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RESEARCH ARTICLE

PETROGRAPHY AND TECTONIC PROVENANCE OF THE TERTIARY ROCKS OF CHANGKI VALLEY, MOKOKCHUNG DISTRICT, NAGALAND, NORTHEAST INDIA

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ABSTRACT

The Tertiary rocks of Changki Valley constitute a part of belt of Schuppen - a most prominent morphotectonic unit of Naga Hills stretching along the western margin of Nagaland State. The Barail Group (Tikak Parbat Formation), Changki Formation and Tipam Group (Tipam Sandstone Formation) have been studied for their petrographic features and tectonic provenance. Based on the study, it may be inferred that the Tertiary sediments under question are mostly lithic in nature and received their detritus from a recycled orogen , especially the collision orogen provenances. The coal bearing Tikak Parbat Formation appears to have derived its detritus from the newly risen NHO to the east as well as the newly uplifted Himalaya and Trans – Himalayas to the north. The Changki Formation calls for a foreland uplift province besides recycled orogen whereas a collision orogen provenance together with uplifted igneous & metamorphic terrenes adjacent to the crustal suture may be assigned to the Tipam Sandstone Formation.

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INTRODUCTION

The Changki valley with its spectacularly developed Tertiary sequences, occupies north-eastern part of the Belt of Schuppen, the western most morpho-tectonic unit of NE – SW trending Naga Hills (Fig. 1). The other two morpho-tectonic units of Naga Hills namely, Inner Fold Belt and the Ophiolite Belt, occupy the central and eastern most parts respectively. The Naga Hills constitute northern extension of the N – S trending Indo-Burma (Myanmar) Range (IBR) that stretches for about 1,250 km along length (Acharyya, 2015). Owing to its location on the eastern extremity of the Indian plate, Naga Hills provides unique opportunity to study the tectono-sedimentary evolution of the Northeast India. The present study is an attempt to document the modal composition and tectonic provenance of the Tertiary rocks developed in Changki Valley, Mokokchung District, Nagaland.

Study Area

The area under study covers nearly 125 square kilometres bounded between North parallels of 94^0 20' & 94^o 30' East meridians of 26^0 24' & 26^0 30' of the Topographic Sheet No.83 G/7 of Survey of India.

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It includes areas lying near Changki, Longnak, Chungliyimsen, Atuphu, Mangkolemba and Mongchen Villages of Changkikong Range in the Mokokchung District, Nagaland (Fig. 1). The area can be approached from Mariani in Assam, the nearest railhead of NF-Railway on Guwahati – Dimapur – Dibrugarh rail route. The NH 39 connecting Mariani and Mokokchung via Changki passes through the area.

Lithological units, their distribution and field relationships

The Tertiary succession (Evans, 1932; 1964) of the study area exhibits well preserved cyclic pattern and normal stratigraphic succession except along the western face of the Changkikong range where the thrusted contact between the successive litho-units has been recorded. It comprises of coal bearing Tikak Parbat Formation of the Barail Group (Oligocene), the Changki Formation and Tipam sandstone Formation of the Tipam Group (Miocene). The Tipam sandstone Formation in turn is overlain by Dihing Formation. The geological map of the study area (Fig.1) depicts the distribution of various litho-units. The distribution and field relationships of various litho-units are briefly described below.

BARAIL GROUP

The coal bearing Barail rocks in the area are represented by Tikak Parbat Formation.

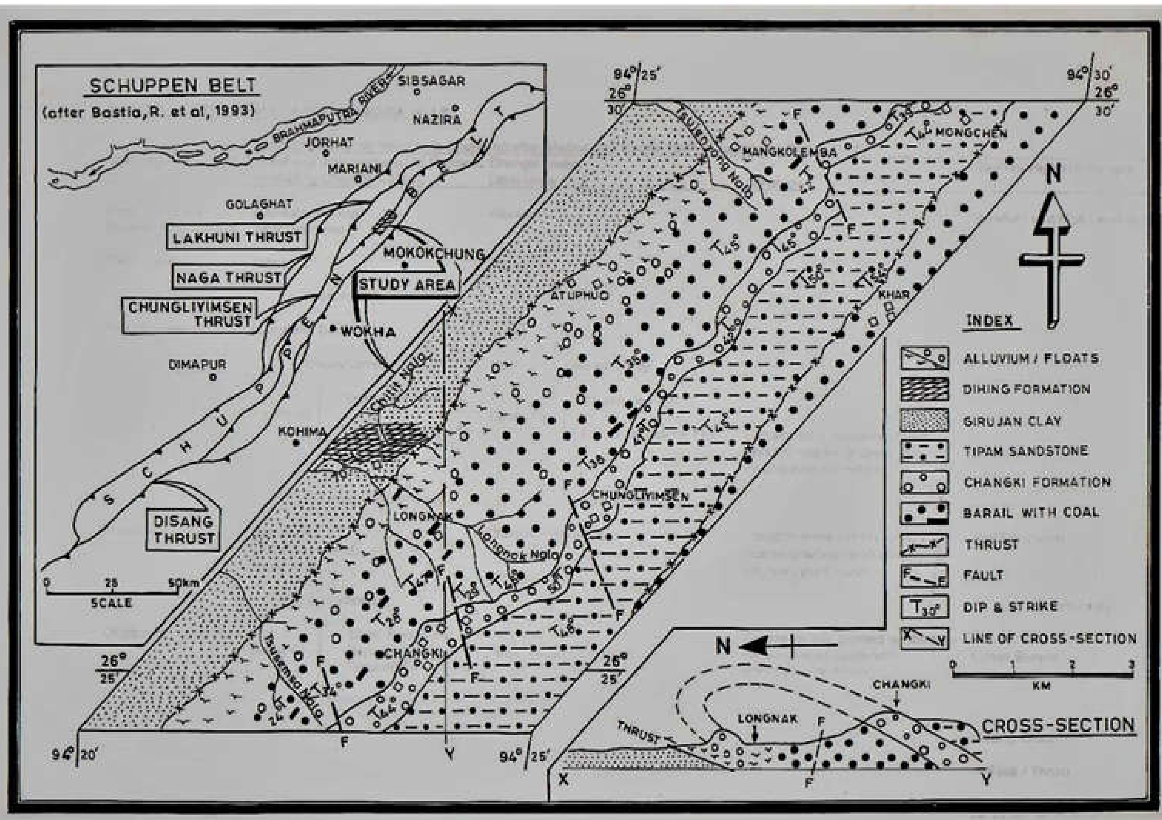

Fig. 1. Geological map of Changki valley, Mokokchung district, Nagaland.

