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A comparison between geochemistry of metapelites of Hindoli and Jahazpur Groups: Two Precambrian low-grade metasedimentary sequences in NW India

A. Saxena¹, M.K. Pandit^{1*} and B.S. Bali²

1. Department of Geology, University of Rajasthan, Jaipur 302055, India

2. Department of Geology & Geophysics, University of Kashmir, Srinagar 180 005, India

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Abstract

The Bundelkhand-Aravalli craton is the most important lithotectonic unit in the central and western India where Paleoproterozoic Aravalli Supracrustal sequence has been deposited over an Archaean basement, the latter also known as the Banded Gneiss Complex (BGC). A NE-trending linear metasedimentary sequence, designated as the Jahazpur Belt occurs along the eastern fringe of the Aravalli Supergroup. This belt comprises low-grade metasedimentary assemblages of Hindoli (lower unit) and Jahazpur (upper unit) Groups. Although predominantly pelitic in composition, both the groups show subtle variations in geochemical characteristics, such as in SiO₂, Al₂O₃, TiO₂ etc. and critical trace element (Th, Sc, Rb, etc.) characteristics. CIA (Chemical Index of Alteration) values vary from 73 to 79 in Hindoli metapelites and from 71 to 81 in Jahazpur metapelites indicating moderate to high degree of weathering and alteration in both the cases. The CIA data underline a granodioritic to tonalitic source composition for Hindoli metasediments and a relatively more felsic source (granitic) for Jahazpur metapelites. A probable and likely provenance for the Hindoli metapelites could be analogous to the Banded Gneiss Complex (BGC) which includes TTG gneisses as a major component.

Keywords: Metapelite, Geochemistry, Jahazpur Belt, Precambrian, NW India,

1. Introduction

Geochemical characteristics of pelitic rocks can be used to decipher the provenance characteristics and paleoweathering process(s). Their well-preserved geochemical signatures and perfect homogenization offer reliable constraints in such studies including the tectonic and crustal extraction events and mantle evolution (Taylor and McLennan, 1985; Nesbitt and Young, 1982; Fedo et al., 1995; Bhat and Ghosh, 2001). It has also been demonstrated that low-grade metamorphic rocks can also be used in such studies as their chemical characteristics may not have been significantly altered. Metapelite geochemistry has been successfully employed to deduce the provenance and to examine post depositional compositional changes in many Precambrian terranes of the world (*for details see* Wronkiewicz and Condie, 1987; 1989; Feng and Kerrich, 1990; Fedo et al., 1996). In the Indian context such studies have been carried out in some parts of Himalaya and southern Indian craton (Bhat and Ghosh, 2001; Dayal and Murthy, 2006; Rao and Prasad, 1995; Mishra and Rajamani, 2003; Nagrajan et al., 2007).

However, not much is known from the Precambrian terrane of NW India exposed along the NE- trending Aravalli Mountain range.

Present study is aimed to compare the geochemical characteristics of two Precambrian low-grade metasedimentary sequences, namely Hindoli and Jahazpur Groups that form the SE fringe of the Aravalli Fold Belt in NW India (Fig. 1). The main purpose of the paper is to infer the provenance characteristics for these groups by using metapelite geochemistry as a tool and to contribute in resolving the issue of the geological ages of these groups which has remained contentious ever since the pioneer studies by Heron (1936). He classified the present day Mangalwar Complex, Hindoli and the Jahazpur Groups as part of the Banded Gneiss Complex (BGC), the Aravalli Group and the Raialo Group, respectively; thereby assigning an Archaean age to the BGC and a Proterozoic age to the Hindoli and Jahazpur Groups. On the contrary, Raja Rao and Gupta (1965), Prasad (1982), and Gupta et al. (1980) included all these three sequences into Bhilwara Supergroup of Archaean age. Some of the more recent studies identify both Hindoli and Jahazpur Groups as Proterozoic in age (Bose and Sharma, 1992). We have analyzed metapelite samples from both the sequences and results are compared and discussed in this paper.

