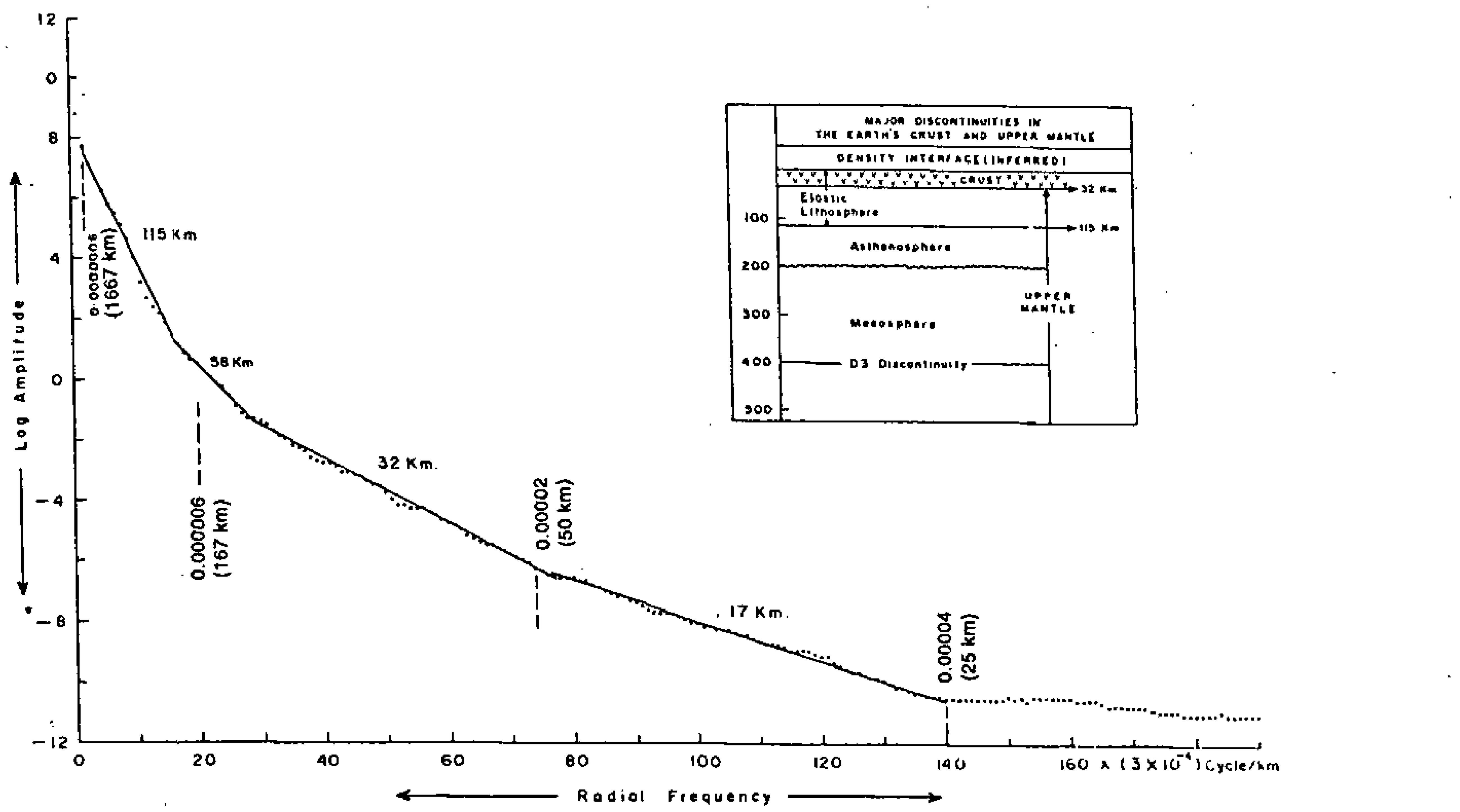


Figure 2. Radial spectrum of Figure 1. Inset shows a direct comparison of layers determined from seismological data with those obtained from the analysis of gravity data.

basins, rift valleys, granite massifs, etc. are of limited size when compared to the overall size of the study area. Moreover, these outcropping (zero depth) features appear to be represented as white noise in the spectrum. The average depth of interfaces obtained from this analysis can be attributed to the globally recognized seismic discontinuities (inset of Figure 2) situated at depths of 17 km (between the upper and the lower crust); 32 km and 58 km (Moho); and 115 km (top of low velocity layer). The interface located at an average depth of 58 km given by the second line segment does not correspond to any discontinuity that is recognized globally. However, a considerable part of the Himalayan foothills is covered by the gravity data where the crustal thickness exceeds 50 km. Therefore, this interface at 58 km depth might correspond to the average depth of the Moho in the sub-Himalayan region covering this data set.

