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# Field and Petrographic Studies of the Guwahati Metapelites, Assam, NE India: Evidence for Post- Metamorphic K-Metasomatism

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***Authors' contributions***

*This work was carried out in collaboration among all authors. Author ND formulated the problem, drafted the manuscript and created the figures. Author ACM designed the study and meticulously organised the references. Author MR carried out petrographic study and author AB provided valuable suggestions during field work. All authors read and approved the final manuscript.*

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## ABSTRACT

In this study, we report mineralogical features of post-metamorphic K-metasomatic assemblage of high-grade metapelites from Guwahati, the northern extension of the central part of the Shillong Plateau, NE India. Several reaction textures of metasomatic metapelites are shown and they offer clues for relevant reactions for metasomatic modification of pre-metasomatic metapelites. Two sets of mineral reactions are recognized, which include, the alteration of high-temperature of all kinds of aluminium-silicate phases of pre-metasomatic metapelites into low-grade minerals and the replacement of coexisting metamorphic plagioclase and quartz by K-feldspar due to the

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involvement of K-rich fluids at the end of all deformational events. Our structural study indicates the rocks of the area are intensely deformed with multiple folding events and post-kinematic shearing and faulting which cross-cut the dominant foliation of the rocks. The deep-seated K-rich metasomatic fluids moved into shear zones and migrated along the foliation plane, grain boundaries of minerals transforming the parent metapelites into metasomatic rocks. As a result of metasomatic changes, all pre-existing features disappear and metapelites turn into K-feldspar -rich granitic rock.

*Keywords: Cordierite; Shillong Plateau; K-metasomatism; myrmekite.*

## 1. INTRODUCTION

Metapelites from several localities in the high-grade terrain of the Shillong Plateau have received much attention during the past few decades. The hilly tracts of Meghalaya and some parts of Goalpara and Kamrup districts of Assam expose high-grade metapelites with profusely developed monazite, xenotime and zircon, which have immense potential in dating the geological events. The U–Th– $Pb_{total}$ monazite, xenotime and zircon geochronology provides a powerful technique to elucidate the timing of thermal events for establishing their relationship with regional and global tectonic processes. For this reason, they have been subjected to extensive petrological, chronological, geochemical and tectonic scrutiny by several workers [1-10]. However, the petrological, thermochronological history of the Guwahati metapelites [3] is somewhat cloudy and it is obscure whether these high-grade metapelites are a continuation of those situated towards the south in Meghalaya [4,5,7,8]. In this present study, observation of our structural and petrographic studies of the Guwahati metapelites demonstrate clear evidence of the involvement of post-metamorphic K-rich fluids in transforming highly deformed metapelites into metasomatic rocks.

## 2. METHODOLOGY

The methodology adopted includes geological field investigation, collection of fresh rock samples, detailed observation of important field structures of the rocks, detailed petrographic and textural study of rock thin sections under a polarized microscope.

## 3. GEOLOGICAL BACKGROUND

The study area, Guwahati (26.1158° N, 91.7086° E) represents a northern extension of the central part of the gneissic complex of the Shillong Plateau (Fig. 1). The Shillong Plateau represents an extreme north-eastern extension of the Precambrian Indian Peninsula and is made up of the Neoarchean–Proterozoic to Early Palaeozoic (2.6–0.5 Ga) basement gneissic rocks [4,5,11,12], the Paleo-Mesoproterozoic intracratonic Shillong basin consisting of metasedimentary supracrustal rocks of the Shillong Group [13] and Proterozoic–Early Palaeozoic (881–479 Ma) equigranular to porphyritic granitoid plutons intruding into the basement gneisses and the Shillong Group of rocks [11,14,15,16,17,18] suggested the region as a north-eastern and eastern extension of the Eastern Ghat Belts, and the Chottanagpur Gneissic Complex respectively. The western part of the Shillong Plateau (Garo-Goalpara Hills region) is characterised by predominantly metabasic rocks with garnet corona, co-folded with quartzofeldspathic, migmatitic gneisses, orthopyroxene bearing metapelites, and post-kinematic dioritic intrusion. On the contrary, the central Shillong Plateau (e.g.Nongstoin, Kynshi, Sonapahar, Patharkhammah, Guwahati) is dominated by metapelites with coronitic cordierite and garnet-free metabasic rocks, banded iron formations, calc-silicate gneisses [19,2].The deformational history of the Shillong Plateau is characterized by different episodes of folding ($D_1$, $D_2$, $D_3$ and $D_4$) and a ductile to brittle–ductile shearing episode pre-dates the last folding $D_4$ deformation [19,2,20,21]. The N–S sinistral shears and mylonitization are seen to superpose the folds of earlier generations [19,20,22]. The widespread distribution of varying metamorphic grades of the characteristic NNE-trending sinistral shears and related folds throughout the Shillong Plateau indicates the early Palaeozoic southward movement of the Indian block relative to the Australo-Antarctic block in the east [23].

