TECTONIC SETTING OF GABBROIC ROCKS IN THE WESTERN PART OF THE LUPA GOLD FIELD, SOUTH-WEST TANZANIA

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ABSTRACT

There is a pronounced occurrence of gabbroic rocks in the western part of the Lupa gold field, SW Tanzania. These rocks occur in the peripheral part around the Saza-Chunya granodiorite with which it makes a gradational, unchilled contact. The rocks have been altered or metamorphosed to low-grade greenschist facies as indicated by the presence of secondary epidote, penninite, chlorite, sericite and calcite. The majority of major-element oxides show scattered variation trends against immobile elements such as Zr, indicating some degree of element mobility during post- crystallization processes of alteration or metamorphism. Major- and trace-element data show that the gabbroic rocks in the study area are calc-alkaline. REE patterns show that the rocks are highly evolved with a high $(La/Yb)_N$ *ratio of about 30 and* $(La/Sm)_N$ *ratios of between 18-40. The highly evolved nature of the studied rocks is shown also by low values of magnesium between 56-62%. The gabbroic rocks in the western part of the Lupa gold field seem to have been formed in the continental arc setting.*

INTRODUCTION

The Lupa Gold Field (LGF) lies within Lupa block, which is one of the eight structural blocks in the NW-SE trending Palaeoproterozoic Ubendian Belt of SW Tanzania (Daly 1988, Fig. 1). The western part of the LGF is located between latitudes 8°15'S and 8°30'S and longitudes 32°45'E and 33°15'E, and covers a total area of about 1,000 km^2 (Fig. 2). The geology of the LGF has been described by several workers (e.g. Kennerly 1962, MacFarlane *et al.* 1962, MacFarlane & MacDonald 1964, Teale *et al.* 1962, Kimambo 1979, Cahen *et al.* 1984, van Straaten 1984). The country rocks are made up of granitic gneisses with amphibolitic bands that strike NW-SE and dip steeply towards the SW. The country rocks are intruded by plutons and dykes of mafic and felsic composition. Mylonites and chlorite-sericite-epidote shists occur along the shear zones. The Ubendian rocks are overlain unconformably by Neoproterozoic continental sedimentary rocks of the Bukoban Supergroup. The rock sequence is capped locally by Cenozoic volcanic rocks and sediments. The present study focussed on the tectonic setting of the gabbroic rocks that occur in the western part of the Lupa gold field, SW Tanzania, based·on major- and trace-element data.

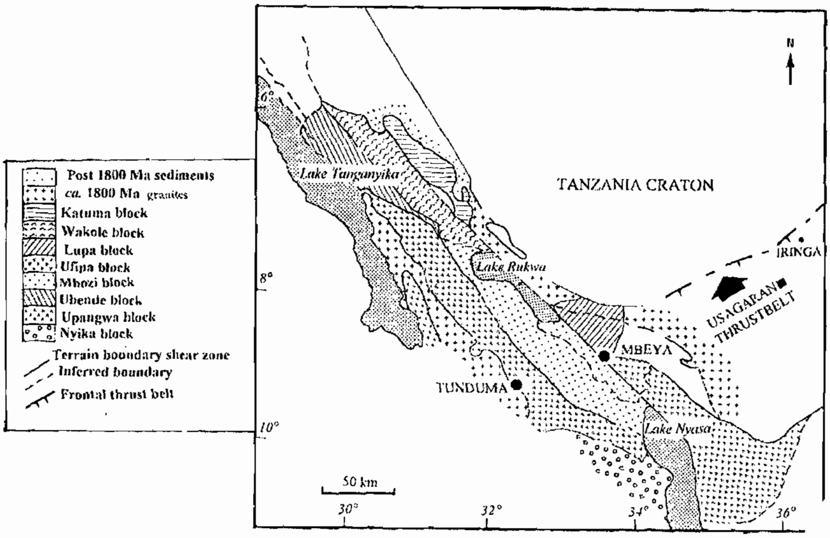

Fig. 1: Sketch map of the structural blocks of the Ubendian belt (after Daly 1988).

Geological background

There is a pronounced occurrence of gabbroic rocks in the western part of the LGF, SW Tanzania. These rocks occur in the continuous pluton surrounding the Saza-Chunya granodiorite that intrude the granitic gneiss (Fig. 2). The contact between the gabbro and the Saza-Chunya granodiorite is gradational. The outermost margin of the gabbro crosscuts the NW-SE trending compositional banding in the gneisses but its contact is not chilled. In the northern part of the study area the gabbro makes a gradational, unchilled contact with Ilunga volcanic rocks. The gabbroic rocks intrude the meta-mafic rocks in the NW boundary.

