Facies, fossils and correlation of Late Miocene fluvial sequences of the Himalayan foreland basin

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The Late Miocene (7.9 Ma to 5.1 Ma) fluvial sequences of the Siwalik Group (Churia Group in Nepal) are characterized by the predominance of multistoried sandstones with subordinate overbank mudstones. Due to temporal and spatial variability and facies preference of different organisms, precise correlation on a regional or interregional scale often poses problems. As part of the objectives of the biostratigraphy subgroup of the IGCP Project 449, this paper attempts to correlate these sequences in India and Nepal, spread over a distance of 700 km on the bases of molluscan, ostracode and charophyte assemblages which, though facies controlled, occur abundantly in overbank mudstones.

THE >6000 m-thick Mio-Pleistocene clastic fluviatile sequence – the Siwalik Group/Churia Group (Nepal) – which occurs all along the length of the Himalayan foothills, originated from the continent-to-continent collision of the Indian and Eurasian plates. The Himalayan orogenic belt which contributed these sediments controlled the sedimentation history and evolution of the foreland basin.

In contrast to Pakistan where the major Siwalik lithofacies are not commonly time-transgressive, those of the India–Nepal sector show extensive temporal and spatial variability, particularly in the Middle Siwalik Subgroup. The sedimentary style of this subgroup (10.1 Ma–5.1 Ma)[1,2] comprising Nagri and Dhok Pathan formations is characterized by thick sequence of predominant multistoried sandstone complex (the gray salt- and pepper-sandstone) with subordinate overbank mudstone units. This sedimentary style reflects a significant event commencing around 10 Ma and is related to the deformation along the Main Central Thrust[3–5]. In Nepal, the initiation of this event is dated around 7.5 Ma (refs 6–8). The Middle Siwalik fluvial sediments show vertical facies variation in an overall coarsening upward sequence with a concurrent increase in grain size and frequency of conglomerate lags. The sheet geometry, low mudstone content, frequent erosional events and unchannelized sandstone bodies suggest their deposition during sheet floods in a braided stream environment[9,10]. Correlation of such sedimentary sequences has been facilitated by magnetostratigraphic studies[1,4,6,11,12]. The magnetic polarity results, however, are not always compatible with the ages indicated by the contained fossil faunas and floras as in the case of Nepal Siwaliks[8]. These discrepancies may be attributed to either inadequate knowledge about the age and distribution of fossil content or to sedimentary gaps.

Insofar as the Middle Siwalik Subgroup is concerned, the vertebrate fossils, though well documented and age diagnostic, are not uniformly distributed in rocks but occur in pockets, hence not always easy to collect. On the other hand, the overbank mudstones are mostly rich in molluscan shells, rodent and fish remains, ostracodes, charophyte gyrogonites, and palynomorphs and plant remains. These fossil groups are thus not only more useful for age determination and correlation but also for palaeoecologic, palaeoclimatic and taphonomic studies including state of preservation, ratio of open and closed valves (bivalves and ostracodes), opercula vs complete shells (gastropods), etc.

As part of the objectives of the biostratigraphy subgroup of the IGCP Project 449 to collect information and prepare database for a wide range of biological evidences from fluvial sequences, we attempt here to collate the available evidences of the molluscan, ostracode and charophyte remains from the Dhok Pathan Formation of the Kangra and Dehradun re-entrants in India and equivalent formations from the Surai Khola and Binai Khola sections in Nepal.

Kangra re-entrant

Although vertebrate fossils are extensively known from the Middle Siwalik Subgroup of Haritalyangar and other areas of the Kangra re-entrant in Himachal Pradesh, there are not many records of molluscan, ostracode and charophyte occurrences. However, these fossil remains are well documented from one locality in the vicinity of Daulatpur (Figure 1) in Kangra district. The 1750 m thick Middle Siwalik sequence in this area is overlain by the Upper Siwalik Boulder Conglomerate. The uppermost 150 m of the sequence assignable to Dhok Pathan Formation and dated between 7.9 Ma and 6.9 Ma (ref. 12) is

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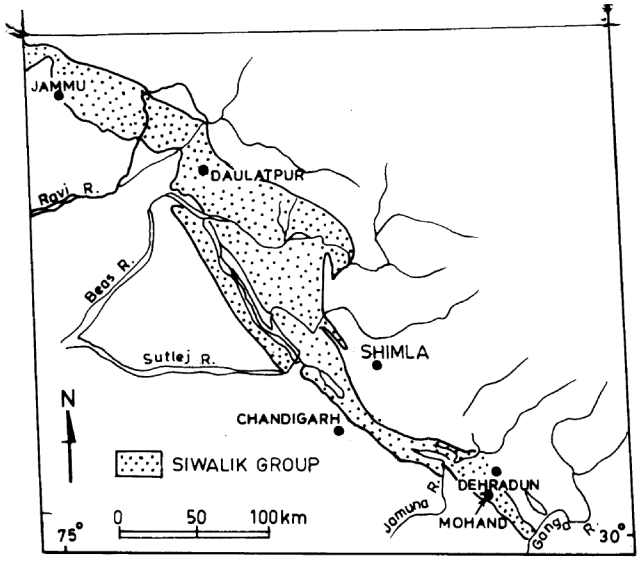

Figure 1. Part of the Siwalik belt of northwest Himalaya and the Kangra and Dehradun re-entrants.

well exposed in stream sections east of Daulatpur and comprises gray, multistoried sandstones with interbedded gray, chocolate and pink overbank mudstones[13]. The molluscs, ostracodes and charophytes occur only at two levels in gray chocolate mudstones in one of the stream sections (Section GII) and are absent in the adjoining stream sections[13].

