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Volcano-sedimentary sequence in the Munger-Rajgir metasedimentary belt, Gaya district, Bihar

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Abstract: We report occurrence of a volcano-sedimentary lithoassemblage comprising a bimodal volcanic suite along with mafic pyroclasts, tuff, banded chert and banded iron formations in close juxtaposition with Munger-Rajgir metasedimentary belt, situated near Bathani village in Gaya district, Bihar. The mafic volcanics consist of pillow basalts and pyroclastics. Pyroclasts of various shape and size occur, which include lapilli to large (>20 cm) spindle-shaped bombs. The felsic volcanics consist of porphyritic rhyolite and aphyric rhyolite. The association of pillow lava, rhyolite, explosive fragments and volcanogenic and chemogenic sediments suggest eruption of mafic/felsic magmas and ejection of pyroclasts in sub-aqueous condition. This finding puts the Munger-Rajgir belt in an entirely novel litho-stratigraphic perspective.

Keywords: Munger-Rajgir metasedimentary belt, bimodal volcanism, pillow basalt, sub-aqueous eruption

Introduction

Munger-Rajgir metasedimentary belt is situated in parts of Munger, Nalanda and Gaya districts of Bihar. The mega-fold structure of the Rajgir belt and occurrence of several hot springs in the vicinity has attracted geologists from the time when geological mapping of the Indian subcontinent was still in its nascent stages. Medlicott (1869) correlated the rocks of the Rajgir area with the Dharwar and Supra Dharwar Formations. Krishnan (1956) correlated these rocks with the Bijawar series of the Purana Group and assigned late Precambrian age for these rocks. Bhagwan Das (1967) and Mazumdar (1988) correlated Munger-Rajgir Formation to sub-metamorphic rocks of the Son and Narmada valley in central India and suggested that the Munger-Rajgir Formation might constitute an orogenic entity. Sarkar et al. (1964) reported the age of quartzite from the eastern part of Munger-Rajgir belt as 358-420 million years by K-Ar dating. Banerji (1991), proposed “Munger Orogeny” around the date given by Sarkar et al. (1964). However, in the latest Geological map of India published by the Geological Survey of India (1998, 7th Edn.), the Munger-Rajgir metasediments have been depicted as probable time equivalent with the lower Vindhyans. These have experienced mild metamorphism (Sarkar and Basu Mallick, 1979, 1982) and overall lithology and structure do not exactly conform to the nature of the Vindhyan sequence.

The present work reports the finding of a volcano-sedimentary sequence in the western part of the Munger-Rajgir metasedimentary belt. This sequence is situated in the north-west of the Rajgir fold belt near Bathani village of Gaya district (Fig.1). Occurrence of such volcano-sedimentary sequence was hitherto not reported from the Munger Rajgir metasedimentary belt and provides a new perspective to the understanding of the litho-stratigraphic set-up of the area.

Geological Setting

The most prominent geological feature in the study area is the NE-SW-trending Rajgir fold belt comprising alternate quartzite and phyllite unit. According to Srivastava and Sen Gupta (1967) this fold belt comprises two distinct quartzite bands interbedded with phyllites, whereas Thiagarajan and Banerjee (1967) and Sarkar and Basu Mallick (1979) contend that the Rajgir fold belt comprises a quartzite unit bounded by upper and lower phyllite units. These metasedimentary units have been intruded in the northern part by granite and basic rocks at places (Sarkar and Basu Mallick, 1979).

The quartzite unit displays very well-preserved primary sedimentary structures such as stratification, cross-bedding, ripple marks, mud cracks and convolute-bedding. The phyllite unit is gradational as well as in sharp contact with quartzite. The phyllite is essentially thinly laminated and shows variegated colour and of ferruginous nature.

The alternate quartzite and phyllite units of the Rajgir fold belt have preserved clear evidences of two phases of deformation. The first phase of folding (F1) has given rise to the regional fold structure with closure at Giriak in NE and the dominant NE-SW-trending bedding parallel schistosity. The F1 is inferred to be a south westerly plunging isoclinal syncline (Srivastava and Sen Gupta, 1967). The second generation fold (F2) is marked by NE-plunging minor folds, with closure at Ratnagiri. This phase of deformation is represented by

