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A NOTE ON SEISMO-TECTONICS OF CHOTANAGPUR PLATEAU

BY

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INTRODUCTION

Chotanagpur has received considerable attention of Geologists with a view to win over its rich mineral resources. However, no detailed study of the seismotectonics of this tract comprising of Palamau, Hazaribagh, Gaya, Dhanbad, Ranchi and Singhbhum districts has been made.

The earliest mention of earthquake occurrence in this region was by De. Ballore (1904) who indicated that the Damodar Valley is unstable and had an earthquake epicentre along its bounding faults. Auden (1946) however considered that the region feels only the fringe effects of earthquakes which originate in the Gangetic and Brahmputra plains extending from North Bihar; through Bengal, to Assam. In his opinion since the region forms a part of the stable Peninsula and has not undergone faulting or folding since the Mesozoic era, although it has subsequently been subjected to regional uplifts, severe shocks do not originate in this region. This view is a result of lack of data, as Chotanagpur is a land without a written history and the records are a few of all that has occurred more than two centuries ago. From the seismic point of view little is known and the published work or observations of great authenticity do not exist. This note describes in brief the available evidences on earthquake occurrences and the geomorphological and tectonic evidences for an evaluation of seismo-tectonic setup of the area, which indicates that Chotanagpur plateau should have higher seismic status as severe shocks can occur in this region. As many river valley projects and industrial undertaking have been constructed and are under planning or construction, a severe shock in their vicinity could result in great calamity and disaster.

EARTHQUAKES IN CHOTANAGPUR PLATEAU

Historical records of earthquake occurrences in Chotanagpur plateau are very meagre. The records of earlier history were mostly burnt during 1857 mutiny. Also the area being a jungle country and inaccessible, before the discovery of its vast mineral resources in the nineteenth century, was mostly inhabited by tribal people, who considered all tremblings and rumblings of the earth as the call or curse of "Marang Buru", their mountain God. They all worshipped the highest mountains, and had no very clear conception as to what "Buru" or mountain their devotions should be specially paid, but he was honoured as Lord of the jungles and the ground shakes and trembles at his command. A legend, among these beliefs, and fables which is associated with Gandhammias spring, gives the first indication of a likely earthquake disaster which affected the plateau, forming huge fissures in the ground and rock slides at the site and was probably responsible for many deaths as described below :

The Gandhammias spring is about 9 miles NW of the Kanki Village; temperature 92°F. It is situated at the south end of Soranga Ghat, close to the road

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from Badam to Ramgarh on the left bank of Gandhammia nadi. About 60 yds. down the same bank of the nadi, and from under a block of gneiss rises another spring of the same temperature as the other. The water leaves a white deposit on the rocks and is almost tasteless, but smells, of sulphuretted hydrogen. Cattle drink it, and the natives worship the spot as the residence of a deity. They also use the water in the treatment of skin diseases. The native belief is that long ago, when the road through Soranga ghat was more used than it is now, a large caravan of merchants travelling with pack bullocks once halted on the banks of this nala (river): at the same time an ugly old woman passing by came and asked for alms, which were refused her, so she went farther on to where another caravan was encamped, the members of which proved more charitable, and gave her something. Out of gratitude for this she advised them to place the packs on their bullocks and march on at once, as something dreadful was about to happen. They therefore followed the old hag's advice, but had no sooner departed than the earth opened and swallowed up those who remained, bullocks, packs and all; some few managed to escape, and fled to a hill about two miles off, but when they halted, the earth opened and swallowed them up also. In this way the natives account for the hot springs which rise in both places and mark the spots where the members of the caravan were entombed. (Revenue Survey Report by Capt. E.W. Samuells in Statistical Accounts of Bengal, by W.W. Hunter, Vol. XVI, 1877, p. 43).

Oldham (1883) in his catalogue of Indian Earthquakes from the earliest times to the end of A.D. 1869 has listed the following two earthquakes in Chotanagpur plateau :

1868, JULY, 31ST

HAZARIBAGH—Lasted ten seconds; appears to have come from the north or north east; Felt slightly at Bugodhur, preceded by a loud noise. Proc. Asiat. Soc. Bengal, 1868, p. 257.

1868 SEPT, 30TH

MANBHUM—Lasted one minute, direction apparently from east to west—Friend of India.

