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Full Length Research Paper

Compositional features of precambrian pegmatites of Ago-Iwoye area South Western, Nigeria

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The increase in global demand for rare metal Ta-Nb deposits has caused a resurgence of interest in the search for economically viable deposits. Precambrian pegmatites occurring as near vertical dykes have been studied, with the aim of determining their compositional features and possible economic values. Four thin sections were prepared from the pegmatites of the study area for petrographic study. A total of twenty five samples comprising whole rock pegmatites and extracts of mica were analyzed for major and trace elements using inductively coupled plasma-atomic emission spectrometry analytical technique (ICP-AES). Petrographic study shows that quartz, microcline, plagioclase are the main mineral constituents under transmitted light. From the results, the whole rock pegmatite is considerably siliceous, but with noticeable depletion of silica in the mica extract. Average Fe_2O_3, Mgo, Mno, and TiO_2 values are low in all samples (< 2.00%). The samples are fairly enriched in Rb, Sr, Zr, but comparatively, poor in the rare metals Ta, Nb, W, Cs and Sn. Rare metal mineralization enrichment indices mainly, Ta vs Nb, Ta vs K/Cs, plots, show its depletion in rare metal mineralization, suggesting Ago-Iwoye pegmatites to be barren in rare-metal mineralization when compared with other rare-metal pegmatites across the world.

Key words: Muscovite, pegmatite, mineralization, precambrian, amphibolites.

INTRODUCTION

The Ago-Iwoye study area lies between longitude 3° 54' E to 4° 00' E and latitude 6° 55'N to 7° 00' N Ijebu-Ode Sheet 280 N.E. (Figure 1). The area is also well accessible by networks of major and minor roads as well as untarred roads, with foot paths linking the environs together. In recent times there has been renewed interest in the study of pegmatites globally because of its attractive economic potentials. In Nigeria also, the study of pegmatites had arouse interest over the years for instance Jacobs and Webb (1946) studied the pegmatites of Nigeria and highlighted that it is restricted within a confine of 400 km NE-SE trending belt; however, studies carried out by Garba (2003) and Okunlola (2005) showed that the pegmatites are not restricted only to these confines. The occurrences in the Southeastern part of the Nigeria, notably around Obudu hills were presumed to extend into Northeast Brazil (Garba, 2003; Ekwueme, 2004). The Nigerian pegmatites evolved during the time span of 600±530 Ma, (Matheis and Caen, 1983), which indicates the formation (Orogeny) in the periods of Pan African magmatism.

Precambrian pegmatites of Nigeria are known to host a variety of rare metals, namely tantalum, niobium, tin, tungsten, columbite as well as lithium and their various uses which include the production of microchips and microprocessors for computers and electronics, aircraft construction, casting, galvanizing, production of containers, metal wears. More importantly, the tantalum and niobium contained in this specialty metals are used for heat and corrosion resistant steels and alloys applied in space ships and gas turbines (Okunlola, 1998; Adekoya et al., 2003; Garba, 2003; Okunlola and Ogedengbe, 2003; Akintola, 2004; Okunlola, 2005; Okunlola and Jimba, 2006; Okunlola and Somorin, 2005;

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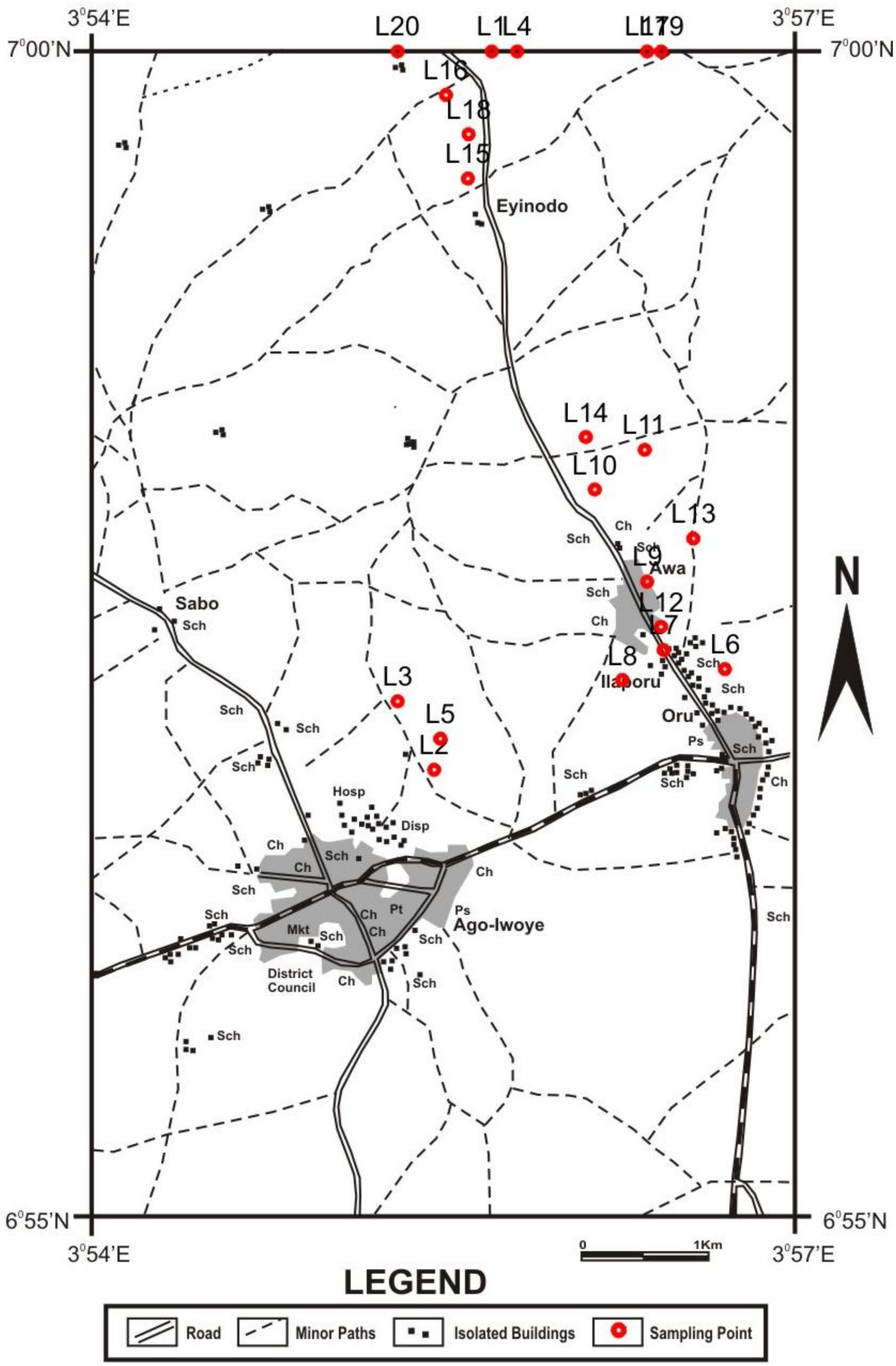


Figure 1. The location map Ago-Iwoye study area showing the sampling points.

Okunlola and Akintola, 2007; Okunlola and Akintola, 2008). Okunlola (2005) classified the metallogeny of the rare metal Ta-Nb pegmatites of Nigeria, outlining 7 broad fields namely Kabba - Isanlu, Ijero - Aramoko, Keffi-

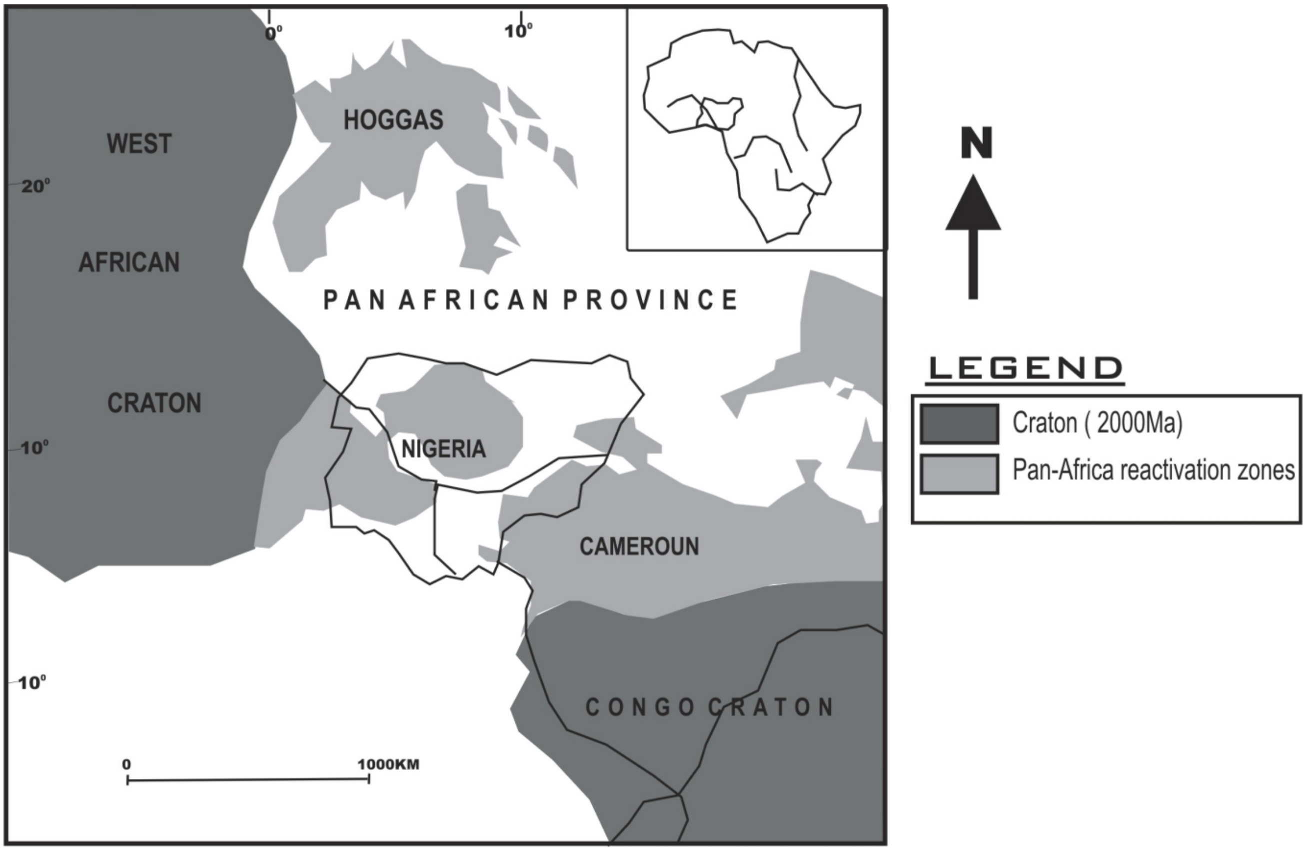


Figure 2. Map showing Pan African province of basement complex. Adapted after Elueze (1985).

