Global Scientific JOURNALS

GSJ: Volume 8, Issue 7, July 2020, Online: ISSN 2320-9186
www.globalscientificjournal.com

Petrology of the Igarra Metaconglomerate: Implications for tectonic history, provenance and source materials.

I.O. Ajigo

Department of Applied Geology, Federal University of Technology P.M.B. 704, Akure, Ondo State, Nigeria. e-mail: ioajigo@futa.edu.ng

Abstract: Petrographical and geochemical characteristics of the Igarra metaconglomerate have been examined to reveal their tectonic history, provenance and source materials.Field and laboratory petrographic studies revealed that mineral association in both matrix and clast of metaconglomerate are characteristic of low to medium grade of metamorphism.Fifteen (15)samples each of matrix and clast of Metaconglomerate were selected for geochemical analysis. This involved the use of ICP-MS and ICP-AES to analyze from solution, using a modified aqua regia (1:1:1 HNO_3:HCl:H_2O), a partial digestion that provided valuableinformation regarding mobile and easily soluble species, such as sulphides and checking resultsby internal and external standards.Metaconglomerate have clasts of different sizes ranging from pebbles, cobbles and boulders which are polyminctic in character. Most of the pebbles are quartzitic and granitic composition but pebbles and boulders of calc-silicate gneiss and carbonate compositions were also observed.Most of the pebbles are quartzitic and granitic composition but pebbles and boulders of calc-silicate gneiss and carbonate compositions were also observed. The deformed conglomerates are typically matrix-supported (with approximately 60 to 80 % matrix by volume)

Qualitatively, the grain size of the clasts is in the order quartz > granite>carbonate. Quantitatively, strain varies throughout the region and between clast types, with the strongly strained clasts usually in spatial proximity to ductile shear zones. Majority of the samples plots in the L = Stectonite field with the percentage range of 50% and 70%.In their discriminating binary diagram using the DF1 vs DF2 functions, the analyzed samples from both matrix and clast of the Igarra metaconglomerate fall into the field of quartzose sedimentary provenance.Samples of matrix of the metaconglomerate plot in the arkose field while those of the clast plot between arkose and greywacke. This spread of the clast is attributed to the heterogeneous nature of their source material which indicate difference in composition.In the plot for tectonic setting, clast favor the field corresponding to passive continental margin settings while the matrix is plotted in the Island Arc environment of continental nature.Based on the geochemistry of the samples from the metaconglomerate of the Igarra schist belt, aderivation of the detrital material from intermediaterocks on the upper continental crust with occasional tilt towards either felsic or mafic affinity is postulated.

Key words: Metacohglomerate, Provenance, Tectonic setting, Igarra, Clast, Matrix.

1. Introduction

Igarra is the largest occurrence of Metaconglomerate in Nigeria. Other conglomerates of Precambrian origin referred to as littoral have been described near Anka in Sokoto province, near Yelwa on the river Niger E-N-E of Osi River in Ilorin province and along Zungeru –Minna road in Niger state. Inspite of the fairly wide zonal distribution between Igarra Metaconglomerate, Durumi pebbly member and Zamfara valley, they show considerable similarity in the composition and nature of their matrices, size and shape of clasts as well as their relationship and association with other rock types (Turner, 1983).The Igarra schist belt being one of the many schist belts in Nigeria and is arguably the most extensively researcheddue to its proximity to Igarra, a focal point in geological research in Nigeria. The most easterly schist belts in south-western Nigeria it is located around the Okene migmatitic nucleus. It trends NNW-SSE with a length of roughly 50km;it is joined to the west by the Owo belt and to the east by the Okene-Lokoja belt which may have extended into the Muro Hills in the north. The presence of both calcareous rocks and conglomerates is peculiar to the Igarra belt which sets it apart from the other schist belts in Nigeria. Theserock types, together with quartzites, occur as bands in the dominant biotite schist.

Metaconglomerate are restricted in occurrence to area around Igarra and Otuo where they occur generally as low-lying bodies. The rock unit consists of clast of varying sizes, some clasts measure up to 267cm long while others are few centimeters in length. The diversity of sizes in the clast may be attributed to the prevalence of high energy in the medium that deposited the originalclasticsedimentary particles. The clasts are made of different lithologies including quartzite, calc silicate and granite. In this contribution, provision is made both of the geological structural and geochemical characterization of the meta-conglomerate of the Igarra area, with a view to establishing tectonic history, provence and source materials.

2. Regional Geological setting

The Igarra Schist belt is an integral part of the Nigerian Basement Complex. Geochronological and field evidences have confirmed the polycyclic nature of the Nigerian basement rocks, while the Pan-African event is the last orogeny to have affected them (Rahaman, 1988; Dada et al., 1993; Dada, 2006). The evolution of the Nigerian basement during the Late Proterozoic is considered to be related to the processes taking place in the plate boundary context (Caby, 1989). A plate tectonic model of an ensimatic domain has been suggested for the evolution of some of the Schist Belts (e.g. Rahaman,1988). Caby and Boesse (2001) reported the intrusion of these Basement rocks by the Pan-African granitoids.

Thebasement terrane is situated between West African craton to thewest, Congo craton to the southeast and East Saharan block (Fig. 1),and is part of a 4000 km long and several hundreds of kilometerswide orogen extending from the Hoggar to Brazil (Caby, 1989). Theentire north-south trending block boundary is collectively calledthe Trans Saharan fold belt. This fold belt was formed in the Neoproterozoic,between 750 and 500 Ma by continental collision betweenthe converging West African craton, Congo craton and EastSaharan block (Ferre et al., 2002; Dada, 2006). The Trans-Saharanbelt is characterized by high-grade metamorphism, early thrustnappedevelopment, numerous granite intrusions and lateorogen-parallel tectonics (e.g. Black and Liegeois, 1993).

The southern part of the Trans-Saharan belt is the Dahomeyide which stretches from theeastern margin of the West African craton to the border of the Congo craton. It is made up of several continentalblocks amalgamated during oblique collision (Ajibade and Wright,1989) similar to that of the Aïr-Hoggar in the north (Liegeois et al., 1994).

