Journal of Nepal Geological Society
Vol. 5 No. 1, 1988, 22-44

THE DISTRIBUTION OF INTENSITY OF THE BIHAR-NEPAL EARTHQUAKE OF 15 JANUARY 1934 AND BOUNDS ON THE EXTENT OF THE RUPTURE ZONE

M. R. Pandey *

and

Peter Molnar **

ABSTRACT

We have recompiled the descriptions of damage and destruction caused by the 15 January 1934 Bihar-Nepal earthquake, given by both Dunn et al. (1939) and by Major General Brahma Sumsher J. B. Rana (1935), to infer bounds on the dimensions of the rupture zone of that earthquake. The distribution of damage in northern India was very uneven, and much of that destruction was closely associatd with slumping, fissuring, and tilting of the ground. The absence of any preferred orientation of the fissures and the prevalence of sand and water issued from fissures suggest that this disruption of the earth's surface was limited to surficial layers and not to faulting of the basement beneath that area. Thus much of the damage in northern India, perhaps the majority, was not due to shaking or to high accelerations of the ground, but rather to disruption ot the earth's surficial layers.

Except for three short trips to parts of Nepal by. J. B. Auden, Dunn and his colleagues has access to little information from Nepal, and their descriptions of the effects of the earthquake in Nepal were brief. Rana, however, made extensive compilations both of destroyed buildings and of casualties in various districts and towns in Nepal, and it appears that the greatest destruction lay in the parts of Nepal that Auden did not visit. Where Rana and Auden gave independent assessments of the damage, their reports agreed sufficiently well, that the particularly heavy toll reported to have been taken by the earthquake in the mountainous terrain of east-central Nepal probably is not an exaggeration. This area, in fact, includes the epicenter of the earthquake recalculated from arrival times of P waves.

---

* Department of Mines and geology, Kathmandu
** Department of Earth, atmospheric, and Planatary Science,
M. I. T. Cambridge, Massachusette 02139. U. S. A.

Thus in contrast to Dunn et al. and others who have followed them, we think that rupture zone of this earthquake lay beneath the lesser Himalaya and not beneath the plains of northern India. The east-west dimensions are difficult to constrain, but surely reach 100 km, the length of the zone of maximum destruction in Nepal. The region for which Dunn et al. assigned an intensity of VIII, on the Rossi-Forel scale, extended as far east as Darjeeling and somewhat west of Kathmandu, for a total distance of about 300 km, however, and the abrupt decrease in destruction west of Kathmandu and east of Darjeeling might indicate that the length of the rupture was this amount. Given the uncertainties in evaluating the dimensions, it probadly would be best to allow both extrems, or 200 ± km, in evaluations of recurrence intervals and earthquake hazards.

INTRODUCTION

Among the four great earthquakes that have affected the Himalayan belt in the last 100 years (those of 1897, 1905, 1934 and 1950), more ambiguity surrounds the 1934 Bihar-Nepal earthquake than any of the others. Following the earthquake, the Geological Survey of India deputed several of its geologists, including J.B. Auden, J.A. Dunn, A.M.N. Ghosh, and D.N. Wadia to evaluate the destruction and the geological effects associated with that earthquake in India. Auden also traveled to Kathmandu and briefly to two other parts of Nepal, up to the foot of the Himalaya and across the southeast corner of the country to Darjeeling (Figure 1). Compared with the thoroughness of the investigation in the plains of India, however, these brief trips to Nepal provided very incomplete coverage of the damage in Nepal caused by the earthquake. Consequently, the strong emphasis on the destruction in India in the reports submitted by the officers of the Geological Survey of India left the impression that the epicenter of the 1934 Bihar-Nepal Earthquake lay not within the Himalaya but south of the range in the plains of India (Dunn et al., 1939).

This impression has subsequently been promulgated by others, such as Richter (1958), Seeber and Armbruster (1981), and Singh and Gupta (1980). Seeber and Armbruster (1981), in particular, developed this inference further and concluded that slip occurred on a plane lying beneath the Indo-Gangetic plains and dipping gently northward. They reported an epicenter for the earthquake that also lay beneath the plains and not beneath the Himalaya, where most well-located moderate earthquakes have occurred.

Apparently unbeknownst to the officers of the Geological Survey of India, Nepalese oficials also gathered extensive information on the destruction brought by the earthquake. The extent of damage and the numbers of casualties in various districts in eastern and central Nepal were compiled in a book by Major General Brahma Sumsher J. B. Rana, which was published in the Nepali language in Nepal in 1934 and a second edition was printed in 1935 (Rana, 1935). Differences in building construction between India and Nepal and the different causes of damage, which include not only shaking of the ground but also slumping and landsliding, make it difficult to compare intensities in India and Nepal. Nevertheless, the extensive destruction in eastern Nepal in the mountainous areas of the Lesser Himalaya support the inference that the rupture zone, and therefore the epicenter, lay beneath the Himalaya, and not just south of the range, if there at all. In fact, the relocated epicenter of the earthquake calculated by Chen and Molnar (1977) lies within the area of Nepal where damage was most severe (Figure 1). Thus we think that the 1934 Bihar-Nepal earthquake probably occurred beneath the

Himalaya, and that the nature and extent of faulting associated with it probably are typical of great earthquakes in the Himalay.

In this paper, we first summarize briefly the evidence given by Dunn et al. (1939) for destruction in India. Then we recompile the extensive information given by Rana (1935) for Nepal, when possible comparing and augmenting is with auden's descriptions of the same areas. With this information, we discuss the probable extent and orientation of the rupture.

DAMAGE AND INTENSITIES IN INDIA, ACCORDING TO DUNN ET AL. (1939)

From what Dunn and his colleagues saw, damage was most severe in two parallel belts in the plains of India and in the Kathmandu Valley (Figure 1). The zones of highest intensity, IX and X on the Rossi-Forel scale, were in no way concentric, and one one of the principal features of the distribution of damage, and therefore of the inferred intensity distribution, was the existence of numerous cases of "rapid and often inexplicable changes in intensity throughout even the area of maximum damage" (Dunn et al., 1939, p. 8 an 14). Not surprisingly this variability posed a difficult problem to Dunn and his colleagues in their effort to relate the damage to faulting or to an epicenter of the earthquake.

The Slump Belt: The northern zone of high intensity lay mostly south of the border with Nepal and parallel to it. Throughout this area there was very extensive slumping, tilting, fissuring, and sinking of the ground, and much of the damage there was due primarily to slumping; "not a house of any weight within this area escaped tilting and sinking and few were inhabitable" (Dunn et al., 1939, p. 17). "Fissuring of the ground in this belt was severe an emission of sand reached its maximum, covering the floors of houses, streets and drains in towns, and covering the countryside with thick mantles of sand. Wells were choked with sand almost to the brim" (Dunn et al., 1939, p. 17). Finally, "of nearly 900 miles (1500 km) of line belonging to the Bengal and North Western Railway traversing North Biha, scarcely one mile of track was undisturbed. Embankments subsided, the track was distorted and every bridge was damaged" (Dunn et al., 1939, p. 20, see also p. 31 and p. 197-209). No clear surface faults, however, were reported.

For several reasons we think the slumping, fissuring, and tilting of the ground was a surficial phenomenon and not due to faulting in the underlying bedrock. First, had there been faulting, surely the strike of the fault would have been roughly easterly, and the style of faulting would have been either thrust, as it is for most earthquakes in the Himalaya (eg. Baranowski et al., 1984; Chandra, 1978; Fitch, 1970; Ni and Barazangi, 1984; Rastogi, 1974), or normal, as was found for one earthquake beneath the plains of India (eg. Chandra, 1978; Molnar et al., 1973, 1977). We expect that fissures caused by such faulting with an easterly trend would also trend easterly. The orientations of fissures, however, "rarely showed any constancy in direction," (Dunn et al., 1939, p.32) and clearly do not show a tendency for an east-west alignment (Table 1), unless the orientations that were reported are a biased sample. In fact, those reported by Ghosh in Dunn et al. (1939), all of which are listed in Table 1, seem to show a preponderance of northerly orientations. Note, however, that orientations were given for only a small fraction of the fissures mentioned, which were so ubiquitous in the slump belt.