Nasarrawa, Lema -Ndeji, Oke Ogun, Ibadan -Osogbo and Kushaka - B/Gwari. The Ago-Iwoye Pegmatites occurrence which is parts of the Precambrian pegmatites in parts of Southwestern Nigeria is to be studied with the aim of elucidating their petrographic and geochemical features with a view to understanding their genesis and economic potentials.

METHODOLOGY

Systematic geological mapping followed by thin section petrographic studies of fresh whole rock samples was carried out. The whole rock and muscovite extracts of the pegmatite samples were then analyzed for major, minor, trace; and rare earth elements using inductively-coupled plasma atomic emission spectrophotometry (ICP-AES), at Activation Laboratories LTD. (ACTLABS) Ancaster, Ontario Canada. The geochemical analytical procedure involves addition of 5 ml of perchloric acid ($HClO_4$), trioxonitrate (V) HNO_3 and 15 ml Hydrofluoric acid (HF) to 0.5 g of sample.

The solution was stirred properly and allowed to evaporate to dryness after it was warmed at a low temperature for some hours. 4 ml of hydrochloric acid (HCl) was then added to the cooled solution and warmed to dissolve the salts. The solution was cooled; and then diluted to 50 ml with distilled water. The solution is then introduced into the ICP torch as aqueous - aerosol. The emitted light by the ions in the ICP was converted to an electrical signal by a photo multiplier in the spectrometer, the intensity of the electrical signal produced by emitted light from the ions were compared to a standard (a previously measured intensity of a known concentration of the elements) and the concentration then computed.

Geological setting, field description and petrography

Rocks of the precambrian basement complex underlie the project area. The precambrian basement of Africa can be divided into three large masses or cratons (Figure 2). These are the Kalahari craton, Congo and West African cratons. They are separated from each other by a number of mobile belts active in late precambrian and early Paleozoic times. The Nigerian Basement Complex lies east of the Congo craton in a mobile belt affected by the Pan African Orogeny Nigeria is underlain by precambrian basement complex rocks, younger granites of Jurassic age and Cretaceous to Recent sediments (Figure 3). The basement rocks occupy about half of the land mass of the country, and is a part of the Pan-African mobile belt lying between the West African and Congo cratons (Black, 1980). There are however contrasting documentation of the evolution of the basement rocks. However loosely, the basement is grouped into three major groups lithostratigraphically namely Migmatite-Gneiss Quartzite Complex: comprising biotite and biotite hornblende gneisses, quartzites and quartz schist. Schist Belts, comprising paraschists and meta igneous rocks, which include schist, amphibolites, amphibole schist, talcose rocks, epidotic rocks, marble and calc-silicate rocks. They are mainly N-S to NNE-SSW trending belts of low grade supracrustal (and minor volcanic) assemblages.

Other secondary rocks used in delineating them are carbonates, calc gneiss and banded iron formation (BIF) and older granites,

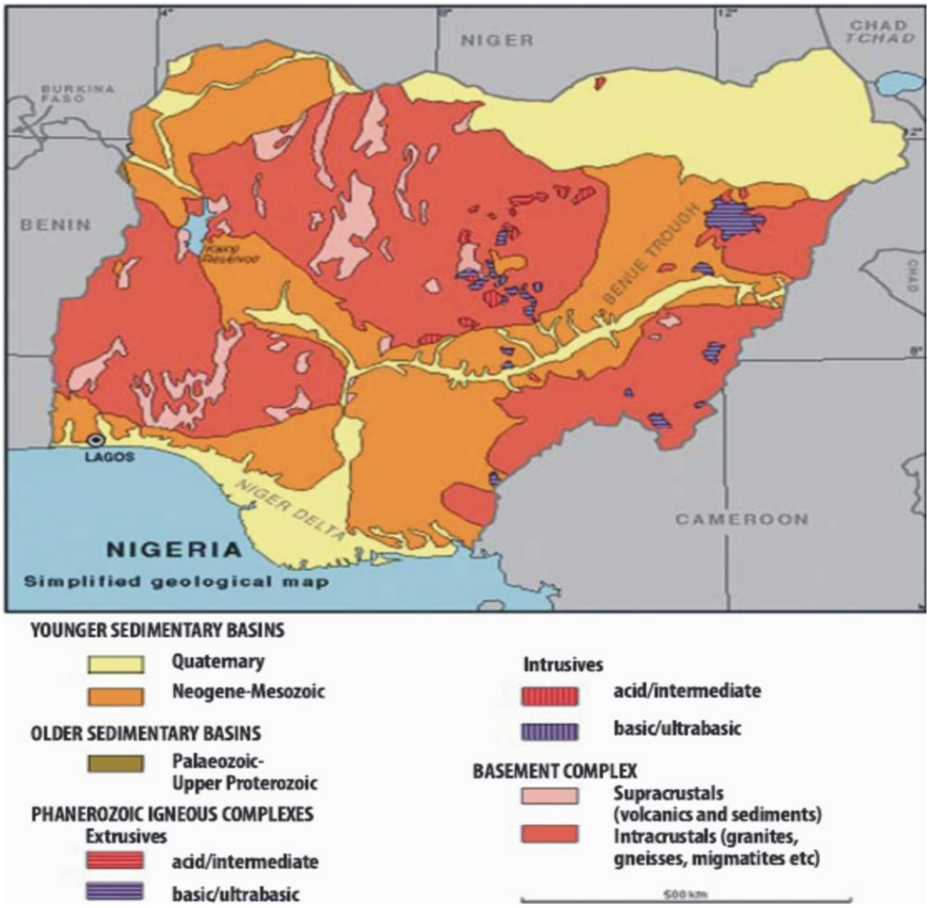


Figure 3. Generalized geological map of Nigeria (Oyawoye, 1972).

which include granite, granodiorite, diorite charnockite, pegmatites and aplites. The Ago-Iwoye study area covers the northeastern part of the map of Ijebu-Ode sheet 280 NE. The rock types observed in this area include coarse porphyritic granite, biotite- granite-gneiss, banded gneiss, quartzite and quartz schist, amphibolites schist; and pegmatite occurring as near vertical intrusions into the older rocks (Figure 4), these pegmatites trend in the NW-SE direction. The *coarse* porphyritic granite occurs as a massive body and mostly contains minerals like quartz, microcline feldspar, and muscovite. The biotite-granite-gneiss is a metamorphic rock in which mineral biotite is the most abundant. Other minerals include quartz, muscovite and microcline feldspar. These rocks underlie a substantial part of the study area and occur as massive outcrops. They are mainly porphyroblastic in texture and dominantly granitic in composition. Phenocrysts of feldspar are pervasive on many of the outcrops while some contain mafic xenoliths or relicts. The banded gneiss also underlies the study area; it is massive and consists of alternating bands of felsic minerals mainly plagioclase feldspars and quartz, and the dark bands consist of mafic mineral like biotite.

The quartzite outcrops which form prominent ridges occur as jointed rocks with conspicuous display of incipient schistose texture. Discordant intrusions of late quartz vein are common across the outcrops. The amphibolites on the other hand occur as low lying discontinuous lenses usually along the contact of the gneiss, they are fissile. The main minerals include quartz, plagioclase, microcline, biotite, and hornblende, while accessory minerals include chlorite, apatite and opaque minerals. The pegmatite occurs as coarse in equigranular veins, milky white in appearance; the main mineral assemblages include quartz, microcline and muscovite with subordinate garnet. The petrography of Ago-Iwoye pegmatite reveals that the predominant mineralogical constituents include plagioclase, microcline, microperthite, quartz, biotite and accessory opaque minerals mainly schroll (Table 1). Quartz exhibits euhedral shape with wavy extinction. The plagioclase feldspar exhibits polysynthetic twinning with microperthite development which is exsolution growth while microcline displays cross-hatch twinning or pericline twinning and is often graphically intergrown with quartz; biotite generally occurs as dark brown platy grains within the samples (Figure 5a(i), b(i), c(i), d(i), a(ii), b(ii), c(ii), d(ii)).

