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PETROCHEMISTRY OF AMPHIBOLITES FROM MATHURAPUR, DISTRICT SANTHAL PARGANAS, BIHAR

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Abstract

Amphibolites of Precambrian age around Mathurapur occur in two distinct geologic settings i.e., (i) as discordant bodies associated with orthopyroxene-bearing gabbros (massive amphibolite) and (ii) as concordant bands following the general foliation direction (S_2) of the gneissic country rock (schistose amphibolites). Both varieties of amphibolites have igneous parentage and have affinities with high alumina olivine tholeiite magmatic liquid. The massive amphibolites have formed due to retrograde alteration of orthopyroxene gabbros, whereas, schistose amphibolites probably represent a separate metamorphosed basic magmatic phase in the area.

Introduction

The major rock types in the area around Mathurapur (24°21′45″ N : 86°38′15″ E) include well differentiated metagabbros (olivine metagabbro, orthopyroxene metagabbro and other comagmatic basics), amphibolites and granite-gneisses. The rocks show imprints of regional metamorphism (middle amphibolite facies) associated with Satpura orogeny. The amphibolites are grouped into two distinct categories (viz. massive and schistose) on account of differences in their field association, texture and mineral assemblage. The massive amphibolites occur in a variable zone (5 to 10 m) along the peripheries of gabbroic bodies (particularly associated with most evolved orthopyroxene metagabbros), which occur as discordant intrusives. These amphibolites exhibit crude foliation of the gneissic country rock. The schistose amphibolites occur as continuous or detached bands (several metres to a few km in length and 50 to 100 m in width) sharing the dominant regional foliation (S_2) of the granite gneisses. The present paper deals with the mineralogy, chemistry and genesis of the above amphibolites.

Petrography

Schistose amphibolites: These are well foliated medium to coarse-grained rocks with hornblende and plagioclase arranged in alternate bands. Plagioclase, hornblende and augite (0–20%) constitute about 98% of the rock. Opaques, sphene and zoisite are present as accessory minerals. Bluish green hornblende is observed replacing augite. Plagioclase mostly occurs as subhedral, untwinned grains and constitutes about 50% of the rock.

Massive amphibolites: These are medium-grained, dark coloured, massive rocks with crude schistosity defined by linear arrangement of hornblende. Under microscope, the igneous texture is often seen more or less preserved while pyroxenes (both ortho and clino) are extensively replaced by moderately pleochroic olive green hornblende. Plagioclase has recrystallized into untwinned granular aggregates often retaining its lath-shaped form and without any significant change in its composition. Composition varies widely in different samples (An_{52-75}) similar to orthopyroxene gabbros. Some of these rocks (A/75) contain appreciable amount (up to 9 %)

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of garnet which occurs either as xenoblasts or cluster of granular aggregates replacing mafic minerals. The main constituents of these amphibolites are plagioclase (~40%), hornblende (35-60%) and relict pyroxenes (3-25%). Magnetite and chlorite are minor accessory minerals.

Analytic Techniques

Major elements were determined by wet chemical methods and have accuracy under 2%. The elements Cu, Zn, Ni and Co were estimated by atomic absorption spectrophotometry whereas Cr, V, Sr and Ba were determined by emission spectrography and have accuracy within ± 10 and ± 30 by respective methods.

Geochemistry

Major and trace element analyses of amphibolites with comparisons are given in Table I. Figure 1 shows the inter-element variations of amphibolites and Mathurapur gabbros. The gabbros show familiar crystal-fractionation trends. The massive amphibolites plot with orthopyroxene metagabbros which support field and petrographic observations that they were formed due to retrograde alteration of the associated gabbros.

The composition of schistose amphibolites broadly resembles massive amphibolites (both are hypersthene and olivine normative), but show salient chemical differences in their Fe, Ti, K, P, Ni and Cr contents and Na/K, K/P, K/Ba and Cr/Ni ratios (Table I), which support field and petrographic evidences that the two amphibolites are not comagmatic. The plots of schistose amphibolites also suggest the same (Fig. 1).