A second reason for our not thinking that the slump belt is underlain by a fault or faults that ruptured through bedrock during the earthquake is Dunn et al.'s (1939, p. 32) deduction that the sand emitted from fissures and vents emanated from shallow depths of only a few meters. Oldham (1899) and his deputies had drawn the same conclusion for the majority of fissures and vents in Assam and Bengal following the 1897 Assam earthquake. Thus although the shallowness of the fissures does not show that faulting did not occur beneath them, the absence of a connection between the fissures and underlying faults removes the need for attributing the cause of one to the existence of the other.

Finally, as Oldham (1899) inferred for the 1897 earthquake, the damage to railroad tracks in north Bihar showed no characteristic patterns that could be used to infer a regional strain field. The damage instead reflected the apparently randomly oriented slumping and tilting that characterized the deformation throughout the slump belt.

Monghyr-Patna: High intensities of IX-X on the Rossi-Forel scale were reported from four cities that define a second east-west belt along the Ganga river between Monghyr and Patna (Figure 1). Monghyr "was the worst affected town in Bihar, and here the devastation was most spectacular as far as the collapse of buildings was concerned" (Dunn et al., 1939, p. 18). It lies at the southern edge of the Indo-Gangetic plains, and beneath part of the city Archaean rocks crop out. "As a rule buildings on rock outcrops were damaged less than those on alluvium" (Dunn et al., 1939, p. 18), but by no means did all of those built on bedrock escape damage. "The entire town was reduced to ruins, scarcely a house or hut escaped destruction or damage" (Dunn et al., 1939, p. 216). Moreover, "the damage done to buildings in Monghyr was entirely due to the severe shaking which the towns received; neither fissures nor slumping of the ground were noticeable except near the edge of the river on the north" (Dunn et al., 1939, p. 18). No surface faulting was reported. One possible explanation for the high intensities is that the amplitudes of seismic waves propagating southwards in the sediment and sedimentary rocks of the Ganga basin increased as the thickness of these sedimentary layers decreased, much as amplitudes of water waves increase as they approach the shore.

A very narrow zone of high intensity (IX) extended west of Monghyr along the Ganga River, through the cities of Barh and Patna and slightly east of Monghyr (Figure 1). "In Patna the worst damage took place along the river front," and "similarly, at Barh the effects of the earthquake were more pronounced approaching the river" (Dunn et al., 1939, p. 20) Although Dunn et al. (1939) made no statement about the existence or absence of fissures or slumps near the river in Patna and Barh, their presence near the river in Monghyr sugests to us that the damage in Patna and Barh might have been enhanced to slumping, fissuring, and tilting.

The region assigned an intensity of I - VIII in India: Dunn et al. (1939) considered this region to be quite well defined; within it "practically every brick building bore some stamp of the earthquake" (Dunn et al., 1939, p. 22). Moreover, "fissures and sand vents occurred sporadically within the area enclosed by isoseismal VIII which lies north of the Ganges, but were considerably less in importance than within the higher isoseismals" (Dunn et al., 1939, p. 22). Gosh (Dunn et al., 1939, p. 262-263) also reported fissures, sand vents, and associated subsidence southwest of Patna, at Bikram (25° 27′ ;84° 51′), and southwest of Monghyr at Luckeeserai (25° 12′ ;86° 06′); damage associated with this disruption of the surface apparently defines the southern lobe of the I-VIII isoseismal (Figure 1). Otherwise the shaking within the region enclosed by this isoseismal probably was relatively uniform; the greater destruction in localized areas within this area apparently was due, in most cases, to fissuring, slumping and tilting of the ground.

The I - VIII isoseismal extended east to include Darjeeling and the region surrounding it, but not to Kalimpong, roughly 20 km. east of Darjeeling (Figure 1). "In Darjeeling several houses totally collapsed. Other were damaged by the crashing of hevy masonry chimneys through roofs and upper floors" (Dunn et al., 1939. p. 23). The destruction of many buildings, however, "could be ascribed to age, weak construction and poor foundations" (Dunn et al., 1939, p. 259). " In the area of maximum damage, even in the midst of fallen houses, ferro-concrete structures stood almost unharmed, as also did well-constructed recent buildings of brick or dressed stone" (Dunn et al., 1939 p. 260). Thus, damage, although significant, was less than that throughout the Shillong plateau during the 1897 Assam earthquake (Molnar, 1987; Oldham, 1899) or in Dharamsala, Kangra and neighboring towns during the 1905 Kangra earthquake (Middlemiss, 1910; Molnar, 1986). Moreover, as we describe below, it was less than that in many districts of Nepal to the west of Darjeeling.

In this respect, it is noteworthy that Kalimpong clearly lay outside of the I - VIII isoseismal. "No loss of life or property was reported at Kalimpong" (Dunn et al., 1939, p. 271). This statement is contradicted somewhat by another: "Many walls were slightly cracked and few badly damaged" (Dunn et al, 1939, P.287) but clearly the intensity decreased markedly east of Darjeeling.

Summary: The impression that we gain from both the distribution and the various causes of damage is that if faults ruptured bedrock in northern India, then the locations of such faults are not revealed clearly by the distribution of intensity. Much of the destruction was due to fissuring, slumping, and tilting of the ground. The rest was due to shaking, but the lack of a central area in which the shaking was demonstrably stronger than elsewhere suggests that the waves did not originate within the plains of India.

The only possible exception to this is near Monghyr, beneath which faulting might have occurred. From the tectonic setting of Monghyr, such faults probably would have been normal faults (eg. Molnar et al., 1973, 1977). Even if such faulting did occur there, however, it probably was not the faulting that generated the waves that caused extensive damage to distant regions, such as Kathmandu or the rest of Nepal. Such normal faulting would be analogous with that occurred beneath the Aleutian Trench in association with aftershocks following the 1965 Rat Islands Earthquake of 1965 (Stauder, 1968). The mainshock was associated with oblique underthrusting of the Pacific Ocean floor beneath the Aleutian Islands, some 100-200 km north of the aftershocks showing normal faulting.

The moderate damage to Darjeeling and the virtual lack of it in Kalimpond implies that the epicentral area definitely lay west of Kalimpong, and quite possibly west of Darjeeling. The edge of the rupture zone, alternatively, may have lain between Darjeeling and Kalimpong.

MACROSEISMIC EFFECTS OF THE EARTHQUAKE IN NEPAL

Although J.B. Auden visited the Kathmandu area and made two other trips into other parts of Nepal, there are vast areas that he did not visit. In particular, it appears that he did not visit most of the areas where destruction appears to have been greatest. Since Rana (1935) did summarize the damage in most of the areas that Auden visited, however, we can make some intercalibration of their observations.

Kathmandu Valley: The destruction in the Kathmandu Valley was particularly great. On the basis of Auden's reports an intensity I - X was assigned to parts of the valley, and I - IX to the rest. Auden (Dunn et al., 1939, p. 388) stated that in 1920 there were 66,440 houses in the Kathmandu Valley; 12,397 (or nearly 19%) were completely destroyed by the earthquake, and 25,658 (38%) were badly fractured (see Rana [1935, p. 105] and Table 2).

