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Provenance, tectonic setting and age of the sediments of the Upper Disang Formation in the Phek District, Nagaland

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ABSTRACT

Integrated petrographic and geochemical studies of sandstones, and geochemical studies of shales of turbidites from the Upper Disang Formation, Phek district, Nagaland have been carried out to determine their provenance, weathering conditions and tectonic setting. Paleomagnetic studies were carried out for magnetostratigraphic purposes. Studies indicate that most of these sediments were derived from felsic and mafic sources with minor contribution from low to medium grade metamorphic rocks. Most of the felsic components have been transported from distant sources as evidenced from extensive reworking of grains. The most likely source rocks are the granite/granite gneiss of the Karbi Anglong crystalline complex to the west of the study area. However, the bulk of the sediments have been contributed from nearby basic and ultrabasic sources. This would correspond to the fast rising Naga Ophiolite, which probably emerged above sea level during the Mid-Eocene. Prevailing high temperatures and humid climate caused intense chemical weathering of the source rocks. The sediments from the west were transported great distances by turbidity currents into an easterly deepening basin. Sediments from the nearby east were rapidly dumped on the seafloor causing rapid mixing, leading to textural and chemical immaturity. Paleomagnetic studies endorse published paleontological evidence to indicate that most of the sediments of the Upper Disang Formation were deposited during the Late Eocene. Deposition took place in a westward-migrating accretionary-prism complex in an active-margin setting at the convergence of the Indian and Burma plates. This was a rapidly-closing basin where anoxic conditions prevailed. Towards the end of the Eocene this basin closed completely with the destruction of the Tethyan Ocean.

1. Introduction

Clastic sedimentary rocks are good indicators of past environments and hence offer clues to their source rocks and geodynamic settings of their origin. Interpretations can be made by a variety of methods, including petrographic and geochemical analyses. Petrographic studies provide information on provenance including tectonic setting, paleoclimate and paleogeography, effects of transportation and addition of chemically deposited minerals during sedimentation and diagenesis. Determination of heavy mineral associations is indispensable for provenance studies.

However, in the study of fine grained sediments such as shale, petrography loses its significance and any interpretation relies on geochemistry. Geochemical analyses of sedimentary rocks take into consideration the distribution of various elements, which helps to identify their sources, decipher tectonic uplift, climatic variability and weathering and allows inferences to be made about transportation, sedimentation and sorting of terrestrial detritus (McLennan et al., 1993; Cullers, 1994; Condie et al., 1995; Cox et al., 1995). Numerous studies have shown that the geochemistry of rare earth elements (REE), high-field strength elements (HFSE), Cr, Co and Sc have an added advantage over other elements in deciphering provenance, since these elements, generally thought to be transported nearly wholly and unfractionated into sedimentary basins, are unaffected by secondary processes such as erosion, sedimentation and diagenesis, and thus may reflect the composition of the parent material (Taylor and McLennan, 1985; Bhatia and Crook, 1986; McDaniel et al., 1994). The REE pattern of fine grained siliciclastics and some elemental ratios such as Eu/Eu* give an idea of crustal abundances in source areas. On the other hand, mobile elements such as Na and Ca are useful in the evaluation of degree of chemical weathering, which depicts paleoclimate in source regions (Nesbitt and Young, 1982).

Chronostratigraphic correlation between rocks from different paleoenvironments, including those with poor fossil content, is

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feasible using magnetostratigraphy (Nawrocki et al., 2003). Magnetostratigraphy is widely used in varied depositional environments throughout the world for stratigraphic correlation and relative geochronology (Opdyke and Channell, 1996). The recognition of characteristic magnetic polarity and subsequent correlation with a standard chronostratigraphic chart provides an additional key in age determination. Magnetozones are independent of lithogenic constraints, such as lateral lithofacies variations, permitting good correlation amongst Cenozoic successions (Sangode and Bloemendal, 2004).

The Disang turbidites comprise a thick sequence of Tertiary rocks, divided into Lower and Upper formations. They are spread over large parts of Nagaland. Being monotonous they have been given very little attention. Moreover, tracing of their continuity is difficult, as they are intensely deformed and lack reliable criteria for stratigraphic correlation, such as age diagnostic fauna, marker horizons and widespread lateral lithofacies variations (Evans, 1932; Mathur and Evans, 1964). Hence, paleomagnetic studies have been carried out in the study area for the first time with a view to complement the sporadic data available for the sediments.

2. Study area

The geodynamic evolution of the Himalayan and Indo-Myanmar (Burma) Ranges (IMR) is a consequence of the convergence of the Indian Plate against the Eurasian and Burma plates respectively. The fragmentation of Gondwanaland and northward flight of the Indian Plate led to its convergence and subsequent subduction under the Eurasian Plate along the Tethyan zone in the north and Burma Plate in the east. This caused the obduction and emplacement of the Naga Ophiolite along the IMR with the destruction of oceanic lithosphere.

