An experimental annual forecast of all-India mean summer monsoon rainfall using neural network

Accurate long-range forecast of rainfall can provide significant boost to the economy and the agricultural prospects of the country by allowing better planning of agricultural strategies. Such long-range forecasts can also help in crisis (e.g. draught) preparedness. Conventionally such forecasts are generated using either statistical or dynamical methods. However, in spite of persistent efforts by scientists and operational agencies, success in long-range prediction has been limited. This is particularly true for prediction for longer than a season in advance. Although some of the statistical models have shown considerable skill in forecasting Indian summer monsoon rainfall (ISMR)[1], their range does not exceed a few months. Besides, most of these statistical (regression) models require a number of observed parameters, many of which are not available until before onset. This has been one of the major obstacles in attempts to generate very long range (VLR, one year or more) forecast of monsoonal rainfall.

An attempt at VLR forecast of ISMR was made using neural networks[2]. Neural networks (NN) which have found applications in diverse areas in recent years, provide an alternative modelling and simulation tool for complex processes. The usefulness of neural networks for simulating atmospheric processes has been emphasized in the recent years[3]. In particular, in a recent work, it was shown that a generalization of the structure of a conventional NN has the potential for generating VLR forecast of ISMR with good accuracy[2]. Subsequently, an extensive statistical evaluation of the performance of this generalized NN was carried out by generating 73 hindcasts for the period 1821 to 1993. Results of these analyses, presented elsewhere[4], show that the generalized network can generate annual forecast with average (over 73 cases) error less than half the standard deviation of the data, with absolute error about 36 mm. Encouraged by these results, we have generated annual forecasts of ISMR for 1995 and 1996 using this method; the purpose of the present note is to convey and record these forecasts for future evaluation.

These forecasts were generated using ISMR data for 50 years prior to 1995, taken from Parthasarathy *et al*[5]. Although the ISMR data for 1995 is in principle now available, we did not have this information while generating this forecast. Thus the forecast for 1995 provides an immediate evaluation of the success of the forecast (and the method). The forecast for 1996 will provide a more rigorous evaluation next year. The forecasts are given below:

1995	855 mm
1996	868 mm.

We want to emphasize that this forecast is a purely experimental one, to provide an objective evaluation of the forecast skill of our method; it is thus not meant for any operational use. Besides, there are two factors which can adversely affect the accuracy of the forecast for 1996. The first of these is a general weakness of the method in that it often fails to capture very large (more than twice the standard deviation) departures from the mean, a weakness shared by most statistical methods. The second is specific to this particular forecast: since we did not have the observed data for 1995, the forecast for 1996 uses the forecast value for 1995, among other parameters. Thus any error in forecast of 1995 will have some effect on the forecast of 1996. It will be interesting to check next year how our forecasts compare with observations.

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A call for palaeoseismic investigations to constrain the repeat time of great earthquakes in the Himalaya

The Himalaya and the region of the adjoining Ganga plains have a history of disasters due to the occurrences of great earthquakes in the past. As the geological processes leading up to such earthquakes are continuing, these regions are threatened by the future occurrences of similar great earthquakes. Assessment of seismic hazard in these regions requires the estimation of the average repeat time of future great earthquakes over specific fault segments. The repeat times are usually estimated on the basis of Gutenberg–Richter recurrence relation. This relation has been obtained for the entire

