Active tectonics in and around Kimin-Ziro area, Lower Subansiri District, Arunachal Pradesh, NE India

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Active tectonics in and around Kimin-Ziro area, Lower Subansiri District, Arunachal Pradesh, NE India

by

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with 8 figures

Summary. The paper presents neotectonically-evolved landforms along the foothills of Arunachal Himalaya as well as within the Outer and Lesser Himalayan domains, along the Kimin-Ziro valley section, where tectonic activity is dated to 22–14 ka by OSL technique. High-resolution satellite data suggest the presence of a highly mature, almost flat Brahmaputra floodplain evolved during the recent geological past, in which palaeochannels had a very high sinuosity. Subsequent events of uplift resulted in the formation of entrenched meanders due to incision of the valley floor. As the process of incision was unable to keep pace with the rate of uplift, after initial attempts to incise the major channels abandoned their sinuous courses and instead followed a straight braided course from near the point of emergence of Himalayan Frontal Thrust (HFT). The data suggest that tectonic activity along the Main Boundary Thrust (MBT) and HFT during the Holocene have played significant role in geomorphic evolution.

Introduction

The geomorphic records in mountains and in their Forelands reflect the interplay of orogenic tectonics and global climatic changes and therefore, provide a unique opportunity to understand 1) regional and temporal variations in climate, 2) local *vs.* regional tectonics, and 3) the role of climate and tectonics in the production, transport and deposition of sediments.

The Himalayan mountain belt shows abundant evidences for crustal adjustments (Khattri et al. 1994, Acharya 1982). Neotectonism throughout the Himalayas is attributed to the continuous northward movement of the Indian plate (Molnar 1986, Valdiya 1993). In view of the evolutionary theories of thrust belts, it is important to understand the pattern and focus of crustal deformation. In case of the forward thrust model, the maximum deformation is focused at the mountain front, i. e. the Siwaliks in case of Himalaya. Whereas, the theories that consider the role of erosion and associated adjustments due to the increased thrust sheet loading suggest an out-of-sequence deformation occurring within the orogenic belts.

Evidence of active tectonics is documented from the (1) Kumaun and Garhwal regions of Uttarakhand (Bali et al. 2003, Valdiya 1986, 1991), (2) while the Nepalese sector indicate maximum deformation along the mountain front (Lave & Avouac

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2001), and also the out-of-sequence thrusting has been reported along the Marsyandi River (Wobus et al. 2005), (3) the Western Himalaya, investigations along the Sutlej River indicated high exhumation rates at the geomorphic transition of Higher and Lesser Himalaya (Theide et al. 2004). However, studies indicate that neotectonic deformation is rather more pronounced in the NE Himalaya possibly due to the present day tectonic environment of the Himalaya and its proximity with the NE syntaxis (Roy & Singh 2002, Devi & Singh 2006). In the NE Himalaya, few site-specific studies have documented evidence of neotectonic deformation (Agarwal et al. 2007, Srivastava & Misra 2008). The significance of monsoon-induced erosion and the formation of out-of-sequence thrusts within the Siwaliks were highlighted in the Eastern Himalaya of Sikkim (Mukul et al. 2007). In the NE Himalaya, the influence of a N-S trending fault in the uplift of the Siwalik rocks during the Holocene period is observed at the site where the Kameng River emerges from the mountains (Srivastava & Misra 2008). Geomorphic features like uplifted fluvial terraces, abrupt changes in channel pattern, steep triangular facets are seen developed in response to the activity along the N-S and NE-SW trending faults in the Lohit and Dibang river valleys (Misra 2007).