The molluscan assemblage[13], which is dominated by freshwater bivalves, comprises *Lamellidens jammuensis*, *L. subparellelus*, *Parreysia edwini* and *P. tatrotensis*. The close affinity of the bivalve taxa with that occurring in the Binai Khola section of Nepal is discussed and elaborated in the sequel.

The ostracode taxa[14] comprise *Ilyocypris monstrifica*, *I. angulata* and *Leucocythere jaini*, while the rich charophyte assemblage[15,16] comprises *Nitellopsis merianii*, *N. huangi*, *N. helvetica*, *N. bicarinata, Chara globularis*, *Sphaerochara prolifera*, *S. tewarii* and *Lychnothamnus breviovatus*. The abundance of several species of *Nitellopsis* and of the stenothermic palearctic ostracode genus *Leucocythere* indicate the existence of permanent, cool lacustrine environment with bathymetry between 3 and 10 m. The occurrence of two species of the highly ornamented *Ilyocypris* indicates current action by streams joining the lacustrine body[14]. We thus see that not only the ostracode and charophyte assemblages but also the sedimentary style and nature of sediments – occurrence of mottled clayey siltstones immediately at the top of major sand body and the limited lateral extent of the fossiliferous mudstones – indicates that the lacustrine body had a small circumscribed area within the flood plain of the river channel. The bathymetry of the overbank lacustrine body as indicated by the chrophyte assemblage is corroborated independently on sedimentological criteria in Pakistan where most Miocene Siwalik lakes had water depths less than 10 m (ref. 17).

Dehradun re-entrant

In the Dehradun re-entrant, the Middle Siwalik Subgroup attains a thickness of 2200 m. Extensive sedimentological studies in several stream sections and particularly in the Mohand Rao section near Dehradun show that the multistorey sandstone complexes were formed by frequent avulsions leading to formation of coalescing alluvial megafans by ephemeral streams under warm and humid climatic conditions[10]. The grayish brown mudstones immediately underlying the Boulder Conglomerate in Mohand Rao section[4] have yielded an interesting assemblage of Mio-Pliocene charophytes and ostracodes. Further work on this assemblage is in progress[18]. In the adjoining Sukh Rao section, 800 m from the top, a giraffid mandibular ramus of *Hydaspitherium megacephalum* has recently been discovered in the multistoried sandstones[19]. This particular taxon was hitherto known only from the Dhok Pathan Formation of Potwar and Haritalyangar.

Surai Khola Section (Western Nepal)

Perhaps the most complete sequence of Neogene molassic sediments of the Siwalik Group (designated as Churia Group in Nepal) is exposed in the Surai Khola Section (Figure 2). The section comprises five lithological units and the palaeomagnetic dating indicates a time scale from 13 to ca. 1 Ma (ref. 8). The beds equivalent to the Middle Siwalik Subgroup here comprise the upper part of the Lower Member of the Chor Khola Formation (dated 10.1 Ma) up to the middle of the Surai Khola Formation (dated 5.9 Ma)[8,20]. These works also deal comprehensively with the biostratigraphy and geology of this section. First massive multistoried salt and pepper sandstones appear in the Upper Member of the Chor Khola Formation. They, however, become the dominating facies in the overlying Surai Khola Formation.

The molluscan fauna, here dominated by gastropods, occurs at five stratigraphic levels designated as Horizon S1-S5 (ref. 21). Horizon S1 in the Upper Member of the Chor Khola Formation contains *Parreysia? binaiensis, Lamellidens* sp. and a few gastropods. Shells are poorly preserved in the dark brownish gray mudstones which also contain charophyte gyrogonites. Since these charophytes have not been systematically described, precise correlation with the Kangra or Binai Khola assemblages is not possible. Gurung[21], however, suggests that this horizon is at the same stratigraphic level as Horizon Bl-1 of Takayasu *et al.*[22] in the Binai Khola section. In gen-