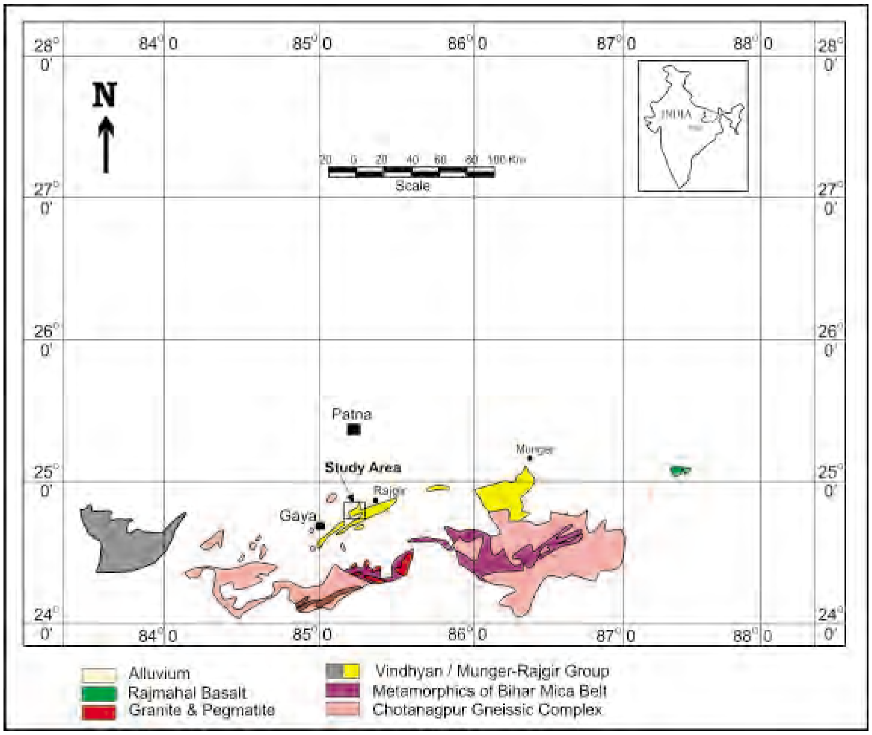

Fig.1. Location and simplified geological map of Bihar published in Miscellaneous Publication no. 30 of Geological Survey of India (2009).

subvertical to steep, south-easterly dipping axial-planar cleavage (S2) trending NE-SW in the phyllite unit (Sarkar and Basu Mallick, 1979, 1982). The interference of the two fold systems has produced a structural basin at Rajgir (Rajgir basin)

Present Work

During the course of geological mapping in the northwestern part of the Toposheet no. 72H/5, a volcano-sedimentary sequence situated northwest of the northern limb of the Rajgir fold belt was noticed. Occurrence of this volcano-sedimentary sequence in close association with the Munger-Rajgir metasediments has major implications on the established stratigraphy (Srivastava and Sen Gupta, 1967; Sarkar and Basu Mallick, 1979) and its tectono-magmatic evolution.

The reported volcano-sedimentary sequence is well exposed in more than 15 sq km area near Bathani village of Gaya district. This sequence comprises pillow basalt, phyllite tuff, mafic pyroclastic rock, tuff, rhyolite, chert and banded iron formations (Fig. 2). A minor band of garnet-mica schist is also present in the contact zone of the mafic pyroclastics, chert and the coarse granite.

Lithology

The litho-units of volcano-sedimentary sequence of the study area have been classified into three divisions: (i) mafic volcanics, comprising pillow basalt and mafic pyroclasts (ii) acid volcanics, comprising rhyolite and (iii) volcano-sedimentary sequence comprising tuff, banded chert and banded iron formation (BIF).

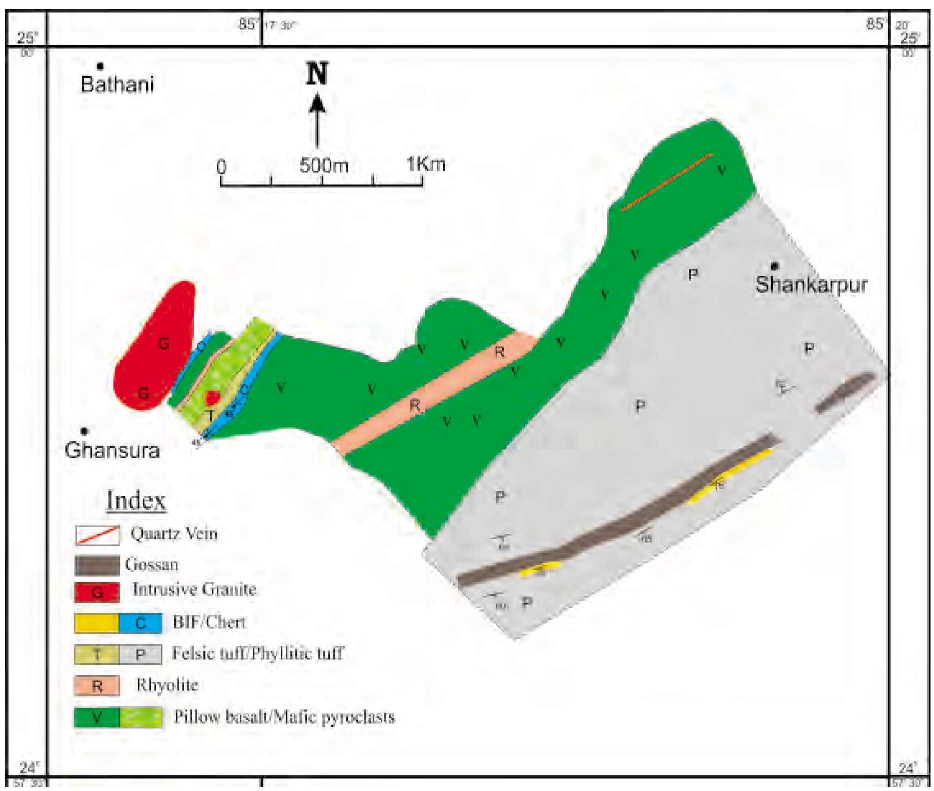

Fig. 2. Traverse geological map of the study area.

