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TANGSHAN EARTHQUAKE OF JULY, 1976 AND ITS AFTERSHOCKS[1]

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Introduction

China is one of the seismically most active regions of the world, where 500 to 1000 destructive earthquakes are reported to have occurred during the last 2000 years (Seismological Committee, 1956). Of these the Sian earthquake of January 23, 1556 was responsible for almost same number of deaths as the recent earthquake in the industrial city of Tangshan on July 28, 1976. The greatest economic loss due to the recent earthquake was reported to have occurred in the Kailuan region which is China's foremost coal producing area. Serious damage was also caused as far as 150 km. from the epicentre at Tientsin and Peking. During the earthquake, flashes of light were seen on the horizon by numerous observers.

In the present paper, seismological data for Tangshan earthquake of July 28, 1976 and its aftershocks has been studied. The source mechanism and aftershock characteristics have been discussed.

Epicentral Parameters

The epicentral parameters of the Tangshan earthquake of July 27, 1976 (according to G.M.T.) as determined by the International Seismological Centre, U.K. were as follows:

Epicentre	39.56°N
	117.87°E
Origin time	19 hr 42 m 54 sec
Focal depth	10 Km
Magnitude	MB (ISC) = 6.1
	(USGS) = 6.3
	MS (USGS) = 8.0

The main earthquake was followed by numerous aftershocks out of which the largest (MS = 7.4) one occurred about 14 hours later. Another strong aftershock (magnitude 6.5) occurred on November 15, 1976 in the same region.

Regional tectonics in north-east China

Tapponier and Molnar (1977) have reviewed in detail the tectonics of China and have supplemented their results based on an interpretation of Land sat (Satellite) imagery (Fig. 1). It is seen that most of the damaging earthquakes in the past have occurred along the margins of the Ordos block. In its south eastern margin, Wei Ho graben bends to a north-easterly direction and joins the Fen Ho en echelon graben system which stretches to the vicinity of Wu Tai Shan (40°N, 113°E), 700 Km to the north-east. This system comprises a series of elongated depressions filled with fiat Quaternary alluvium and bordered by steep normal faults, specially on their southeastern sides. All normal faults trend approximity N 50°E.

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Other straight fault segments trending in a more north easterly direction (N 20°E) are primarily strike slip. No significant seismic activity has been reported in China north of 42°N latitude or east of 122°E longitude in China.

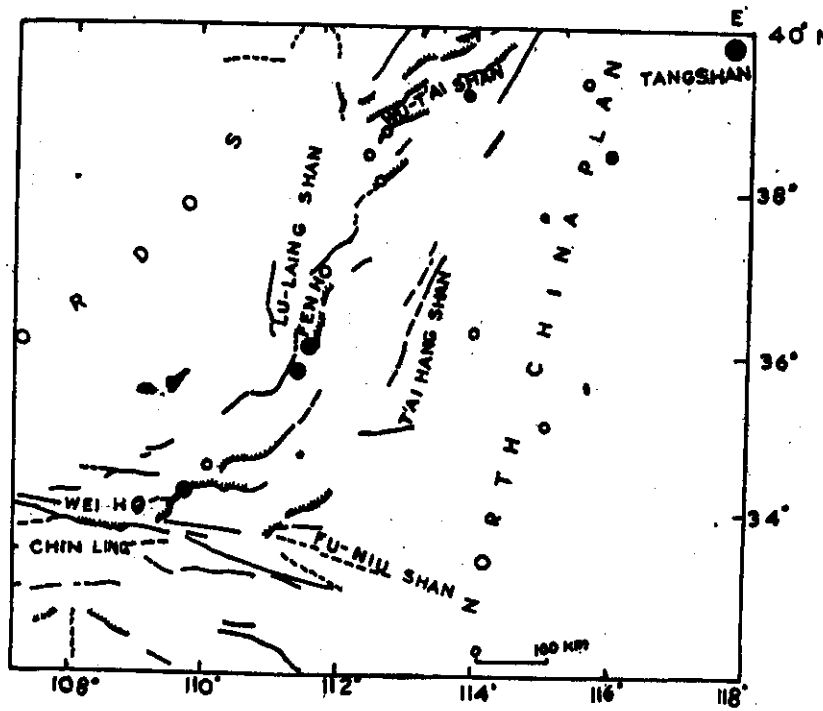

Fig. 1 Tectonics of northeast China (After Tapponier and Molnar, 1977)

The catalogue prepared by Gutenberg and Richter (1956) shows only one earthquake of magnitude 6.5 on 23.9. 1945 at a distance of about 100 Km east of Tangshan earthquake. After the installation of world wide standardised seismic network which resulted in improved epicentral locations only one earthquake of slight intensity in the vicinity of Tangshan earthquake could be located during the period 1964-1975.

