Earthquakes in India and neighbourhood

KARAN SINGH

Colaba Observatory, Bombay

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ABSTRACT. The present paper deals with the geological structure of the seismic belt of India and neighbourhood. The relation of the epicentres of earthquakes to the tectonics of the region has been described and the seismic belt has been divided into six major seismic zones. The origin of activity in these seismic zones of Cutch, Baluchistan, Kashmir, Northern India, Assam and Burma has been traced to various groups and systems of the geological age. The Himalayan zone is a part of the great belt of Tertiary folding; the effects of which have not yet died down. The earth movements in Cutch area are considered to be a part of the same events of the Tertiary age which brought the folding, faulting and subsidence of the Baluchistan coast line and indicates the persistence of instability in this region.

The Baluchistan arc is marked by a sharp re-entrant angle near the Quetta region which forms a nucleus of all the earth movements. There is a large gathering up of the strata in this region. The frequency of major earthquakes in the Kashmir region is much less, even though the wedging of the Peninsular rocks has caused considerable deflection of the mountain waves. This may be due to the fact that the over-thrusting of rocks from both sides of this bend is directed towards a central axis. There seems to be a southward migration of seismic activity in Northern India and the locus of activity is along the southern margin of the hills. There is a sharp re-entrant angle near the boundary of Assam, Burma and China. The Himalayan and Burmese mountain arcs have been very sharply deflected by the peninsular rocks and the duel forces of the sharp wedging due to the thrust faults of the Himalayas and the Burmese mountain arcs have complicated and intensified the seismicity of the Assam region. The seismic activity of this region shows that Assam is one of the most unstable regions of the world and has been the scene of nearly a dozen major earthquakes during the last century.

1. Introduction

1.1. *Origin of Earthquakes* — Using geological time as a yardstick, processes like the volcanic activity, melting or forming of ice, erosion and sedimentation disturb more or less continuously, the isostatic equilibrium inside the earth's crust. An uneven flow of heat currents creates strains on the earth's crust which slips along lines of weaknesses, called fault lines.

Earthquakes of structural origin due to straining of underlying rocks are called 'tectonic earthquakes'. The immediate cause of tectonic earthquakes is attributed to the slipping of rocks along a fault plane. A fault plane is usually a zone of fracture on the two sides of which the rocks have been relatively displaced. The Kangra earthquake of 1905, the Assam earthquakes of 1897 and 1950 and the San Francisco earthquake of 1906 were all characterised by faulting.

1.2. *The structure of India* (*Fig. 1*) — The history of Indian earthquakes shows that most of the destructive earthquakes have occurred in or along the foothills of the great Himalayan mountains while the region south of the Indo-Gangetic plain has remained free from major earthquakes. The 'foredeep' lying in front of the Himalayas persisted throughout the Pleistocene and seems to have been filled up only in recent times. The bottom of the foredeep still seems to be undergoing changes, giving rise to occasional earthquakes.

The Indian Peninsula is a seismically stable part where the processes of mountain building ceased to be active long ago. There are some faults and fractures in this region but they are all inactive during the recent times. Feeble shocks are, however, felt occasionally in the region and it may be that the faults have not yet reached complete equilibrium. These peninsular faults vary greatly in age.

1.3. *Himalayan Orogeny* — The direction of movement in the Himalayan arc is towards south, that in the Burma arc is towards west and in the Baluchistan arc it is eastward. A northerly movement of Indian Peninsula seems to have caused the sediments of the Tethyan basin to be thrust over it all along the northern border. The sediments deposited in the geosyncline of the Tethys during the Mesozoic were compressed and folded into mountain chains by the movement of the Indian Peninsula whose northern edge got incorporated in the rising Himalayas. The shape of the belt of folding was determined by the shape of the continental mass (composed of old and unyielding rocks) against which the sedimentary rocks were thrust. Wadia (1931) suggested that ridges of continental India extend upto Kashmir and Baluchistan in the northwest and west beneath the younger rocks and that they obstructed the free movement of the mountain waves. In the northeast of Assam a wedge of the ancient rocks of peninsular India has deflected the trend lines of