*Corresponding author.

E-mail address (es): mpandit_jp1@sancharnet.in

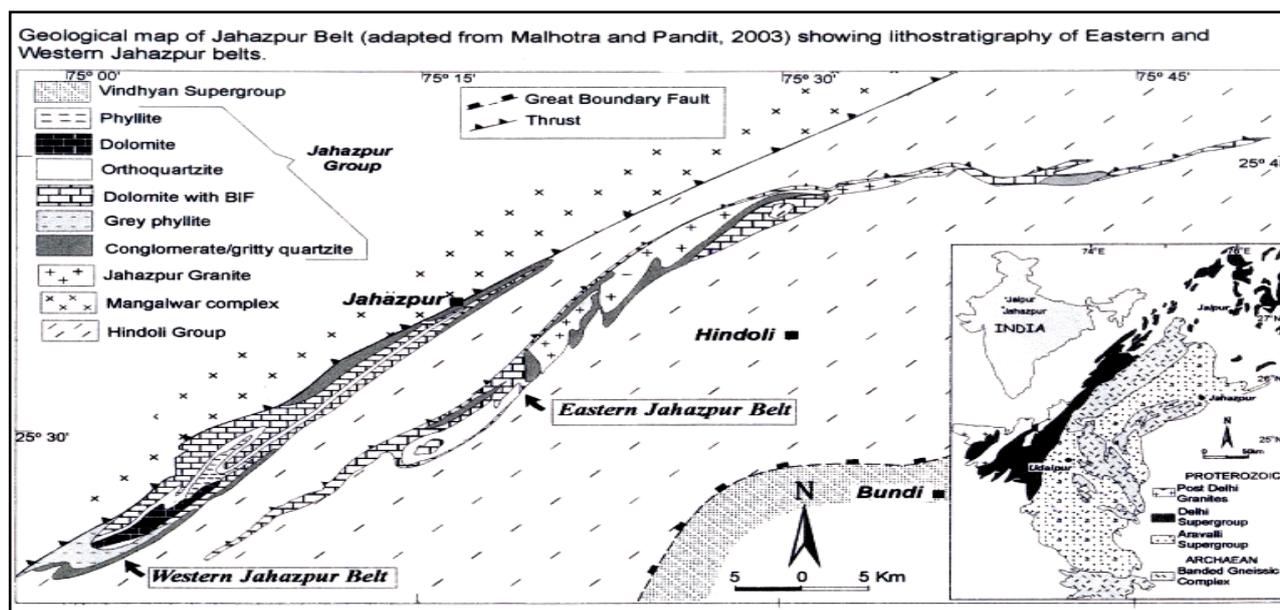


Fig. 1. Lithostratigraphic map of part of NW India showing the disposition of Hindoli and Jahazpur Groups in NW India (adapted from Malhotra and Pandit, 2000 and Geological Survey of India publications).

2. Geological Setting

The Indian shield can be subdivided into three prominent Precambrian cratonic nuclei, namely Dharwar in southern India, Singhbhum in eastern India and Bundelkhand-Aravalli in central and western India. The oldest unit in Bundelkhand is the Banded Gneiss Complex (BGC of Heron, 1953) which has been dated at 3.3 Ga (Gopalan et al., 1990; Roy and Kröner, 1996; Wiedenbeck et al., 1996). It is in turn overlain by two Proterozoic supracrustal sequences, namely Aravalli (Palaeoproterozoic) and Delhi Supergroups (Meso- to Neo-proterozoic). There are number of metasedimentary belts within or around BGC and other older rocks. One such metasedimentary belt, designated as the Jahazpur belt, occurs along the eastern fringe of the Aravalli Supergroup, (Fig. 1). It contains two stratigraphic units, the older Hindoli Group and a younger Jahazpur Group with an intervening unconformity between the two (Malhotra and Pandit, 2000). Heron (1953) correlated Jahazpur series with the Raialo series and assigned it a post-Aravalli and pre-Delhi, Mesoproterozoic status. Sharma and Roy (1986), Sharma (1988), Bose and Sharma (1992) considered that Hindoli Group was deposited over Jahazpur Granites thus according a Proterozoic age to both Hindoli and Jahazpur Groups. The Structural and stratigraphic break between the Jahazpur and Hindoli Groups was also observed by Malhotra and Pandit (2000). According to Pandit et al. (2003), the Jahazpur carbonates show similarity in C-isotopic characteristics with some Paleoproterozoic carbonates of Aravalli Supergroup, however, they did

