579	0.955	0.780	0.736	0.851	-0.119	0.651	0.846	1

7. DISPERSION PATTERN

The distribution of elements simply reflects the distribution of lithologic units although other deep seated processes may modify the basic relation, weathering, erosion and variety of surficial environmental processes can also modify the pattern of the surfical environment.

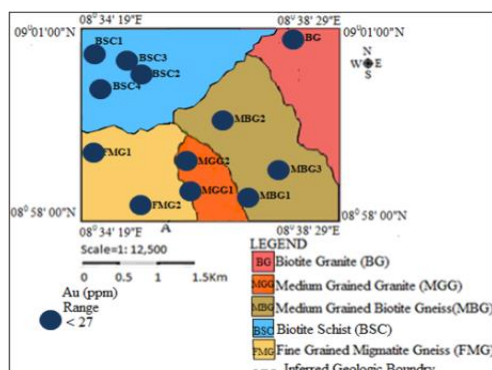


Figure 7.1: Distribution of Au in Rocks

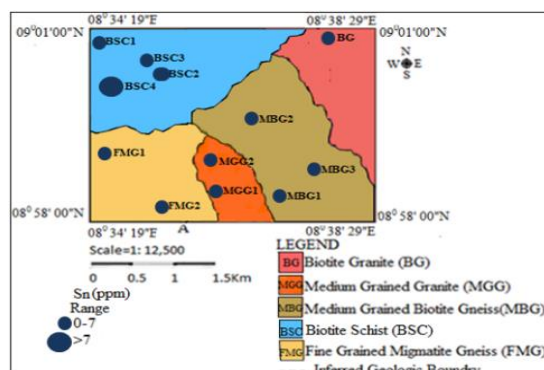


Figure 7.3: Distribution of Nb in Rocks

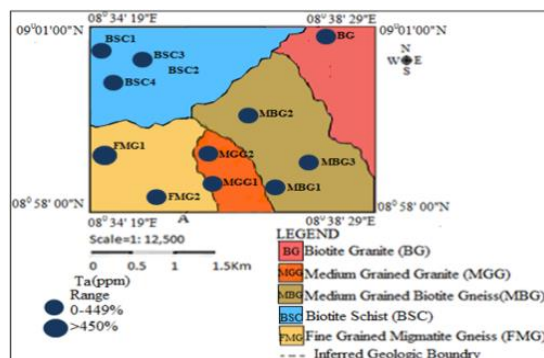


Figure 7.4: Distribution of Ta in Rocks

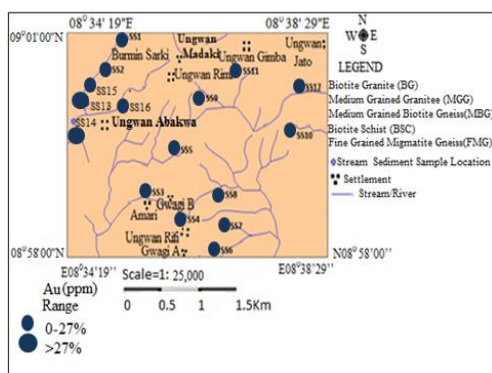


Figure 7.5: Distribution of Au in Stream sediment

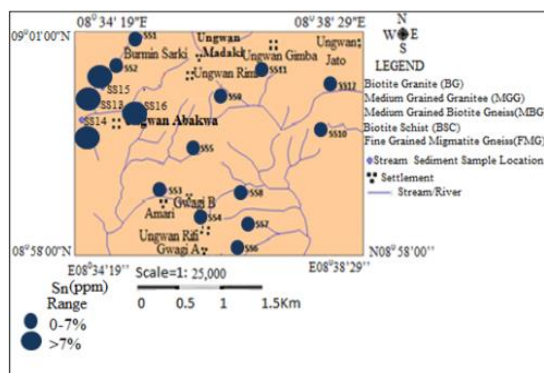


Figure 7.8: Distribution of Sn in Stream sediment

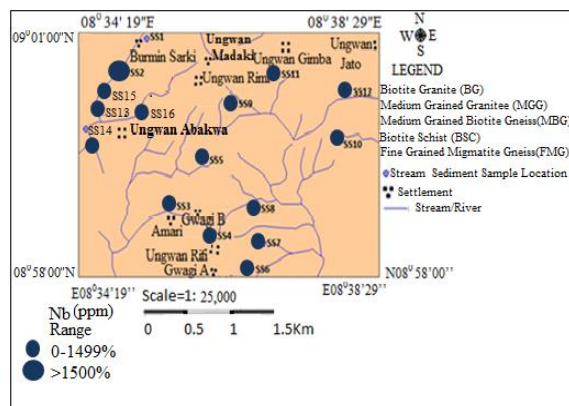


Figure 7.7: Distribution of Nb in Stream sediment

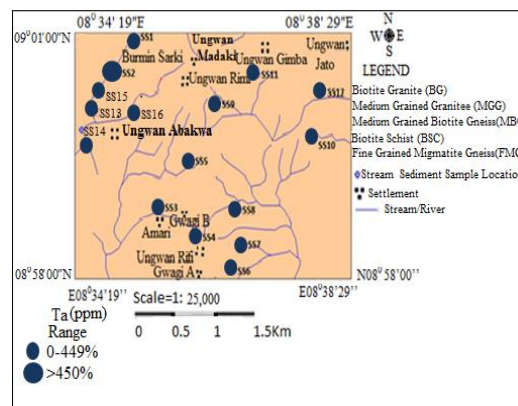


Figure 7.8: Distribution of Ta in Stream sediment

Note: BG-Biotite granite; MGG-Medium grained biotitegranite; MBG-Medium grained biotitegneiss; BSC-Biotiteschist; FMG-Fine grained migmatite gneiss.