RESULTS AND INTERPRETATION

The analytical results are presented in Tables 2 and 4. Major element distribution shows that the barren pegmatites of Ago-Iwoye are siliceous; this is not unrelated to the fact that pegmatite bodies, barren of rare – metal mineralization are ubiquitous in the Nigerian Pan-African basement. They are found associated with all the major lithologies of the basement, that is, gneisses, migmatites, schist and granitoids. The morphology and major mineral composition (quartz-feldspar-mica) are

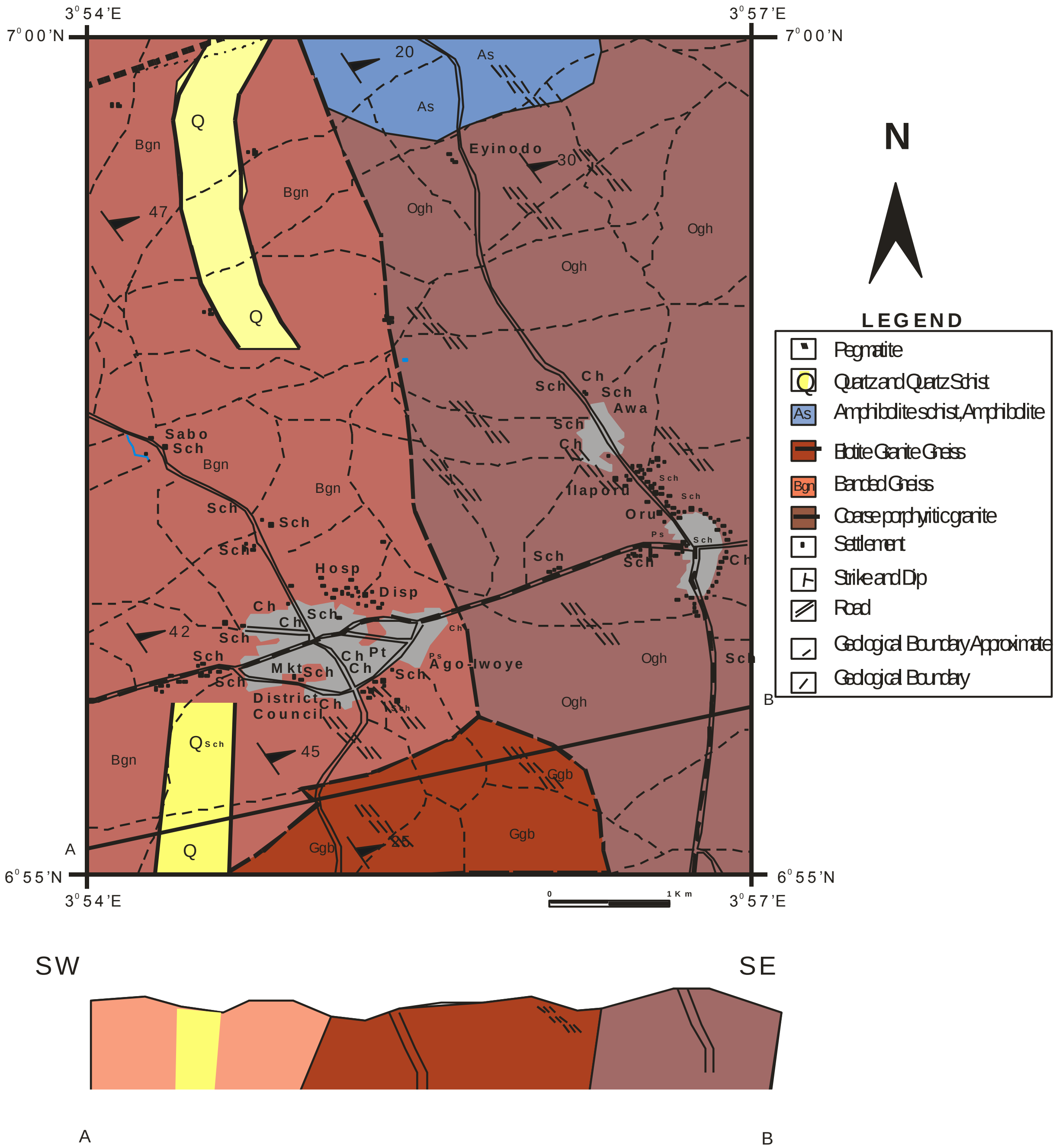


Figure 4. Geological map of Ago-Iwoye area southwestern Nigeria.

mostly not different from those of the rare-metal types, which account for the reasons why the Ago-Iwoye pegmatites are being siliceous, despite the barren nature of the pegmatite of this study area. The silica content SiO_2 ranging between 61.23 and 81.13% with an average value of 73.74% for the whole rock samples of Ago-Iwoye pegmatites, while it also ranges between 48.18 and 57.47% with an average value of 52.65% for the mica extracts of this study area. These SiO_2 values for the whole rocks and mica extract samples of Ago-Iwoye pegmatites are greater than 14% in all the samples and it is the major oxide used in classifying igneous rocks using the Total Alkali Silica (TAS) diagram which divides the rocks into ultra basic, basic, intermediate and acidic on the bases of their silica content (Le maitre et al., 1989; Cox et al., 1979). From this classification, it can be inferred that the Ago-Iwoye pegmatite was derived from igneous protolith, which is acidic. Further, the values

Table 1. Average modal composition (%) of minerals in Ago-Iwoye pegmatites.

Minerals	P5 (%)	P6 (%)	P7 (%)	P8 (%)
Plagioclase (Pl)	-	-	15	35
Microperthite (Mp)	60	-	-	-
Quartz (Q)	30	30	10	-
Biotite (B)	-	-	10	-
Microcline (M)	-	65	60	-
Accessories (A)	10	5	5	65

P5-P8 Represent photomicrographs of pegmatites from Ago-Iwoye study area.

Table 2. Major element oxide composition of Ago-Iwoye Pegmatites (weight %).

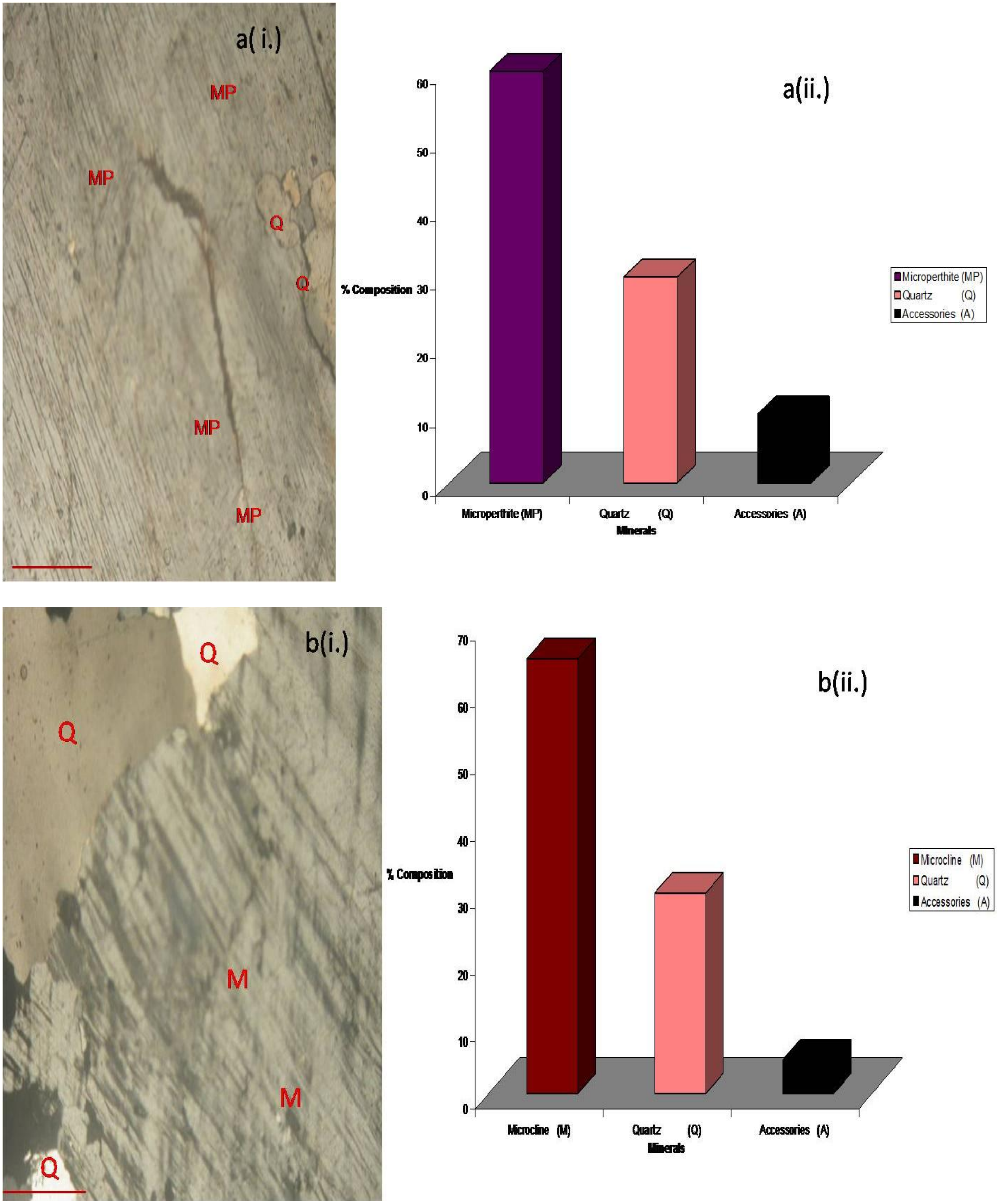
Oxides	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SiO_2	71.72	72.45	73.84	61.23	76.98	71.66	70.54	71.93	67.14	72.2	74.61	73.68	74.23	73.59	78.26
Al_2O_3	15.81	16.39	15.99	15.86	11.96	16.82	17.13	16.72	17.63	16.53	12.21	13.21	14.66	15.86	12.05
Fe_2O_3	1.31	0.75	0.99	2.46	2.46	1.2	1.47	0.82	1.47	1.18	2.5	2.79	1.87	1.24	2.15
MnO	0.081	0.021	0.025	0.038	0.048	0.041	0.031	0.019	0.025	0.066	0.033	0.02	0.007	0.004	0.007
MgO	0.13	0.09	0.2	0.78	0.43	0.12	0.14	0.15	0.16	0.18	0.21	0.19	0.06	0.02	0.05
CaO	0.77	0.88	1.01	3.91	1.53	0.61	0.52	0.98	0.09	0.85	0.6	0.61	0.42	0.28	0.19
Na_2O	4.8	5.34	4.79	2.26	2.18	5.16	4.91	5.88	3.03	6.91	3.71	4.28	5.13	5.36	4.08
K_2O	3.4	3.5	3.41	8.48	4.12	2.98	3.63	1.9	9.65	1.09	4.76	3.39	3.27	3.4	3.14
TiO_2	0.041	0.03	0.032	0.377	0.141	0.04	0.037	0.036	0.017	0.019	0.195	0.241	0.079	0.102	0.112
P_2O_5	0.1	0.07	0.06	2.62	0.12	0.14	0.06	0.1	0.16	0.11	0.03	0.07	0.03	0.04	0.03
LOI	0.84	0.6	0.66	0.78	0.66	1.07	1.22	0.99	0.37	0.68	0.03	0.13	0.52	0.88	0.16
Total	99	100.1	101	98.81	100.6	99.82	99.71	99.52	99.73	99.82	98.9	98.62	100.3	100.8	100.2

