SEISMICITY AND TECTONIC SETUP OF THE AREA AROUND DELHI

By

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ABSTRACT

An evaluation of earthquake data in relation to the tectonic setup of the area around Delhi has been carried out. Statistical analysis of the instrumental data together with studies regarding strain rebound increments and tectonic flux revealed that the NE-SW trending minima zone interpreted on the tectonic flux map possibly indicates a zone of fundamental fracture in the basement having the pattern of regional tectonic lineaments which is likely to have genetic relationship with the majority of earthquakes recorded in this area.

INTRODUCTION

Earthquakes could be one of the major geological hazards to the environments of the area around Delhi where urban and industrial developments are progressing at fast rate. In the year 1963, there was considerable increase in the frequency of earthquakes in Sonepat area where quite often thundering sounds accompanied by shaking of the ground were reported. Since then the seismological observatories at Lodi Road and Ridge in Delhi; Sonepat; Rohtak and Meerut have recorded numerous low magnitude earthquakes with epicentres located in all direction from Ridge observatory. The available seismological data of minor earthquakes for the period June 1963 to December 1973 have been studied in relation to the geo-tectonic setup of the area.

HISTORICAL RECORDS AND CONSIDERATIONS FOR SEISMICITY STUDIES

Historical records of past earthquakes are scanty. The 1720 Delhi earthquake; 1956 Khurja earthquake; and 1960 Gurgaon earthquake had their epicentres located in the neighbourhood of Delhi. The two most important known earthquakes which affected Delhi region are (1) Delhi earthquake of 15th July 1720 and (2) Mathura earthquake of 1st September 1803. The Mathura earthquake of 1803 reportedly gave a violent shock which was felt upto Calcutta. This caused extensive fissures in the ground near Mathura through which water rose with considerable force. There is mention of a Kumaon earthquake of 1803 (8,9) which had intensity VIII in Delhi area and had thrown down the cupola of Qutabminar, but the date of occurrence of this earthquake is not given. Whether this Kumaon earthquake of 1803 is the same earthquake which has been referred as the Mathura earthquake of 1st September 1803, is not known. In the year 1842, again there was an earthquake of lesser intensity having epicentre near Mathura. Intensity VII on M.M. Scale in Delhi area had been recorded during 1960 Gurgaon earthquake but during 1956 Khurja earthquake it was moderately affected. The intensity of known earthquakes in Delhi area or its vicinity possibly had not exceeded IX on M.M. Scale which as per empirical relationship corresponds to Richter magnitude 6.7(5).

While utilising empirical method for determining the value of Richter magnitude from M.M. intensity scale, caution is necessary because the intensity of the earthquake in an area varies considerably depending upon the local geological conditions and also its location with reference to the epicentre. The damage to the civil structure is generally related to its design, foundation condition, local and regional geological setup, the distance of the structure from active tectonic lineaments and also the

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orientation of the structure in space with reference to the direction of the earthquake wavefront. Hence, determination of design earthquake parameters for a site needs careful scientific/engineering appraisal and seismo-tectonic evaluation of all the available quantitative data. The study related to seismicity of an area, therefore, needs proper exploration for identification of active tectonic lineaments, instrumentation across their traces and collection of data on long term basis for properly understanding the cause of earthquakes, the place of origin and their true behaviour.

According to the concept given by Beloussov (1954) in Ray (1964,(7) the fundamental dynamics of the crust is generated by vertical oscillatory movement along the planes of tectonic lineaments which are deep regional dislocations bordering crustal blocks of significant dimensions. The paper discusses one such tectonic lineament; deformations or sudden dislocations along which might be causing earthquake in Delhi region.

GEOTECTONIC SETUP

In the area under consideration the rocks belonging to Delhi supergroup of Proterozoic age are exposed in small discontinuous hillocks which lie within wide expanse of flat terrain mainly comprised of aeolian and some alluvial deposits of Quaternary age. The rocks exposed around Delhi are quartzites with thin interbeds of mica-schists. An isolated rock outcrop south of Rohtak is probably the extension of the rocks exposed west of Rewari. These comprise slates, carbonaceous phyllites and minor quartzites. In the area south-west of Karnaul, calc-schists, calc-gneiss, marble, calc-silicates and quartzites are exposed in which instrusive granite bodies are also present. Pegmatites intruding the country rock are throughout present in the area. The trends of faults and major shear zones generally vary from NNE-SSW to ENE-WSW. The strike of the formations varies from NNE-SSW to NE-SW, in general. Two axes of folding trending NNE-SSW and NW-SE have been noted. NNE-SSW trending structures are doubly plunging and tightly folded whereas the folds with axial trend NW-SE are broad and open.