They occur as sub-parallel thrust slices in the central and eastern parts of the area. The lower contact of each Barail strip with the Tipam Group is a thrust while the upper contact with the overlying litho-units is normal. Due to thrusted nature of lower contacts, the thickness of different Barail strips is found to be variable. The Tikak Parbat Formation occupies the lower contour levels extending all along the western slope of Changkikong range. It attains a thickness of about 900-950 meters near Changki village which gradually decreases to 500-600 meters toward the north near Mongchen. Broadly, it comprises the alternating sandstones, shales and sandy shales towards base and medium to coarse grained multistoried sandstones towards the top. Laterally impersistent coal seams of variable thickness occur at two levels in the Barail succession. At places well developed current and wave formed sedimentary structures are nicely preserved. The beds show a NNE-SSW to NE-SW trend with a general dip of 24^0 to 47^0 towards ESE to SE. The amount of dip increases near the tectonised contacts.

Changki Formation: In the Changki Valley there occurs a thick sequence of very coarse to pebbly sandstones, sandy shales and lag deposit containing silicified wood fossils being reported for the first time. These are found sandwiched between underlying coal bearing Barails (Tikak Parbat Formation) and overlying Tipam Sandstone Formation of Tipam Group. The lower and upper boundaries with Barails and Tipams respectively are marked by sharp unconformities. This sequence is strikingly different from alternating shale, mudstone, and shale-sandstones with minor conglomerate found towards the base of Surma Group. The thickness of Changki Formation varies from 200 meters in the south near Changki to less than 110 meters in the north near Mongchen. On the basis of its stratigraphic position, it may be correlated with Surma Group (Ganju *et al*, 1986).

Tipam Group: The Tipam Group of rocks are represented by the lower arenaceous members – the Tipam Sandstone Formation and upper argillaceous members – the Girujan clays. The mottled Girujan clays occupy the lower contour levels in the western part of the study area. They follow a NE-SW trend and show thrusted contact with the Barail rocks occurring towards east. The massive to false bedded feldspathic and ferruginous sandstones, well bedded calcareous sandstone and alternating thinly bedded sandstone- shale sequences together constitute the Tipam Sandstone Formation. These are well developed near the crest as well as all along the eastern face of Changkikong range. The current and wave formed sedimentary structures as well as the penecontemporaneously deformed sedimentary structures are quite common. The overall attitude of beds remains similar to Tikak Parbat and Changki Formations except for local variations in the amount of dip.

Dihing Formation: In the western part of the study area following the Mariani- Mokokchung road, there occurs a small patch of highly weathered rocks unconformably overlying the Girujan clay Formation. It comprises of unconsolidated pebble beds, gravels, clays and sands. The beds show a NW-SE trend with a general dip of 70^0 toward southwest.

Local structural features- folds, faults and joints: The most conspicuous structural feature in the study area is the presence of two sub-parallel NE-SW trending thrust running along the western and eastern margins of the Changkikong range. These have been designated as West Changkikong thrust and Khar thrust respectively (Iqbal, 1972). In general, they show a south easterly dip with varied dip amount between 24^0 & 54^0. In the area, the beds attain a steeper dip near the thrusted contact but they exhibit a homoclinal sequential arrangement away from the tectonised contacts. The cross section of the area drawn along X-Y line (Fig. 1) clearly demonstrates the thrusting and subsequent erosional phenomenon resulting in a NE-SW trending anticlinal valley- the Changki Valley. The Changkikong range has been traversed by four sub-parallel NNW-SSE trending fault planes. Among the joints, the most prominent set observed, show NE-SW and NW-SE trending patterns.

MATERIALS AND METHODS

The petrographic composition of the clastic detritus present in a stratigraphic unit relates, in general, to the rates of source area uplift and basin subsidence (Dickinson and Rich, 1972; Dickinson and Suczek, 1979; Dickinson *et al*., 1983; Miall, 1990) and thus the sandstone composition can be suitably used in understanding the tectonic provenance. Accordingly, in the present study, an attempt has been made to identify and define the tectonic provenance of the Barail Group, Changki Formation and Tipam Sandstone Formation using the petrographic method suggested by Dickenson and Suczek (1979), and Basu *et al* (1975). For the purpose nearly 200 thin sections in all involving each lithostratigraphic unit were studied. More than 200 points were counted in each thin-section to estimate the petrographic features of frame work grains, matrix and cement as presented below.

Quartz: Three basic type of quartz (Conolly, 1965) are easily recognizable namely, non-undulatory quartz, undulatory quartz and polycrystalline quartz. Non-undulatory quartz grains are commonly identified by their complete extinction upon a slight (less than one degree, according to Blatt and Christie, 1963) rotation of flat microscope stage. On an average it constitutes 52 %, 58 % and 48 % of the total quartz in Tikak Parbat, Changki and Tipam sandstone Formations respectively. Monocrystalline undulatory quartz which shows typical undulose extinction (Blatt and Christie, 1963) comprises, on an average, 47 %, 46 % and 40 % of total quartz in all the three Formations respectively. Polycrystalline quartz is a composite grain consisting of 2 to 3 units and sometimes more than three units. They are usually distinguished from metaquartzite fragments by the presence of smooth, non-sutured boundaries between separate units. The total absence of polycrystalline quartz with 2-3 units in Changki and Tipam Formations (average < 0.5% in Tikak Parbat Formation) is remarkable. Well rounded recycled quartz and volcanic quartz with smooth subhedral outline (Fig. 2) are also seen in few thin sections of Changki and Tipam Sandstone Formations. In almost all the Formations quartz grains are found to be inclusion free, mostly coated with iron- oxide. Some of the quartz grains in Changki Formation show epitaxial growth of mica along their periphery (Fig.3). Invasion of quartz grains by calcium carbonate cement, especially in Tipam Sandstone, produces irregular isolated quartz grains exhibiting 'island' texture (Fig. 9).