not find any $\delta^{13}\text{C}$ excursion generally seen in Paleoproterozoic carbonates including Aravalli type region around Udaipur. The Jahazpur Belt is sandwiched between the cratonic terrane of BGC and associated supracrustals on its west and the Paleo- to Meso-proterozoic sediments of Vindhyan Supergroup (see Malone et al., 2008) on the east. Heron (1917) correlated this belt with the Gwalior series of Central India while Gupta (1934) designated it as the eastern part of Aravalli Supergroup (erstwhile System). Deb et al. (2002) reported U – Pb zircon ages between 3259-1877 Ma for the felsic volcanics, interbedded with the Hindoli metasedimentary rocks. Hindoli Group is an assemblage of low-grade metamorphic sequence of metagreywackes, metapelites with a bimodal volcanic sequence. The Jahazpur Group rocks are exposed as two NE - SW trending sub-parallel linear belts; the eastern belt and the western belt. The Hindoli Group has been broadly classified by Malhotra (1998) into a Lower Hindoli Formation (LHF) and an Upper Hindoli Formation (UHF). The LHF dominantly constitutes a bimodal volcanic sequence while UHF comprises a turbidite assemblage of metagreywacke and metapelite with BIF, dolomite and chert. The rocks of Jahazpur Group occur in two linear sub-belts, designated as the western and the eastern sub-belts (Malhotra and Pandit, 2000). These two sub-belts contain a sequence of dolomite, BIF, orthoquartzite and carbonaceous phyllites, unconformably overlying the basement. The entire litho-package is developed in the western sub-belt while only the lower part of the sequence is exposed in the eastern belt. The eastern belt is intruded by composite granitoid pluton; the Jahazpur granite.