Results of detailed studies carried out along the least explored, Panyor River (Ranga Valley) in the Kimin-Ziro areas, NE Himalaya are presented here. Direct observation here is made difficult by a well-preserved thick forest cover (resulting from high annual precipitation), which in turn hides the geomorphic expressions of tectonic processes and also limits them to very few outcrops. The aim of the present investigation is to present geomorphic evidence of neotectonic activity along the mountain front and within the Lesser Himalaya and to reveal the pattern of neotectonic movement in view of orogenic development. High-resolution satellite data have been used to study the geological, geomorphological and tectonic setting of the area. The neotectonic activity in the area – especially in Outer Himalayas and the Piedmont Zone (occupied mainly by the Brahmaputra Basin) – is exhibited in the form of entrenched meanders, asymmetrical terraces, triangular faceted cliffs, highly dissected topography, high bifurcation ratios of the drainages etc.

Methodology

The morphotectonic features of the area has been studied using IRS-ID, LISS-III, Band 1–4 (Path/Row 112/52) and IRS-ID, PAN (Path/Row 113/52) satellite data. In addition, SOI toposheet nos. 83 E/14 and 83 E/15 have also been used to identify the nature of drainage pattern and cases of river metamorphosis. Subsequently, the satellite data have been verified along many geological transects surveyed across the area. The digital data have been studied and analysed using the ERDAS 8.5 and Arc-View 3.2 software. The numbering and measurement of the various stream orders has been carried out after onboard digitization.

Geological setting

Although, attempts have been made to geologically explore the Arunachal Himalaya since early times (Acharya 1982, Acharya & Sastry 1979, Evans 1964, Kumar, 1997, Kumar & Singh 1980, Prakash & Singh 2000, Singh 1993, Singh & Devi

2006, SINGH & JAIN 2007, TEWARI 2003, YIN et al. 2006), detailed structural data are not yet available due to the remoteness of the area and presence of thick forest cover. Geologically, the area shows almost all the geological and structural units which occur in the Central Himalaya.

The outermost Himalayan Belt of the Cenozoic foreland basin stretches along a long line. The Siwalik Belt rises over the Holocene Brahmaputra alluvium in the south having a tectonic contact, called the Himalayan Frontal Fault (HFF). The Lesser Himalayan terrain in Arunachal Pradesh is quite complex. It consists of two main units in the Subansiri sector – the Gondwana Belt in the south and the Lesser Himalayan crystallines in the north, medium to high-grade predominantly gneissic metamorphic rocks. This whole sequence is thrust over the Lesser Himalayan sedimentary belt along the Main Central Thrust (MCT) (fig. 1).

Geomorphology

Geomorphologically, the area can be classified into: i) high relief structural hills, ii) low relief structural hills, iii) highly dissected hills, iv) dissected hills, v) river terraces and vi) piedmont zone.

The high-relief structural hills normally have a relative height difference between 1,000–1,500 m, few may have a relief up to 2,000 m. The low relief structural hills are normally associated with the frontal fold-thrust belt and their relative relief is generally restricted to 1,500 m. Major lineaments normally bound the low-relief