Feldspar: The feldspar content of Tikak Parbat , Changki and Tipam Sandstone Formations ranges from nil to 5.6 % (average of 1.5 %), to 8.16 % (averaged to 3.0 %) and 3.36 to 21.55 % (averaged to 13%) respectively. Among feldspars mostly sodic plagioclase and orthoclase varieties are present, the former being absent in Changki Formation. In Barails orthoclase dominate over plagioclase feldspars while they share fifty-fifty in Tipam sandstones. The overall grain size corresponds to that of a very coarse sand and granule particles, grains being sub-rounded and coated with thin iron – oxide, (Fig.4).

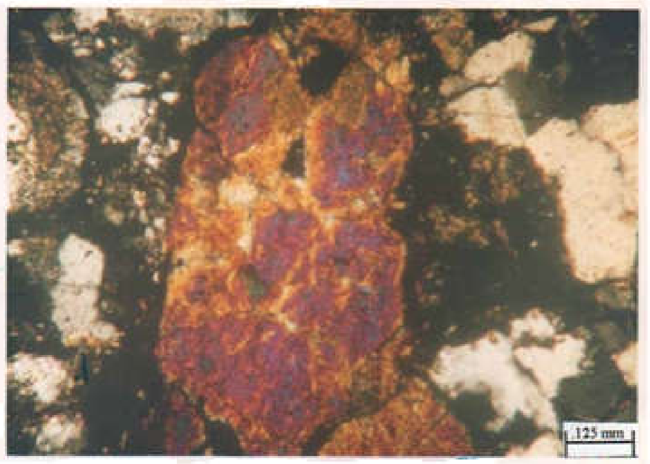

Fig. 2.

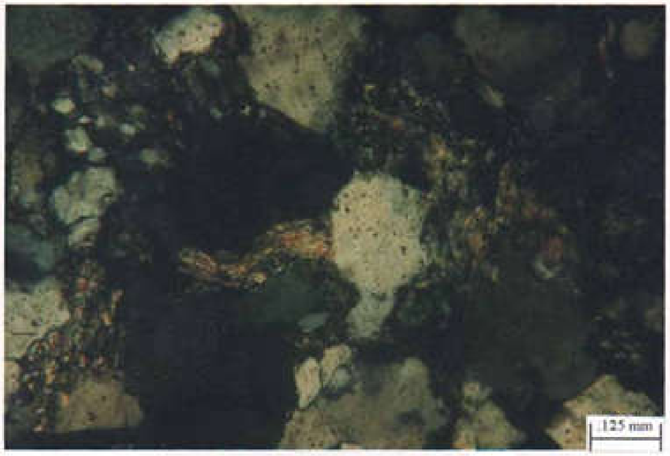

Fig. 3.

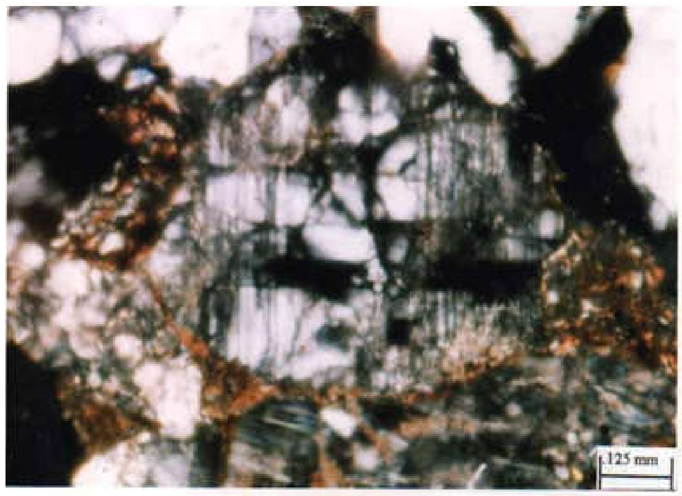

Fig. 4.

Dislocated twin laminae are sometimes visible in thin sections. Such detrital feldspars commonly exhibit evidence of having been replaced by recrystallised sericitic matrix or diagenetic alteration. Most of the feldspar grains are unaltered except for a few samples where little amount of altered feldspars were also encountered. Among the Tertiary sediments studied, feldspars record an upward trend and ultimately pre-dominate the Tipam Sandstone Formation (Fig. 5).

Muscovite: Flakes of detrital muscovite measuring about 25mm are also observed in few thin sections. They, however, show degradation to sericite and replacement by ferruginous cement.

Fig. 5.3

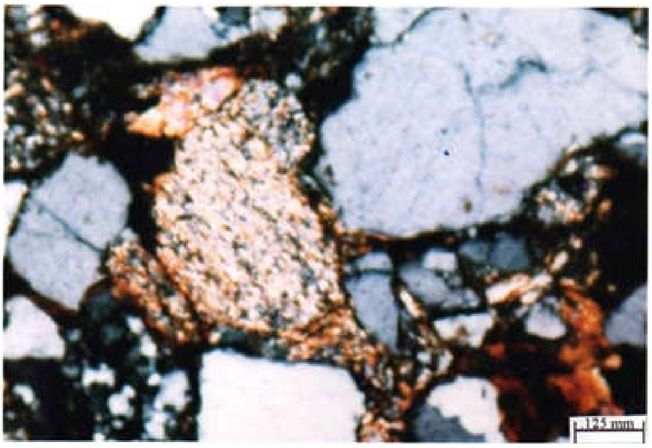

Fig. 6.

Fig. 7.