Oxides	16	17	18	19	20	21	22	23	24	25
SiO_2	75.98	81.13	79.66	76.64	77.38	57.47	48.41	53.38	48.18	55.8
Al_2O_3	14.16	11.57	12.24	13.65	13.14	24.69	31.2	28.4	30.91	26.77
Fe_2O_3	1.2	0.89	1.1	1.18	0.75	3.82	3.6	3.15	4.08	3.31
MnO	0.05	0.02	0.04	0.08	0.08	0.06	0.05	0.04	0.04	0.04
MgO	0.11	0.08	0.17	0.17	0.06	0.57	0.5	0.69	0.59	0.46
CaO	0.57	0.42	0.32	0.62	0.49	0.03	<0.01	0.01	0.02	0.11
Na_2O	5.43	3.34	2.36	4.93	5.22	0.61	0.49	0.54	0.65	0.47
K_2O	1.66	1.69	2.79	2.08	2	8.08	9.98	8.85	9.95	8.4
TiO_2	0.05	0.04	0.03	0.04	0.02	0.17	0.23	0.16	0.2	0.26
P_2O_5	0.06	0.07	0.05	0.09	0.07	<0.01	<0.01	<0.01	0.01	<0.01
LOI	0.7	0.7	1.2	0.5	0.7	4.5	5.5	4.7	5.3	4.3
Total	99.98	99.99	99.98	99.99	99.95	99.94	99.96	99.95	99.96	99.95

The numbers **1, 2, 3,………25** represent sample numbers. 1-20: whole rock pegmatite samples from Ago-Iwoye. 21-25: Muscovite extracts from Ago-Iwoye pegmatite.

obtained for the silica contents of this study area are comparable to the Ipetu Ijesha barren pegmatites (Elueze, 1982).

Fe_2O_3 (0.75 to 2.79%; 3.15 to 4.08%), MnO (0.004 to 0.081%; 0.04 to 0.06%), MgO (0.02 to 0.78%; 0.46 to 0.69%), CaO (0.09 to 3.91%; 0.01 to 0.11%), TiO_2 (0.02 to 0.377%; 0.16 to 0.26%), P_2O_5 (0.03 to 2.62%; 0.001 to 0.01%), values for the whole rock and muscovite extract samples of Ago-Iwoye pegmatites respectively are generally low. Mean contents of major oxides, Al_2O_3 (14.68%; 28.39%), Na_2O (4.46%; 0.55%), and K_2O (3.52%; 9.05%) for the whole rock and muscovite extract samples of Ago-Iwoye pegmatites respectively compare favorably with the Ipetu Ijesha barren pegmatites and Kafin Maiyaki barren pegmatites (Elueze, 1982; Garba, 2003; Okunlola, 2005). Trace and rare earth element


a(i.)
MP
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a(ii.)
% Composition
0
10
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Microperthite (MP)
Quartz (Q)
Accessories (A)
Minerals
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Accessories (A)
b(i.)
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% Composition
0
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Microcline (M)
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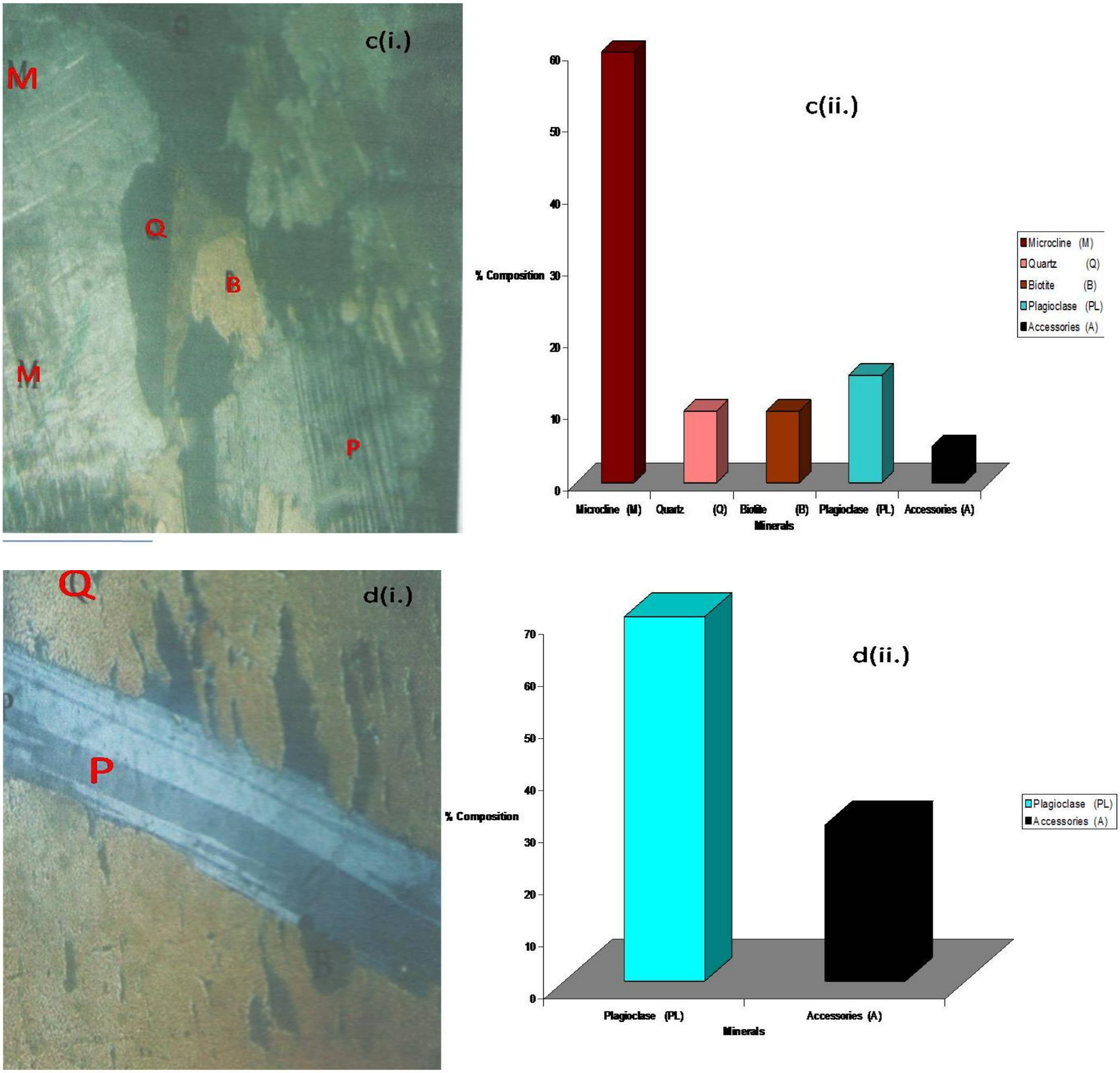

Figure 5. a(i) Photomicrograph of Pegmatite in transmitted light showing MicroPerthite (MP), and Quartz (Q). b(i) Photomicrograph of Pegmatite in transmitted light showing Microcline (M), and Quartz (Q). c(i) Photomicrograph of Pegmatite in transmitted light showing Microcline (M), Plagioclase (PL), Biotite(B) and Quartz (Q). d(i) Photomicrograph of pegmatite in transmitted light showing Plagioclase (PL). a(ii), b(ii), c(ii) and d(ii) are modal distributions of estimated minerals in Ago-Iwoye pegmatites; (Bar scale =20 mm; Resolution: 150 dpi).

data (Tables 3, 5 and 6) show the values of the following trace element Rb (106.85, 504.74 ppm), Cs (4.57, 23.24 ppm), Nb (21.88, 170.8 ppm), Ta (6.54, 12.52 ppm), Be (4.5, 10.2 ppm), Th (2.98, 0.28 ppm), Hf (3.82, 0.54 ppm), Y(16.15, 2.04 ppm), Sn (3.9, 46.6 ppm), Sr (89.43, 3.26 ppm) for the whole rock and muscovite extract samples of Ago-Iwoye pegmatites respectively, has values that are significantly lower than the averages for the rare metal pegmatites of Ijero-Aramoko-Ara, Kushaka-Birni Gwari, Oke –Ogun, Isanlu-Egbe and

Table 3. Trace and Rare earth element data of Ago-Iwoye Pegmatites (ppm).

