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Search for Provenance of Oligocene Barail Sandstones in and around Jotsoma, Kohima, Nagaland

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Abstract: Provenance of the Oligocene Barail sandstones has been ascertained by means of petrographic and heavy mineral studies. Petrography reveals an abundance of angular to sub-rounded monocrystalline, non-undulatory quartz followed by lithic fragments. The overall composition of sandstones matches with those of sublith-arenites. The heavy mineral suite of Barail sandstones displays rounded to sub-rounded as well as euhedral / angular grains of iron oxide, zircon, tourmaline, rutile, kyanite, sillimanite and staurolite in decreasing order of abundance. Petrography coupled with heavy mineral suite suggests for a mixed provenance dominated by a sedimentary source of recycled orogenic provenance in a foreland basin setup.

Keywords: Petrography, Heavy minerals, Provenance, Barail Group, Nagaland.

INTRODUCTION

Much of the present knowledge of the stratigraphy, structures and tectonics of Naga Hills owes to the pioneering works of the Geological Survey of India, Oil and Natural Gas Corporation and the Directorate of Geology and Mining, Government of Nagaland. The pioneering works of Mallet (1876), Evans (1932) and Mathur and Evans (1964) laid the foundation of northeast Indian geology. Since then useful studies on the lithostratigraphy, sedimentology, structural, and regional correlations have been attempted by Bhandari et al. (1973), Dasgupta (1977), Banerjee (1979), Chakravarty and Banarjee (1988), Naik et al. (1991), Biswas et al.(1994), Pandey and Srivastava (1998), Nandi (2000), Srivastava (2002), Srivastava and Pandey (2004, 2008) and Acharya (2007). Most of the earlier workers have related the stratigraphic inconsistencies to that of the complex tectonic regime of the region.

The recent past has witnessed growing interest in interpreting the tectonic provenance using detrital modes; as these reflect the provenance and tectonic settings (Dickinson, 1970; Ghosh, 1990, Ingersoll et al.1993; Uddin and Lundberg.1998b; Singha and Das, 1999; Horton et al. 2002). Nevertheless, alterations due to weathering, abrasion and sorting during transportation (Suttner, 1974), depositional environment (Davis and Ethridge, 1975), palaeoclimate (Suttner et al. 1981) and post depositional changes generally modify the sandstone composition (McBride, 1985; Uddin and Lundberg., 1998a). Recycling, long transport, and palaeoclimate generally increase quartz content of sediments at the cost of other grains. Interpretations based solely on such modified compositions may result distorted provenance settings (Mack, 1984; Dickinson, 1988). However, there are certain mineral species that can be used directly as provenance indicator (Blatt et al. 1980).

In recent years Singh et al. (2004) have successfully used heavy minerals in deciphering the provenance and tectonic settings of the sedimentary deposits from the western Himalayan foreland basin. The present study is also an attempt to infer provenance characteristics of the Oligocene Barail sandstones using frame work compositions and heavy mineral assemblages.

GEOLOGY OF THE STUDY AREA

The rocks of Nagaland in Kohima synclinorium occur in NE-SW trending linear belts. The study area lies in the western part of the synclinorium. A number of folds with different style and geometry characterize the area and suggest multiple episodes of deformation. In addition, there are faults traversing the study area.

Geologically, there are three distinct morphotectonic units in Nagaland, the Ophiolites and related sediments in the east, Schuppen belt in the west and the Inner fold belt in the middle (Mathur and Evans, 1964). Except for Disang Group of rocks; all other Cenozoic lithostratigraphic units are found in the Schuppen belt in thrusted blocks, whereas presence of Disang and Barail Group of rocks with minor Surma sediments characterize the Inner fold belt which is occupied by two synclinoria, the Patkai synclinorium to the north and Kohima synclinorium to the south. The study area (94°-94° 05'51" N and 25°39' 48" - 25°45'E) that forms a part of the Kohima synclinorium is comprised of Cretaceous to Eocene Disang Group of rocks (dominantly argillaceous), followed by the Disang- Barail Transition (Pandey and Srivastava, 1998) which in turn passes gradually into the Oligocene Barail Group of rocks (dominantly arenaceous, Fig.1, Table 1). The Barail sandstones of the study area are light grey to grey in colour and possess fine to medium- grained character with occasional shale intercalations. The sedimentary structures observed in these rocks include bifurcating ripples, planar cross beddings, small scale channels, pinch and swell structures and bioturbation. At places intensive bioturbation has imparted mottled character to the sandstones.