TheNigeria sector of the Dahomeyide comprises of a wider western andnarrower eastern domains on the basis of some petrological attributes (Ferreet al., 1996).Basement complex rocks in the western domain includegneisses, migmatites, supracrustal rocks largely of greenschist toamphibolite facies, Pan African granites and undeformed dykes(Rahaman, 1988). Gneisses, Migmatites and supracrustal rockshave yielded Archaeanand Proterozoic ages (e.g. Bruguier et al., 1994; Annor, 1995;Okonkwo and Ganev, 2012) and bears the imprints of Liberian (ca2700 Ma), Eburnean (ca 2000 Ma) and Pan African (ca 600 Ma)orogenic events (Grant, 1970; Oversby, 1975; Van Breemen et al.,1977; Fitches et al., 1985; Rahaman, 1988; Dada, 1998). Both thePan African granites and undeformed dykes have yielded upperProterozoic ages (Tubosun et al.,1984; Dada et al.,1993; Dada, 1998;Ige and Holness, 2002).
The bed of meta-conglomerate mapped in the in the Igarra Formation is located within the central part of the area in a triangular axis of Igarra-Okpe-Otuo. The geologicalfeatures described below refer to this centralmeta-conglomerate, which contains clast of different sizes, shapes and composition.The meta-conglomerate is only affected by D1 ductile deformation structures and M1 greenschist facies (chlorite zone) regional metamorphism, whereas D2-D3 tectono-metamorphic events have not been documented.

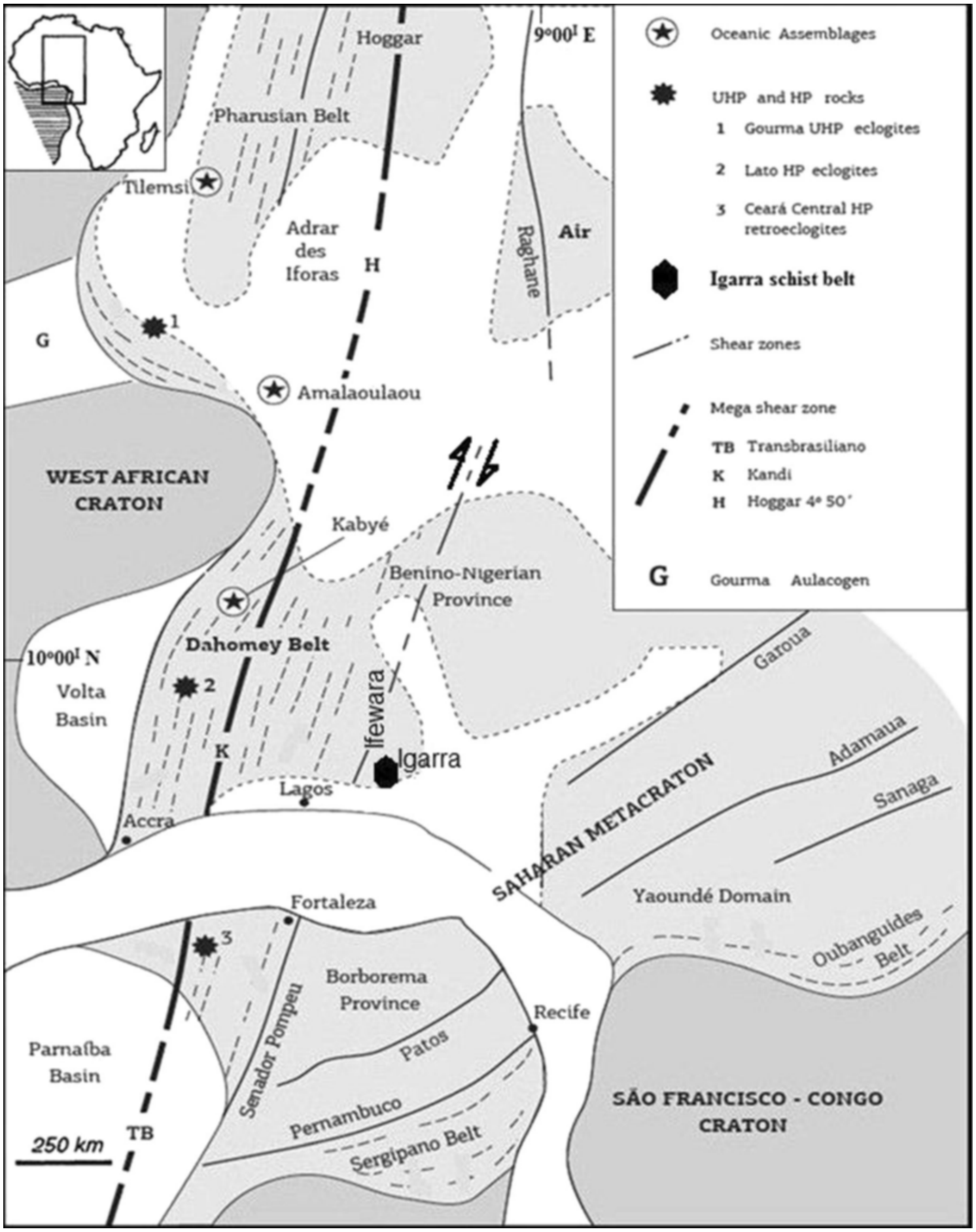

Figure 1. Regional fit between the northern Borborema Province (NE Brazil) and southern Nigerian shield (Africa) highlighting the main vertical shear zones and the location of Igarra schist belt with respect to other regional features,(after Udinmwen & Oden, 2016).

3. Materials and Methods

Detailed field mapping of the study area, using base maps, satellite images was carried out resulting in the collection of over fifty rock samples of both matrix and clast. Field observations were made on each outcrop including megascopic identification of minerals present in the rock outcrops, texture, degree and pattern of weathering, color of fresh rock surface, and measurement of strike and dip values.The area was traversed and mapped across strike such that samples of representativemetaconglomerate were taken along profiles and within the study area. Therefore sampleswere labeled using different codes according to whether they are matrix or clast.

Samples were taken insitu using the sledge hammer targeting fresh surfaces and portions of the samples with good proportions of matrix and clast held intact.Clasts were chiseled out of the matrix and both the clasts and matrix from each location are well labeled with C denoting clasts and M denoting matrixes.Microscopic petrographic studies were carried out in the Petrology Laboratory of the Department of Applied Geology, Federal University of Technology, Akure, Nigeria. Photomicrographs were generated withthe aid of digital camera and the modal content of the rocks analysed bystudying the photomicrographs with *ImageJ*.

Fifteen (15) different samples each of matrix and clast of Metaconglomerate were selected for geochemical analysis. This involved the use of ICP-MS and ICP-AES to analyze from solution, using a modified aqua regia (1:1:1 HNO_3:HCl:H_2O), a partial digestion that provided valuableinformation regarding mobile and easily soluble species, such as sulphides and checking resultsby internal and external standards. Depending on grain size about 1 to 5 kg per sample were crushed and an aliquot was ground to <200 mesh prior to this. The sample is introduced into the plasma by nebulizing a solution containing the sample and by transporting the resulting aerosol to the plasma in the sample injector gas. The injector gas punctures the center of the bottom of the plasma, and the sample travels through the plasma, which dissolves, melts, vaporizes, atomizes, ionizes, and, finally, excites the outer-shell electrons of the free atoms and ions of elements in the sample. The relaxation of an excited electron is accompanied with the emission of a photon of light. The energy of this photon is characteristic of the atomic energy level transition and, thus, is characteristic of the element.

