Paper No. 29

SEISMICITY AND TECTONIC HISTORY OF THE INDO-GANGETIC PLAINS

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SYNOPSIS

The seismicity of an area depends to a large extent on its tectonic history. Areas of recent tectonic movements show higher activity. An attempt has been made in this paper to describe the tectonic history of the development of the Indo-Gangetic Plains which indicates that the Bengal basin and the Ganga basin, which show great seismic activity, probably developed during the last phase of the Himalayan orogeny. These movements are still continuing and cause frequent earthquakes in the region.

INTRODUCTION

The northern parts of the Indian sub-continent, including the Himalayan region, are frequently affected by earthquakes at short intervals. It is a common observation that the frequency of earthquake is very high in areas of active orogenesis.

The Indo-Gangetic Plains, covering an area estimated at over 250,000 sq. miles, forms a monotonous level surface filled with alluvium covering the rocks and structures below them. Thus the geology and the tectonic history of this region has remained a matter of speculation. This was mainly due to an apparent lack of interest as no economic mineral deposits were expected in this region. With the launching of the Five Year Plans, the establishment of the Oil and Natural Gas Commission, and construction of the Multipurpose projects in the highly seismic zones, renewed interest has been created to unravel the hidden mysteries below the alluvium and the Siwaliks. On the basis of the available data a possible explanation on the "Geotectonic Position and Earthquakes of the Gango-Brahmputra region" was given by Mithal and Srivastava (1959). This aroused a great interest amongst the Indian Geologists and Geophysicists and a number of papers based on actual field data have recently been published.

The interpretations put forward in this paper are based on records of the famous Indian earthquakes and other available geological and geophysical data. Unfortunately most of the results of the gravity, magnetic and seismic prospecting carried for oil exploration

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have not been published so far and hence the available data for such an extensive subject dealing with so vast an area is so meagre that it permits only to draw a tentative conclusions, which may be modified in future.

TECTONICS

The Indian sub-continent including India, Pakistan and Ceylon is composed of three distinct units : Deccan Peninsular shield, Himalayan belt and Sedimentary alluvial basins of the Indo-Gangetic Plain. The Deccan shield with the island of of Ceylon forms a single crustal block and has remained as a stable triangular plateau having suffered little or no folding since the Pre-Cambrian times. It has however been subjected to fracturing resulting in a set of crustal blocks (Fig. 1). These blocks are considered stable and practically aseismic but as these are bounded by fault zones, their shaking due to sympathetic vibrations and marginal adjustments are possible. It is also