Elements	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ta	14.1	7.4	8.7	4.6	33.8	13.5	5.8	3.9	5.4	1.2	5.6	4.5	4.6	3.8	2.3
Cs	15.5	5.8	6.8	4.6	2.6	9.3	7.1	4.2	8.1	1.5	0.6	0.6	0.5	0.5	0.5
Rb	106	92	107	247	88	97	96	71	251	24	112	111	121	122	105
Sn	1	1	3	2	2	1	1	2	1	1	4	17	8	8	1
Nb	31	22	27	13	44	27	17	17	7	4	28	33	23	31	8
Sr	15	26	27	925	455	27	21	32	16	15	57	34	19	24	9
Y	9	11	13	55	9	6	3	7	2	6	112	36	7	9	12
Ba	13	19	22	2703	3646	41	46	15	37	32	427	342	168	218	75
Hf	1.5	1.5	1.6	0.8	3	0.4	0.8	0.4	0.3	0.8	16	17.4	8	7.4	13.8
Th	2.9	3.1	3.7	4.5	4.9	0.8	0.8	0.7	1	0.4	8.5	10.5	6.7	4.5	3.2
W	1	1	2	1	1	1	1	2	1	1	1	1	1	1	4
Be	5	3	3	2	1	12	6	6	2	7	4	4	3	3	2
Zr	26	27	19	18	90	10	16	9	10	19	402	566	213	221	367
Ga	18	16	18	18	12	20	17	17	12	14	22	31	27	29	27
Zn	40	30	50	80	50	30	30	30	100	90	90	190	50	40	40
U	3	2.6	3.3	2	2.4	9.3	2.5	2.1	1.9	2.3	2	1.9	1.4	1.4	2
Ti	0.9	0.5	0.8	1.1	0.3	0.4	0.4	0.3	1.5	0.2	0.5	0.5	0.6	0.5	0.3
Cu	70	10	50	50	90	40	20	170	20	80	80	50	20	20	50
Li	14	7	7	6.8	5	4.2	14	10.4	3.1	1.7	1	1	1	1	1

Elements	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Co	1	1	1	4	3	28	1	1	1	1	1	1	1	1	1
V	5	5	5	34	12	5	5	5	5	5	5	7	5	5	5
Ni	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Sc	4	5	5	1	3	4	3	1	1	1	2	2	1	1	1
Pb	20	25	28	28	13	18	13	12	40	24	16	11	12	9	7
Mo	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2
La	3.2	3.8	4	37.3	26.9	1.9	2.2	2.6	1.9	1.3	42.8	64.1	3	2.2	24.1
Ce	8.2	9	9.6	88.9	42.6	4.1	14.1	5	4.3	2.6	97.4	129	25.1	22.2	70.7
Pr	0.99	1.18	1.23	12.2	5.63	0.53	0.53	0.56	0.52	0.29	13.3	18.6	1.06	0.73	9.08
Nd	4.7	5.2	5.5	48.3	18.9	2.5	2.1	2.3	2.1	1.4	48.5	68.3	4.7	4	32.8
Sm	1.4	1.6	1.7	11.3	3.4	0.8	0.6	0.6	0.5	0.4	13	18.2	1.5	1.4	8.6
Eu	1.01	0.15	0.15	3.79	1.31	0.1	0.1	0.11	0.06	0.08	1.72	2.23	0.08	0.1	0.59
Gd	1.2	1.5	1.9	11.9	3	0.8	0.7	0.8	0.4	0.5	14.6	21.8	2.1	2.7	7.7
Tb	0.3	0.4	0.5	1.8	0.4	0.2	0.1	0.2	0.1	0.2	3.2	4.2	0.7	0.9	1.7
Dy	1.9	2.3	2.5	9.7	2.1	1.4	0.7	1.4	0.4	1	20.9	25.8	4.9	6.4	11.7
Ho	0.3	0.4	0.4	1.9	0.4	0.2	0.1	0.1	0.2	4	4	5.5	1.2	1.5	2.3
Er	0.8	1	1.3	5.3	1.1	0.6	0.4	0.8	0.1	0.5	12.3	18	4.1	5	7.1
Tm	0.15	0.17	0.22	0.67	0.16	0.11	0.05	0.16	0.05	0.09	1.68	2.67	0.67	0.77	1
Yb	1.3	1.3	1.6	3.6	1	0.9	0.5	1	0.2	0.8	10.3	15.6	4.2	4.8	6.2
Lu	0.18	0.19	0.24	0.5	0.16	0.13	0.07	0.15	0.04	0.12	1.34	2.21	0.63	0.69	0.84

Elements	16	17	18	19	20	21	22	23	24	25
Ta	2.2	1.8	5	1.5	1	10.9	11	15.4	11.6	13.7
Cs	7.4	4.9	3.9	3.6	3.4	39.9	24.7	14.6	17.7	19.3
Rb	105.7	65.9	90.3	65.1	59.9	678.5	529.3	348.2	544.2	393.3
Sn	7	3	4	3	8	63	15	18	24	113
Nb	37.8	18.9	20.9	13.2	14.8	234.7	137.4	119.7	138.7	214.5
Sr	10.4	10	30.1	18.3	17.7	1.1	1.5	5.7	2.3	5.7
Y	5	1.3	11.9	3.3	4.4	3	0.2	3.5	1.1	2.4
Ba	31	10	57	11	22	32	25	95	17	40

Table 3. Contd.

Hf	0.4	0.1	0.7	0.9	0.6	0.7	0.4	0.4	0.5	0.7
Th	0.9	0.2	1.1	0.7	0.5	0.2	0.2	0.6	0.2	0.2
W	1.4	2.6	3.8	1.7	1.6	11.4	19.3	22.9	22.3	17.1
Be	6	5	5	6	5	9	13	12	9	8
Zr	6.1	1.6	7	16.6	8.8	5.3	3.8	4.8	6.3	7.1
Ga	19.5	15.4	16	15.6	15.6	90.8	90	72.4	97.9	89.9
Zn	16	3	1	5	443	18	6	8	6	10
U	0.9	0.5	2.3	1.6	1.2	1.1	0.1	1	0.5	0.8
Ti	0.1	0.1	0.1	0.1	0.1	0.3	0.2	0.1	0.1	0.1
Cu	12.5	4	1.6	2.7	1.4	2.6	0.4	0.7	1.2	1.2
Li	3.4	0.2	0.7	0.4	5.8	16.1	13.6	11.3	14.2	0.2

Elements	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
Co	2.1	0.6	0.8	1.2	1	1.8	0.5	1.2	0.6	1
V	8	8	8	8	8	8	18	8	8	8
Ni	3.9	2.5	1.3	1.7	3	1.6	0.6	1.1	0.6	1.8
Sc	8	4	3	2	3	53	29	24	21	42
Pb	19.4	5	3.1	14.1	14.4	1.2	0.8	1.3	0.6	4.7
Mo	0.8	0.9	0.4	0.6	1	0.7	0.5	0.7	0.5	0.7
La	2.2	0.4	2.3	1	2.5	0.1	0.1	0.9	0.1	0.7
Ce	3.8	0.7	4.7	2	2.9	1.5	0.3	2.5	0.1	1.2
Pr	0.49	0.09	0.59	0.22	0.51	0.07	0.02	0.29	0.02	0.27
Nd	1.4	0.3	2.6	0.6	1.7	0.6	0.3	1	0.3	1.2
Sm	0.54	0.09	0.83	0.15	0.45	0.2	0.09	0.33	0.07	0.31
Eu	0.07	0.04	0.15	0.05	0.09	0.03	0.02	0.05	0.02	0.06
Gd	0.69	0.16	1.23	0.22	0.53	0.3	0.05	0.38	0.07	0.34
Tb	0.17	0.04	0.32	0.07	0.12	0.07	0.01	0.08	0.02	0.07
Dy	0.97	0.21	1.96	0.41	0.73	0.53	0.08	0.51	0.15	0.37
Ho	0.17	0.03	0.36	0.09	0.15	0.1	0.02	0.11	0.03	0.06
Er	0.48	0.1	1.07	0.29	0.41	0.25	0.03	0.29	0.09	0.2
Tm	0.11	0.02	0.17	0.06	0.09	0.07	0.01	0.05	0.02	0.03
Yb	0.86	0.13	1.23	0.51	0.7	0.43	0.05	0.39	0.14	0.21
Lu	0.13	0.02	0.18	0.09	0.12	0.07	0.01	0.06	0.02	0.04

The numbers **1, 2, 3,………25** represent sample numbers. 1-20: Whole rock Pegmatite samples from Ago-Iwoye. 21-25: Muscovite extracts from Ago-Iwoye pegmatites.

