Malpa rockfall disaster, Kali valley, Kumaun Himalaya

A massive rockfall occurred on 18 August 1998 at 3 a.m. on the dip slope of a ridge near Malpa in the Kalli Valley flowing through the Great Himalayan terrane. Massive quartzite interbedded with thin bands of garnet-bearing sericite schist dipping 60–70° north-eastward had slid down. Nearly vertical joints striking perpendicular to the foliation plane are responsible for the slope failure. A prominent shear zone exhibiting flat-and-ramp structure in the brittle regime has been identified. Continuously heavy rain contributed to the decrease of cohesion and shearing resistance, leading to instability and resultant slope failure and free falls of the rock masses.

The site of rockfall tragedy, that took a toll of more than 200 persons, lies within the Great Himalaya located 43 km north of Dharchula on the bank of the River Kali – at latitude 30°01'55" and longitude 80°45'07". The 3000 to 2100 m high terrane (Figure 1) is delimited by the Vaikrita Thrust and Trans-Himadri Fault (THF), both trending NW-SE.

The Great Himalayan terrane comprises Precambrian 'Central Crystalline Zone' divided into the Vaikrita Group of sillimanite–kyanite–garnet schists and gneisses, calc-silicate rocks and migmatite and intrusive Tertiary granites in the north and the Munsiari Formation made up of sericite–chlorite schist, micaceous quartzites, carbonaceous phyllites, lenticular marble and mylonitized porphyroblastic granodiorite and augen gneiss in the south[1–6]. The Vaikrita Thrust (VT) separates the Munsiari from the Vaikrita rocks. The

