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COMPOSITIONAL COMPARISON OF BIOTITES FROM SYNCOLLISIONAL NEOARCHEAN BUNDELKHAND MIGMATITE GNEISS AND PALAEOPROTEROZOIC CHIPLAKOT GNEISS INDIA: IMPLICATION TO INFER THE PROTOLITH OF HOST MELT

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ABSTRACT

The major oxide compositions of biotite from syn-collisional peraluminous Bundelkhand migmatite-gneiss and Chiplakot gneiss were compared to determine the source rock of their host melt. Biotite from the Bundelkhand migmatite-gneiss (BMB) had higher FeO^t wt.% (Avg. - 25.73 wt.%, std. - 1.4) and FeO^t/MgO (4.11, Std. - 0.61) compared to Chiplakot gneiss biotite (CGB; FeO^t wt.% -22.12, Std. - 0.99). This suggests that the host melt for BMB was more leucocratic in nature. The high Al_2O_3 wt.% (Avg. -16.49 wt.%, std. - 0.51) and SiO_2 wt.% (Avg. - 35.07 wt.%, Std - 0.52) with a positive correlation between them in the CGB suggest that it was formed from a peraluminous melt. This type of melt is generated from a pellitic source in a syn-collisional tectonic environment. On the other hand, BMB shows low SiO_2 wt.% (Avg. - 33.91 wt.%, Std. - 1.2) and Al_2O_3 wt.% (Avg. - 16.03, Std. - 0.29) and has a negative correlation between SiO_2 and Al_2O_3 wt.%. This suggests that the peraluminous host melt in BMB was generated from an igneous source in a syn-collisional tectonic setting.

INTRODUCTION

Biotite is an important ferromagnesian mineral in most intermediate and felsic igneous rocks. It is also associated with a few mafic rocks as a minor phase. The composition of biotite is susceptible to both the nature and the physicochemical conditions of its host magma. In metamorphic rocks, an association of biotite with specific minerals is used to define the facies, sub-facies or zones corroborated by the petrogenesis of metamorphic rocks. The targeting of primary Biotites in igneous rocks is crucial and also can be used to infer the petrogenesis of the host rock and its composition, temperature, and depth of crystallization. Four major reviews on biotite focused on the physicochemical condition and nature of host magma ((Abdel-Rahman, 1994; Foster, 1960; Speer, 1982 and references therein).

Numerous studies have been carried out on different igneous complexes worldwide regarding the composition and nature of melt (Abdel-Rahman, 1994; Albuquerque, 1973; Beane, 1974; Bucholz et al., 2014; Burkhard, 1991; Cenki-Tok et al., 2016; Eugster and Wones, 1962; Kumar et al., 2021a, 2021b; Skjerlie and Johnston, 1992; Tang et al., 2019)

However, little work has been carried out to characterize the source of the magma using the composition of biotite. In the present study, we try to compare the composition of biotite carried out from two different granitic complexes of known protolith and tectonic environment and distinct petrogenic history (G. Kumar et al., 2021b; Panwar and Kumar, 2022) Here we introduce the compositional variation of biotite formed from different sources (e.i., Igneous and sedimentary) in the same tectonic setting i.e., syncollisional tectonic setting.

Biotite analyses used in the current study

The Proterozoic and Palaeozoic crystalline nappe/ klippe with associated sedimentary rocks are well exposed in Kumaun Lesser Himalaya (KLH) (Valdiya, 1980). The Chiplakot and Askot klippe are exposed in eastern Kumaun Lesser Himalaya (Fig. 1a). The Chiplakot klippe is bounded by the North Chiplakot Thrust and the South Chiplakot Thrust (Fig. 1b), tectonically separating the underlying metasedimentary rocks of Tejam Group and Berinag Formation of the Kumaun Lesser Himalaya (Valdiya, 1980). The Chiplakot klippe is well exposed along the Kali, Darma, and Gori valleys. The Askot group of rocks are magmatic in nature and tectonically separated from calcareous and metasedimentary nature of Garhwal groups of rock Ghose (1972). Proterozoic granites and granite gneisses from Askot and Chiplakot klippe are calc-alkaline metaluminous (I-type) to syncollisional peraluminous (S-type) (Panwar and Kumar, 2022).

