

Application of Geochemical Mapping in Unraveling Paleoweathering and Provenance of Karewa Deposits of South Kashmir, NW Himalaya, India

Nadeem A. Bhat^{1*}, B. P. Singh², Aijaz A. Bhat³, Som Nath⁴ and D. B. Guha⁵

Geological Survey of India, ¹State Unit, Andhra Pradesh, Hyderabad - 500 068; ³State Unit, Karnataka and Goa, Bangalore - 560 001;

⁴Northern Region, Lucknow - 226 024; ⁵Western Region, Jaipur - 302 004, India

²Department of Geology, Banaras Hindu University, Varanasi - 221005, India

*E-mail: mnadeem83@gmail.com; nadeem.bhat@gsi.gov.in

ABSTRACT

Ninety Six composite stream sediment samples of Karewa deposits from parts of Pulwama and Budgam districts of south Kashmir were analysed for major, trace and rare earth elements to understand the nature of weathering and provenance. A-CN-K and A-CNK-FM plots of the samples indicate almost similar contents in Al₂O₃, CaO, Na₂O, K₂O and MgO as those of upper crust, reflecting very poor to moderate weathering history. Similarly, the low to moderate chemical index of alteration (CIA) values (33.97 to 68.87), chemical index of weathering (CIW) values (57.68 to 84.80) and plagioclase index of weathering (PIA) values (31.49 to 75.67) suggest a low to moderate intensity of weathering in source area. The discriminant function diagrams revealed quartzose sedimentary provenance, with some of the samples falling in intermediate igneous source, probably reflecting recycled orogen provenance. The sample data show fractionated REE patterns with (La/Yb)_{cn} varying from 7.42 to 9.52 and a negative Eu anomaly 0.64 - 0.71, is regarded as evidence for a differentiated source. In La-Th-Sc diagram, sediments fall in a region of mixed source rocks with two samples falling in basic source rock area. The samples fall close to the values of UCC, PAAS and NASC, indicating large provenance with variable geographical and geological setting. On La/Th plot, the sediment data fall into the range of UCC, indicating that the sediments did not have a uniform provenance.

INTRODUCTION

Weathering of crustal rocks is one of the principal mechanisms controlling the geochemical distribution and cycling of elements at the interface of the atmosphere, hydrosphere, lithosphere and biosphere (Taylor and McLennan, 1985; Middleberg et al., 1988; Condie et al., 1995; Bock et al., 1998; Elzien et al., 2014; Bhat, 2017). During the process of weathering, minerals and rocks are physically disintegrated, dissolved and carried out through various agents to form sediments (Krishnamurthy et al., 1986; Nesbitt et al., 1996; Fontes et al., 1993; Mullins, 1998; Last and Smol, 2001; Jin et al., 2001, 2003; Laird et al., 2003; Rose et al., 2004). The chemical record of the sediments is also affected by factors such as source rock, sorting and processes during transportation, sedimentation and post depositional reactions etc. (Nesbitt et al., 1996; Fedo, et al., 1997; Feng and Kerrich, 1990; Cullers and Podkovyrov, 2000).

Major oxides, some trace elements such as Sc, Ga, Th, Pb, Cr, Zr, Rb, Sr, and rare earth elements (REEs) are useful indicators for studying geological processes including weathering and provenance of sedimentary basins (Bhatia, 1983; Taylor and McLennan, 1985; Bhatia and Crook, 1986; Roser and Korsch, 1986, 1988; McLennan and Taylor, 1991; McLennan et al., 1993; Last and Smol, 2001; Jin et al., 2001; Das and Haake, 2003; Jin et al., 2003). The REEs and high

field strength (HFSE) elements including Y, Zr, Ti, Nb, Ta, Th, Sc, Hf, and Co are most suitable for provenance determination, because of their relatively low mobility during weathering, transport, diagenesis and metamorphism (Nesbitt and Young, 1982; Taylor and McLennan, 1985; Condie et al, 1995; Cochran and Berner, 1996; Berner and Cochran, 1998; Grunsky et al., 2009).

During recent past, numerous studies have been carried out in Kashmir valley on geochemical characterization of the sediments and water. Jeelani and Shah (2006) analyzed water and sediment samples of Dal Lake of Kashmir to monitor natural and anthropogenic influence. The study suggested that the lake is influenced by natural and anthropogenic activity. Ahmad and Chandra (2013) and Chandra et al. (2016) studied the loess paleosol sediments of the Karewa Group of Kashmir valley. They found a mixed source rocks for the sediments with a large provenance, which apparently have undergone weak to moderate recycling processes. Dar et al. (2014) analyzed soil samples and pedogenic carbonate nodules from three representative loess paleosol sections for micromorphic, $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ isotopic ratios to provide information on the palaeo-ecology and palaeoclimate of the Kashmir valley. Sheikh et al (2014) studied the water and sediment chemistry of Wular Lake, Kashmir to assess the weathering and anthropogenic impact. As per the USEPA sediment quality standards and Geoaccumulation Index, the lake is affected by natural and anthropogenic activity. Rashid et al. (2015) inferred low to moderate chemical weathering in the source region for clay-silt dominant sediments of Wular lake, north Kashmir. Mir and Jeelani (2015) indicated moderate weathering and immaturity of the sediments in river Jhelum and its tributaries in Kashmir valley basin. Similarly, Mir and Mir (2015) carried out geochemical mapping in parts of Ganderbal and Bandipora districts of north Kashmir. Babeesh et al. (2017) carried out the geochemistry of late Quaternary loess - paleosol horizons of Mansbal area of Kashmir valley and inferred weak to moderate weathering of the parent material derived from mixed source rocks, which apparently have undergone weak to moderate recycling processes.