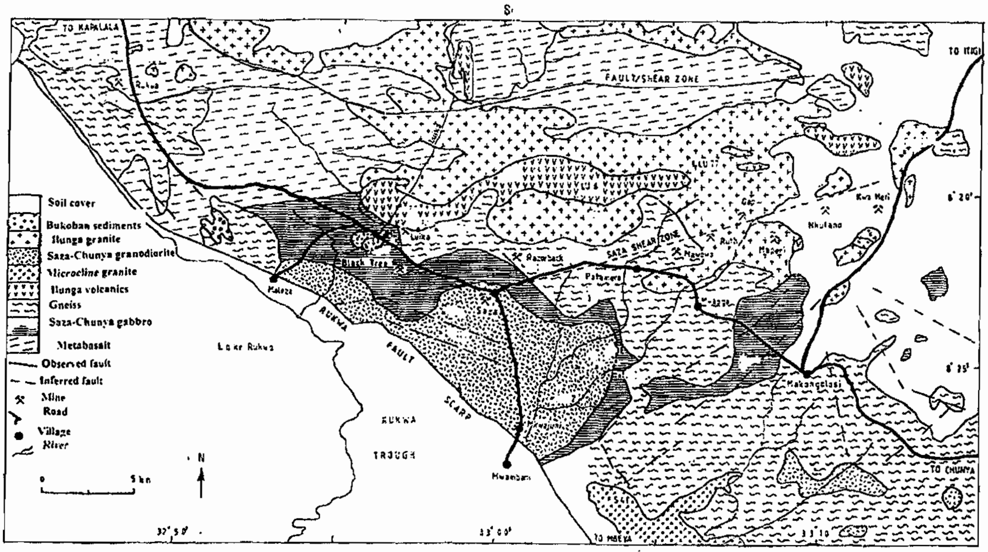

Fig. 2: Geological map of the western part of the Lupa gold field, Tanzania

METHODS

Thirty samples of gabbro were collected for petrographic studies. Eleven unaltered samples were then selected for whole rock chemical analyses. The whole rock chemical analyses for major-, trace- (Cr, Ni, V, Sr, Rb, Ba, Nb, Y and Zr) and rare-earth elements (REE) were done by inductively-coupled plasma atomic emission spectroscopy (ICP-AES) at the Geochemical Laboratory of the Department of Geology, University of Helsinki, Finland, following the methods of Walsh and Howie (1980) and Thompson and Walsh (1983).

A model Jobin Yvon 70+ICP was used with plasma-torch, cooling, and gas flow rates of 12.3, 0.2, and 0.4 litres/minute, respectively. The high-resolution monochromator with a grating of 2,400 grooves/mm was used in the analyses. For the major-element analysis of the rock material, 100 mg of the sample were mixed in a platinum crucible with 0.7 g of $LiBO_2$. Anhydrous Li_2SO_4 (0.3 g) was added to the mixture to accelerate the subsequent HCl dissolution stage. After cooling, the sample was dissolved in 15 ml of6 M HCl at 90 °C in a magnetic stirrer. The cooled sample was made up to 200 ml in double-distilled water containing 0.25 ml of H_2O_2. Standard reference rock samples, SY-2 and MRG-1, were used fto determine the accuracy of the analytical data. Two duplicate analyses were done to check the precision of the analytical results. The concentrations of FeO were determined by titration. Loss on ignition (LOI) was determined by igniting the powdered sample at 1000 °C for one hour.

For the REE and other trace-element analyses, 2 g of the powdered rock sample were mixed in a platinum dish with 8 g of Na_2O_2. The sample was then covered and sintered in an electric furnace for 45 minutes at 480 °C. After cooling, 330 ml of double-distilled water were added, followed by 60 ml of 6 M HCl. The dissolved sample was made up to 500 ml with double-distilled water. An aliquot of 100 ml was taken for trace-element analysis into which 25 ml of 0.8 M oxalic acid and 3 ml of 1.3 M $Ca(NO_3)_2$ were added to precipitate the REE with calcium oxalate. The precipitate was then allowed to settle for 24 hours after which it was decanted and washed twice with 0.1% oxalic acid and ignited for 30 minutes at 900 °C in a muffle furnace. After cooling, the residue was dissolved in 5 ml of 0.5 M HNO_3 and made up to 100 ml with double-distilled water containing 0.2 ml of H_2O_2 ready for ICP-AES analysis. Synthetic standard solutions were used to control the quality of analytical data when needed.