The destruction was most complete at Bhaktapur (Figure 2) and neighboring villages in the eastern part of the valley. This is reflected in part by the ratio of the number of houses "totally destroyed" to the number of those "much fractured" (Table 3), a ratio that is greater than one only in Bhaktapur, among the subdivisions of the Kathmandu Valley listed by Rana (1935). Most, but not all, of the temples in Bhaktapur were destroyed completely of severely damaged (Table 4). Rana (1935, p. 186) reported that the damage in the Kathmandu Valley associated with a major earthquake in 1833, although definitely less than the amount associated with the 1934 earthquake, was also a maximum in and near Bhaktapur. Thus, the greater damage there than to surrounding areas probably is a result of local amplification of ground motion due to local conditions.

"Isoseismal IX follows very approximately the boundary between hard rock and the alluvial sands, gravels and clays" (Dunn et al., 1939, p. 389). Auden estimated that 25% of the houses in the towns of Kathmandu and Patan (Figure 2) collapsed (Dunn et al., 1939, p. 390-391), but the statistics reported by Rana (1935) suggest that a smaller fraction were completely destroyed (see Table 3). Perhaps, when Auden visited Kathmandu, many of the "much fractured" houses had been torn down, leaving the impression of greater collapse than had occurred. Buildings built on bedrock, however, survived better than those on young sediment, and in particular the three temples Boudhnath, Pashupatinath, and Swayambunath "escaped severse damage" (Dunn et al., 1939, p. 391). Since "subsidence of the ground, and tilting and slumping of the houses were entirely absent" (Dunn et al., 1939, p. 19), the greater destruction of buildings built on unconsolidated sediment was almost surely due to amplification of the ground motion in the sediment-filled Kathmandu basin.

The variation in destruction in and near the Kathmandu Valley and, in particular, the lack of severe damage to structures built on bedrock may indicate that Kathmandu, like Darjeeling, may not have been in the epicentral area of the earthqauke.

The area west and north of the Kathmandu Valley (Figure 2): Auden (Dunn et al., 1939, p. 386) included a small area northwest of Kathmandu within the isoseismal I - VIII, but he did not visit the village where destruction seemed to be most severe 'Syabru (25°08" , 85°20"), and he excluded it from that isoseismal. In other towns-Nawakot (27° 55', 85° 10'), Trisuli Bazar (27° 56', 85° 08'), and Betrawati (27° 59',°85°11')--damage was confined to large and small cracks, except for one village built on an alluvial terrace. Dunn et al. (1939, p. 387) assigned intensities of VII or less to these regions and to those west to Kathmandu.

These assignments seem justified in light of what Rana (1935) reported. First note that there were many fewer casualties (Table 2) and many fewer houses damaged (Table 3) west of Kathmandu than east of it.

In the district West No 1 (Figure 3), the temple of Nawakot Bhairabnath was "fractured al around" and the upper floors were tilted (Rana, 1935, p. 78). The northern portion of the guesthouse of the temple of Sri Bharaibi was destroyed; the roof settled on both sides. The Temple of Burhi Devi also tilted. The uppermost floor of the only 7-storey house collapsed, and the lower 2 or 3 floors were cracked. These reports suggest more damage than that reported by Auden in Dunn et al., (1939), but not so much as to suggest that Nawakot lay as close to the epicenter of the earthquake as the areas east of Kathmandu.

In Gurkha in the district West No 2, the upper palace with the Temple of Sri Kalika Devi was damaged. The northern slope of the roof, 30 hat (about 15 m) in length and 3 hat (about 1.5 m) in breadth, and which supports the cupola of the temple, collapsed. Just west of this, a roof 3 hat (about 1.5m) by 14 hat (about 7 m) also collapsed. Pillars cracked, as did a large stone over a cave. Cracks in the pavement of the palace were opened to a "width of two fingers" (Rana, 1935, p. 79). In the lower palace, a roof of length 20 hat (about 10 m) collapsed on the west side, and the southern portion of the wall was cracked. This damage clearly was less than that in the Kathmandu Valley.

In the district West No 3, the earthquake "sounded like a motor" (Rana, 1935, p. 79). In the Kaski subdistrict there were some landslides. One house was destroyed in Pokhara, but there were no casualties of people or animals there. In Bandipur 50 to 60 houses cracked and 10 or 11 collapsed, but there were no casualties, The government houses were among those cracked (Rana, 1935, p. 80).

In the district West No 4 (Figure 3), there was only rare damage to houses.

In Chisapani Gadhi (Figures 1 and 3), a government house, the Temple of Batuka Bhairaba, a storehouse, the new buildings of the Gadhi, and the custom office building were all destroyed. In Bhimphedi, Simaltar, Markhu, Chitlang, Kulekhani, Tistung and Palaung (Figure 3), houses were destroyed (see Table 3), there were landslides, and there were fissures and cracks in the roads (Rana, 1935). The much larger number of casualties in this area than in the others west of Kathmandu (Table 2) suggests that destruction should also have been greater, an inference, however, that seems contradicted by the number of houses destroyed or heavily damaged (Table 3). Nevertheless, Dunn et al. (1939) assigned an intensity VIII to part of this area; Auden traversed it enroute to Kathmandu. Thus if this area lay in the epicentral area where shaking was most intense, it probably lay near the western boundary of that area. The abrupt decrease in destruction to west makes its position analogous with that of Darjeeling near the east end of the epicentral zone.

The area east of Kathmandu: Nearly half of the people in Nepal killed by the earthquake (Table 3) and most of the houses "completely destroyed" or "much fractured" (Table 4) were from the mountainous area east of Kathmandu. Particularly noteworthy is the ratio of the numbers of houses "completely destroyed" to those "much fractured"; this ratio is greater than one in the districts East No 3, East No 4, and Sindhuli Gadhi. Auden, however, visited only the southern and eastern parts of eastern Nepal, and apparently his route did not take him into these three districts of greatest devastation. Consequently Dunn et al. (1939) did not assign most of the area a high intensity, of I - IX, and did not include this area in the epicentral region of the mainshock. In fact, the recalculated epicenter of Chan and Molnar (1977) lies within the district East No 4 (Figure 3), and we infer that the epicentral region underlay much of the mountainous region east of Kathmandu.

In the district East No 1 (Figure 3), up to the border with Tibet, all government buildings were destroyed, including storehouses, barracks, and a powder magazine (Rana, 1935, p. 75) Many private houses were fractured, and some collapsed. In Kodari, the millet granary was destroyed (Rana, 1935, p. 80), and 6 or 7 people died. The exact number in not known. In Tatopani, the storehouse for salt was destroyed. All 113 houses of Palchok and all houses of Tauthalikot were destroyed. Finally, there were many landslides in this district.

In the district East No 2, the government storehouse, the governor's house, the post office, the government employees' houses, barracks, a granary, and many private houses were among those listed as completely destroyed (Rana, 1939, p. 76). In Rasuwa Gadhi, some houses were destroyed by rockslides and landslides, but others were destroyed by snaking. In particualr, government houses, chauki (check posts), salt storehouses, and millet storehouses were destroyed. Many people were wounded (Rana, 1935, P. 81).

For the district East No 3, Rana (1935, p. 76) used the phrase "reduced to a hell" frequently. We infer this to mean complete destruction. He describes private houses, a granary, a government storehouse as well as all of the houses of villages and settlements with this expression, Moreover, two or three famous gumbas (gompas) were destroyed and many archives were lost in the northern mountain districts (Rana, 1935, p. 119). The most famous of these was in Namche Bazar.

In the district East No 4 (Figure 3), the destruction seems to have been most complete. The market in Bhojpur was 'reduced to a hell" (Rana, 1935, p. 73), and the first task for a soldier on leave in Bhojpur was to disinter the numerous people and corpses in the debris (Rana, 1935, p. 70). Among the other buildings specifically described as having been destroyed were a district courthouse, a granary, and private houses. In addition new springs were reported (Rana, 1935, p. 76), which suggests that there was some permanent deformation of the ground. (Rana 1935), p. 73) also reported numerous landslides; "the green mountains became white." For 20 to 25 minutes after the earthquake, visibility was lost in the dust." Finally, people reported hearing sounds from the north just before the mainshock and often throughout the following day. "A panic was created among the people by frequent loud sounds from the north, which continued into the night of 3 Magh", the second night after the earthquake (Rana, 1935, p. 77). This could have been due to landslides or aftershocks. Althought this type of information cannot usually be used to determine reliably the direction of the source, it is more consistent with the epicenter lying in the hilly terrain than with it beneath the plains of India.