METHODOLOGY

Samples of Barail sandstones were collected from fresh exposed sections in and around Jotsoma village. A total number of 15 samples were used in thin section preparation for petrographic studies. Since the rock samples were hard

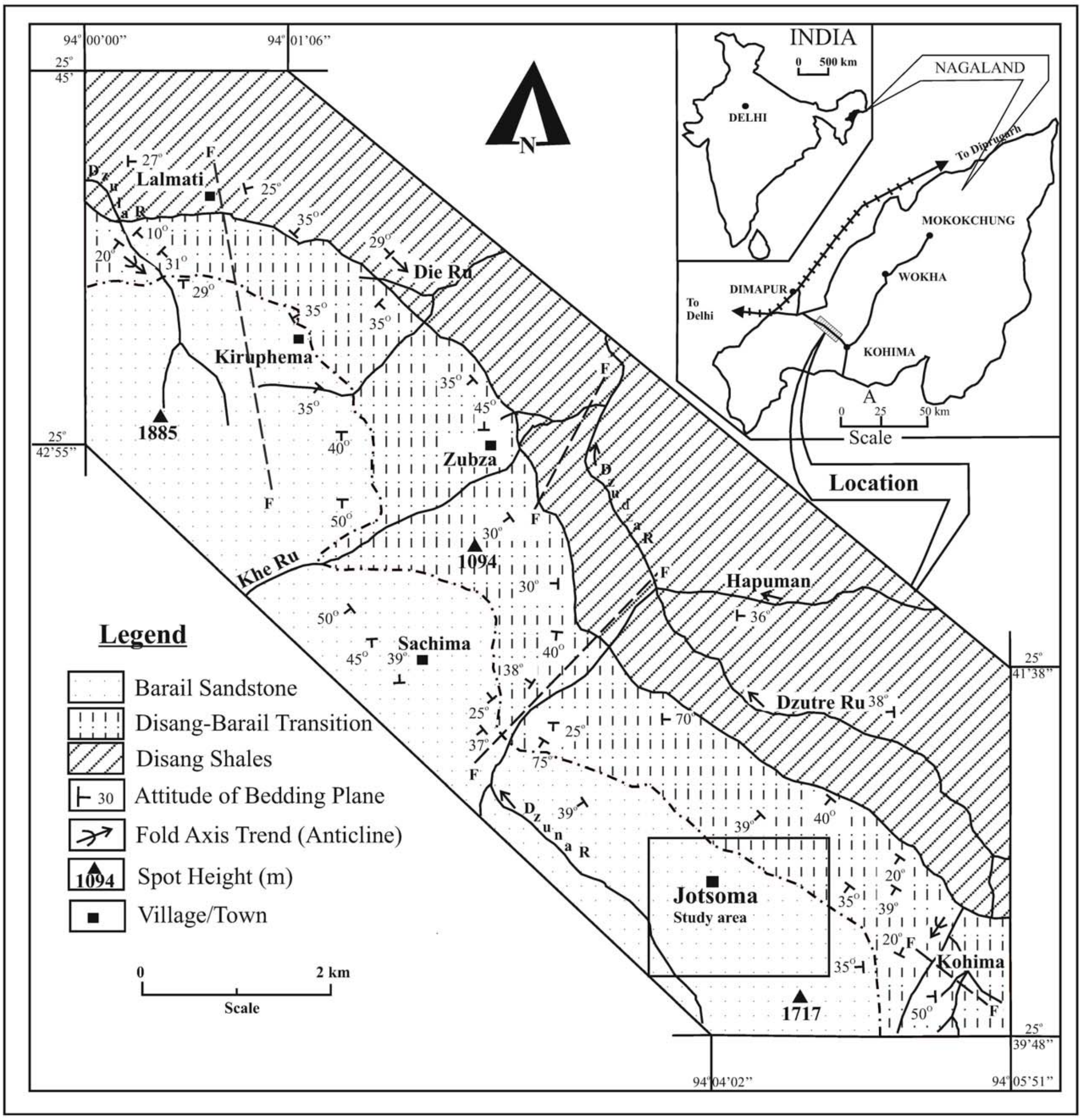

Fig.1. Geological map of the study area.

Table 1. Lithostratigraphy of the study area

Sequence	Lithology	Age	Reference
Barail Group	Sandstone with minor shale	Oligocene	Krishnan (1982)
DBTS (Disang-Barail Transitional sequences)	Sand, silt and shale alternations	Upper Eocene	Pandey and Srivastava (1998)
Disang Group	Shales with minor sandstone	Upper Cretaceous to Middle Eocene	Krishnan (1982)

and compact; their disintegration for heavy mineral separation was not possible and hence the method suggested by Folk (1980) have been used. Samples for heavy mineral separation were crushed gently, washed properly and then subjected to alternate treatment with hydrogen peroxide, distilled water and dilute hydrochloric acid plus stannous chloride and zinc foil, followed by boiling for about 5 to 10 minutes so as to remove the authegenic clay, carbonate and ferruginous coatings on the grains. After thorough washing and drying; 100 mesh and 120 mesh fractions were separated through sieving using bromoform (sp.gr.2.89). Heavy minerals thus separated were mounted on glass slides using Canada balsam. A total number of thirty grain mounts were prepared and studied under the microscope for identification of the heavy mineral species.