7.1 Metal Ratio

Metal Ratio examines the abundance or concentration of metal at each sampling point relative to their background concentrations per metal in a sample (Nishida *et al.*, 1982; Chon *et al.*, 1985; Fakayode and Olu-Owolabi, 2003).

Metal ratio less than 1.0 have not attained levels of metal enrichment, elements with metal ratio 1.0 are regarded as areas with optimal enrichment and areas with value greater than 1.0 were locations with enhanced metal concentration.

$$\text{Metal Ratio (MR)} = \frac{\text{Concentration of metal in sample}}{\text{Background concentration of metal}}$$

7.2 Metal Enrichment Maps

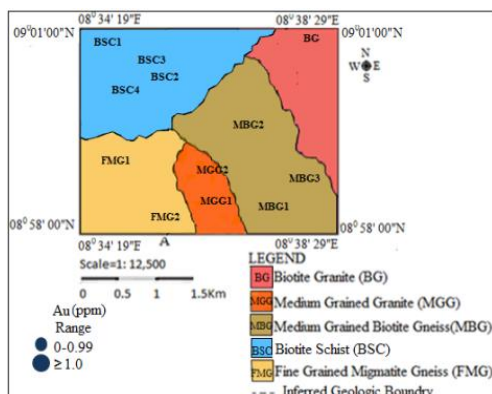


Figure 7.9: The enrichment map of Au in the area describing areas of high concentration value

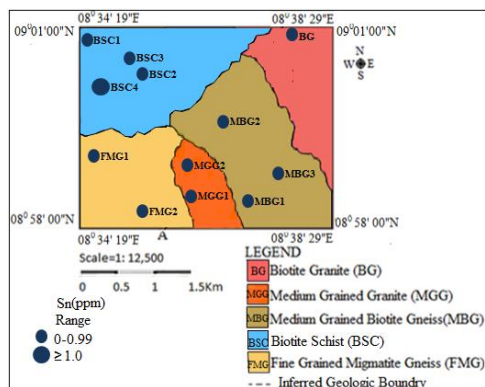


Figure 7.10: The enrichment map of Sn in the area describing areas of high concentration value

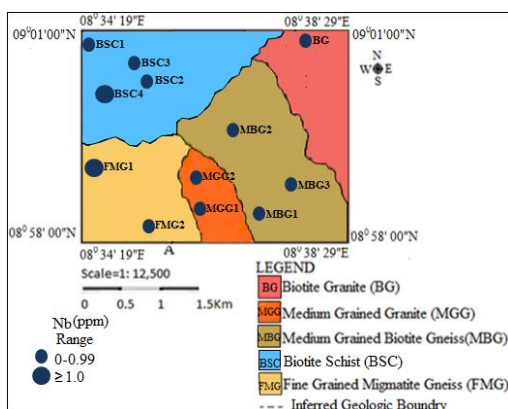


Figure 7.11: The enrichment map of Nb in the area describing areas of high concentration value.