Auden did not visit the district East No 4, or those between it and Kathmandu.

Rana noted that the destruction of a granary in Dharan, landslides, fissures, new springs, and more water in the rivers. He also stated that among government buildings only the powder magazine was less damaged than the others (Rana, 1935, p. 77). Auden traversed this area, and he noted that the damage to Dharan Bazar (26° 49′ , 87° 17′), "was very severe...and in every house one of or more walls had fallen" (Dunn et al., 1939, p. 384). "Several walls of the Pindeswari temple, and the outer walls of the Bijapur temple were badly damaged." He noted, however, that: "The houses in Dharan Bazar are beadly constructed, having a core of undressed rounded boulders, taken from the river, faced on both sides by bricks set in mud binding." Auden also corroborated the occurrence of landslides (Dunn et al., 1939, p. 385). He included these areas within the I - IX issoseismal.

Auden described the damage in the town of Dhankuta as "very uneven. The hospital and male and female jails collapsed completely, while the kutchery and Bara Hakim's quarters, which are higher up on the ridge, were cracked so severely as to necessitate demolition. In contrast to this damage, the main part of the bazar was practically unaffected, except for minor cracks" (Dunn et al., 1939, p. 386). Rana's description (1935, p. 175) is nearly identical. Dhankuta was assigned an intensity I - VIII, which accords with the milder terms used by Rana for this district than for East No 3 or East No 4.

Rana avoided the phrase "reduced to a hell" in his appraisal of the damage in the district East No 6, or Chainpur (Figure 3) and stated that damage was less than at Dhankuta (Rana, 1935, p. 175). He lists temples, houses, the post office, and the court house as destroyed, and he notes that roof tiles on the prison fel and hurt many prisoners, but the general impression that he gives is one of less destruction than in areas farther west.

Auden described the damage in the village of Chainpur (27°17′ ,87° 20′) as "very slight. Two houses fell while some others were cracked, but the majority of buildings and the temples escaped completely (Dunn et al., 1939, p. 396). A few kilometers northeast "at Nundhaki (27° 19°, 87° 28°) there was little damage to the village itself, but numerous landslides were noticed in the neighborhood." Nevertheless he included these towns within the I - VII isoseismal. Thus this area may have lain outside of the epicentral zone, but if it did, probably it was not far from that zone.

In Taplejung (27° 21′, 87° 40′), in northeastern Nepal, only the jail was damaged. Some houses in the market area were slightly cracked, but no significant losses were incurred (Rana, 1935, p. 175). Moreover, landslides apparently did not occur. The factual part of Auden's report was virtually identical to Rana's; Auden stated (Dunn et al., 1939, p. 386-387): "Reports which reached Kathmandu suggested that the town [of Taplejung] had been wiped out...The only building which suffered severe damage was the jail...Taken as a whole the damage was slight." He also noted that "at Dumahan(27° 22′ ,87° 37′) a few of the houses were cracked but the damage was slight" (Dunn et al., 1939, p. 386). Thus damage in the northeast corner of Nepal was notably less than that farther west, in districts East No 3 and No 4.

Rana's (1935, p. 77) description of damage to Ilam (the easternmost district of Nepal) was brief. He noted the collapse of some government houses and offices and some private houses, but the numbers of houses destroyed and fractured are less than those for areas farther west. Moreover, the small number of casualties in Ilam (Table 2) accords with the general impression of decreassing destruction eastward. He did state, however, that news of damage in Darjeeling suggested that there was more damage there than in Ilam. Both areas were included within the I - VIII isoseismal given by Dunn et al. (1939), and clearly the areas to the west of Ilam would have been assigned greater intensities had Dunn et al. (1939) known of the destruction there.

Udaipur suffered serious damage (Rana, 1935, p. 175). Auden reported "almost complete collapse" of buildings in the village of Udaipur (26° 59′ 86° 32′) Dunn et al., 1939, p. 385), and much less damage in Risku (26° 58′ ,86° 26′), a small village to the west (Dunn et al., 1939 p. 384). Auden did not visit villages farther north (in the districts East No 3 and No 4), but he was informed that many were totally destroyed.

Damage in Sindhuli seems to have been greater than in Dhankuta and East No 6; Rana (1935, p. 78) stated that all stone houses were damaged. The governor's house collapsed causing one death and one injury. Some other government houses were destroyed, and some were "tilted". The greater number of houses "completely destroyed" than "much fractured" (Table 4) suggests a high itensity.

It appears that Auden did not visit the areas where destruction seems to have been greatest. Nevertheless, the assignments of Intensities of I - VIII and IX to the areas in eastern Nepal visited by Auden and the clearly greater devastation in districts west of there, which Auden did not visit, makes it almost certain that all of East No 3 and East No 4 would have been assigned intensities of at least IX and probably X. Probably much of the districts East No 1, East No 2 and Sindhuli would also have been assigned intensities of I - IX, possibly X.

The Terai: Rana (1935, p. 85) reported that the devastation was apparent from the eastern border of Nepal to Chitwan. Both destruction and loss of life were greater in towns than in smaller villages, because in the latter houses were built of bamboo and covered with thatched roofs. There were fissures virtually everywhere, sometimes as wide as 3 to 4 yards (or meters) and as deep as 2-3 bamboos (20-30m). Some fields were covered with sand, and water seeped from many fissures. The railway from Amalekhganj to Raxaul (Figures 1 and 3) was disrupted at many places. Thus the description is similar to that of Dunn et al. (1939) for north Bihar, and to those of Auden, for the parts of the Terai that he visited. Dunn et al. (1939) included most of the terai between the eastern border of Nepal and the longitude of Raxaul within the I - IX isoseismal (Figure 1).

In Birgunj, large solid houses made of baked bricks and probably with lime mortar were destroyed. Those included government offices, the governor's house and the Muralidarbar (Rana, 1935, p. 86-87). The destruction of private and government buildings amounted to Rs. 300,000 to 400,000. The numberous fissures and cracks and the seepage of water from that was responsible for disrupting the railroad and probably for much of the destruction of buildings. Auden traversed this area and made similar observations. He also noted that both destruction and the occurrence of fissures were less in the northern area, near Amalekhganj than farther south. He assigned Amalekhganj an intensity of only I - VII and the town of Birgunj I-VIII (Figure 1).

In Mahotari, Rana reported a wide range of destruction (Rana, 1935, p. 88). The governor's house had some fractures, but the house of the assistant subha (officer) collapsed to the foundation. In Dhanukha the temples of Sri Ram Chandra and of Janaki did not suffer at all, but the residential quarters of the Mahantas (priests) also collapsed to their foundations. Some brick houses and the jail were also destroyd. Auden did not visit this area.

Both Rana and Auden were in agreement that the worst damage in the Terai occured in the Siraha-Saptari district. In Jaleswar and Hanumannagar all solid houses, of baked brick construction, were destroyed (Rana, p. 85). On the basis of reports that he heard, Auden assigned Jaleswar an intensity I - X, noting that "houses had slumped extensively into the ground" (Dunn et al., 1939, p. 383). He did not visit Hanumannagar either (Figure 1), but both his and Rana's (1935, p. 175) descriptions of damage to the town of Siraha were similar to those for these other towns; sand vents were prevalent, kutchapucca (in this context, baked brick) houses "all collapsed, ... but the mudplastered bamboo huts suffered little damage." From the descriptions, it is not clear why Jaleswar was assigned I - X, and Siraha and Hanumannagar only I - IX.