Petrography

The gabbroic rocks are characterized by anhedral, granular texture of pyroxenes and hornblende. Plagioclase (labradorite) form subhedral crystals (laths). The mineralogy comprises labradorite (60%), hornblende (35%) and pyroxenes (5%). Accessory minerals are magnetite, titanomagnetite, ilmenite, titanite and quartz. Magnetite, titanimagnetite and ilmenite appear as complex aggregates of opaque minerals. Some samples show ophitic to sub-ophitic texture whereby subhedral, disoriented laths of plagioclase are wholly or partially enclosed by large, anhedral grains of augite. Labradorite grains have been sericitized and saussaritized producing clinozoisite, epodote, sericite, calcite and secondary albite. Schillirized labradorite grains are cloudy under low-power magnification. Some hornblende has been altered to chlorite and penninite. Some grains of augite have been uralized to secondary hornblende and tremolite-actinolite.

RESULTS

Effects of alteration

The gabbroic rocks have suffered some degree of alteration/metamorphism as shown by the presence of secondary minerals such as chlorite and penninite in the margins of some hornblende grains. Likewise, few grains of augite have been altered to tremolite-actinolite. Clinozoisite, epidote, calcite, titanite and secondary quartz are commonly formed under low grade (greenschist-facies) regional metamorphism or late stage deuteric alteration of plagioclase. The evidence of alteration comes also from the high LOI (1.83-2.85 wt %) for analysed samples. Samples that showed high degree of alteration under the microscope (e.g. high content of secondary minerals) were not chemically analysed. The plot of major-element oxides against immobile elements such as Zr (Figs. 3a, b) show scattered trends suggesting element mobility during alteration or greenschist-facies metamorphism.