The spectral analysis of gravity data revealed the presence of four density interfaces in the crust and upper mantle zone beneath India. As there is close correspondence between gravity interfaces and seismic discontinuities, the present analysis also serves as direct evidence for the variation of density at these boundaries in addition to a change in the seismic wave velocity.

1. Ludwig, W. J., Nafe, J. E. and Drake, C., *The Sea* (ed. Maxwell, A. E.), Wiley Interscience, N.Y., 1970, vol. 4, pp. 53–84.
2. Spector, A. and Grant, F. S., *Geophysics*, 1970, **35**, 293–303.
3. NGRI, Bouguer gravity anomaly map of India (1:5,000,000) NGRI/GPH-2), National Geophysical Research Institute, Hyderabad, India, 1975.
4. Qureshy, M. N. and Warsi, W. E. K., *Geophys. J. R. Astron. Soc.*, 1980, **61**, 235–242.
5. Verma, R. K., *Gravity Field, Seismicity and Tectonics of Indian Peninsula and the Himalayas*, D. Reidel and Allied Publishers, Madras, 1985.
6. Verma, R. K., *Geodynamics of the Indian Peninsula and the Indian Plate Margin*, Oxford and IBH Publishing Co., New Delhi, 1991.
7. PGW, 1975, Magnetic data processing software – MAGMAP; Paterson, Grant and Watson Ltd., Toronto, Canada.

Received 23 May 1994; revised accepted 9 January 1996

Quaternary palaeolakes in Kumaun Lesser Himalaya: Finds of neotectonic and palaeoclimatic significance

K. S. Valdiya*, B. S. Kotlia, P. D. Pant, Manik Shah, Nidhi Mungali, Sunita Tewari, Nalin Sah and Moulishree Upreti

Department of Geology, Kumaun University, Nainital 263 002, India
*Jawaharlal Nehru Centre for Advanced Scientific Research, Jakkur Campus, Bangalore 560 064, India

Movements in the geologically recent time on the North Almora Thrust; South Almora Thrust; on related subsidiary thrusts and faults caused blockade of the river Kosi west of Almora and of the Thuli Gad east of Pithoragarh in the Kumaun Lesser Himalaya. The fault movements resulted in the formation of lakes that have since vanished due to revival of neotectonic movements. Stretching more than 7 km in length, these palaeolakes are presumably the

biggest so far known in Kumaun. The lacustrine deposits comprising carbonaceous clays in Pithoragarh, and silty ferruginous clay capping the fluvio-lacustrine deposits in the Kosi valley promise to hold important palaeoclimatic clues. Preliminary radiocarbon dating of carbonaceous clay, rich in charcoal fragments, indicates that the Wadda lake at Pithoragarh was formed about 44,000 years BP and, probably, lasted until about 2000 years BP.

ACROSS the length of Kumaun in the central sector of the Himalayan arc, the Almora Thrust has brought a thick synclinal pile or nappe of the Precambrian metamorphic rocks, intimately associated with gneissose granites, over and against the Middle-to-Upper Proterozoic sedimentary rocks[1–4] (Figures 1 and 2). The two flanks of this folded thrust, known as the North Almora Thrust (NAT) and the South Almora Thrust (SAT), are characterized by multiplicity of thrusts and strike faults, which have given rise to schuppen structures. Recent studies have demonstrated that both the flanks (NAT and SAT) of the tightly compressed Almora synclinorium have registered appreciable movements in the Quaternary period[5,7].