The Precambrian rocks of Guwahati are co-folded bands of hornblende, biotite - bearing tonalitic gneiss, quartzofeldspathic gneiss, calc-silicate gneiss, amphibolite and cordierite - bearing metapelites, medium- to coarse-grained granite and post -kinematic grey porphyritic granitic rocks. The metapelites are scarce in the area and our collected samples occur mostly as narrow biotite salvages within pink granite (Fig. 2a) and in the zone of intense deformation, we observe occurrence of post-metamorphic, K-metasomatic metapelites of the area (Fig. 2b). However, the pre-metasomatic cordierite - bearing metapelites [8] which are preserved as relics within metasomatic rocks demonstrate that the metapelites of the Guwahati area had witnessed multiple deformations and related metamorphism prior to K-metasomatism. Our structural studies show that strongly flattened $S_2$ foliation, axial planar to tight to isoclinal earlier folds and subsequent superposed folding, and post-kinematic shearing, fracturing and minor faulting.

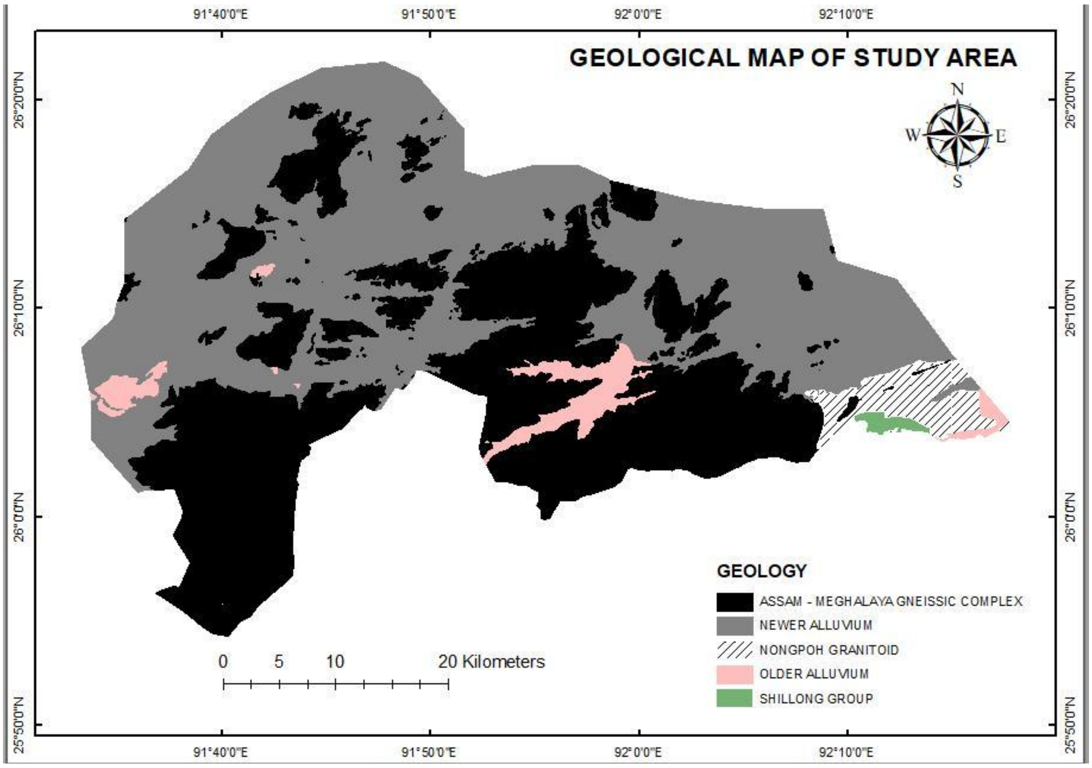


**Fig. 1. Generalized geological map of the study area in and around Guwahati showing the disposition of different litho units of the Shillong Plateau (GSI data)**