The present work is a part of National Geochemical Mapping Programme of Geological Survey of India, to identify new prospective areas for mineral deposits and demarcate areas of potential geo-environmental hazards (Bhat and Bhat, 2014). This work is the first surface sediment multi element geochemical study in Pulwama and Budgam districts of Kashmir valley and it is aimed at identifying the palaeo-weathering and source characteristics of the Karewa deposits based on soil geochemistry.

STUDY AREA

The study area covers the parts of Pulwama and Budgam districts of South Kashmir, Jammu and Kashmir state, in Survey of India

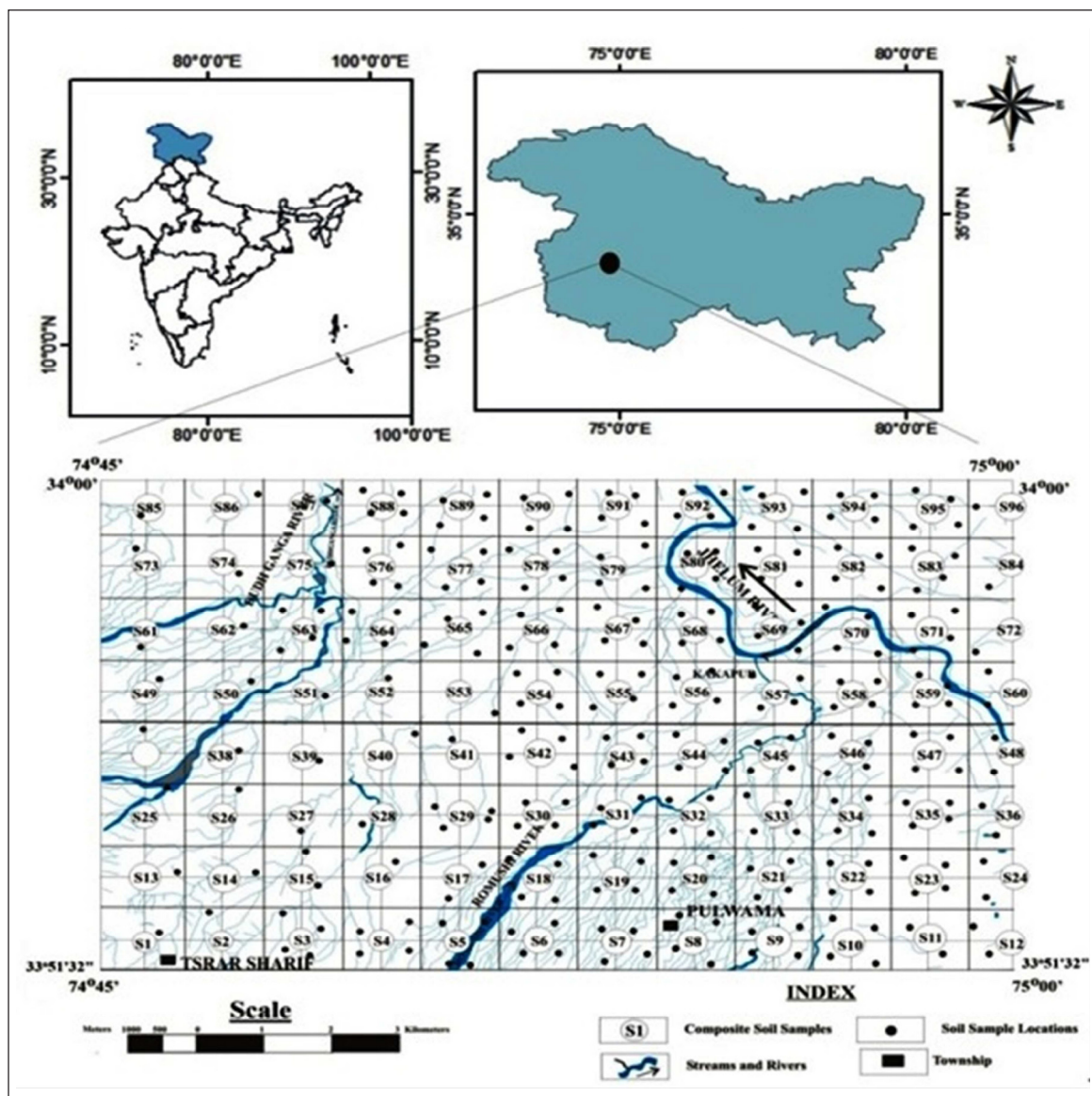


Fig 1. Location Map of the study area showing sampling sites of stream sediments.

toposheet No. 43K/13, bound by latitudes 33°51'32" N and longitudes 74°45'00" E, covering an area of 400 sq. km. Geologically, the area is covered by semi-consolidated sediments of Karewa Group, which are underlain by Permo-Triassic sequence and overlain by Recent alluvium (Bhatt, 1975). Panjal Traps, Mamal and Zewan formations (Paleozoic succession) form the basement for Karewa rocks and are exposed towards the north-eastern part of the study area. The Plio-Pleistocene Karewa rocks are commonly divided into two lithologic units, the lower Karewa (Hirpur Formation) and upper Karewa (Nagum and Dilpur Formations) (Bhatt, 1989). Lower Karewa rocks are gently inclined and better exposed on the Pir Panjal side, have an unconformable contact with overlying nearly horizontal upper Karewa rocks which are better exposed on the Great Himalayan side (Bhatt, 1975). The undifferentiated Quaternary sediments include recent alluvium, alluvial tracts, flood plains, river terraces, and talus and scree fans (Bhatt, 1976).