Auden also noted that "sanding, fissures and slight faults in the alluvium occurred sporadically as far as the Siwalik hills, but were not common beyond Nipania (26° 48', 86° 21')", and that "the only damage at Nipania was the occurrence of cracks in the **Kutcha-Pucca** houses" (Dunn et al., 1939, p. 383)). Throughout this area it appears that the degree of damage correlates with the extent of fissuring and slumping and, therefore, is not a measure, of shaking of the ground.

In Biratnagar, the governor's house was damaged and six people were wounded. Cracks formed in the jail, and one or two people were wounded, but the prisoners did not suffer. The houses of the forest officer, the revenue officer, the assistant auditor, and the overseer, however, were rendered useless by numerous cracks in the walls (Rana, 1935, p. 88). A granary suffered a similar fate, but Rana (1935, p. 175-176) noted that, as elsewhere, granaries with wood (Dunn et al., 1939, p. 383) girders and with galvanized iron roofs were not destroyed. Auden corroborated this (Dunn et al., 1939, p. 383): "Most of the houses, built of wood with corrugated iron roofs, escaped severe damage, some being quite unaffected. The new granaries built of steel girders with corrugated iron roofs and sides were also quite undamaged." Auden noted that "sand vents and fissures were rare around Biratnagar, but became worse" farther north (Dunn et al., 1939, p, 383). Finally both Auden and Rana made a point of noting that buildings of different construction underwent different degrees of damage.

In Jhapa (Figure 3), there were no brick or adobe houses, and brobably it is largely for this reason that there were no casualties (Rana, 1935, p. 89). There was, however, exterior fissuring with widths of some cracks reaching 1.5 to 2 hat (nearly 1m). As elsewhere, buildings supported by wooden pillars, even with galvanized iron roofs, survived with little damage.

Finally in Butwal there were no losses.

Summary

First, note that although Auden did not see many of the areas described by Rana, where they both did offer discriptions, such as for Tapelejung, Biratnagar, Chainpur, Dharan and Dhankuta, these descriptions agreed with one another. This agreement cannot reflect the repeating of information from the same source; Rana's book was published in Nepal long before Dunn et al.,'s (1939) memoir was published, but not much before Auden wrote his sections of that report, in 1935 and 1936 (J. B. Auden, personal communication, 1986). The reference to but one official memorandum of the Nepalese government (Dunn et al., 1939, p. 382) implies that Dunn and his colleagues were unfamiliar with Rana's book. Thus, where Rana and Auden made observations, they did so independently and they agreed. Yet, Rana's observations leave little doubt that the area where destruction both was greatest and was not due to slumping, fissuring, or tilting was precisely the interior mountainous region of eastern Nepal that Auden did not visit.

From the information given by Rana, the greatest destruction was in the mountain districts of East No 3, East No 4 and western Dhankuta, Sindhuli Gadhi, and Udaipur Gadhi. Damage was distinctly less in areas to the east, such as in northeastern Nepal, in Ilam and farther east in Darjeeling, and it decreased abruptly east of Darjeeling. Similarly damage in the districts west of Kathmandu was slight, decreasing abruptly west of Chisapani Gadhi. Although there was considerable damage in parts of the Terai, as in northern India to the south, much of this damage can be ascribed to slumping, fissuring and tilting of the ground.

CONCLUSIONS

We conclude that the fault that ruptured underlay the Lesser Himalaya and not the plains of northern India.

The destruction in the plains can be largely ascribed to slumping, fissuring, and tilting of the ground; there is no obvious evidence of strong ground motion, except in Monghyr. Extensive damage in Monghyr was caused not only by the 1934 earthquake, but also by the 1833 earthquake, which caused extensive damage in Kathmandu (Dunn et al., 1939, p. 116-117), and by several other events. Baird Smith (1843, p. 1039) wrote: "It is a remarkable fact, that Monghyr seems to suffer more from Earthquake shocks, from whatever direction these may come, than any other place in its vicinity." Thus the shaking in Monhyr was probably not a reflection of its proximity to the epicenter of the 1934 earthquake or to a fault that ruptured during that earthquake, but rather to local site conditions. If a fault that ruptured in the 1934 earthquake did lie beneath the plains of northern India, its location is not defined clearly by the distribution of damage and, in particular, by surface faulting or strong ground motion.

In contrast, the damage in Nepal clearly was due to shaking, and from Rana's reports that damage was comparable or greater than in northern India. The concentration of that damage in areas not visited by Auden explains why Dunn et al., (1939) did not recognize it. Because seismicity is common in the Lesser Himalaya, with fault plane solutions of moderate earthquakes showing underthrusting of India beneath the Himalaya (Baranowski et al., 1984: Chandra, 1978; Molnar et al, 1973, 1977; Ni and Barazangi, 1984: Rastogi, 1974), we presume that slip of that type occurred in 1934. The agreement of Chen and Molnar's (1977) relocated epicenter with the zone of highest intensity concurs with this view.

The dimensions of the rupture are difficult to constrain tightly. Probably the north-south dimension is about 100km, the approximate width of the zone of high intensity in the Himalaya and the distance of moderate earthquakes from the front of the range. The sparsity of inhabitation in the greater Himalaya, however, makes determining the northern edge of high intensities difficult, and accordingly the northern edge of the rupture is not well-defined. The most intense shaking, not due to local soil conditions, was in the districts East No 3, East No 4 and their surroundings. The east-west dimension of this area is about 100km. If this high intensity reflects a close proximity to the fault that slipped, the east-west length of the fault must be at least 100km. The high intensities of I - IX and X, however, might be due in part to localized conditions, as it clearly was in Bhaktapur or in Monghyr, and the rupture zone might be large than that defined by the highest intensities in east-central Nepal. Instead the abrupt decrease in intensity east of Darjeeling and west of Kathmandu and Chisapani might define the boundaries of the rupture alone. In that case the east-west dimension would be about 300 km.

Thus for the purpose of evaluating earthquake hazards, it probably would be sensible to assume dimension of 200 ± 100 km. Perhaps in the absence of tight constraints on recurrence intervals for such earthquakes and for the purpose of evaluating the specific hazards for eastern Nepal, it would be safest to assume the small end of this range (100 km), even if an earthquake with a magnitude of 8.4 is unlikely to be associated with a rupture with a length of only 100 km. Clearly when viewed in the context of the slip rate between India and the Himalaya, however, we lack evidence to decide whether a zone 300 km or 100 km in length ruptured.

ACKNOWLEDGEMENTS

A travel grant from the National Science Foundation of the U. S., permitting one of us (P. M.) to attend a conference in India on Neotectonics in south Asia, made it possible for us to collaborate on this study. Additional support was provided by the National Aeronautical and Space Administration of the U. S. through Grant MAG5-795.

REFERENCES

Baird Smith, R., Memoir on India earthquakes. Part II. Historical summary of Indian earthquakes with some remarks on the general distribution of subterranean disturbing forces throughout India and its frontier countries, **J. Asiatic Soc. of Bengal. 12,** 1029-1056, 1843.

Baranowski, J., j. Armbruster, L. Seeber and P. Molnar, Focal depths, and fault plane solutions of earthquakes and active tectonics of the Himalaya, **J. Geophys. Res., 89,** 6918-6928, 1884.

Binni and Partners, Geology of of the Kathmandu Valley, (Map and Report), World Health Organization Proj. Nepal 0025, appendix 4.4 March 1973.

Chandra, U., Seismicity, earthquake mechanisms and tectonics along the Himalayan mountain range and vicinity, **Phys. Earth Planet. Int., 16,** 109-131, 1978.

Chen, W,-P. and P. Molnar, Seismic moments of major earthquakes and the average rate of slip in Central Asia, **Geophys., Res., 82,**2945-2969, 1977.