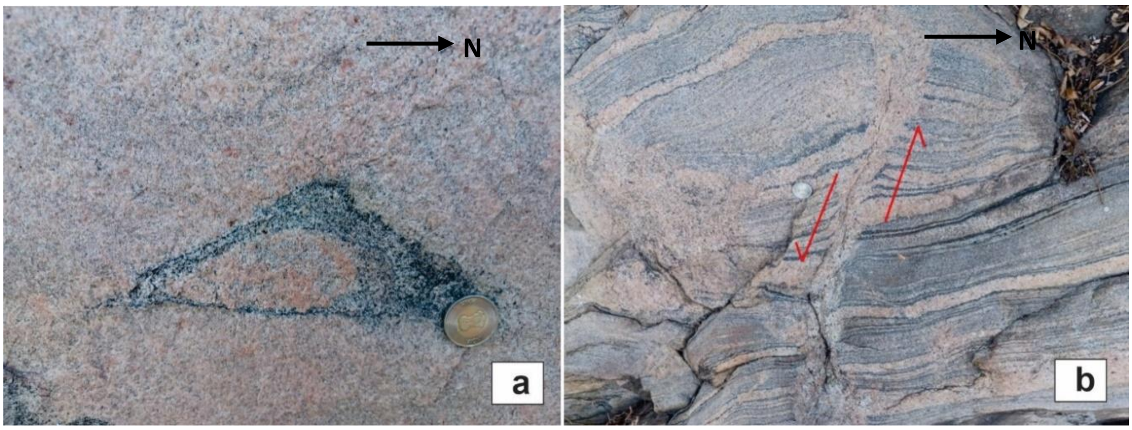


**Fig. 2. (a) Occurrence of metapelites as small-scale salvages of biotite within K-feldspar rich granite. (b) Thin bands of gneissic rocks in association of relics of pre-metasomatic metapelites in the intense zone of deformation, where the shear zone cross cut the foliation plane. See replacement of shear zone as well as foliation plane by K-feldspar as cross cut metasomatic veins. Note the presence of small pods of metasomatic K-rich granite at the central left part of the figure**

# 4. RESULTS AND DISCUSSION

## 4.1 Petrography

Microscopic study of relics of pre-metasomatic metapelites indicates that they are strongly deformed, flattened and characterized by a well-developed foliation defined by the alignment of sillimanite, biotite, the long axis of plagioclase and quartz that swerve around the pre-$S_2$ porphyroblasts of cordierite. The porphyroblasts of cordierite contain tiny inclusions of sillimanite, biotite, and quartz, which represent the earliest (syn-$S_1$) metamorphic assemblage [4,5,8]. The metasomatic metapelites, the major concern of the present study, show inadequate amounts of plagioclase, cordierite, sillimanite and several textures of relevant metasomatic reactions for the consumption of these phases. Some of these, for example, are (i) symplectitic intergrowth of muscovite + chlorite within the decomposed core of cordierite (Fig. 3a), (ii) pseudomorphic replacement of cordierite by K-feldspar + biotite + chlorite (Fig. 3b), (iii) development of thick rim of K-feldspar + biotite around cordierite (Fig. 3c), (iv) stabilization of thin rim of K-feldspar at the contact between sillimanite and quartz (Fig. 3d) and (v) presence of tiny inclusions of sillimanite within K-feldspar (Fig. 3e) are common. The first appearance of metasomatic K-feldspar in the present rocks is marked by the penetration of K-feldspar along the fracture plane of deformed plagioclase grains ($An_{26}$) (Fig. 3f). K-feldspar tends to replace adjacent plagioclase crystals along grain boundaries in some thin sections. The relics of plagioclase grains within K-feldspar are sub-rounded and irregular and display myrmekite with tiny quartz vermicules (Fig. 3f) although myrmekites in the present rocks are not common. The only clue to the formation of large-scale metasomatic K-feldspar in the present rocks is the presence of relics of metamorphic plagioclase and quartz which are preserved within metasomatic K-feldspar (Fig. 3f). This feature is common in almost all thin sections.

## 4.2 The Sequence of Metasomatic Reactions

The post-metamorphic, K-metasomatic mineralogical modifications involve two sets of reactions: (i) alteration of high-temperature all kinds of aluminium-silicate phases of pre-metasomatic metapelites and (ii) stabilization of K-feldspar at the expense of plagioclase and quartz in the rocks.

