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GEOCHEMISTRY AND PETROGRAPHY OF PYROXENITES FROM METTUPALAIYAM ULTRAMAFIC COMPLEX, TAMIL NADU

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Abstract

The Mettupalaiyam ultramafic complex (MUC) in Tamil Nadu is a major lithological association consisting mostly of Pyroxenites, Peridotite, Gabbro, Anorthosite gabbro in a predominantly gneissic grantite-granite terrain. Pyroxenite occurs as thin lenses and bands, at times attaining moderate thickness. Major, Trace and rear earth element geochemistry and petrography of pyroxenites collected from well exposed outcrops near Thenkalmalai areas of this complex are presented in this paper and their Petrogenetic significance is discussed.

The geochemical signatures of the pyroxenites show a significant variation in major and trace element concentration. The pyroxenites show SiO_2 composition ranging from 49.6-55.5%, Al_2O_3 from 6-13.6%, MgO from 3.6-14.3%, CaO from 8.4-15.5% and TiO_2 from 0.24-1.7%. Bulk composition/whole rock analyses indicate that the magma type is tholeiitic but trending towards a calc-alkaline. The pyroxenites are poor in incompatible and high field strength (HFS) elements like Rb, Sr, Hf, and Ta.

Total rare earth element (∑REE) content varies in a limited range and exhibits limited REE fractionation in both LREE and HREE. The pyroxenite sample shows Negative Eu-anomalies with slight enrichment of HREE. Primitive mantle normalized multi-element spider grams suggest that the melt parental to these pyroxenites was derived from a mantle source enriched in several trace trace elements.

Introduction

The Mettupalaiyam Mafic-Ultramafic complex located in the western part of Tamil Nadu forms a part of the Archean Complex of the peninsular shield. The detailed studies lead to the recognition of an array of rock types including leucogabbro, anorthosite with chromites layers, pyroxenites, and peridotite, occurring as layers in close association. They show a flat E-W trending linear bodies showing sub-parallelism to the trend of main shear. The pyroxenites in the complex occur as a thin lenses and bands where as some outcrops shows moderate thickness. The ultramafic and mafic association represents dissected pattern and are considered to have been emplaced along reactivated lineaments, shear zones and deep crustal fractures. These rocks form part of Bhavani layered complex, emplaced into the rocks of the Sathyamangalam Group and was subjected to three phases of deformation (Selvan, 1981; Baskar Rao et al., 1996).the general geology of the study area is given in Fig. 1. The general trend of the foliation of the different litho units within MUC is ENE-WSW with moderate southerly dip in the southern part and moderate to steep northerly dip in the northern part. All the litho units had undergone high degree of deformation as evident from shearing, flattening and compression with well developed linear and planar fabrics.

Fig. 1: Geology and sample location map of the study area (Source: Geological survey of India-1993)

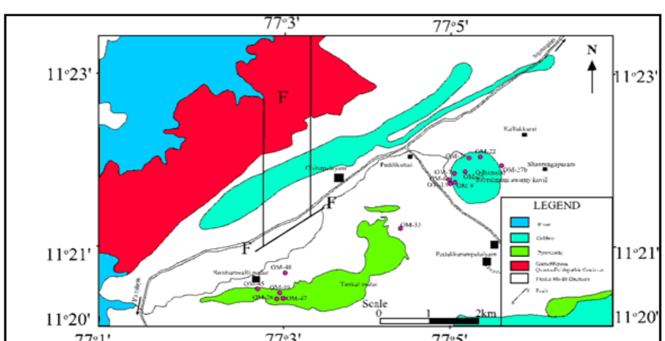

Fig. 1 . Geology and Sample Location Map of the Study Area (Source: Geological Survey of India -1993)

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Petrography

Petrographic analysis was performed on 20 thin sections cut from the hand samples collected in the field. Pyroxenite is the dominant lithology in the studied area. In hand specimen, the pyroxenites are coarse grained dark grayish in color. Pyroxenites in thin section are texturally characterized by distinct adcumulate texture. They are quite mafic and probably represent pyroxene rich and plagioclase poor portion of cumulate. The sample OM-37 and OM-40 is composed of coarse grained clinopyroxenes, orthopyroxenes and medium grained hornblende crystals. Most of the grains show euhedral crystal surfaces. The accessory phase being the magnetite and ilmenite, concentrated characteristically along the grain boundaries.