Rock Fragments: Rock fragments which are identified by their compositional and textural criteria (Dickinson, 1970), constitute an important component of the Tertiary sediments in the area. In the Tikak Parbat, Changki and Tipam Sandstone Formations, their percentage including chert, ranges from 15.12 to 40.66 % (averaged to 25%), 7.71 to 42.24 % (averaged to 23 %) and 4.46 to 33.31 % (averaged to 18 %) respectively. The order of abundance of different rock fragments in Barail Group includes Chert > Orthoquartzite >Quartz- Mica tectonite > Sandstone > Shale + Siltstone > Metaquartzite >Limestone > Physilites ; that of Changki Formation ; Chert > Shale + Siltstone > Quartz – micatectonite > Physilites > Orthoquartz > Sandstone > Metaquartzite ; and Tipam Sandstone Formation display Chert > Quartz – mica tectonite > Shale + Siltstone > Physilites > Orthoquartzite > Metaquartzite > Sandstone > Limestone. (Fig. 6) indicate strong tectonic control over depositional events. The Changki Formation may be characterised by the predominance of chert and its varieties (Fig.7) namely, microcrystalline and radiolarian cherts (average 62 % of the total rock fragments). Sporadic occurrence of volcanic rock fragments showing vesicles filled with spherulitic chalcedony is a remarkable feature of Changki Formation.

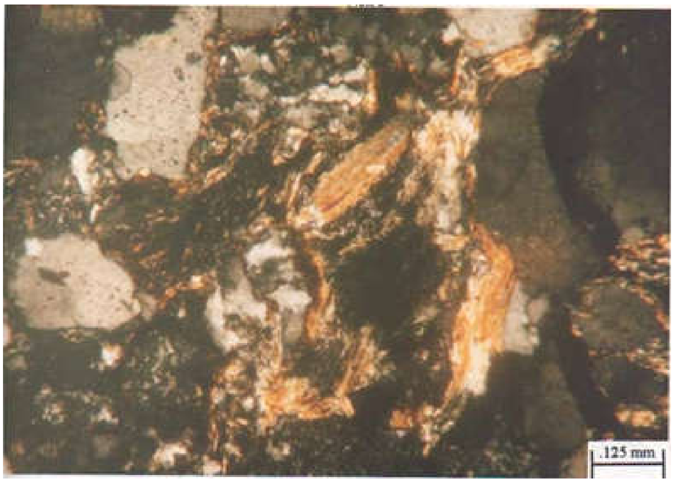

Fig.8.

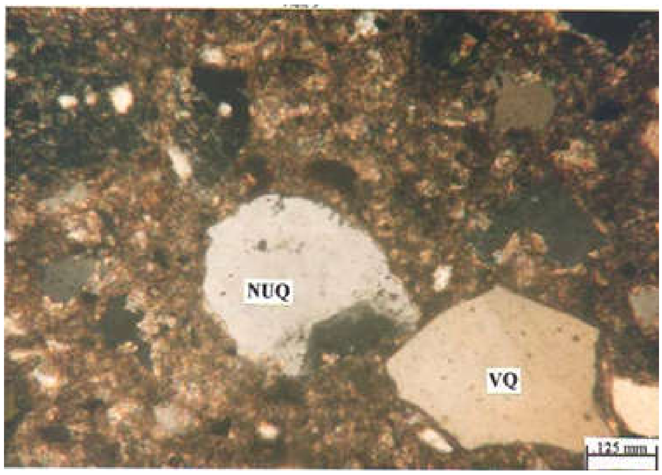

Fig. 9.

Heavy Minerals: The Tertiary sediments under study are, in general, poor in heavy minerals yield. On an average they constitute nearly 1% by volume in which opaque minerals dominate over non-opaque. The heavy mineral assemblages present in Barail Group, Changki Formation and Tipam Sandstone Formation may be presented as Tourmaline - Zircon - Rutile - Garnet –Chloritoid, Garnet - Chloritoid - Hornblende - Staurolite - Kyanite –Tourmaline, and Epidote - Garnet - Chloritoid - Hornblende - Sillimanite - Kyanite – Zircon respectively.

Matrix and Cement: Particulate sericite or reconstituted complex aggregates of chert and argillaceous material comprise, what is called as matrix in the clastic sedimentary rocks. It usually occurs as fibrous or finer laths in the pore spaces (Fig. 8) and on an average constitute about 7.31 % (range 3.80% to 22.48%), 7.8% (range nil to 16.67 %) and 7.09% (range 1.66% to 20.42%) in Tikak Parbat, Changki and Tipam Sandstone Formations respectively.