DAMUDAH—Loud Rumbling noise, lasted five seconds; travelled from south-west by south to north east by north—Ibid.

HAZARIBAGH—Three distinct undulations lasting forty five seconds.

BIRHUM—in Birbhum slight—Ibid.

De Ballore (1904) in his "Seismic Sketch Map of India" shows an earthquake epicentre south of Hazaribagh on the northern bank of Damodar river near the site of Gandhammias hot springs. De Ballore based his general findings on the seismic catalogues of Oldham, Von Hoff and Mallet and the Annual ones of Perrery, Fuches, and Detaile. De Ballore emphasised that each point plotted in this "Seismic Sketch Map of India" represents the place which marks as nearly as possible the position of the epicentre, and not the place at which recorded to have been felt only.

The foregoing descriptions indicate that an earthquake of considerable magnitude occurred in the Chotanagpur plateau on Sept. 30, 1868 or some earlier date, and one of the possible location of its epicentre was along the northern bank of Damodar near Gandhammi hot springs. This appears to be a probable epicentral site as the region falls along the boundary faults forming the Damodar Valley trough which are probably active.

As the earthquake activity in the Chotanagpur plateau was sporadic and the region was very inaccessible and thinly populated, mention of other earthquake occurrences are not available in old records and documents. However, instances of their being felt in the region have been mentioned by various authors. The Bengal District Gazetteer on Manbhum (now divided as Dhanbad and Purulia districts of Bihar and West Bengal) published in 1911 mentions that "no earthquake has within the memory of man (which cover a period of few decades) has done any serious damage, though that of June 1897 was felt and more recently smaller shocks in May and August 1909" (p. 142). The 1909 shocks appear to be of local origin as no major shocks in north Bihar, Bengal or Assam occurred at this time. The Bihar and Orissa Gazetteer on Hazaribagh (Lister 1917) mentions that "earthquakes have been felt but buildings have not been destroyed" in Hazaribagh district. Similar reports of earthquakes having been felt in Gaya, Ranchi and Singhbhum regions are noted in the old records, which bring out reference to the Great Bihar Earthquake of 1934 and Great Assam Earthquake of 1897.

During the 1934 Bihar Earthquake, the region around Monghyr showed very high intensity, and great damage occurred in the region. This region, which shows tectonic affinities with Shillong plateau (Sarkar, 1968) probably had an earthquake epicentre of large magnitude which occurred within a short interval of time of the occurrences of the main shock in north Bihar. The Monghyr and North Bihar regions thus appear to belong to the same seismotectonic unit and have close inter connections.

The effects of 1934 Bihar Earthquake are remembered well by many of the inhabitants of Chotanagpur plateau. However, some observers report to have, felt earthquakes at later times as well. Dr. S.N. Roy, Chairman, Municipal Board, Hazaribagh, felt an earthquake shock in the rainy season (August/September) of 1938 during which he felt the vibrations to be "coming from east resembling passing of a loaded truck at top gear". Similar occurrence of shocks felt in Hazaribagh were reported to have occurred in late 1937 and early 1938.

Data obtained during the last few years indicate that a large earthquake of Magnitude 5·2 occurred on May 8,1963 in Ranchi plateau with its epicentre south of Lohardaga at lat. 22·5°N and long. 84·5°E, probably along the Western extension of the Copper Belt Thrust zone. During April 1969 a number of shocks were felt in Tatanagar and neighbouring region with its epicentres probably along the Copper Belt Thrust zone.

ORIGIN OF EARTHQUAKES

Presence of numerous faults within the domain of Chotanagpur plateau is suggestive of tectonic origin of the earthquake. In a tectonic earthquake large segments of the earth move relatively to each other, to attain equilibrium by relieving an accumulation of stresses, and trembling and shaking of ground is a related phenomenon. Many indeterminate factors are involved in the cause and mechanism of earthquakes. Current thinking starts with the basic concepts of geological processess responsible for orogenic metamorphic cycles and the formation of mountains and depressions, producing stresses, deformations, failures and release of energy. The lack of detailed knowledge of the materials and their behaviour, and geological processes operative at depths greater than a few kilometers below the surface, are obstacles in the way of establishing a valid and universal hypothesis regarding causes of earthquakes and their mechanism. However, based on the study of geological associations of most of the earthquakes, which are responsible for damage to the structures and originate at shallow depth, the mechanism of earthquakes is described by elastic rebound theory. This theory states that if the strain deformation in the rock in a region increases to an amount beyond the breaking strength of the material a break occurs permitting the material to snap back into a new equilibrium along the two sides of the fracture (fault) which sometimes may cut through the earth's crustal layers and be visible at the ground surface. The vibrations caused by the rupturing are propagated in all directions and felt or heard and recorded as earthquakes.