Petrogenesis

Ti, P, Cr and Ni are considered amongst the elements least susceptible to migration (mobile) during alteration and metamorphism even at the highest grades and thus, can be used for discrimination of metabasic rocks (Winchester and Floyd, 1976; Floyd and Winchester, 1978). Further, Ti and P are hygromagmatophile elements and are preferentially concentrated in the liquid phase as fractional crystallisation proceeds. Based on above facts the present authors propose a diagram (Fig. 2) which is capable of discriminating ortho- and para-amphibolites without significant discrepancy. Fig. 2 shows the covariation (with smooth linear trend) and abundance of these elements in different suites of basic igneous rocks. The plots of metagreywackes from same locality (Hörmann *et al* 1980, Table X) scatter widely and those of metasomatic amphibolites (Smithson *et al* 1971) show a horizontal trend (Fig. 2). The plots of schistose- and massive-amphibolites (together with orthopyroxene gabbros) show a linear trend with little deviation on the aforesaid diagram indicating their igneous parentage. The plots of these in Niggli si/alk and Niggli 100 mg-c-(al-alk) and mg/c diagrams (Leake, 1964) also suggest the same.

The inset in Fig. 2 presents the variation of Ti/Zr in oceanic ridge basalt (N-MORB) from Mariana (Wood *et al* 1981) which shows a smooth linear trend with a similar promise of being utilized for discrimination of amphibolites.

The positive correlation of compatible elements Ni and Cr with Mg has been advocated by many (e.g. Hörmann *et al* 1980) as a strong evidence in favour of magmatic origin of the rocks. The correlation between Ni and Mg in both schistose

TABLE I. Major- and trace-element data for amphibolites and orthopyroxene gabbro with comparisons.

	Massive amphibolite						Schistose amphibolite			Ortho-pyroxene meta-gabbro (av. 14)	Abyssal oceanic tholeiite *	Island arc tholeiite *	Island tholeiite *	High-alumina tholeiite *	Conti-nental rift tholeiite *	Deccan tholeiite (av, 4) **
	A/92	A/41	A/53	A/112	A/75	A/57	A/11	A/125	A/30							
SiO_2	45.75	47.37	47.06	47.49	47.38	52.73	48.56	47.70	49.37	47.82	49.8	51.1	49.4	51.7	50.3	48.66
TiO_2	0.89	1.00	0.79	1.03	1.07	1.19	0.55	0.61	1.09	0.83	1.5	0.83	2.5	1.0	2.2	2.46
Al_2O_3	16.57	15.95	15.41	15.27	15.46	14.07	17.47	14.95	14.88	15.84	16.0	16.1	13.9	16.9	14.3	15.26
Fe_2O_3	1.89	1.79	3.51	2.58	2.28	2.43	1.82	2.05	1.86	1.73	10.0+	11.8+	12.4+	11.6+	13.5+	3.37
FeO	8.71	8.60	9.25	10.26	10.35	9.34	6.77	7.11	7.40	10.22	—	—	—	—	—	9.88
MnO	0.16	0.19	0.24	0.22	0.21	0.22	0.15	0.18	0.18	0.20	—	—	—	—	—	0.18
MgO	8.81	7.55	9.88	10.44	6.42	7.44	7.05	7.35	6.75	9.29	7.5	5.1	8.4	6.5	5.9	5.72
CaO	11.72	13.32	8.32	6.29	11.42	8.48	12.17	12.86	12.53	9.76	11.2	10.8	10.3	11.0	9.7	9.64
Na_2O	1.90	2.08	2.15	2.25	2.40	2.75	2.02	3.10	2.65	2.13	2.75	1.96	2.13	3.10	2.50	2.33
K_2O	0.27	0.26	0.40	0.35	0.24	0.49	0.43	0.86	0.74	0.23	0.14	0.40	0.38	0.40	0.66	0.50
P_2O_5	0.14	0.12	0.16	0.22	0.18	0.28	0.09	0.11	0.19	0.15	—	—	—	—	—	0.34
H_2O^+	1.68	1.66	1.70	1.82	2.54	1.11	1.73	1.41	1.34	1.62	—	—	—	—	—	1.81
Total	98.49	99.89	98.87	98.22	99.95	100.53	98.81	98.29	98.98	99.82	—	—	—	—	—	100.15
(ppm)																
V	—	40	35	—	40	50	10	20	50	34	—	—	—	—	—	388
Cr	—	50	50	—	15	20	100	100	60	45	300	50	250	40	160	87
Ni	—	70	55	—	25	25	35	35	30	81	100	25	150	25	85	62
Co	—	20	30	—	30	20	20	20	20	33	32	20	30	50	38	—
Cu	—	65	80	—	65	45	80	20	20	75	—	—	—	—	—	119
Zn	—	25	30	—	40	30	30	50	50	26	—	—	—	—	—	147
Ba	—	10	15	—	10	50	10	15	50	10	11	50	100	115	170	254
Sr	—	105	70	—	105	175	35	105	70	91	135	225	350	330	350	243
Na/K	6.3	7.2	4.8	5.8	8.9	5.0	4.2	3.2	3.2	8.3	17.6	4.4	5.0	6.9	3.4	4.2
K/P	3.7	4.1	4.8	3.0	2.5	3.3	9.1	14.9	7.4	2.9	—	—	—	—	—	—
K/Ba	—	216	221	—	199	81	357	476	123	191	105	66	32	29	32	16
Cr/Ni	—	0.7	0.9	—	0.6	0.8	2.9	2.9	2.0	0.6	3.0	2.0	1.7	1.6	1.9	1.4
D.I.	17.9	19.5	20.6	21.1	22.1	29.6	20.1	21.2	27.0	19.2	—	—	—	—	—	26.23