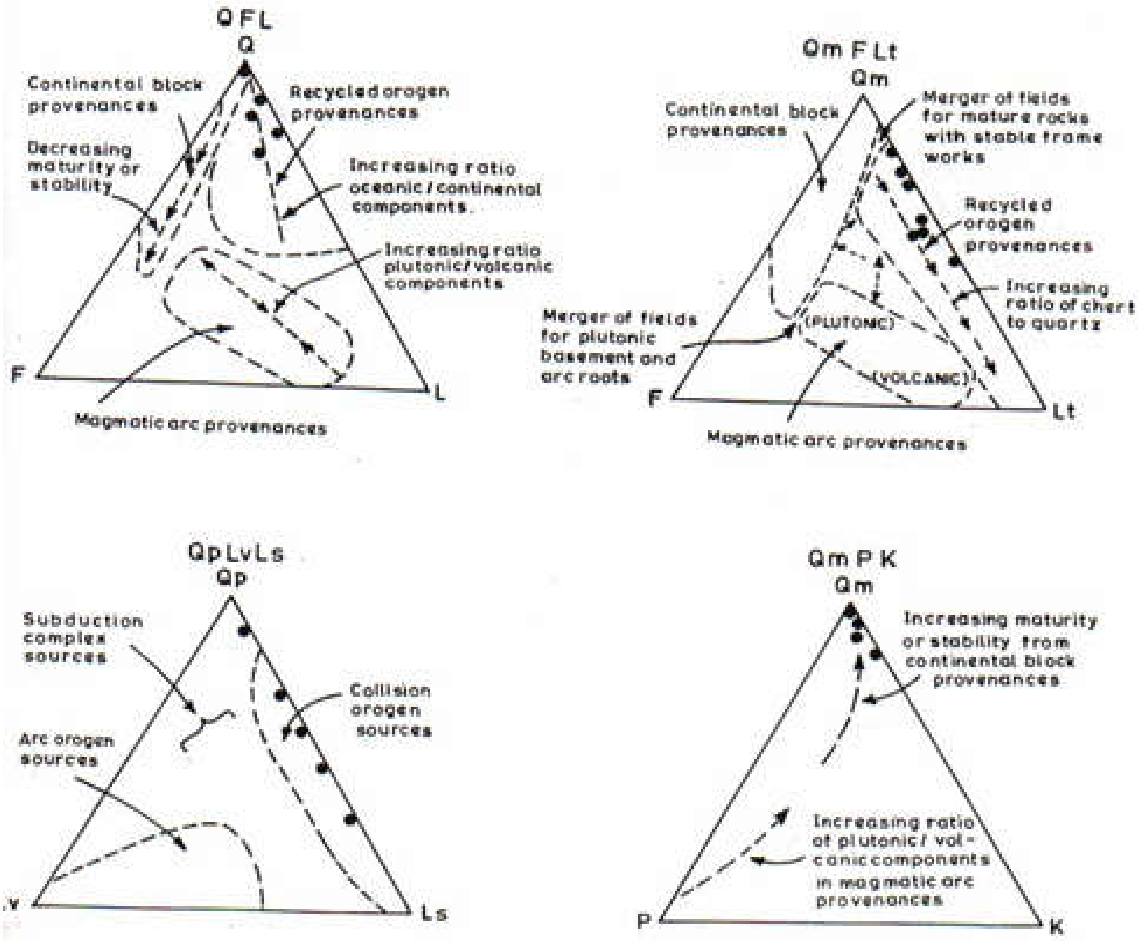

Fig. 10. Ternary plots of detrial sandstone composition (after Dickinson and suczek, 1979) Showing tectonic setting of barail group

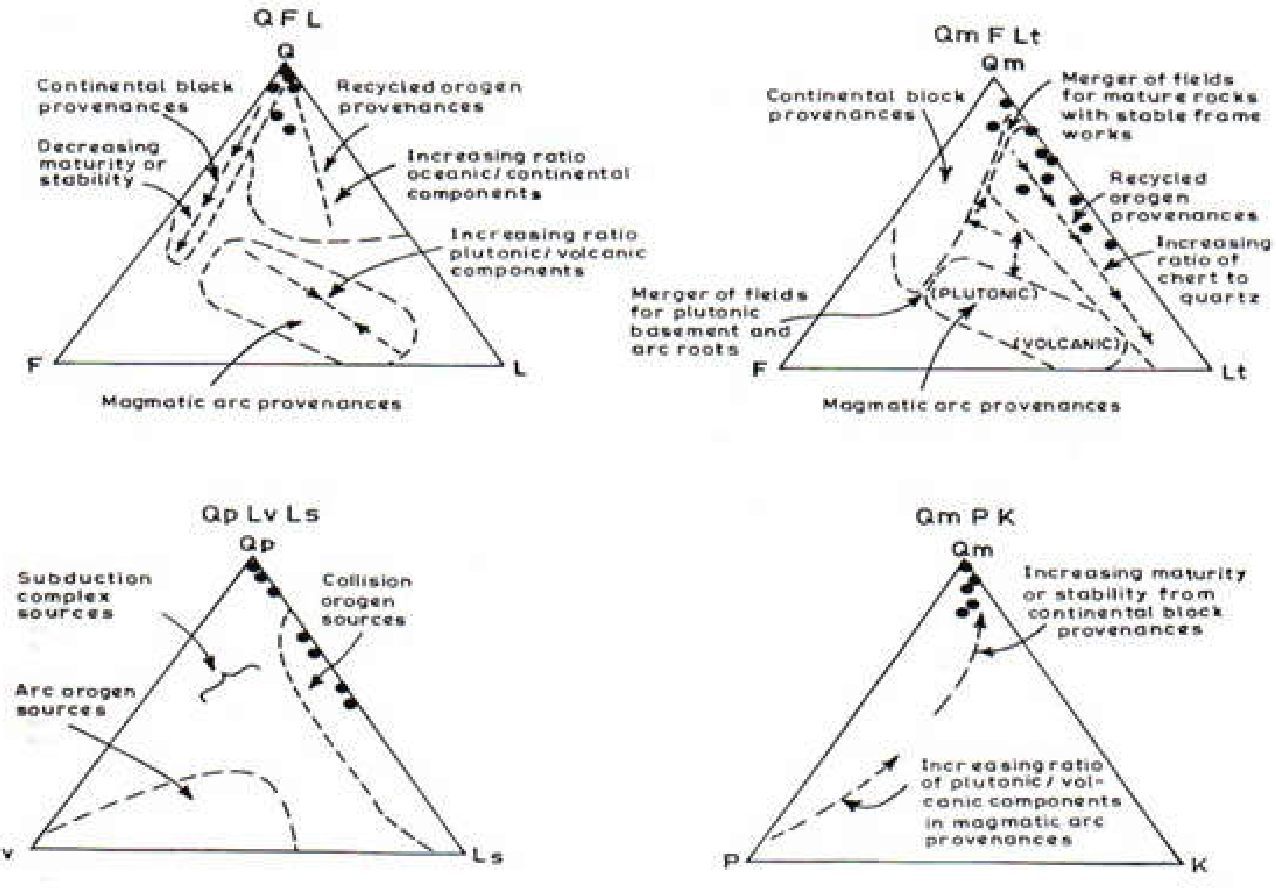

Fig. 11. Ternary plots of detrial sandstone composition (after Dickinson and suczek, 1979 showing tectonic setting of changki formation