RESULTS

Petrography

Barail sandstones of the study area are hard and compact and typically display bluish grey and light yellow colours. They range in size from medium to very fine sand and possess an average composition of Q-64.10%, F-1.27%, RF-6.20%, Mica-1.28%, HM-1.29%, CT-6.39%, MX-19.33%. The recalculated data indicates that the rocks belong to sublith arenite category (e.g. Folk, 1980).

Among the framework grains, quartz is the most abundant constituent. Majority of quartz grains are sub-angular to sub- rounded. A few well rounded grains are also seen. Non- undulatory quartz grains dominate over undulatory quartz (fig.2a). Enlargement of quartz grains by siliceous growth is not very uncommon. At places, matrix/ cement has digested the detrital grain boundaries. Rock fragments rank second after quartz and include sedimentary, metamorphic and igneous in descending order of abundance (Figs.2d, e). Sedimentary rock fragments include sandstones with zircon, siltstones and chert. Among other categories of rock fragments, schist characterizes the metamorphics, where as bits of vitrified glasses to the volcanic. Though sparse, sodic plagioclase with its characteristic albite twinning (Fig.2b) and sporadic K-feldspar grains (Fig.2c) represent feldspars. In addition, a few biotite, muscovite and chlorite flakes showing various degrees of bending (Fig.2f) were also found.

Particulate sericite and reconstituted complex aggregates of chert and argillaceous material constitutes the matrix component of the Barail sandstones. Matrix usually occurs as fibrous or finer laths in the pore spaces (Figs.2a, b) and on an average makes up 19.33% by volume. Among cements; iron oxide, silica and calcium carbonate occur as interstitial pre-filling material.

Heavy Minerals

The heavy mineral suite in the Barail sediments depicts a cosmopolitan nature. It comprises dominantly of non-opaque variety and includes zircon, tourmaline, rutile, kyanite, sillimanite, and staurolite (Figs.3a,b,c). Iron oxide constitutes the opaque variety. An overall dominance of the ultra stable heavy minerals (ZTR = 85.29) is conspicuous (Fig.4). Analysis of the heavy minerals further indicates that the well rounded and sub-angular to sub-rounded varieties dominate over the angular variety (Fig.5).

Zircon

It is the most dominant heavy mineral present in all most all the samples analyzed. It occurs as colourless prismatic, angular, sub rounded to well rounded grains. Some of the zircon grains show randomly distributed inclusions of opaque as well as non-opaque minerals. High refractive index, straight extinction, high order polarization colour and zoning are quite distinct.

Tourmaline

It exhibits a variety of colours like greenish yellow/ pale yellow, brown, pale brown and green. It shows intense pleo-chroism, the dominant colours being olive and pale green. Though not very common; inclusions of non-opaque minerals were observed. Well rounded to sub rounded as well as prismatic grains are common. In some of the tourmaline grains pitting and spotting like features were also recorded.

Rutile

It is identified by its characteristic blood red and dark pale brown colours. High refractive index and week pleochroism are conspicuous. Elongated sub rounded grains dominate over those of prismatic in shape.