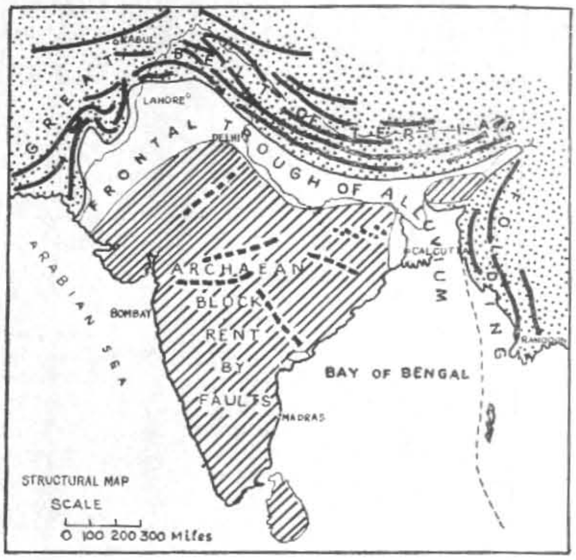

Fig 1

the Himalayas. Near Quetta in Baluchistan, trend lines of the mountains have similarly been deflected. This Himalayan zone is a part of the Eurasian earthquake belt that extends from the Alps to the East Indies. It forms part of the great belt of the Tertiary folding: the effects of which have not yet entirely died down especially at its eastern end.

The mountain building movements were probably somewhat earlier in Arabia than in Baluchistan and Himalayas and they were still later in the Burmese arc and the Indonesian Archipelago. After the upper Cretaceous movements, a ridge was formed which later developed into the Baluchistan arc, separating Sind from Baluchistan. The Assam–Burma ridge was created in a similar way.

The end of the Eocene was marked by the breaking up of the geosyncline. The Baluchistan and Burma arcs were still largely under the sea. Intense vertical movements during the middle Miocene, affected all the areas and were accompanied by large granitic intrusions into the central Himalayas. The Assam plateau was raised during the same time. The Siwaliks were folded probably in early Pleistocene along with the Pir Punjab Range.

2. Relation of epicentres to tectonics

The seismic belt of India and neighbourhood (Fig. 2) is divided into the following six major seismic zones.

2.1. Zone 1—*Cutch*

Cutch contains Jurasic and Lower Cretaceous sediments which might have been uplifted during the early tertiary. From the geographical view point, to the north, south and east of Cutch lies the Rann, which is a desert of sand, mud and saline deposits. It seems to have been the bottom of an appreciable inlet of the sea which for the most part has been filled up and only a small gulf of Cutch has remained. The land of Baluchistan coastline once extended into the Arabian Sea some 60 miles off the present line of demarcation. This had been faulted down and now forms a submerged line of ridges. A ridge, continuing southwest and crossing the entrance to the Gulf of Oman, begins near Karachi and is probably a continuation of the Kirthar range. The folding, faulting and subsidence of this part beneath the Arabian Sea developed as a result of the forces active during the Tertiary age.

There is a great dislocation running for a distance of nearly 90 miles through the northern parts of the Rann of Cutch during the great Cutch earthquake of 1819 and this is more or less in continuation of the inferred faulting that led to the subsidence of the southern coast of Baluchistan and Sind. There was a general uplift of the country to the north and subsidence to the south, with a maximum differential movement of about 30 feet. There was a great flooding in the southern parts of the Rann of Cutch due to its subsidence. The earthquake was felt practically over the whole of the Indian subcontinent and caused extensive damage to building in the Cutch area. In the eastern portions of Anjar, 1500 houses were destroyed and an equal number damaged; the western portions built on rocky foundations having escaped with very little damage. Permanent changes in level had been observed at several places. There were strong after-shocks till 20 November 1819. Minor topographic changes occurred at the time of strong earthquakes of 1844 and 19 June 1845. From 19 to 25 June 1845 sixtysix shocks were reported and much damage done.

The only earlier severe earthquake known in this region is the one of 1668 in which according to a report in Oldham's catalogue (1883), the town of Samaji situated on the delta of the Indus sank into the ground with 30,000 houses.

According to Tandon (1959), an earthquake shock of magnitude 7 and a depth of focus of 13–18 km caused destruction to life and property at Anjar, on 21 July 1956, in the Rann of Cutch. The damage in Anjar was mostly confined to the eastern portion of the town which is located on weak foundations; the western portion of the town with trap rock foundations suffered much less. Earth fissures occurred near the northern boundary of the Cutch mainland.