MATERIAL AND METHODS

Fine stream sediments transported by running water were collected from lower order streams from first, second and third orders, which represent 1 sq. km area. The stream sediments were collected at 3 to 5 places up stream over a distance of 100 meters within the 1x1 km

grid. Where the grids were devoid of streams, slope wash samples were collected. After drying, each sample was powdered and sieved through 120 micron mesh, coned and quartered and were packed in 500 g food grade bottles. Major oxides, Cr, Rb, Sr, Y, Zr, Nb, Ba, Ga, Sc, V, U, Th, Pb, Ni, Co, Cu and Zn were analysed by XRF (Make and Model: M/S Panalytical; MAGIX, 2.4 KW Sequential XRF Spectrometer). REEs, Sn, In, Hf, Ta, Mo, W, Ge, Be were analysed by ICPMS (Make and Model: ICPMS - Perkin Elmer Sciex ELAN -6100). As, Sb, Bi and Se were analysed by VG-AAS, Li and Cs by F-AAS, Cd and Ag by GF-AAS (Make and Model: VARIAN: AA Series and Perkin Elmer: PE Series). Standard reference material GSD10 with known element concentrations was analysed after each batch of 20 samples for accuracy and duplicate samples after each batch of 10 samples were analysed for repeatability (Bhat, 2017).

RESULTS

Major Oxides

The statistical analysis of major, trace and REEs of stream sediments of study area and their comparison with Post Archean Australian Shale (PAAS) (Taylor and McLennan, 1985), Upper Continental Crust (UCC) (Wedepohl, 1995) and North American Shale

Table 1. Statistical analysis of major, trace and REE's of 96 stream sediments samples of study area and comparison with UCC (Wedepohl, 1995), PAAS (Taylor and McLennan, 1985) and NASC (Gromet et al., 1984).

	Min.	Max.	Mean	Std. Dev.	Coef. of Var.	PAAS	NASC	UCC
Major Oxides (Wt %)								
SiO ₂	47.56	65.90	59.87	3.21	0.05	62.8	64.8	66
Al ₂ O ₃	11.77	14.85	13.19	0.64	0.05	18.9	16.9	15.2
Fe ₂ O ₃	4.81	7.46	5.75	0.49	0.08	7.22	5.65	5
CaO	1.14	10.63	3.64	1.85	0.51	1.3	3.63	4.2
MgO	1.97	3.00	2.40	0.21	0.09	2.2	2.86	2.2
Na ₂ O	0.97	1.40	1.13	0.09	0.08	1.2	1.14	3.9
K ₂ O	1.97	2.82	2.38	0.17	0.07	3.7	3.97	3.4
MnO	0.05	0.11	0.08	0.01	0.14	0.11	0.06	0.08
TiO ₂	0.66	0.92	0.79	0.05	0.06	1	0.7	0.5
P ₂ O ₅	0.11	0.50	0.22	0.09	0.39	0.16	0.13	-
LOI	5.96	14.13	8.39	1.42	0.17	6.00	-	-
Total	95.17	100.75	97.87	1.04	0.01	-	-	-
CIA	33.97	68.87	56.42	7.82	0.14	-	-	-
CIW	57.68	84.80	74.58	6.42	0.09	-	-	-
PIA	31.49	75.67	58.61	10.16	0.17	-	-	-
Trace Elements (ppm)								
Ba	397.11	544.98	465.86	26.45	0.06	650	636	550
Co	11.00	27.00	17.75	2.78	0.16	23	25.7	10
As	4.00	22.60	9.70	2.48	0.26	-	28.4	1.5
Cu	19.00	92.00	28.80	8.04	0.28	50	-	25
Nb	8.00	20.00	16.34	1.52	0.09	19	13	25
Ni	23.00	64.77	40.34	7.45	0.18	55	58	20
Rb	81.34	134.40	104.06	9.48	0.09	160	125	112
Sc	12.00	29.00	17.21	3.03	0.18	16	14.9	11
Sr	82.00	197.00	119.66	22.81	0.19	200	142	350
Th	7.92	14.91	11.22	1.39	0.12	14.6	12.3	10.7
V	47.00	109.04	85.38	11.65	0.14	150	130	60
Zr	160.00	295.00	214.51	24.46	0.11	210	200	190
U	2.34	5.65	3.02	0.54	0.18	3.1	2.66	2.8
Hf	5.03	9.63	7.34	0.89	0.12	5	6.3	5.8
Cs	5.00	5.50	5.01	0.05	0.01	15	5.16	3.7
Sb	0.20	0.90	0.60	0.14	0.24	-	2.09	0.2
Rare Earth Elements (ppm)								
La	34.05	55.06	41.14	3.72	0.09	38.20	31.10	30.00
Ce	63.92	103.18	77.61	6.71	0.09	79.60	66.70	64.00
Pr	7.47	12.01	9.04	0.78	0.09	8.83	7.70	7.10
Nd	30.41	48.05	36.43	3.01	0.08	33.90	27.40	26.00
Sm	5.80	9.22	6.97	0.57	0.08	5.55	5.59	4.50
Eu	1.18	1.86	1.42	0.11	0.08	1.08	1.18	0.88
Gd	5.12	7.67	6.09	0.45	0.07	4.66	4.90	3.80
Tb	1.23	1.91	1.50	0.12	0.08	0.77	0.85	0.64
Dy	6.00	4.90	7.63	6.00	0.46	4.68	4.17	3.50
Ho	1.11	0.91	1.40	1.11	0.08	0.99	1.02	0.80
Er	3.39	2.79	4.23	3.40	0.25	2.85	2.84	2.30
Tm	0.40	0.65	0.51	0.04	0.07	0.41	0.48	0.33
Yb	2.67	4.14	3.27	0.23	0.07	2.82	3.06	2.20
Lu	0.41	0.62	0.49	0.04	0.07	0.43	0.46	0.32
(La/Yb) _N	7.42	9.54	8.47	0.42	0.05	9.2	6.9	9.2
Eu/Eu*	0.60	0.71	0.67	0.02	0.03	0.66	0.69	0.65
ΣREE	161.26	257.03	194.98	16.34	0.08	183	157	146