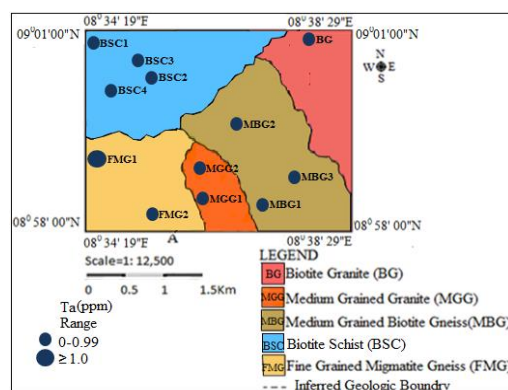


Figure 7.12: The enrichment map of Ta in the area describing areas of high concentration value.

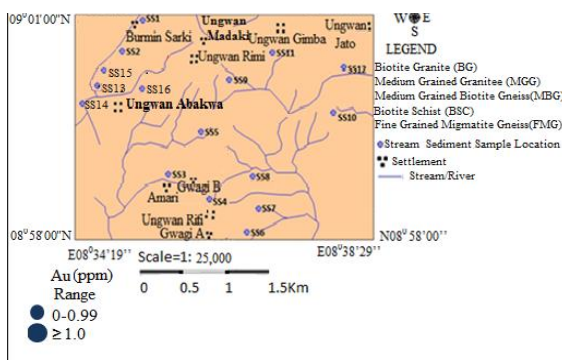


Figure 7.13: The enrichment map of Au in the area confirming areas of high concentration value.

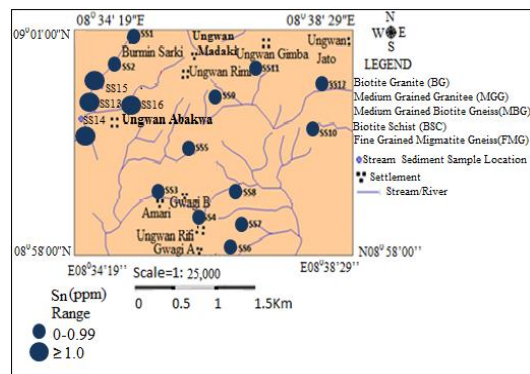


Figure 7.14: The enrichment map of Sn in the area confirming areas of high concentration value.

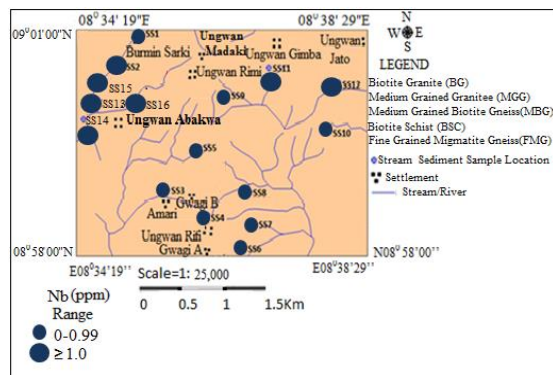


Figure 7.15: The enrichment map of Nb in the area describing areas of high concentration value.

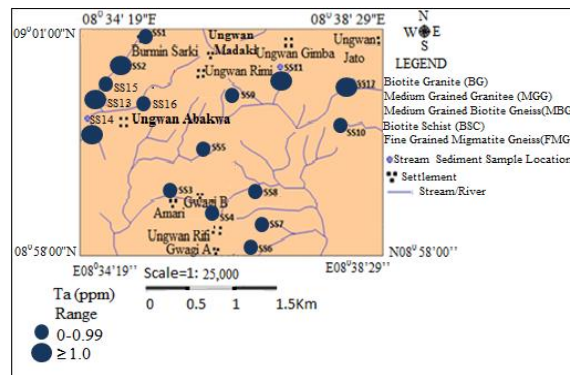


Figure 7.16: The enrichment map of Ta in the area describing areas of high concentration value.