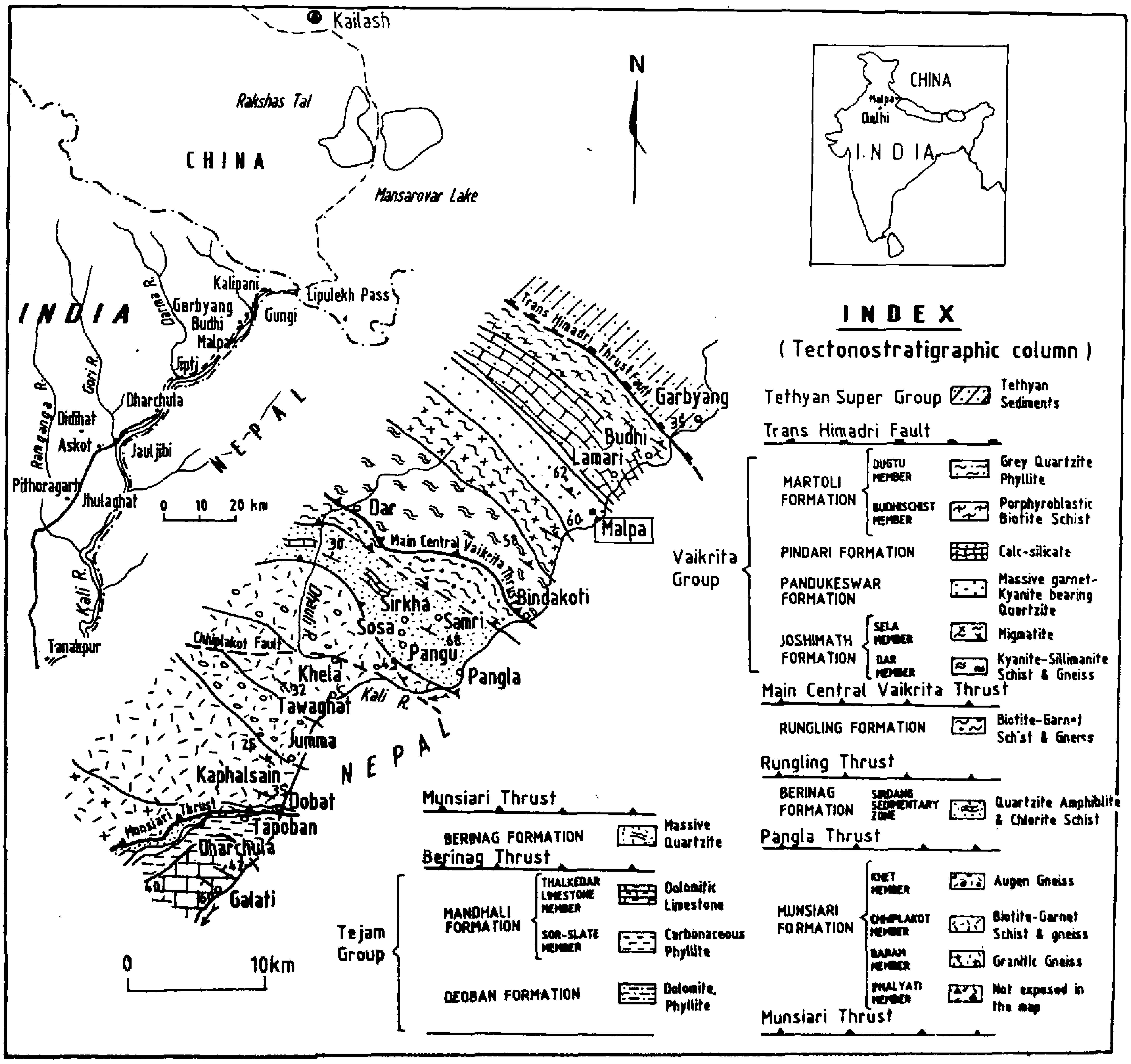

Figure 1. *Left*, Route map between Tanakpur and Kailas–Mansarovar. *Middle*, Geological map of the 'Central Crystalline Zone' along the Kali valley.