The present study shows not only
SAT are active, but also that the sym|
subsidiary faults and thrusts and faul
have caused upliftment of the downs
is evident from the geomorphic de
described in the following sections.
cerned streams, but also those whic
oblique to these, reveal eloquent evi(
of the terrains. These movements res
ade of streams; such as the Kosi river
(District Almora) and the Thuli Gad
(District Pithoragarh), giving rise to
are no large fans, cones or accumulat
where in the valleys downstream of t
could have dammed the streams. The
unaccompanied by perceptible strike
causative active faults precludes the
velopment of pull-apart basins. Late
ments, possibly in the opposite sense
disappearance of these lakes. The mu
races upstream of the active faults,
mild deformation of terrace deposits
faults, point to the tectonic movem(
pearance of the lakes.

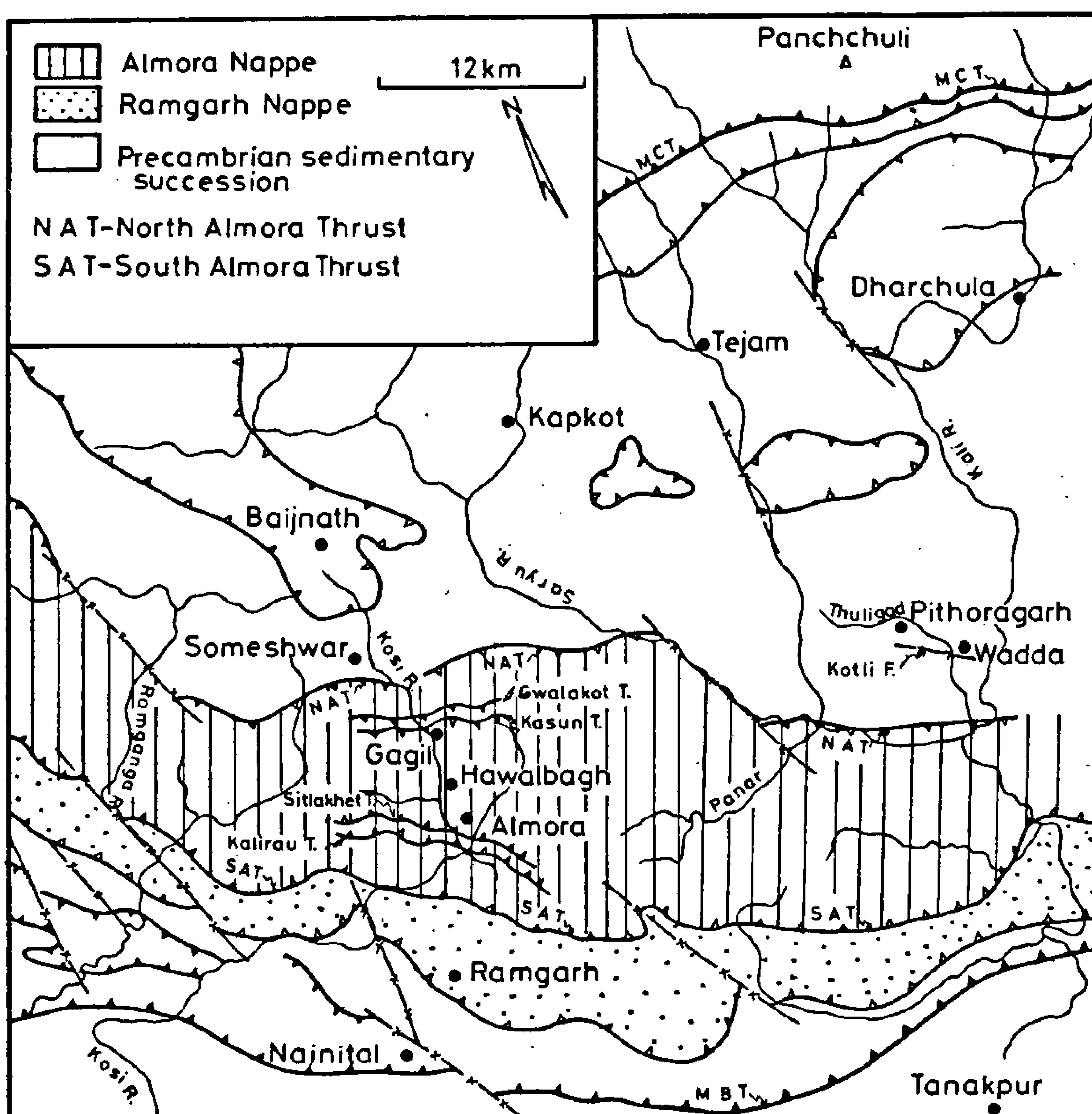


Figure 1. Sketch tectonic map of a part of Kumaun Himalaya showing Almora Nappe defined by the Thrusts and positions of active faults and thrusts.