Composition (NASC) (Gromet et al., 1984) is presented in Table 1. Major elemental analysis shows that sediment samples are rich in SiO₂ followed by Al₂O₃, Fe₂O₃, CaO, MgO, K₂O, Na₂O, P₂O₅, TiO₂ and MnO. Harker diagrams are used to compare the abundance of major oxides along SiO₂ axis (Fig 2). In Harker diagrams, SiO₂ vs. Al₂O₃, Fe₂O₃, Na₂O, K₂O, MnO, P₂O₅ and TiO₂ plots showed a positive correlation with a rough linear trend. Negative correlation is observed for CaO, MgO and LOI against SiO₂. A gradual decrease in CaO, MnO and LOI content with an increase in SiO₂ content may be due to the multiple sources of the sediments.

In comparison with the average UCC and PAAS and NASC, representative continentally derived sediments, values of Taylor and McLennan (1985) and Gromet et al., (1984), the stream sediments are depleted in SiO₂, Al₂O₃, Na₂O and K₂O. However, the UCC normalized Fe₂O₃, MnO, TiO₂ and MgO shows higher concentration than the UCC but follow similar pattern to that of PAAS. This suggests that the

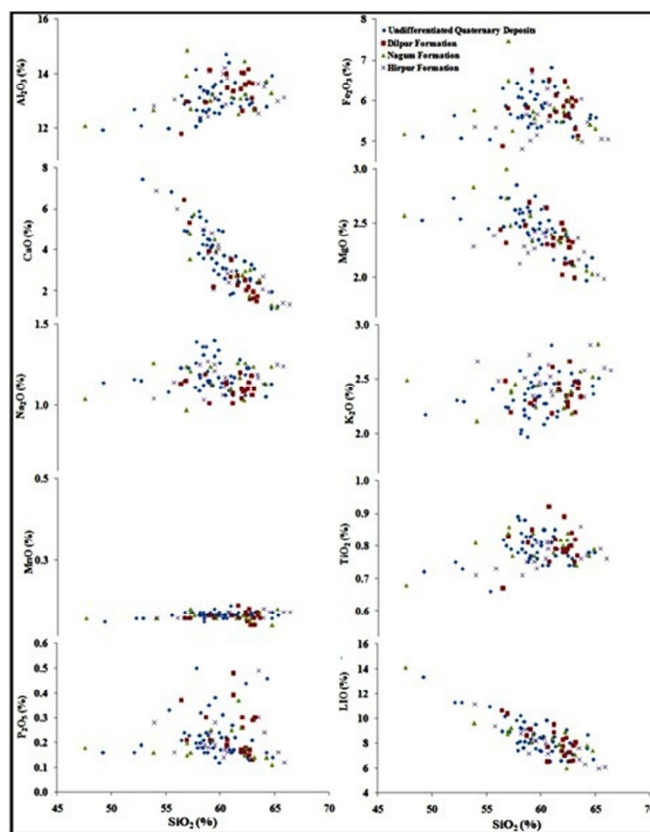


Fig 2. Harker diagrams of major oxides versus SiO₂ of the stream sediments.

ferromagnesian minerals are least affected by the modifications during weathering. The negative anomalies of Na₂O followed by K₂O (Fig. 3) indicate relatively more alteration of plagioclase feldspar than the K-feldspar. However, CaO shows wide range of variation in its concentrations with respect to UCC, as it varies greatly and shows both positive and negative anomalies on UCC normalized spider diagrams (Gallet et al., 1996). The less maturity of the sediments is indicated by higher values of CaO with respect to PAAS (Mahjoor et al., 2009). TiO₂ contents in the studied sediments are significantly higher than the UCC. However, it is slightly lower than the PAAS. The enrichment of TiO₂ is generally ascribed to the presence of Ti-bearing phyllosilicates (biotite and chlorite). These minerals generally reside in fine sediments such as clays. It also suggests significant contribution from the mafic source rocks.