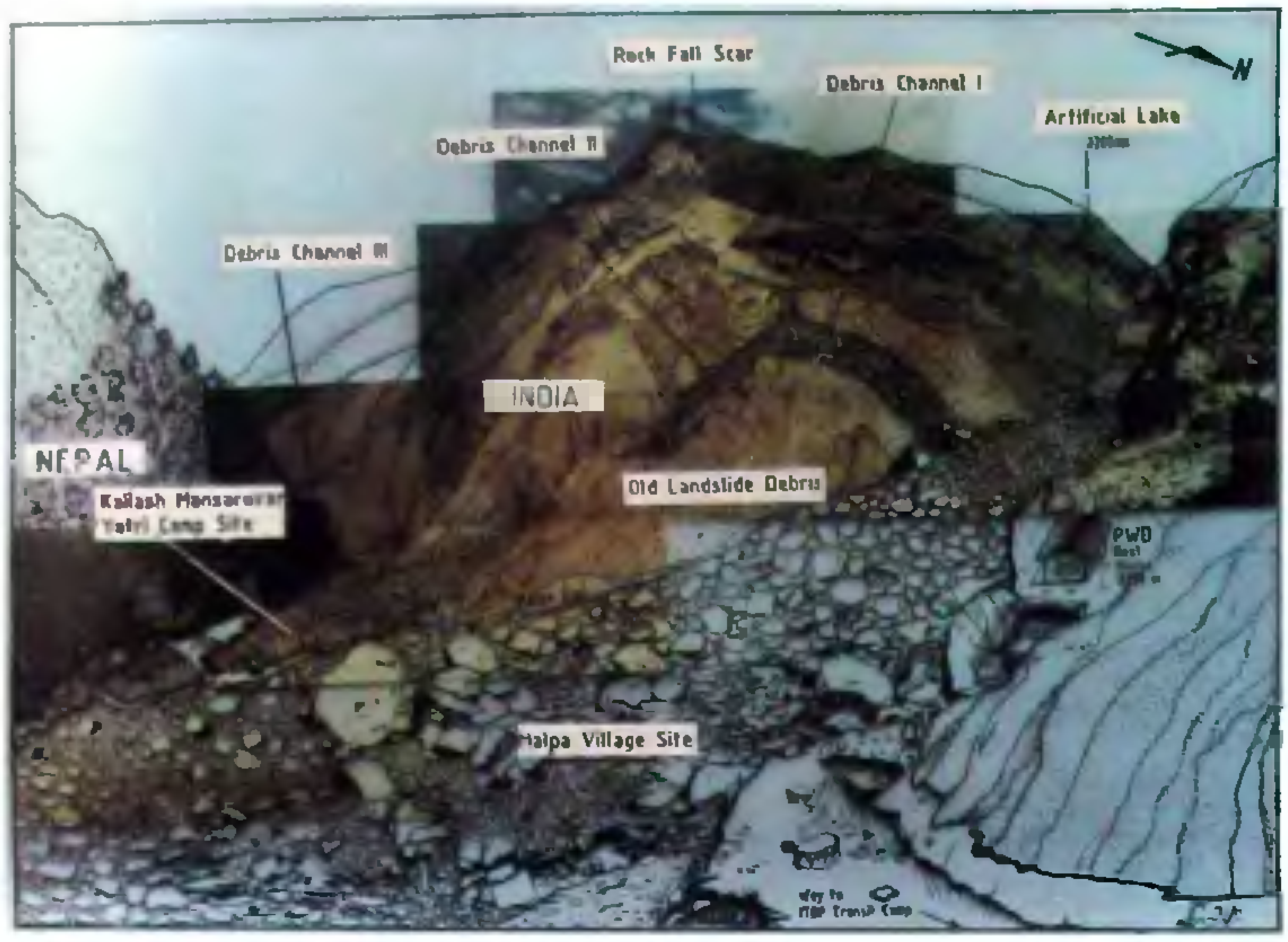

Figure 2. Diagramatic sketch and photo view of the site of tragedy looking southward from the ITBP camp site.