The Bundelkhand craton is situated in the northernmost part of the Indian Precambrian shield, occupying an area of about 26000 km^2 (between 24º.05'N and 25.50'N and 78º00'E and 80º50' E) in south-western Uttar Pradesh and northeastern Madhya Pradesh, India (Fig. 1c). Nearly 80% outcrop of the Bundelkhand Craton is composed of volcano-plutonic felsic to intermediate igneous rocks. The remaining 20% are made up of gneisses, banded iron formation (BIF), mafic-ultramafic suites, quartz reefs, and mafic dykes (Basu, 1986). The craton has been divided into two halves by the nearly E-W trending Central Bundelkhand Tectonic Zone (CBTZ).

The CBTZ has about 200 km in length and 1-4 km wide, extending from Mahoba to Babina through Mauranipur (Pati, 1999). The CBTZ is characterized mainly by high-Mg mafic rocks, BIF and TTG rocks, which are tectonically in contact with felsic volcanic (Singh and Slabunov, 2014), covered by supracrustal rocks. The E-W trending vertical crustal-scale shears are prominent in the CBTZ (Malviya et al., 2006; Singh et al., 2018) and produced syncollisional s-type granitic melt (Kumar et al., 2021).

Biotite is the only ferromagnesian mineral crystallized in the Chiplakot gneiss and Bundelkhand migmatite gneiss (Kumar et al., 2021b; Panwar and Kumar, 2022). Biotite from Chiplakot gneiss formed in syncollisional tectonic environment from sedimentary sources (Panwar and Kumar, 2022) and the biotite from migmatite-gneiss from Bundelkhand craton derived from igneous sources in syncollisional tectonic environment (Kumar et al., 2021b) have been used to study the composition variation of biotites of these complexes (Table-1). The Chiplakot gneiss biotites (CGB) are Palaeoproterozoic gneisses. These biotites were associated with ms-pl-Kf as major minerals and zrn-ap±mag as accessory minerals (Whitney and Evans, 2010) and follow the preferred direction corroborated with gneissic characters (Panwar and Kumar, 2022). The Neoarchean Bundelkhand migmatite biotite (BMB) is primarily associated with qz-Kf-pl and zrn-ap-mag documented as accessory phases (Kumar et al., 2021b).

Compositional Discrimination and Likely Source:

The compositional variation of biotite representing two magmatic rock groups (CGB and BMB) are summarised in Table 1. The major elements composition of 56 biotites analyses used in the present study for comparison of chemical compositions of magmas generated from different sources in the same tectonic setting (e.i. syn-collision). The biotites from these rocks reveal distinct chemical compositions. The FeO^t from BMB varies between 24.05 wt.% and 30.22 wt.% (Avg. = 25.73 wt.% Std = 1.40) and is higher than CGB (20.04-24.15; Avg. = 22.12; Std = 0.99). it is in good agreement with the FeO^t/MgO ratio of both (BMB- FeO^t/MgO = 3.41-4.99, Avg. = 4.11Std = 0.61; CGB - FeO^t/MgO = 2.44-3.49, Avg. = 2.91, Std = 0.31). The high FeO^t/MgO ratio for BMB is caused by the generation of relatively low amounts of melt from the source.