Kyanite, Sillimanite and Staurolite

Kyanite occurs as colourless, moderately rounded

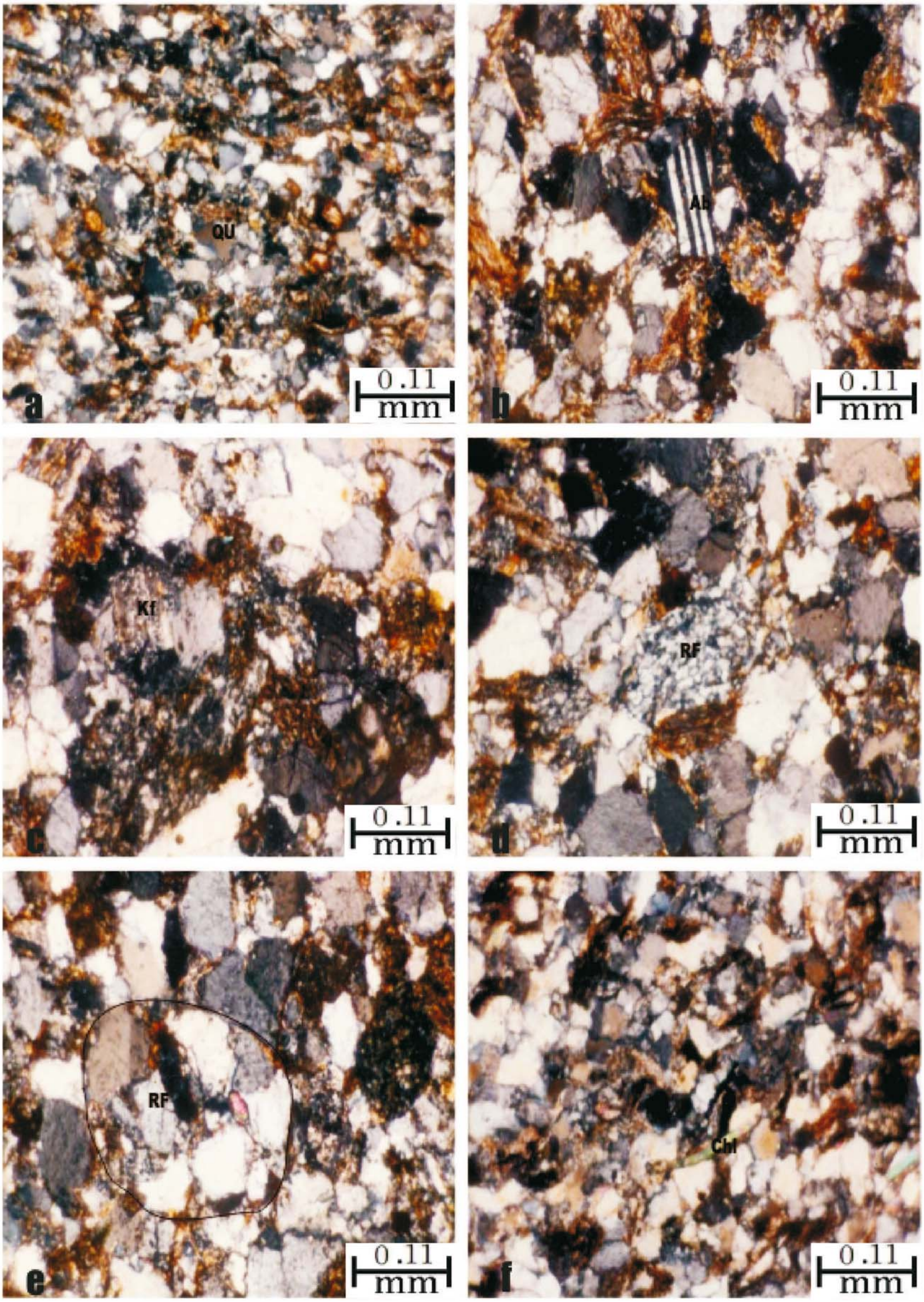

Fig.2. Photomicrographs showing **(a)** undulatory quartz (QU). **(b)** plagioclase (Al) physillites also can be seen. **(c)** siliceous overgrowth on K- feldspar (Kf). **(d)** rock fragment (RF) **(e)** sandstone rock fragment (RF), zircon can also be seen **(f)** chlorite flake (Chl), and undulatory quartz. Angular quartz grains and iron cement can also be seen