Dunn, J.A., J.B. Auden, A.M.N. Ghosh, and D.N. Wadia, The Bihar-Nepal Earthquake of 1934, Geol. Sury. India Mem 73, 1939.

Fitch, T.J., Earthquake mechanisms in the Himalayan, Burmese, and Andaman regions and continental tectonics in central Asia, **J. Geophys. Res, 75** 2699-2709, 1970.

Khattri, K. and A.K. Tyagi, Seismicity patterns in the Himalayan plate boundary and identification of the areas of high seismic potential,**Tectonopysics, 96,** 281-297, 1983.

Lyon-Caen, H. and P. Molnar, Constraint on the structure of the Himalaya from an analysis of gravity anomalies and a flexural model of the lithosphere, **J.Geophys. Res., 88,** 8171-8191, 1983.

Lyon-Caen, H. and P. Molnar, Gravity anomalies, flexure of the Indian plate, and the structure, support, and evolution of the Himalaya and the Ganga basin, **Tectonics, 4,** 513-538, 1985.

Middlemiss, C. S., the Kangar Earthquake of 4th April, 1905, Mem. Geol. Surv. India, Vol. 37, Geol. Surv. India, Calcutta, 1910 (reprinted 1981).

Molnar, P., The distribution of intensity associated with the 1905 Kangra earthquake and bounds on the extent of the rupture zone, **J. Geol. Soc. Ind.** (In press) 1987a.

Molnar, P., The distribution of intensity associated with the 1899 Assam earthquake and bounds on the extent of rupture zone, **J. Geol. Soc. Ind.** (submitted August 1986). 1987b.

Molnar, P., T. J. Fithch, and F. T. Wu, Fault plane solutions of shallow earthquakes and contemporary tectonics in Asia, **Earth Planet. Sci Lett., 16,** 101-112, 1973.

Molnar, P., W.P. Chen, T.J. Fitch, P. Tapponnier, W.E.K. Warsi, and F.T. Wu, Structure and tectonics of the Himalaya: A brief sumary of relevant geophysical observations, **Himalaya: Sciences de la Terre, Colloques Internationaux du CNRS, No . 268,** Centre National de la Recherche scientifique, Paris, 269-294, 1977.

Ni, J. and M. Barazangi, Seismotectonics of the Himalayan collision zone; Geometry of the underthrusting Indian plate beneath the Himalaya, **J.Geophys, Res., 89,** 1147-1163, 1984.

Oldham, R.D., Report on the Great Earthquake of 12th June 1897. Mem. Geol Surv. India, Vol. 29, Geol. Surv. India, Calcutta, 1899 (reprinted 1981).

Rana, Maj. Gen. Braham Sumsher J.B., Nepalko Bhukampa, (The Great Earthquake of Nepal),Published by the author in Kathmandu, second ed., 1935.

Rastogi, B.K., Earthquake mechanisms and plate tectonics in the Himalayan region, **Tectonophysics, 21,** 47-56, 1974.

Richter, C.F., Elementary Seismology, W. H. Freeman, San Francisco, 1958.

Seeber, L. and J. Armbruster, Great detachment earhtquakes along the Himalayan arc long-term forecasts, Earthquake Prediction: An International Review, Maurice Ewing Series 4, ed. by D.W. Simpson and P.G. Richards, Amer. Geophys. Un., Washington, D. C., 259-277, 1981.

Seeber, L., J. Armbruster, and R. Quittmeyer, Seismicity and continental collision in the Himalayan arc, in **Zagros, Hindu-Kush, Himalaya. Geodynamic Evolution, Geodyn. Ser.,** Vol. 3, Amer. Geophys. Un., Washington, D.C., 251-242, 1981.

Singh, D.D., and H.K. Gupta, Source dynamics of two great earthquakes of the Indian subcontinent: The Bihar-Nepal earthquake of January 15, 1934 and the Quetta earthquake of May 30, 1935, **Bull. Seismol. Soc. Amer., 70,** 757-773, 1980.

Stauder. W., Tensional character of earthquake foci beneath the Aleutian trench with relation to sea-floor spreading **J. Geophys. Res. 73.** 7693-7703, 1968.

Table 1. Orientations of fissures in the slump Belt, reported by Ghosh in Dunn et al (1939).

Location	Orientation	Page number
Sitamarhi (26° 35′, 85° 29)	N 80°E	210
	North-northwest	210
	N78° W	211
Madhubani (26° 22′ , 86° 05′)	North	213 (2 places)
Rajnagar (26° 24′ , 86° 10′)	North	214
	East	215
Notihari (26° 40′ , 84° 55′)	North	221
Muzaffarpur (26° 07′ , 85° 24′)	East	223
	West-northwest to Northwest	223
	North-northwest	223 and 224
Motipur (26° 18′ , 85° 12′)	Northwest	226
Darbhanga (26° 08′ , 85° 54′)	West-northwest	227
Sakri (26° 12′ , 86° 06′)	North	229
Pandaul (26° 15′ , 86° 04)	West-northwest	230
Pusa (25° 59′ , 85° 40′)	West-northwest to Northwest	231
	Northeast	231
	East-northeast	232
Phulparas (26° 21′ , 86° 29′)	East	234
Supaul (26° 06′ , 86° 36′)	Northeast	235
	East-northeast	235
	N10° E	235
Madhipura (25° 56′ , 86° 48′)	North-northeast	236
Purneah (25° 48′ ,87° 30′)	North	240 (2 places)
Forbesganj (26° 18′ , 87° 18′)	North	241

Table 2. Houses destroyed by the 1934 Earthquake.

Region	Completely destroyed	Much fractured	Slightly fractured	Total
Kathmandu Valley				
Kathmandu	725	3735	4146	8606
Outskirt of Kathmandu	2892	4062	4267	11221
Patan	1000	4170	3860	9030
Outskirts of Patan	3977	9442	1598	15017
Bhaktapur	2359	2263	1425	6047
Outskirts of Bhaktapur.	1444	1986	2388	5818
Totals	**12397**	**25658**	**17684**	**55739**
Eastern Mountainous Region				
East No 1	9628	19391	-	29019
East No 2	4687	10738	-	15425
East No 3	21107	15548	-	36655
East No 4	15048	5	-	15053
Dhankuta	6623	15120	-	21743
Sindhuli Gadhi	3486	3154	-	6640
Udayapur Gadhi	1052	3917	-	4969
Ilam	2316	3112	-	5428
Totals	**63947**	**70985**	**-**	**134932**
Western Mountainous Region				
West No 1	582	1720	-	2302
West No 2	186	461	-	647
West No 3	19	65	-	84
West No 4	8	1	-	9
Chisapani Gadhi	-	18	1266	1284
Palpa	-	3	-	3
Totals	**795**	**2268**	**1266**	**4329**
Terai				
Western Terai	-	4	6	10
Chitwan	-	-	-	-
Birgunj	3654	854	2546	7054
Sariati and Mahattari	-	4323	268	4591
Sirha and Saptari	87	428	-	515
Biratnagar	13	1	64	78
Jhapa	-	-	-	-
Totals	**3754**	**5610**	**2884**	**12248**
Totals for Nepal	**80893**	**104521**	**21834**	**207248**

Table 3. Casualties of the 1934 Earthquake.