+ total iron as Fe_2O_3; * source of data (Condie, 1982); ** source of data (Krishnamurthy and Cox, 1980).

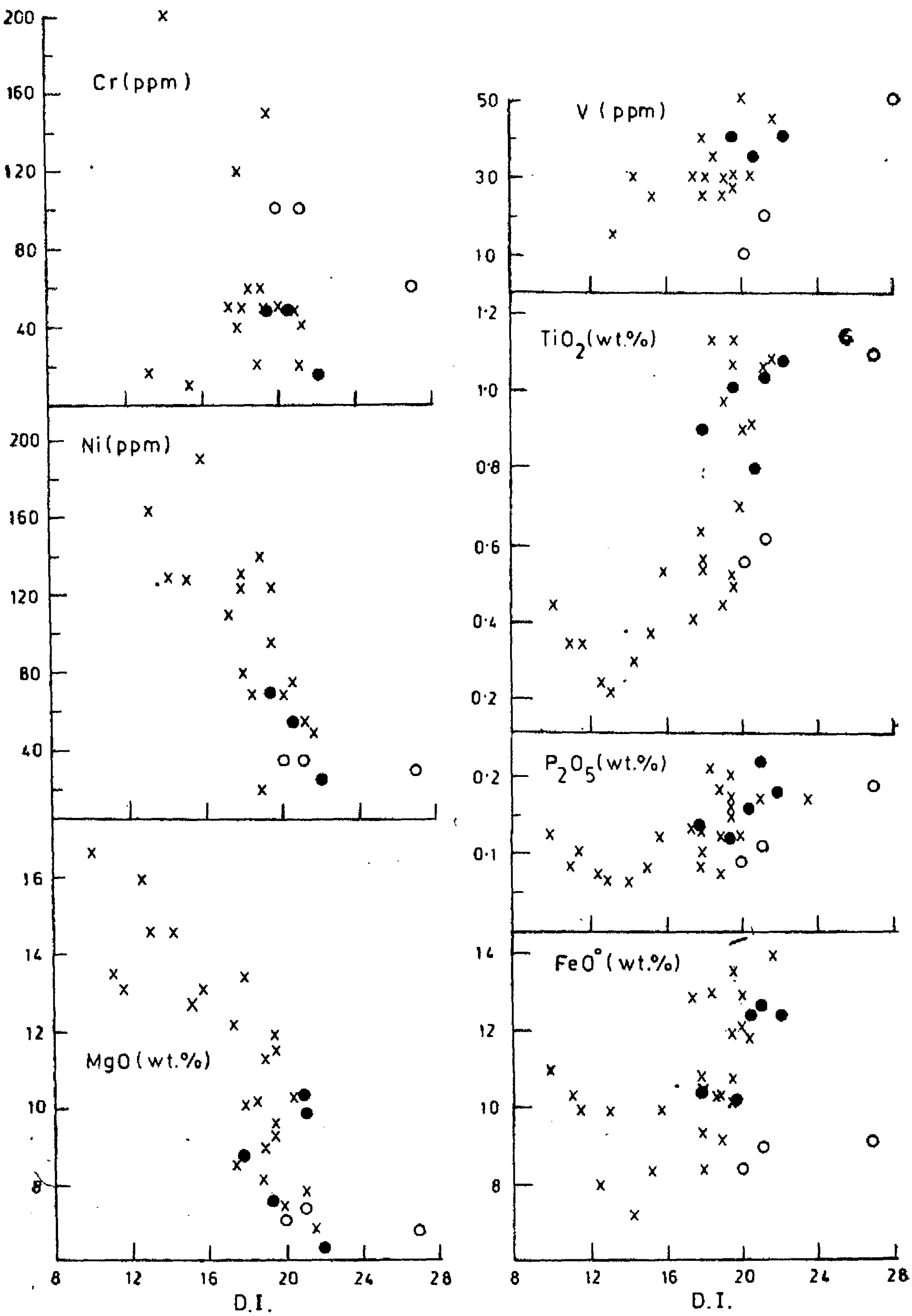

Figure 1. Differentiation Index (D.I., Thornton and Tuttle, 1960) *versus* major and trace element plots of metagabbros (crosses), massive amphibolites (solid circles) and schistose amphibolites (open circles) from Mathurapur.