Geochemistry

Seven representative pyroxenite samples were analyzed for bulk chemistry at National Geophysical Research Institute (NGRI) Hyderabad. Major elements were determined by X-ray fluorescence Spectrometry (XRF) using Philips MAGIX PRO Model 2440. Trace and REE elements were analyzed by Inductive Coupled Plasma mass Spectroscopy (ICP-MS) using a Perkin Elmer SCIEX ELAN DRC II. The geochemical signatures of pyroxenites show a significant variation in major and trace elements. The SiO_2 abundance covers a narrow compositional range of (49.6-55.5wt %). The pyroxenites shows a slight concentration of TiO_2 (0.24-1.7wt %). MgO content varies from (3.6-14.3wt. Major, Trace, and rare earth element (REE) concentration are given in (Table 1). The pyroxenites shows a high concentration of Total iron (8.4-16wt %), MgO (3.6-14.3wt %) with moderate enrichment of TiO_2 (0.24-1.7wt %) and depleted alkalies Na_2O (0.39-2.5wt %); K_2O (0.03-1.5wt %). Bulk composition/whole rock analyses indicate that the magma type is tholeiitic but trending towards a calc-alkaline nature also supported by AFM diagram (Irvin and Banger) (Fig. 2). A plot for SiO_2-K_2O based on (Peccerillo and Taylor 1976) (Fig. 3) indicates that the samples belong to low-K tholeiitic series. The element Mn, Ti, and P are relatively immobile and insensitive to hydrothermal processes. Based on the TiO1, MnO, P_2O_5 triplot (proposed by Mullon 1983) most of the samples fall within the Calc-alkaline basaltic (CAB) field but trending towards boninite field which represents MnO rich sector of CAB field (Fig. 4). Thus it could be inferred that the tectonic environment of eruption is volcanic arc environment and the studied sample falls within the Calc-alkaline basaltic field. Concentration of compatible trace elements in pyroxenites like V (263-309.4ppm), Cr (9877.1-21200.4ppm), Co (87.0-111.5ppm) and Ni (676.8-1055.4ppm) are high while these pyroxenites are poor in incompatible and HFS elements like Rb, Hf, Ta, Th, and U. Sr shows a remarkable low concentration ranging from (0.37-0.94wt%).

Table 1 Representative Major (wt %) and trace (ppm) element composition of Pyroxenites from Thenkalmalai (Mettupailium Ultramafic complex), Tamilnadu, South India