The structural features in these rocks having several near strike faults correspond with the Aravalli trend having NNE-SSW to NE-SW direction. Qureshy (1964)(6) has found NE-SW trends of the Bouguer gravity contours in parallelism with the Aravalli and Eastern-ghat strike and the NW-SE trends in parallelism with the Dharwar and Mahanadi strikes. According to him gravity maximas generally indicate horst structures whereas the gravity minimas indicate a graben. Between horst and graben differential movements have been interpreted to occur along fundamental zones of weaknesses indicated on gravity anomaly map (Qureshy 1964)(6). From this map it is evident that in the area lying west of Delhi, a gravity maxima passes through Ajmer, Khetri and Panipat whose trend is N35°E-S35°W. The NW-SE trending gravity anomaly areas are not defined in Delhi region.

QUANTITATIVE MEASURES OF SEISMICITY

India Meteorological Department has furnished seismological data as regards main characters of the earthquakes such as, their magnitude, the location of epicentres, depth of focus, and the frequency of earthquakes, which generally indicate the tectonic features. The authors have utilised these data for studies related to strain rebound increments and tectonic flux.

If elastic strain is built up along the fault plane, ultimately it results into displacement and the potential energy is released in the form

of seismic waves. Benioff (1949 & 1955) (2,3) has established that the elastic strain is directly proportional to the fault displacement and also to the square root of the potential energy released as seismic wave during an earthquake. Amand (1956)[1] has proposed specific seismicity and tectonic flux as two measure of seismic activity. According to him, the tectonic flux is proportional to the rate of strain released in an area whereas the specific seismicity is related to the rate of energy released. Hence the maps contoured in either measure can express the seismic activity of a region[1].

Both the parameters mentioned above are dependent upon the determination of the energy released by an earthquake. Richter 1935[4] had designed a magnitude scale to compare the energies released by the earthquakes. Gutenberg and Richter(1942)[4] have found an expression for calculating the energy released by an earthquake having known its magnitude. The formula is given below:-

Log $E^{\frac{1}{2}}$ = 4.5 + 0.9M where E is the energy released in ergs and M is the Richter Magnitude of an earthquake.

Utilising the above mentioned formula and the concepts of Benioff and Amands, the strain rebound increments and tectonic flux maps have been prepared (Fig.2&3). The strain rebound increments is a graph showing the cumulative strain factor 'E' in $(ergs)^{\frac{1}{2}}$ given by Gutenberg and Richter's equation plotted against period of June 1963 to Dec. 1973 for thirtysix shallow earthquakes of magnitude 3 and above. Each rod shown in the graph (Fig.2) represents one earthquake and the relation between rod height and magnitude has also been shown. For preparation of tectonic flux map (Fig.3) the same 36 earthquakes of magnitude 3 and above have been considered and five minutes latitude and longitude area has been taken as a unit. The results of the above mentioned studies are outlined below:-

(a) Statistical studies: The earthquakes range in magnitude from 0.9 to 4.2. The zones of concentration of epicentres (I) 20 to 25km, (II) 40 to 45km, and (III) 60 to 70km. are located towards WSW, NW & WNW respectively from Delhi Ridge observatory (Fig.3). It has been observed that depth of focus of majority of earthquakes falling in zone-I range from 3km. to 7km. Similarly the focus of earthquakes falling in zone-II and III are ranging from 7 to 12km., and 12 to 17km. (Fig.1).

(b) Strain rebound increment studies:- The data available for study covers a short period. It is, therefore, inadequate for arriving at conclusions regarding rate of strain release, However, it reveals that the period of quiescence is followed by a period of increased seismic activity which persists till the entire accumulated strain is released either by one shock of greater magnitude or several shocks of lesser magnitude. The cycle is repeated one after the other.

(c) Tectonic flux studies:- The energy release contour map (Fig.3) having a contour interval of 1×10^{7} $(ergs)^{\frac{1}{2}}$, has revealed three maxima zones. Between these maxima zones there are two minima zones of which one trending NE-SW and lying south of Sonepat and Narnaul is more pronounced. The other minima zone trends N30°W-S30°E and passes through Meerut. It may be noted that the zones of concentration of epicentres mentioned earlier are located by the side of NE-SW minima zone whereas the epicentres located in the vicinity of N30°W-S30°E trending minima zone are few and sparsely distributed.