Structural data were collected across ten different sites where two- and three-dimensional exposures of Metaconglomerate were available within the Igarra schist belt. This involves careful search for locations in which the clasts are not tightly buried or cemented to the matrix; such areas are usually along roadcuts, quarries or sink holes where water action has significantlyweakened the matrix strength thereby exposing the clast due to differential weathering. Usually, the orientationof the long axes of the clasts was first measuredbefore carefully pulling the clast out of the matrix to measurethe lengths of the three mutually perpendicular axes(X, Y and Z where $X \geq Y \geq Z$). In cases where the planecontaining the long axis of the clast was not exposed, the clast is carefully detached from the matrix before measuring itslength and orientation within plausible errors. Measurementof 50-60grains of clast in three-dimension from the ten sites was achieved in the course of this studyand Flinn diagram wasused for three-dimensional strain analysis.From three-dimensional data, over 80 % of the totalclast population has their X/Z plane parallel to minerallineation; thus, measurement was made of two-dimensional dataparallel to mineral lineation (X/Z plane) as this planerecords maximum strain.

4. Results and Discussion

4.1. Petrography

From a sedimentary point of view, the metaconglomerateis classified as a polymict paraconglomerate. Most of its clasts are flattened due to deformation, consisting mainly of sub-rounded to rounded, mediumsphericity and poorly sorted pebbles and cobbles of granitoids, calc-silicate, quartz, meta-pelites and minor boulders. Metaconglomerate have clasts of different sizes ranging from pebbles, cobbles and boulders which are polyminctic in character (Fig. 2). Most of the pebbles are quartzitic and granitic composition but pebbles and boulders of calc-silicate gneiss and carbonate compositions were also observed. The dominant pebbles are granitic while calc-silicate pebbles are common only at the contact with the latter. Pegmatitic pebbles are few, containing crystals of quartz and feldspar. Under the microscope, the calc-silicate pebbles are texturally and mineralogically identical to the calc-gneiss. Granitic pebbles are made up of quartz, microcline and biotite. Some of the granitic pebbles show cataclastic texture due to tectonic deformation. There is a marked variation in clast sizes and shapes. Pebbles sizes vary from 0.5cm x1cm – 80cm x 80cm. The shapes are ovoid, elongate, elliptical and sub-angular. Ovoid and elongate shapes are the most dominant. A mutually parallel elongation of clast is common and this seems to be due to tectonic stretching and flattening. Elongation has resulted in instances in which the proportion of length to width of the clast is large. Most granitic, quartzose and quartzitic pebbles are ovoid to elliptical while calc-silicate marble and amphibolite pebbles are generally elongate. This relationship between composition and shape is due to the differential resistance of the clasts to deformation. Majority of the pebbles lie conformably within their schistose matrix, with long axes parallel to the general foliation.

Matrix is generally greenish-grey, fine-grained and lack strong foliation. Essentially, matrix is of quartz-biotite schist or calc-silicate composition. Common minerals in calc-silicate matrix include sericite, hornblende, diopside and tremolite. Quartz grains observed show varieties of colours from colourless to gray colour indicating their pleochroic nature, they show low relief and sub-hedral shape. Chlorite grains have pale blue colour and exhibits pleochroism which ranges between colourless to pale blue (Fig. 3). They have sub-hedral shape with low to moderate relief and a perfect cleavage. Biotite has anhedral to sub-hedral shape; it is of moderate relief, pleochroic from golden yellow to brown colour. Epidote is anhedral to sub-hedral in shape, stronglypleochroic between dark grey and brown while hornblende of moderate relief. Schistose matrix show typical lepidoblastic texture and the mineralogy features biotite, quartz, epidote and muscovite prominently with preferred orientation which tend to flow around the clast more easily.

Diopside, tremolite and biotite are poikiloblastic towards other minerals mainly quartz. Actnolite occur as fibrous crystals, the long axis of which may align and define foliation. At microscopic scale, cleavage planes are markedby sericite + chlorite + quartz alignment. This assemblagewith lepidoblastic texture is typical of greenschist facies (chlorite zone) metamorphism. The intracrystallinedeformation of minerals inside clasts is distinguished bydeformation lamellae, undulose extinction and sub-grainsin quartz, and kinked or tapered albite twins towards thegrain boundary and also undulose extinction in feldspars. In some cases clast appear as recrystallized segregations of calc-silicate material.

GSJ: Volume 8, Issue 7, July 2020
ISSN 2320-9186

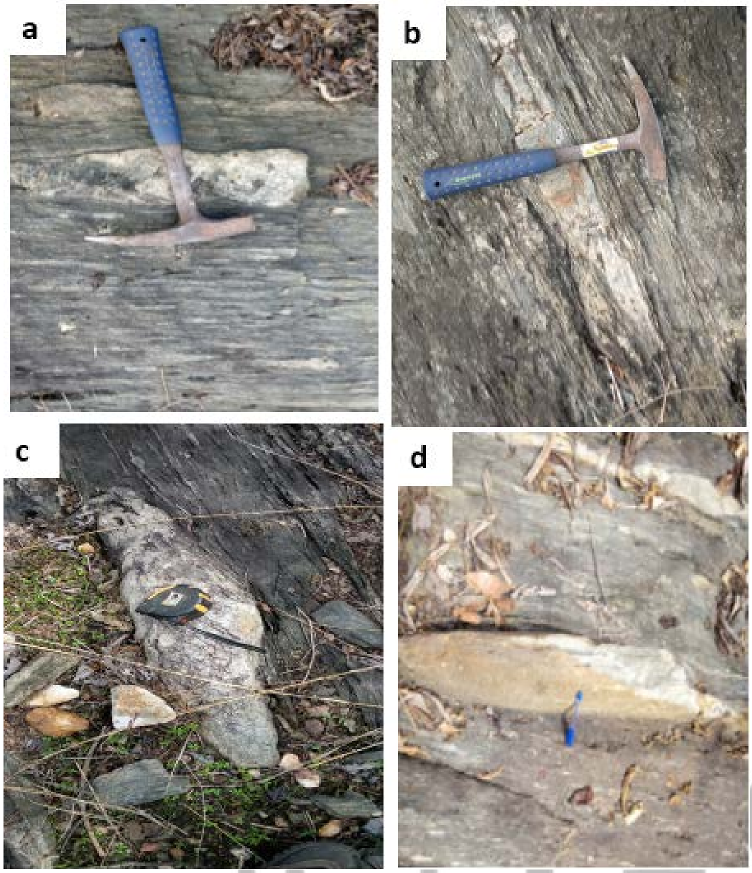

Figure 2: Variety of clasts in the Igarra metaconglomerate:(a)Variably strained clasts differential resistance of the clasts to deformationin location 2;(b)Strongly strained quartzitic clast in location3;(c)Weakly strained calc-silicate clasts in location 7;(d)Moderately strained granitic clast in location 10.