Mafic Volcanics

The mafic volcanics are represented by a suite of sub-aqueous pillow basalt (Fig. 3a) and mafic pyroclastic rocks (Fig. 3b). Pillow basalt is fine grained and the chilled margin around periphery of the pillows is surrounded by vesicles. The vesicles are deformed, elongated having elliptical cross-sections and are rarely filled with secondary minerals. Fragment size of pyroclastics ranges from a few mm to more than 20 cm (Fig. 3b). The longer axes of the volcanic bombs and blocks measure from a few centimetres to more than 20 cm. A minor band of garnet-mica schist with garnet megacrysts is also associated with pillow basalt, mafic pyroclastic rock and volcanogenic sediments (Fig. 3c).

Petrographic study reveals that the pillow lavas are essentially plagioclase-phyric basalt with matrix of augite, plagioclase, Fe-Ti oxides and altered glass. Phenocrysts of reddish-brown olivine and light-brown-coloured augite and laths of plagioclase within fine-grained groundmass of plagioclase and augite are observed (Fig. 4a). Laths of plagioclase are at places completely or partially enclosed by augite and olivine phenocrysts giving rise to ophitic to subophitic texture (Fig. 4a). Phenocrysts of pyroxene in basalt occasionally exhibit lamellar intergrowth (Fig. 4b). The mafic pyroclastic rocks comprise twinned and normal augite with olivine phenocrysts in fine-grained matrix of plagioclase, augite and Fe-Ti oxide (Fig. 4c). Both augite and olivine phenocrysts contain numerous inclusions of Fe-Ti oxides (Fig. 4 c and d).

Felsic Volcanics

Two felsic volcanic units in the study area have been identified on the basis of field characteristics and petrographic studies. The outcrop of rhyolite shows distinct porphyritic texture and also bears a few mafic enclaves (Fig. 5a). The dominant porphyritic rhyolite bears large feldspar phenocrysts in a very fine-grained glassy matrix (Fig. 5b). The phenocrysts comprise high-temperature minerals like sanidine, anorthoclase, sodic plagioclase (Fig. 5b and c), along with the microcline and perthite (Fig. 5d) in fine-grained groundmass of quartz and feldspar. Sanidine and anorthoclase phenocrysts occur in discrete mono-mineralic form and also as composite megacrysts consisting of several crystals. The minor lithounit is aphyric rhyolite with negligible mafic mineral content and occurs in close association with the porphyritic unit. In thin sections it reveals typical rhyolitic features, viz., characteristic glassy texture and a groundmass consisting of fine-grained quartz and feldspar (Fig. 6a and b) with rare phenocrysts of augite.