Trace Elements

In order to evaluate nature and chemical behaviour of various trace elements during weathering processes, the average concentrations

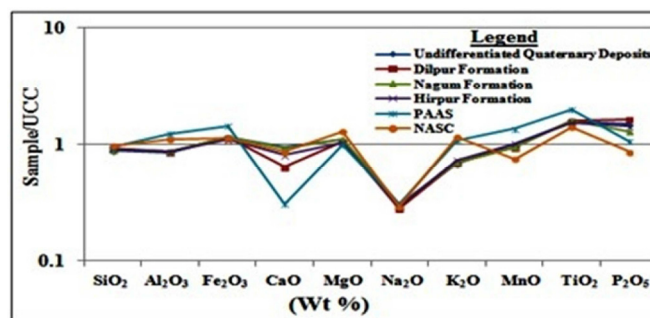


Fig 3. UCC normalized spider diagrams for major oxides of stream sediments (PAAS and UCC values after Taylor and McLennan, 1985; NASC values after Gromet et al., 1984).

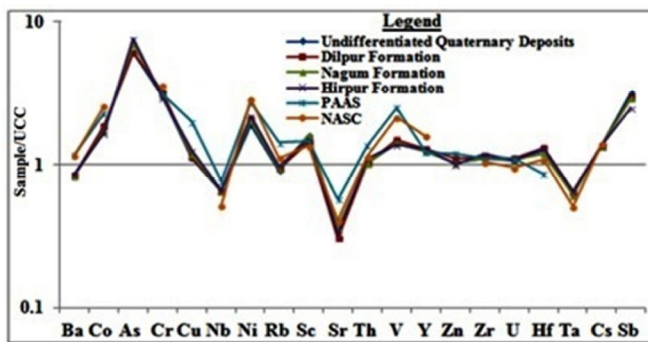


Fig 4. UCC normalized spider diagrams for trace elements of stream sediments (PAAS and UCC values after Taylor and McLennan, 1985; NASC values after Gromet et al., 1984).

of trace elements are plotted in Upper Continental Crust (UCC) normalized spider diagram (Fig. 4). All sediments have almost similar contents in trace elements and are enriched in Sc, Zr and Hf. These elements are commonly associated with heavy minerals, such as zircon, which is resistant to weathering. Barium and strontium mostly reside in plagioclase and K-feldspars, respectively (Puchelt, 1972, Bhat, 2017). The mean value of Ba is same as the UCC, and the mean value of Sr is similar to NASC and lower than the UCC indicating that the weathering of plagioclase was more responsible than K-feldspars. Elements such as Co, Cr, Ni, Th, V, Zn and Cs are enriched as compared to UCC but show negative anomaly with respect to PAAS and NASC. The lower values of the elements are due to their lower concentration in parent rock and association with clay minerals. This is in agreement with similar studies elsewhere (Nesbitt et al., 1980; Wronkiewicz and Condie, 1980; McLennan and Taylor, 1991; Taylor and McLennan, 1985; Awwiller, 1994). In general, low intensity weathering conditions were prevailing in the source area as compared to the conditions for PAAS and NASC before the sediments were contributed.

Rare Earth Elements

All the analyzed sediment samples have similar concentrations of the REEs. Chondrite normalized patterns are typical for shale in general, enriched in LREEs. All samples have pronounced negative Eu anomalies, ranging from 0.64 – 0.71. The Eu anomaly parallels the depletion of Na₂O and CaO, which suggests its development in response to plagioclase weathering (Nyakairu and Koeberl, 2001). Figure 5 illustrates that despite the difference in the absolute abundances, the samples show REE pattern that are similar to PAAS, but slightly differ in the HREE content compared to the UCC and NASC. The chondrite normalized La/Yb ratio ranges from 7.42 to 9.52, with most sediment having slightly higher values than those of PAAS and UCC.

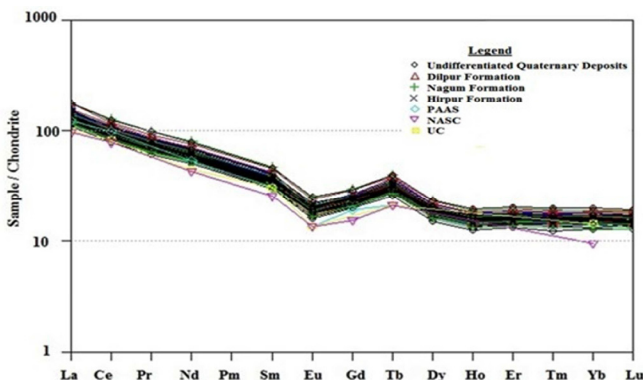


Fig. 5. Rare earth element plots of sediment samples normalized to chondrites after Taylor and McLennan (1985).