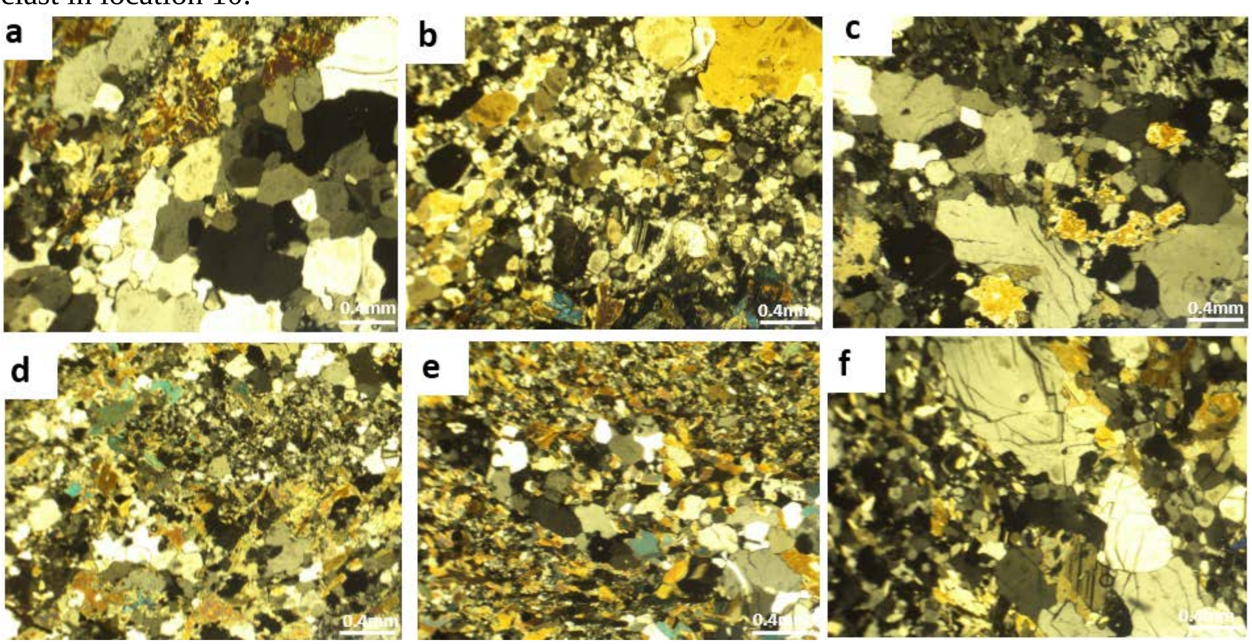

Figure 3: Photomicrograph representing different view from thin sections of: (a), (b) & (c) clast;(d), (e) & (f) matrix of metaconglomerate

4.2.Structure

The Pan-African mobile belt is associated with compression atits boundary with theWest African Craton and shearing at theSaharanMetacraton boundary (Ferré et al. 1995). Ocan (2016) noted that at least four episodes of ductile deformation(D_1–D_4) and late semi-brittle shear zones and faults(D_5) accompanied by four episodes of regional metamorphismand a late contact metamorphism around large intrusions affectedthe Igarra region. The major structures in the Igarra schist belt that have been identified by different authors include foliations, mineral lineations, folds and shearzones which are believed to originate from multiple episodesof deformation (Odeyemi 1976; Rahaman 1989;Annor 1998; Egbuniwe and Ocan 2009; Oden andUdinmwen 2014a, b; Ocan 2016; Udinmwen 2016).

The deformed conglomerates are typically matrix-supported (with approximately 60 to 80 % matrix by volume), and polyminctic containing pebble to boulder-sized clasts of quartz, carbonate and granitic composition. Some of the largest boulders are of flaggy quartzite composition. Qualitatively, the grain size of the clasts is in the order quartz > granite>carbonate. Quantitatively, strain varies throughout the region and between clast types (Fig.) with the strongly strained clasts usually in spatial proximity to ductile shear zones. This investigation cut across the strain of these clast types.

The orientations of measured clast axes are generallyconsistent at individual sites regardless of the clasttype. The majority of the long axis of clast populations indifferent locations trend approximately within the angular range of 300^0 to 350° or 140 to 160° with low angle plunges. The maximum stress axes(minimum stretching direction) for all the sites arein a NNE–SSWdirection.A total roughly50-60 data points from each from ten locations was used to analysestrain and the type of tectonite produced by thedeformation. The Flinn diagram(Fig. 4), shows that themetaconglomerate clasts has variable strain magnitude. This confirms that the clasts are derived from different sources and hence their different response to stress.

Majority of the clasts evaluated exhibited both flattening and constrictive strain. Majority of the samples plots in the L = Stectonite field with the percentage range of 50% and 70%. Locations 6, 7 and 10 have the highest percentage in the L = Stectonite field. Locations 1, 2, 8 and 9 are next in the L = S tectonite field with 60% each. Locations 5, 3 and 4 are least in this regard with 55%, 50% and 15% plotting in the L = S tectonite field respectively (Table 1). The tectonic field SL is the next dominant and then followed by LS tectonite field. Tectonic fields L and S are the least plotted in the data with majority of them plotting zero percent.