Volcano-sedimentary Sequence

The volcano-sedimentary sequence comprises both clastic

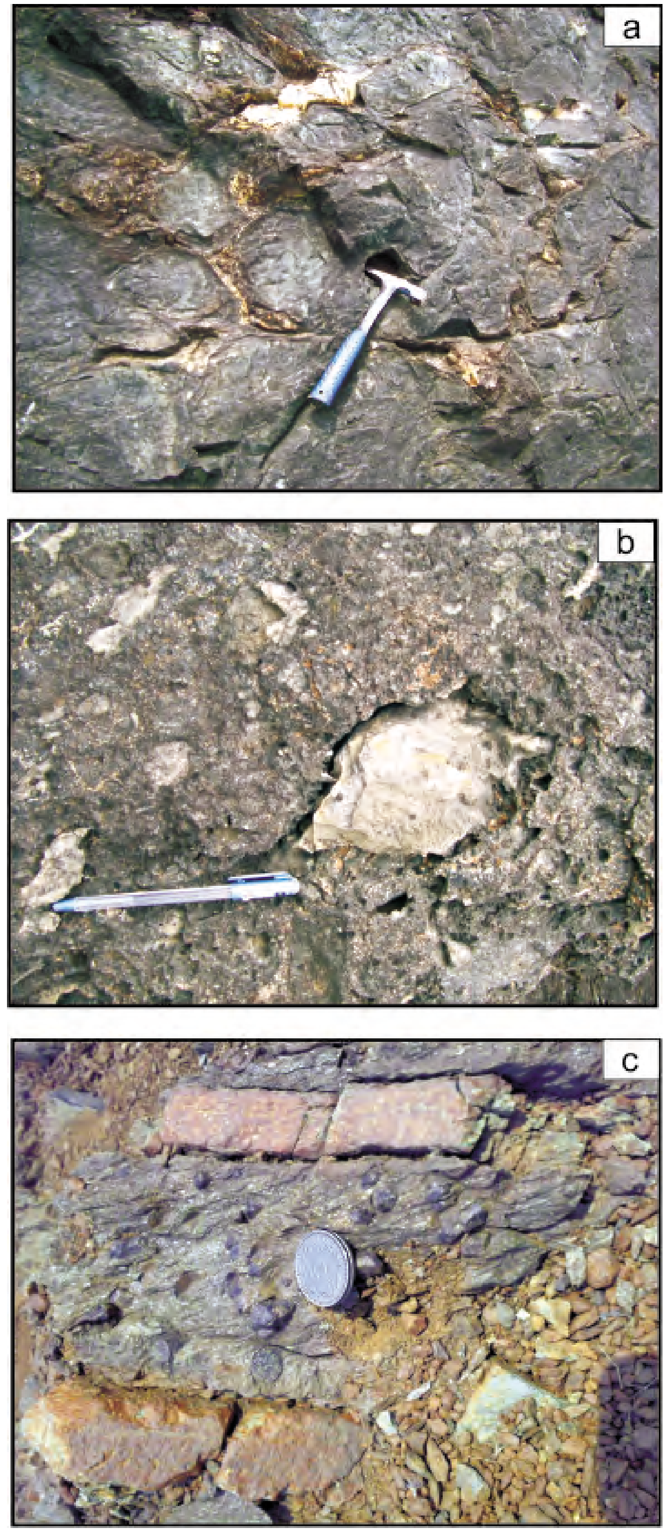

Fig. 3. Field photographs showing presence of (a) cluster of pillows in basalt (b) mafic pyroclastic rocks having spindle-shaped-volcanic bomb and pyroclasts of various shape and size and (c) garnet-mica schist with garnet megacrysts.

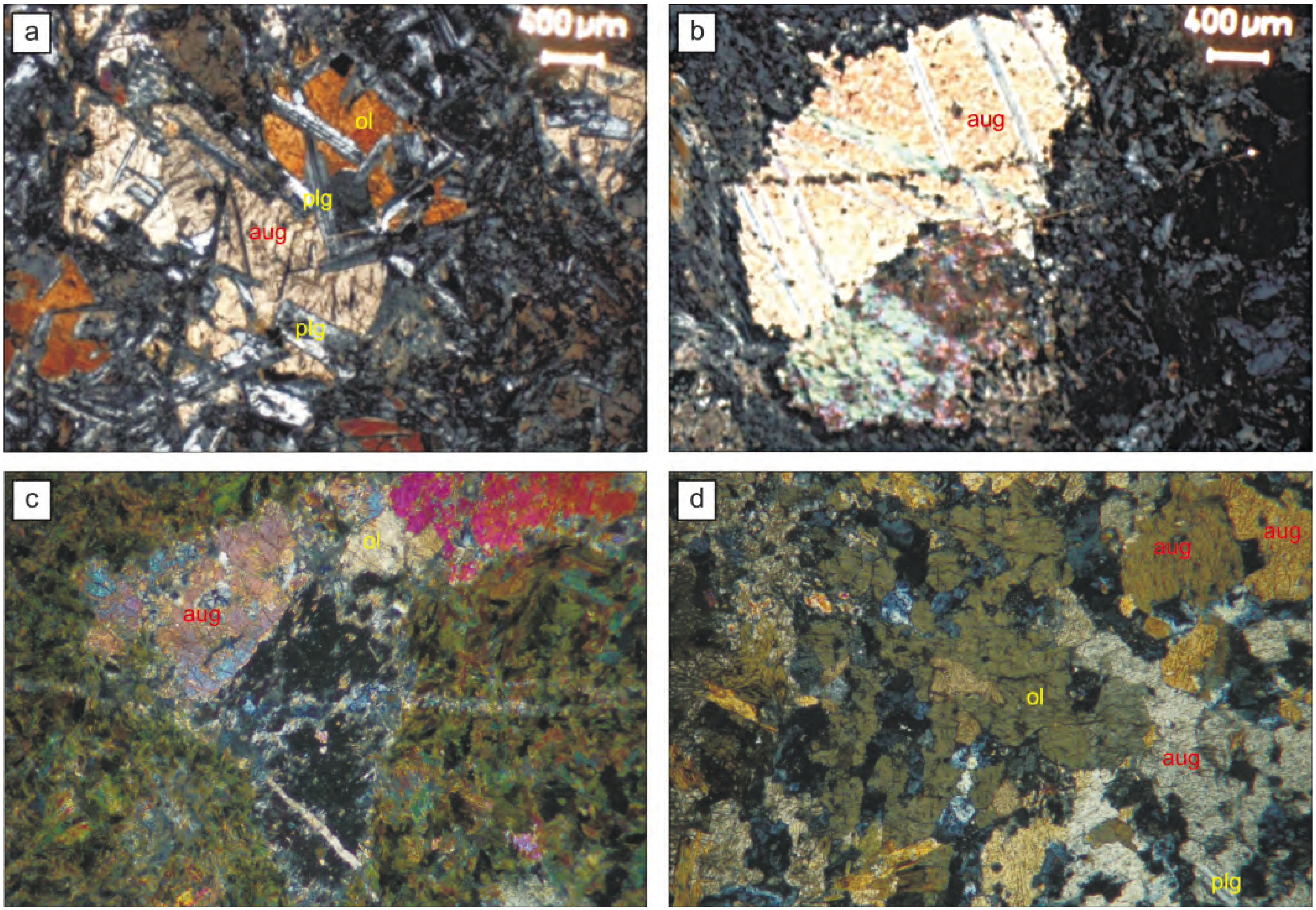

Fig. 4. Photomicrograph of basalt illustrating (a) reddish-brown olivine and light-brown-coloured augite phenocryst, laths of plagioclase along with quartz grains, and laths of plagioclase are in ophitic to sub-ophitic relation with augite and olivine, (b) augite phenocryst showing lamellar intergrowth, (c) twinned augite phenocryst, olivine and iron-titanium oxide (d) mafic pyroclastic rock showing presence of olivine and augite phenocrysts and iron-titanium oxide. ol- olivine; plg – plagioclase; aug - augite