Share but are comparable to the Ilesha barren pegmatites (Elueze, 1982; Okunlola, 2005) and the Nasarawa-Kafin-Maiyaki barren pegmatites (Garba, 2003). The Rb/Sr ratio is low when compared to other rare metal mineralized pegmatites of Nigeria (Matheis and Emofurieta, 1987; Okunlola and Ocan, 2002; Okunlola, 2005; Elueze, 1980, 1981) but compares with the barren Nasarawa pegmatites (Garba, 2003). The K/Rb ratio have values that are significantly higher than those of the rare metal pegmatites of Nigeria but are comparable with values of the barren pegmatites and granitoids (Kuster, 1990; Garba, 2003). From the plot of K/Rb versus Cs (Figure 6a), and the plot of K/Rb versus Rb (Figure 6c, d) (Staurove et al., 1969) for the mica extracts and whole rock pegmatites of Ago-Iwoye which separates barren fractionation sequence and mineralized pegmatites show the Ago-Iwoye pegmatite samples as plotting in the barren field, confirming the low degree of fractionation.

From the works of Garba (2003), it is believed that extreme fractionation of lithophile elements such as Rb and Cs is a common geochemical feature of granitic pegmatites, especially the rare-metal bearing types. Late – stage progressive fractionation crystallization leads to decrease in K: Rb ratio suggesting metasomatism and invariably mineralization. However, this assertion is not in consonance with values obtained for the Ago- Iwoye pegmatites in which the K/Rb ratio was on the higher side due to no late-stage progressive fractionation crystallization; hence, no mineralization. Further, from the plot of K/Rb versus Cs (Figure 6a), and the plot of K/Rb versus Rb (Staurove et al., 1969). From Figure 6c and d,

Table 4. Range and average values of major elements in the whole rock and muscovite extracts of Ago-Iwoye pegmatites in mass fraction (weight %).

Elements	Ago-Iwoye samples (pegmatite)			
	Whole rock (N = 20)		Muscovite extracts(N = 5)	
	Range	Average(%)	Range	Average(%)
Si_2O	61.23 - 81.13	73.74	48.18 - 57.47	52.65
Al_2O_3	11.57 - 17.63	14.68	24.69 - 31.20	28.39
Fe_2O_3	0.75 - 2.79	1.49	3.15 - 4.08	3.59
MnO	0.004 - 0.081	0.04	0.04 - 0.06	0.05
Mgo	0.02 - 0.78	0.18	0.46 - 0.69	0.56
CaO	0.09 - 3.91	0.78	0.01 - 0.11	0.04
Na_2O	2.26 - 6.91	4.46	0.47 - 0.65	0.55
K_2O	1.09 - 9.65	3.52	8.08 - 9.98	9.05
TiO_2	0.02 - 0.377	0.08	0.16 - 0.26	0.20
P_2O_5	0.03 - 2.62	0.20	0.01 - 0.01	0.01

Table 5. Range and averages of some of the trace elements in the whole rock and muscovite extracts of Ago-Iwoye pegmatites (ppm).

Elements	Ago-Iwoye samples (pegmatite)			
	Whole rock (N = 20)		Muscovite extracts (N = 5)	
	Range(ppm)	Average(ppm)	Range(ppm)	Average(ppm)
Ta	1.0-33.8	6.54	10.9-15.4	12.52
Cs	0.5-15.5	4.57	14.6-39.9	23.24
Rb	24-251	106.85	378.2-678.5	504.74
Sn	1-17	3.9	15-113	46.6
Nb	4-44	21.88	138.7-243.7	170.8
Sr	9-925	89.43	1.1-5.7	3.26
Y	1.3-112	16.15	0.2-3.5	2.04
Ba	10-3646	396.75	17-95	41.8
Hf	0.3-17.4	3.82	0.4-0.7	0.54
Th	0.2-10.5	2.98	0.2-0.6	0.28
W	1-4	1.56	11.4-22.9	18.6
Be	1-12	4.5	8-13	10.2
Zr	1.6-566	102.66	3.8-71	5.46
Ga	12-31	19.01	72.4-97.9	88.2
Zn	1-443	70.4	6-18	9.6
Ti	0.1-1.5	0.47	0.1-0.3	0.16

It can be inferred that the Ago-Iwoye pegmatites are relatively unfractionated (*primitive*) when compared with the rare-metal pegmatites. While Rb is an indicator of the degree of fractionation in the granitic pegmatites, Cs appears to be the most important discriminator of the rare-metal pegmatites (Figure 6a). The degree of albitization is revealed by the triangular Ti-Sn-(Nb+Ta) discriminate plot, which is in the zone of non-albitization (Figure 7) for the Ago-Iwoye pegmatites. This plot also reveals a poor degree of albitization and it indicates a significant difference between the mineralized and unmineralized pegmatite samples (Matheis and Emofurieta, 1990; Okunlola and King, 2003; Okunlola and Somorin, 2005; De Kun, 1965; Jacobson and Webb, 1946). However, they are comparable to the rare metal barren pegmatites of Nasarawa, Kafin Maiyaki and Itakpe Central Nigeria (Garba, 2003; Okunlola, 2005). The variation diagram plot (Figure 6e) of Na_2O/Al_2O_3 versus K_2O/Al_2O_3 reveals the igneous ancestry of the pegmatite which plot in the granite-igneous field of Garrells and Mackenzie, thus indicating and suggesting a granitic-igneous ancestry for the Ago-Iwoye pegmatites. Samples also plot in the field of volcanic arc granites on the Rb versus Y+Nb diagram (Figure 6l), while crustal thickness during emplacement of these pegmatite bodies (Figure 6o) reached about 30 km as shown from the Rb/Sr plot