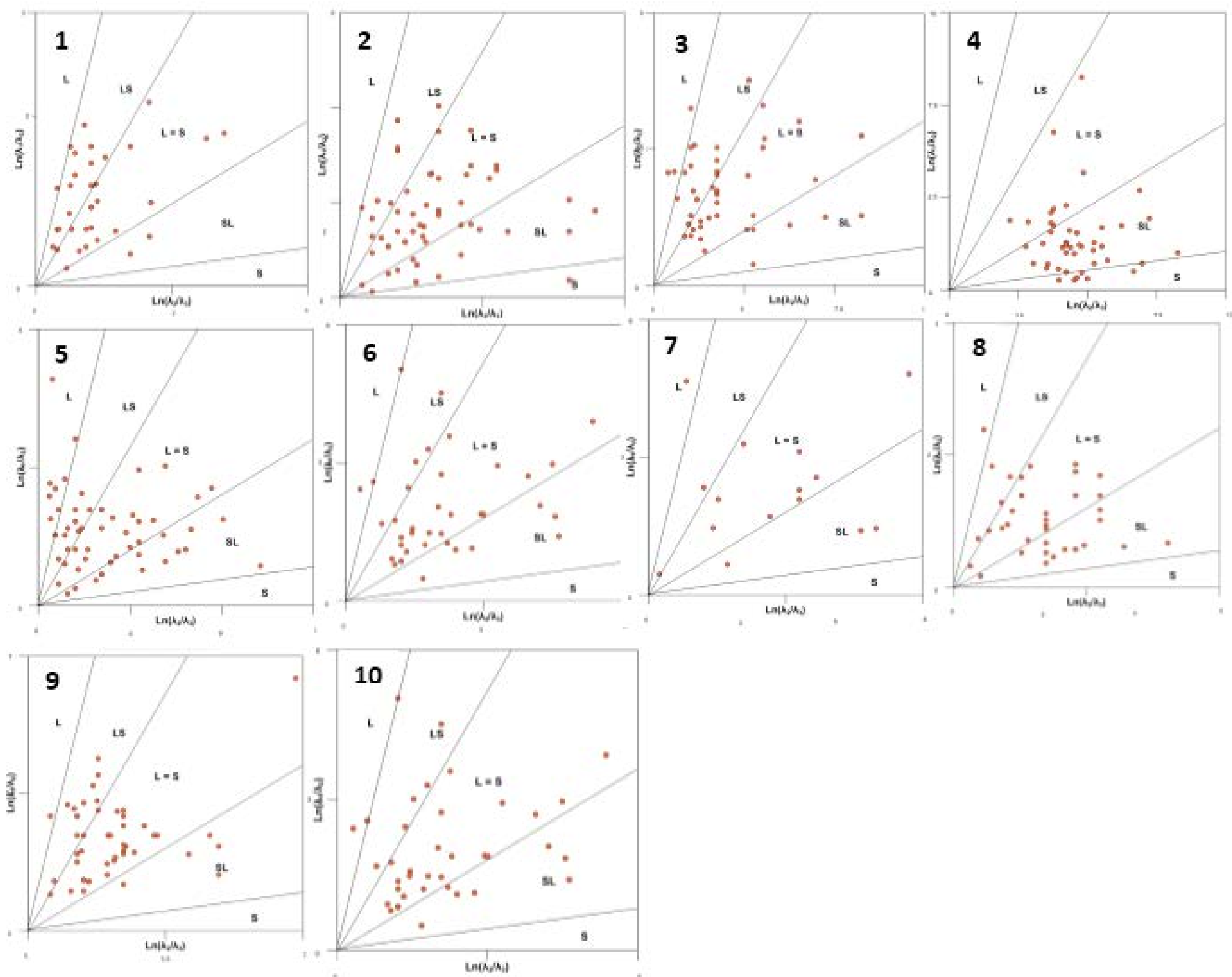

Figure 4:Flinn diagram for measured clasts dimensions from location 1 to 10 of the studyarea.

Table 1: Summary of tectonic classification of the study area.

Location	Tectonic Classification (%)				
	L	LS	L=S	SL	S
1	-	35	60	5	-
2	-	15	60	25	-
3	5	30	50	15	-
4	-	-	15	75	5
5	10	15	55	20	-
6	-	10	70	20	-
7	-	-	70	30	-
8	-	10	60	30	-
9	-	30	60	10	-
10	-	10	70	20	-

4.3.Geochemistry

Geochemical composition of major elements from clast of metaconglomerate show Calcium and Iron as the most abundant with 1.81% and 1.46% average composition respectively. Phosphorus and Sodium are least with average composition of 0.024% and 0.02% respectively (Table 2). For the trace elements, Manganese has the highest average composition of 207.7ppm. It is followed by Chromium with average composition of 26.5% while phosphorus is the least with average composition of 0.026ppm. Comparatively, Al, K, P, Mg, Ba, Cr and Ca show higher values in samples of the matrix of metaconglomerate than in their clast counterparts. The reverse is however the reverse is the case for Ca, Cu and Mn. Sr, Fe and Zn are completely below detection limits of 0.5ppm, 2% and 3ppm respectively.

Table 2: Concentration selected elements of Metaconglomerate from the study area.

S/N	Cr	Mn	Ni	Ti	V	Sr	Pb	P	Ba	La	Al	K	Na	Mg	Fe	Zn	Cu	Ca
CB1	20	250	9	0.027	5	11	7	0.019	33	17	0.95	0.26	0.02	1.03	1.84	17	21	1.15
CB2	12	288	6	0.032	4	11	10	0.024	25	29	0.7	0.18	0.02	0.64	1.46	13	76	1.42
CB3	16	118	8	0.005	<1	13	8	0.008	4	<1	0.11	0.02	0.01	0.02	1.36	10	34	0.56
CB4	13	253	5	0.027	3	16	7	0.025	33	9	0.41	0.16	0.03	0.23	0.78	10	20	1.67
CB5	34	353	10	0.033	5	27	33	0.018	13	10	0.62	0.24	0.03	0.57	1.61	44	33	2.07
CB6	12	303	7	0.02	3	17	6	0.032	6	7	1.02	0.26	0.08	0.73	1.5	16	13	1.95
CB7	17	355	9	0.032	6	37	6	0.044	29	12	0.76	0.05	0.04	0.24	1.03	20	9	0.75
CB8	158	230	40	0.033	10	5	143	0.015	16	10	0.32	0.21	<0.01	0.33	1.93	162	77	0.86
CB9	9	218	6	0.04	11	10	14	0.014	34	5	0.93	0.54	0.02	0.75	1.38	20	36	0.93
CB10	16	314	7	0.054	9	20	10	0.059	28	55	0.69	0.4	0.03	0.57	1.18	14	34	2.27
CB11	13	130	7	0.013	1	23	6	0.018	4	<1	0.46	0.04	0.04	0.04	1.04	5	40	1.53
CB12	25	301	9	0.029	2	13	52	0.016	14	13	0.53	0.23	0.03	0.52	1.54	209	32	1.57
CB13	13	270	8	0.03	4	13	8	0.019	6	7	0.92	0.29	0.04	0.74	1.49	15	12	1.61
CB14	30	345	14	0.049	16	11	<3	0.048	72	18	0.7	0.21	0.02	0.43	1.71	30	12	0.27
CB15	9	332	4	0.021	3	18	5	0.026	14	17	0.63	0.12	0.03	0.57	1.07	9	19	2.24
MB1	50	7	9	0.213	0.71	<0.5	52	27	165	7	1.19	0.98	0.01	0.77	<2	<0.3	4	0.093
MB2	104	21	17	0.314	1.06	0.6	65	26	98	21	3.17	2.64	0.07	2.66	<2	<0.3	<3	0.075
MB3	53	17	5	0.106	0.36	<0.5	20	29	9	17	1.07	0.69	0.04	0.75	<2	<0.3	4	0.061
MB4	80	13	9	0.207	0.95	<0.5	40	23	75	13	1.89	1.66	0.02	1.66	<2	<0.3	4	0.054
MB5	99	23	11	0.258	1.62	<0.5	49	23	114	23	2.76	1.93	0.12	2.08	<2	<0.3	4	0.053
MB6	68	13	11	0.243	1.41	<0.5	51	28	66	13	2.67	1.88	0.12	2.05	<2	<0.3	<3	0.043
MB7	38	24	12	0.147	0.3	<0.5	66	19	100	24	1.68	1.13	0.03	1.08	<2	<0.3	<3	0.072
MB8	52	18	7	0.17	2.03	<0.5	28	18	39	18	2.96	1.41	0.19	1.39	<2	<0.3	7	0.047
MB9	103	6	15	0.316	0.49	0.5	65	21	145	6	3.02	2.74	0.02	2.53	<2	<0.3	7	0.08
MB10	97	14	13	0.271	0.98	<0.5	58	17	163	14	2.67	2.4	0.02	2.35	<2	<0.3	3	0.063
MB11	53	55	4	0.093	0.74	<0.5	16	21	33	55	1.23	0.6	0.1	0.66	<2	<0.3	<3	0.052
MB12	71	15	8	0.208	2.48	<0.5	38	17	83	15	2.36	1.52	0.13	1.7	<2	<0.3	<3	0.048
MB13	56	10	8	0.201	1.67	<0.5	36	24	59	10	2.42	1.44	0.14	1.67	<2	<0.3	<3	0.036
MB14	34	26	11	0.139	0.36	<0.5	61	17	86	26	1.6	1.04	0.03	1.02	<2	<0.3	<3	0.07
MB15	121	47	19	0.361	0.64	0.6	74	29	98	47	3.31	2.9	0.03	2.99	<2	<0.3	<3	0.074