Furrer (1964) Considers that such tecto-mechanical movements of the part of crustal layers cannot cause shaking in magnitude equal to that caused by an earthquake of medium intensity. In his opinion explosions owing to nuclear phenomenon in the deep crustal layers and upper mantle initiating melting of rocks, migmatization and vulcanism are more probable causes of earthquakes, and such processes could be the cause of initial fractures and faultings due to the generated mobile zones. Later operating forces introduce the tectonics of faulting.

The causes and processes which are responsible for the release of energy are thus not fully understood. However, it is very evident that the causes and processes which were responsible for development of various parts of the earth's surface which must have been accompanied by great earthquakes, may still be operative or repeated or renewed to produce earthquakes. Thus in order to evaluate the seismic potentialities of a region, it is essential to establish its geotectonic framework and monitor if crustal layers are undergoing distortions. This will require detailed geological and structural mapping, establish orogenic cycles, demarcate faults, shear zones and other tectonic lineaments and measure the variation of the physical characteristics in the crust of the earth, indicating accumulation of energy and consequent movements and deformations with suitable instruments. This study alongwith data of known earthquake will help in a better understanding of the mechanism of earthquake occurrence and evaluation of seismic risks.

GEOLOGY OF CHOTANAGPUR AREA

Prior to the evaluation of seismicity of the region a study of its geological set-up is essential. Table 1 and Fig. 1 gives the generalised stratigraphic and orogenic-metamorphic cycles and phases in Chotanagpur plateau.

Chotanagpur forms a chain of highland south of Sone and Ganges river and is classified as a plateau which inturn comprises of many subplateaus lying as distinct geomorphological units in relation to each other and the differentiation in various geomorphological units is an indication of different tectonic framework, varied lithology, and drainage pattern.

These high lands, as plateaus and sometimes a range of hills and isolated peaks, form four distinct physiographic units in the region : (1). The Hazaribagh-Ranchi plateau, (2). Champaran—Koderma—Giridih—Monghyr—Sub-plateau, (3). Dhanbad plains, and (4). Damodar Valley trough. The development of these units described in detail by Dunn (1941) appears to be intimately connected with the cymatogenic uplift (Tipnis and Srivastava 1968) and volcanism of the Satpuran land mass, and the region appears to have not yet attained stability which is indicated by movements in the Tertiary, Pleistocene and Present times. When viewed from plains of Bihar the sub-plateau appears to look like a part of range of hills uniform in height, which in reality is the edge of the plateau elevated about 245m (800 ft.) from the level of Ganges plain. The slope of this plateau to the East is uniform and finally merges with the plains of Bengal. The deep valley of Lilajan river forms the western boundary of the sub-plateau. The southern boundary consists of 300 to 370m (1000 to 1200′) high faces of the Hazaribagh plateau as far as its eastern extremity, where for some distance a low and undistinguished high land runs eastward to the western spurs of Parasnath Hills. This plateau so contained has a general elevation of about 400m (1300′). In this belt north of Koderma the streams are rapidly cutting down-wards. The headwaters of these streams are extremely active and are rapidly cutting back into the plateau, removing the alluvium and forming widespread bad land along the edge of the plateau, which merge into the deeply dissected belt to the north. The whole of this dissected belt is clear evidence of comparatively recent uplift. Uplift has occurred in stages and alluvium deposited during earlier stages of uplift at the debounchment of the rivers has been eroded and left as terraces and cliffs, examples of which can be noted on the Koderma—Patna Road. Also the manner in which some of the larger streams tend to deposit segments within their debounchment suggest a reversal of movements with subsidence at the extreme northern edge of the belt.

The Hazaribagh and Ranchi Plateau have an average height of 615m (2000 ft.) with a number of isolated conical Peaks going upto 770m (2500 ft.) height. The rise of the Hazaribagh plateau is abrupt along its north eastern and southern sides, but in the west it narrows and decends slowly in the neighbourhood of Simaria and Jabra, where it curves to the south and connects with the Ranchi plateau. The plateau is being subjected to rapid erosion around its edges, and is a region of differential block movements along its sides.