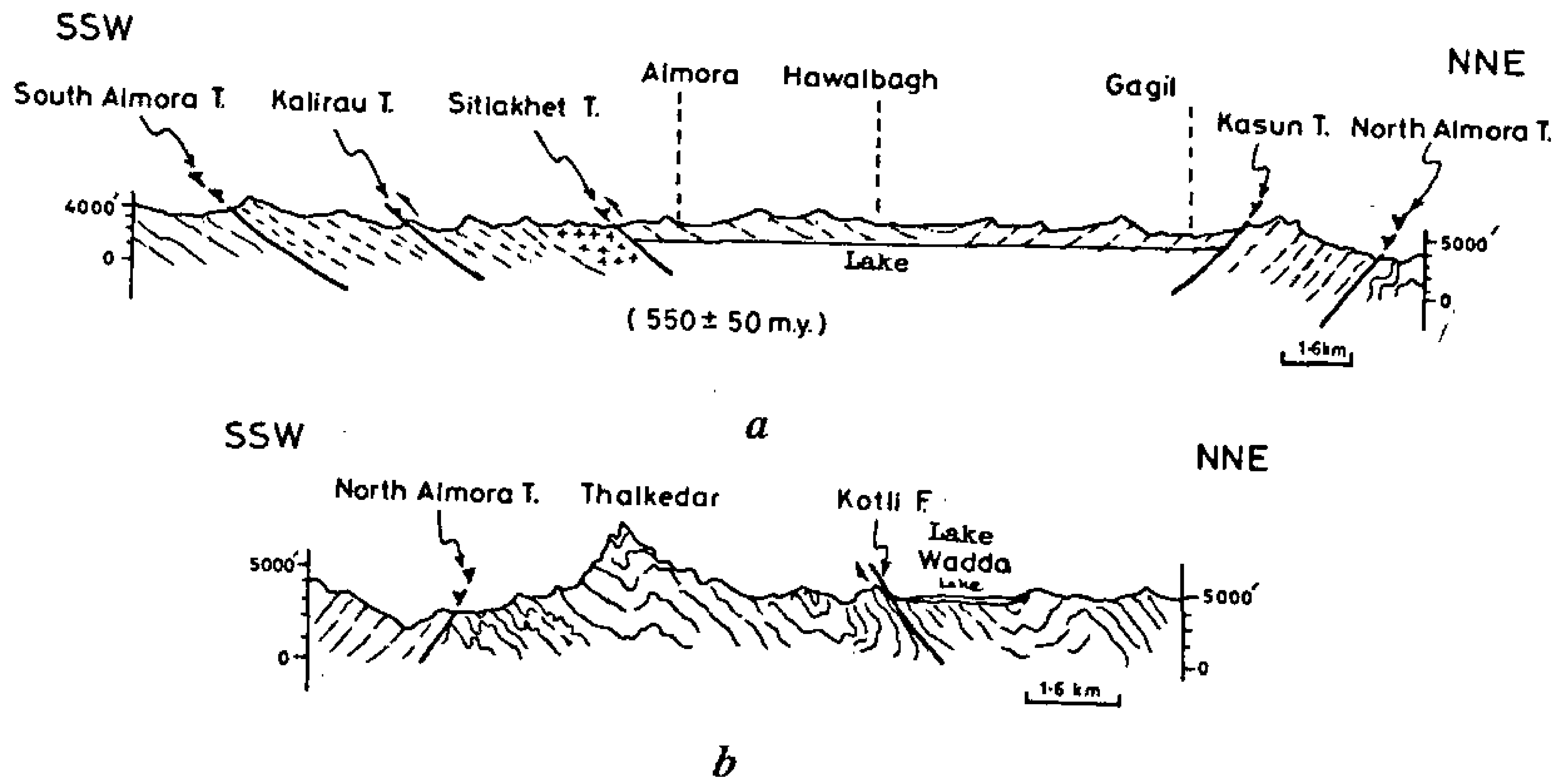


Figure 2. Diagramatic cross sections of the Almora Nappe along the Kosi valley in the *a*, west; and *b*, east of Pithoragarh.