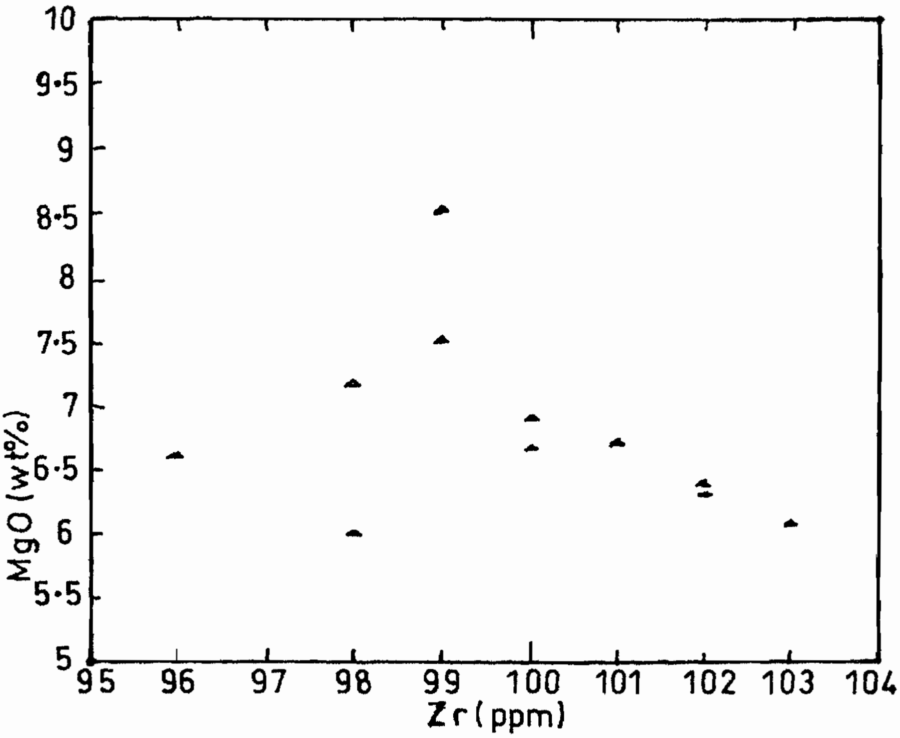

Fig. 3a: Zr-MgO plot of gabbroic rocks from Lupa gold field, Tanzania

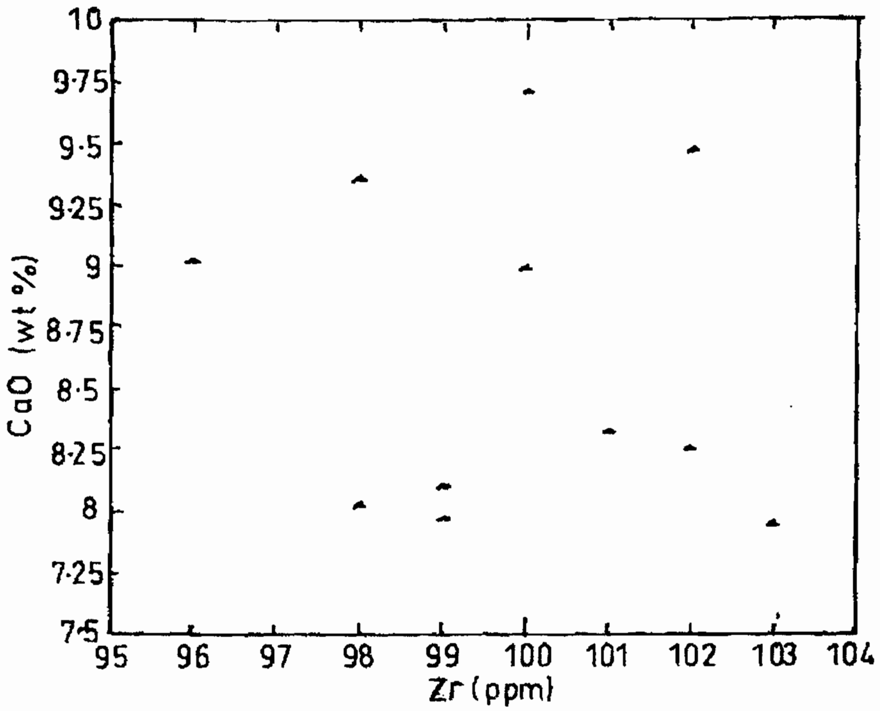

Fig. 3b: Zr-CaO plot of gabbroic rocks from Lupa gold field, Tanzania

Major-element composition

Silica showed a narrow range of concentration (47-51 wt %) typical of basaltic composition while the concentration of Al_2O_3 ranges from 15.2-16.8 wt % (Table 1). The magnesium number (Mg #) [100 x Mg/(Mg+Fe)] of the studied rocks ranges between 52-62%. The Mg # varies antithetically with Zr implying early fractionation of Mg-bearing minerals such as olivine and pyroxenes from the melt. All major elements show scattered variation trends against silica and highly immobile elements such as Zr and Nb (Figs. 3a, b). In the AFM (A = Na_2O + K_2O, F = FeO and M = MgO) diagram (Irvine & Baragar 1971, Fig. 4) the gabbroic rocks plot in the calc-alkaline field.

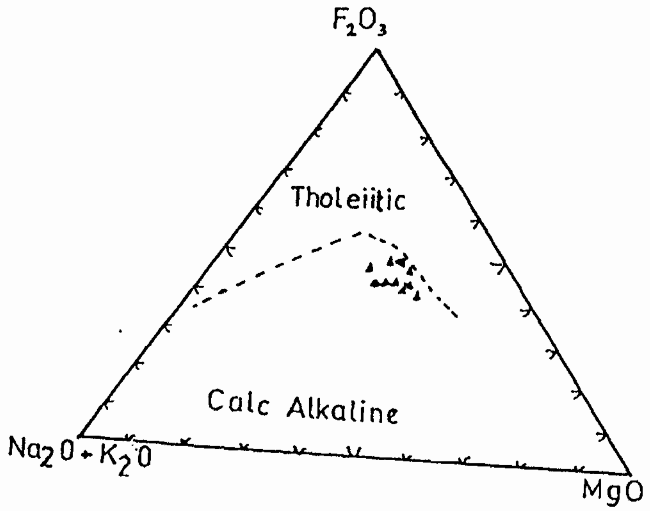

Fig. 4: AFM diagram (Irvine & Baragar 1971) of gabbroic rocks from Lupa gold field, Tanzania

Trace-element composition

The rocks were characterized by relatively low K/Rb ratio (< 600) and high Rb/Sr ratio (≥ 0.4) while Ni, Sr, Rb and Ba showed antithetic variation pattern with Zr (Figs. 5a, b) and V and Nb displayed positive correlation with Zr (Table 2). Cr and Y showed scattered variation patterns with Zr (Figs. 5a, b). Using the Ti/1000-V diagram (Shervais 1982), the studied rocks may be classified as calc-alkaline basalt equivalents (Fig. 6). In the Zr-Yx3-Ti/100, Zr-Sr-Ti/1000 and Ti-Zr diagrams (Pearce & Cann 1973) the studied rocks lie in the field of calc-alkaline basalts (Figs. 7, 8, 9). The Log Zr vs Log (Zr/Y) diagram (Pearce1975, 1983) suggests that the gabbroic rocks were formed in the continental arc environment (Fig. 10).