(N.B.: CB = Clast; MB = Matrix. Concentration of trace elements, Cu and Zn in ppm, while other major elements are in %)

4.3.1. Source material and provenance

Contrasting values in the major element composition can be used as a tool to determine sediment provenance (Roser and Korsch, 1988; Fedo et al, 1995; Girty et al, 1996; Meinhold et al 2007). With the objective to establish diagrams for the determination of sediment source type, Roser and Korsch (1988) generated discriminating functions using major elements. In their discriminating binary diagram using the DF1 vs DF2 functions, (Fig. 5a), the analyzed samples from both matrix and clast of the Igarra metaconglomerate fall into the field of quartzose sedimentary provenance. Girty et al (1996) found that sediments from a mafic source show Al_2O_3/TiO_2< 14 values, while for felsic sources, the ratio is between 19 and 28. For the Igarra metaconglomerate samples, the Al_2O_3/TiO_2ratio is between 6 and 13 for matrix, thereby conforming to mafic sourcewhile that of the clast have few of the samples falling outside 19 and 28. This indicates that the sediment source for the matrix component is of mafic source.The variability in the values for the clast samples can be explained by the fact that they were initially sourced from different environments as terriginous sediments.

Saupe and Vegas (1987) have used the K/Al vs Na/Al and (Fe + Mg)/(Al/Na) vs K/(Al-Na) to classify clastic sedimentary rocks into shale, greywacke and arkoses. Samples of matrix of the metaconglomerate plot in the arkose field while those of the clast plot between arkose and greywacke (Fig. 5c). This spread of the clast is attributed to the heterogeneous nature of their source material which indicate difference in composition.

Cullers (2002) used the Th/Co and La/Sc ratios discriminate sediments from basic sources from those of felsic composition. Values of Th/Co > 0.3 and La/Sc > 0.7 are characteristic of sediments from felsic source whereas La/Sc < to 0.4 is related to mafic sources. The analyzed samples of the two components of the Igarra metaconglomerate in this diagram fall into the field of mafic sources (Fig. 5b).

