Geol. Bull. Univ. Peshawar, Vol. 26, pp. 35–43, 1993

Two clinopyroxenes from Upper Swat: Their chemistry and its petrogenitic implications

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ABSTRACT: *Two sets of clinopyroxene analyses, one from the andesite of Utror volcanics and other from a troctolite patch in diorite from Deshai, Upper Swat, are used to ascertain the magmatic affinity and tectonic setting of their host rocks. Both the sets indicate igneous crystallization in island arc-related oroganic environments. Clinopyroxene data from the volcanic rock indicate calcalkaline affinities,while, those from troctolite appear to have grown from a tholeiitic magma.*

INTRODUCTION

The Utror volcanics of the Late Cretaceous age represent the eastern part of the extrusive component of the Kalam-Dir igneous complex. Associated with these volcanics are the pre- and post-volcanism diorites (see Hamidullah et al., 1990; Hamidullah & Onstot, 1992; Zeitler, 1985; Treloar et al., 1989). These volcanics comprise of a suite of basalt, basaltic andesite, andesite, rhyolite, dacite, ignimbarite, agglomerates and tuffs which extend from Kalam in Upper Swat through Dir to Afghanistan west of Shahai Qila (Fig.1). The Kalam-Dir igneous complex is part of the Kohistan arc(s) system which is delineated by the main Mantle Thrust (MMT) from Indian plate in the south and by Main Karakoram Thrust (MKT) from the Eurasian plate in the north (see Tahirkheli et al., 1979; Bard, 1982: Coward et al., 1986; Khan et al., 1991). Preliminary field and petrographic studies of the complex were carried out by Sultan (1970) and Jan and Mian (1971). On the basis of rock chemistry Majid (1979), Majid and Paracha (1980) and Majid et al. (1981) attributed the origin of these volcanics and associated diorites to subduction related calcalkaline magmatism in the Kohistan arc(s) system. Hamidullah et al. (1990) and Shah (1991) worked out the petrology and rock chemistry of the western part of the complex at Dir and drew similar conclusions. Sullivan (1993) in a detail study of the complex reported the presence of tholeiitic component with the calcalkaline lavas.

The chemical composition of primary clinopyroxene in basic rocks is considered to be registering magmatic affinities of the parent liquid (Kushiro, 1960; LeBas, 1962; Hamidullah & Bowes 1987; Literrier et al., 1982). Due to the scarcity of suitable specimens magmatic characters of the Utror volcanics and associated diorites have so far not been testified on the basis of mineral chemistry. Petrographic data indicate that among the volcanic rocks only basalts and basaltic andesites contain phenocrysts of clinopyroxene and hornblende. Plagioclase phenocrysts are however, common to all the volcanics (see Majid & Paracha, 1979; Majid, 1980; Majid et al., 1981; Hamidullah et al., 1990; Hamidullah & Onstot, 1992). In the diorites no clinopyroxene has been reported. However, mafic-ultramafic patches in the gneissose quartz diorite, contain clinopyroxene (see Hamidullah & Onstot, 1992). A small outcrop/patch (UT47) of such type has been noticed south of Deshai, along Usho river