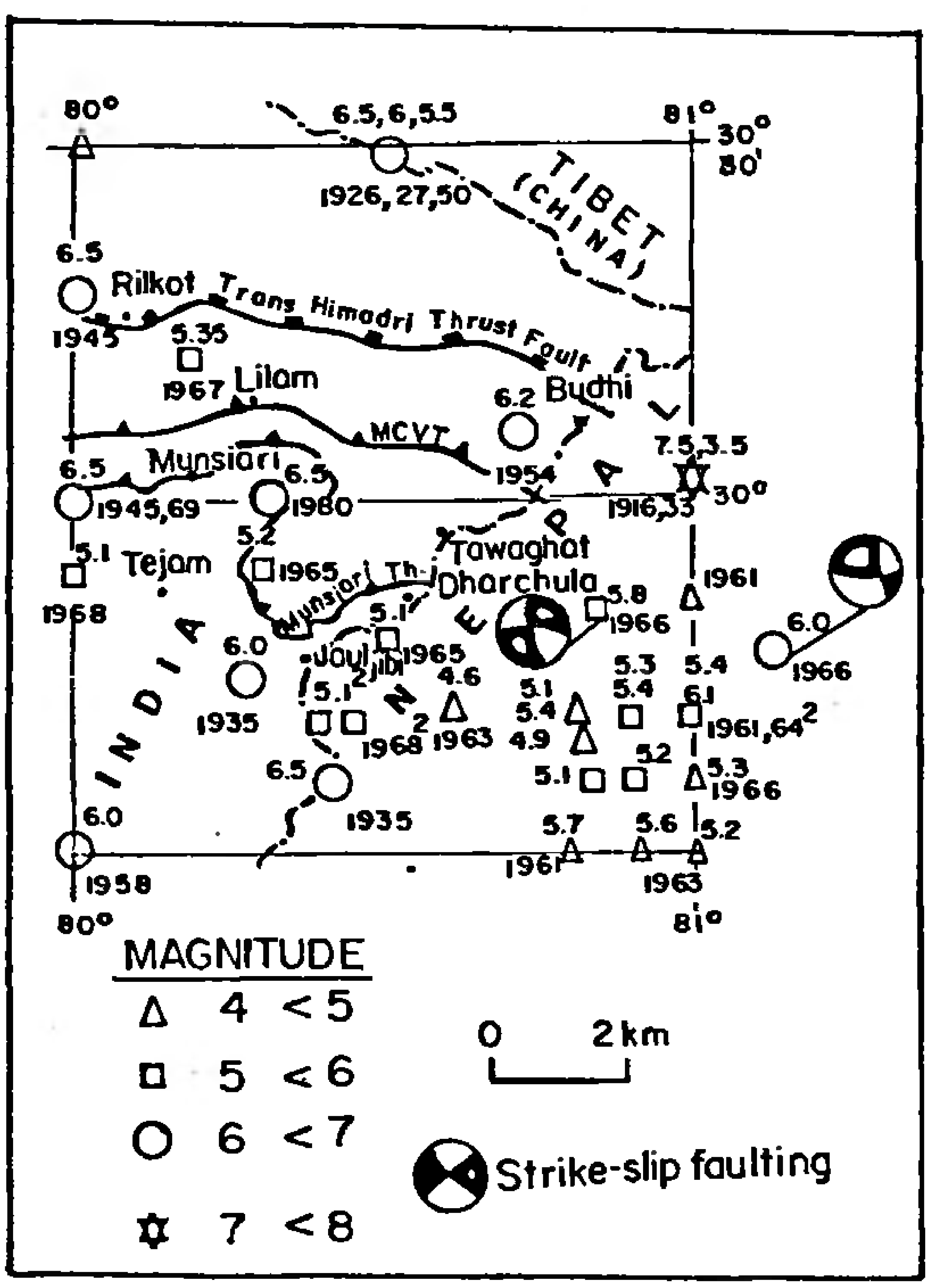

Figure 3. Epicentral map of the northeastern Kumaun Himalaya and adjoining northwestern Nepal.

rock formations involved in the Malpa landslide belong to the Pandukeshwar Formation of the Vaikrita Group consisting of dominantly massive quartzite with thin bands of garnet-bearing sericite schist, calc-silicate rocks, psammitic gneiss, amphibolite and migmatite. Foliation planes with vertical joints and fractures striking perpendicular to them provided surfaces of failure. The fracture spacing at the ridge crest and just below it varies from a few to tens of centimetres. The present Malpa rockfall involved the rocks dipping 60°–70° northeast and a series of shear planes that indicate southward thrust movement of the quartzite.

The area around Malpa is generally covered by small shrubs while higher ridge-crests and upper slopes are characterized by barren surfaces with scanty grass. However, on the Nepal side across the Kali the area is thickly forested. Old scars of earlier rockfalls are seen in the grassy land in the southwestern side of the Malpa ridge. The village is situated on the fan-shaped landslide debris (8–12 m thick) and terrace deposits. Thus the Kali and its tributaries have witnessed repeated damming of channels due to huge landslides and rockfalls as evidenced by old rockslide debris and terrace deposits at Lameri, Budhi, Garbayang and Gunji.

Recent rockfall

The sudden rockfall from heights of 3000 to 2100 m, which occurred on 18 August 1998 at 3.00 a.m., brought down rock chunks varying from 1 to 5 m in size. The dust cloud generated spread 1 to 2 km on either side of the Kali valley. The rockfall started on 16 August morning, giving an early warning and killing three mules. The rockfall was followed immediately by flash flood in the Malpa stream due to bursting of the debris dam that was formed due to rockfall. The Malpa stream was blocked at a height of 2280 m. The flood brought huge amount of bouldery debris to the other side of village Malpa where the camping site of Kailas–Mansarovar tourists and pilgrims was located. The dam gave way on 17 August night. On 18th night there was yet another rockfall blocking the stream again and giving rise to a lake. On 19th evening the lakewater burst out and flushed some of the dead bodies into the Kali river. The rockfall continued till 21 August. In all 221 people died including 60 members of Kailas–Mansarovar team, 120 porters, 9 GREF personnel, 8 ITBP person-