DISCUSSION

Paleo-Weathering Indices of Source Area

Chemical weathering of sediments and soils has been quantitatively estimated by calculating chemical index of alteration (CIA), plagioclase index of alteration (PIA) and chemical index of weathering (CIW) (Nesbitt and Young, 1982; Harnois, 1988; Fedo et al., 1995). Nesbitt and Young (1982) and Nesbitt et al. (1996) used the ternary diagrams (A-CN-K) considering Al₂O₃-(CaO + Na₂O)-K₂O and (A-CN-K-FM) considering Fe₂O₃ + MgO-(CaO + Na₂O + K₂O)-Al₂O₃ to deduce weathering trends. On both the A-CN-K and A-CN-K-FM diagrams, samples of the study area show almost similar contents in Al₂O₃, CaO, Na₂O, K₂O and MgO as similar to upper crust, reflecting very poor to moderate weathering history (Fig 6A and B).

The chemical index of alteration (CIA) was calculated with the formula:

$$CIA = ([Al_2O_3 / (Al_2O_3 + CaO^* + Na_2O + K_2O)] \times 100)$$

Where CaO* is the amount of CaO incorporated in the silicate fraction of the studied samples (Fedo et al., 1995). The calculated CIA values of the stream sediments ranged from 33.97 to 68.87, suggesting a low to moderate chemical weathering. Quantitative measure of plagioclase weathering is estimated by calculating the plagioclase index of alteration (PIA) as below.

$$PIA = ((Al_2O_3 - K_2O) / (Al_2O_3 + CaO^* + Na_2O - K_2O)) \times 100$$

Similar to the A-CN-K diagram, the plagioclase weathering trend of the samples fall on a single line indicating slight enrichment of anorthite. The sediments samples plot close to the Al₂O₃-K₂O apex of the triangle and display low CaO* values (Fig 7A), which indicate gradual depletion of anorthite and enrichment of secondary aluminous clay minerals with increased chemical weathering. The chemical index of weathering was calculated with the formula:

$$CIW = Al_2O_3 / (Al_2O_3 + CaO + Na_2O) \times 100$$

The PIA values of the studied sediments are comparable to the calculated values of CIW (Harnois, 1988) which does not include K₂O. Optimum fresh value for CIA and CIW is 50 and optimum weathered value for CIA and CIW is 100. CIW value of sediments in the present study varies from 57.68 to 84.80 with a mean value of 74.89. Both the indices are lesser than those of average shale, indicating degree of weathering in study area is low to moderate (Fig. 7B). The low to moderate values of CIA and CIW suggest that the feldspars were not fully converted to clay minerals (Nesbitt and Young, 1982; Maynard et al., 1995). Though hydro-climatic conditions are able to carry the mechanical disintegration of source rock material but due to short distance of sediment transportation from source rocks maturity of sediments is not achieved. The negative anomalies of SiO₂ and Al₂O₃ suggest semi-arid climatic conditions as these elements remain stable under such climate (Guo, 2010; Bhat, 2017).

Provenance

Major elements, trace elements and the REEs were used to infer the provenance of sediments. The geochemical signatures distinguish the sources of the sediments into four provenance zones, mafic, intermediate or felsic, igneous and quartzose sedimentary. For this purpose, the discriminant function diagrams proposed by Roser and Korsch (1986) have been used. The discriminant functions for the two plots used to discriminate the sediments from the study area are as follows:

The formula for raw oxides is given as:

$$\text{Discriminant Function (DF1)} = -1.773TiO_2 + 0.607Al_2O_3 + 0.76Fe_2O_3 + (T) - 1.5MgO + 0.616CaO + 0.509Na_2O - 1.224K_2O - 9.09$$

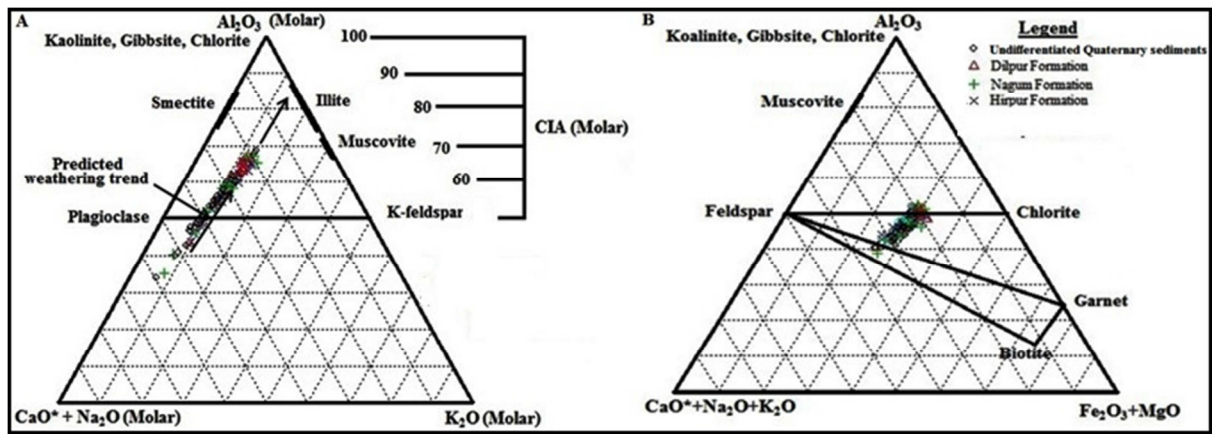


Fig. 6. Triangular diagrams showing weathering trend of studied samples (after Nesbitt and Young, 1982). (A) A-CN-K triangular diagram. (B) A-CN-K-FM triangular diagram.