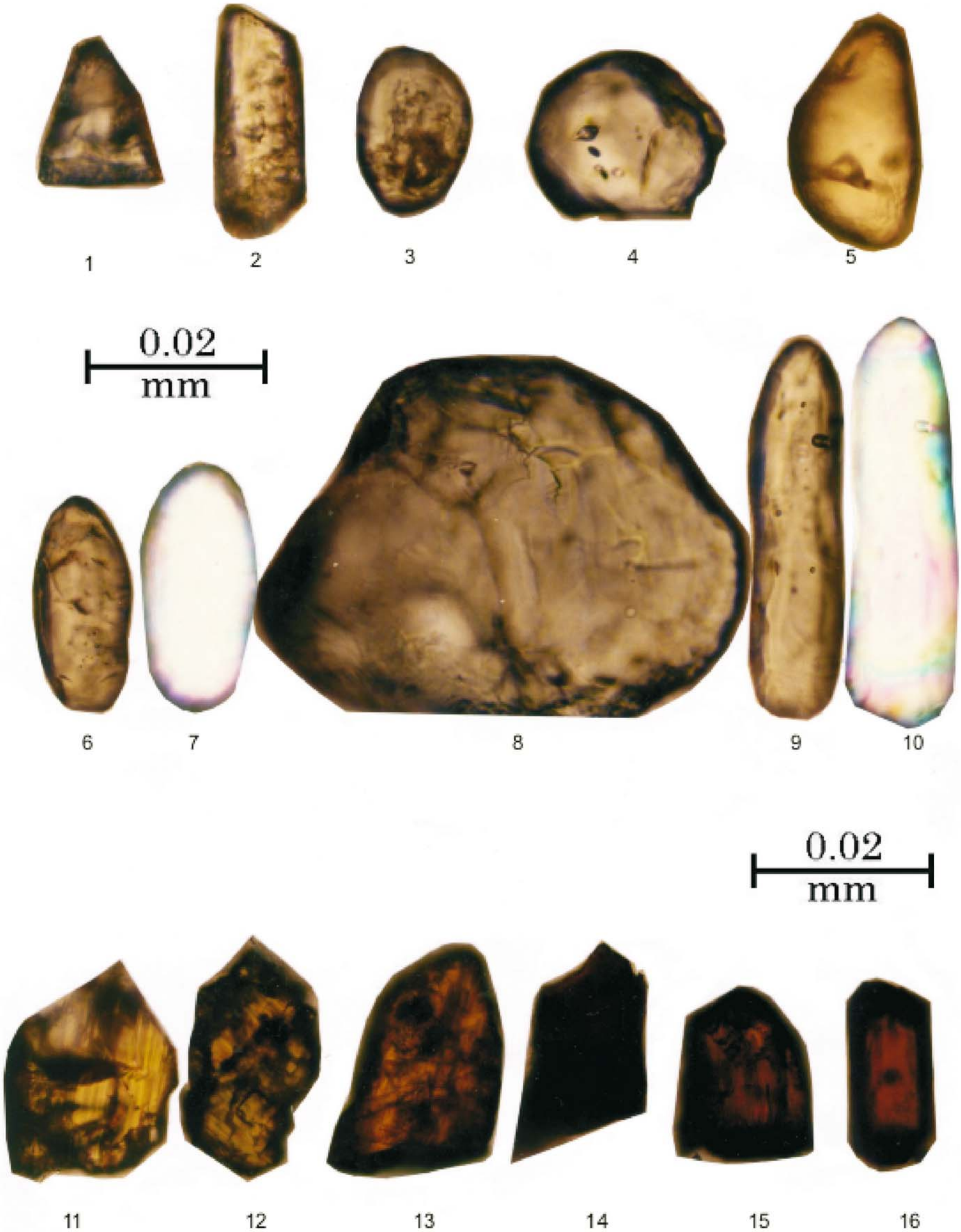

Fig.3a. Euhedral, sub rounded to well rounded grains of Zircon. Zircon, with and without inclusions and with dark boundaries can also be seen (1 to 10). Euhedral to sub rounded, orange and deep red varieties of rutiles (11 to 16).Striations and dark boundaries can also be seen.