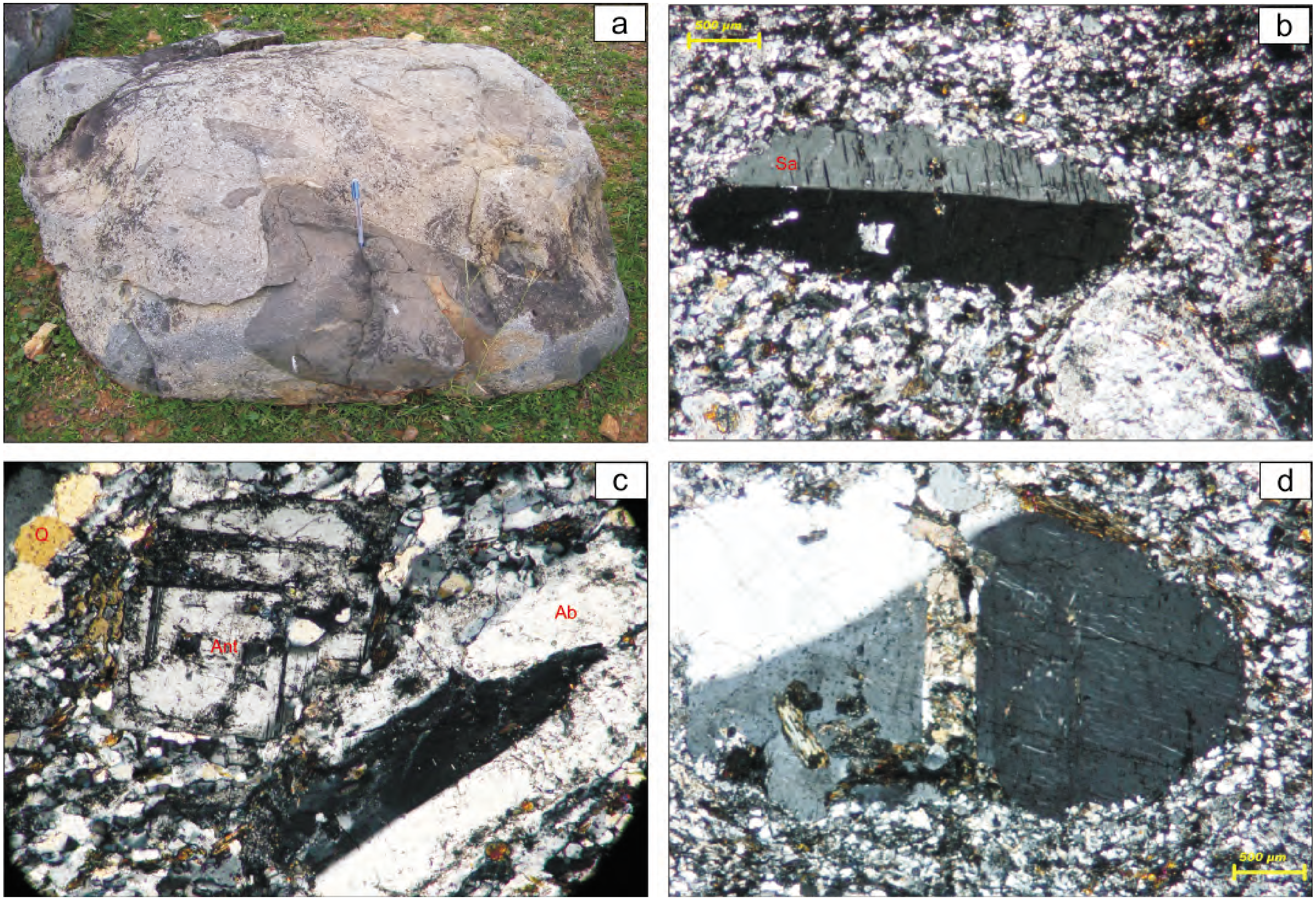

Fig. 5. Photograph and photomicrograph of acid volcanic rocks (a) Outcrop of porphyritic rhyolite with mafic enclave, (b) tabular crystal of sanidine in fine-grained matrix of feldspar and quartz in porphyritic rhyolite, (c) anorthoclase and sodic-plagioclase phenocryst along with quartz grains and (d) perthite in fine-grained groundmass of quartz and feldspar. Ant-anorthoclase; Ab-albite; Q-quartz; Sd – sanidine.