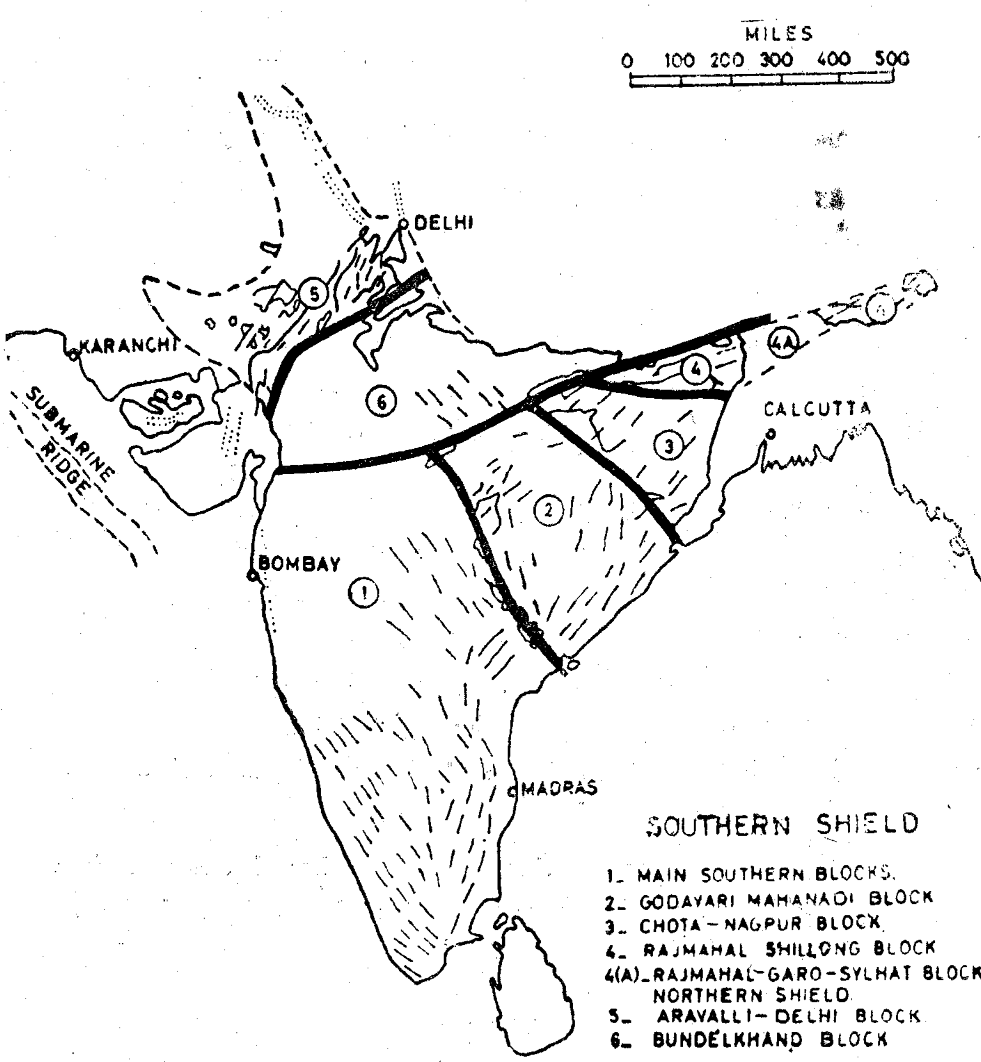

Figure No. 1 Structural Blocks of Peninsular Shield considered that the dynamic processes which separated India from Africa and Australia, and which have perhaps not yet entirely ceased are responsible for the earthquakes in the Peninsular shield area.

No detailed geological work has been carried out in the Himalayan region and the sedimentary alluvial basins. However, the origin of the two is intimately connected and have been discussed by several authors. The Himalayan mountains and the sedimentary alluvial basins are considered to have formed due to the same tectonic movements. This was initiated by the uplift of the Tethys floor to form the inner Himalayas, breaking up of the Gondwana land and the eruption of the Deccan lava. The later upheavels (during post Eocene times) again raised the remnants of the Tethys with folds of the outer Himalayas followed by the post-Miocene movements raising the lesser Himalayas. During the end phases of this great Tertiary orogeny were formed the outer most sub-Himalayas. All these movements are well marked by the transverse ranges separated from each other by parallel reverse faults. The faults, north of the "Great Boundary Fault" and the "Krol Thrust" appear to be related with the first two uplifts of the Himalayas and those in the south with later orogenic movements parallel and sub-parallel to the "Gango-Brahmputra Rift." This also indicates that the fracture pattern in the northern part of the Peninsular shield have controlled and influenced the later movements in the outer Himalayan zone.

The knowledge of the base and the basement rocks of the Indo-Gangetic Plain is mostly a matter of conjecture and unless more data is made available any explanation offered may remain doubtful. Agocs (1956) on the basis of the aeromagnetic survey, of a large part of the Indo-Gangetic plain in Uttar Pradesh, Bihar and parts of Punjab indicated that the basement floor varies from 500 to more than 30,000 feet deep, increasing in thickness towards the foot of the Himalayas. He also suggested that the basin may be segmented into several transverse sections bounded by major faults. Later geophysical surveys have confirmed most of the observations of Agocs.

On a study of the various informations available Mithal and Srivastava (1959) suggested that the floor of the Indo-Gangetic Plain is gently sloping towards the Himalayas and the thickness of the sediments varies from 5000 feet or more at the southern margins. Along the northern fringes at the foot hills it may be 10,000 feet or more in the Uttar Pradesh and Bihar, 4000 feet to 12,000 feet or more in Bengal basin, and 20,000 feet or more in the Upper Assam Valley. Considering the above and the tectonic pattern the alluvial tracts of India have been Sub-divided into the following basins (Fig. 2).

(i) Cambay and Cutch basin,
(ii) Jaisalmer basin,
(iii) Punjab basin,
(iv) Ganga basin,

(v) Assam basin,

(vi) Bengal basin.