Region	Men	Women	Total
Kathmandu Valley			
Kathmandu	254	225	479
Otskirts of Kathmandu	79	166	245
Patan	250	297	547
Outskirts of Patan	871	826	1697
Bhaktapur	433	739	1172
Outskirts of Bhaktapur	65	91	156
Totals for the Kathmandu Valley	**1952**	**2344**	**4296**
Eastern Mountainous Region			
East No 1	163	192	356
East No 2	52	43	95
East No 3	330	527	857
East No 4	698	899	1597
Dhankuta	162	154	316
Sindhuli Gadhi	51	58	109
Udayapur Gadhi	295	257	552
Ilam	41	51	92
Totals for the Eastern Mountainous	**1792**	**2182**	**3974**
Western Mountainous Region			
West No 1	4	6	10
West No 2	0	1	1
West No 3	0	1	1
West No 4	0	1	1
Chisapani Gadhi	25	27	52
Totals for the Western Mountainous Region	**29**	**36**	**65**
Terai			
Western Terai	0	0	0
Birgunj	16	28	44
Sariahi and Mahattari	31	20	51
Sirha and Saptari	17	23	40
Biratnagar	13	36	49
Jhapa	0	0	0
Totals for the Terai	**77**	**107**	**184**
Totals for Nepal	**3850**	**4669**	**8519**

Table 4. Damage and destruction of temples in Bhaktapur.

Name	Date of Construction	Extent of damage
Bhaktapur Old Palace	B.S. 1510 (1454 A.D.) King Yaksha Malla Restored in B.S. 1734 (1678 A.D.)	Heavily damaged
Temple of Shiva	B.S.1517 (1460 A.D.) King Yksha Mall	Completely destroyed
Temple of Bishnu	B.S. 1714)1658 A.D.) King Jagat Prakash Mall	Completely destroyed
Temple of Barahi	B.S. 1729 (1673 A.D.) Repaired in B.S.1918 (1862 A.D.)	Completely destroyed
Temple of Krishna	B.S.1732 (1676 a.d.) King Bhupendra Malla	Completely destroyed
Temple of Bhairab	B.S. 1742 (1686 A.D.) King Bhupendra Malla	Completely
Palace with 55 Windows	B.S. 1756 (1700 A.D.) King Bhupendra Mall	Heavily damaged

Table 5 . Damage and destruction of temples in Kathmandu

Name	Date of Construction	Extent of damage
Teleju Temple	B.S. 1621 (1565 A.D.) King Mahendra Malla	Only the cupula tumbled
Temple of Kathmandu Mahadev (East of Mulkot)	B.S.1621 (1565 A.D.) King Mahendra Malla	Completely Destroyed
Temple of Mahabishnu (South of Mulkot)	B.S.1694 to 1724 (1638 to 1668 A.D.)	Completely Destroyed
Stone Monument in front of Degutale	B.S.1727 (1671 A.D.) King Pratap Mall	Completely Destroyed
Stone Statue of King Pratap Malla Riding On an Elephant Situated south of Rani Pokhari	B.S.1727 (1671 A.D.) King Pratap Mall	Completely Destroyed
Basantapur	B.S.1827* (1771 A.D.) King Prithvi Narayan Shaha	Heavily Damaged

* Listed by Jangabahadur Rana (p. 115) as B.S. 1727, but this is not consistent with the name of the reigning king that he also gives.

Table 6 . Damage and destruction of temples in Kathmandu

Name	Date of Construction	Extent of damage
Mahabauddha Temple	B.S.1609 (1553 A.D.)	Only the foundation survived
Temple of Machhendra Nath	B.S. 1678 (1622 A.D.) Restored after the earthquake of B.S. 1890 (1833 A.D.)	Completely destroyed
Degutale Restored after a fire	B.S. 1692 (1636 A.D.) King Shiva Singha Malla in B.S. 1721 (1665 A.D.)	Completely destroyed
Temple of Biswesar Mahadev (Bhaideval)	B.S.1735 (1679 A.D.)	Completely destroyed
Chyasim Deval	B.S. 1780 (1724 A.D.) King Nagendra Malla	Heavily damaged
Temple of Kumbheswar	B.S. 1794 (1738 A.D.)	Completely destroyed

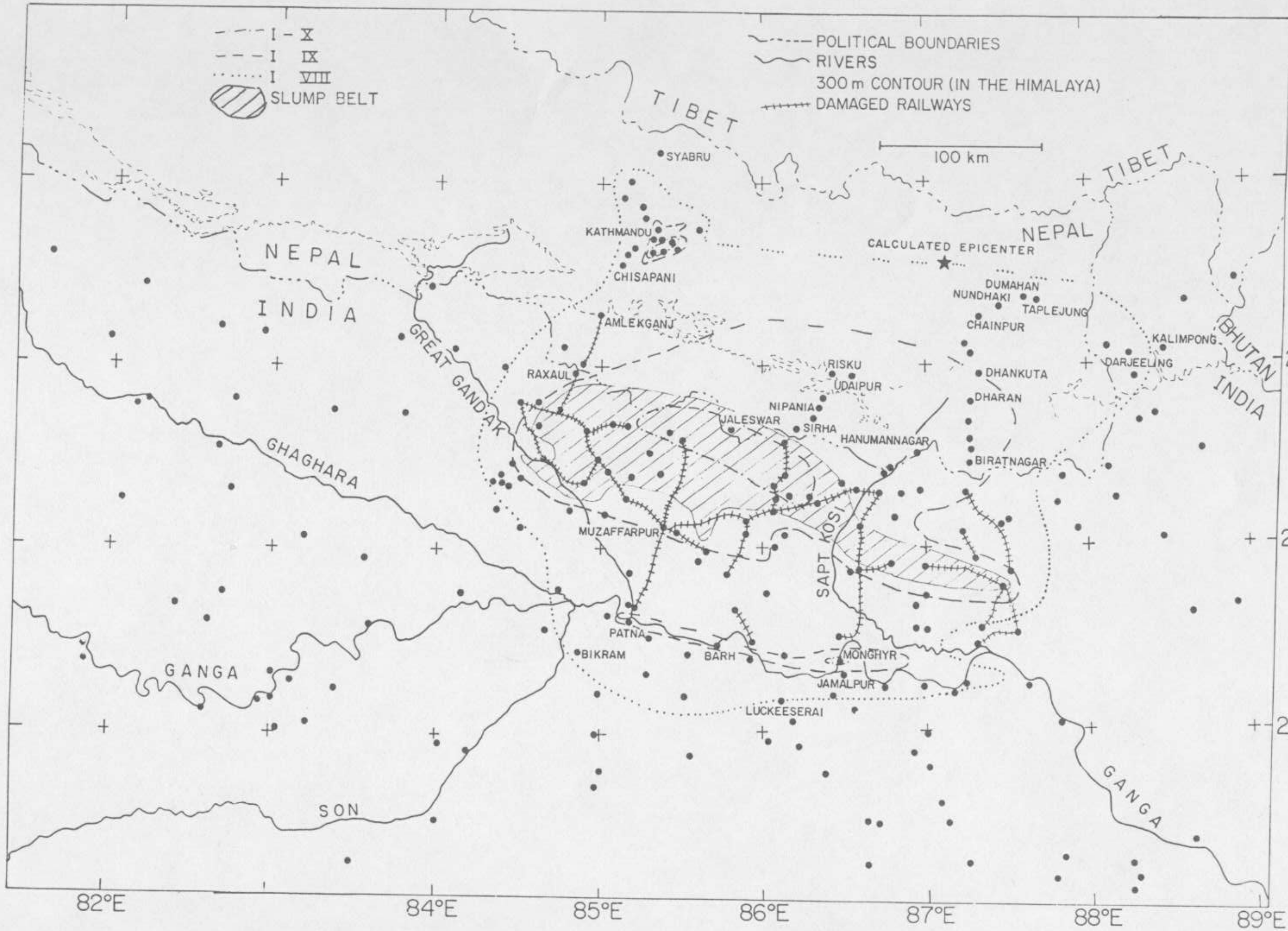

Figure 1 Map showing localities from which damage was reported in Dun et al. (1939). Segments of railways for which there was reported damage and the area call the "slump belt" are also shown. The 300 m contour defines, roughly the edge of the Himalaya. Isoseismals were taken from Dunn et al. (1939) and do not include the information reported by Rana (1935).