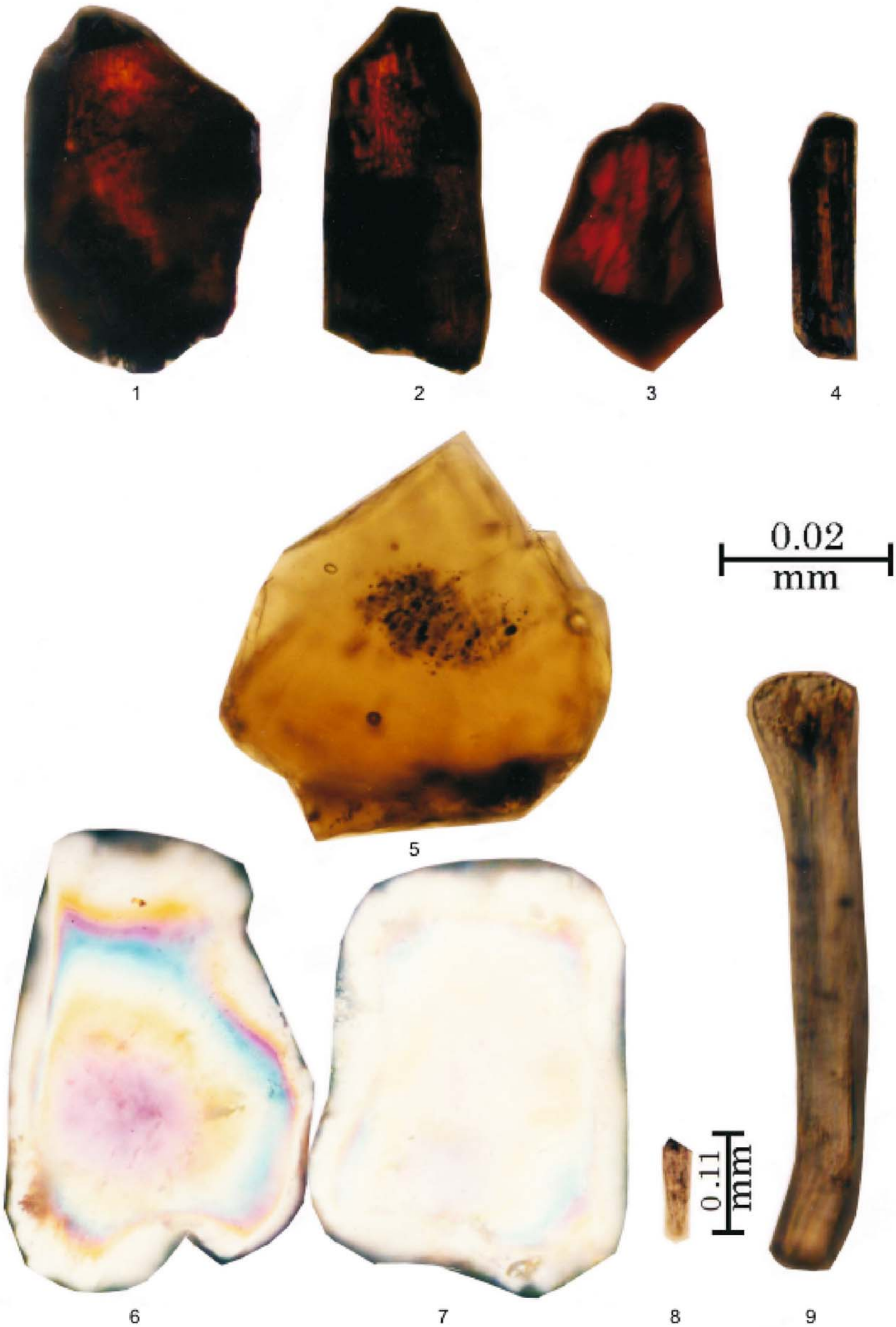

Fig.3b. Deep red prismatic rutile (1 to 4). Golden yellow colour sub angular grain of Staurolite with hackly fracture (5). Sub rounded Kyanite (6 and 7). Angular and sub rounded varieties of silliminite (8 and 9).