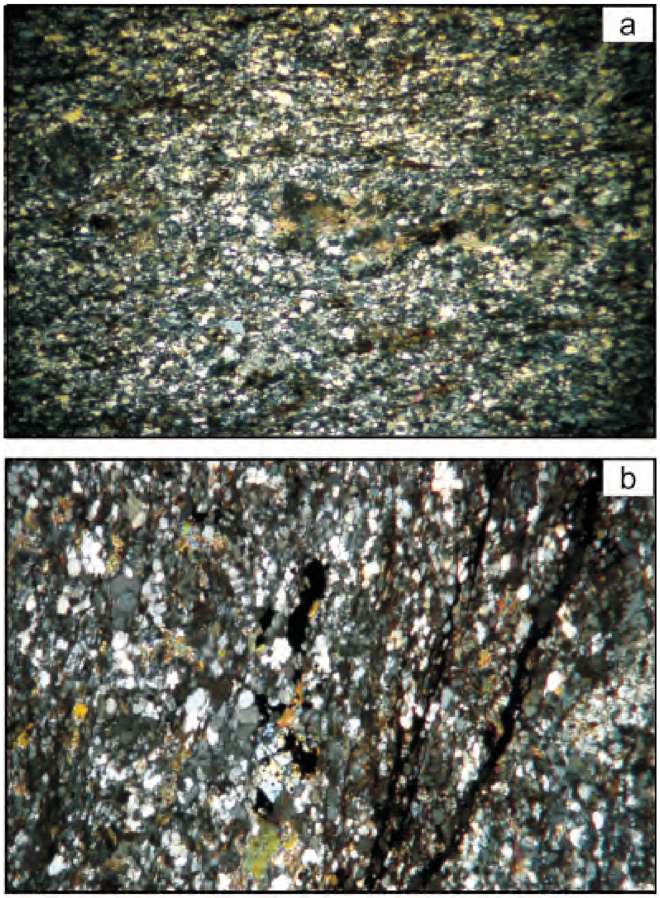

Fig. 6. Photomicrograph of fine-grained rhyolite showing (a) felsic rock fragments within fine-grained matrix of feldspar and quartz and (b) presence of minor augite within fine-grained groundmass of feldspar and quartz.

and non-clastic components. The clastic component comprises volcanogenic tuff layers while the non-clastic component comprises banded chert and BIF.

Tuff

In the field the tuff occurs in bedded, laminated or layered form (Fig.7a) and thus are classified and described under volcano-sedimentary sequences of the area. The volcanogenic tuff occurs as acidic tuff and phyllitic tuff. The acidic tuff is friable and variegated in colour, with distinctly developed foliations (Fig.7a). At places oxidised surface of acidic tuff is highly limonitic giving gossan-like appearance. The tuff also displays discontinuous laminations caused by compaction and welding of original pumice fragments (Fig.7b). Acid tuff occasionally consists of phenoclasts that reveal its pyroclastic origin. Phyllitic tuff is extremely fine grained, well laminated and shows development of mineralised sheen on the bedding surfaces (Fig.7c).

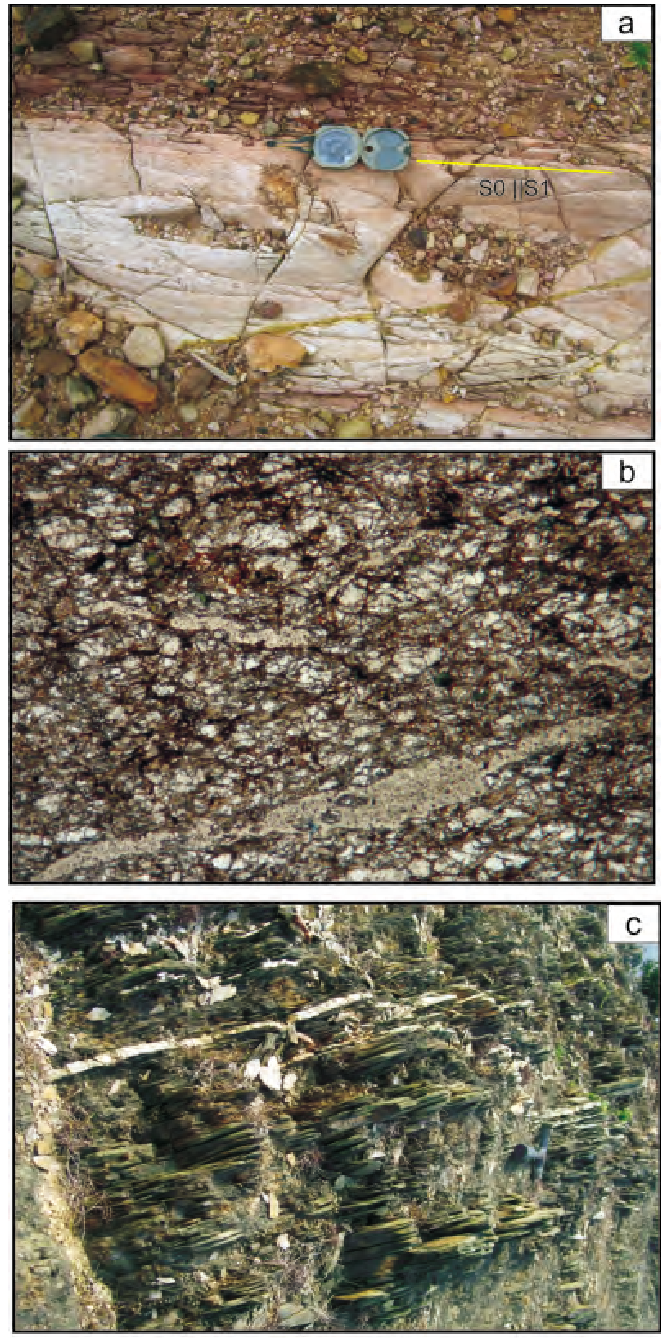

Fig. 7. Photograph of (a) felsic tuff with foliation (S1) parallel to bedding (S_0), (b) photomicrograph of welded tuff showing discontinuous lamination (plane polarized light) and (c) photograph of quartz veins emplaced parallel to the foliation in phyllitic tuff.