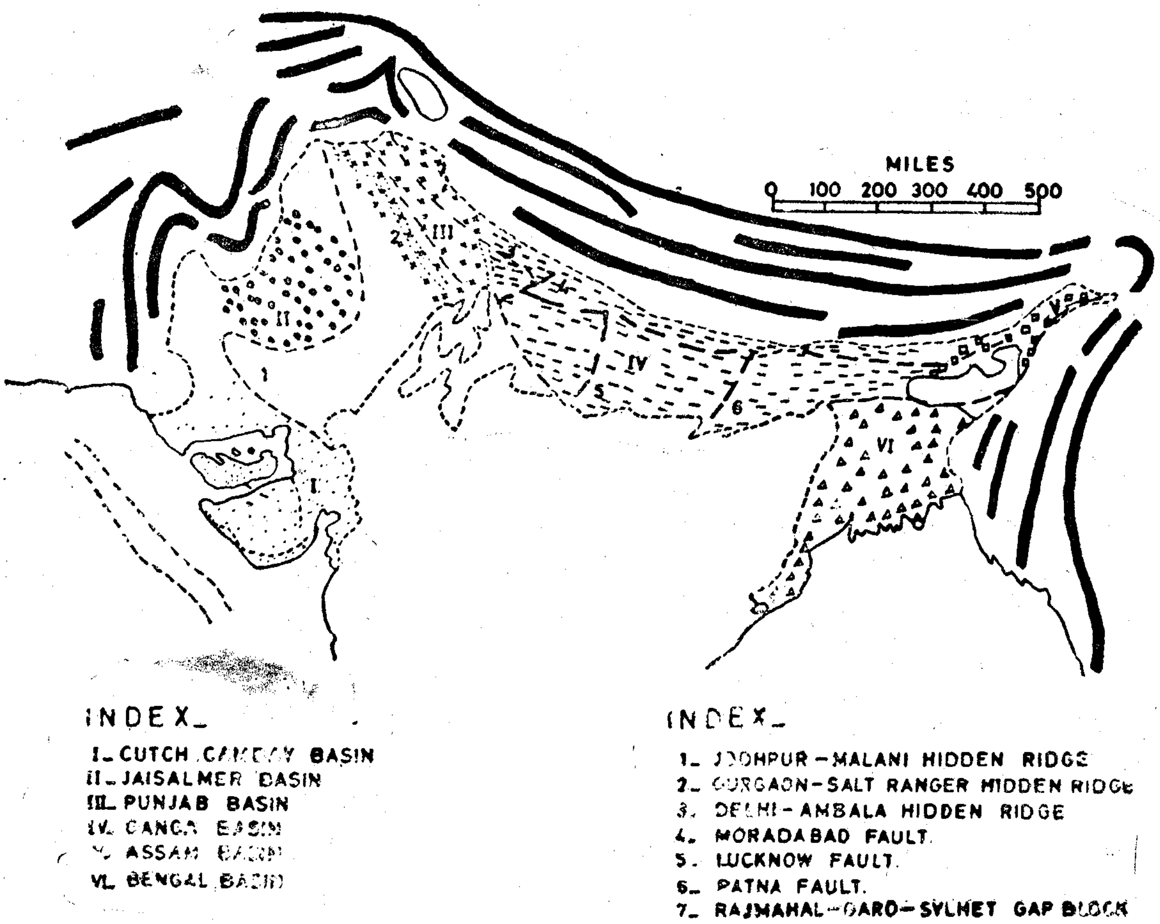

Figure 2 Sedimentary Alluvial Basins of Indo Gangetic Plains

The Penisular shield during the late Mesozoic was composed of seven Blocks. These blocks were bounded by the coastal faults, Gondwana rifts and other faultings, and were responsible for the present shape of the southern margins of the shield. The Indo-Gangetic Plains were then probably occupied by the northern sloping Aravalli-Delhi and Bundelkhand blocks with extensions of the present Aravalli, Satpura, Kaimur and Vindhyan ranges. Subsided and hidden ramifications of these ranges have been investigated and a few of these have also been confirmed by geophysical investigations followed by drilling by the Oil and Natural Gas Commission and the Exploratory Tube Wells Organisation of India.

The Aravalli-Delhi block, thus appears to have broken up during the first Himalayan orogeny and the subsided grabens, between the hidden horsts (ridges) extending along (i) Delhi-Ambala, (ii) Gurgaon-Sargodha-Salt Range, (iii) Jodhpur-Malani, and (iv) the Submarine ridge sub parallel to Sindh-Cutch coast line seem to be responsible for the development of the Punjab, Jaisalmer and Sindh-Cutch-Cambay basins.

The Punjab basin, lying within the Aravalli and Delhi strikes on the southeast and the Himalayan trends on the north, forms a "nuclear basin" with 'anisochronous' frame work. The Jaisalmer, Cutch and Cambay basins are "discordant" in relation to the tectonic pattern. The Assam basin also seems to have subsided during the first uplift of the Himalayas and formed a 'nuclear basin' with 'isochronous' frame work.