It is confirmed through the field observations and microscopic study of the BMB (Kumar et al., 2021b). Biotite is the major site to sink Al-content along with muscovite in igneous rocks. The Al_2O_3 (15.41- 16.37 wt.%; Avg. = 16.03 wt.%, Std = 0.29) content for BMB is lower than CGB (15.39-17.46 wt.%, Avg. = 16.49 wt.%, Std = 0.51). Moreover, the presence of muscovite in CGB (Panwar and Kumar, 2022) indicates the likelihood of more aluminous sources being responsible for generating CGB. However, there is no evidence of any aluminosilicate apart from biotite in Bundelkhand migmatite. This suggests that the most probable source for BMB is igneous rock. Both BMB and CGB analyses show a negative correlation between MgO and Al_2O_3 wt.% (Fig. 2a) corroborated by typical syn-collisional tectonic setting. However, upon a closer view, it appears that the negative curve for CGB is steeper than that of BMB. This suggests that the strong negative relationship between Mg-Al in CGB may be due to the pellitic nature of its protolith, however, a slightly negative cure between Al-Mg corresponds to igneous protolith for BMB.

Additionally, BMB exhibits a negative correlation between SiO_2 and Al_2O_3, while CGB shows a positive correlation between the two elements (as indicated in Fig. 2b). The low levels of Al_2O_3 wt.% and SiO_2 wt.%, along with the negative correlation, suggest that the BMB likely originated from an igneous protolith. On the other hand, the high wt.% of SiO_2 and Al_2O_3, along with a positive correlation, suggests a pellitic source for the CGB. According to Zhou (1986), the origin of host granitoid melt can be predicted by plotting $FeO^t/(FeO^t+MgO)$ against MgO for biotite composition. This suggests that the BMB and CGB host melt were formed from crustal sources with different levels of mafic content, as shown in Figure 2c.

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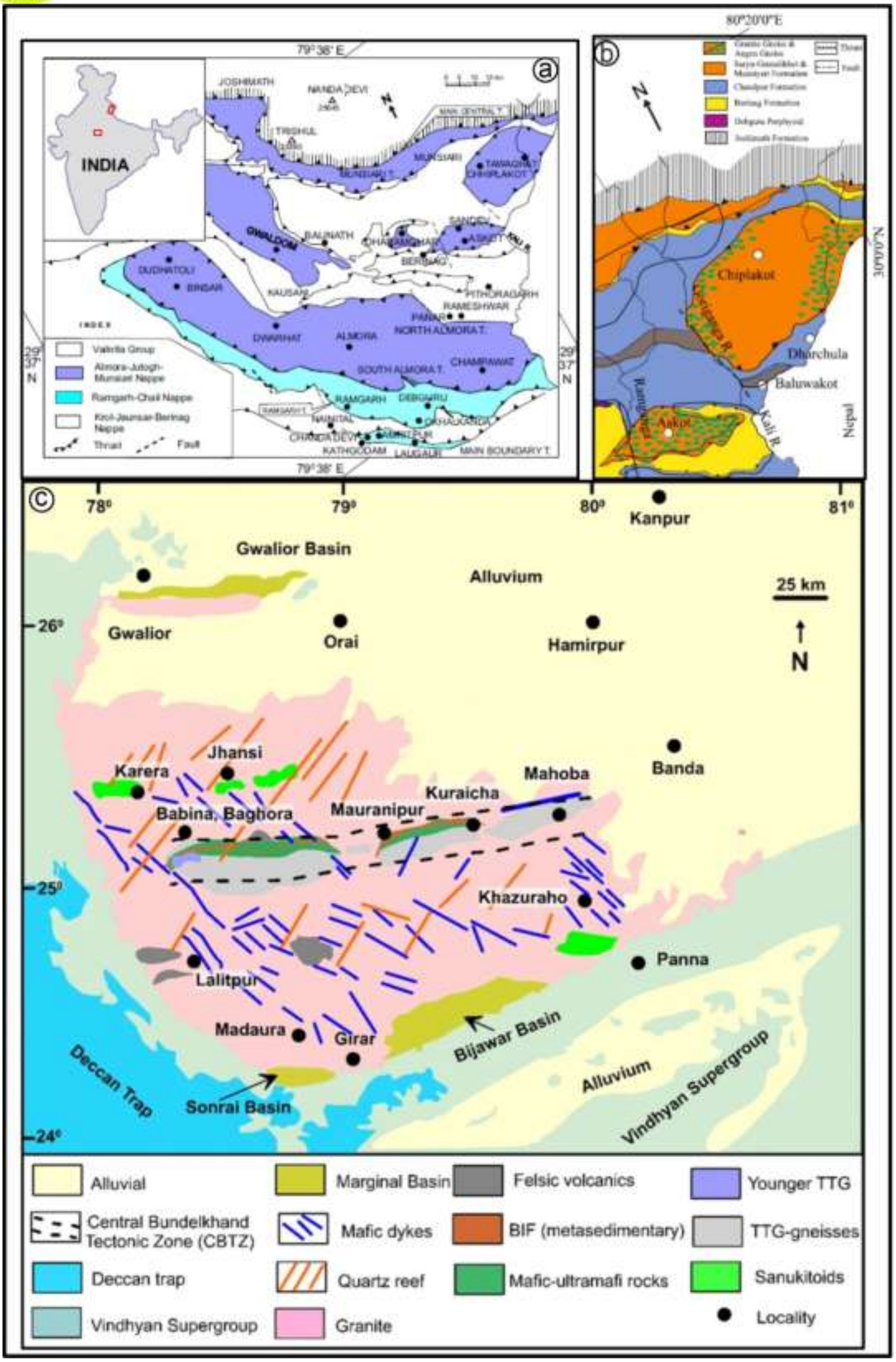