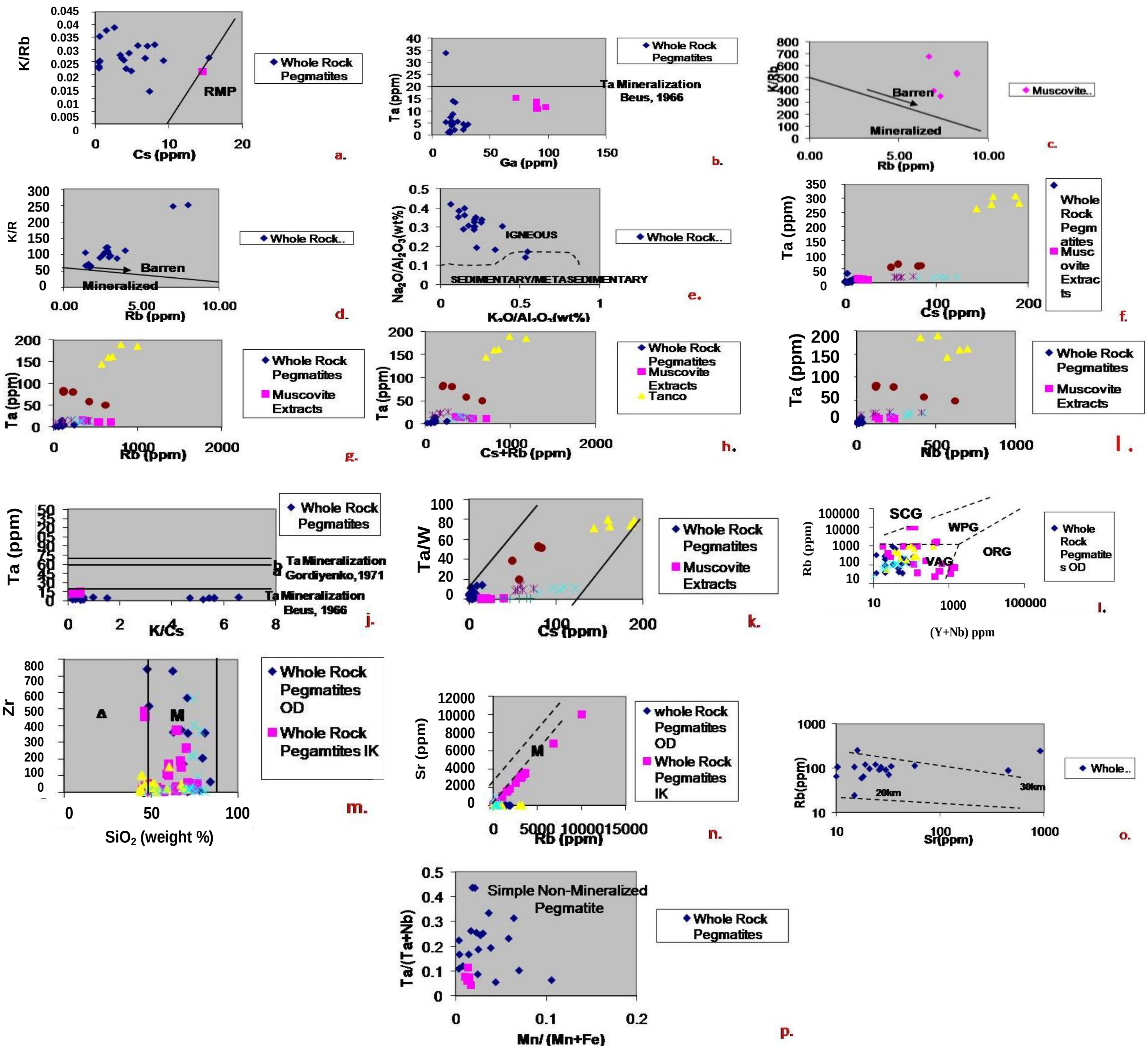

Figure 6. (a) Plot of K/Rb versus Cs for Ago-Iwoye pegmatite (Cerny, 1982); (b) Plot of Ta versus Ga for the Ago-Iwoye pegmatite; (c) K/Rb versus Rb distribution pattern in the Muscovite extracts of Ago-Iwoye Pegmatites. Arrow indicate normal differentiation trend (Staurove et al., 1969); (d) K/Rb versus Rb distribution pattern in the whole rock Pegmatite of Ago-Iwoye Study area. Arrow indicate normal differentiation trend after Staurove et al. (1969); (e) Plot of Na_2O/Al_2O_3 versus K_2O/Al_2O_3 (Wt%) showing variation diagram for the Field of Igneous and Meta Sedimentary Rocks of Ago-Iwoye Pegmatites (Garrels and Mackenzie, 1971). (f) Plot of Ta versus Cs for the pegmatites of Ago-Iwoye study area (Moller and Morteani, 1987); (g) Plot of Ta versus Rb for the pegmatites of Ago-Iwoye study area (Moller and Morteani, 1987); (h) Plot of Ta versus Cs+Rb for the pegmatites of Ago-Iwoye study area (Gaupp et al., 1984); (i) Plot of Ta versus Nb for the pegmatites of Ago-Iwoye study area; (j) Plot of Ta versus K/Cs ratio for the pegmatite's of Ago-Iwoye study area (Gordiyenko, 1971; Beus, 1966); (k) Plot of Ta/W ratio versus Cs for the pegmatites of Ago-Iwoye study area. The Ta/W ratio increases with increasing elements fractionation as indicated By Cs (Moller and Morteani, 1987); (L) Rb versus (Y+Nb) discriminant diagram for the whole rock sample pegmatites Of Ago-Iwoye =AOI compared to those of Olode = OD, Komu= IK, and Awo= AO, (Pearce et al., 1984). VAG-Volcanic Arc Granite, ORG- Oceanic Ridge Granite, WPG- Within-Plate Granite, SCG- Syn-Collisional Granite; (m) Zr-SiO_2 Plots of the pegmatites of Ago-Iwoye compared to those of Olode=OD, Komu=Ik and Awo=AO pegmatites; (n) Sr-Rb Plots of the Ago-Iwoye pegmatites compared to those of Olode=OD, Komu=Ik, and Awo=AO pegmatites; (o) Plot of Rb-Sr for the pegmatites of Ago-Iwoye study area (Condie, 1976); (p) Plot of Ta/ (Ta+Nb) versus Mn/(Mn+Fe) variation plots of the Ago-Iwo Pegmatites.

Table 6. Elemental ratios of selected major and trace elements of pegmatites from Ago Iwoye study area.

Ratio	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
K/Rb	7.0666667	3.5384615	3.962963	0.267027	0.1934066	3.5925926	4.5714286	2.21875	15.6875	1.6
K/Ba	0.2170508	0.1528763	0.1286345	0.0026036	0.0009378	0.0603196	0.0654899	0.1051207	0.2164469	0.0282685
Na/K	1.2618955	1.3637485	1.2555737	0.2382175	0.4729556	1.5477275	1.2090268	2.7662077	0.2806573	5.6664703
Rb/Sr	0.0266194	0.0315723	0.0264482	0.0284921	0.0388544	0.0254959	0.0313806	0.0222086	0.0319065	0.0376913
Ba/Rb	0.1226415	0.2065217	0.2056075	10.94332	41.431818	0.4226804	0.4791667	0.2112676	0.1474104	1.3333333
Zr/Hf	17.333333	18	11.875	22.5	30	25	20	22.5	33.333333	23.75
Sr/Rb	0.1415094	0.2826087	0.2523364	3.7449393	5.1704545	0.2783505	0.21875	0.4507042	0.063745	0.625
Rb/Cs	6.8387097	15.862069	15.735294	53.695652	33.846154	10.430108	13.521127	16.904762	30.987654	16
Ta/W	14.1	7.4	4.35	4.6	33.8	13.5	5.8	1.95	5.4	1.2
K/Cs	0.1820426	0.5008017	0.4161704	1.5299026	1.3150723	0.2659249	0.424301	0.375431	0.988708	0.6030607
Zr/Zn	0.65	0.9	0.38	0.225	1.8	0.3333333	0.5333333	0.3	0.1	0.2111111
Th/U	0.2800655	0.5564464	1.0951854	6.7995671	0.7305957	0.7977748	0.7955643	1.2514365	9.8870802	2.8566032
Ta/Nb	0.4548387	0.3363636	0.3222222	0.3538462	0.7681818	0.5	0.3411765	0.2294118	0.7714286	0.3
Nb/Ta	2.1985816	2.972973	3.1034483	2.826087	1.3017751	2	2.9310345	4.3589744	1.2962963	3.3333333
K_2O/Na_2O	0.7083333	0.6554307	0.7118998	3.7522124	1.8899083	0.5775194	0.7393075	0.3231293	3.1848185	0.1577424
Na_2O/Al_2O	0.3036053	0.3258084	0.2995622	0.1424968	0.1822742	0.3067776	0.2866316	0.3516746	0.1718661	0.4180278
K_2O/Al_2O_3	0.2150538	0.2135448	0.2132583	0.5346784	0.3444816	0.17717	0.2119089	0.1136364	0.5473625	0.0659407

Ratio	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
K/Rb	186.66667	185	242	244	210	14.283784	13.44898	23.153846	18.083333	17.617647
K/Ba	0.6966715	1.1285093	1.4022669	1.4091166	1.1614261	2.9238346	1.7665292	0.7560819	2.1185789	2.3329293
Na/K	1.9649123	3.2647059	6.3684211	5.0833333	11.666667	10.163462	6.59	3	3.557377	3.3841808
Rb/Sr	3.8125	3.0810811	1.3884298	1.7868852	0.7142857	0.2932829	0.1517451	0.6312292	0.1689708	0.3672788
Ba/Rb	25.125	32.528736	26.625	29.864865	26.594203	15.25	16	10	18.444444	14.666667
Zr/Hf	0.5089286	0.3063063	0.1570248	0.1967213	0.0857143	0.0983917	0.1517451	0.3333333	0.281106	0.2954925
Sr/Rb	0.0092513	0.0082262	0.0161534	0.0129434	0.0347451	0.0444398	0.1402531	0.0406214	0.1569265	0.0754455
Rb/Cs	5.6	4.5	4.6	3.8	0.575	1.5714286	0.6923077	1.3157895	0.8823529	0.625
Ta/W	6.5838733	4.688935	5.427546	5.64332	5.211772	0.1861668	0.2862308	0.5936977	0.4794978	0.4881765
K/Cs	4.4666667	2.9789474	4.26	5.525	9.175	0.38125	0.5333333	7	3.32	0.0198646
Zr/Zn	1.4740015	1.5740241	1.2740718	1.0214154	0.5680405	0.4883062	0.5366828	0.084814	0.144427	24.575247
Th/U	0.2	0.1363636	0.2	0.1225806	0.2875	0.0582011	0.0952381	0.2392344	0.1136364	0.0675676
Ta/Nb	5	7.3333333	5	8.1578947	3.4782609	17.181818	10.5	4.18	8.8	14.8
Nb/Ta	1.2830189	0.7920561	0.6374269	0.6343284	0.7696078	0.305709	0.505988	1.1822034	0.4219067	0.3831418
K_2O/Na_2O	0.3038493	0.323997	0.3499318	0.3379571	0.3385892	0.3834746	0.2886776	0.1928105	0.3611722	0.3972603
Na_2O/Al_2O_3	0.3898444	0.2566238	0.2230559	0.2143758	0.2605809	0.1172316	0.1460674	0.2279412	0.152381	0.152207

Table 6. Contd.

Ratio	21	22	23	24	25
K/Rb	616.81818	352.86667	61.087719	236.6087	69
K/Ba	0.2095498	0.3312961	0.0773117	0.4857356	0.174279
Na/K	0.0674807	0.0438861	0.0545396	0.0583917	0.0500126
Rb/Sr	0.009883	0.0156478	0.0210931	0.0151737	0.0177248
Ba/Rb	0.0471629	0.0472322	0.2728317	0.0312385	0.1017035
Zr/Hf	7.5714286	9.5	12	12.6	10.142857
Sr/Rb	0.0016212	0.0028339	0.0163699	0.0042264	0.0144928
Rb/Cs	17.005013	21.42915	23.849315	30.745763	20.378238
Ta/W	0.9561404	0.5699482	0.6724891	0.5201794	0.8011696
K/Cs	0.1680599	0.3353199	0.5030558	0.4665257	0.3612
Zr/Zn	0.2944444	0.6333333	0.6	1.05	0.71
Th/U	0.5707696	0.5294525	0.8384264	0.4443102	0.5087324
Ta/Nb	0.0464423	0.0800582	0.128655	0.0836337	0.0638695
Nb/Ta	21.53211	12.490909	7.7727273	11.956897	15.656934
K_2O/Na_2O	13.245902	20.367347	16.388889	15.307692	17.87234
Na_2O/Al_2O	0.0247064	0.0157051	0.0190141	0.0210288	0.017557
K_2O/Al_2O_3	0.327258	0.3198718	0.3116197	0.3219023	0.3137841

The numbers **1, 2, 3 ....25** represent sample numbers.1-20: Whole rock Pegmatite samples from Ago-Iwoye. 21-25: Muscovite extracts from Ago-Iwoye pegmatites.

of Condie (1976). The plots of Zr/SiO_2 (Figure 6m) and Sr/Rb (Figure 6n) reveal samples plotting completely in the magmatic *"M"* field suggesting pegmatite outcrops around Ago-Iwoye area to be genetically magmatic with no post magmatic metasomatism and poorly differentiated.