The whole of the Cutch and Saurashtra lie in a seismic belt and destructive earthquakes have occurred there in the past. The frequency of major earthquakes does not seem to be much, but

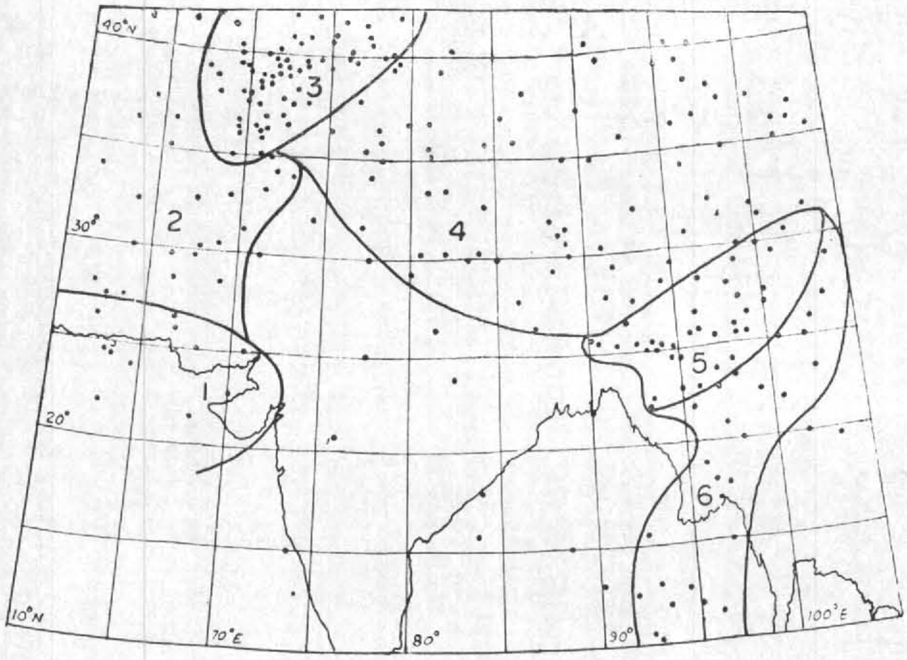

Fig. 2. Earthquake epicentres 1917-1956

earthquake shocks and tremors occur very frequently. Ever since the occurrence of the disastrous and historic earthquake in 1819, which brought about many geographical changes, till the Anjar tragedy of 1956, many shocks of lesser magnitude have been recorded and the region is regarded as highly seismic.

2.2. Zone 2 — *Baluchistan*

The greater part of Baluchistan is composed of younger Tertiary rocks and includes the Siwalik series of Miocene to Pleistocene age. The oldest rocks are of carboniferous age.

The trend of Baluchistan arc is interrupted by a sharp re-entrant angle in the region of Quetta and Dera Ismail Khan with a gathering up of the strata there. The Sulaiman and the Kirthar ranges run southward from Dera Ismail Khan and Quetta respectively.

There are three main tectonic elements in this region, having a central folded mountainous tract marked by abundance of limestone. The western fringe is a zone of shales of Oligocene age. A long boundary fault separates the mountains from the flat desert plain on the west. This fault-line marks a line of earthquake epicentres in the past.

The vicinity of Quetta is marked with the development of thrust faults and the folds have become more tightly packed there. The rocks on the northwest side are thrust over the rocks of the southeast side. This condition of great strain has been constantly giving rise to earthquakes here. The epicentres of earthquakes lie in a haphazard manner and are grouped around Quetta as shown in Fig. 3. The axis of all the epicentres coincides with the strike of the rocks and no earthquake has occurred twice on the same line as the tectonic earthquakes are known to completely relieve the rocks of their accumulated stresses. The country to the west of the fault of the great Chaman earthquake of 1892, subsided a foot and moved bodily 2½ feet southwards. The faulting of the surface was not observed in other earthquakes of the region. The frequency of earthquakes in this region indicates that the accumulated stresses are being continuously relieved and these movements may bring relief from the stresses accumulated in the past.