Among the first set of reactions, the conversion of cordierite porphyroblasts into muscovite and chlorite or K-feldspar + biotite ± chlorite or K-feldspar + biotite (Fig. 3a-c) is significant. This low-temperature assemblage may be accounted for by the following metasomatic reactions.

$$\text{Cordierite} + K^+ + OH^- + H_2O = \text{Muscovite} + \text{Chlorite} \quad \text{(i)}$$

$$\text{Cordierite} + K_2O + H_2O = \text{K-feldspar} + \text{Biotite} + \text{Chlorite} \quad \text{(ii)}$$

$$\text{Cordierite} + K_2O + H_2O = \text{K-feldspar} + \text{Biotite} \quad \text{(iii)}$$

Reaction (i) is a low-temperature alteration of biotite and pinitization of cordierite forming chlorite and muscovite through hydration by a $K^+$-bearing fluids [24], and is most commonly observed in the present rocks. Reactions (ii) and (iii) show that cordierite becomes unstable and is replaced by K-feldspar at higher $\mu_{K2O}$ in fluids. The reaction of cordierite alteration into biotite and K-feldspar as shown in (ii) and (iii) has been experimentally determined, which shows that even relatively at a low concentration of the K - component in the fluids, it is sufficient to produce biotite after cordierite [25].

The widespread post-metamorphic metasomatic alteration of sillimanite and stabilization of K-feldspar can be represented by the following reaction (Fig. 3d):

$$\text{Sillimanite} + 5\ \text{Quartz} + K_2O = \text{K-feldspar} \quad \text{(iv)}$$

This reaction greatly reduces the abundance of sillimanite in the metasomatic rocks. The coexistence of sillimanite and quartz has been observed in many high-grade rocks but at higher $a_{K2O,}$ in fluids, sillimanite becomes unstable and is replaced by K-feldspar [26,27]. This also accounts for the reaction texture such as tiny inclusions of sillimanite within K-feldspar (Fig.3e).

The replacement of metamorphic plagioclase by K-feldspar is a major feature of K- metasomatism which can be accomplished by several processes [28,29]. However, in the present case, replacement of coexisting metamorphic plagioclase and quartz by K-feldspar in presence of K -rich fluids is the most dominant process of K-metasomatism. The relevant reaction is as follows.

$$NaAlSi_3O_8 + CaAl_2Si_2O_8 + K^+ + H_2O = KAlSi_3O_8 + NaAlSi_3O_8 + Ca^{2+} \quad \text{(v)}$$