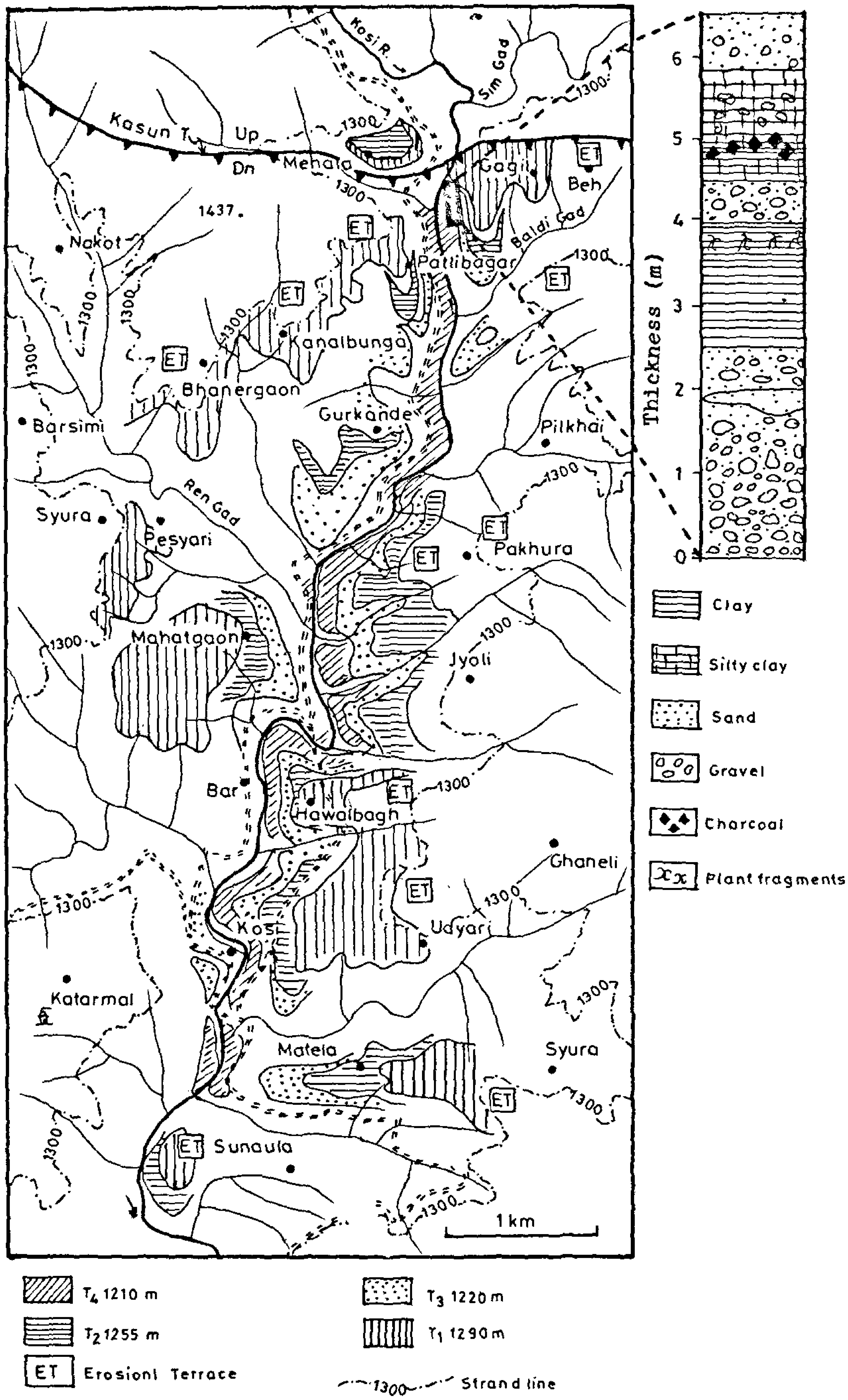
In the Almora–Kausani region in the central Kumaun[1,3,8], the Kosi river flows through a geomorphologically mature old terrain that is being rejuvenated as a result of recurrent episodic uplift. This is borne out by various geomorphic features such as multiplicity of fluvial terraces (four depositional terraces are observed along the Kosi river), deep (15–30 m) incision by streams, entrenched meanders, series of 0.5–2.6 m high waterfalls in all subsequent streams and by the wide valley of the Kosi with very gentle slopes (6–10°) becoming a deep gorge having convex walls immediately on its crossing the active thrusts of the SAT zone.