The Damodar River which starts in Palamau district 40 km. from the boundary of Hazaribagh forms a trough between Hazaribagh plateau on the north and Ranchi plateau of the South resulting from fractures at their present edges which caused the land between them to sink to considerable depth. This trough is considered to date back to Upper Carboniferous Lower Gondwana period. But the present position of the Chope coalfield on the Hazaribagh plateau, Itkhori Coal fields (32 km. North of Chope coal fields) and Giridrh coal field north of Damodar in relation to Jharia, Bokaro, Ramgarh and North and South Karanpura and other coal field in Damodar Valley, indicates that all these regions probably had interconnections forming a large basin, which later was subjected to differential uplifts with respect to each other. The coal measures in the Chotanagpur thus were probably deposited at higher elevations with respect to the present level of the bounding gneisses and the Damodar Valley trough does not appear to be the old basin, rift or graben in which Gondwana sedimentation took place. The Damodar Valley trough appears to be a branch of Satpura rift initiated in Pre-Rajmahal times, and culminating in Deccan Traps activity. The traps on alteration produced the bauxite deposits of Ranchi Plateau. The main step like subsidence of Chotanagpur is thus probably post-Deccan Trap and later erosion has produced the present Configuration. The Damodar Valley also shows evidences of rejuvenation in the incised meanders, raised flood plains and terraces of sandy and alluvial soil faced here and there with rocky, ledges, sag ponds filled with clayey and sandy materials and steep cliffs of hard gravelly sediments furrowed into countless small channels by the discharge of surface drainage. The northern boundary of the, Damodar Valley trough between the Ranchi and Hazaribagh plateau is deep as far as the south eastern corner of the Hazaribagh plateau, where the Konar catchment starts. On the south, the Damodar follows the edge of the Ranchi plateau, till it has passed Ramgarh, after which it turns to the north east probably along a major fault, leaves on the south a wide and level valley on which Subernrekha river begins to intrude, till it is abruptly diverted by Singpur hills to the south. On the south of the Damodar the ground rises sharply to the Ranchi plateau indicating major fracture and recent uplifts. Seen from the north the edge of Ranchi plateau has the appearance of a range of hills.

Further to the east, where the Damodar turns northwards, a triangle of hills probable bounded by major faults rises. On the north of the Damodar upto the Parasnath Hills the ground rises gently upward upto the water divided of Jamunia river. The Damodar Valley passes tamely towards east into Dhanbad and Purulia alluvial plains.

According to Dunn (1939) the above geomorphological configuration of the Chotanagpur plateau north of Singhbhum region has resulted due to northerly tilt and uplift, during Tertiary and Pleistocene times, of the order of 760 to 820 mts. (2500 to 2700 ft.) at latitude 23° with respect to Rajmahal region along latitude 25° which acted as a hinge, and north of the hinge progressive down warping in response to the Himalayan uplift produced the accumulation of over 2000 meters of fresh water sediments.

This northerly tilt of the Chotanagpur plateau probably formed the northern half of the cymatogenic upwarp which produced median fractures along the Damodar trough, resulting into uplift and subsidences along medians and cross fractures in steps of 245m (800 ft.), and 368m (1200 ft.) from the alluvial plains, to the top of the plateau and subsidence of 245m (800 ft.) along Damodar in between the Hazaribagh and Ranchi plateau. The Chotanagpur plateau thus represents a horst topography which has not been peneplained so far. This geotectonic pattern is indicative of comparatively late uplift and it is likely that the movements have not stabilised so far and could produce earthquakes.

The rocks of Chotanagpur have undergone various degrees of metamorphism at depth and their present position near surface is a result of uplifts and other orogenic movements. As stated earlier comparative study of Chotanagpur metamorphic orogenic cycles with that of Shillong plateau reveals similarities between the two and the metamorphic, lithologic and tectonic characteristic of both Chotanagpur and Shillong plateau are thus interrelated to each other as both have been affected by the Indian Ocean orognnic cycle (350-600 ml.). At present they also appear to be geomorphologically similar to one-another. The comparative study of drainage pattern, orientation and development indicates similar tectonic control.