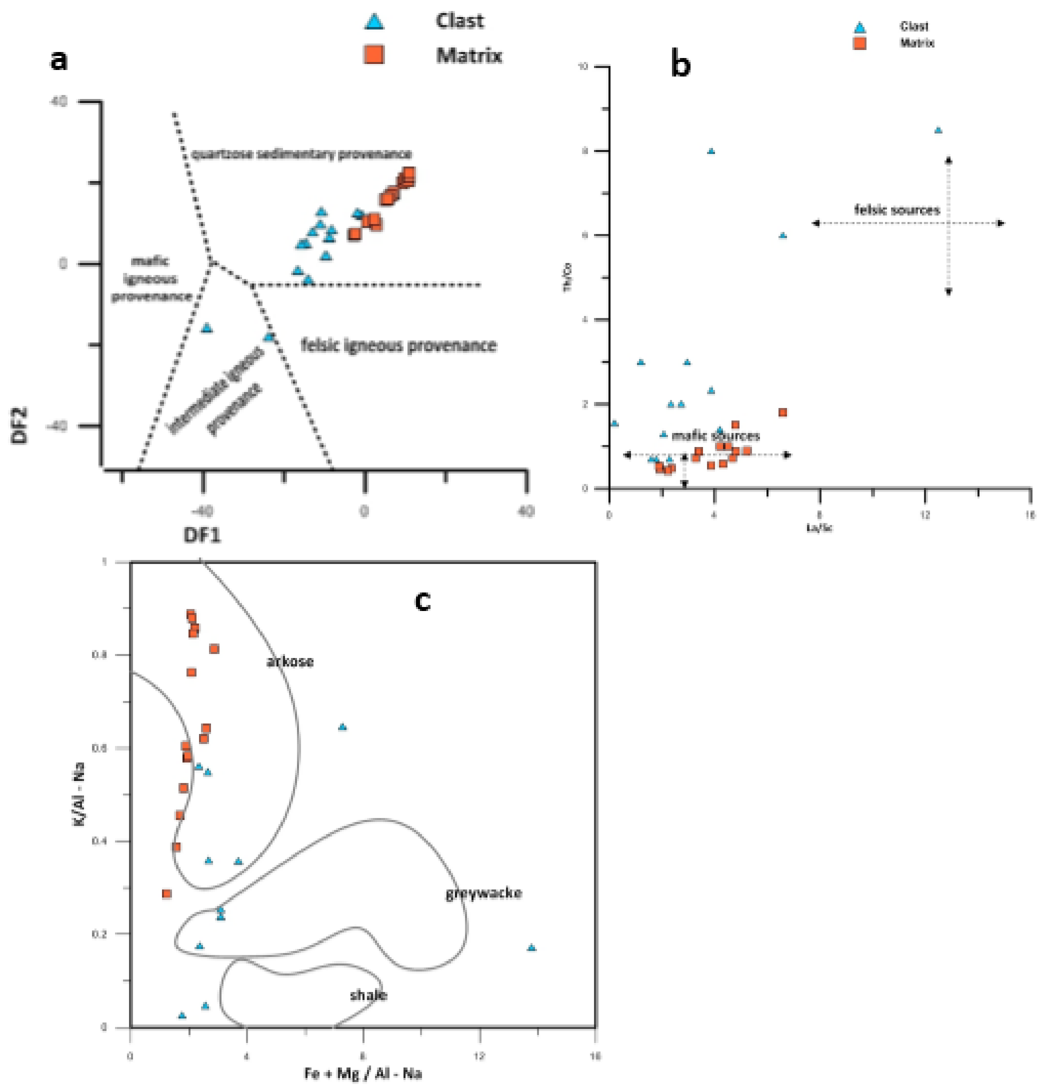

Figure 5: Discrimination diagram for: (a) sedimentary provenance (after Roser and Korsch, 1988)(DF_1 = 30.638 TiO_2/Al_2O_3 - 12.541 Fe_2O_3/Al_2O_3 + 7.329 MgO/Al2O3 + 12.031 Na_2O/Al_2O_3 + 35.402 K_2O/Al_2O_3 - 6.382. DF_2 = 56.5 (TiO_2/Al_2O_3-10.879 (Fe_2O_3/Al_2O_3) + 30.875 (MgO/Al_2O_3) - 5.404(Na_2O/Al_2O_3) + 11.112 (K2O/Al2O3) - 3.89) (b) Th/Co vs. La/Sc diagram for provenance discrimination (after Cullers, 2002) (c) Plots of(Fe+Mg)/(Al-Na) vs. K/(Al-Na) for metaconglomerate(after Saupe and Vegas,1987).

4.3.2. Tectonic setting

Tectonic setting of sedimentary basin and the nature of the original sediment source are known to significantly control the chemical composition of clastic rocks (Gonzalex et al 2017). Consequently, clastic rocks of different tectonic settings will show the particular geochemical features of the terrain where they were formed. Thus determination of tectonic settings in which sedimentation occurred can be achieved using geochemistry as a tool (Bhatia, 1983, 1985; Roser and Korsch, 1988;Floyd and Leveridge, 1987; McLennan and Taylor, 1991).
Bhatia (1983) applied the weight percentage (wt%) of TiO_2 and (Fe_2O_3 + MgO) ratios to distinguish four possible tectonic setting: (a) Passive Margin (PM) (b) Active continental Margin (ACM) (c) Continental Island Arc (CA) and (d) Oceanic Island Arc (OIA). This relationship is

capable of eliminating the possible effect of SiO_2 mobilization by post depositional processes and allow s the investigation of dispersion of sample distribution. Results of analysis show that the two components of the metaconglomerate samples plot separately: clast favor the field corresponding to passive continental margin settings while the matrix is plotted in the Island Arc environment of both continental and oceanic nature (Fig. 6a).

Trace elements, due to their low mobility during sedimentary processes are used to discriminate the tectonic setting, (Bhatia 1983, 1985; Taylor and McLennan, 1985; Bhatia and Crook 1986; McLennan et al 1993).In the La-Th-Sc triangular diagram (Fig. 6b), the analyzed samples plot into the continental Island Arc (CA) field.

Transition trace element (TTE) like Sc, V, Cr, Co, Ni are fixed in chlorite-type clay minerals during weathering and so a source composition signal may be transferred to pelites. But variability of oxidation states leads to changing solubilities depending on the Redox conditions during sedimentation, (Breit and Wanty, 1991; Heinrichs et al 2012). The Cr/V ratios of the matrix of metaconglomerate are similar to the post-Archean shale average of Taylor and McLennan (1985) with only slight deviation due to larger V concentration. The absolute concentration are higherin the matrix than the clast (Fig. 6c). Low V and Cr concentrations show admixture from a felsic source while large Cr and V concentrations carries more mafic admixture (Heinrichs et al 2012). Concentration of Cr and V may reflect source composition modified by a weak signal from depositional redox state while Cr/V ratios at low concentration in some cases may result from heavy mineral sorting.