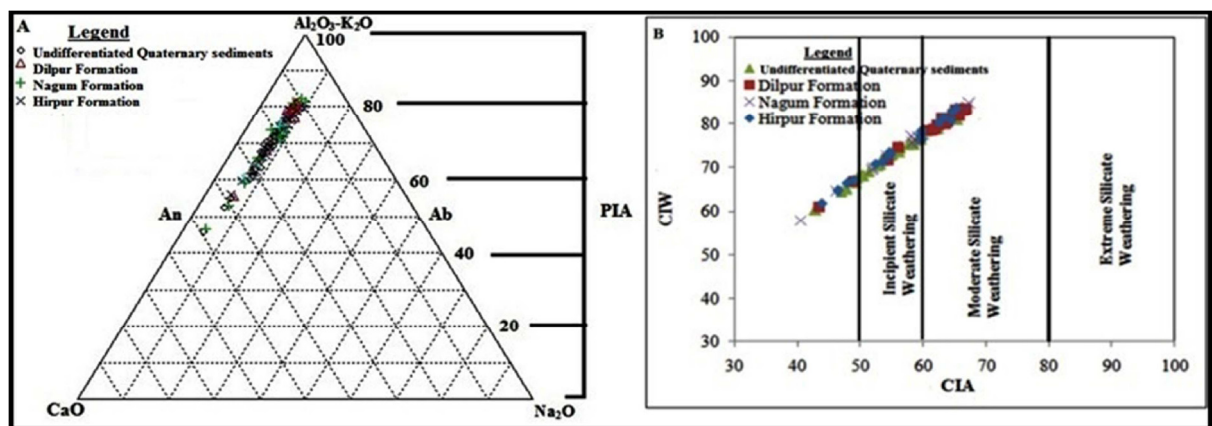


Fig.7. Triangular plot of Al_2O_3 - K_2O , CaO^* and Na_2O . The scale showing the plagioclase index of alteration (PIA) is shown at right (An, anorthite and Ab, albite). B. Scatter plots of CIA vs CIW for stream sediments of study area.

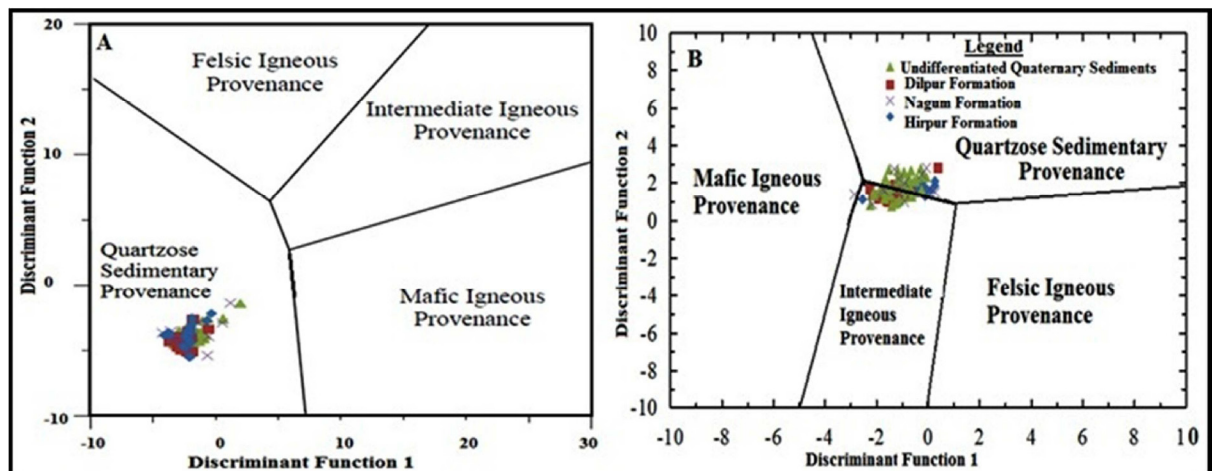


Fig.8. Discriminant function diagrams using major elements for the provenance signatures of the sediments (Roser and Korsch, 1988). A. Based on raw oxides. B. Based on ratio plot.

$$\text{Discriminant Function (DF2)} = 0.445TiO_2 + 0.07Al_2O_3 - 0.25Fe_2O_3(T) - 1.42MgO + 0.438CaO + 1.475Na_2O + 1.426K_2O - 6.861.$$

While that of the ratio plot is given as:

$$\text{Discriminant Function (DF1)} = 30.638 \frac{TiO_2}{Al_2O_3} - 12.541 \frac{Fe_2O_3(T)}{Al_2O_3} + 7.329 \frac{MgO}{Al_2O_3} + 12.031 \frac{Na_2O}{Al_2O_3} + 35.402 \frac{K_2O}{Al_2O_3} - 6.382$$

$$\text{Discriminant Function (DF2)} = 56.500 \frac{TiO_2}{Al_2O_3} - 10.879 \frac{Fe_2O_3(T)}{Al_2O_3} - 3.89.$$

$$\frac{Al_2O_3 + 30.875 MgO}{Al_2O_3} - 5.404 \frac{Na_2O}{Al_2O_3} + 11.112 \frac{K_2O}{Al_2O_3} - 3.89.$$