Presence of numerous hot springs, lying in close association with faults and Monghyr orogenic trend is also suggestive of some kind of energy accumulation and higher thermal gradients inside the ground, which in turn may be an indication of some subsurface operative geological processes. These springs are considered by Chatterjee (1968), to be affected by Mesozoic volcanicity and/or post Gondwana tectonic movements, because of their being located in pre-Cambrian crystalline shield subjected to large scale tectonic dislocalions. In his opinion the path of circulation of such springs developed following extensive dislocations in the marginal fringes and wedge blocks of the Peninsular shield commencing from late Tertiary periods and continuing till present day in some cases, deriving their heat from a source generated from large scale dislocation and deformation movements which were subsequently trapped in a thermo-static condition in the geologic past. or the heat is being supplied by magmetic emmanations not necessarily deep seated which are normally ubiquitou in zones of extensive and intensive movements. As the Chotanagpur region at present is being subjected to seismic movement the thermal springs and seismicity of the region appears to be genetically interrelated.

SEISMOTECTONIC UNITS

One of the probable geological processes operative in this region appears to be the continued upwarping of the crust which had its median flexures following Damodar Trough. Such an upwarping could also produce readjustments and movements along the pre-existing median and transverse fractures extending to great depths. The various tectonic blocks bounded by such fractured surfaces forming the crust in this region are thus tectonically related to each other and movement in any of these could produce an instability of the whole region with possible movements and readjustments in adjacent blocks. Based on the geomorphologic, metamorphic and tectonic fractures of the Chotanagpur plateau, the region can be subdivided into the following seismic belts each having characteristic seismic activity and tectonic framework : Gaya Monghyr belt, Damodar Valley Trough, Gneissic Belt of Hazaribagh, and Ranchi Plateau, Copper Belt Thrust zone and Singhbhum Thrust.

(I) Gaya Monghyr Belt—This belt has shown the highest seismic activity and many mineral and thermal springs are noted in the region. The Monghyr region probably was the site of a subsidiary epicentre during the 1934 Bihar earthquake with M. M. Intensity greater than IX. This belt forms the marginal fringe of the great mobile belt of the Gangetic trough and is susceptable to great movements.

(2) *Damodar Valley Trough Belt*—This belt, which appears to have developed due to subsidence during cymatogenic warping of Satpura land mass has undergone considerable movements during the recent times as revealed by raised tarrance materials and other features. A major earthquake also appears to have occurred along its banks. A number of mineral and thermal springs are found to occur along this belt near the contacts of Gondwana deposits. This belt thus appears to be the next active belt of this region.

(3) *Gneissic Belt of the Ranchi-Hazaribagh Plateau and Champaran-Koderma-Giridih Sub-Plateau*—This belt also shows evidence of movements and existence of several mineral and thermal springs. The belt consists of many shear zones along which mineralisation has occurred. Some of these shear zones are likely to be active, but the location and their trends are not well demarcated. Also no major shock appears to have originated along them. This belt thus appears to be much less active except along the junctions of the plateau and sub-plateau along which movements may be occurring during present time and earthquakes originate along them. The likely magnitude and intensity of these shocks cannot be forecast with any reliability as the observed data is very meagre. But based on the data in other localities, it indicates that being a part of the Satpura cymatogenic upwarp the region is not stable and earthquake can occur in future. History suggests that these will be of small magnitude.

(4) *Copper Belt Thrust Zone*—This belt has also shown activity during recent times (April 1969) and earthquakes were felt in Tatanagar and surrounding regions. The copper Belt thrust and associated thrusts were formed in Pre-Cambrian time. The rejuvenation of activity along them appears to be related to some local causes which initiated slips along the preexisting fracture surface which requires detailed study.

5. *Singhbhum Belt*—The Singhbhum-Mayurbhanj belt does not appear to have suffered orogenic—metamorphic changes since the Pre-Cambrian. No mineral and thermal springs are reported from this belt. The belt thus appears to have the lowest seismic status during the present time.

SUMMARY AND CONCLUSIONS

Based on the study of past records, geology, and tectonics of Chotanagpur plateau it is noted that the area is seismic and the earthquakes have occurred in the region in the past. Detailed records of the effects of these earthquakes are not available. Thus the probable intensities during future earthquakes in the region can be gauged from the likely seismic potentialities of the various seismotectonic features present in the region and on the basis of observed intensitities along similar seismotectonic fractures in adjacent regions of Madhya Pradesh, North Bihar, Bengal and Assam (Fig. 1 shows the seismic belts of the region showing maximum M. M. Intensities to be considered for design of important structures.)