Rock Type		Pyroxenite						
Sample No		OM-36	OM-37	OM-38	OM-39	OM-40	OM-45	OM-52
SiO_2	55.5	51.8	52.6	51.4	51.8	49.6	53.9	
TiO_2	0.88	0.65	0.24	1.7	0.42	0.58	0.45	
Al_2O_3	13.1	13.6	8.4	10.6	13.7	13	6	
Fe_2O_3	13.5	16	8.4	15.4	11.8	12.6	15.8	
MnO	0.19	0.21	0.11	0.19	0.17	0.13	0.23	
MgO	3.6	6.5	14.3	6.6	8	10.3	7.9	
CaO	10.9	8.4	15.5	12.6	12.7	10.3	15.1	
Na_2O	1.9	2.5	0.39	1.2	1.2	1.7	0.53	
K_2O	0.32	0.13	0.05	0.24	0.09	1.5	0.03	
P_2O_5	0.07	0.08	0.01	0.06	0.03	0.24	0.02	
Total	**99.96**	**99.87**	**100**	**99.99**	**99.91**	**99.95**	**99.96**	
Sc (ppm)	9.9	8.9	8.6	7.7	8.5	8	7.9	
V	298.6	286.5	288.3	263	307.7	309.4	273.7	
Cr	21200.4	10690.4	12720.9	13342.2	11503	11938	9877.1	
Co	111.5	102.5	108.7	104.4	106.1	94.1	87.1	
Ni	1055.4	894.5	1016.5	990.5	851.3	676.8	1013.4	
Cu	60.7	66.3	59	115.7	34.8	90.2	78	
Zn	72.3	57.4	73.8	83	59.4	64.2	46.6	
Rb	16.4	9.7	4.4	6	4.3	11.2	5.5	
Sr	0.57	0.71	0.44	0.53	0.37	0.39	0.94	
Y	1.9	2.2	2.1	1.7	2.2	2.4	2.1	
Zr	0.27	0.32	0.27	0.24	0.37	0.3	0.28	
Nb	3.7	4.4	4.3	4.3	4.7	4.8	4.8	
Ba	19.6	6.6	8	5.8	6.8	7	8.2	
Hf	0.42	0.43	0.45	0.36	0.55	0.49	0.46	
Ta	0.01	0.04	0.05	0.08	0.02	0.02	0.15	
Th	1.3	1.2	1.5	1.03	1.2	0.72	2.7	
U	0.13	0.05	0.21	0.1	0.08	0.1	0.25	
Rare earth element composition								
	OM-36	OM-37	OM-38	OM-39	OM-40	OM-45	OM-52	
La (ppm)		1.16	1.02	1.28	0.83	1.30	1.05	1.15
Ce	2.93	2.91	2.94	2.26	3.40	3.08	2.88	
Pr	0.34	0.34	0.37	0.28	0.38	0.39	0.36	
Nd	1.71	1.91	1.83	1.46	1.94	2.08	1.82	
Sm	0.44	0.48	0.45	0.38	0.50	0.52	0.45	
Eu	0.12	0.13	0.12	0.11	0.14	0.14	0.12	
Gd	0.79	0.85	0.89	0.67	0.89	0.95	0.89	
Tb	0.16	0.17	0.18	0.14	0.20	0.20	0.18	
Dy	1.38	1.48	1.49	1.18	1.55	1.71	1.49	
Ho	0.35	0.38	0.37	0.31	0.39	0.44	0.38	
Er	1.12	1.26	1.21	1.02	1.28	1.43	1.26	
Tm	0.18	0.21	0.19	0.17	0.20	0.23	0.20	
Yb	1.20	1.42	1.26	1.13	1.33	1.51	1.31	
Lu	0.21	0.25	0.24	0.20	0.25	0.26	0.23	
Pb	0.01	0.02	0.01	0.02	0.01	0.01	0.01	
∑REE	12.08	12.81	12.83	10.13	13.75	13.99	12.73	
CeN/YbN		0..66	0.55	0.63	0.54	0.69	0.55	0.59
LaN/SmN		1.66	1.32	1.76	1.35	1.62	1.25	1.58
GdN/YbN		0.54	0.49	0.58	0.49	0.55	0.52	0.56
Eu/Eu*	0.62	0.61	0.57	0.65	0.63	0.60	0.57	
Rb/Nb	4.97	2.48	1.14	1.54	1.03	2.64	1.27	
Th/Nb	2.95	2.24	2.91	1.98	2.15	1.26	4.67	

Fig. 2 AFM diagram for pyroxenites (after Irvin and Baragar, 1975)

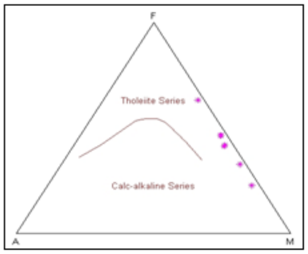


Fig. 3 Rock Classification diagram (K_2O Vs SiO_2 after Peccerill and Taylor 1976)

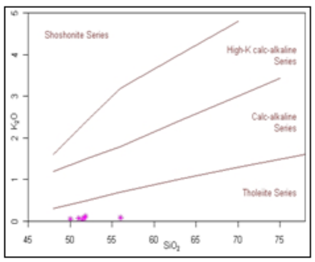
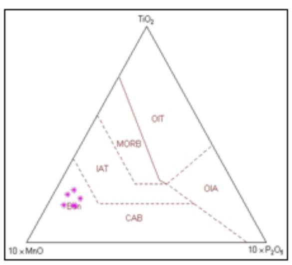