Table 1. Major element (wt. %) composition of gabbroic rocks from western part of Lupa gold field, Tanzania

Sample	MA1	MA2	MA3	MA4	MA5	MA6	MA7	MA8	MA9	MA10	MA11
SiO_2	49.01	47.34	51.0	47.67	51.00	50.12	50.55	49.88	50.00	50.00	49.00
TiO_2	0.90	0.95	0.98	0.99	1.00	0.93	0.70	0.90	1.02	0.98	0.93
Al_2O_3	16.55	16.32	16.41	16.40	15.18	16.73	16.79	16.67	16.79	18.84	16.16
Fe_2O_3	5.69	6.27	5.02	6.48	4.95	4.87	4.02	5.31	4.85	5.00	5.52
FeO	5.18	5.54	4.00	5.06	4.15	4.47	5.61	5.57	5.00	4.23	4.30
MnO	0.16	0.17	0.11	0.17	0.15	0.43	0.13	0.23	0.13	0.17	0.17
MgO	6.39	6.91	6.00	6.72	7.18	6.33	7.53	6.61	6.10	6.68	8.53
CaO	9.46	8.98	8.02	8.33	9.34	8.26	7.97	9.01	7.95	9.70	8.10
Na_2O	2.49	3.07	3.59	3.78	3.48	3.93	2.55	2.94	2.35	2.65	2.93
K_2O	1.57	0.99	1.28	1.04	1.47	1.48	1.77	1.27	1.07	1.93	1.05
P_2O_5	0.12	0.26	0.19	0.31	0.32	0.26	0.23	0.16	0.27	0.35	0.24
LOI	2.01	2.85	2.72	2.76	2.59	2.25	2.39	1.99	2.09	1.83	2.32
Total	99.53	99.65	99.32	99.71	100.08	100.01	100.05	99.8	99.8	100.4	100.3

Table 2. race element and REE (ppm) composition of mafic rocks from western part of Lupa gold field, Tanzania

Sample	MA1	MA2	MA3	MA4	MA5	MA6	MA7	MA8	MA9	MA10	MA11
Cr	91	57	142	76	549	125	369	168	91	1160	1250
Ni	26	116	64	148	135	85	72	86	169	390	120
V	287	291	156	300	171	186	147	347	297	150	160
Rb	27	27	29	24	28	30	28	25	26	26	30
Ba	418	299	604	657	394	826	496	206	1115	595	280
Sr	548	569	663	488	631	212	545	169	175	605	500
Nb	12	11	12	14	10	13	10	10	11	10	9
Zr	102	100	98	101	98	102	99	96	103	100	99
Ti	5396	5695	5875	5935	5995	5575	4197	5396	6155	5875	5575
K/Rb	483	304	366	360	436	410	525	422	342	522	291
Rb/Sr	0.05	0.05	0.04	0.05	0.04	0.14	0.05	0.15	0.15	0.05	0.06
Y	18	22	17	20	21	19	17	22	21	18	23
La	15	20	28	29	23	17	21	17	26	29	47
Ce	36	54	32	64	57	30	30	21	57	64	67
Pr	Nd	Nd	Nd	6.7	Nd	Nd	Nd	Nd	Nd	Nd	6.2
Nd	Nd	Nd	Nd	33.6	Nd	Nd	Nd	Nd	Nd	Nd	30.3
Sm	Nd	Nd	Nd	6.8	Nd	Nd	Nd	Nd	Nd	Nd	6.5
Eu	Nd	Nd	Nd	1.6	Nd	Nd	Nd	Nd	Nd	Nd	1.4
Gd	Nd	Nd	Nd	4.2	Nd	Nd	Nd	Nd	Nd	Nd	3.7
Tb	Nd	Nd	Nd	0.7	Nd	Nd	Nd	Nd	Nd	Nd	0.8
Dy	Nd	Nd	Nd	3.0	Nd	Nd	Nd	Nd	Nd	Nd	2.5
Ho	Nd	Nd	Nd	0.3	Nd	Nd	Nd	Nd	Nd	Nd	0.3
ER	Nd	Nd	Nd	0.7	Nd	Nd	Nd	Nd	Nd	Nd	0.8
Tm	Nd	Nd	Nd	0.1	Nd	Nd	Nd	Nd	Nd	Nd	0.11
Yb	Nd	Nd	Nd	0.6	Nd	Nd	Nd	Nd	Nd	Nd	0.65
Lu	Nd	Nd	Nd	0.1	Nd	Nd	Nd	Nd	Nd	Nd	0.1