Banded Chert

The banded chert occurs in contact with the granite south of the Bathani village (Fig. 2). The bedding in banded chert is defined by alternate chemogenic siliceous and calcareous bands

Fig. 8. Field photograph of (a) banded chert; banding is due to the presence of alternate carbonate-enriched and-deficient bands and (b) ductile flow fold in banded chert plunge 58°→SW.

(Fig. 8a). The outcrop of banded chert shows a large-scale symmetric fold plunging towards southwest. There are numerous ductile flow folds and several asymmetric folds on the limbs (Fig. 8b).

At the contact zone, granite carries xenoliths of surrounding banded chert within it and has also sent multiple apophyses and tongues into chert and other volcano - sedimentary horizons. The metamorphism and/or the hydrothermal alteration of these impure siliceous rocks have occurred due to the proximity to the granitic intrusion. Here, the banded chert appears distinctly

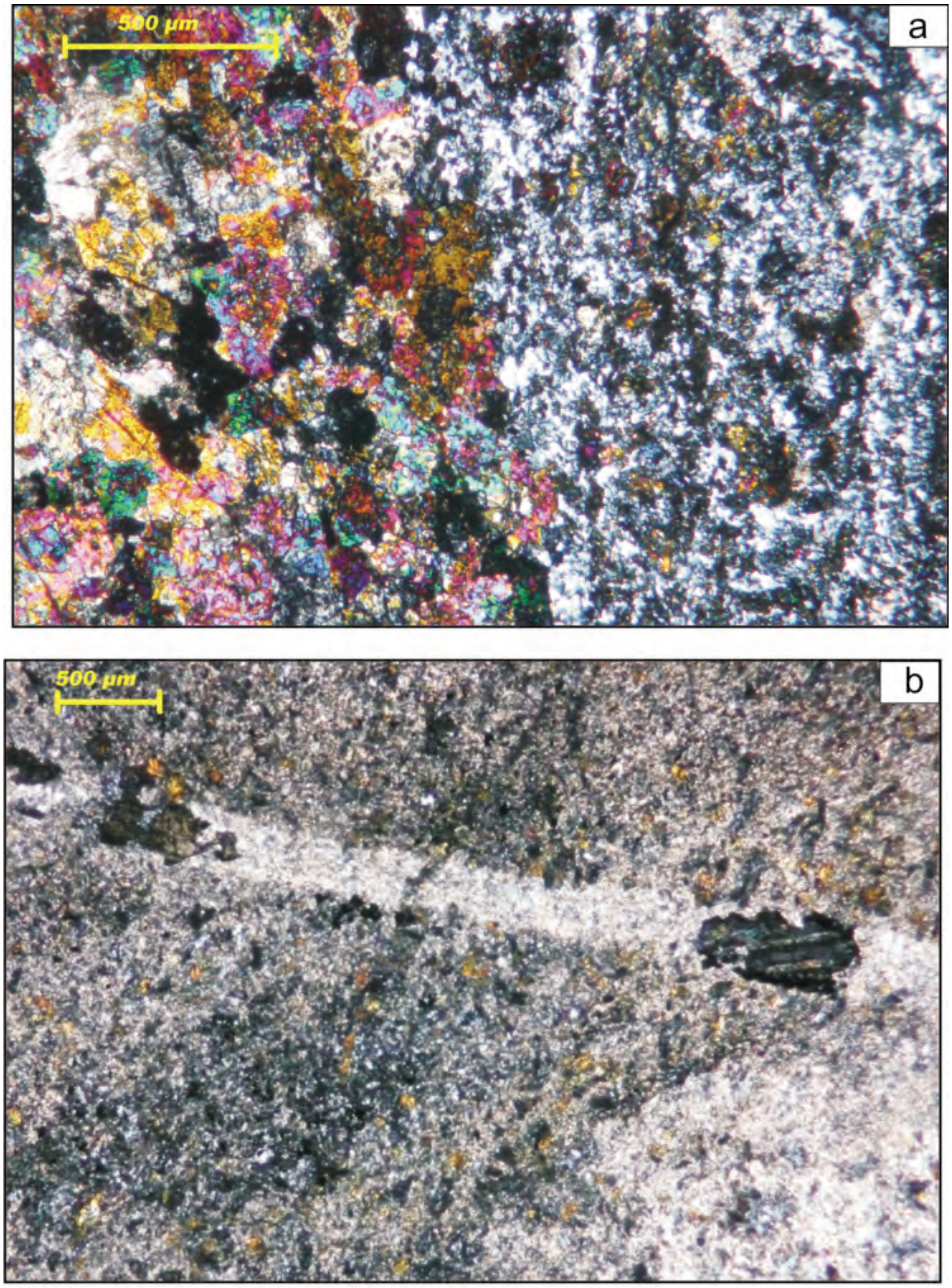

Fig. 9. Photomicrograph of banded chert showing (a) hydrothermal alteration of calcium-enriched chert resulting in formation of epidote and (b) twinned dolomite in calcite matrix.

greenish in colour due to presence of high amount of hydrothermal epidote (Fig. 9a). The epidote generally forms by metamorphism or hydrothermal alteration of carbonate-bearing sedimentary rock caused by granitic intrusions (Dana, 1932). The other evidence of the high-temperature hydrothermal alteration is the presence of twinned dolomite in calcite matrix within banded chert (Fig. 9b), as dolomite develops twinning above 300°C (Barber and Wenk, 2001).