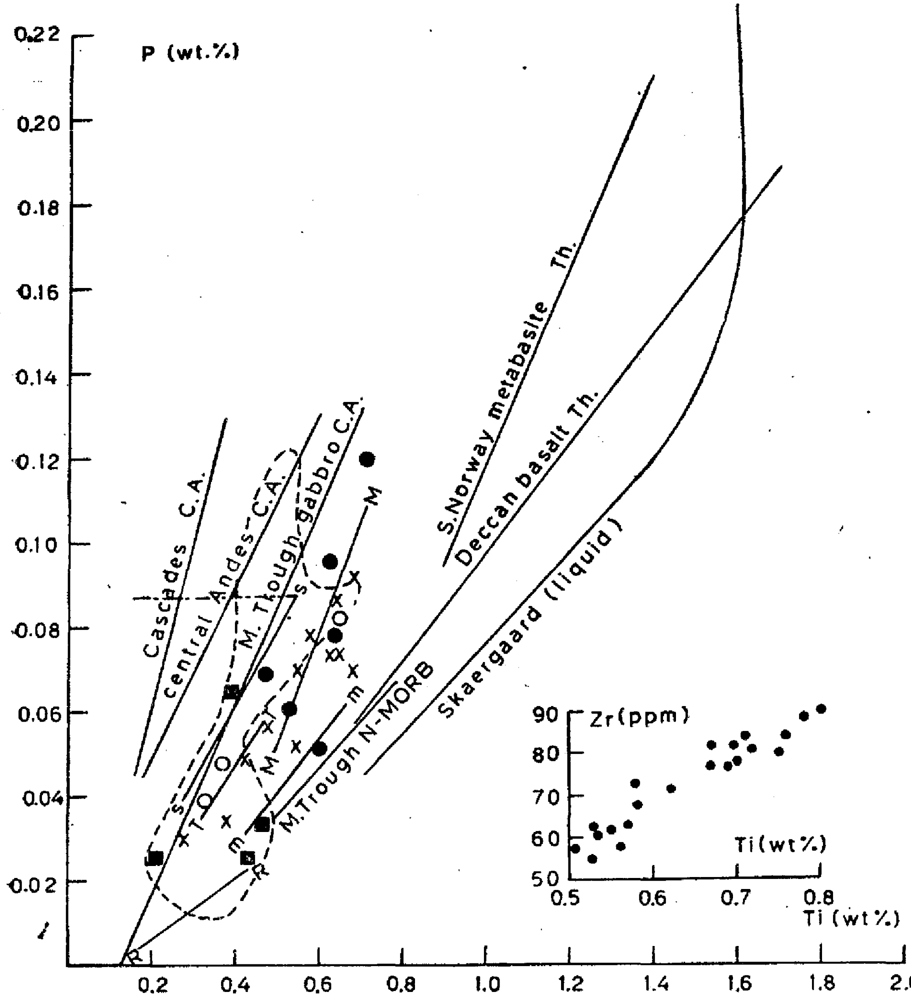

Figure 2. Ti/P plots of various basic igneous rocks (data source mainly from Wood *et al* 1981; Clough and Field, 1980; Ghose, 1976; Sukheswala and Poldervaart, 1958; Miyashiro, 1974; Wager and Brown, 1967), Metagreywackes (Hormann *et al* 1980, solid square), metasomatic amphibolites (Smithson *et al* 1971, dash–dot line), orthopyroxene metagabbros (crosses) and others same as in Fig. 1. Dashed curve encloses the field of greywackes. Stillwater liquid (S), Rhum liquid (R), Tongas tholeiite (T), Mariana seamount basalt (M); Mariana island arc tholeiite (m). The inset shows Ti/Zr plots of Mariana Trough N-MORB.

and massive-amphibolites is apparent (Fig. 1). Cr does not show similar correlation, may be on account of its non-precise spectrographically determined data.

The preceding discussion lends firm support that both massive- and schistose-amphibolites of Mathurapur have igneous parentage. They show chemical affinity with similar magmatic parent liquids (high-alumina olivine tholeiite, Table I), although they are not comagmatic. The schistose amphibolites probably represent a separate (pre-tectonic) basic magmatic phase in the area whose mineral assemblage and texture were completely reconstituted during Satpura orogeny..

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