2.3. Zone 3 — *Northern India*

(*i*) From the Siwalik hills to the main Himalayan range, lie a number of thrust faults one behind the other. Some of them lying in the foreground are of very recent age. The older rocks of the Himalayan system near the foothills of the great Himalayas and to the north of the Indo-Gangetic plain, from the valley of Kashmir to the hills of Assam and Burma, have been thrust over the younger rocks of the Siwalik system in a region known as the Main Boundary Fault Zone of the Himalayas. The main boundary fault is the dominant feature of the Himalayan tectonics. In addition to this, there are similar equally important thrust faults of Tertiary and pre-tertiary rocks belonging to Pre-Pliocene and Post-Pliocene age. The movement has continued up to very recent times. The main

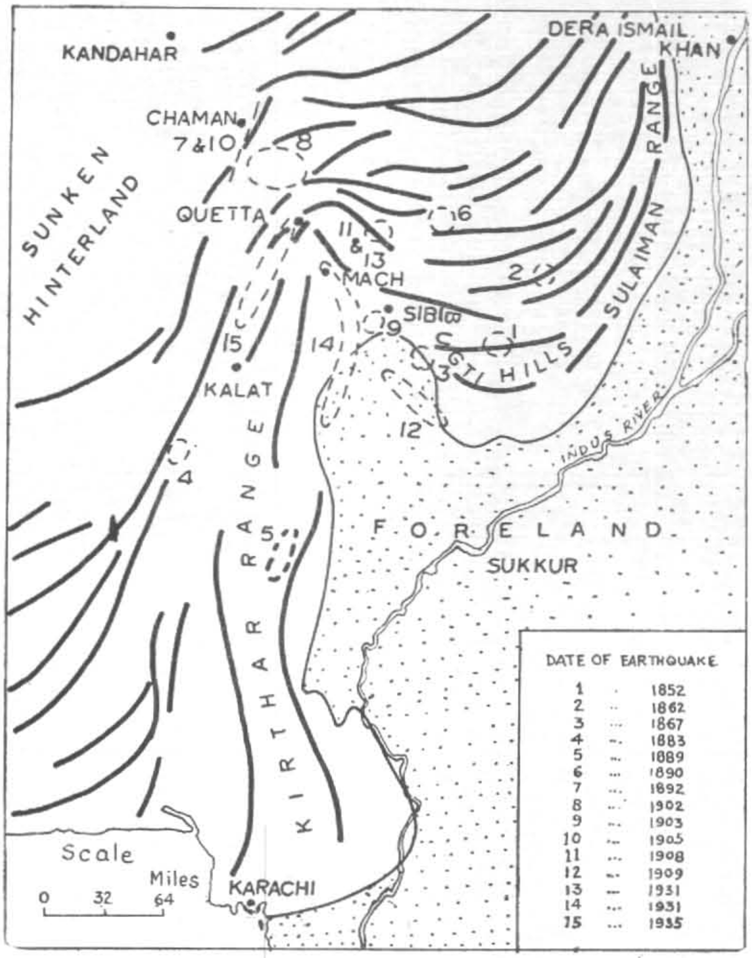

Fig. 3
(*From:* — *W. D. West*)

boundary fault separates the Siwaliks from the older Tertiary rocks. A second fault of equal importance separates the Tertiary from the Pre-tertiary rocks. There seems to be a southward migration of activity along the southern margin of the hills. The epicentre of the Kangra earthquake of 1905 seems to have coincided with the boundary fault which separates the younger Tertiary from the older Tertiary rocks and it may be assumed that the earthquake was due to movements along the boundary fault. The elongation of the epicentral zone in the Bihar earthquake of 1934, in a direction parallel to the great thrusts of the Himalayas, suggests that the movements originated south of the Himalayas along the parallel faults lying under the alluvium. This earthquake appears to have affected much the same area as the less severe earthquake of 1933.

(*ii*) *Aravalli Range* — The Aravalli belt is a tectonic range of Pre-cambrian age. This terminates in Gujarat at the head of the Gulf of Cambay and splays out in different directions; one part of it continues straight into the Laccadives while the other may emerge underneath the Deccan Traps in a NNW-SSE direction. A part seems to join the Satpura range in the eastward direction in southern Rajasthan. The range terminates near Delhi on the other side where it seems to continue into Garhwal in the Uttar Pradesh Himalayas. A part of the structure near Delhi turns sharply towards northwest continuing as a sub-surface ridge bordering the Punjab plains. The northern margin of the Aravalli Range near Delhi consists of patchy exposures interrupted by alluvium.

2.4. Zone 4 — *Kashmir*

There is a spectacular hair-pin bend of the geological formations in the northwest Kashmir. The geological formations have a NW-SE strike on both sides of this wedge. The southwestern side sweeps down and forms the Baluchistan arc. The overthrusting of rocks from both sides of this band is directed towards the central axis and this effect is seen as far as the Karakoram and the

Hindukush mountains and the Pamirs.