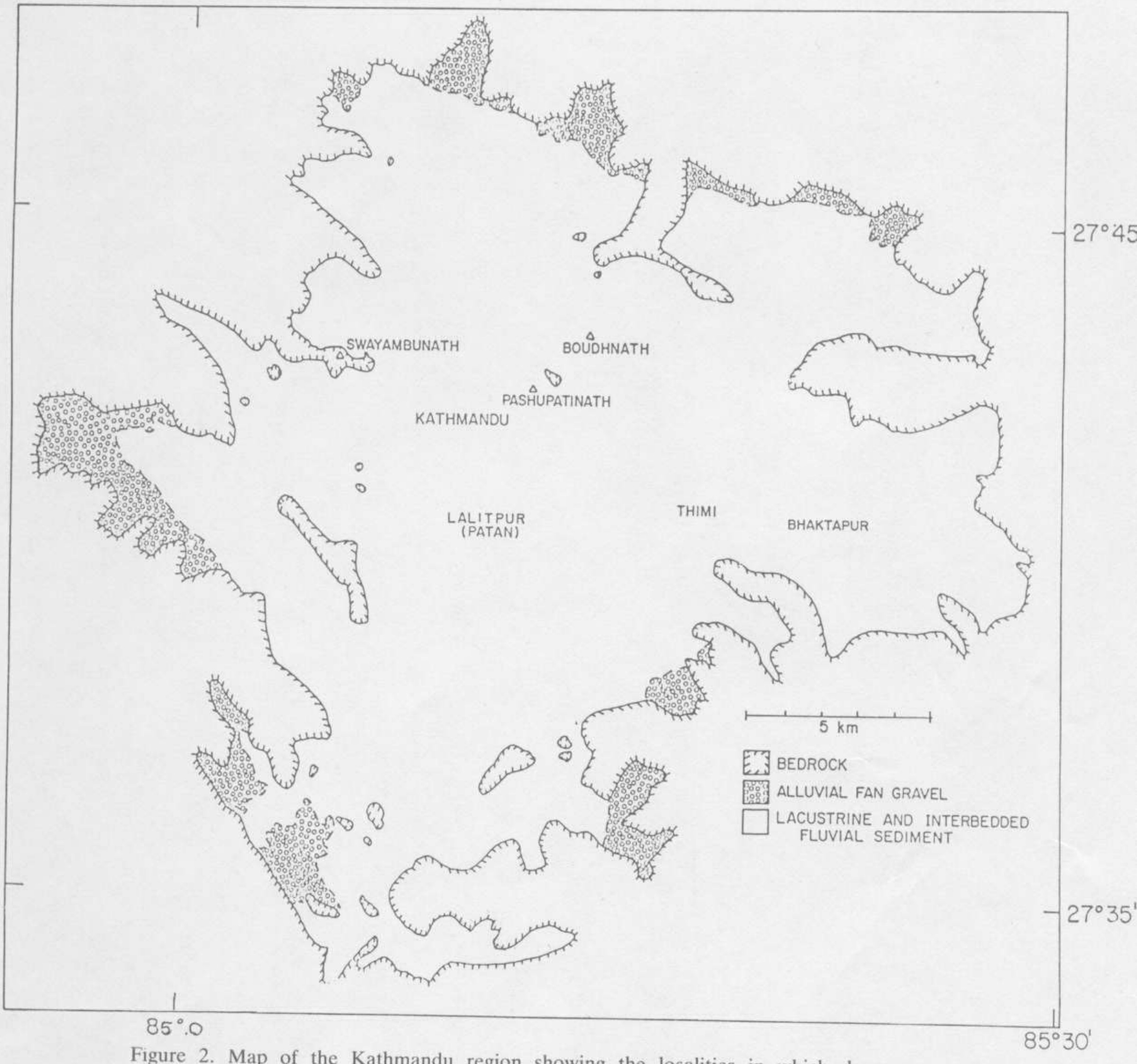

Figure 2. Map of the Kathmandu region showing the localities in which damage was particulrly intense, according to Dunn et al. (1939). Note that most damage was in the valley where lacustrine and fluvial deposits cover bedrock; where bedrock is exposed, damage was not great. Map is from Binnie and Partners (1973).

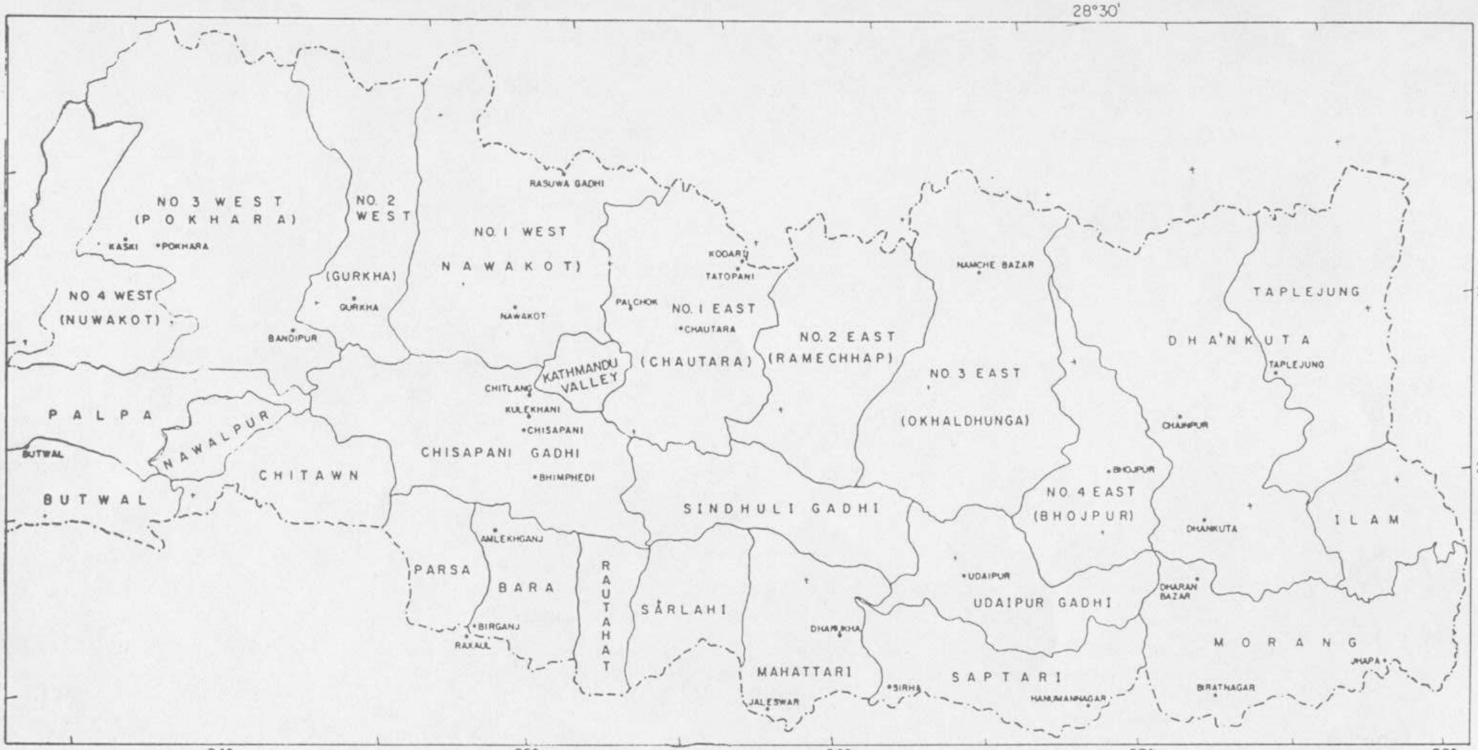

Figure 3. Map of Nepal showing the locations of districts and towns for which Rana gave information about casualties and damage.