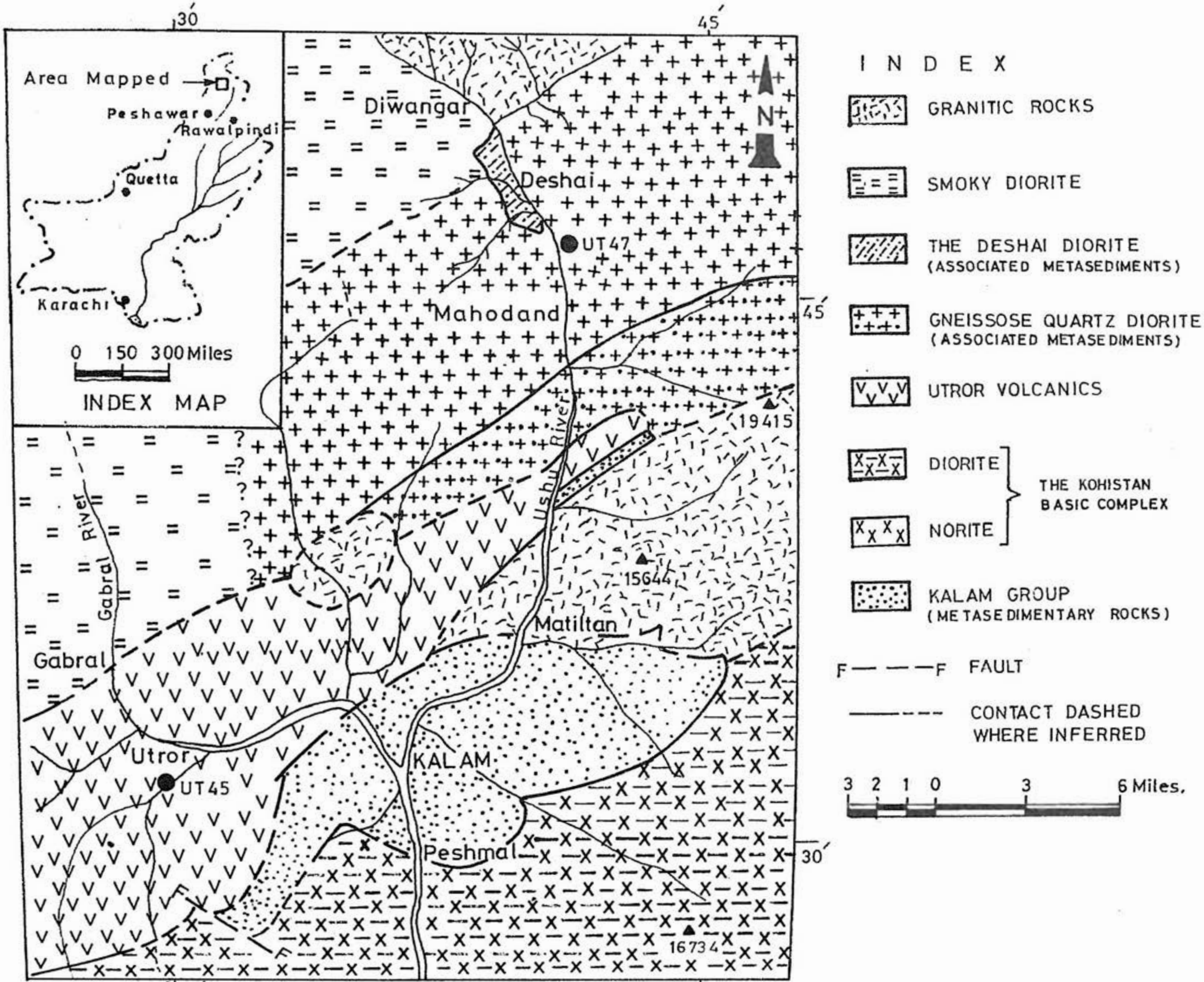

Fig. 1. Geological map of the eastern part of Kalam Diwangar complex (after Majid, 1979)

(Fig.1). It was difficult to establish a meaningful field relationship of this patch with the surrounding gneissose quartz diorite because of the lack of clear contacts. A sample collected from this patch (UT47) turned out to be troctolite, containing olivine (Fo_{73-77}), calcic clinopyroxene and plagioclase (An_{87-97}) (see Figs. 1 & 2).

The present study has been carried out to envisage the magmatic characters of the volcanic rocks on the basis of clinopyroxene chemistry. Clinopyroxene phenocrysts from porphyritic andesite (UT45) collected from Utror, was selected for this purpose. In order to study the nature of the mafic-ultramafic patches, clinopyroxene compositions from the troctolitic patch (UT47) have also been compared.