The plots using the raw oxides (Fig. 8A) reveal that the source of sediments is from quartzose sedimentary provenance, while ratio plots (Fig. 8B) also correspond with the oxide plots showing majority of the samples in quartzose sedimentary provenance. However, some of the samples fall in intermediate igneous source may be recycled orogen

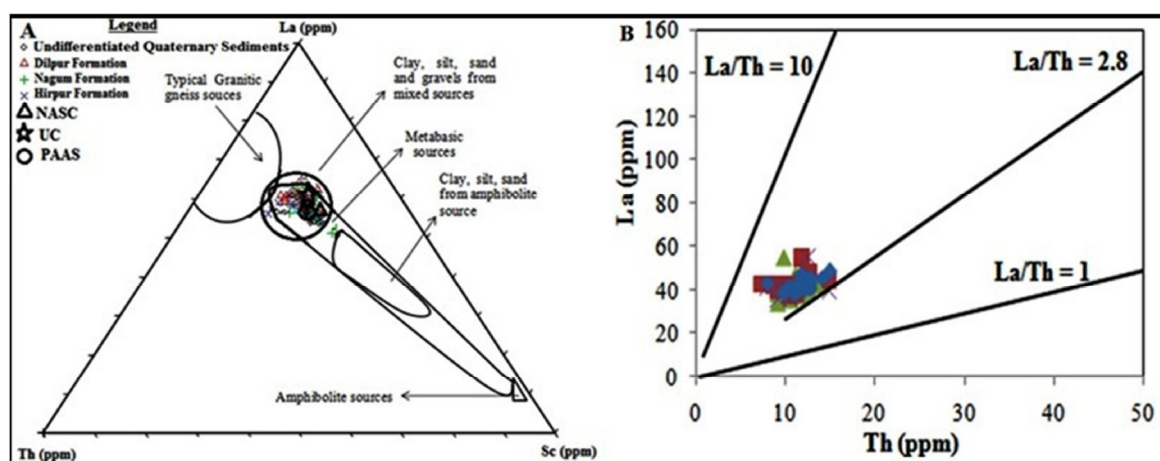


Fig 9. A. Ternary plot of La-Th-Sc for the sediment samples after Cullers (1994a) compared with PAAS, UC (data from Taylor and McLennan, 1985), and NASC (data from Gromet et al., 1984). **B.** La versus Th for the sediment samples. The La/Th = 2.8 ratio is that of upper continental crust (data from Taylor and McLennan, 1985).

provenance. Thus, the sediments could have been derived from a pre-existing sedimentary terrain.

In the La-Th-Sc diagram (Bhatia and Crook, 1986; Cullers, 1994a, b), the sediments fall in a region of mixed source rocks (Fig. 9A). The plotting of samples close to the UCC, PAAS and NASC suggest a vast provenance with variable geographical and geological setting (Gallet et al., 1996; Taylor and McLennan, 1985; Wronkiewicz and Condie, 1980), with two samples falling in basic source region. The clustering of sediment data more or less around the mixed source values suggest that the sediments were mainly derived from a sedimentary provenance with a little contribution from basic rocks. La/Sc, Th/Sc, Co/Th, Cr/Th, and Eu/Eu* ratios in silica-clastic sediments allow to place constraints on the average provenance composition (Cullers, 1988; Cullers, 1994b; Wronkiewicz and Condie, 1980, 1990; Cox et al., 1995; Bhat, 2017), which also favour a mixed provenance for the sediments. On La/Th plot (Fig. 9B), the samples into the range of UC, with most samples having a significant felsic component, which further indicate that the sediments did not have a uniform provenance.

CONCLUSIONS

Geochemical mapping was carried out in South Kashmir, NW Himalayas, to unveil the weathering and provenance of Karewa deposits. In A-CN-K and A-CN-K-FM diagrams, samples of the study area show almost similar contents in Al_2O_3 , CaO, Na_2O , K_2O and MgO as those of upper crust, reflecting very poor to moderate weathering history. The low to moderate values of CIA, PIA and CIW indicate low to moderate degree of weathering. The tectonic discrimination plots of Roser and Korsch revealed that the source of sediments is from quartzose sedimentary provenance with some samples fall in intermediate igneous source, probably recycled orogen provenance. The derivation of the sediments could be from a pre-existing sedimentary terrain. The clustering of sediment data in La-Th-Sc ternary diagram, more or less around the mixed source values suggest that the sediments are mainly derived from a sedimentary provenance with a little contribution from basic rocks. On the La/Th plot, the sediment data fall into the range of UC, indicates that the sediments did not have a uniform provenance.

Acknowledgements: The work has been carried out under Geological Survey of India, Field Season Programme 2013-14. The authors gratefully acknowledge Director General, Geological Survey of India, Addl. Director General and HOD, Geological Survey of India, Northern Region and Dy. Director General, State Unit Jammu and Kashmir for providing necessary facilities for completion of the work.

The authors are also thankful to the officers of Geochemical Lab. GSI, Lucknow for analyses of the samples.

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(Received: 1 December 2017; Revised form accepted: 20 April 2018)