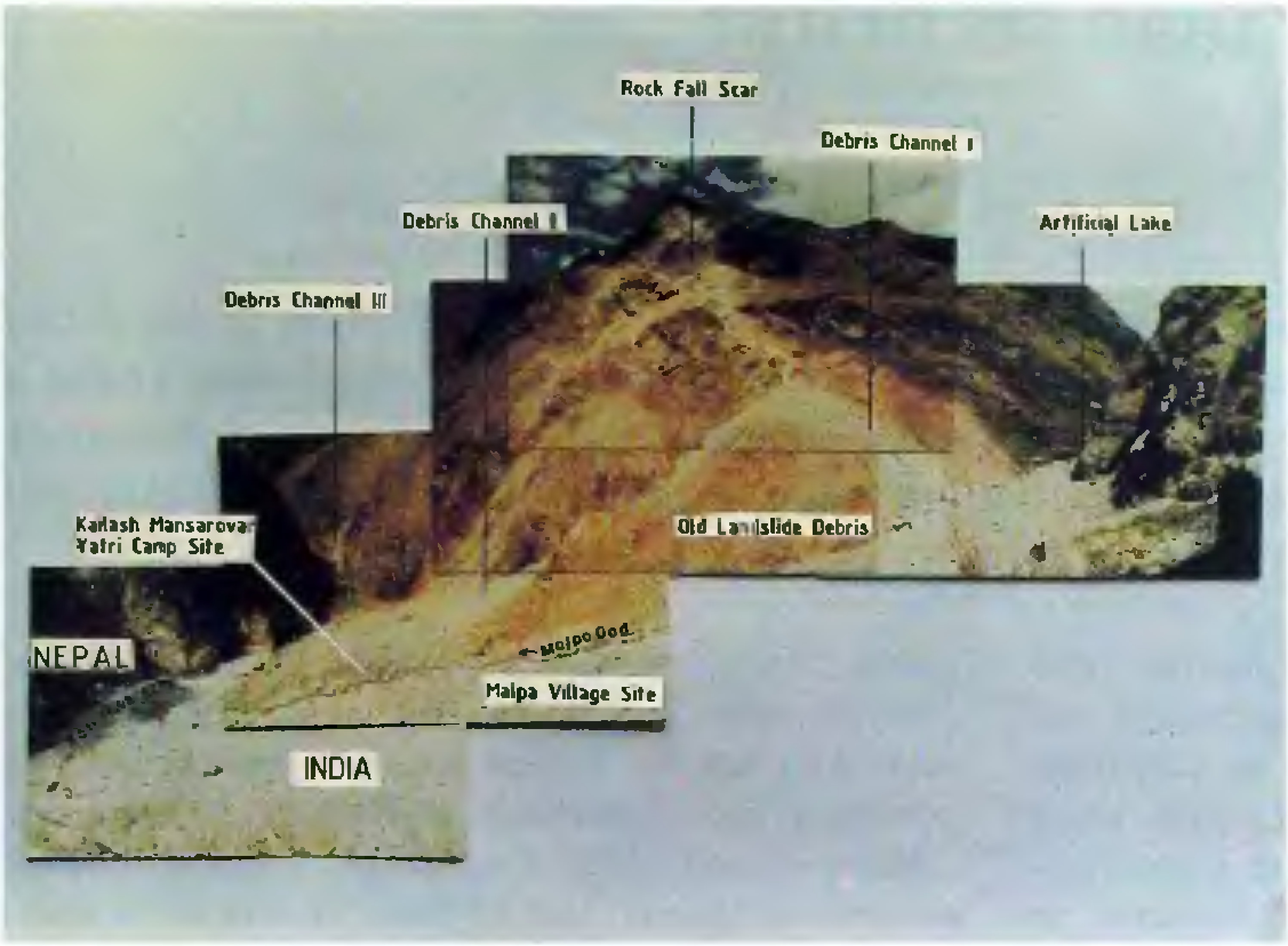

Figure 4. Panoramic photo mosaic of Malpa village and surrounding area, looking southward from ITBP camp site.

nel, 8 PWD labourers and 16 other people of the village with 60 animals.

As a consequence of the rockfall, the Malpa stream changed its course. Earlier the stream followed a path to the east of the village and bridge had been constructed on that stream, but now it is flowing between the village and Nigam's camping site, cutting through deposits consisting of big boulders and loose sands.

Cause

The area located between the VT and T-HF and the proximity of active shear zone (Figure 2) is in the snow-bound terrain where regular freeze-and-thaw cycle has progressively weakened the rock-masses by increasing the fissure spacing to 0.3–0.5 m. Rainfall data show that there was high precipitation for a week preceding the time of disaster. This must have created pore-water pressure in the fractures perpendicular to the bedding planes, culminating in the failure. The shear zone is characterized by ramps-and-flat structure in the quartzite, indicating southward thrust movement in the brittle regime. This must have generated shear stress in the rock and caused the slide (Figure 2).

The northeastern part of the Kumaun Himalaya and the adjoining area in Nepal is seismically active. The area lies in the seismic zone V. Epicentral map of the region reveals that 6.2 magnitude earthquake occurred east of Malpa in 1954 (Figure 3). The strongest earthquake occurred in 1916 of magnitude of $M > 7.0$ in the Dharchula region and ravaged several villages on both sides of the Kali river. The area was jolted by earthquakes again in 1979 and 1980 (ref. 4). There is evidence of movement on the MCT, and the associated thrust planes. The transverse and oblique tear faults have registered vertical as well as lateral movements[4].

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