The subsidence of these basins on southern margins of the rising Tethys geosyncline formed depressions popularly known as the "fore-deep" of Suess. Such subsidences on the margins of geosynclines are a common phenomena and are noted on other parts of the world e.g. Scandia (Scandinavia) got subsided during upper Tertiary with simultaneous uplifts, and volcanic activity in the Norweogian Geosyncline, and the submergence of Cascadia after the upper Jurassic foldings of Sierra Nevada in North America.

Simultaneously, with the second uplift the northern fringes of the Bundelkhand Block started sinking along the southern margins of the Gango-Brahmputra rift or the Neogene Siwalik Trough. Concomitantly, the areas south of the rift in the Ganga basin, which was probably a land mass suffered shearing and fracturing along the NE–SW and NNE–SSW directions. Due to these shears the Ganga basin got splitted in four blocks bounded by the Delhi–Ambala ridge in the West and the Rajmahal Shillong gap block in the east with Moradabad, Lucknow and Patna faults in between, and each of the four blocks appear to be further segmented by criss cross en echelon faults within them. Like the Aravalli-Delhi Block, hidden extensions of the Vindhyan platform and the Kaimur ridges seem to be present underneath the alluvium in these blocks. This is partly confirmed by the reported occurrence of the orthoquartzites (sedimentary origin) at a depth of nearly 13,000 feet in the Terai zone of northern Bihar and at about 4500 feet in the central part of Uttar Pradesh.

The Ganga basin, south of the Gango-Brahmputra rift (occupied by the then "Indo-brahma" river) started sinking by "differential earth movements" during the third uplift of the Himalayas upto the close of the Siwalik sedimentations. It is also likely that later deposits in this basin rest on the Vindhyans. The reported limestones and quartzites met in the deep bore holes below the alluvium near Barielly and Shahjahanpur if proved to be of Vindhyan age will support the above idea.

During the fourth phase of the Himalayan orogeny, the sinking of the already sheared Ganga basin in the south ultimately resulted in the uplift of the Siwalik ranges coupled with the dismemberment of the "Indo-brahma" into three separate river systems of the Indus Ganga and Brahmputra. Simultaneously the northern half of the Bengal basin also collapsed along the earlier formed longitudinal shears forming the Rajmahal-Garo-Sylhet Gap in the Rajmahal-Shillong block of the Peninsula rshield. This gap has helped in the draining of the Ganga and Brahmputra rivers into the Bay of Bengal. The disturbances at this stage along the Delhi-Ambala Ridge were probably responsible for the obliteration of the south westerly flowing legendry river Saraswati into Rajasthan and Cutch.

From the above account it is evident that the sinking of 'blocks' and 'basins' into graben structures have played a greater role in the development of the present configuration of the Ponisular Shield and the Indo-Gangetic plain. It is also worth noting that similar subsidences are also making transverse ridges, valleys or doons in and along the Himalayas. On the basis of detailed structural analysis, Krishnaswamy (1963) indicated a system of block faulting in the Punjab outer Himalayas. Likewise, as a result of studies in connection with the last Kashmir earthquake of 2nd September 1963, Srivastava, et al (1964) have shown that the valley of Kashmir has developed as a sunken block. The Doons and the Kathmandu Valleys also seem to be of similar origin.

SEISMICITY

The Indo-Gangetic Plains have been affected by a number of severe earthquakes in the historic past. The Narbada and Tapti basins of the Peninsular shield and the Cambay and Cutch basins have been affected frequently by earthquakes. The last named area suffered from major shocks (in 1889 and 1956) with great damage to life and property. The Jaisalmer basin does not show activity on its eastern margin but earthquakes have been reported on its western side along the Indus river.

The Punjab basin is composed of sands, silts and clays brought by the Indus and its tributaries. It is noted (Mathur and Kohli, 1959) that the floor of the basin slopes in general at an angle of 1° to 2° towards the Himalayas, and the sediments overlying it from homoclinally dipping structures parallel to the Himalayan ranges. The floor of the central and southern parts of this basin does not show any major active fault zones and is comparatively less susceptible to seismic activity. The Siwalik belt in the north and the Delhi rocks in the east of this basin show considerable seismic activity and the 1905 Kangra earthquake did considerable damage in the northern parts. The earthquakes along the Delhi border in the east are of frequent occurrence indicating that movements are still operative along the the Delhi-Ambala ridge.