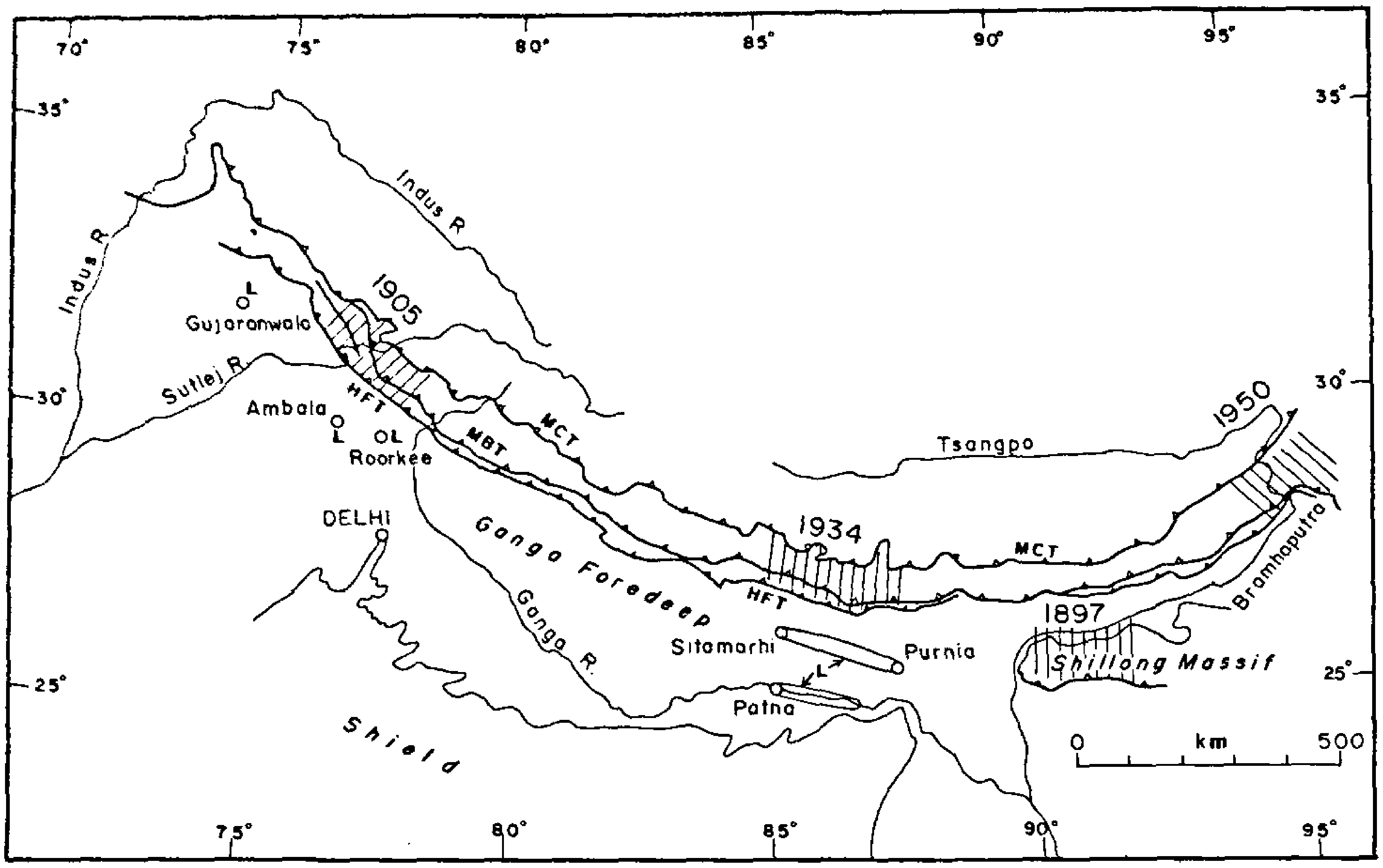

Figure 1. The sites of the great Himalaya earthquakes are shown by hatched lines. The respective years of earthquakes are noted next to their fault zones. The sites of soil liquefaction are identified by letter L. MCT: Main central thrust. MBT: Main boundary thrust. HFT: Himalaya frontal thrust.

seismic source zone as a whole for the Himalaya. Thus, it does not provide an appropriate estimate for the repeated occurrences of great earthquakes over the same fault segments. The historic and instrumental data sets are not extending back in time far enough, and also as we go back in time the information quality in terms of accuracy of magnitude, location, and completeness of earthquake reporting becomes less and less accurate. Therefore, recourse to other techniques such as estimating the strain budget on the basis of rate of convergence of plates, geodectic evaluation of the strain rates using GPS measurements, and palaeoseismicity investigations are taken. The palaeoseismic studies provide the dates of the past characteristic earthquakes which, together with the strain rate estimated from geodetic measurements, can lead to long-term forecasting of future great earthquakes.