Approximately 1–1.5 km wide and 7 km long, extending between the active Sitlakhet Thrust in the south and Kasun Thrust (Figures 1 and 2) in the north[9,10], the Hawalbagh palaeolake is presumably the biggest lake so far known in the Kumaun Himalaya. Since there is no deposition observed south (downstream) of the Sitlakhet Thrust, it appears that it delimits the southern limit of the lake. It is represented by about 7 m thick succession of fluvial (in lower part) and fluvio-lacustrine deposits (in upper part), typically developed at Gagil in the north (Figure 3). A persistent 2–2.5 m thick horizon of ferruginous clay, occasionally containing charcoal pieces, forms the top of the sequence. The silty clay with ill-sorted pebbles grade downwards into brownish clay with negligible amount of silt and which in turn becomes the mixed suite of clasts having sandy matrix – the latter representing the fluvial regime of the ancient Kosi.

The lake originated as a result of ponding of the Kosi following uplift of the downstream (footwall) block of the Almora–Siahidevi Range on the Sitlakhet and Kalirau thrusts (Figures 1 and 2). The strandline of this lake is defined by the surface of the oldest terrace (T_1), discernible all along the western side. The T_1 terrace has been eroded away from a large part of the eastern side of the lake. The lateral interfingering of pebbly clays with unsorted gravels in the Gagil area resulting from landslides – which occurs as fan in a row all along the stretch of the thrust – indicate that the Kasun Thrust was also active during the development of the lake.

Movements on the E–W striking Kotli Fault that runs parallel to the North Almora Thrust in eastern Kumaun lifted up the lofty (> 2600 m) Thalkedar Range and dammed the rivulet Thuli Gad and its tributary Hurkana Gad (Figure 4). The wide mature valley – with slope less than 6° – of the Thuli Gad abruptly becomes a very deep gorge or canyon having nearly vertical walls and with entrenched swings after crossing the active Kotli Fault, corroborates recent movements in the Pithoragarh–Wadda area. The resultant lake stretched about 8 km west-north-west towards Pithoragarh town. A sequence of about 13 m of clays and debris flow is exposed near Wadda (Figure 4). The carbonaceous clays are very finely laminated and contain fragments of charcoal. Mixed with dark brownish clay, the weathered basement rocks (Sor Slate) also form 'pudding stone'. At least three events of debris flow (angular to subangular clasts and fragments of dolomite and slate mixed with brownish black clay) represent debris avalanches triggered presumably by the tectonic movements. The tilting (2–3°) of lacustrine strata (continuously for about 2 km) along the Hurkana Gad, exhibiting entrenched meandering in its terminal part indicates revival of the movements on the active Kotli Fault. This may have caused the effacement of the lake. Possibly, the huge amount of debris flow capping the Quaternary sequence in the area was responsible for the draining of the lake.