Nd = Not determined

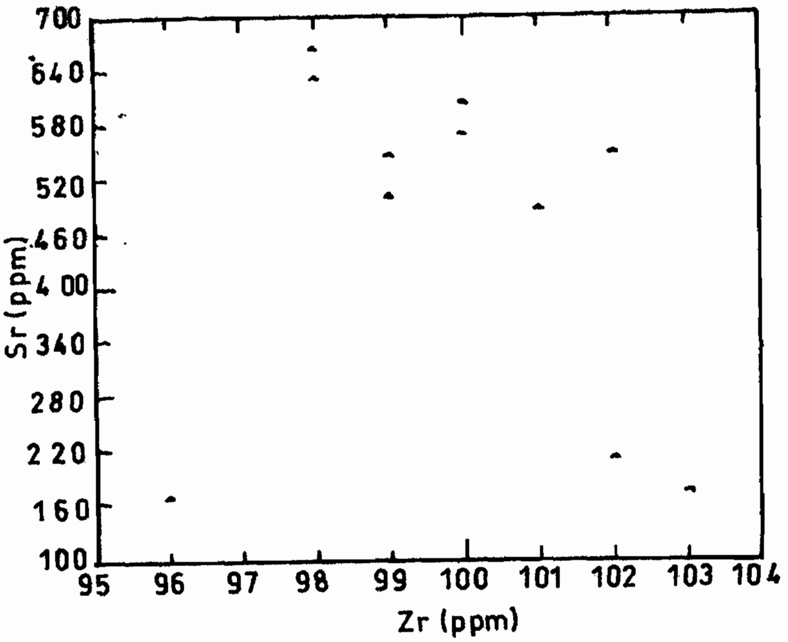

Fig. 5a: Zr-Sr plot of gabbroic rocks from Lupa gold field, Tanzania

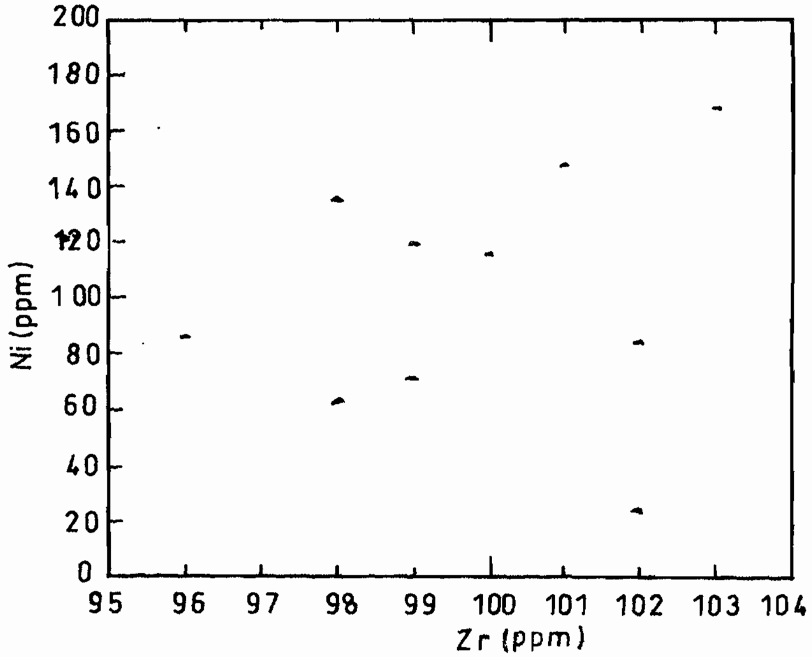

Fig. 5b: Zr-Ni plot of gabbroic rocks from Lupa gold field, Tanzania

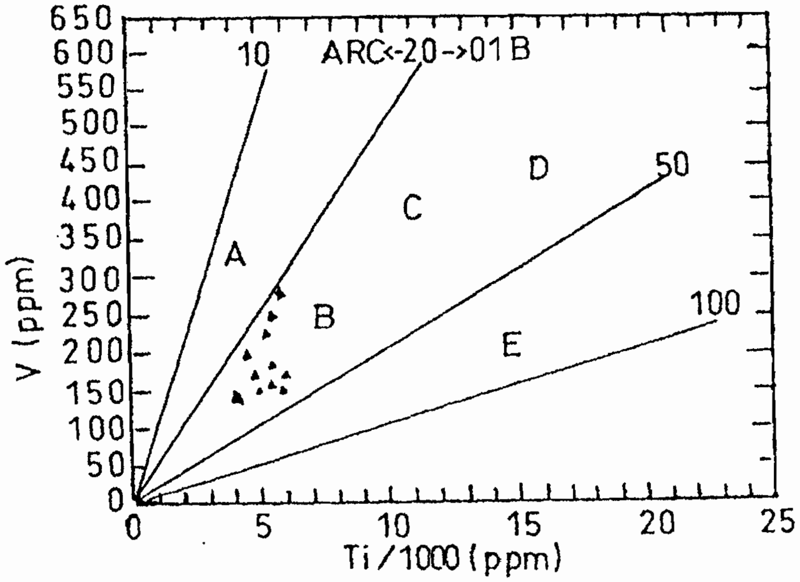

Fig. 6: Ti-V diagram (Shervais 1982) of gabbroic rocks from Lupa gold field, Tanzania. A = Island arc tholeiites, B = Calc-alkaline basalts, C = Mid-oceanic ridge basalts (MORB) and back arc basalts (BAB), D = Continental tholeiites and E = Ocean floor basalts