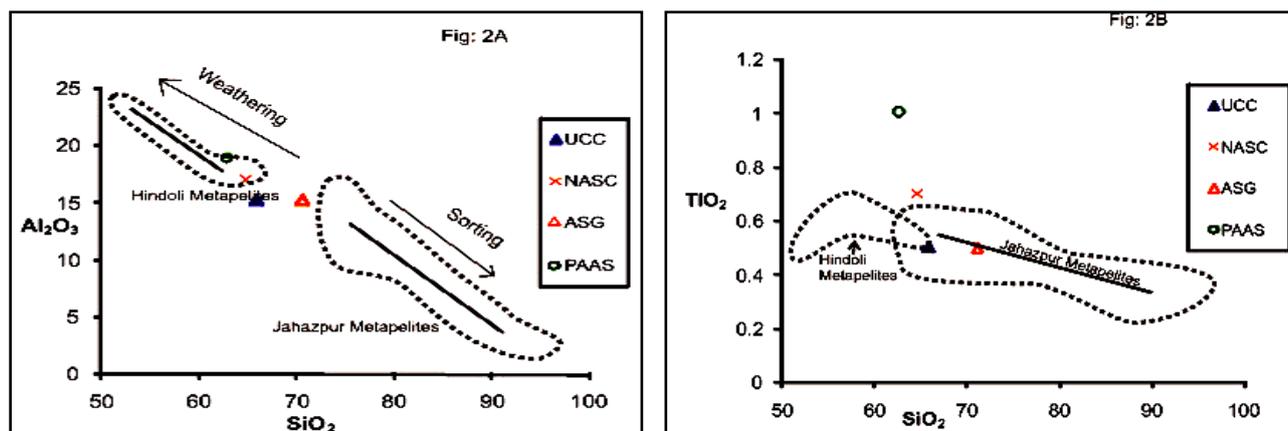


Fig. 2. SiO_2 variation against some major oxides for Hindoli and Jahazpur metapelites; (A) SiO_2 vs. Al_2O_3 diagram showing strong negative correlation and dominant weathering and mineral sorting trends for both Hindoli and Jahazpur samples, (B) SiO_2 vs. TiO_2 diagram showing two different clusters for Hindoli and Jahazpur Samples. Data for UCC and PAAS from Taylor and McLennan (1985) and Young (1999), NASC from Condie (1993), ASG from Banerjee and Bhattacharya (1994), RGP from Bhat and Ghosh (2001) and Migmatites of BGC from Bose et al. (1996) have also been plotted.

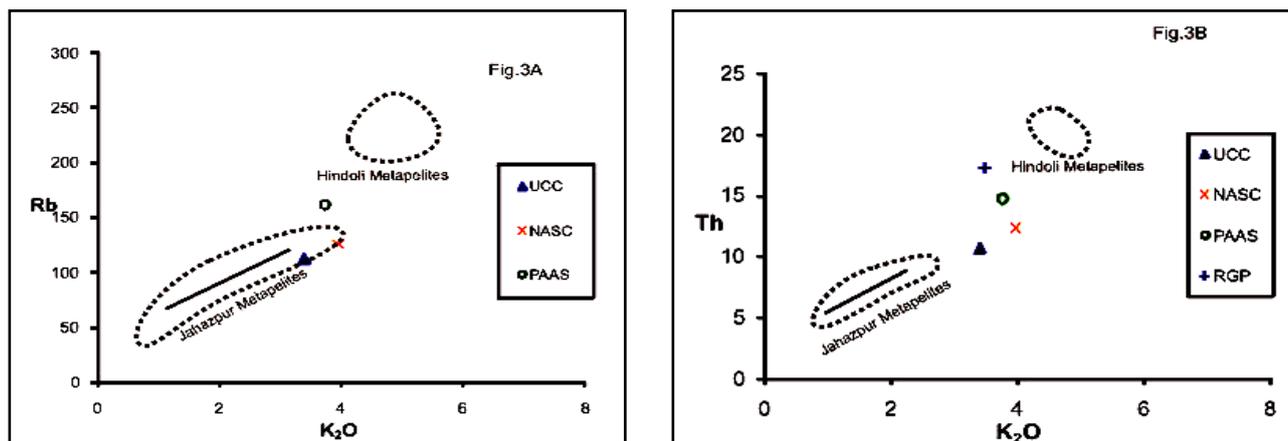


Fig. 3. Variation in trace elements against K_2O in Hindoli and Jahazpur metapelites. (A) K_2O vs. Rb diagram showing two separate clusters for Hindoli and Jahazpur samples. (B) K_2O vs. Th diagram showing difference in both Hindoli and Jahazpur metapelites. Hindoli samples are richer in Rb as well as in Th as compared to Jahazpur phyllites.

This Granite is considered to be intrusive into Hindoli Group and is basement to Jahazpur Group (Sinha Roy, 1985; Gupta et al., 1997).

3. Geochemistry

Seventeen representative samples of Hindoli and Jahazpur metapelite (phyllite) were analyzed for major and trace element geochemistry. The samples were powdered to 200 mesh size in a Ball Mill pulverizer. Pressed powder pellets were prepared and major and trace element analyses were done by Wavelength Dispersive X-Ray Fluorescence (WD- XRF) at Wadia Institute of Himalayan Geology (WIHG), Dehradun (India).