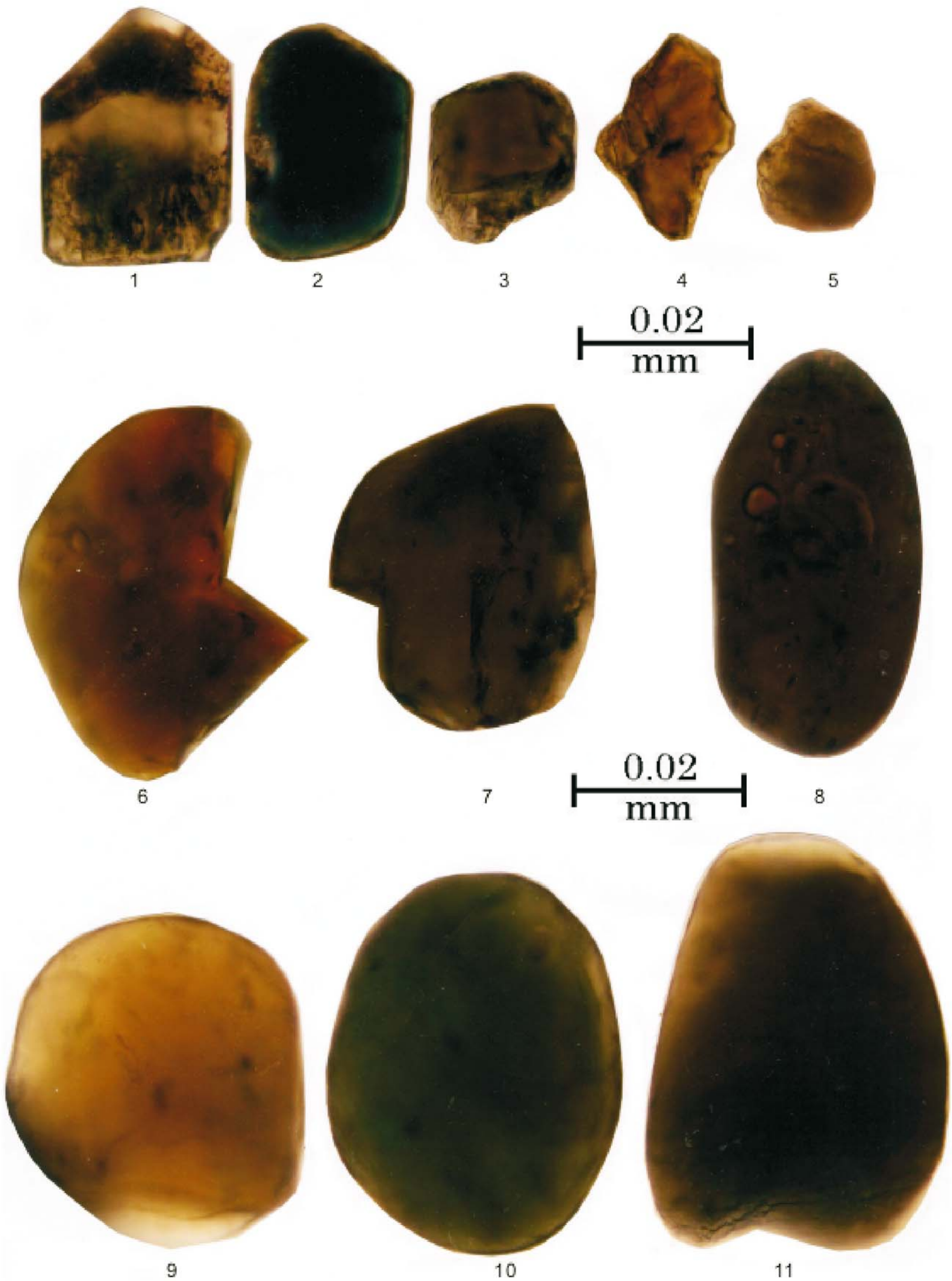

Fig.3c. Euhedral, Sub hedral and well rounded varieties of tourmaline (1 to 11).

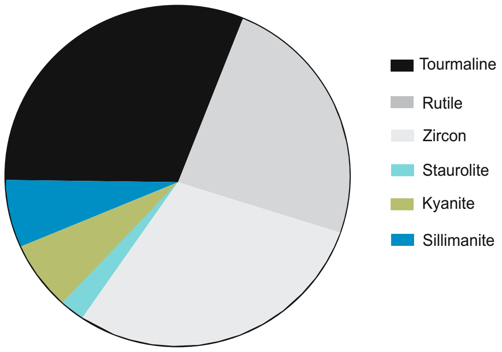

Fig.4. Distribution of various transparent heavy minerals in the Oligocene sediments of the study area.

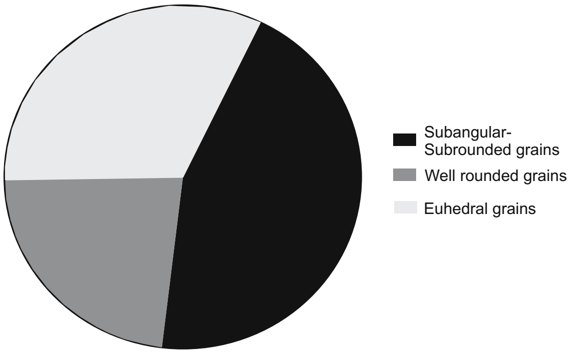

Fig.5. Distribution based on the shape of the transparent heavy minerals in the Oligocene sediments of the study area.

elliptical grains. Step like variations in the interference colours and inclined extinction are diagnostic. Almost all the grains are free from inclusions. Sillimanite is identified by its usually elongated and fibrous shape and a second order green colour. It shows a moderate birefringence and straight extinction. Staurolite, a significant metamorphic mineral, occurs in a very small amount. It was identified by its typical shape and light yellow colour. It shows a high relief but low birefringence. Inclusions are quite common and at times display sieve structure. Most of the grains are angular in shape and display hackly structure. As far as opaque minerals are concerned, these are quite common in all most all the samples examined. They are mostly represented by sub-rounded grains of iron oxide.

DISCUSSION

The following are the significant aspects to be considered for discussing provenance characteristics of the Oligocene Barail sediments in the study area.

1. Abundance of quartz (64.10%; mostly sub-angular to sub-rounded monocrystalline non-undulatory quartz) together with substantial lithic fragments (6.20%; mostly sedimentary and meta-sedimentary rock fragments) and negligible feldspar (1.27%; mostly sodic plagioclase).
2. A cosmopolitan heavy mineral suite with high ZTR index (85.29).

Derivation of quartz having monocrystalline non-undulatory character generally points towards fine- grained schists, phyllites and slates; volcanic and hypabasal igneous rocks and pre-existing sedimentary rocks in a tectonically disturbed region (Blatt et al.1980). This can further be substantiated by the presence of mica including chlorite, sporadic occurrence of vitrified glass and significant proportion of sandstone and siltstone rock fragments in the sediments under question. Based on Fig.6, it may be conceived that the source terrain formed a part of recycled orogen having characteristic abundance of quartz and sedimentary and metasedimentary lithic fragments (Miall, 2000).

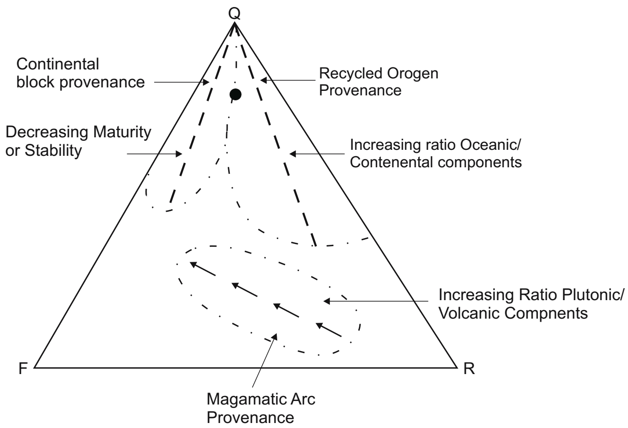

Fig.6. Triangular plot showing dominantly recycled orogen provenance for the Oligocene Barail sediments of the study area (*after* Dickinson and Suczek, 1979).