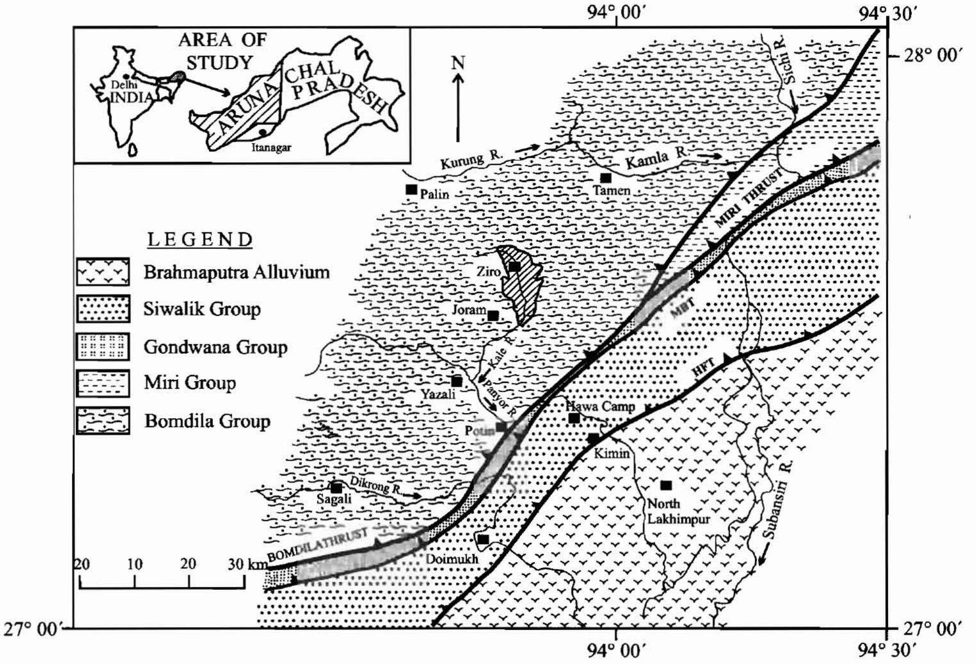

Fig. 1. Generalized geological map of parts of Kimin-Ziro area, Arunachal Himalaya. Box shows the present area of study (modified after MISRA 2007).

structural hills. A highly rugged topography is the characteristic feature of the highly dissected hills and the dissected hills. Three levels of river terraces are prominent along the Dikrong River near Hauj and along Panyor River near Yazuli (fig. 2a, b). A careful study of the satellite data along the piedmont zone reveals classical examples

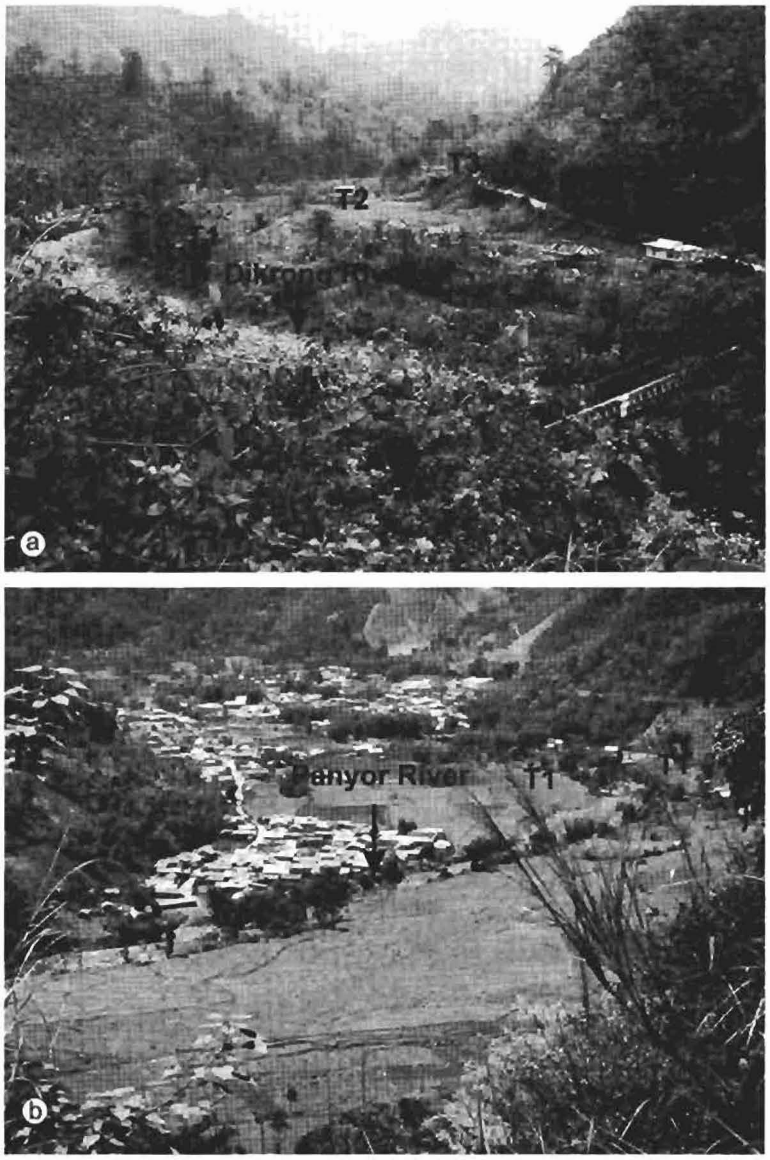

Fig. 2. a) Arrows in the photograph showing three levels of unpaired terraces along the Dikrong River at Hoj. b) Arrows in the photograph showing two levels of paired terraces along the Panyor River at Yazali.