Figure 1: (a) Geological map of the Kumaun Lesser Himalaya, and **(b)** part geological map of eastern Kumaun Lesser Himalaya (after Valdiya 1980) showing the Askot and Chiplakot klippe. **(c)** Geological map Bundelkhand craton (modified slightly after Basu, 1986)

Table 1: Chemical composition of biotites analyses representing the Bundelkhand migmatite-gneiss biotite (BMB) and Chiplakot gneiss biotite (CGB)selected (sources: Kumar et al., 2021b; Panwar and Kumar, 2022).

	Bundelkhand migmatite-gneiss biotite N=18				**Chiplakot gneiss biotite N=46**			
	Min.	**Max**	**Avg.**	**Std.**	**Min.**	**Max**	**Avg.**	**Std.**
SiO_2	30.39	35.25	33.91	1.20	34.09	37.14	35.07	0.52
Al_2O_3	15.41	16.37	16.03	0.29	15.39	17.46	16.49	0.51
TiO_2	1.49	3.08	2.13	0.53	2.02	2.88	2.58	0.22
FeOt	24.05	30.22	25.73	1.49	20.04	24.15	22.12	0.99
MnO	0.12	0.88	0.41	0.22	0.00	0.23	0.09	0.07
MgO	5.33	7.36	6.36	0.68	6.53	9.49	7.66	0.58
CaO	0.00	0.23	0.03	0.06	0.00	0.11	0.02	0.03
Na_2O	0.02	0.13	0.06	0.03	0.07	0.18	0.12	0.03
K_2O	5.64	9.72	8.68	1.11	9.28	10.25	9.76	0.22
BaO	0.00	0.21	0.10	0.09	-	-	-	-
Total	91.26	95.30	93.44	1.31	92.50	97.15	94.60	1.02
FeO^t/MgO	3.41	4.99	4.11	0.61	2.44	3.49	2.91	0.31
XFe	0.65	0.74	0.69	0.03	0.57	0.67	0.62	0.03
XMg	0.26	0.35	0.31	0.03	0.43	0.33	0.38	0.03
TC	715.00	786.00			750.00	840.00		
$f0_2$ (bar)	$10^{-15.11}$	$10^{-16.06}$			$10^{-14.45}$	$10^{-15.12}$		

In comparison to CGB, the BMB has low levels of SiO_2 and Al_2O_3 wt.% (Table 1).