ANALYTICAL TECHNIQUES

More then 100 spots on clinopyroxene grains were analyzed using electron microprobe on ARL-EMX wavelength dispersive system (WDS) combined with TN-2000 Tracer Northern energy dispersive system (EDS) with operating conditions of 15 Kev, 0.2 microamps beam current and a beam diameter of about 7 microns at the Department of Geological and Geophysical Science, Princeton University, USA. K and Ca were analyzed by WDS and other elements by EDS. The unit time for EDS spectra was 50-100 seconds combined with 10 seconds WDS analysis. All analyses were converted to weight percent using the Bence-Albee (1968) reduction scheme. Procedural details are presented in Hollister et al. (1984). Using the procedures of Droop (1987) and Schumacher (1991) and a computer program by the auther, mineral formulae and ferrous-ferric calculations were carried out on the basis of 4 cations and 6 oxygens. Only "close to perfect analyses" presented in Table 1 are used for comparison.

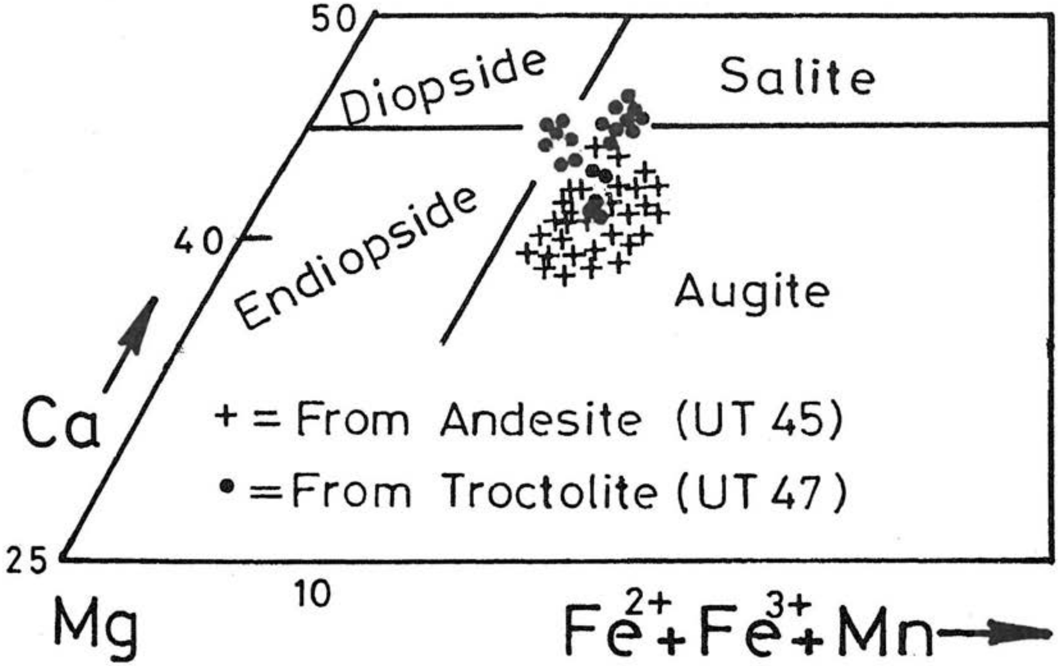

Fig.2. Clinopyroxene compositions from the Utror volcanics and Deshai troctolite in the pyroxene quadrilateral of Pldervaart and Hess (1951).

TABLE 1. CLINOPYROXENE COMPOSITIONS FROM THE ANDESITE AT UTROR AND TROCTOLITE NEAR DESHAI, KALAM, UPPER SWAT. NUMBERS UTCPX103-133 ARE FROM ANDESITE (UT45) AND NUMBERS UTCPX160-224 FROM TROCTOLITE (UT47)