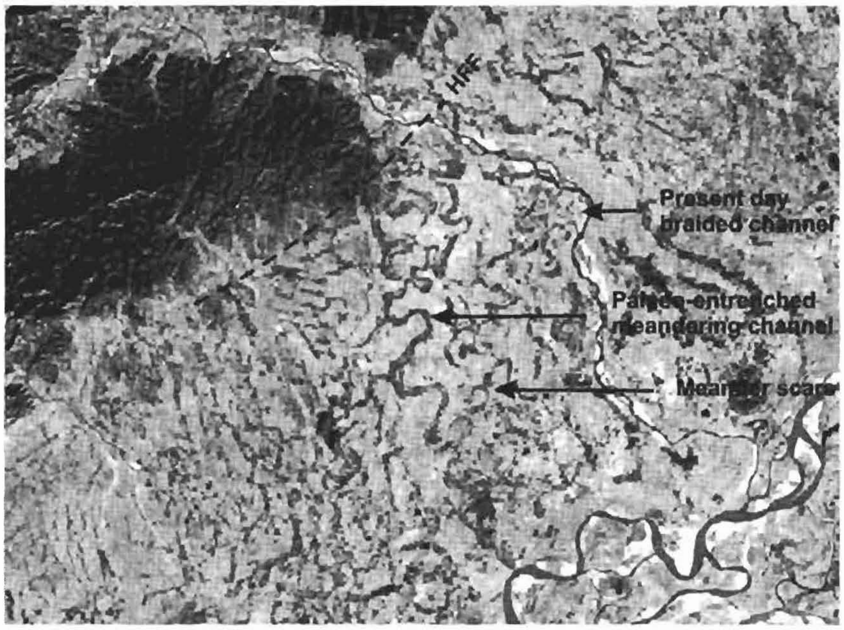

Fig. 3. Active tectonics as revealed by the shifting of channel. Note that drainage pattern has changed from meandering to braided. The increase in the supply of load is possibly due to the excessive erosion in response to rejuvenation.

of river metamorphosis. The palaeo-channels in the piedmont zone appear to be highly sinuous (STRAHLER 1964) with high wavelength/amplitude ratios (between 2.4 to 2.7). Locally, the palaeo-channels have deeply incised their valleys (fig. 3). The present-day channels however, appear to be of a straight or braided character.

Active tectonics

Due to continuous northward movement, the Himalayan mountain belt is still under the process of crustal adjustment. Such adjustment is recorded in the form of neotectonic activity experienced by different segments of the Himalaya and in turn is manifested in distinctive landforms. A systematic study of the geomorphology shows that the area has been neotectonically active in the recent geological past as reflected by seismic events (KHATTRI 1992). The area is classified as zone IV of the Seismic zonation map of India (1996).

Active uplift over the past 13 ka, along the Siwalik belt in the vicinity of the MBT has been documented and is probably responsible for the formation of four levels of terraces along the Kameng River in NE Himalaya (SRIVASTAVA & MISRA 2008). Activity along the HFT has been responsible for the landscape development at the core of NE Syntaxis, where down cutting by Brahmaputra River into the toe of the regional fan surface is observed at around 11 ka (SRIVASTAVA et al. in press). The modern seismicity records from the temporary micro seismic-monitoring at Tipi and to the E in the Ranga valley recorded more than 2000 earthquakes in 10 months. Studies in the zone confining the MBT near Tipi experienced an earthquake of 5.3M on October 12, 1985 at a depth of 9 km. Later, numerous events of 3.0 to 4.5M occurred in this zone at depths of 10–30 km. The epicentres of the earthquakes lie south of the MBT and show a N-S trend (KAYAL 2003). Further, it is to be noted that during the Holocene, both thrusts of MBT and HFT are active and hence the forward thrust model in the NE Himalaya needs a re-assessment.