A severe earthquake was felt on 6 June 1828 in Kashmir valley. About 1000 lives were lost and fissures opened. It was followed by a great number of shocks for some months. There was another very severe shock on 30 May 1885 felt over an area of 11,000 sq. miles; the epicentre being a few miles west of Srinagar. About 3000 lives were lost. From 1923 to 1952 Srinagar felt in all 176 shocks (Bhan 1955) usually of slight intensity. Few of them caused slight damage in the form of cracks in the walls of old kuccha buildings. Earthquakes of moderate intensity have been felt on very few occasions. No severe earthquake seems to have occurred in the present century.

The Hindukush region is seismically very active and one is struck by the striking similarity of all earthquakes of this famous region, which usually occur at a depth of about 200 km. All the earthquakes, which occur very frequently here, show practically the same features. The movements in the Hindukush earthquakes are of the thrust fault type with only a small component of movement in the strike direction. The processes resulting in the upbuilding of the mountain systems are not restricted to the upper crust but are also acting at greater depths with considerable intensity.

2.5. Zone 5 — *Assam*

The main features of Assam are — (1) The alluvium filled trough, (2) the fractured continental fragments and (3) the trend lines of the mountain folds (Fig. 4).

The Naga and Patkai hills are overthrust from southeast over the Assam valley; which is held tightly as if in the jaws of a vice and is being depressed. The northeast end of the Himalayas has a syntaxial structure (hair-pin bend), the geological structure of which is practically unknown. The ranges of the Naga hills continue southward through the Manipur and Lushai hills into Arakan Yoma of Burma with the trend lines running north-south. The valley of Brahmaputra is underlain by the Archean block of the Assam range, with a relatively thin covering of alluvium. This fragment of peninsular India is rent by a number of cross faults trending north and south. These faults have sliced the block into fragments that have been pushed southwards. Chedrang fault formed during the great earthquake of 1897 is one of such faults.

The great Assam earthquake of 1897 was remarkable in many respects. The suddenness with which it began; the extreme intensity of the surface vibrations over a large area; the variations of intensity from place to place; the number of faults along which the movement took place; including a maximum throw of 35 feet in the case of the

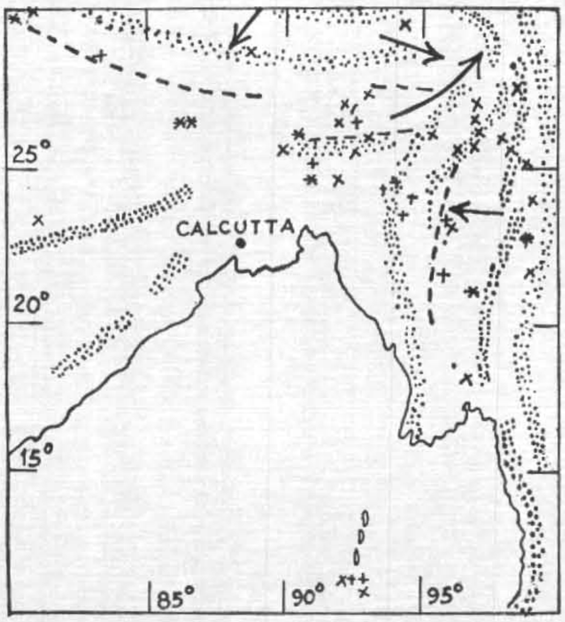

Fig. 4

Chedrang fault; the general upheaval of the country and the remarkable series of after-shocks, all combined to demonstrate the complicated nature of the earthquake. The phenomenon could be explained as due to movement along a nearly horizontal thrust plane accompanied by more steepy inclined secondary thrust plains which reached the surface as actual faults.

Dhubri earthquake of 1930 was located near the northwestern end of the Assam Plateau. Several severe after-shocks occurred further up the valley along the northern border of the range indicating that the lines of fracture developed due to the advancement of the Himalayas towards the south and that a definite zone of weakness exists there.

The great Assam earthquake of 15 August 1950 with the epicentre 29°N and 97°E and of magnitude 8·6, was one of the greatest five which have been recorded in historic times. The earthquake originated probably by the displacement along a major fault surface lying across the Assam syntaxial structure striking northeast to southwest for about 100 miles or so. The fault was probably rather deep seated.