	UTCPX103-106		UTCPX107-109		UTCPX110-115		UTCPX116-122		UTCPX123-129		UTCPX130-133	
	Mean(5)	STD	Mean(2)	STD	Mean(4)	STD	Mean(7)	STD	Mean(7)	STD	Mean(4)	STD
SiO_2	50.862	1.007	51.630	0.540	50.825	0.847	51.379	0.628	51.240	0.520	51.450	0.722
TiO_2	0.318	0.263	0.550	0.280	0.605	0.221	0.401	0.206	0.480	0.344	0.520	0.193
Al_2O_3	2.166	1.133	1.165	0.125	3.185	1.285	1.664	0.870	1.829	0.508	1.965	0.401
Fe_2O_3	3.364	0.491	1.250	0.530	0.738	0.423	2.429	0.809	2.221	0.899	1.725	0.354
FeO	5.548	0.674	7.175	0.405	7.165	0.416	6.130	0.631	6.051	1.118	6.843	0.493
MnO	0.280	0.174	0.300	0.100	0.183	0.188	0.297	0.141	0.313	0.221	0.205	0.122
MgO	16.376	0.742	16.760	0.290	15.828	0.965	16.564	0.509	16.260	0.364	16.415	0.777
CaO	20.026	0.344	19.290	0.160	20.115	0.715	20.180	0.376	20.579	0.505	20.055	0.154
NiO	0.460	0.333	0.185	0.185	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cr_2O_3	0.242	0.158	0.140	0.030	0.203	0.048	0.147	0.085	0.219	0.085	0.165	0.029
Total	99.642	1.016	98.445	0.235	98.845	0.411	99.191	0.618	99.191	0.475	99.343	0.411
Formulae on the bases of 4 cations and 6 oxygens												
Si	1.893	0.032	1.939	0.018	1.900	0.029	1.916	0.020	1.912	0.018	1.916	0.013
Ti	0.009	0.007	0.016	0.008	0.017	0.006	0.011	0.006	0.013	0.010	0.015	0.005
^{iv}Al	0.091	0.043	0.050	0.007	0.100	0.029	0.068	0.027	0.079	0.023	0.081	0.016
^{vi}Al	0.004	0.008	0.002	0.002	0.040	0.032	0.006	0.014	0.001	0.003	0.005	0.003
Fe^{3+}	0.094	0.013	0.035	0.015	0.021	0.012	0.068	0.022	0.062	0.025	0.049	0.010
Fe^{2+}	0.173	0.021	0.225	0.013	0.224	0.014	0.191	0.020	0.189	0.036	0.213	0.017
Mn	0.009	0.006	0.010	0.004	0.006	0.006	0.009	0.005	0.010	0.007	0.007	0.004
Mg	0.908	0.035	0.938	0.015	0.881	0.052	0.920	0.025	0.904	0.017	0.910	0.036
Ca	0.799	0.020	0.777	0.006	0.805	0.029	0.806	0.017	0.822	0.018	0.800	0.009
Ni	0.014	0.010	0.006	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cr	0.007	0.005	0.004	0.001	0.006	0.001	0.004	0.003	0.006	0.002	0.005	0.001

CHEMICAL CHARACTERS OF CLINPYROXENE

The UT45 clinopyroxene analyses appear to be exclusively of calcic-augite composition whereas the UT47 clinopyroxene data straddle around the junction of diopside, salite, endiopside and augite fields, but mostly occur in the calcic-augite field of the pyroxene quadrilateral (Fig.2). On the ^{vi}Al vs ^{iv}Al plot of Aoki and Kushiro (1968), 86% of the UT45 and 91% of the UT47 data show igneous characters (Fig.3a). Using the discriminant analyses factors of Nisbet and Pearce (1977) 80% of the UT45 and nearly all the UT47 spots occupy the field of volcanic arc basalts (above the subduction zone in an island arc). The rest of the UT45 compositions occur in the combined field for volcanic arc basalts and ocean floor basalts, but mostly along the boundary with the field of volcanic arc basalts (Fig.3b). Almost all of the UT45 and UT47 data show non-alkaline (tholeiitic + calcalkaline) characters on the Al_2O_3 vs SiO_2 plot of Le Bas (1962) and Ti vs Ca+Na plot of Leterrier et al., (1982) (Figs.4a,b). When plotted on the Ti+Cr vs Ca plot (Fig.4c), both the UT45 and UT47 data reflected non-orogenic tectonic setting. It was further noted that the clinopyroxene of UT45 have calcalkaline and that of UT47 have tholeiitic characters as is indicated by plotting their analyses Ti vs ^{t}Al plot of Leterrier et al. (1982).