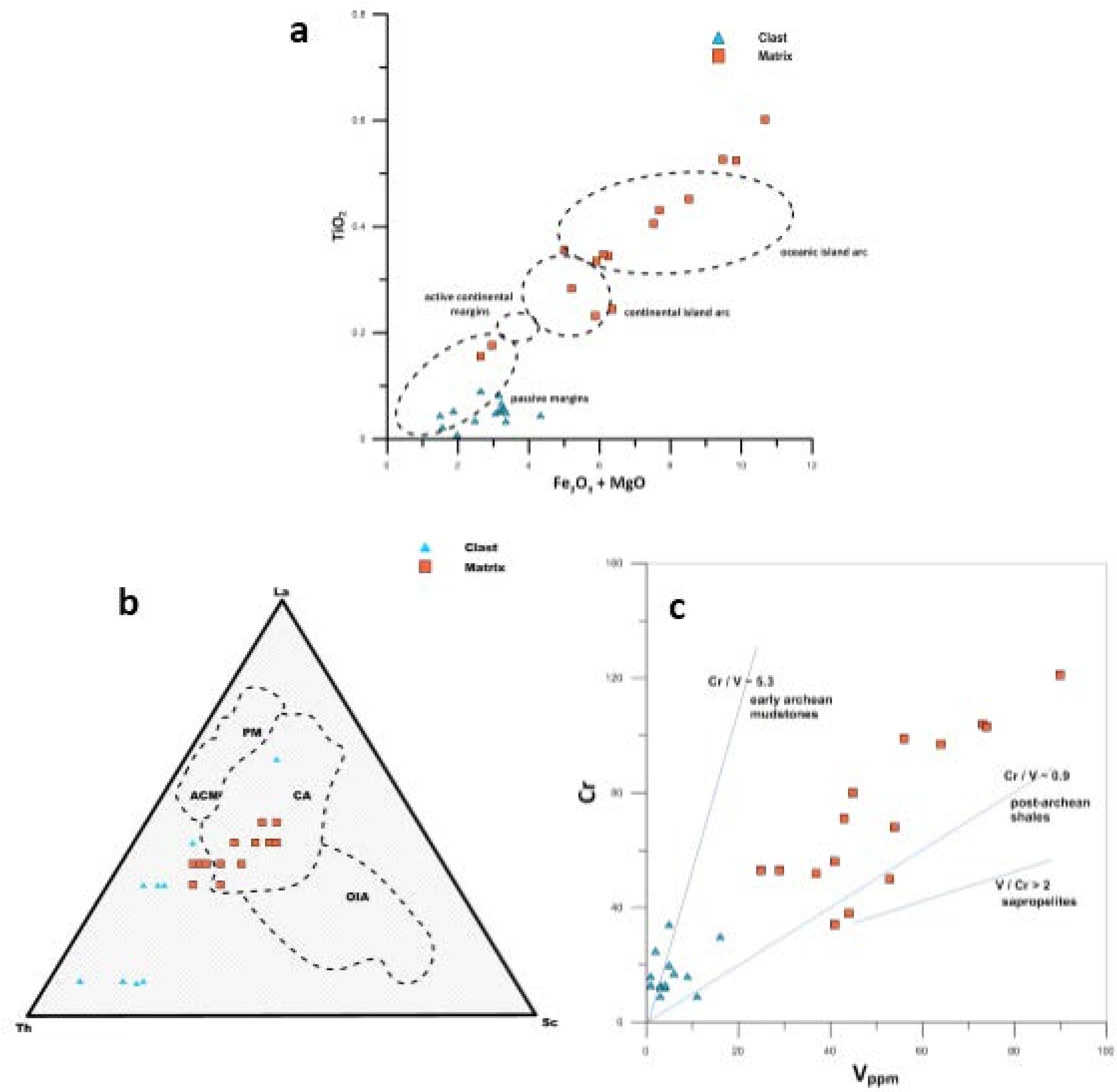

Figure 6: Comparative diagrams of samples of metaconglomerate(a) Plot of Fe_2O_3+ MgO vs. TiO_2 to discriminate tectonic settings (afterBhatia, 1983); (b) La-Th-Sc plot for tectonic setting discrimination (after Bhatia and Crook, 1986). (PM = Passive Margin;ACM = Active Continental Margin; CA= Continental Island Arc; OIA = Oceanic Island Arc); (c) Cr/V ratios.

The Sc/Th versus Cr/Th plot indicates a moderately correlated spread of the metaconglomerate of the Igarra basin. In the Ni-Ti-La plot, the metaconglomerate show a similar pattern with the clast and matrix representing two different cluster where the matrix show a relatively higher Ti/La versus Ni/La ratio than the clast (Fig. 7).

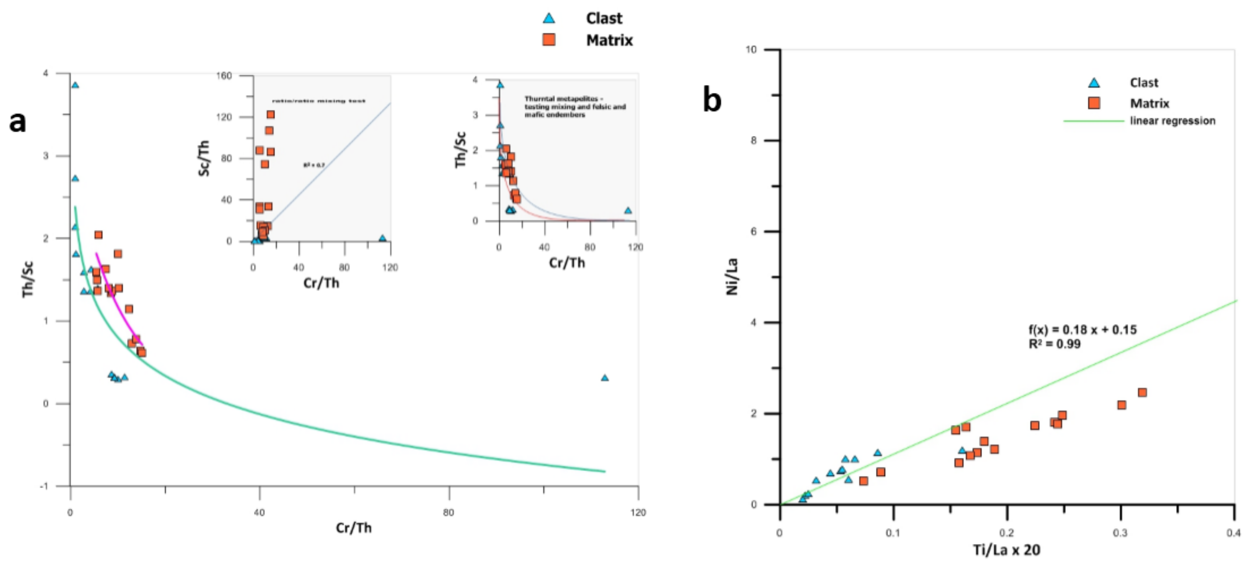

Figure 7: (a) Sc/Th versus Cr/Th correlation plot (b) Ti/La versus Ni/La ratio plot for Igarra Metaconglomerate.

5. Summary and Conclusion

Petrographical examination indicated that the metaconglomerate clast samples from the study area were dominated by minerals such as quartz, biotite muscovite, feldspar and sericite. Matrix is of a slightly more mafic composition equivalent to biotite-schist. The different types of minerals in the samples of metaconglomerate clast reflect the different origin of source materials that constitute the rocks.

Deformed conglomerates in the Igarra schist belt display contrasting strains between the clasts present in each location studied. The clast in all cases are fewer and less abundant than the rock matrix in which they are embedded, hence the rock is designated matrix-supported.

One characteristic feature common to all the clast in metaconglomerate outcrops is there long axis is aligned parallel to the direction of maximum stress (strike direction).The clast are sub-angular, to sub-rounded and very rarely, well rounded. The degree of roundness in the clast may also be a pointer to provenance or source rock evaluation and some clast forming fold structure as a result of deformation.In summary, the variability of finite strain and direction of maximum elongation in the metaconglomerate of Igarra schist belt is interpreted as due to variation in clast composition, grain size and the heterogeneous simple shear deformation that affected the metaconglomerate.This is evident in the distinct clast composition in the Igarra metaconglomerate recording differentamount of finite strain. This finite strain variation is controlled by clast compositionand probably grain size. It is therefore clear that the metaconglomerate of the Igarra schist belt suffered aheterogeneous simple shear deformation.

The determination of the geotectonic environment that hostedthe source rocks forthe Igarra metaconglomerate gave coherent results.By using the classic Roser and Korsch (1988), Saupe and Vegas (1987) and Cullers (2002) diagrams,it is observed that the rocks fall intoquartzose sedimentary provenance, arkorsic and mafic source materials respectively.On the other hand, the discriminating diagrams of Bhatia, (1983) and Bhatia and Crook (1986) for tectonicenvironments projected these samples into the Passive ContinentalMargin-Continental Island Arc fields, showing a clearassociation with a magmatic arc.Cr/V ratio of Taylor and McLennan (1985) placed them as having been derived from Postarchean shales.

Barker (1990) suggested that the coexistence of tremolite and diopside is characteristic of temperatures of the order 500–650 ºC. Depending on the pressure and temperature of formation, texture, mineralogical composition, and chemical data, metamorphism belongs to a greenschist to amphibolite. Based on the geochemistry of the samples from the metaconglomerate of the Igarra schist belt, aderivation of the detrital material from intermediaterocks on the upper continental crust with occasional tilt towards either felsic or mafic affinity is postulated.

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