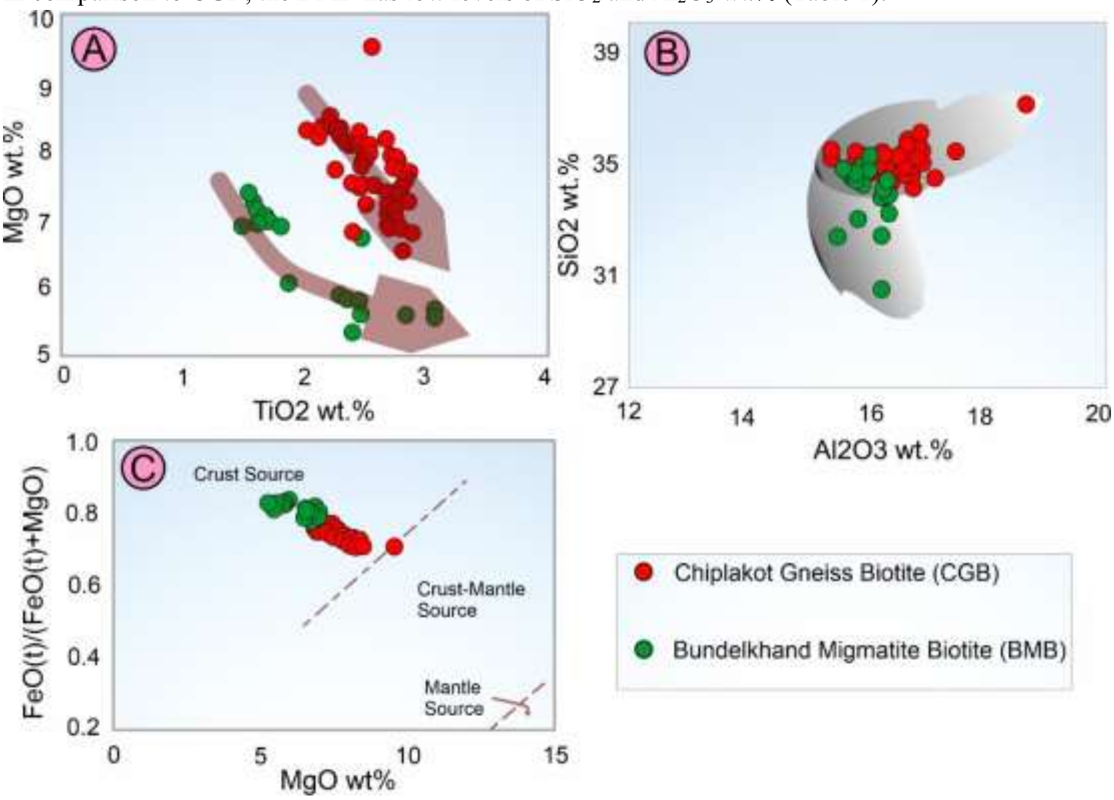

Figure 2: (a) Plot TiO_2 wt.% vs Al_2O_3 wt.% to identify the nature of host magma. **(b)** SiO_2 vs Al_2O_3 wt.% plotted for BMB and CGB to differentiate the source of their host magma **(c)** Plot $FeO^t/(FeO^t+MgO)$ vs MgO diagram to identify host magma source for BMB and CGB (After Zhou, 1986).

Therefore, the observed difference in the major oxides of biotite composition between the BMB and

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CGB complexes seems to have been mainly influenced by the diverse nature of their protolith, despite their tectonic setting.

Conclusion:

In the present study, we have concluded that biotite composition is crucial in determining the nature of the protolith of the host melt. The wt.% of major oxides like Al_2O_3 and SiO_2 wt.% are essential to infer the probable source (igneous or sedimentary) of host melt, even if two biotites were crystallised in a similar tectonic environment. Biotite host melt generated from an igneous source may have low SiO_2 wt.% and a negative correlation to SiO_2 wt.% in a syn-collisional tectonic setting. However, the host melt of biotite generated from a pelitic source may have high SiO_2 wt.% and exhibit a positive correlation with Al_2O_3 wt.%.

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Biotite-gneiss from the Tauern Window, Austria: The main foliation runs parallel from left to right. Width 2 mm. Biotite-gneiss from the Tauern Window, Austria: The main foliation runs parallel from left to right. Width 1 mm. The newly, secondary grown bi, n.d.

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