Seismic maps as above are tentative and require detailed confirmation by installing a network of seismological observatories so that the seismic status of the various tectonic features can be assessed. One seismological observatory exists at Bokaro, Establishment of seismological observations at Palamau, Lohardaga, Hazaribagh, Ranchi, Tenughat Dam Site, Giridih, Jamshedpur, Gaya, Kodarma and Monghyr in Chotanagpur Plateau is recommended. The records from these observatories coupled with regional geological and tectonic mapping of the region will help in more precisely delineating the various seismic zones It is also very important that suitable survey bench marks and measurement of relative movement between Hazaribagh and Ranchi plateau, Damodar Valley Trough and adjacent land masses, copper belt thrust and associated shear zones. and Champaran-Koderma-Giridhra-Monghyr Sub-Plateau be made. It is anticipated that the movements are occurring in these region with respect to each other as well as with respect to alluvial plains of north Bihar.

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REFERENCES

1. Auden, J. B., "Note on Earthquake in Relation to Damodar Valley Project", Goel. Surv. India, Feb. 1946 (unpublished report).

2. Chaterjee, G. C., "Mineral and Thermal Waters of India", International Geological Congress, Vol. 19, Report on the Twenty-Third Session, Czechoslovakia, 1968.

3. Coupland, H., "District Gazetteer on Manbhum", Bengal District Gazetteers, 1911.

4. De Ballore Court F. De Montessus, "The Seismic Phenomena in British India and their Connection with Geology", Mem. GSI, Vol. 35, pt. 3, 1904.

5. Dunn, J. A., "Post Mesozoic Movement in Northern Part of the Peninsular—Bihar—Nepal Earthquake of 1934" Mem. Goel. Surv. India 73—p. 137–142, 1939.

6. Dunn, J. A., Economic and Mineral Resources of Bihar Provinces", Mem. GSI Vol. 79, 1941.

7. Furrer, H., "Earthquakes and Mountain building," Report of the Twenty-Second Session India, Part XI Proceedings of Section 11, International Geological Congress, 1964.

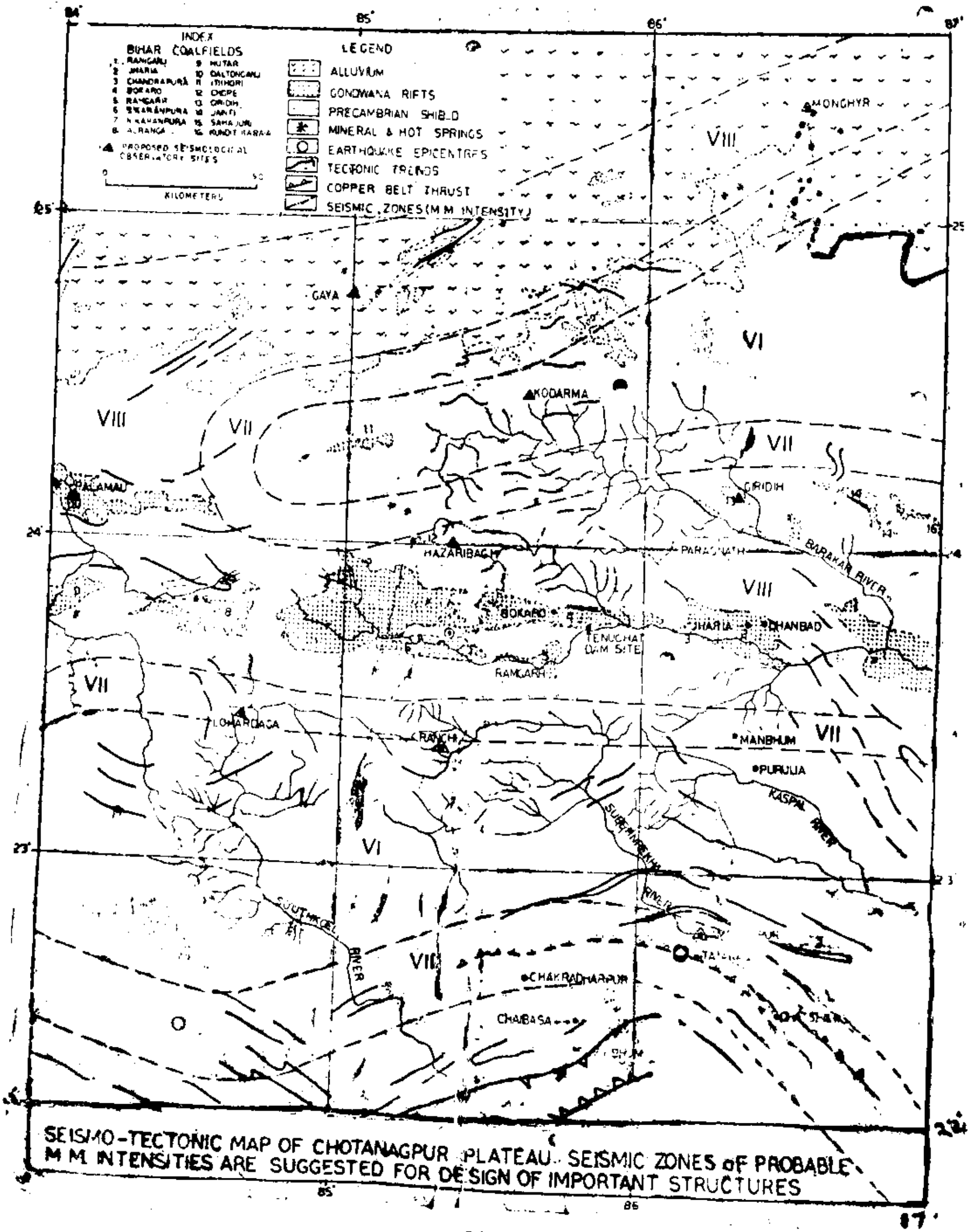
8. Hunter, W. W., "Statistical Account of Bengal-District of Hazaribagh" Vol. XVI, Trubuner and Co., London, 1897.