4. Major and trace element characteristics

The metapelites of Jahazpur Group have a wide variation in SiO_2 content, which ranges from 64 to 94 wt% as compared to a much restricted range shown by Hindoli Group (51 to 66 wt%). Al_2O_3 in Jahazpur rocks varies between 7.5 and 15 wt% while in Hindoli it ranges from 18 to 23 wt%. These two most dominant elements also show a strong negative correlation ($r = -0.9$) with respect to each other (Jahazpur Metapelites $r = -0.76$; Hindoli Metapelites $r = -0.92$); which indicates weathering as a dominant process. These values were also compared with different standards (like UCC, NASC) and Aravalli Supergroup (ASG) samples. The

average of Aravalli samples plots in between these two groups. Majority of samples show a general negative correlation of SiO₂ with other elements. Similar behavior is also observed in case of TiO₂.

The Hindoli samples are relatively enriched (0.5 to 0.8 wt %) as compared to Jahazpur samples (0.35 to 0.62wt %). These two groups plot as separate clusters (Fig. 2) on account of variation in such elemental abundances.

Trace elements are more reliable for inferring the initial constituents of the source rock. Hindoli and Jahazpur metapelites show a large variation in trace elements, particularly in the concentration of large ion lithophile elements. These elements are highly mobile in post-depositional metamorphic and metasomatic processes. Some critical trace element characteristics (Rb, Ba, Th, Sc, and Y) show positive, linear trends with Al₂O₃ and K₂O, indicating a clay mineral control. Rb is abundant in rocks of both Hindoli and Jahazpur Groups.

The high content of Rb appears to be related to a high degree of K-metasomatism in these metapelites. Feldspar is a major host of Rb and Ba in terrigenous sedimentary rocks. In the present study, a high positive correlation between Rb and K₂O ($r = 0.9$) for both Hindoli ($r = 0.7$) and Jahazpur metapelites ($r = 0.95$) suggests that the distribution of these elements is controlled mainly by Rb (Fig. 3a) incorporation into silicate. Both Rb and K contents of rocks may, therefore, be changed by weathering processes, involving formation of clay minerals such as kaolinite that acts as receptor for subsequent addition of K to form sericite/illite during diagenetic and later metasomatic processes.

Zr, Nb, Y, Th, and U are incompatible during most igneous processes; therefore, they tend to be enriched in felsic as compared to mafic rocks. These elements are generally resistant to change during weathering and alteration processes. Th shows positive relationship with K₂O. Hindoli samples show higher values as comparative to Jahazpur phyllites (Fig. 3b). Th in Hindoli Group varies from 18 to 22 ppm (average - 20 ppm), whereas in Jahazpur pelites, it ranges from 5 to 10 ppm (average of 7 ppm). The average Th content of upper continental crustal (UCC) is 10.7 ppm, (Taylor and McLennan, 1985) and in North American Shale Composite (NASC) it is 12.3 ppm.

5. Discussion

These two metasedimentary lithologies have been classified in the 100*TiO₂/Zr versus Al₂O₃/ SiO₂ binary plot (Fig. 4) proposed by Garcia et al. (1994) to measure the maturity of shales. The 100*TiO₂/Zr ratio for Hindoli samples varies from 0.15 to 0.59 and for Jahazpur samples from 0.01 to 0.33. Most of the Jahazpur samples lie in sandstone field while the

Hindoli samples show a shale affinity. These indicate that the Jahazpur metapelites are relatively less mature than Hindoli metapelites and other post Archaean Shale, such as NASC and PAAS. High CIA values reflect the removal of labile cations (e.g. Ca²⁺, Na⁺, K⁺) relative to stable residual constituents (Al³⁺, Ti⁴⁺) during weathering (Nesbitt and Young, 1982). Conversely, low CIA values indicate the near absence of chemical alteration or weathering and consequently might reflect cool /or arid conditions (Nesbitt and Young, 1982).

The A-CN-K plot is a useful tool to examine provenance and weathering histories (and K-metasomatism) because predictable systematic trends are associated with weathering of fresh bed rock (Nesbitt and Young, 1982; Fedo et al., 1995). To achieve the same objective the CIA values of Hindoli and Jahazpur Groups were plotted in the Al₂O₃-(CaO+Na₂O)-K₂O triangular diagram along with some standards i.e. NASC, UCC, PAAS, ASG, BGC, average Granite and average Granodiorite (Taylor and McLennan, 1985).