The isoseismals were found to be elongated along a valley, indicating that the mountains cornering into this region, exercised a great influence on the propagation of seismic surface waves. If geologically the region was homogeneous the isoseismals would be a series of concentric circles. According to Banerji (1953), a block of rock exceeding 200 × 100 × 10 km must have been subjected to breaking strain by the pressure (of the nature of an overthrust) due to a shallow slow movement of the Himalayan arc from northeast to southwest and of the protruding peninsular rock southwest to northeast; thus producing a shearing couple on the block in an anticlockwise direction as shown in Fig. 4.

The local structures seemed to have had an influence on the path of the waves. The movement at Burdwan appeared to come from the north instead of a more northeasterly or easterly direction. This was so probably because the ancient rocks were cut off close on the northern side, along the trend of the boundary fault of the Raniganj coalfield and the waves were refracted at that junction of unlike rocks. The young Tertiary rock of the arcs of the hills between north Lakhimpur and Tezpur had moved forward more freely into a saddle of old concealed ancient rocks while the Subansiri gorge sector had been held back by a shoulder of the buried mass.

The seismic study shows that Assam is one of the most unstable regions of the world and has been the scene of nearly a dozen major earthquakes during the last century.

2.6. Zone 6 — *Burma*

Burma has three main structural divisions —

(1) The Shan Plateau lying on the east consists of the Pre-Cambrian, Palæozoic and Mesozoic rocks folded and uplifted into its present form in the early Tertiary and later times. It has a north-south trend.

(2) The Central Tertiary basin of the Irrawady valley consisting of Tertiary rocks folded and faulted in the late Tertiary.

(3) The folded range of the Arakan Yoma lying on the west consists of Cretaceous and early Tertiary rocks. It was folded in late Mesozoic and early Tertiary times. It is continued southward through Andamans and Nicobar Islands. These zones are separated by zones of faulting. The Central Tertiary belt is a sunken trough, the sinking and folding of which were more or less simultaneous. The eastern side of this trough along the margin of the Shan Plateau is marked by a faulting believed to be of Pliocene age. The faulting which separates the Middle Tertiary belt from the Arakan Yoma is probably of late Tertiary age.

Almost all the epicentres of earthquakes are closely related to the two main zones of faulting.

3. Conclusion

The earth movements in Cutch area are considered to be a part of the same events of the Tertiary age which brought the folding, faulting and subsidence of the Baluchistan coastline and indicates the persistence of instability in this area. The framing of a building code for this region has, therefore, become an urgent necessity and the location of all buildings on suitable foundations has assumed great importance.

The Baluchistan arc is marked by a sharp re-entrant angle near the Quetta region which forms a nucleus of all the earth movements. There is a large gathering up of the strata in this region. The frequency of earthquakes in this region indicates that the accumulated stresses are being continuously relieved and these movements may bring relief from the stresses accumulated in the past.

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There seems to be a southward migration of seismic activity in the northern India and the locus of activity is along the southern margin of the hills. There is a sharp re-entrant angle near the boundary of Assam, Burma and China. The Himalayan and Burmese mountain arcs have been very sharply deflected by the peninsular rocks. The duel forces of the sharp wedging due to the thrust faults of the Himalayas and the Burmese arcs have complicated and intensified the seismicity of the Assam region. To mark the areas of Assam region which are likely to be shaken in future, a study of the distribution of earthquakes, along with a planned geological survey, has assumed a great urgency.

4. Acknowledgements

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APPENDIX I

A list of the important earthquakes in India and neighbourhood is given below —

6 July 1505 — A very severe earthquake felt from U. P. to Persia, causing great damage and loss of life around Kabul. Felt at Agra and Delhi.

May 1688 — Delta of the Indus, caused great damage.

15 July 1720 — Delhi. Damage done to the walls of the Fort and to many houses, cracks developed in the ground and many lives were lost. Aftershocks were felt in Delhi for some weeks. The position of epicentre unknown.

11 October 1737 — Calcutta. Many houses thrown down and the spire of the English Church sank into the ground. Many ships were lost in accompanying hurricane, and great loss of life occurred.

2 April 1762 — Bengal and Burma. Felt most severely along the northeast coast of the Bay of Bengal. Chittagong suffered severely, fissures opening in the ground with fountains of water and sand.

1 September 1803 — U. P. Very severe at Muttra, many pucca buildings and the principal mosques destroyed. Severe in the Simla and Kumaon hills. Damaged the Qutab Minar at Delhi. Felt at Calcutta.