Two clay samples containing charcoal pieces dated (see Figure 4) by G. Rajagopalan at the Birbal Sahni



)-lacustrine terraces (T_1–T_4) representing the Hawalbagh palaeolake in the Kosi valley (inset shows the

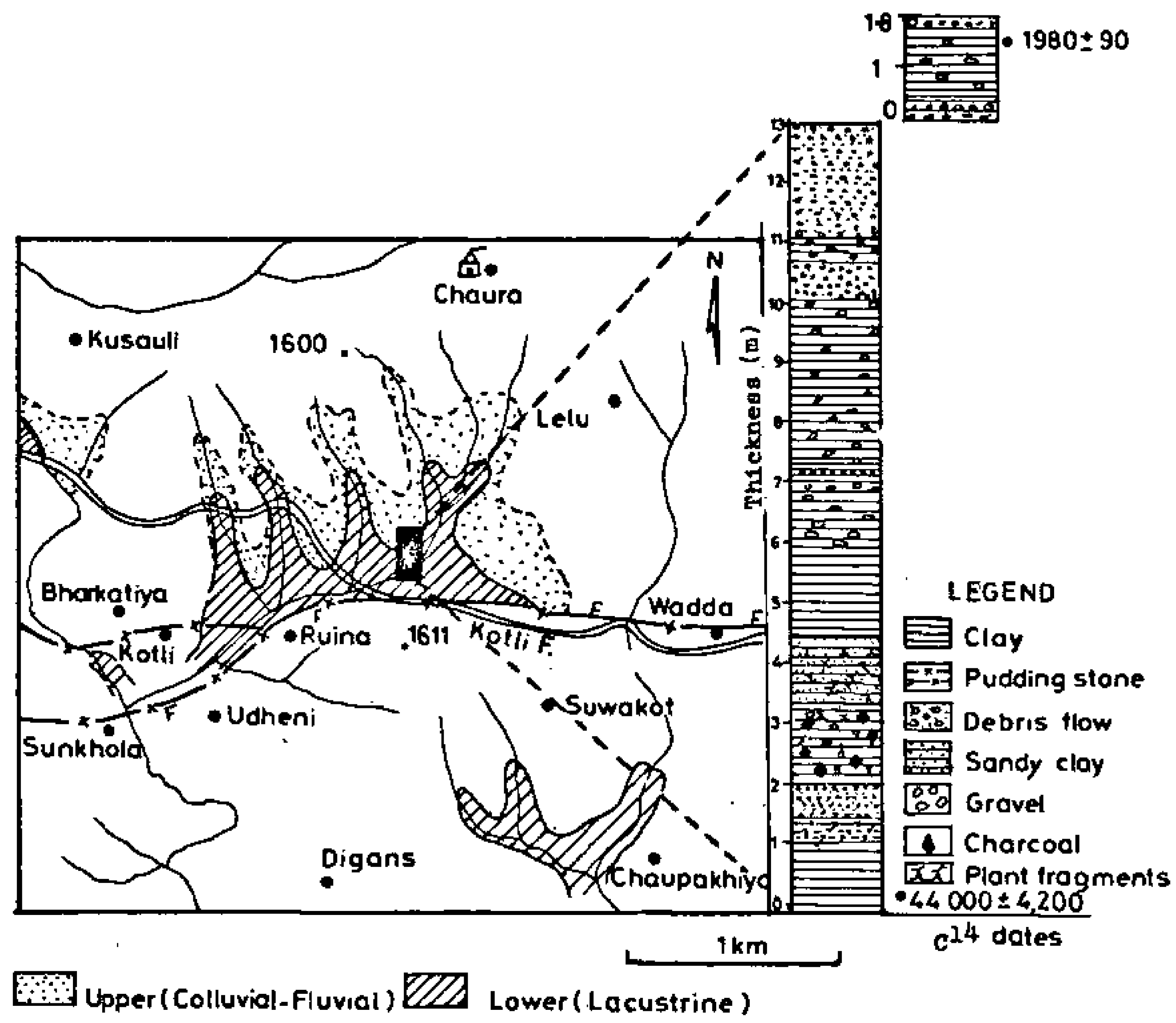


Figure 4. Diagramatic cross section showing extent of the Wadda palaeolake at Pithoragarh (inset shows the lithocolumn).

Institute of Palaeobotany, Lucknow indicate that the Wadda lake was formed about 44,000 years BP and lasted until about 2,000 years BP.