9. Lister, E., "Bihar and Orissa Gazetteers—Hazaribagh", Suptd. Govt. Printing Press, Bihar and Orissa, Patna, 1917.

10. Oldham, T., "Catalogue of Indian Earthquakes from the Earliest Times to the End of A.D. 1869", Mem. GSI, 19, Pt. 3, 1883.

11. Sarkar, S, N. "Pre-Cambrian Stratigraphy and Geo-chromology of Peninsular India", Dhanbad Publishers, India, 1968.

12. Tipnis, R. S. and Srivastava, L. S., "Volcanism, Tectogenesis and Seismicity of Deccan Traps" Bull. Ind. Soc. of Earthquake Technology, Roorkee, Vol. 5, Nos. 3 and 4, Sept.-Dec. 1968.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SEISMO-TECTONIC MAP OF CHOTANAGPUR PLATEAU. SEISMIC ZONES OF PROBABLE M M INTENSITIES ARE SUGGESTED FOR DESIGN OF IMPORTANT STRUCTURES

Fig. 1.

TABLE I

Generalised Stratigraphic and Orogenic-Metamorphic Cycles and Phases in Chotanagpur Plateau. The Ages are in Million of Years Indicating Closing of Events, and those with (Sed.) time of Sedimentation.

Era	Age in million years			
Quaternary	0–1	0–25 *Tilting, Uplift, Step and Block*		
Tertiary	1–60	*Faulting and Rifting during Tertiary and*		
Mesozoic	60–180	*quarternary* (= ?)		
Upper Palaeozoic	180–350	25–90 (?) 130–150 (?) 155–160 (?) Deccan Traps—Rajmahal-Supra-Panchet Bed Sed. 170–225 Lower Gondwana		
Lower Palaeozoic	350–600	358–420 Monghyr		
Upper Proterozoic	600–900			
	900–1600	955 Gaya 850–1550 Singhbhum	930 Gurpa 846–949 Gangpur	890–980 Ranchi-Muri 893–1086 Dhanbad
Middle Proterozoic	1600–2000	Sd. 1700–2000 Singhbhum-Gangpur-Dhanjori		Sed. C. 1600 Kolhans
Lower Proterozoic	2000–2500			
Archean	2500–3000	C. 2700 Iron ore		
Katarchean	3000–3500	C. 3200 Older Metamorphics		