In addition, a wealth of geomorphological evidences for neotectonic activity, viz. triangular faceted cliffs (fig. 4), asymmetrical and symmetrical terraces, entrenched river system, contrasting drainage morphometric styles in adjacent areas, are present (fig. 5).

Anomalies in drainage morphometry

Although the imprints of neotectonic activity are observed almost all along the Panyor (Ranga) River, these are particularly well developed and preserved around Yazuli, Kimin and along the Piedmont fan area. At a number of places, especially in some sections of the Outer and Lesser Himalaya, lower order streams are abundant and show very high bifurcation ratios (figs. 5). The morphometric analysis of the area reveals that the bifurcation ratio between the 1st and 2nd order stream is 5.66, while that of 2nd order to 3rd order stream is 5.09. This high values (AGARWAL et al. 2008) suggests that the area is tectonically active.

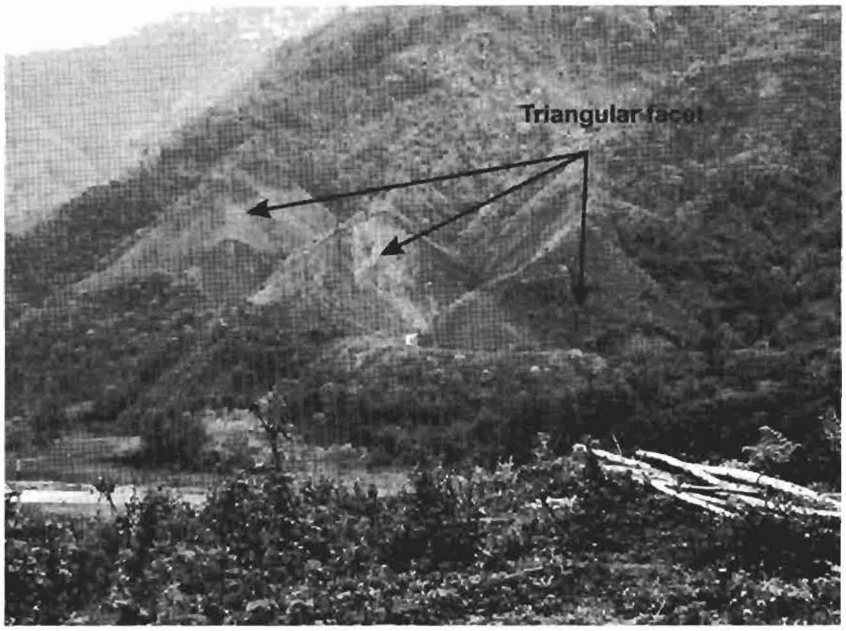

Fig. 4. Triangular faceted cliffs near Potin.

Fig. 5. Higher drainage density of lower order streams as seen from high-resolution satellite data.

Fluvial terraces, river entrenchment and offsetting

At least three levels of terraces, made up of earlier fluvial deposits rise above the present-day river channel. The Dikrong River flowing along a faulted valley has incised through the valley and as such vertical terraces stand at several meters above the valley floor. Three sets of asymmetrical terraces indicate that the Dikrong fault crossing the valley has been active in the recent past (fig. 2a). Similarly two levels of well preserved symmetrical terraces are present at Yazuli (fig. 2b).

The Panyor River of locally high sinuosity within the Outer Himalaya shows a number of entrenched meanders. At places very narrow valley sections (gorges) indicate deep incision (fig. 6). Sudden right angle rotations are observed in the drainage pattern (figs. 6, 7).