16 June 1819 — Cutch. Felt practically over the whole of India, including Calcutta, and was one of the greatest of Indian earthquakes, 2000 lives lost at Bhuj alone. The great mosque of Sultan Ahmed at Ahmedabad destroyed after standing 450 years. An elevation of the ground for 80 miles on the north side of a fault running east-west, temporarily dammed up a branch of the Indus. The Rann of Cutch flooded on the downthrow side of the fault.

September 1827 — Lahore, Fort-Kolitaran, near the city, destroyed and 1000 said to have perished.

6 June 1828 — Kashmir. Very severe. 1000 reported killed. Fissures opened in the city, followed by a great number of aftershocks for some months.

26 August 1833 — Bihar and Nepal. Felt over much the same area as the 1934 earthquake, though possibly not quite as severe.

23 March 1839 — Burma. A very severe earthquake felt over the whole of Burma but most strongly around Mandalay. Amarapoora and Ava destroyed and the stupendous temple of Mingon overthrown.

19 February 1842 — NW India. Felt from Kabul to Delhi, the epicentre probably near Jalalabad. Jalalabad and Peshawar severely damaged.

1 April 1843 — Deccan. The only earthquake in peninsular India known to have caused much damage. Epicentre near Bellary.

24 January 1852 — Upper Sindh. Fort of Kahan ruined, and 350 killed, severe but local.

24 August 1858 — Burma. Very severe, especially around Thayetmyo and Prome, felt in Bengal. Sympathetic shocks in Madras and Bombay.

10 January 1869 — Assam (Cachar). Felt over an area of 250,000 sq. miles, the epicentre being on the northeast side of the Shillong plateau. Earth fissures and sand craters very abundant and their origin discussed for the first time by T. Oldham.

31 December 1881 — Bay of Bengal. Felt over an area of 2,000,000 sq. miles mostly sea.

30 May 1885 — Kashmir. Felt over an area of 110,000 sq. miles, the epicentre being a few miles west of Srinagar. About 3000 lives lost.

14 July 1885 — Bengal. Felt over an area of 230,000 sq. miles. Epicentre northwest of Dacca.

20 December 1892 — Chaman Baluchistan. Associated with a fault running NNE along the western side of the hills. As a result of the earthquake the country west of the fault subsided a foot, and moved bodily $2\frac{1}{2}$ feet southwards.

12 June 1897 — Assam. Probably the greatest earthquake that has occurred anywhere during historic times. Felt over an area of 1,750,000 sq. miles, with the epicentre in the Shillong plateau. Exhaustively studied by R. D. Oldham, who suggested a complicated origin for it. Destruction of stone buildings almost universal in Shillong, Goalpara, Gauhati, Nowgong and Sylhet. Calcutta seriously effected. About 1600 lives lost. Followed by a great train of aftershocks which continued for 10 years.

14 April 1905 — Mag. 8, Epicentre 33°N, 76°E. Kangra. Felt over an area 1,625,000 sq. miles. 20,000 lives lost. Kangra, Dharamshala and neighbouring places completely ruined. Origin attributed by C. S. Middlemiss to movement along one of the reversed Himalayan faults, at considerable depth.

21 October 1907 — Epicentre 38°N, 69°E, Magnitude 8.

21 October 1909 — Baluchistan (Kachhi). Epicentre located on the alluvial plain, very elongated, aligned northwest—southeast. 231 lives lost.

23 May 1912 — Epicentre 21°N, 97°E. Magnitude 8. Burma. Felt over an area of 375,000 sq. miles. Epicentre located close to the Kyankkam fault on the Shan plateau, northeast of Mandalay.

8 JULY 1918 — Srimangal (Assam). Many tea estates ruined. Epicentre 3½ miles south of Srimangal on an alluvial tract. Felt over an area of about 800,000 sq. miles. Sympathetic shocks at the Madras and Arakan coasts. Relevelling suggests that the earthquake was due to subsidence along the southern side of normal fault cutting the rocks below the alluvium.

9 SEPTEMBER 1923 — Epicentre 25·5° N, 91·5°E, southwest of Assam, some damage to structures near epicentre region over west of Assam and northern part of east Bengal. Felt over Assam, Bengal, east Bihar and east Chota-Nagpur.

1 FEBRUARY 1929 — Northwest Himalayas. Epicentre about 25 miles northwest of Abbottabad. Of interest as being a deep focus earthquake the depth calculated to be 160 km.