The Ta-Nb mineralization potential trend as shown from plot of Ta versus Ga (Figure 6b) shows the whole rock and muscovite extract samples of Ago-Iwoye pegmatites plotting far below the boundary of mineralization (Beus, 1966) line suggesting the pegmatites of this study area to be barren. In comparing with the global Ta-Nb endowments, especially from variation plots of Ta versus Cs (Figure 6f), Ta versus Nb (Figure 6h), Ta versus Rb (Figure 6g), Ta versus Cs + Rb (Figure 6i), Ta versus K/Cs (Figure 6j) and Ta/W versus Cs (Figure 6k), Ago-Iwoye pegmatites compare favorably with the barren pegmatites of Pullerstreuth (Moller and Morteani, 1987). They also compare favorably with the barren pegmatites and granitoids of Nasarawa and Kafin Maiyaki Northern Nigeria (Garba, 2003), Itakpe Area Central Nigeria (Okunlola and Somorin, 2005), and plot far below the highly endowed Tanco pegmatites. They also plot far below the marginally endowed White City, Cross Lake, Buckclaim, pegmatites all of Canada, Noumas South Africa (Moller and Morteani, 1987) and Sepeteri Nigeria (Okunlola and Akintola, 2007). These plots confirm the barren nature of the Ago-Iwoye Pegmatites. In the same vein they show the Ago-Iwoye samples plotting far below the boundary of mineralization lines of Beus (1966) and Gordiyenko (1971), and also far below other rare metal pegmatites from across the world. Following after the classification criteria of pegmatites based on bulk chemistry signatures (Cerny, 1991), and the Ta/(Ta+Nb) versus Mn/(Mn+Fe) plot (Figure 6p). The Ago-Iwoye pegmatites are of the simple non-mineralized class. Following after the rare earth element fractionation trends of pegmatites as defined by Ce anomalies observed for the mineralized pegmatites of Northern Nigeria (Garba, 2003), Negative Ce anomalies of rare metal pegmatite are taken to be indicative of oxidizing conditions during mineralization and involve possible interaction between magmatic and melt fluids and host rocks over sometimes long distances (Graff, 1977; Piper, 1974; Curlet et al., 1974; Garba, 2003).

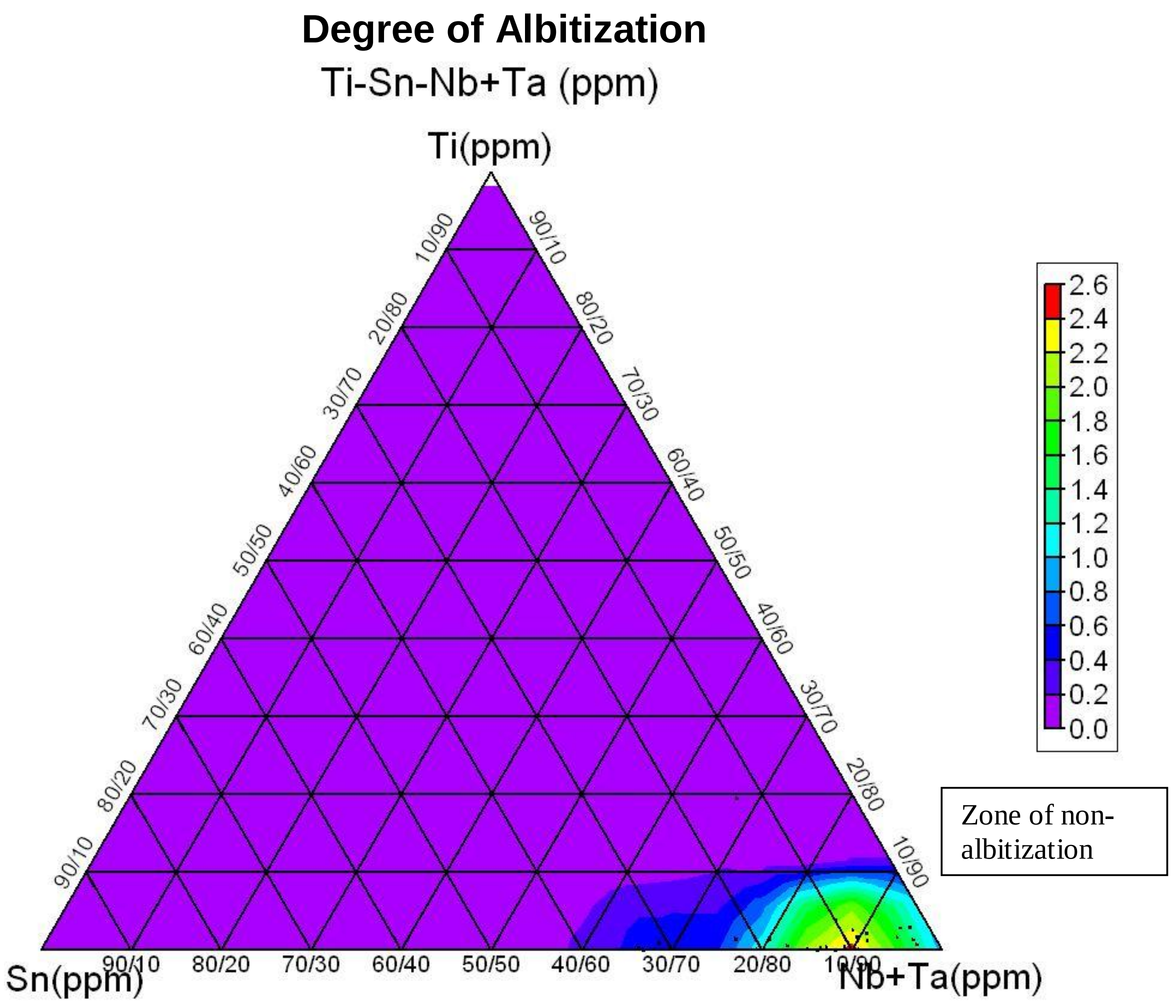

Figure 7. Triangular Ti-Sn-(Nb+Ta) plot for Ago-Iwoye pegmatite's (Kuster, 1990).

The absence of this trend in the samples of the Ago-Iwoye pegmatites rules out the role of late stage or metasomatic fluids in the genesis of these rocks (Figure 8). This further confirms minimal or lack of metasomatic alterations or extensive post magmatic differentiation in their emplacement. This might also mean a close proximity of emplacement to their parent melt sources, which is *"in situ".*

Conclusions

Near vertical dipping coarse grained pegmatite veins occur in association with coarse porphyritic granite, biotite-granite-gneiss, banded gneiss, amphibolites schist, quartzite and quartz schist around Ago-Iwoye area southwestern Nigeria. Petrographic determination shows they are enriched in Microcline and quartz and to a lesser extent in Plagioclase (albite), with interstitial muscovite and accessory biotite. Geochemical studies reveal that they are poorly fractionated. This shows nearness, to their parental melt sources or metamorphic progenitors. Rare metal indicative elements Ta, Nb, Rb, Cs and Sn are depleted in the rock unit while elemental ratio, K/Rb, Ba/Rb suggest low index of fractionation, poor fractionation and barren mineralization. Poor albitization is demonstrated in the Na/K ratio and the Plot of Ti-Sn-(Nb+Ta) after Kuster (1990). While Ta versus Cs, Ta versus Rb and Ta versus K/Cs confirms its apparently poor or barren mineralization compared to other pegmatites bodies in Nigeria and elsewhere in the world.

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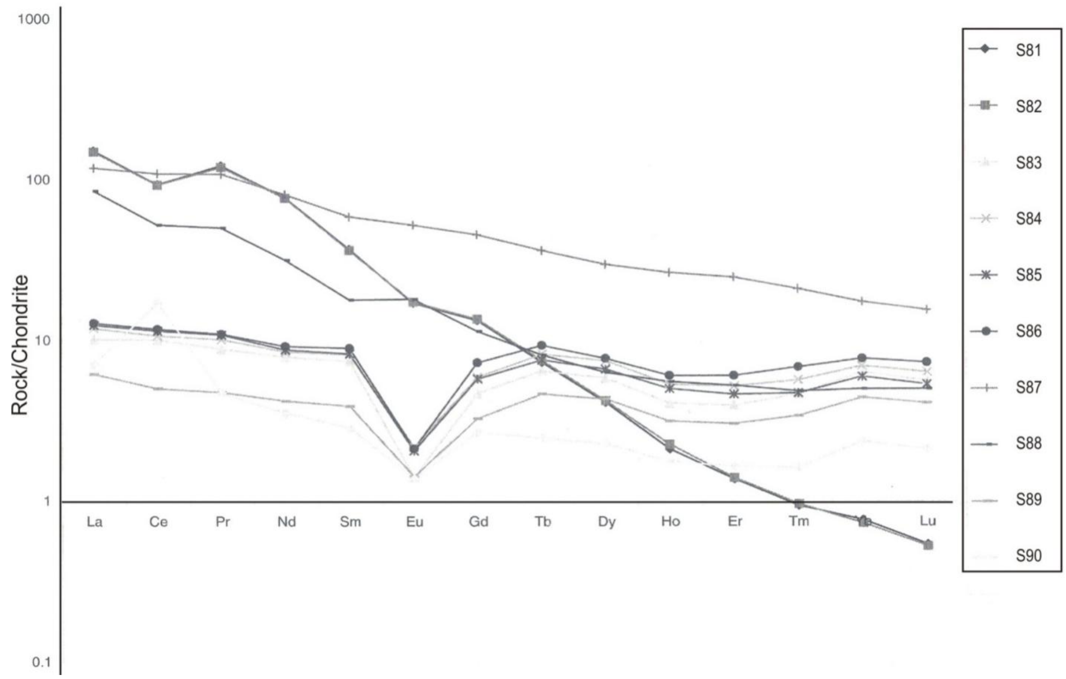

REE Chondrite normalized plots

Figure 8. Rare earth elements chondrite - normalized plots of Ago-Iwoye pegmatite.

of Jamzhall Multimedia were exceptionally supportive.

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