Four great earthquakes have occurred in the Himalaya: in 1897 (Assam), 1905 (Kangra), 1934 (Bihar–Nepal), and 1950 (Assam). These earthquakes have ruptured 250 to 350 km long sectors of this plate boundary leaving other sectors in between them which form seismic gaps (e.g., see refs 1–5). Figure 1 shows the rupture zones of the great earthquakes and the seismic gaps.

The historical record of earthquakes in the Himalaya documents a number of damaging earthquakes, however only the 13th century Nepal earthquake appears to qualify as a great earthquake. The convergence rate at which the Indian plate collides with the Asian plate provides a means to obtain the estimate of accumulating elastic strain in the earthquake belt of the Himalaya. It is estimated to be 15–20 cm/year[1,3]. A period of approximately six and a half centuries have elapsed since the thirteenth century Nepal great earthquakes. Therefore, at least about 10–12 meters or so of strain has accumulated in the seismic gaps. Thus, the above seismic gaps are presently capable of causing a characteristic great earthquake[3,6–8].

An independent estimate of the repeat time of great earthquakes may be deduced from paleoseismic studies. Strong ground shaking during large earthquakes often induces seismogenic geological features such as soil liquefaction, sand blows, and craters. The susceptible soils are composed of cohesionless, water saturated well-sorted sands. The shallow sediments can preserve the signatures of liquefaction in the forms such as infilled craters, feeder dykes, slumping of strata, etc.[9,10]. By radiocarbon dating of the organic material caught in the liquefaction associated structures it is possible to date the palaeoseismic events. Such investigations have been successfully done, for example, for the 1886 Charleston and the 1811/12 New Madrid (USA) earthquakes (e.g. refs 9, 11). Figure 2 illustrates an example of the nature of liquefaction features seen in a trench and their chronological dates obtained using radiocarbon methods[9].

Occurrence of soil liquefaction in Great Indian earthquakes

The cohesionless soils susceptible to liquefaction are expected to exist widely in the plains of Ganga foredeep. The groundwater levels are also very shallow, being conducive to liquefaction. In fact widespread damage due to soil liquefaction in a slump belt about 300 km long in the Ganga plains occurred in the 1934 great Bihar–Nepal earthquake. It encompassed areas of