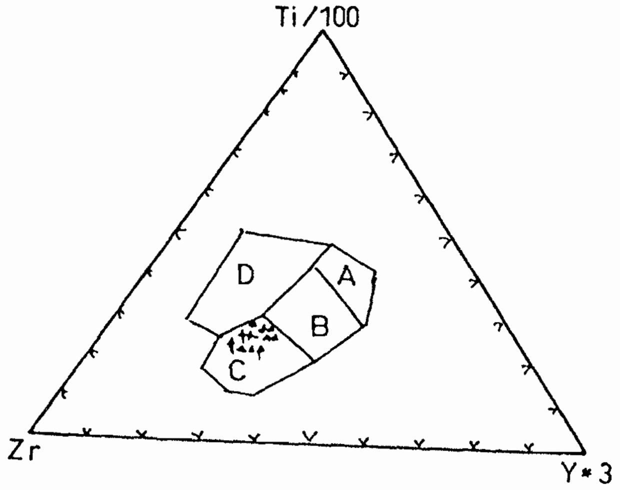

Fig. 7: Ti-Zr-Y diagram (Pearce & Cann 1973) of gabbroic rocks from Lupa gold field, Tanzania. A = Island arc tholeiites, B = MORB, C = Island arc basalts and calc-alkaline basalts, C = Calc-alkaline basalts and D = Within plate basalts

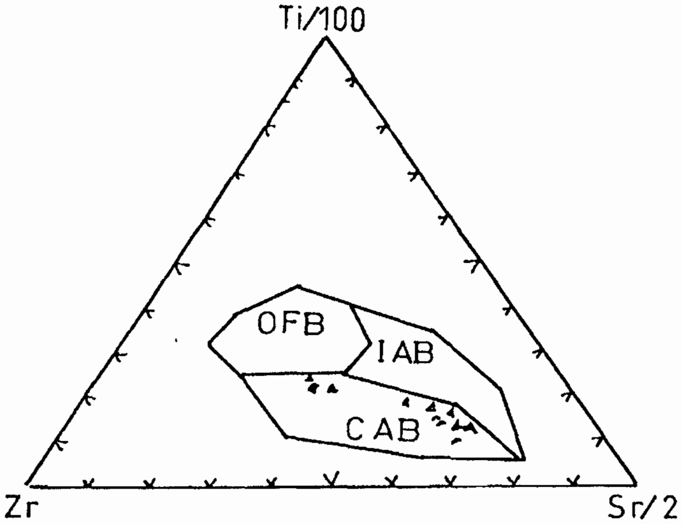

Fig. 8: Ti-Zr-Sr diagram (Pearce & Cann 1973) of gabbroic rocks from Lupa gold field, Tanzania. CAB = Calc-alkaline basalts, IAB = Island arc basalts and OFB = MORB

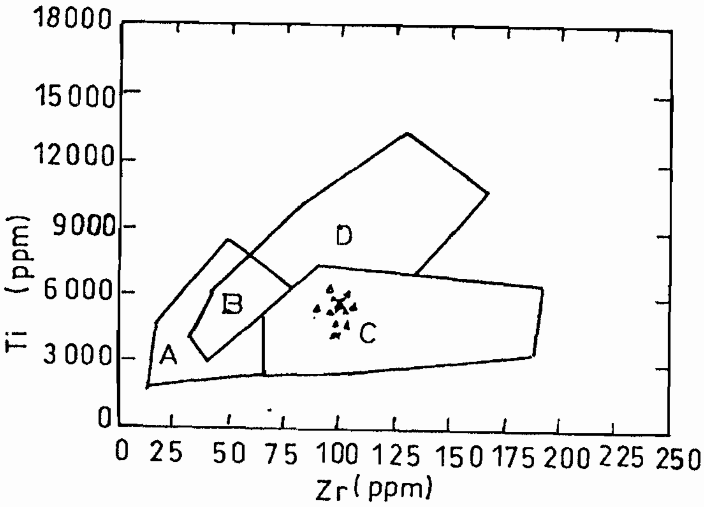

Fig. 9: Zr-Ti diagram (Pearce & Cann 1973) of gabbroic rocks from Lupa gold field, Tanzania. A = Island arc basalts, B = MORB, Island arc tholeiites and calc-alkaline basalts, C = Calc-alkaline basalts, and D = Within plate basalts