In the A-CN-K diagram, intensely weathered samples plot in position commensurate with high CIA (80-100), whereas incipiently weathered samples plot near the feldspar join (CIA= 50-70). The CIA values of Hindoli metapelites vary between 73 and 79 while in Jahazpur pelites they deviate from 71 to 81. These CIA value indicate moderate to high degree of weathering and alteration. In A-CN-K diagram (Fig. 5) Hindoli and Jahazpur samples show a trend that indicates an unweathered plagioclase - K-feldspar source composition.

The Hindoli samples form a cluster while the Jahazpur samples define an array of CIA values. Their backward projection shows granite to granodioritic source material which is more similar to the BGC. The Th/Sc versus Sc plot (Fig. 6) is a useful discriminator for deciphering source rock characteristics (McLennan and Taylor, 1991; Cullers, 2002) because it is generally unaffected by the sorting process. Th/Sc vs. Sc diagram shows that most of Hindoli metapelite samples fall in the Beitbridge Group (Fedo et al., 1996) which have had somewhat more felsic source and also overlap with the Mozan Group (Fedo et al., 1996) of rocks.

The Th/Sc ratio can be plotted against concentration of Sc that is more sensitive to provenance composition than REE (Fedo et al., 1997a). The Hindoli metapelites fall close to UCC, PAAS, and NASC values (Fig. 6) underlining a felsic rather mafic source.