8. DISCUSSION

The plots of TAS diagram ($\text{Na}_2\text{O}+\text{K}_2\text{O}$ vs SiO_2) adapted (after Cox-Bell, 1979) display the rock classification plots, and therefore it classifies the rocks as essentially granites, granodiorite (quartz diorite) and diorite reached. Harker diagrams show insignificant inverse variation in the major elements with respect to silica as index of differentiation (abscissa) except in the case of Na_2O and K_2O . Potassium (K_2O) and sodium (Na_2O) show somewhat opposite behaviour, as the two major oxides increases with increase in SiO_2 trend (linear variation), but when silica value reached to about 73% it begins to show a scatter trend. Thus, the inverse or linear slopes fairly defined the trends and their relationships, which possibly indicate fractionation or hybridization (Hassanen *et al.*, 1996). These suggest that the granitoids in the area may be cogenetic and may likely be sourced from the same magmatic suites. The plot of $\{(\text{FeO}_{\text{tot}}/\text{FeO}_{\text{tot}}+\text{MgO})\text{vs SiO}_2\}$ adapted (after Frost *et al.*, 2001) showed the granitoids to be magnesian, which has a magnesium number ranging from (0.54-1.05%) and that suggests low iron enrichment and the migmatite gneiss to be predominantly ferroans with Fe-number ranging from (1.63-12.44%) and so manifest strong iron enrichment.

The plots of molecular ratio A/CNK vs SiO_2 (after Chappell & White, 1974) depicts the granitoids and migmatites gneiss to be mildly peraluminous

to strongly peraluminous and that shows high enrichment in Al_2O_3 relative to alkaline lime ($\text{Al}_2\text{O}_3 > \text{Na}_2\text{O}+\text{K}_2\text{O}+\text{CaO}$).

The plot of Na_2O vs K_2O in adapted (after Macdonald, 1968) shows all the rocks in the area as subalkaline.

The plot of K_2O vs SiO_2 after (Rickwood, 1989) shows the granitoids as medium-low-K-calc alkaline series (M-LKCA) to tholeiitic series (low K-calc alkaline series). Plot of A/CNK vs SiO_2 modified after (Tarney, 1976) depicting the granitoids and the migmatites gneiss as essentially S-type because of the absence of normative diopside in all the rocks in the area and it supports the notion that the normative corundum is greater than 1% in all the rocks which according to Chappel and White (1974) is a confirmation that they are probably S-type indicating sedimentary protolith. The Plots of TiO_2 vs SiO_2 modified (after Chappel and White, 1974) also confirmed sedimentary protoliths.

The correlation co-efficient and factor analyses were also employed in order to support the inter-relationship of these pathfinder elements. The factor analysis display three major factors which are namely: Factor 1: Ta, Nb, W, Th, U, Pt, V, Sb (mostly pathfinders of gold); Factor 2: U, Ba, Hf, Pb, Cu, Zr; and Factor 3: Rb, Zn, Sr, Sb. Table 2 displays the correlation co-efficient between other associated elements in the area. The

positive correlation reveals the inter-elemental relationship and possibly behaves similarly.

Metal Ratio entails the concentration of metal in sample divided by the background concentration of metal. This is employed so as to measure the areas with good prospect for base metals (including gold) in the area.

The metal ratios obtained for both the rock and stream sediments in the area SS13, SS14, indicate high promise for gold in the area while FMG1, SS2, SS11 and SS12 of the prospect area indicate exceptionally high enrichment values of pathfinders to gold. Furthermore, enrichment map derived from the metal ratio values show the areas of better promise for gold and its associates (pathfinders).

9. CONCLUSION

UngwanRimi and environs is essentially underlain by four different sets of lithologic units. The plutonic bodies are generally granite and granodiorite to diorite. Geochemically, the rocks are generally peraluminous, subalkaline, calc-alkaline to tholeiitic. The granitoids as intrusions into the pre-existing migmatite gneisses are magnesian, while the migmatite gneisses are generally ferroans in composition. Hence, the rocks are S-type which strongly suggest that, they are probably derived from sedimentary protoliths.

The geochemical distribution pattern revealed relative concentration of the pathfinder elements of gold in the area.

The correlation coefficient and factor analysis supported the possible association between the pathfinder elements of gold in the area. Furthermore, the enrichment map derived from the metal ratio values for both the rocks (possible primary source) and stream sediments (secondary) the study area to be potential for gold mineralization.

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