Trace and Rare-Earth Elements distribution patterns of rocks of Chilas Complex and Kamila Amphibolites, Kohistan Arc, North Pakistan

Allah B Kausar†*, Hiroshi Yamamoto‡, Kazuya Kubo§, Yutaka Takahashi§, Masumi U Mikoshiba§ and Hafiz U Rehman†‡

† Geoscience Laboratory, Geological Survey of Pakistan, Shahzad Town, Islamabad 44000, PAKISTAN
‡ Department of Earth and Environmental Sciences, Faculty of Science, Kagoshima University, Kagoshima, JAPAN
§ National Institute of Advanced Industrial Science and Technology, Geological Survey of Japan, Tsukuba 305-8567, JAPAN

** To whom correspondence should be addressed. E-mail: kausar_20001@yahoo.com*

The Kohistan Arc is situated in the northwestern part of Pakistan and formed during subduction in the Tethys Ocean between the Indian and Asian continental plates (Tahirkheli 1979). From north to south, the interior of the Kohistan arc comprises Jurassic to Cretaceous sedimentary rocks called Yasin Group followed by a sequence of arc type volcanic rocks called the Rakaposhi Volcanics. The southern margin of the Rakoposhi Volcanics is bounded by large-scale granitic plutons called the Kohistan Batholith, which are intruded by huge volumes of noritic gabbros (Chilas Complex) during a phase of intra-arc rifting and mantle upwelling (Treloar et al. 1996), which indicates a change of the tectonic framework with opening of a backarc like that behind the Mariana Arc. The rock assemblages of the Chilas Complex are more or less deformed, exhibiting foliation and ductile shear zones at places with a geochemical trend between tholeiitic and calc-alkaline compositions (Khan et al. 1993). The southern margin of the Chilas Complex consists of imbricated and variously metamorphosed gabbros, diorites, granodiorites, granites and metavolcanics called the Kamila Amphibolites with a tholeiitic geochemical trend. In the south, the Kamila Amphibolites are separated from the Jijal Complex by a shear zone, the Pattan fault. The southern margin of the Jijal Complex is bounded by the Main Mantle Thrust (MMT), where the Kohistan Arc is juxtaposed against Indian continental crust. Not surprisingly, there has been much interest in and debate about the origin of these juxtaposed and diverse magamtic complexes of the Kohistan Arc.

Basically, the Chilas Complex is composed of two distinct rock associations: 1) the Main Facies Zone (MFZ), formally known as gabbro-norite association, and 2) Thak Gah Ultramafic-Mafic Association (TGUM), formally known as Ultramafic-Mafic-Anorthosite Association (UMA). Genetic relationship between these MFZ and TGUM and the origin of their magmas are still uncertain, although many geological and petrological aspects on the Chilas Complex have been discussed by many workers (e.g. Khan et al. 1989).

The TGUM is composed mainly of ultramafic (dunites, wehrlite, websterite) and mafic (gabbros, gabbronorites, anorthosites etc) sequences. The rock assemblages of MFZ include a wide range from gabbronorites to trondhjemites, with the main lithologies typically being gabbros and diorites. The Kamila Amphibolites is also a composite body, predominantly consisting of amphibolites, with subordinate hornblendites, hornblende gneisses, diorites, gabbros, plagiogranites, metavolcanics and minor metasediments. According to field and petrographic characteristics, the rock assemblages of Kamila Amphibolites are classified into “fine-grained metavolcanics; referred herein as Group-1”; which are intruded by “coarse-grained plutonic rocks, referred herein as Group-2”.

The present study is focused on the trace and rare earth element (REE) geochemistry of an extensive sampling of the major rock types of the Chilas Complex and the Kamila Amphibolites. The geochemistry of the trace and REE provides a sensitive and powerful petrogenetic tool that, integrated with the existing information on the batholith, is used to provide insights into sources, generation and evolution of the batholithic magmas.