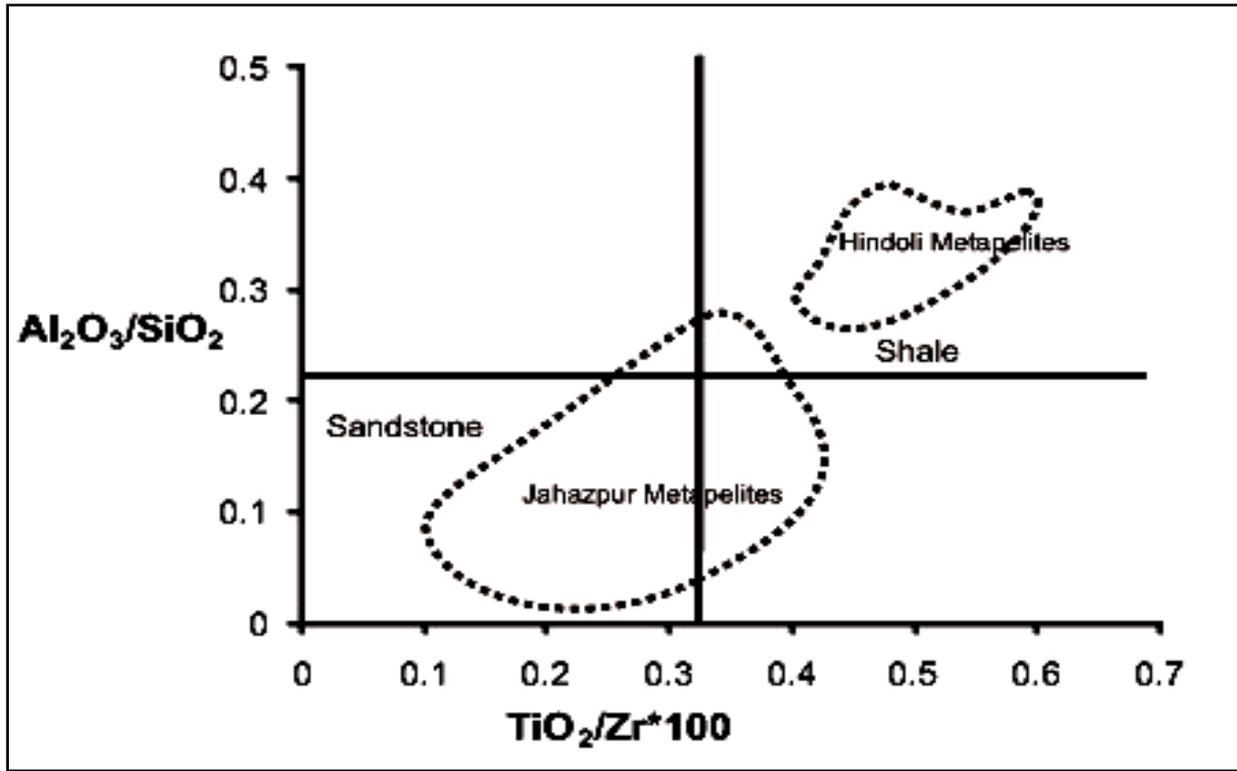


Fig. 4. Al_2O_3/SiO_2 vs. $100*TiO_2/Zr$ diagram showing shale affinity for Hindoli and sandstone affinity for Jahazpur metapelites (fields after Garcia et al., 1994)

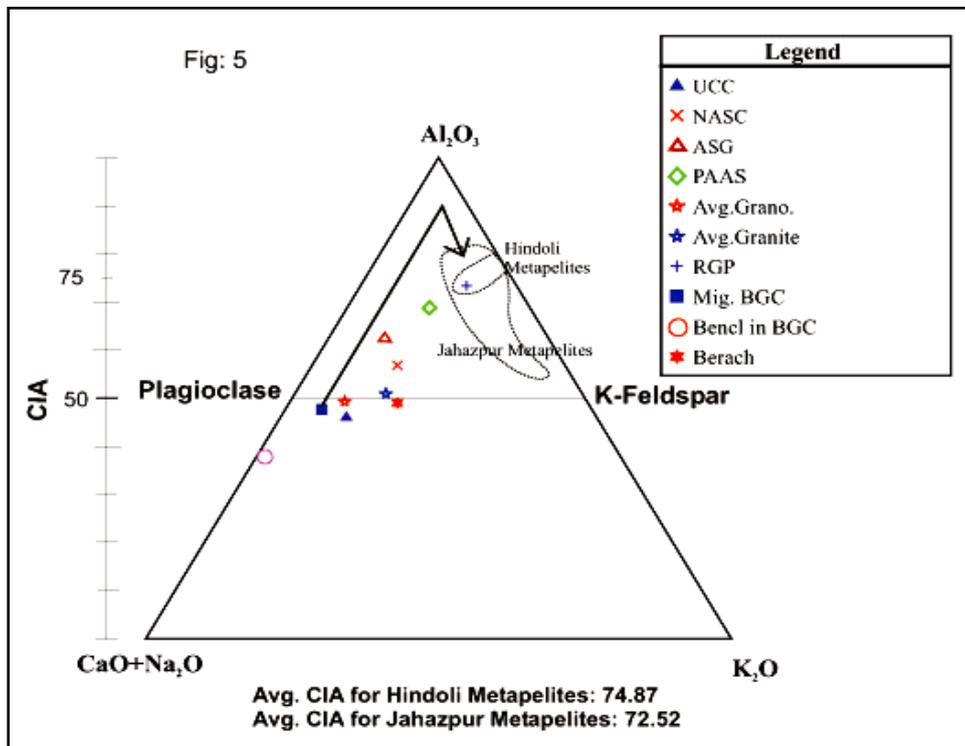


Fig 5. $Al_2O_3-CaO*+ Na_2O- K_2O$ (A-CN-K) diagram showing a cluster for Hindoli metapelites and a linear trend for Jahazpur samples (Nesbitt and Young, 1982). Hindoli sample values overlap Jahazpur Group field.