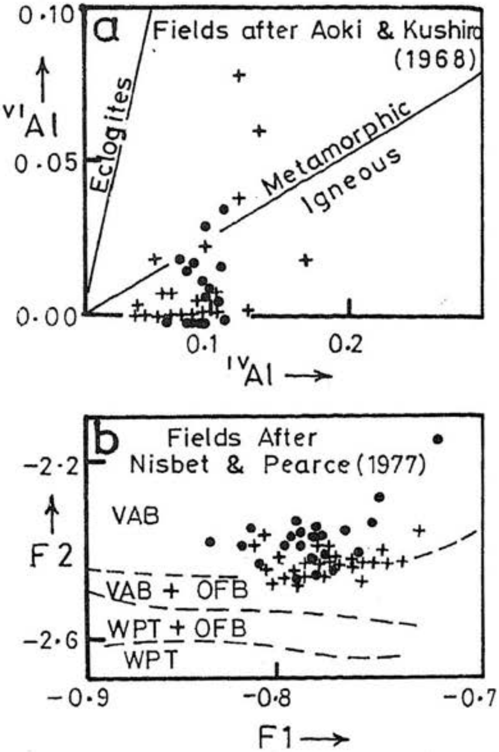

Fig.3. Clinopyroxene data shown on (a) ^{iv}Al vs ^{vi}Al and (b) F2 vs F1 plots.

DISCUSSION

The chemistry of clinopyroxene from Utror volcanics indicate these lavas to be calcalkaline and could be generated in orogenic environment of a subduction zone (see Ringwood, 1974; Jakes & White, 1976; Nisbet & Pearce, 1977). This interpretation is in accordance with the conclusions drawn by previous workers (Majid, 1979; Majid & Paracha, 1980; Majid et al., 1981; Hamidullah et al., 1990; & Sullivan, 1993). On the other hand, clinopyroxene from the troctolitic patch in the gneissose quartz diorite though indicates orogenic environment, its crystallization appears to have occurred from a magma of tholeiitic characters. Olivine (Fo_{73-77}), plagioclase (An_{87-97}) and highly calcic clinopyroxene occur as cumulate phases in this rock, an assemblage not found either in volcanics or the surrounding diorite(s). However, Symes et al. (1987) have described orbicular norites and diorites intruding into gneissose quartz diorites, along the Ushu river, Deshai, shown as Deshai diorite in Figure 1. The norite indicates cumulate layering, and contains orbicules with olivine or clinopyroxene as cores surrounded by orthopyroxene reaction rims. Olivine is Fo_{69}, clinopyroxene is diopsidic and plagioclase is An_{79-93}; a mineral