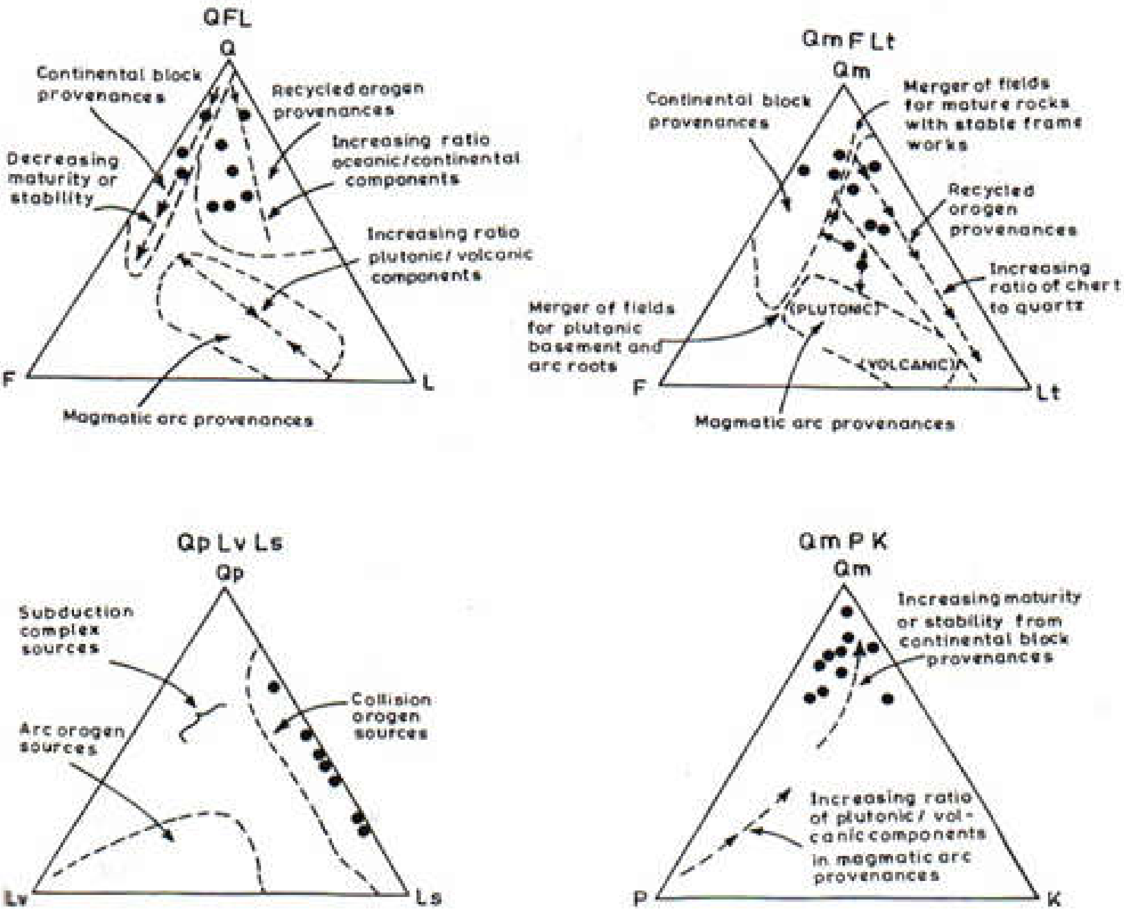

Fig. 12. Ternary plots of detrital sandstone composition (after Dickinson and suczek, 1979) showing tectonic setting of Tipam sanstone formation

Chlorite characterised by its green colour and low birefringence is also present in small amounts. The amount of sericitic matrix, however, decreases with an increase in grain-size of sandstones, especially exhibited by Changki Formation. The fine 'white mica' or sericite flakes commonly appear as intergrowths with detrital grain along their periphery or intermixed chert and sericite matrix (Fig. 9). However, the nature and distribution of matrix resemble the protomatrix (primary), orthomatrix (recrystallized primary matrix), epimatrix (produced by diagenetic alteration of framework grains) and pseudomatrix (deformed original grains) of Dickinson (1970, p.702). Iron oxide (FCT), silica (SCT) and calcium carbonate (CCT) occur as interstitial pore filling cement. The cement as a whole constitute nearly 4.27% (range 1.73 to 8.44%, FCT >SCT > CCT), 5.2% (range 1.39 to 19.67 %, FCT > SCT > CCT) and 10.25% (range 0.41 to 30.54%, FCT > CCT > SCT) in Tikak Parbat, Changki and Tipam Sandstone Formations respectively.

Tectonic Provenance: As referred earlier, the detrital modes of siliciclastic suites provide information about the tectonic setting of basins of deposition and associated provenances (Dickinson, 1970; Schwab, 1971, 1975; Dickinson and Rich, 1972; Crook, 1974; Davis and Ethridge, 1975; Dickinson, *et al*. 1983; Miall , 1990). Accordingly in the present study, an attempt has been made to interpret the tectonic provenance and associated depositional environments of Tertiary sediments of Changki Valley, based on the data generated through textural and mineralogical studies. The QFL, QmFLt, QpLvLs and QmPK plots after Dickinson and Suczek, 1979 were used in the present investigation to discriminate the tectonic provenances of Tertiary sediments under question. The following modal quantities have been used in the Ternary plots:

Q = Monocrystalline and Polycrystalline quartz grains, including Chert (Q=Qm=QP)
Qm = Monocrystalline quartz
Qp = Polycrystalline quartz, including Chert
F = Monocrystalline feldspar (F = PK)
P = Plagioclase feldspar
K = Potassium feldspar
Lv = Volcanic (hypabyssal) fragments
Ls = Sedimentary fragments
Lm = Metamorphic fragments
L = Unstable polycrystalline lithic fragments (L=Lv+Ls+Lm)
Lt = Total lithic fragments including polycrystalline quartz (Lt = L + Qp)
D = Dense minerals

Since most of the Tertiary sandstones in the study area belong to lithic category, care has been taken to distinguish recrystallised detrital matrix (orthomatrix), diagenetic pore-filling matrix (epimatrix) and squashed lithic grains (pseudomatrix) as suggested by Dickinson, 1970. Based on the positions of the data points in QFL, QmFLt, QpLvLs and QmPK plots after Dickinson and Suczek (1979) (Fig.10, 11, & 12), it may be broadly concluded that the Tikak Parbat , Changki and Tipam Sandstone Formations, received their detritus from a recycled orogen, especially the collision orogen provenances.