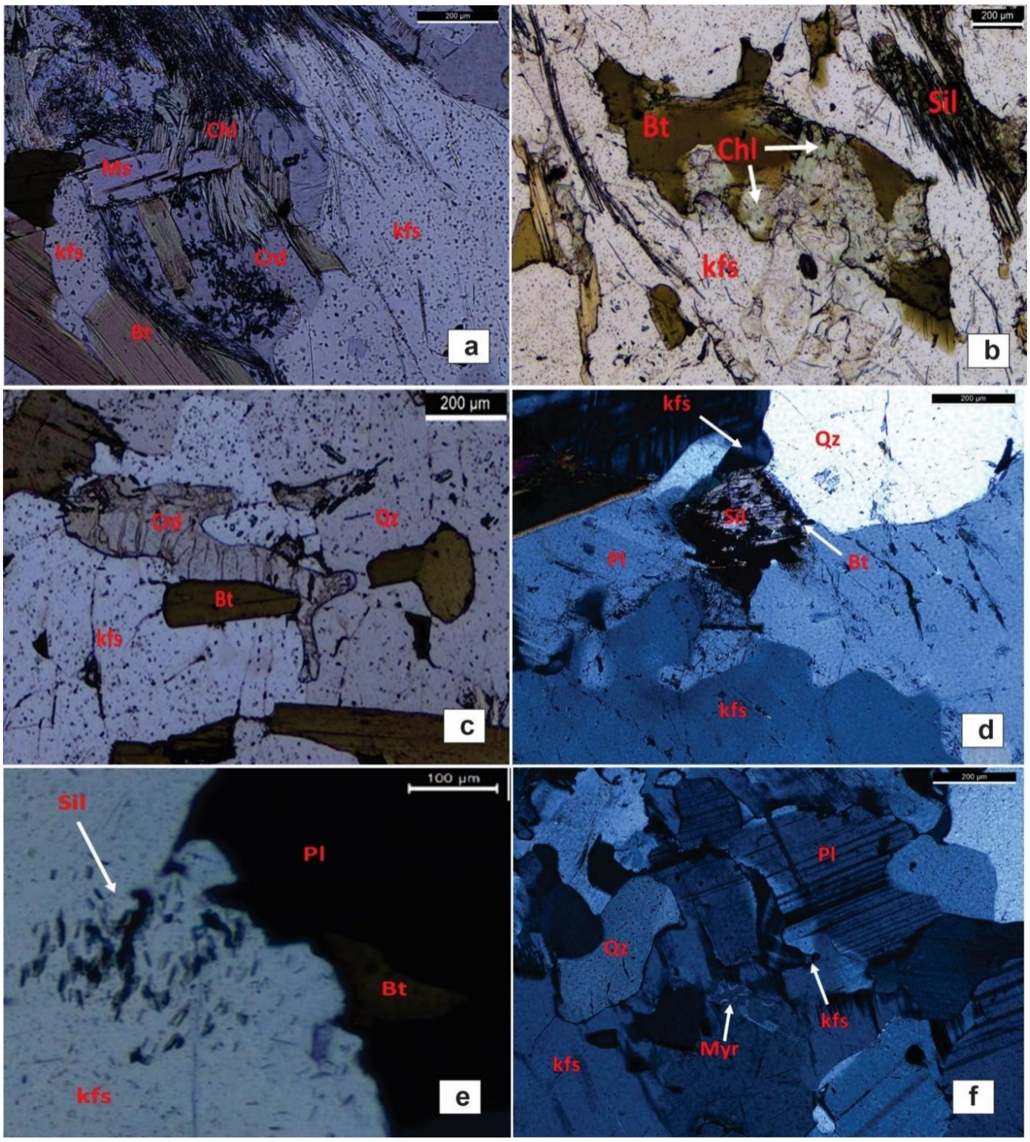


**Fig. 3 (a) Symplectitic intergrowth of muscovite + chlorite within the decomposed core of pinitize cordierite. (b) Pseudomorphic replacement of cordierite by K-feldspar + biotite + chlorite. Note that biotite alters into chlorite. (c) Inclusion of altered cordierite grains within the thick rim of K-feldspar + biotite indicates the replacement of cordierite due to the K-activity of the prevailing fluid phase. (d) Formation of the thin rim of K-feldspar at the equilibrium contact of sillimanite and quartz. Note the paucity of matrix sillimanite in another part of the thin section. (e) Presence of tiny inclusions of sillimanite within K-feldspar indicates a paucity of matrix sillimanite. (f) Penetration of k-feldspar along the fracture plane of deformed metamorphic plagioclase grain with albite - twin. Note the presence of inclusions of sub-rounded and irregular altered grains of plagioclase and quartz within K-feldspar, but the grain boundary between plagioclase and quartz is separated by replacing K-feldspar. In some parts (lower middle), the altered grain of plagioclase displays very small myrmekite with tiny quartz vermicules**

It is important to mention that the above reaction is reversed of the myrmekite- forming reaction of Becke (1908) [30]. In fact, myrmekites which are the salient feature of many metasomatic rocks are not common in the present metasomatic metapelites, although the presence of tiny quartz vermicules indicates a rare occurrence of myrmekite (Fig. 3f) in a few samples. In fact, in-situ replacement of plagioclase by metasomatic K-feldspar in the present rocks is minimal.

## 5. CONCLUSION

Our close field observation and petrographic studies demonstrate that the metapelites of the study area are overprinted by an intensive episode of post-metamorphic, K-metasomatism which has destroyed and obliterated all the pre-existing metamorphic textures, including foliation of the original rocks. Several reaction textures indicate modifications of high-temperature minerals of pre-metasomatic metapelites into low-grade assemblage and replacement of metamorphic plagioclase and quartz by K-feldspar in the presence of K-rich fluids. The newly formed metasomatic minerals thus include K-feldspar, albite, quartz, myrmekite, muscovite, chlorite and apatite and all these newly formed minerals together with pre-existing unreplaced metamorphic plagioclase have consequently produced K-feldspar -rich granite. In the zone of intense metasomatism, the existence of post-kinematic shear zones and minor faults have formed a fracture network for the movement of fluids. The K-rich metasomatic fluids, derived from deep-seated sources probably from the mantle, moved into shear zones and migrated along the foliation plane, grain boundaries and microfractures in minerals, transforming the parent metapelites into metasomatic rocks. During progressive metasomatism, all the shear zones and fractures have been replaced by K-feldspar due to prevailing K-rich fluids (Fig. 2b), and this indicates that the event of K-metasomatism post-dated all deformational and metamorphic events.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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