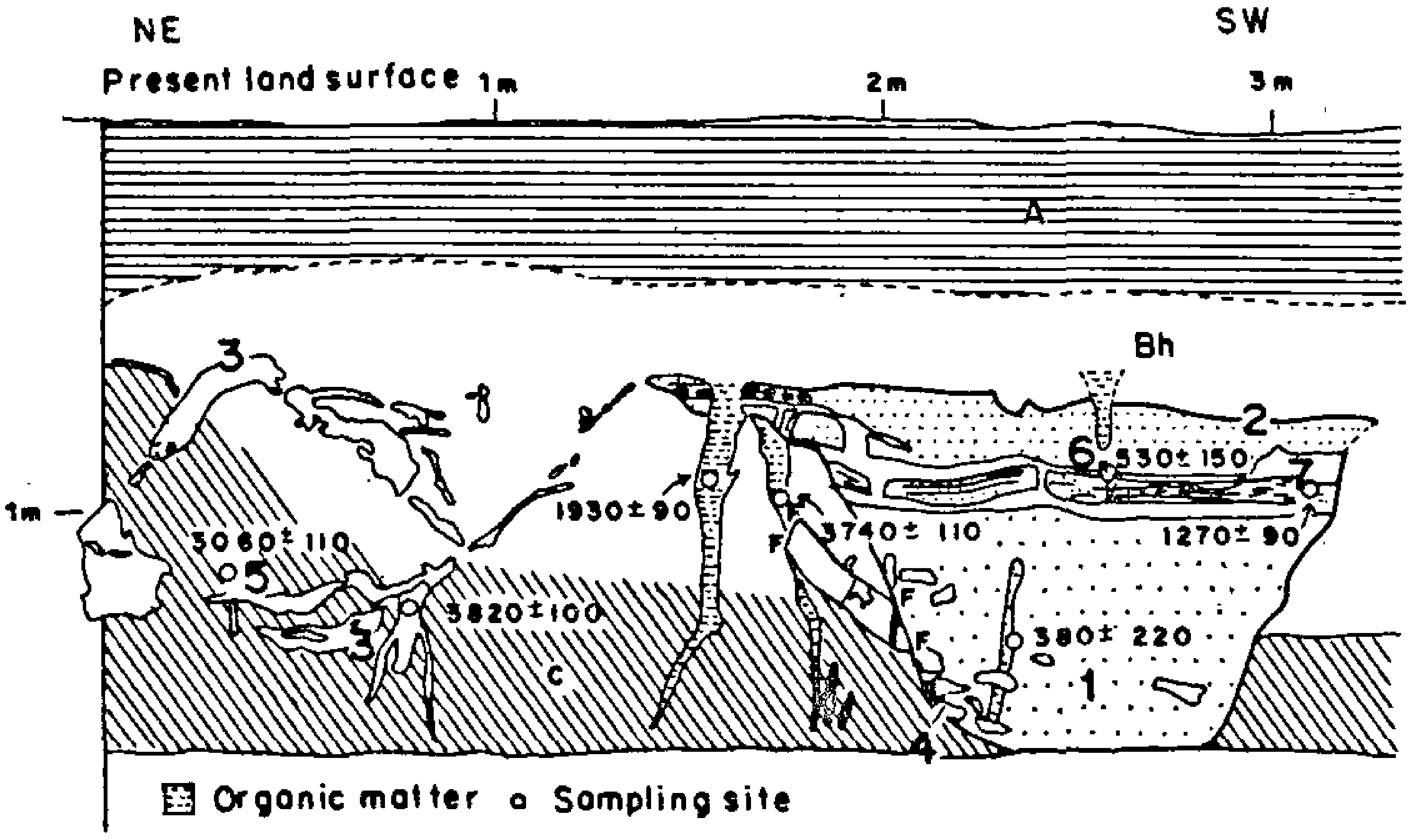

Figure 2. Cross-sectional trench at a site where seven samples were dated by ^{14}C analysis. The preserve crater (1) has the same internal grading and bedding (2) and slumped clasts of Bh material (4). A preserved conduit or sandblow (3) is northeast of crater. Faulting (F) associated with formation of the crater offsets roots dated at 3740 ± 110 years before present. Dates obtained from roots crosscutting the infilled crater yielded ages of 530 ± 150 years (6), 380 ± 220 years, and 1270 ± 90 years (7). Dates from the infilled crater indicate that it was emplaced after 3740 ± 110 but before 1270 ± 90 years BP (adapted from Talwani and Cox[9]).

Purnea, Darbhanga, Muzzafarpur and Champaran districts[12]. Similarly extensive sand cratering is reported in the 1897 great Assam earthquake[13]. The liquefaction of the soils was reported at fewer and areally smaller localities for the 1905 great Kangra earthquake around Roorkee. Ambala and Gujranwala districts[14]. Thus, a possibility appears that the experience of palaeoseismicity studies in the cases of Charleston and New Madrid earthquakes could be used to establish further constraints on the repeat times of great earthquakes in the Himalaya.

Some of the localities in the alluvial belt of the Ganga foredeep that have been reported to have suffered soil liquefaction are shown in Figure 1. It is suggested that palaeoseismic investigations of such localities be taken up urgently. Selected sites should be trenched and explored for liquefaction signatures that may have preserved datable organic material from past earthquake events. The known liquefaction sites could be studied for characteristic geomorphic features. In addition, seismic noise studies can be quickly conducted at these sites using portable accelerographs to characterize the noise spectrum and the shallow velocity structure. These characteristic features together will serve to identify further sites in the regions of Ganga foredeep in front of the seismic gaps for similar studies.

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Cholera toxin, zonula occludens toxin and accessary cholera enterotoxin gene-negative *Vibrio cholerae* non-O1 strains produce the new cholera toxin

Vibrio cholerae non-O1 have been reported to produce cholera toxin (CT), although certain strains did not do so[1]. In recent years, several other extracellular products such as a heat stable toxin (NAG-ST), a thermostable direct haemolysin, El Tor-like haemolysin, a shiga-like toxin, haemagglutinin and zot[2] produced by *V. cholerae* non-O1, have been reported to play some role in causing disease. However, none of these virulence factors alone was considered