DISCUSSION

The formational and structural trends varying from NNE-SSW to NE-SW recorded in the outcrop area correspond fairly well with the Bouguer gravity contours (Qureshy 1964); the trends of the lineaments indicating gravity maxima and minima (Qureshy 1964); the trend of the Delhi-Hardwar Ridge and Moradabad fault (Tectonic Map Oil & Natural Gas Commission 1968), and the trend of the pronounced depression in the top of Archaean-Proterozoic basement contours shown in the area lying west of Delhi on the Tectonic map of India by Geological Survey of India (1963). The NE-SW trending minima zone indicated on the tectonic flux map falls in the central portion of the basement depression mentioned above. The eastern limit of the Delhi-Hardwar ridge shown on the Tectonic map (O.N.G.C.-1968) also passes through this basement depression though its trend is N35°E-S35°W. No tectonic lineament trending NNW-SSE is shown in this area on the Tectonic Map of India (G.S.I. 1963 and ONGC 1968). The N30W-S30E trending minima zone indicated on the tectonic flux map corresponds roughly with the trend of Archaean-Proterozoic basement contours shown in the area east of Delhi. Possibly it is a much subdued feature. Therefore, it is surmised that the NE-SW trending minima zone interpreted on tectonic flux map indicates the same basement lineament which has been marked on the tectonic map forming the eastern limit of Delhi-Hardwar ridge as the skewness of 10 degree in interpreted trend is insignificant specially when the feature is concealed below a thick cover of Quaternary deposits. This NE-SW trending minima zone represents a zone of fundamental fractures in the basement having the pattern of regional tectonic lineaments and possibly has genetic relationship with the majority of earthquakes recorded in this area.

The data studied represent only a short period of time. Precise geodetic surveys and instrumental record of minor shocks across this zone may provide better understanding of the seismic status of this feature. Geophysical techniques, if utilised, may help in delineation of the seismogenic feature interpreted on the basis of seismological data because, if present, it lies covered under thick Quaternary deposits in the area.

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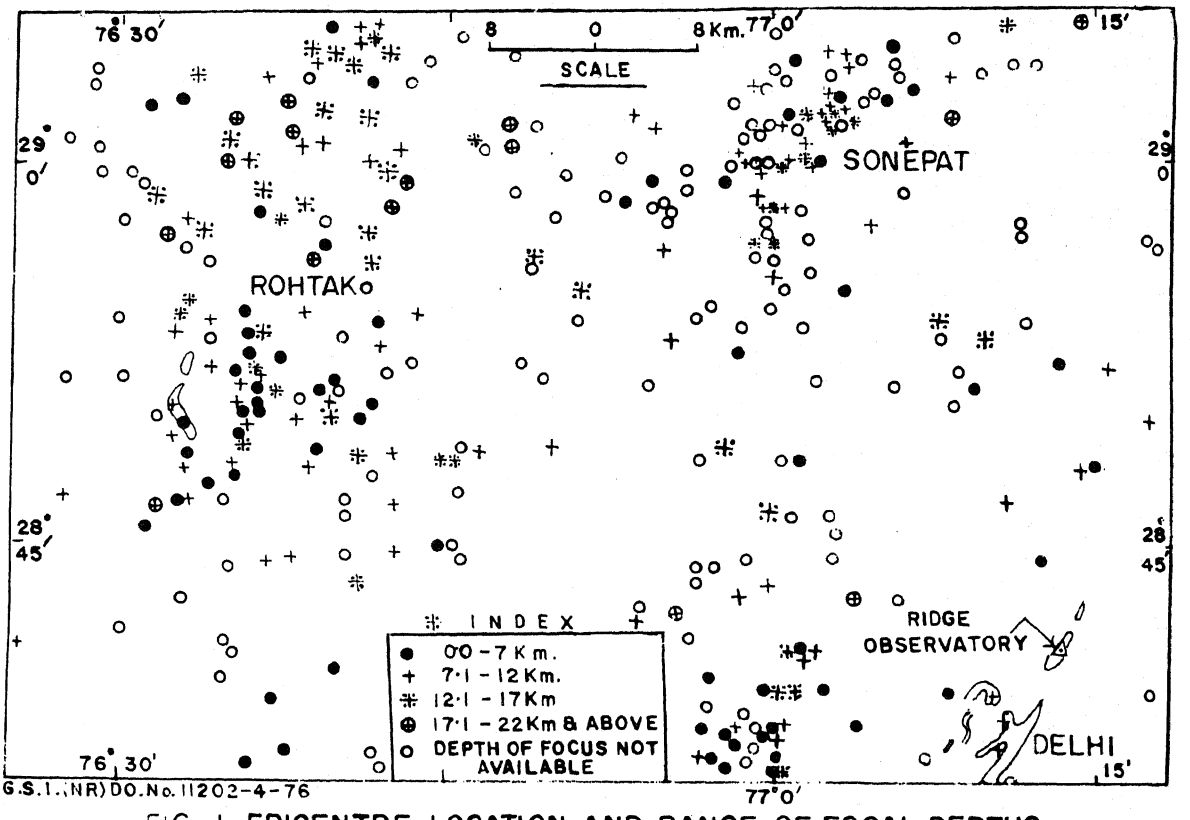