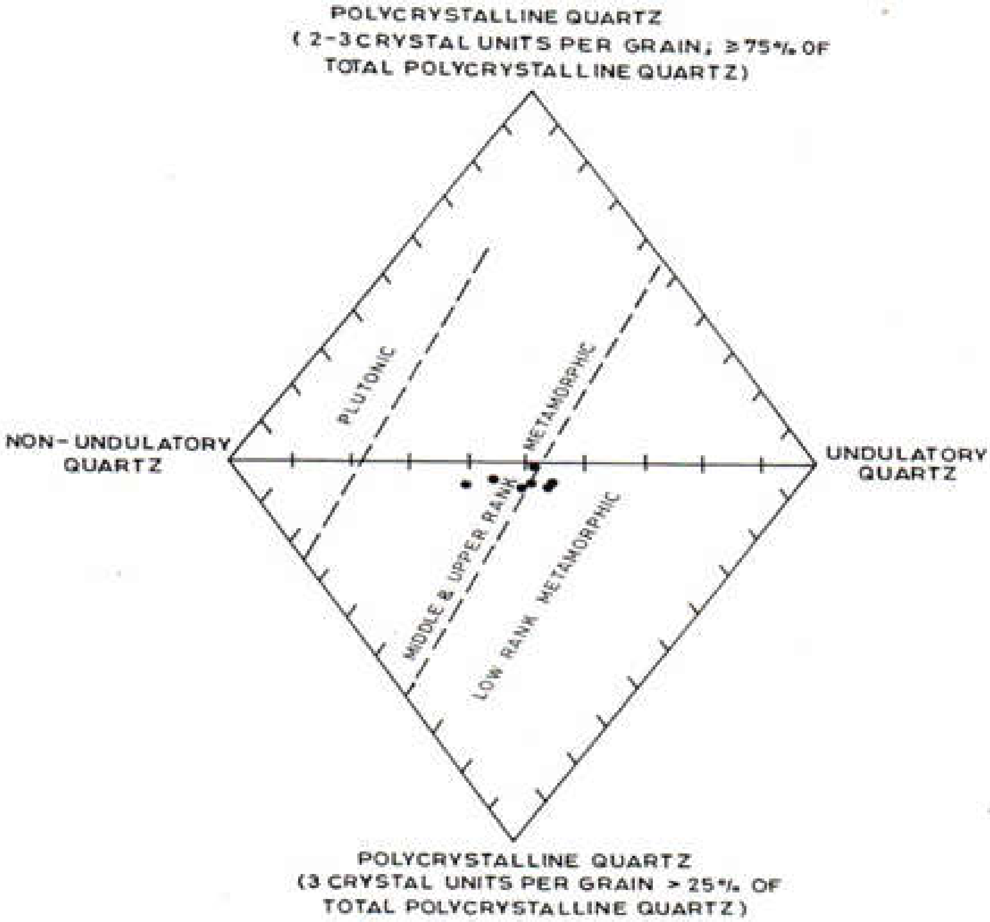

Fig. 13. Diamond diagram after basu *et al.* (1975) for barail group

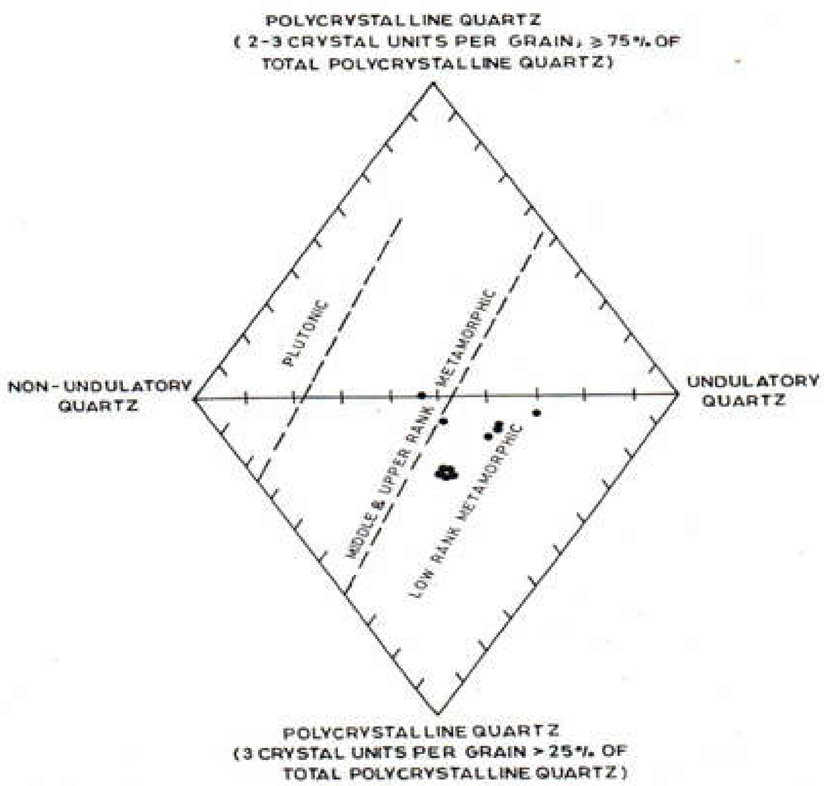

Fig. 14. Diamond diagram after basu *et al*. (1975) for changki formation

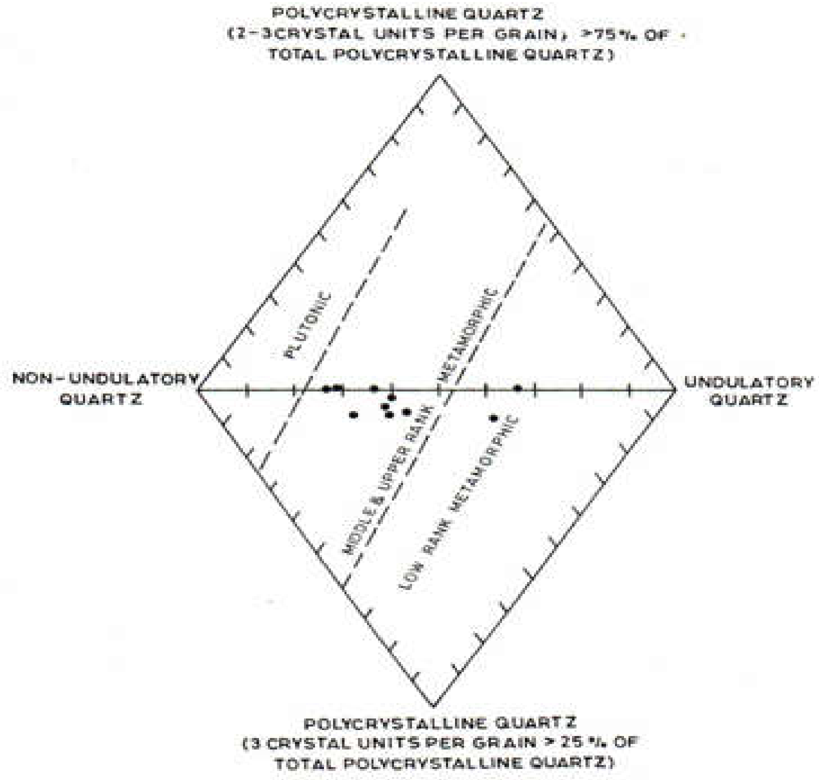

Fig. 15. Diamond diaream after basu et al. (1975) for tipam Group

Such orogens are composed largely of nappes and thrust sheets of sedimentary and meta- sedimentary rocks that represent sequences present along and near the preceding continental margins prior to their juxtaposition along a suture belt. Associated with these terranes there would be ophiolitic melanges and structurally dislocated plutonic terranes of basement blocks or magmatic arcs involved in the crustal collision. The collision derived sediments is mainly shed longitudinally from the evolving orogen into closing remnant ocean basins as turbidites, but also enters foreland basins flanking the orogen and complex successor basins developed along the suture belt (Dickinson and Suczek, 1979). In the north-eastern part of Indian sub-continent , bordering Nagaland to the east , there occurs a NE-SW trending about 90 km long and narrow belt of ophiolite suite of rocks (Naga Hills Ophiolites =NHO) which appears to have served as principal source rock for development of Tikak Parbat , Changki and Tipam Sandstone Formations. The NHO has a varied litho-assemblage ranging from members of the meta- ultramafites to the oceanic sediments including chert, radiolarian chert, limestone and greywacke. The metaultramafites consists of dunite, harzburgite and minor Lherzolites; while the cumulate mafic-ultramafics are constituted of clinopyroxenites. Lherzolites, wehrlite, websterite and gabbro. The volcanic and volcanoclastic rocks include basalts, spilites, hyaloclastites and agglomerates. This ophiolite belt is overlain by the Naga metamorphic and underlain by Disang flysch along with thrusted contacts (Agrawal, 1984). The metamorphic rocks in the ophiolite belt are mafic green schist, glaucophane schist, hornblende schist, serpentine schist, tremolite – actinolite schist and phyllite. The Naga Hills Ophiolite, which forms the northern segment of Indo-Burman Ranges (IBR), joins the eastern Himalayan through Mishmi Hills in the north. Further north occurs the Tiding suture with serpentinite, metavolcanics and other metamorphic rocks having the huge granodiorite-batholites on its back and linking physically the eastern end of the Indus-Tsangpo Ophiolite (ITO) and northward outcrop continuity of the Myitkyina and Mandalay Ophiolite (MAMO) of Central Burma, now Myanmar (Acharyya, 1982; Acharyya *et al*., 1984).

Conclusion