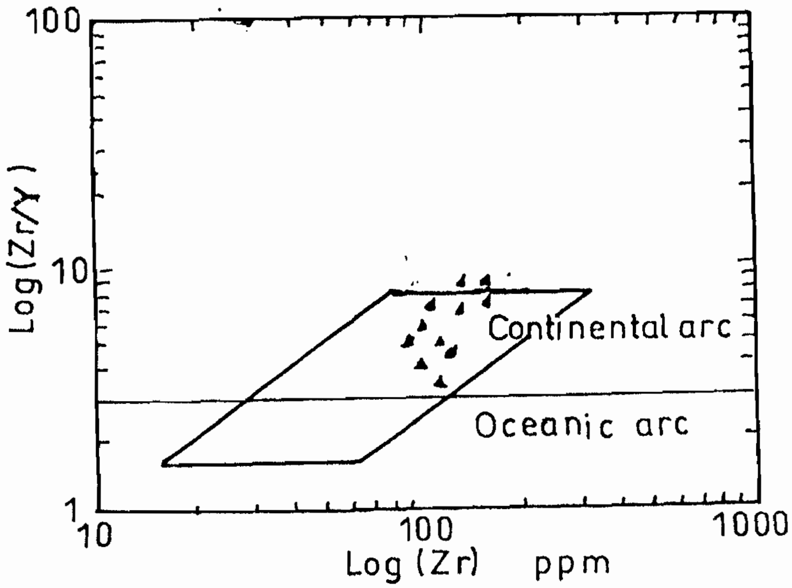

Fig. 10: LogZr-Log Zr/Y diagram (Pearce 1983) of gabbroic rocks from Lupa gold field, Tanzania

The Mid-Oceanic-Ridge (MORB)-normalized patterns show that the gabbroic rocks were enriched with Large Ion Lithophile Elements (LILE), including Rb, K, Sr and Ba. They also show a pronounced negative anomaly in Ti and a trough for Nb and Zr (Fig. 11).

Rare-earth element composition

The rocks were enriched in light rare-earth elements (LREE) and relatively poor in heavy rare-earth elements (HREE) (Table 2). The middle rare-earth elements (MREE) concentrations were intermediate between that of LREE and HREE. The rocks were highly fractionated as shown by their high $(La/Sm)_N$ ratios of between 18-40. They show also the evolved pattern in the chondrite-normalized plot (Fig. 12), with a $(La/Yb)_N$ ratio of about 30. This reflects a high degree of fractional crystallization of the parental magma. The HREE show fractionated patterns with a $(Tb/Lu)_N$ ratio of 2.0. This suggests early fractionation of the garnet from the melt or in the residue at the melting site, since the garnet retains HREE (Hanson 1978).

DISCUSSION

The gabbroic rocks in the western part of the LGF have intruded the granitic gneiss because they crosscut the NW-SE trending compositional banding in the gneisses. However, the contact between the gabbroic rocks and the Saza-

Chunya granodiorite is a gradational one suggesting that the two rock suites were formed from a single magma by fractional crystallization. The presence of secondary minerals including epidote, chlorite, penninite, sericite and traces of calcite in the studied rocks is a clear indication that they had suffered some degree of alteration or low-grade greenschist-facies metamorphism. The effect of these post crystallization processes is evidennt from the scattered variation trends of mobile major-element oxides (e.g. FeO, CaO, MgO, Na_2O and K_2O) and trace-elements (e.g. Ni, Rb, Sr and Ba) against immobile trace-elements such as Zr.

The AFM (Fig. 4) and Ti/1000-V (Fig. 6) diagrams show that the gabbroic rocks are calc-alkaline suggsting that they were formed in the arc setting. The low Mg # of 52-62 suggests that the studied rocks were formed by fractional crystallization of basaltic magma and not as direct derivatives of primitive magmas that had undergone little or no fractionation after separation from their mantle sources. The high degree of fractional crystallization is also shown by the large LREE/HREE and MREE/HREE ratios (Table 2). The REE profiles indicate also fractionation of HREE during the partial melting as shown by the high $(Tb/Lu)_N$ ratio of about 2.0 This might be caused by early fractionation of garnet from the melt or its retention in the residue at the melting site. Pronounced enrichment in LREE and LILE relative to HREE indicates that the gabbroic rocks have affinities with the continental arc setting.

The high negative anomaly in Ti and a trough for Nb suggest that the rocks have affinities with orogenic, calc-alkaline rocks or continental tholeiites and not MORB. A small trough in Zr might reflect fractionation of zircon in the residue during partial melting of the source rocks. Trace-element geochemistry involving immobile elements indicate that the gabbroic rocks in the western part of the Lupa gold field are calc-alkaline and they were fromed in the continental arc complex.

CONCLUSION

The present study of gabbroic rocks from the western part of the Lupa gold field enebles the following three suggestions to be made:
First, the gabbroic rocks appear to have been subjected to alteration or low-grade, greenschist-facies metamorphism. Secondly, major-element geochemistry might not be suitable for studying the palaeotectonic setting of altered rocks because the major-elements are mobile during alteration or metamorphism. Finally, the gabbroic rocks in the western part of the Lupa gold field appear to be calc-alkaline and to have been formed in the continental arc setting probably within the orogeny-related continental margin.

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