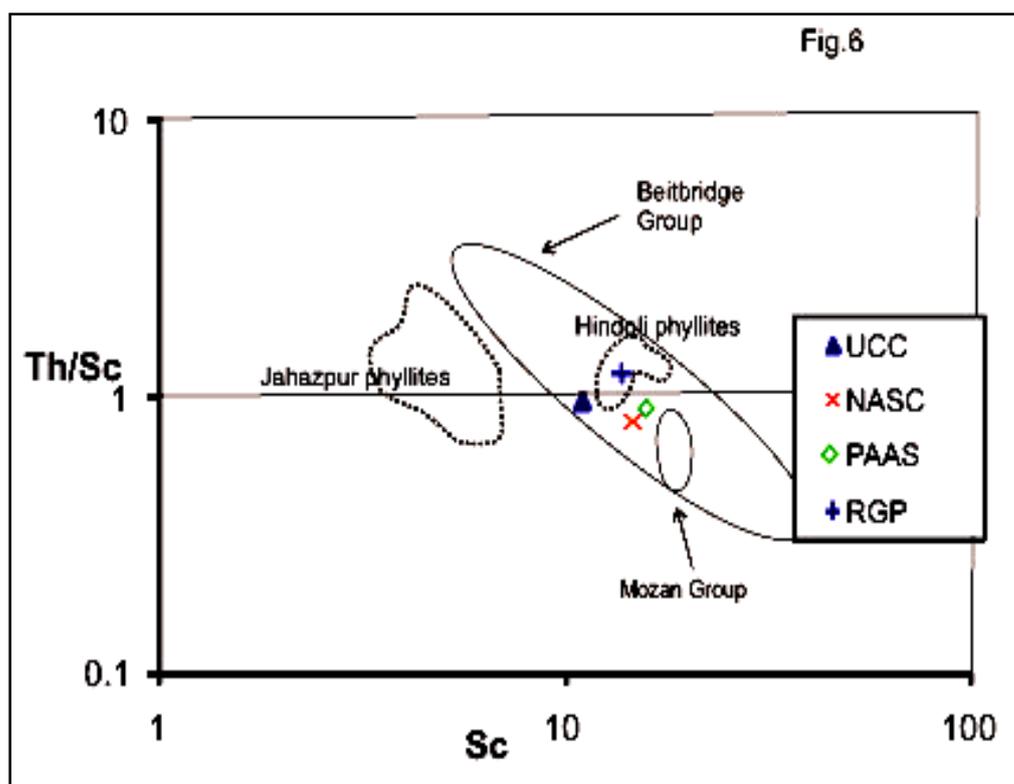


Fig 6. Th/Sc vs. Sc diagram showing similarity between Hindoli metasediments and Beitbridge Group rocks (Boryta and Condie, 1990). However, Jahazpur samples show some scatter trend but they also lie near Th/Sc =1 value.

6. Conclusions

Both Hindoli and Jahazpur Group rocks have closely comparable geochemical characteristics and elemental trends. A granodioritic to tonalitic source composition for Hindoli metasediments can be inferred from the CIA data while Jahazpur metapelites can be related to a more felsic source (granitic). A probable and likely source for the Hindoli metapelites might be the Banded Gneiss Complex (BGC) or similar lithology, which is mainly composed of granite gneiss (at times trondhejmitic) and minor hornblende granite and amphibolites (Gopalan et al., 1990; Ahmad and Tarney, 1994). The higher SiO₂ abundance and a high SiO₂/MgO ratio of Jahazpur metapelites suggest a fairly large felsic component in the provenance. It is also reflected by higher Th/Sc ratio. Hindoli as well as Jahazpur Group of rocks contain considerably higher amount of K₂O than expected (indicated by less steep trend; Fedo et al., 1995), which can be attributed to a possible K-metasomatism. The rocks affected by K-metasomatism generally exhibit lower values than the premetasomatised composition (Fedo et al., 1995). Metasomatic enrichment of potassium to sediments and sedimentary rocks produces mineralogical changes that alter the earlier composition (Glazner, 1988; Nesbitt and Young, 1982; Sutton and Maynard, 1992; Condie,

1993; Fedo et al., 1997a, 1997b). K-metasomatism is particularly common, which involves conversion of kaoline to illite by reaction with K- bearing pore water (Fedo et al., 1995).

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