Fig. 4 TiO_2-MnO-P_2O_5 triplot for Pyroxenite. (after Mullen 1983)



Total REE value of pyroxenites varies from (10.13-13.99ppm) with limited REE, (Ce_N/Yb_N= 0.55-0.69) and LREE fractionation (La_N/Sm_N= 1.32-1.66). The HREE also conclude limited fractionation (Gd_N/Yb_N= 0.49-0.58) with negative Eu anomaly.

Condritic normalized REE plot (after Sun and McDonough (1989) of pyroxenites reflects negative Eu anomaly with slight enrichment of HREE (Fig. 5). The negative Eu anomaly in these samples may be interpreted as due to fractionation of plagioclase ± hornblende and can be imposed when the melt phase enters the stability field of plagioclase. The Low LREE and slight enriched trend of HREE may be retained some what by clinopyroxenes or to a greater extent by hornblende. Relative to primitive mantle most of the samples shows the relative enrichment of LILs and LREEs (Fig 6). They are further characterized by a low Th abundance and a distinct Nb-Ta, Zr-Hf trough. These features are characteristic of tholeiitic basalts produced at destructive plate margins or within plate tholeiites contaminated by continental crust (Hawkesworth et al., 1994). In order to understand the tectonic environment of the studied samples the plot Ti/1000 &V (after Shervais, 1982) shown in (Fig. 7) depicts that the studied samples fall in the Arc tholeiitic environment.

Fig. 5 Chondrite normalized REE diagram for the Pyroxenites after Sun and McDonough (1989)

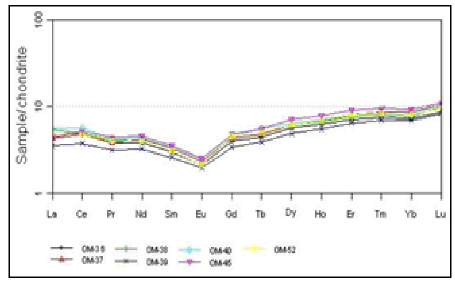


Fig. 6 Primitive Element-normalizes multi-element diagram for Pyroxenites after Sun and McDonough (1989)

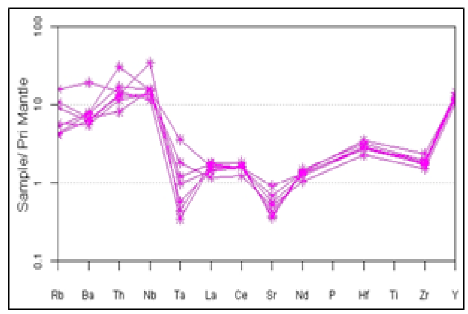
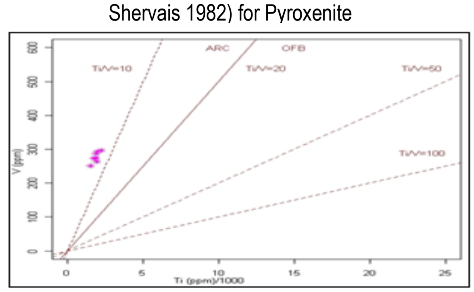


Fig. 7 Ti/1000 Vs V tectonic discrimination diagram (after Shervais 1982) for Pyroxenite



Conclusions

The geochemical constraints of the pyroxenites of Mettupalaiyam ultramafic complex suggest island arc magmatism. The major element relations of pyroxenites suggest tholeiitic to calcalkaline signatures of typical island arc environment. They are further characterized by a low Th abundance and a distinct Nb-Ta, Zr-Hf trough. These features are characteristic of tholeiitic basalts produced at destructive plate margins or within plate tholeiites contaminated by continental crust. The studied samples show depleted trend in HFSE. The –Ve Eu anomaly observed in the pyroxenite samples signify the role of plagioclase fractionation in their petrogensis.

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