The Naga Hills, being part of the IMR, represent the westernmost expanse of the Indo-Myanmar collision, where huge quantities of Cenozoic sediment were deposited in the Assam-Arakan Basin. The evolution of this basin is intimately linked to subduction of the Indian Plate beneath the Burma Plate in the east. Due to the NNE motion of the Indian Plate, extensive compression caused ocean basin sediments of the Naga Hills to be highly folded and faulted. The continuing eastward movement of the Indian Plate is being accommodated by underthrusting along the major lineaments of the region.

The Naga Hills is tectono-stratigraphically classified into five distinct units from east to west (Fig. 1), namely, Nimi Formation/Naga Metamorphics, Naga Ophiolite Belt (NOB), Disang flysch lying within the Inner Fold Belt (IFB), Belt of Schuppen (BoS) and Jopi/Phokphur Formation (Ghose et al., 2010). The Nimi Formation is well exposed in Nimi village. It comprises low-grade, highly deformed calc-psammopelitic litho-assemblages with interbands of phyllite, quartzite, limestone and quartz-sericite schist and represents an accretionary prism formed in an arc-trench gap (Agrawal and Ghose, 1986). This metamorphic belt contains large limestone deposits. Along the western tectonic boundary with the ophiolite the Naga Metamorphics are overlain unconformably by Mid-Cretaceous, Orbitolina-bearing, limestone and arkose (Acharyya et al., 1986). To the south of this belt in Phokhungri Village is another large body, representing the Naga Metamorphics that is made up of mica schist, granitoid gneiss and feldspathic metagreywacke.

The NNE–SSW trending NOB is tectonically sandwiched between flysch sediments in the west and metamorphics in the east. The lithological association of the NOB include serpentinized peridodite, mafic–ultramafic cumulates, mafic volcanics, plagiogranite and oceanic sediments such as chert and limestone. Sarkar et al. (1996) dated a basalt flow (whole rock K–Ar) found juxtaposed with red and green chert at 148 ± 4 Ma. Baxter et al. (2011) assigned the radiolarian chert a Kimmeridgian to mid-Tithonian age.

The Jopi/Phokphur Formation constituting cover sediments, represents an ophiolite-derived coarse, clastic sedimentary cover comprising repetitive sequences of polymict boulder-conglomerate–sandstone, sub-greywacke, shale and carbonaceous matter that unconformably overlie the ophiolite. These rocks were deposited under shallow marine and fluviatile conditions during Late Eocene–Oligocene (Ghose et al., 2010).

The IFB is represented by a thick monotonous sequence of shale, mudstone, slate, phyllite, fine-grained sandstone and siltstone of

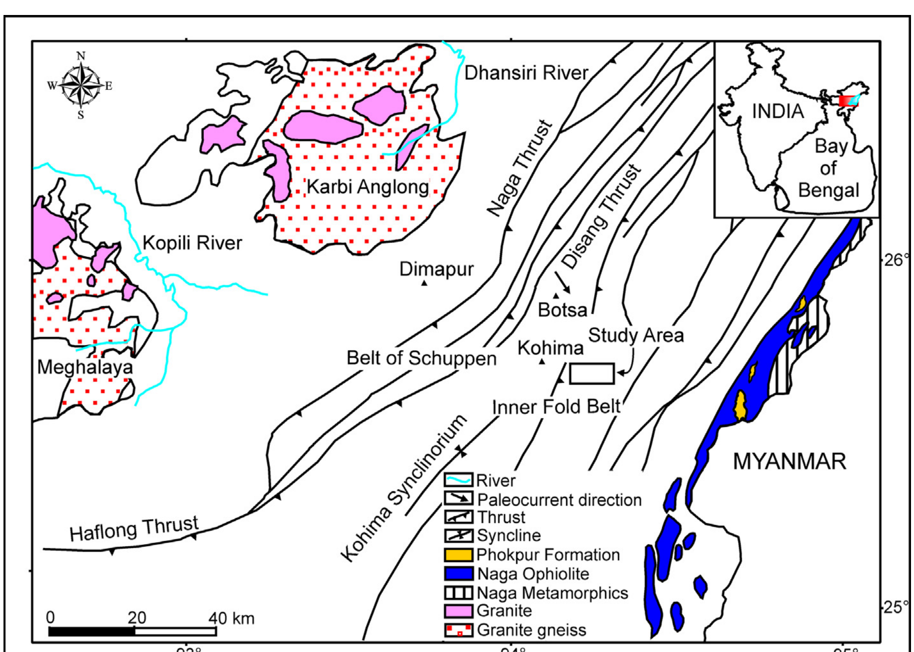

Fig. 1. Lithotectonic map of NE India (after Nandy, 2000). Inset map of India showing part of NE India, which is the likely provenance of the sediments (red rectangle) and Nagaland (shaded blue). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)