The coal bearing Tikak Parbat Formation appears to have derived its detritus from the newly risen NHO to the east as well as the newly uplifted Himalaya and Trans – Himalayas to the north. The high chert content (average 13.5% of total rock fragment) together with other sedimentary rock fragments (average 7% of total rock fragment) including fragments of limestone (average 0.5% of total rock fragment) and a substantial amount of tectonites and physilites (average 2.75% of total rock fragment) indicate significant contributions from melange terrenes caught along the suture belt. Moderately high quartz content (average 87%) together with high ratio of K-feldspar to plagioclase further reflects contributions from continental surfaces having low gradients (Dickinson and Suczek, 1979). Besides recycled orogen, the Changki Formation calls for a foreland uplift province. On an average high quartz content (89%), strikingly low feldspar content (KF / PF =16.67 %), high chert content (14.26% of total rock fragment) and abundant sedimentary lithic fragments of less stable varieties (average 5.06% of total rock fragment) , all indicate derivation from a newly uplifted foreland fold- thrust belt, the contained sedimentary particles being recycled very coarse to granule, even pebble size. Such a tectonic provenance could possibly be the newly uplifted thrust slices of Barail sediments, Phokpur and Jopi Formations (volcaniclastics and sedimentary sequences associated with NHO) during the Late Oligocene tectonic activity. This is the period when northern and north eastern prolongations of Indian subcontinent collided with the Himalayan microcontinent to the north and the Central Burma (now Myanmar) micro continent to the east respectively (Acharyya, 1986; Agrawal and Ghosh, 1986). Presence of volcanic rock fragments containing vesicles filled with chalcedonic quartz , altered grains of hornblende, metaquartzite and schist rock fragments , together with tectonised quartz- mica schist and physilite (average 3.45% of total rock fragment) etc. further points towards a varied provenance comprising basic , ultrabasic and metamorphic rocks. The Tipam Sandstone Formation with its moderately high feldspar (Q/F = 4.33), moderate quartz (71.53%) and lithic contents (11.94%) requires a collision orogen provenance together with uplifted igneous metamorphic terrenes adjacent to the crustal suture. Further, presence of subordinate chert (average 5.58% of total rock fragment), limestone and other sedimentary rock fragments (average 5.4% of total rock fragment) attest contributions from melange terrenes. It is quite likely that during post collision period (Middle Miocene) the NHO might have been further uplifted together with associated igneous and metamorphic terrenes. The above interpretations on tectonic provenances can further be substantiated through the Diamond Diagram plotting (Fig.13, 14, &15) after Basu *et al*. (1975). It indicates a mixed low rank, middle and upper rank metamorphic, dominantly low rank metamorphic and predominantly middle and upper rank metamorphic source rocks for the Tikak Parbat, Changki and Tipam Sandstone Formations respectively.

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