Sedimentary deformation at Lake Ziro

Ziro lake is a N-S trending wide basin formed by the Kale River, a tributary to Panyor (fig. 8). The basin is ~11 km long and ~5 km wide and dotted by 5–20 m high mounds composed of relict fluvial sediments. The basal 5–15 m multi-storeyed, cross-bedded sands are fining upward, overlain by 2–8 m thick fine floodplain sediments and also sediments of lacustrine origin. The vertical thickness of the profile increases towards the southern end of the basin. The basal part of the sequence often shows post-sedimentary deformations such as sandstone dykes and fractures, deformed cross bed laminae (fig. 8). These deformation structures can be associated with seismic events as: (1) they occur in a seismically active region of the NE Himalaya, in the proximity of NE Syntaxes, (2) the lake basin is bounded by several NE-SW trending lineaments. The structures are restricted to the basal part of the sequence, where undeformed sedimentary cover underlie deformed beds, (3) corresponding structures

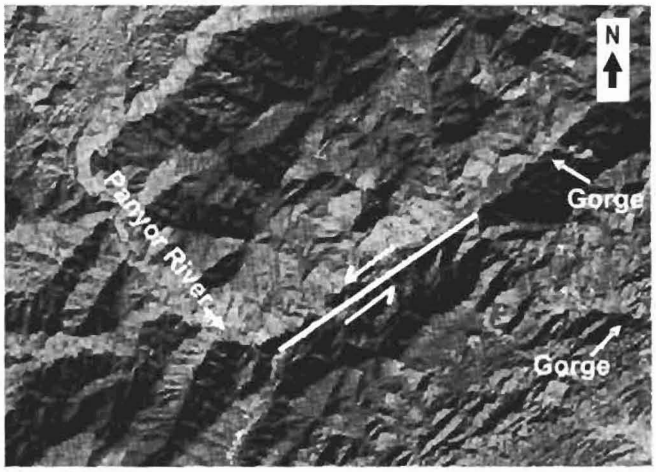

Fig. 6. Satellite image showing the offsetting of the Panyor River valley by left-lateral strike-slip fault. Note the deep incision of the valleys marked by arrows.

Fig. 7. Field photographs showing the abrupt change in the Panyor River flow direction (marked by arrows) near Kimin.