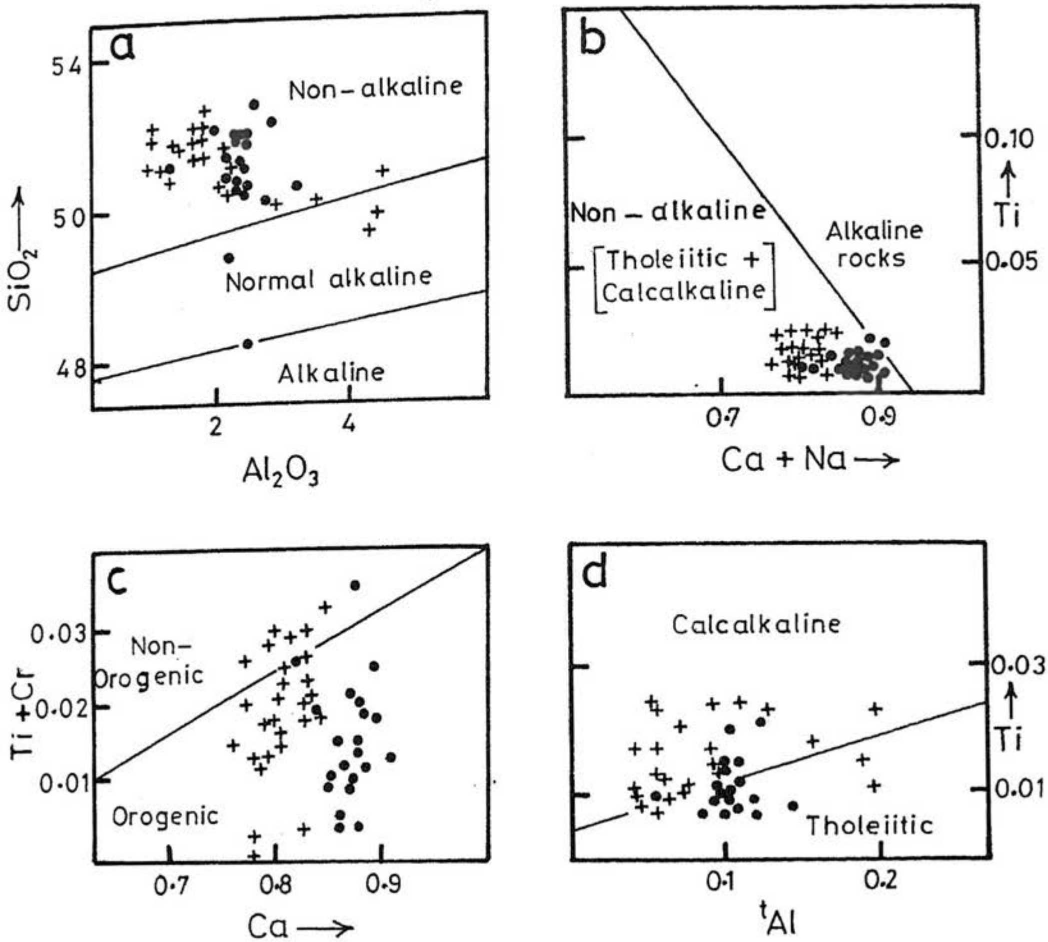

Fig. 4a-d. Clinopyroxene compositions shown on various affinity and tectonic setting discrimination diagrams of LeBas (1962) and Leterrier et al (1982). Symbols as in Figure 2.

chemistry close to that of the presently studied troctolite. Therefore, the troctolite may be representing an early assemblage accumulated before the formation of orthopyroxene reaction rims in the magmatic chamber. Latter on, these cumulates were probably brought upwards by the dioritic magma. Interestingly, the mineral chemistries of both the troctolite and layered norite show a close resemblance to those of the ultramafic association of the Chilas complex for which Khan et al. (1989) have suggested derivation through the melting of a sub-arc mantle source (see also Khan, 1993). The plagioclase of the troctolite was selected for dating using the $^{40}Ar/^{39}Ar$ techniques, but due to the presence of excess argon a highly discordant spectrum with dates varying from 435±10 Ma to 1950±28 Ma were obtained (see Hamidullah & Onstot, 1992). These dates are considerably higher than the accepted ages of rocks in the Kohistan island arc. Therefore, it is difficult to establish a solid view about the origin of the mafic-ultramafic patches under investigation on the basis of the present data. However, these data have revealed the presence of tholeiitic cumulates in the area, which if thoroughly investigated may provide an important clue in the jig-saw puzzle of the Kohistan arc(s) system construction.

Acknowledgements: The analyses were performed during the Fulbright postdoctoral Fellowship of the principal author (1985-86) at Princeton University, USA. The lab. work was supported by NSF PYI program, EAR84-51696 (TCO). C. Kulick (Princeton) is acknowledged for assistance in laboratory and Mr. Durrani for drafting the figures.

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