FIG-1. EPICENTRE LOCATION AND RANGE OF FOCAL DEPTHS

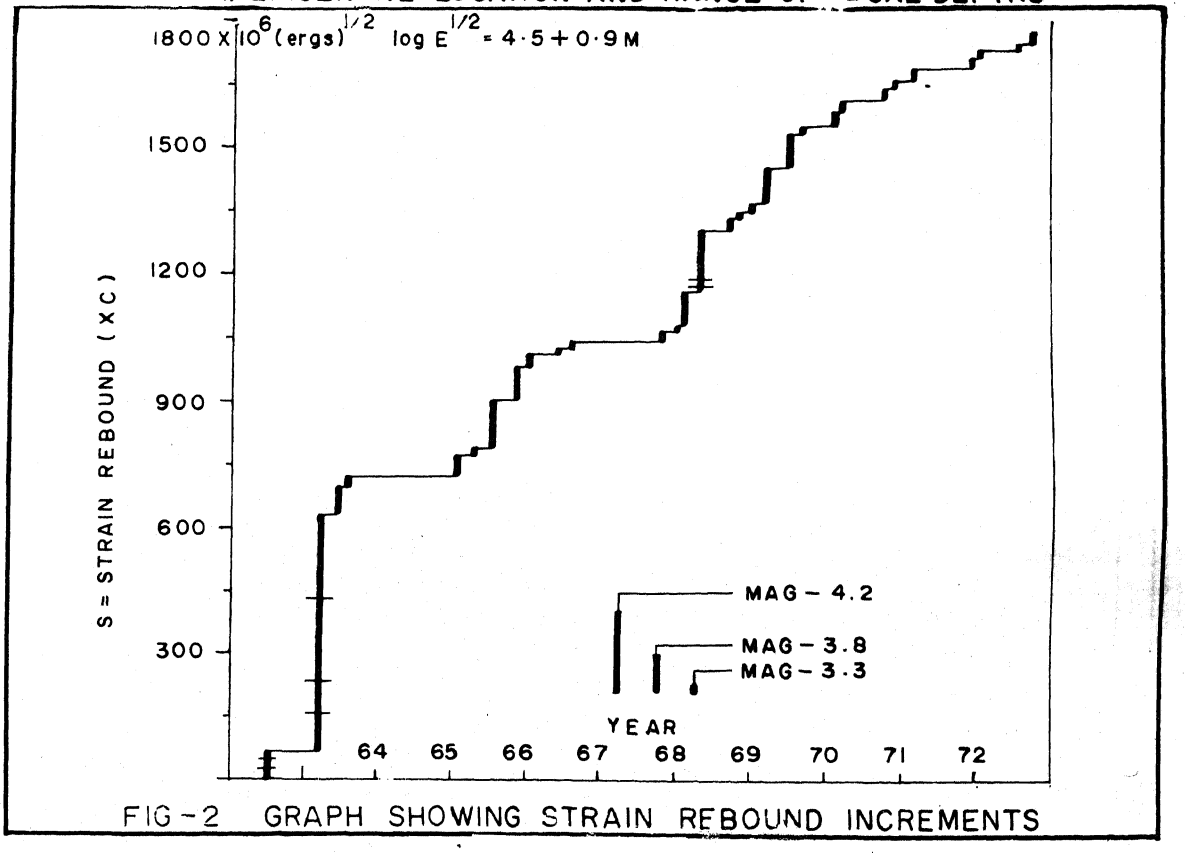

FIG-2 GRAPH SHOWING STRAIN REBOUND INCREMENTS

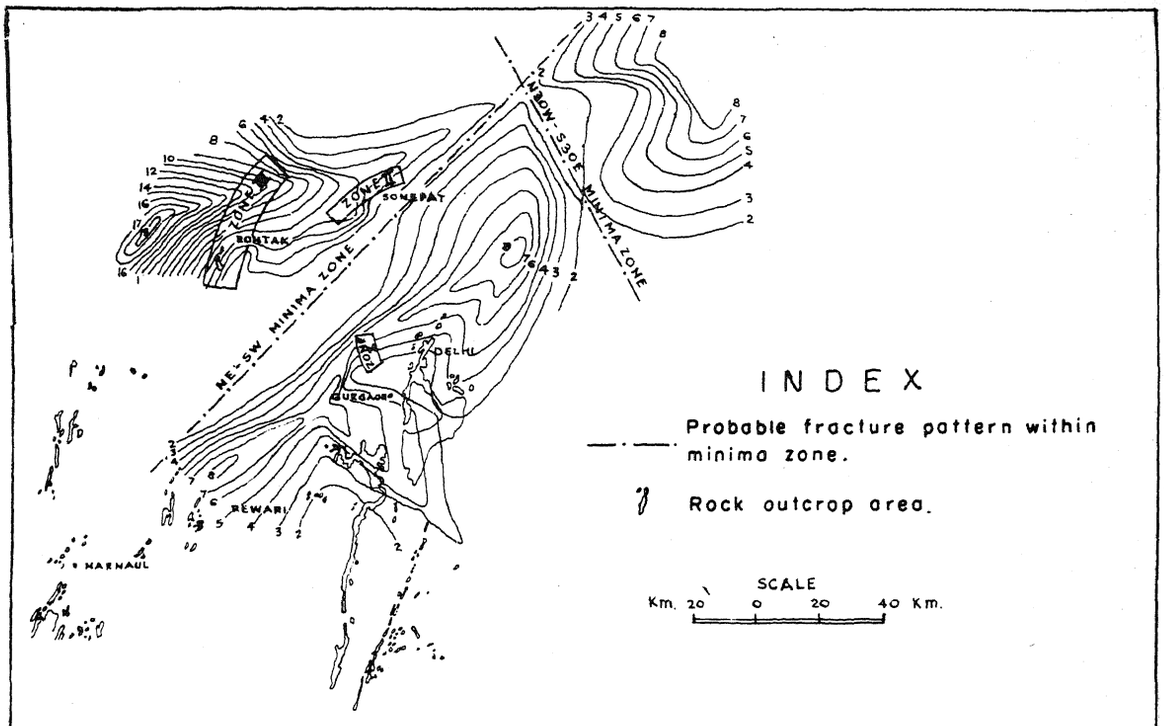

Fig. 3 TECTONIC FLUX MAP SHOWING ZONES OF CONCENTRATION OF EPICENTRES

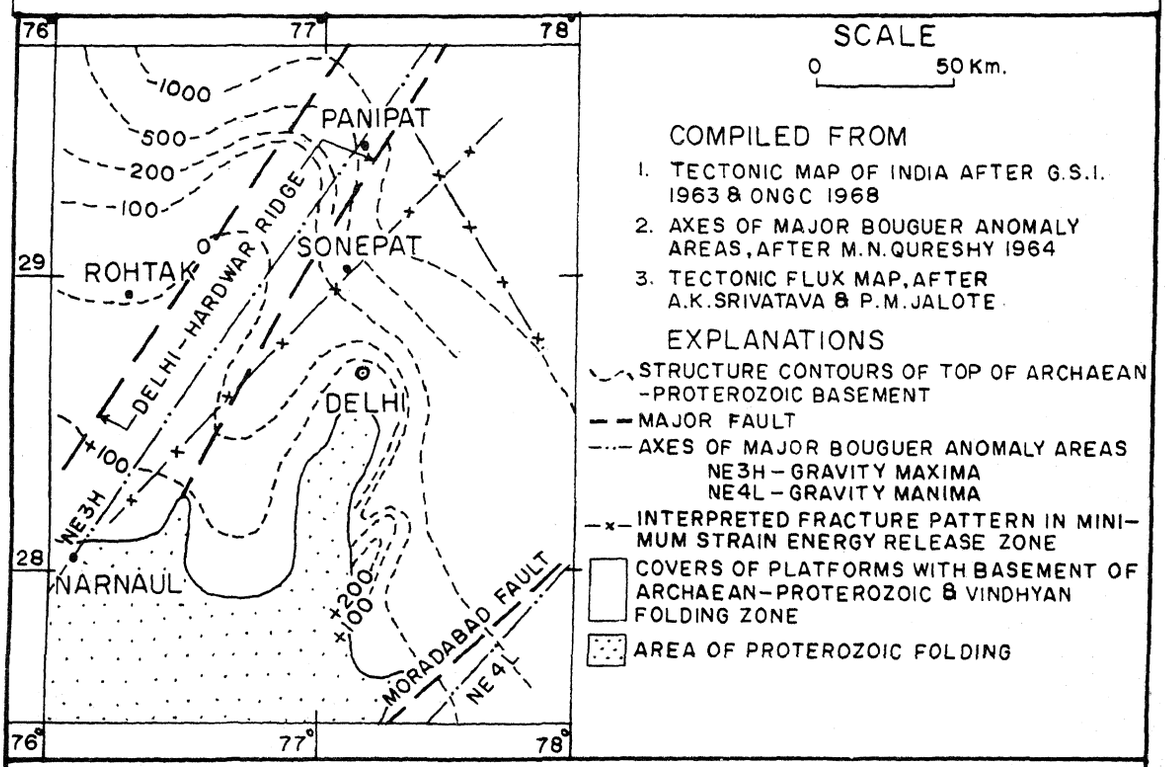

FIG – 4 TECTONIC MAP OF THE AREA AROUND DELHI

DISCUSSION

V.P. Kamble (India)

A detailed study on the "Recent seismic activity associated with Tear faults in Delhi and neighbourhood" has been carried out by us.

i) The distribution of averaged earthquake foci showed that there are several dipping planes particularly towards North of Rohtak, NNE & E towards Najafgarh.

ii) There is also a very systematic localised migration of seismic activity with a velocity between 2-11 km/year.

iii) The strain release patterns though showing NE trend are associated with different faults.

iv) The geological structure is complex and there are several parallel faults.

The question is that whether the authors have taken into account these factors while evaluating the correlation between fault planes and earthquake distribution.