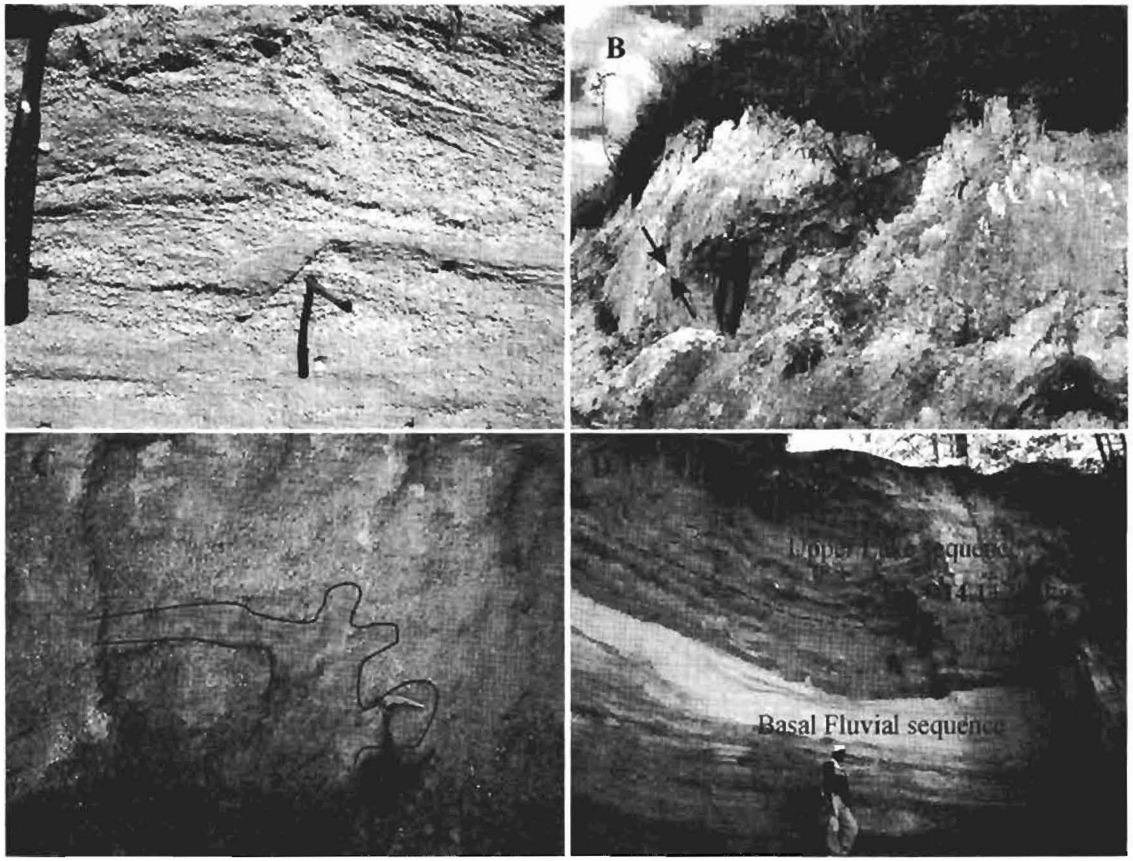

Fig. 8. (A) Deformed cross beds exposed at the base of the section in southern part of the Ziro lake. (B) Calcrete filled fracture exposed in the upper part of the sequence (< 14 ka). (C) Sand dyke exposed in the middle of the sequence. (D) A generalized section exposed along the margins of the lake, where upper part is dated at ~ 14 ka.

are observed over the whole lake basin and (4) the layers are horizontal and are not influenced by any slope failure. Optically Stimulated Luminescence (OSL) dating places event of seismic deformation between 22–14 ka (details communicated separately).

Discussion and conclusions

The principal compressive stress field in the Himalayan orogeny, formed as a result of collision of the Indian and the Eurasian plates has changed from N-S to NE-SW during post collisional times. Quaternary and Recent neotectonics have reactivated and transformed many of the thrust faults in the High Himalaya into strike-slip faults (Searle et al. 1987). The present-day ESE/SE extension of the Indian subcontinent has modified a number of pre-existing and newly formed fracture planes into normal faults (Valdiya 1998).

In the present area, the Ranga (known as Panyor in the upstream) River flows in a wide braided channel across the piedmont surface. Satellite data clearly show that earlier the same river flowed along a sinuous valley in recent geological past (fig. 3). This segment appears to be a part of the Brahmaputra floodplain earlier. The sinuosity of the river must have been quite high as can be seen by the presence of 'hair pin' meanders having sinuosity index values around 2.2. Satellite data as well as the field observations show that these sinuous palaeomeanders are also deeply incised. The incision and the entrenchment of the palaeo-channels show that the present-day piedmont zone at some point of time was an almost level surface. This region started rising as a result of the tectonic uplift along the HFT, which seems to be an emergent thrust at least in this section of the orogen-foreland junction. During this uplift, initially the highly sinuous river systems started cutting their own valleys; however, the rate of uplift was so intense that the vertical incision of the rivers was unable to keep pace with it. Finally, the sinuous river systems abandoned their channels from the place of their entry into the plains (HFT) and started flowing in the present-day braided and straight channels.

The pieces of evidence for neotectonic activity viz. seismic activity, triangular faceted cliffs, asymmetrical and symmetrical terraces, entrenched river system, contrasting drainage morphometric styles in adjoining areas, support the view that there is a marked neotectonic control on the geomorphic evolution of the area. This activity had continued till the later part of the Quaternary, affecting and modifying the geomorphological features formed earlier and is still active even today. Records of seismic activity over the past 22–14 ka from the sedimentary fill of lake Ziro further confirm observations on nature of neotectonic active.

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