Heavy mineral analysis involving varietal studies seems to be more significant than that of the conventional heavy mineral studies as it reduces the problems associated with differentiation due to changing hydraulic conditions and diagenesis (Mishra and Tiwari, 2005). Some minerals are representative of a particular type of source rocks, where as others are more common and almost found in nearly all the possible type of the parent materials. In the present context a significant contribution from sedimentary source has been envisaged as sub-angular to sub-rounded (occasionally well rounded) grains dominate over those having euhedral outline. Euhedral grains usually reflect less transportation as well as a non-sedimentary supply.

Zircons are mostly rounded to sub-rounded and thus point towards a recycled orogen. In addition presence of a few euhedral (first generation) colourless zircons not only suggests an igneous source (Mishra and Tiwari, 2005) but possibly short distance transportation. Tourmaline grains are mostly polycyclic and show variety of colours. Blood red as well as orange colour elongated rutile often with sub-rounded dark boundaries supports sedimentary derivation. However, occurrence of a few prismatic rutile with sharp boundaries may be attributed to high grade metamorphic as well as acid igneous rocks (Force, 1980; Milner, 1962). Presence of first generation staurolite, sillimanite and kyanite in the sediments indicate a provenance comprising of metamorphic source dominated by green schist and amphibolites. However, occurrence of a few smoothened sillimanite grains indicates either long distance transportation or a sedimentary source. Absence of unstable/ metastable varieties of the heavy minerals coupled with negligible feldspar in the Oligocene Barail sediments could be due to partial destruction under humid climatic condition (Morton, 1987). High ZTR index (85.29) points towards a low to moderate relief in the provenance.

In light of the above, the heavy minerals of the study area may be broadly categorized into two different groups signifying at least two major sources. These are (1) first generation staurolite-sillimanite-kyanite relating to the un-roofing of the medium to high grade metamorphic terrain and, (2) rounded to sub rounded ultra stable heavy mineral species (zircon, tourmaline, rutile) derived from a sedimentary source terrain.

Most of the heavy mineral grains occupy the GM corner of the triangular diagram after Nechaev and Isohording

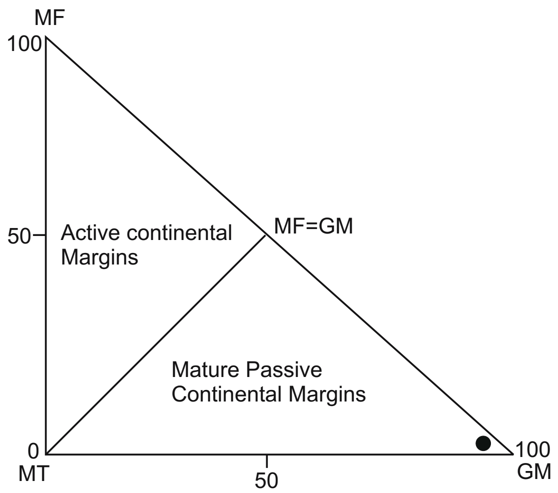

Fig.7. Provenance determination showing a passive margin setting of the provenance (*after* Nechaev and Isohording,1993).

(1993) that characterizes a passive continental margin setting (Fig.7). Nevertheless, it is pertinent to note that Singh et al. (2004) when plotted heavy minerals of the foreland basin sediments in the said diagram, they too occupied the same field i.e. the passive continental margin setting. Thus, considering the overall characteristics of the Barail sediments discussed above; especially the interpretation of a recycled orogen as a provenance, it may be logical to conceive a foreland basin set-up rather than a passive continental margin setting.

SUMMARY AND CONCLUSIONS

Petrographic study of the Oligocene Barail sandstones reveals dominance of sub-angular to sub-rounded monocrystalline non-undulatory quartz in association with substantial sedimentary as well as metasedimentary rock fragments. Feldspar and mica record their general paucity. The overall composition of the Barail sandstones matches with those of sublithic arenites. The heavy mineral analysis depicts a cosmopolitan suite characterized by rounded as well as euhedral varieties of zircon, tourmaline, rutile, kyanite, sillimanite and staurolite along with some opaque minerals. Most of the heavy mineral grains are polycyclic in nature. The petrographic composition as well as heavy mineral assemblages of the Barail sandstones is suggestive of a foreland basin setup receiving sediments from recycled orogenic provenance. Besides a major sedimentary contribution; depocentre had also received sediments from higher grade metamorphic rocks. However, minor contributions from igneous source terrain cannot be ruled out.

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