B. Ramachandran (India)

a) It is better to use the term tremor at many places as earthquakes are a much larger phenomena.

b) According to the authors seismological data generally indicate tectonic features. This is rather a vast generalisation, which need further elucidation with reference to this particular case.

c) The relation of concentration epicentres to the depth of focus does not appear to be very valid.

d) In the tectonic flux map, the NW-SE fracture is not explained nor correlated to any tectonic lineament. It is said to correspond to "Archean proterozoic contact" and is a subdued feature. This needs further elucidation.

Author's Closure

With regard to the question of Mr. Kamble, we wish to state that the information furnished by Mr. Kamble requires reconsideration particularly relating to his interpretation of several different parallel faults. The bedrock geology is concealed below a thick cover of quaternary deposits in the area, hence the interpretations must be confirmed by proper exploration. The authors have already taken into account all the data.

With regard to the querries of Mr. Ramachandran, we wish to state that

a) Once the magnitude of the earthquake is specified, there should not be any confusion.

b) Everywhere in the world efforts are being made to delineate tectonic features based on seismological data. Similar effort has been made in this case also.

c) The validity of concentration of epicentres in relation to the depth of focus has not been discussed. The data regarding the depth of focus given in the paper is a record of fact brought out by the present studies.

d) It is evident from the tectonic flux map that the maxima zones by the side of NW-SE trending minima zone are not so well pronounced as found by the side of NE-SW trending minima zone, hence this feature has been considered as subdued compared to the NE-SW trending minima zone. Since the paper deals with the seismicity of Delhi area which mostly falls in NE-SW trending minima zone, this feature has been considered more significant than the other minima zone for this area. The NW-SE trending minima zone might also be indicating a tectonic lineament in parallelism with the trend of contour of the Archaean-Proterozoic basement.