5 MAY 1930 — Near Pegu (Burma). spicentre 17·3°N, 96·5°E. Felt over a land area of 220,000 sq. miles. About 550 lives lost. The epicentre along elongated tract SSE of Pegu, aligned N—S. Origin thought by J. Coggin Brown to be connected with the boundary faults of the Shan Plateau, but perhaps intensified by increasing strains due to the growths of land into the Gulf of Martaban.

3 JULY 1930 — Epicentre 25·8°N, 90·2°E. Dhubri, Assam. Epicentre at northwestern end of the Garo hills. Felt over an area of about 350,000 sq. miles. Origin thought by E.R. Gee to be mainly due to movement along a line of tectonic weakness at the margin of the Assam Range, accentuated by the disturbance of isostatic equilibrium consequent upon the rapid denudation of the range.

27 AUGUST 1931 — Epicentre 29·8°N, 67·3°E. Mach, Baluchistan. Epicentre located down the Bolan Pass and along the junction of the hills with the Kachhi plain. Felt over an area of 370,000 sq. miles. About 200 lives lost.

14 AUGUST 1932 — Epicentre 25·8°N, 95·7°E in NW, Burma. Focal depth about 130 km. Semi-destructive near the epicentral region and some damage over eastern part of northeast Assam. Felt over Assam and north and east Bengal. Some damage near the epicentre.

15 JANUARY 1934 — Epicentre 26·5°N, 86·5°E. Mag. 8·3. North Bihar. One of the most severe in Indian history. Felt over an area of 1,900,000 sq. miles. At least 10,000 lives lost. Epicentre occupied a belt aligned WNW—ESE and running for some 80 miles from east of Motihari through Sitamarhi to Madhurai. Origin attributed by D. N. Wadia, J. A. Dunn, J. B. Auden and A. M. N. Ghosh to movement along a fault or series of faults below the alluvium.

31 MAY 1935 — Quetta. Epicentre 29·6°N, 66·5°E. Epicentral area a narrow tract running 68 miles SSW from Quetta through Mastung. Felt over an area of only 100,000 sq. miles, but very severe at the epicentre. About 25,000 lives lost and great material damage in Quetta. Exact origin unknown but the focus was probably shallow.

20 OCTOBER 1937 — Epicentre 30°N, 78·2°E near Dehra Dun. Presumably some damage near epicentre where it was felt very severely. Felt also over north U. P., east Punjab, east Kashmir and Simla-Kumaon hills.

14 MARCH 1938 — Epicentre 21·5°N, 75·8°E in the Satpura range. Depth of focus about 40 km. Felt over Central India, Western India, major part of C. P., part of Rajasthan, Kathiawar and Hyderabad State, over an area of 400,000 sq. miles.

26 JUNE 1941 — Epicentre 12·5°N, 92·5°E. Mag 8·1. Andaman. Extensive damage to buildings in Andamans, felt over Colombo, Madras, Calcutta and Bombay. Few killed and injured.

23 OCTOBER 1943 — Epicentre 27·5°N, 93·5°E in Assam. Destructive over northeast Assam and minor damage over northern part of Assam. Felt over Assam, Bengal and major parts of Bihar and northeast Orissa.

27 NOVEMBER 1945 — Epicentre 24·5°N, 63·5°E. Magnitude 8·25. Mekran.

29 JULY 1947 — Epicentre 28·5°N, 94°E about 100 miles northwest of Dibrugarh. Damage to buildings in parts of northeast Assam, felt over Assam, in Bengal upto Calcutta and in Bihar upto Purnea.

15 AUGUST 1950 — Epicentre 28·6°N, 96·5°E, Mag. 8·6, depth of the order of 15 km. Assam, northeast border of Assam in the Sinkiang province of China. One of the greatest five ever recorded in history.

22 MARCH 1954 — Manipur-Burma Border. Epicentre 24·38°N, 95·15°E. Felt over a large part of Eastern India and neighbourhood

21 JULY 1956 — Rann of Cutch. Epicentre 23·20°N, 70°E. Mag. 7 and a depth of focus nearly 13-18 km. Caused maximum destruction to life and property at Anjar. 115 lives lost and hundreds injured. An area of about 750 sq. miles in central Cutch suffered maximum damage.

This list is based mainly on the Presidential Address, West, W. D. (1937), Proceedings of the 24th Indian Science Congress.