The field, petrographic and geochemical data suggest that the various rock types from MFZ and Group-2 of the Kamila Amphibolites are linked through fractional crystallization and evidence for common parentage includes a close spatial and temporal association, systematic variations in mode and mineralogy, and progression through time towards more evolved compositions. The dissimilarities between the rock assemblages of the Group-1 of Kamila Amphibolites and Group-2 and MFZ are illustrated by comparison of their major and trace elements characteristics. In particular, the rocks belonging to Group-1 differ from the rocks of Group-2 and MFZ in having relatively low SiO_2, Al_2O_3, P_2O_3 and Na_2O contents, and higher MgO, FeO, CaO and TiO_2. Trace element distinctions of Group-1 relative to Group-2 include lower abundances of most incompatible elements (particularly Ba, Rb and Sr), lower $(La/Sm)_N$ and $(La/Yb)_N$ ratios, and higher abundances of transitional elements. Two chemically distinct groups can also be recognized on the basis of N-MORB-normalized spidergrams, excluding alkali (K, Rb) and alkaline earth (Sr, Ba) elements. The patterns representing rocks of Group-2 and MFZ do not differ significantly and are remarkably parallel, with only minor crossing of these elements; and the part of the pattern from Ta to Yb lies parallel to but slightly lower than MORB, presumably reflecting the pre-subduction characteristics of the mantle wedge. In contrast, Rb, Ba, Th and K are enriched above this level. A marked depletion at Nb and Ta is a characteristic of island arc tholeiitic magmas.

The Group-1, fine-grained metavolcanics are different from the rocks of Group-2 and MFZ in their MORB-normalized element patterns. The most striking difference is the relative enrichment in HFSE particularly in Ti, Ta and Nb in Group-1 relative to Group-2 and MFZ. By comparison with Group-2 and MFZ, rocks of Group-1 show no negative Ta-anomaly, and very small negative Nb-anomaly, and part of the curve from Th to Gd also discriminates these rocks from the Group-2 and MFZ. The difference in trace element contents and patterns supports the conclusion that the rocks of Group-1 and MFZ are not the deformed protolith of other plutonic rocks of the Kamila Amphibolites and Chilas Complex. On the contrary, these metavolcanic basic rocks are genetically related among themselves and the similar REE distribution in these rocks suggests that all these rocks have a common source region, but show a greater influence of an N-MORB source with possible contribution of a less depleted mantle source.

The result of this study further suggests that many of the basic assemblages from the MFZ and Group-2 may be the products of cumulus enrichment processes and the crux of the argument relies on their REE data. In common with many island arc suites, magmas from the Chilas Complex and Group-2 of Kamila Amphibolites have variable Eu anomalies. The positive to negative Eu anomalies in the REE profiles for the basic to more evolved rocks indicate that fractionation has taken place during magma evolution. More basic magmas, with less than 53 wt % SiO_2 have positive anomalies indicative of accumulation of more plagioclase than is lost due to crystal settling. The flat profile, as shown by some samples suggests that Eu gained by plagioclase settling into it compensated Eu loss by plagioclase fractionation. Similarly, the study of Hakesworth et al. (1977) of the Scotia arc shows similar REE distribution.

The main conclusion that can be reached on the basis of geochemical studies is that there is a bimodality of compositions, Group-1 having clear MORB affinities, the Group-2 and MFZ clear island-arc affinities. We would suggest that the complex-metavolcanic amphibolite association of the Kamila Amphibolites, and similar units occurring elsewhere in the Kamila Amphibolites, having N-type MORB affinity and may represent fragments of pre-existing oceanic crust. But the assemblages of the metaplutonic rocks of the MFZ and Kamila Amphibolites from the study area differ significantly from MORB by a characteristic over-abundance of LILE over other incompatible elements such as REE or HFSE and pronounced depletion in Ta and Nb. We relate this to an original tectonic setting of southern Kohistan above the Tethyan actively subducting plate to the north. Fluids enriched in water-soluble LILE are released from the subducting slab by dehydration of OH-bearing minerals inhomogeneously impregnating the overlying mantle wedge, the actual source region of these rocks. Therefore, the mantle-derived heat and material contributed of the rock assemblages of the metaplutonics of the Kamila Amphibolites and MFZ of the Chilas Complex.

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