1. Heim, A. and Gansser, A., *Mem. Soc. Helv. Sci. Nat.*, 1939, **73**, 245.
2. Valdiya, K. S., *Geology of Kumaun Lesser Himalaya*, Wadia Institute, Dehradun, 1980, pp. 291.
3. Merh, S. S., *Him. Geol.*, 1977, **7**, 26–42.
4. Misra, R. C. and Valdiya, K. S., *J. Geol. Soc. India*, 1961, **2**, 78–90.
5. Valdiya, K. S., *Ann. Tecton.*, 1992, **6**, 34–84.
6. Valdiya, K. S., *Curr. Sci.*, 1993, **64**, 873–885.
7. Valdiya, K. S., Rana, R. S., Sharma, P. K. and Dey, P., *J. Geol. Soc. India*, 1992, 509–528.
8. Misra, R. C. and Sharma, R. P., *Him. Geol.*, 1972, **2**, 330–341.
9. Powar, K. B., *J. Univ. Poona*, 1971, **40**, 103–110.
10. Rai, S. P. Unpubl. Ph D thesis, Kumaun University, 1993, p. 160.

ACKNOWLEDGEMENTS. This study is supported by a CSIR grant. We thank Dr G. Rajagopalan, BSIP, Lucknow for providing the radiocarbon dates. BSK is grateful to the Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore for supporting visit for the laboratory work.

Received 17 May 1995; revised accepted 16 December 1995

Characterization of immunogenic components of *Hyalomma anatolicum anatolicum* – the vector tick of bovine tropical theileriosis

Anu Parmar and A. S. Grewal

Department of Veterinary Immunology, Punjab Agricultural University, Ludhiana 141 004, India

Native polyacrylamide gel electrophoresis (PAGE) and immunoblotting assays were used to characterize the immunogenic proteins of salivary gland extract (SGE) and saliva of *Hyalomma anatolicum anatolicum* tick. Native PAGE of the SGE revealed 10 proteins of molecular weights 56, 60, 64, 66, 120, 148, 220, 264, 300 and >300 kDa. In the immunoblot assay of the tick SGE, mice hyperimmune serum reacted with only one protein of 66 kDa. In contrast to the SGE, the tick saliva revealed only 2 proteins of 264 and 66 kDa. The 66 kDa protein was also observed in the tick larvae extract. These results suggest that the 66 kDa tick antigen may be one of the likely proteins of relevance to anti-tick immunity and subunit vaccine development for *H. anatolicum anatolicum*.

H. ANATOLICUM ANATOLICUM is the most common tick vector of *Theileria annulata*, a lymphocytotropic and erythrocytotropic protozoan, causing high mortality in European dairy cattle (*Bos taurus*) and their cross-bred progeny (*B. taurus* × *B. indicus*) in India and other tropical countries. Thus, bovine tropical theileriosis has become a major constraint in cross-breeding programmes aimed at upgrading the local dairy cattle for high milk production. The use of chemical acaricides for the control of ticks has the obvious disadvantages of development of resistant tick strains, environmental pollution, public health hazards and high costs. A novel approach for control of ticks (ectoparasite arthropods) by immunization with tick antigens is becoming an interesting area of research[1–3]. In *H. anatolicum anatolicum* tick immunity studies in this laboratory, acquired immunity has been demonstrated in cross-bred calves following a single infestation with adult *H. anatolicum anatolicum* resulting in 60–65% rejection of the tick larvae. In addition, a significant proportion of the attached larvae and nymphs failed to feed normally on blood[4]. Subsequently, it was demonstrated that artificial immunization with adult tick salivary gland extract homogenates emulsified with Freund's Incomplete Adjuvant (FIA) produced protection manifested by rejection of tick larvae challenge infestations. The SGE induced anti-tick immunity was enhanced using *Ascaris* helminth extract in the adjuvant emulsion[5], a known immunomodulator of IgE immune responses[6].

The present study was undertaken to analyse the salivary gland immunogenic sub-components in the tick salivary gland by polyacrylamide gel electrophoresis (PAGE) and immunoblotting, using hyperimmune serum from inbred Balb/c mice in our pursuit for the development of murine monoclonal antibody probes to tick salivary antigens. An attempt in this direction would help in the development of an effective subunit anti-tick vaccine. Gill *et al.*[7] characterized the salivary gland antigens of *H. anatolicum anatolicum* by SDS-PAGE and