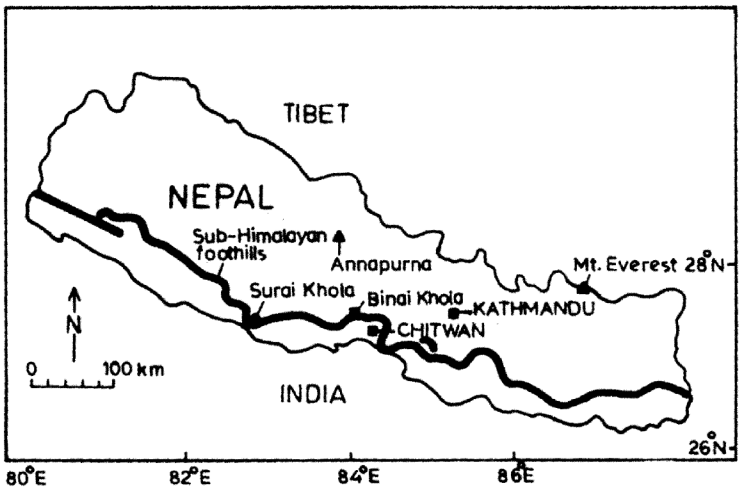

Figure 2. Map of Nepal showing the location of Surai Khola and Binai Khola sections and the southern limit of the Churia (Siwalik) Group.

Table 1. Correlation of the lithounits of the Siwalik Group of the Himalayan Foreland Basin

Approx. time (m.y.)	Johnson *et al.*[1] Pakistan	Present paper Kangra	Corvinus and Rimal[8] West Nepal	Tokuoka *et al.*[7] Central Nepal		Approx. time (m.y.)
			Dhan Khola Formation	Deorali Form.		1.5
	Upper Siwaliks	Upper Siwaliks		Chitwan Form.		
			Dobatto Formation			3.6
					Upper Member.	
5.9						
	'Bhandra'	(Boulder Conglomerate)				
					Middle Member	5.9
			Surai Khola Formation	Binai Khola Form		
	Dhok Pathan Formation	Dhok Pathan Formation				
					Lower Member	7.5
7.9			Upper Member			
	Nagri Formation	Nagri. Formation	Chor Khola Formation			
					Upper Member	9.5
10.1						
	Chinji Formation	Lower Siwaliks	Lower Member	Arung Khola	Middle Member	
13.1			Bankas Formation			
					Lower Member	

eral, the molluscan fauna of the Chor Khola and Surai Khola formations belongs to genera which are commonly found living in low energy environment ranging from pond, marsh, lacustrine to margins of slow flowing rivers, but generally avoid fast-flowing rivers[21].

Binai Khola Section (West-Central Nepal)

The lithostratigraphy and magnetostratigraphy of the Churia Group in the Binai Khola (Figure 2) and Arung Khola valleys in west-central Nepal have been well established[7] and rich assemblages of bivalves[22], gastropods[23], and charophytes[24] have been documented from this area.

Bivalve and charophyte dominated assemblage (as at Daulatpur in Kangra) occurs in the Lower Member of the Binai Khola Formation. The succession here comprises alternating beds of sandstones and subordinate mudstones. The charophyte gyrogonites occur in mudstones while bivalves occur in dark gray to black mudstone and fining upward silty sandstones. These fossils are associ-

ated with fish scales, crocodile teeth and bone fragments[22]. The three new species of bivalves – *Lamellidens arungensis*, *Parreysia zigzagicostata* and *P. binaiensis*[22] from the Lower Member of the Binai Khola Formation (sampling horizon Bl-1) are closely related to and may even be conspecific with *L. subparellelus*, *P. edwini* and *P. tatrotensis* respectively recorded from Daulatpur and other Siwalik localities in India. Liu[24] recorded six taxa of charophytes of which two are new and endemic to the region, three are cosmopolitan and one known from the Pliocene of China. Only *Nitellopsis globula* (a junior synonym of *N. merianii*) is common with the Daulatpur assemblage. The state of preservation of these charophytes – broken apical portions and flaked-off lime spirals – indicates that the assemblage is not *in situ* and has suffered moderate degree of transportation by slow-flowing streams[24].

Conclusions

The paper stresses the role of molluscs, ostracodes and charophyte gyrogonites in correlating fluviatile sediments like those of the Middle Siwalik Sub-Group which show temporal and spatial variability. Besides, these fossil groups provide additional inputs about palaeoecology and taphonomy. The bivalve and charophyte dominated assemblage recorded from the Late Miocene Dhok Pathan Formation of the Daulatpur area in Kangra district is correlatable with similar assemblages from the Upper Member of the Chor Khola Formation and the Lower Member of the Binai Khola Formation in Nepal as several species are common to these formations (Table 1). Palaeoecological information is provided by several genera of molluscs which indicate deposition in a low energy environment ranging from marsh, pond, lacustrine to margins of slow flowing rivers. Based on analogy with the living representative, the occurrence of several species of the charophyte genus *Nitellopsis* (as at Daulatpur) indicates the existence of cool, permanent lakes in the flood plains of the river channel with bathymetry 3–10 m. The proximity of the lake to a stream or river (implying current action) is further indicated by the occurrence of the ostracode genus *Ilyocypris*.

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