The Ganga basin, with an approximates area of 1,40,000 square miles, extending from Delhi to Rajmahal and continuing upto the the Garo Hills represents the northern slope of the Peninsular Shield. The thickness of sediments in this basin appears to be gradually increasing towards north, and towards the foot hills it becomes enormous due to the development of the 'Gango-Brahmputra Rift' at the fringes of the Himalayas. As stated earlier the floor of the basin lying between the Delhi-Ambala hidden rigde and the Rajmahal-Garo Sylhet gap block appears to be further subdivided into four block by en echelon subterranean faults – i.e. the Moradabad fault with ENE trend, Lucknow fault with NE to NNE trend and the Patna fault with NE–SW trend. Thus the Ganga basin appears to be composed of huge blocks bounded by the hidden ridges and the faults and the boundaries of these blocks have shown seismic activity in the past. The 1505 earthquake at Agra, the 1803 earthquake at Mathura and the 1720, 1825, 1830, 1831, 1842 and other recent earthquakes at Delhi indicate that the eastern side of the Delhi-Ambala ridge is still active and is the cause of occassional earthquakes in the region. The Moradabad fault appears to have released energy in the past, which caused the 1803 Upper Ganga earthquake and the Meerut earthquakes of 1833 and 1852. The earthquake of 1808 at Banda, and of 1825 and 1864 at Lucknow indicate activity along the Lucknow fault. The region around Patna fault have been subjected to great activity and 1833 and 1934 Bihar-Nepal earthquakes in the area were of very high magnitudes, responsible for great damage to life and property. The Himalayan foot hills forming the northern borders of the Ganga basin is an area of moderate seismic activity but the southern margins have not shown much activity in the recent past.

The Rajmahal-Garo-Sylhet-gap block, bordering the Ganga basin in the east, is a subsided burried mass, with cross shears extending towards south upto the coast of Bay of Bengal. Earthquakes are of frequent occurrence in the Bengal Basin (includiug east Pakistan) and the epicentres appear to be mostly concentrated near the eastern and western boundaries, though earthquakes have also been recorded from within the basin. All the epicentres of the earthquakes in this basin appear to be closely related with the shears of the subsided block and the less conspicuous subterranean ridge extending from Rajmahal to east of Cooch Bihar.

Geologically the Assam region, the most seismic region of India has been worked out for almost 75 years. The knowledge gained is highly valuable and is based on geological mapping, drilling and geophysical survey. Little is known about the geology of the Assam Himalayas which are believed thrusted towards this basin from the north. The Shillong plateau, Mikir hills, and the thrusted Naga hills form its southern and eastern margins. The Assam region has witnessed many severe earthquakes in the 19th and the 20th century, which have caused great damage in the area.

During the 1897 great Assam earthquake the accelerations are estimated to have exceeded gravity. Among the innumerable other earthquakes, the 1843, 1845, 1930, 1943 and 1950 Assam earthquakes were very destructive in intensity. The epicentres of most of the destructive earthquakes lie in sorrounding mountainous belt outside the alluvial tracts, and the movements are more connected with the last phase of the Himalayan orogeny; and the basement below the valley appears to be have adjusted most of its strain due to block faulting.

CONCLUSIONS

The evolution of the Indo-Gangetic Plains has passed through different geotectonic stages. The first stage of movements, concomitant with the rise of Himalayas, appear to have produced the Sindh -Cutch-Cambay basin, Jaiselmer basin and the Punjab basin by the breaking up of the Aravalli-Delhi block of the Peninsular shield. The Assam basin also appear to have developed during this phase of the movements. The Gango-Brahamputra Rift (or the Neogene Siwalik trough) got developed by the sinking of the northern fringes of the Bundelkhand block during the second uplift of the Himalayas. The Ganga basin was then probably a land mass extending upto Shillong Plataeu, and the southern half of the Bengal basin formed a continental shelf of the Bay of Bengal.

The Ganga basin, south of the Gango-Brahmputra rift, got dismembered into four blocks during the third uplift of the Himalayas, and started sinking culminating in subsidence of the Rajmahal-Garo-Sylhet gap in the fourth uplift of the Himalayas. This ultimately established the depression for the development of the present configuration of the rivers of the Indo-Gangetic Plains.

The Indo-Gangatic plains show more activity along the boundaries of the subsided Bengal basin and the block of the Ganga basin, indicating that the shears have not adjusted their strains upto the present day, and are the cause of very frequent earthquakes in the regions. The activity in the other basins is more related with the instability in the surrounding mountainous belts and the hidden ridges, while the basements have almost adjusted themselves except the Cutch and Cambay basin where adjustments are still taking place.

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