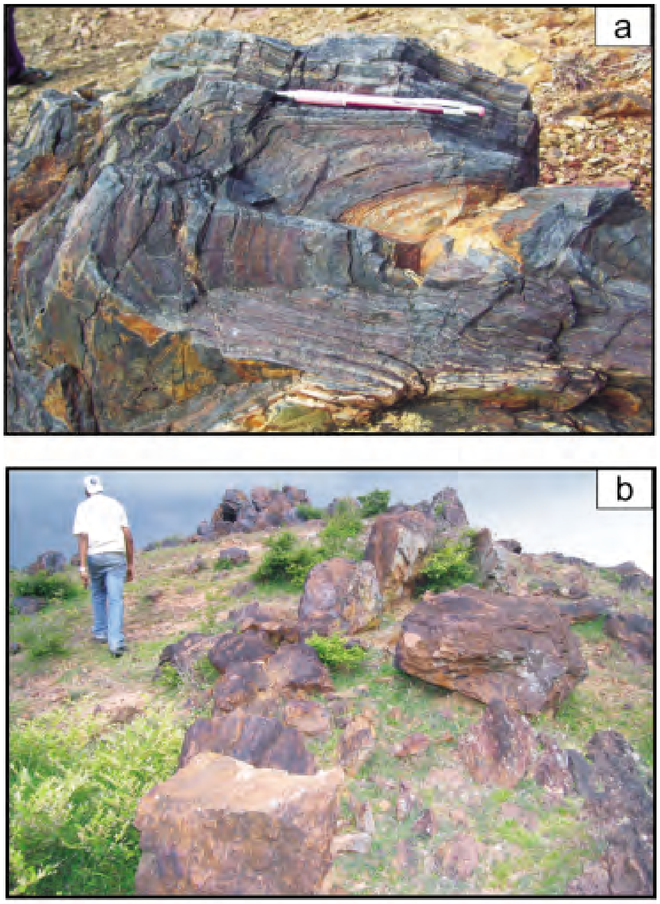

Fig. 10. Field photograph of (a) moderately plunging symmetric fold in BIF plunging 50° → SW and (b) gossan horizon associated with phyllitic tuff and BIF horizon.

Banded Iron Formation

A horizon of banded iron formation (BIF) comprising alternate magnetite, jasper and chert layers overlies the phyllitic tuff (Fig.10a). The BIF also shows occurrence of numerous pyrite grains embedded within it. A highly oxidised zone, most likely a gossan (Fig.10b) of about 15 to 20 m thickness and an extent of approximately 2 km has been identified at the extension of the BIF horizon in the phyllitic tuff. This oxidised zone has a number of old workings.

Discussion

The field and petrographic characteristics of the lithounits of Bathani area discussed in the previous sections undoubtedly establish that this sequence is a part of a volcano-sedimentary sequence. The presence of pillow basalts, mafic pyroclasts and tuff horizons in the Bathani area indicates that the emplacement of the lavas occurred in subaqueous explosive conditions. Occurrence of the felsic volcanics like rhyolite along with mafic pillow lavas is a result of bimodal volcanism in the area.

The felsic magma was the precursor to the voluminous acid tuff present in the area, as the tuffs are basically derived from the cooler, more silicic and more volatile-rich upper part of the magma chamber (Hildreth, 1979; Smith, 1979). Martin and Sigmarsson (2007) describe the genesis of a variety of peralkaline rhyolite in Iceland similar to the porphyritic rhyolite of Bathani area. They show that such rocks can form through both fractional crystallisation and partial melting of the basaltic crust.

Emplacement of pillow basalt with mafic pyroclastic rocks and rhyolite requires a multi-source and multi-stage mechanism probably like an island-arc type set up (e.g., Hawkesworth and Powell, 1980; Dupuy et al., 1982; Sekine and Wyllie, 1982a, b; Kay, 1984; Wyllie, 1984; Arculus and Powell, 1986). Subaqueous emplacement of mafic lavas associated with pyroclasts can occur in diverse tectonic setup like continental or oceanic rifts, subduction zones associated with island arc or even ophiolite belts around the world (Wilson, 1989; Condie, 1997). Thus detailed geochemistry is required for identification of the tectonic setup in which the volcano-sedimentary units of Bathani were emplaced.

Conclusion

Detailed gelogical mapping led to the discovery of bimodal volcanic suite associated with volcanogenic sediments, BIF and chert horizon in Bathani area. Further studies on geochemistry and radiometric dating of these rocks are essential for better understanding of the tectonic evolution of the terrane.

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