Data

The data for this study has been taken from the Catalogues of Gutenberg and Richter, the bulletins of the International Seismological Centre (ISC) and the monthly listing published by the U.S. Geological Survey. However due to changes in the detection capability of the world-wide seismic stations after 1962-63, the spatial distribution and the computation of 'b' values has been confirmed to data for 11 years as given by ISC. P wave first motion was based on the Bulletins of (ISC), supplemented by the original readings of seismograms from Indian Seismological network. Observations from both short period as well as long periods were included to maximise the data. More emphasis was given to long period data while drawing the nodel planes. The angles of incidence at the focus were computed using the Jeffreys Bullen travel time tables.

Results & Discussions

Fig. 2 shows the seismicity around Tangshan region during the period 1964-74 based on the data from ISC bulletins. It may be noticed that the epicentres being aligned in northeasterly direction indicate the trend of faults in the region. The recent Tangshan earthquake occurred across the section of the fault zone which in the past did not exhibit any marked seismic activity. Thus, the Tangshan earthquake has occurred in a seismic gap. According to Shunmin et al (1977), "the region was bounded by the rhombic block, the northeast fault zone, therefore appeared to be in a state of temporary equilibrium, forming an interlocking regional stress field. The strain energy was gradually accumulated within the interlocking portion of the rhombic fault block and a large seismic focus was then developed. As a result of drastic changes in the regional stress field a righ lateral shear fracture zone was generated along the seismogenic fault and the "interlocking" was overcome as to give rise to an earthquake. As discussed later, the nature of faulting for this earthquake was normal from the P wave first motion data.

Fig. 3 gives the cumulative number of earthquakes which have occurred along the northeast striking fault. The arrows indicate moderate earthquakes which have occurred during the years 1964-1977. It may be seen that there is seismic quiescence preceding moderate earthquakes along different segments of this fault zone. The recent Tangshan earthquake occurred about 1½ years after the damaging earthquake of February 4, 1976 located 500 Km away in northeast China.

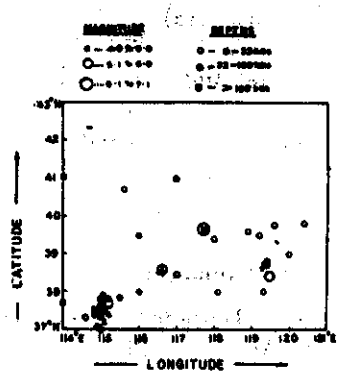

Fig. 2 Seismic activity around Tangshan (1964-1974). Main Tangshan earthquake shown by big circle with a cross

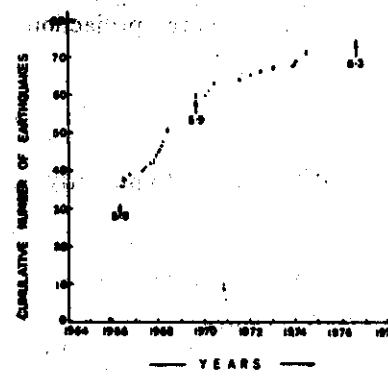

Fig. 3 Cumulative number of earthquakes in northeast China (1964-1977)

Rikitake (1977) has summarised the significance of seismic gaps in which earthquakes have been reported to have occurred. Srivastava and Chaudhury (1978) have delineated a potential seismic gap in Himachal Pradesh, India where damaging earthquake may take place. The observations as deduced from Tangshan earthquake point out the significane of recognising potential seismic gap for earthquake prediction experiments.

Fig. 4 (a) and (b) show the plot of first motion P wave data on lower half of focal sphere for the main Tangshan earthquake as well as its largest aftershock. It would be seen that

the focal mechanism for both these earthquakes are almost similar. The aftershock data, is of superior quality as compared to that of the mainshock. This is possibly due to the occurrence of a foreshock a few minutes prior to the main event which has disturbed the onset of P waves for main event.

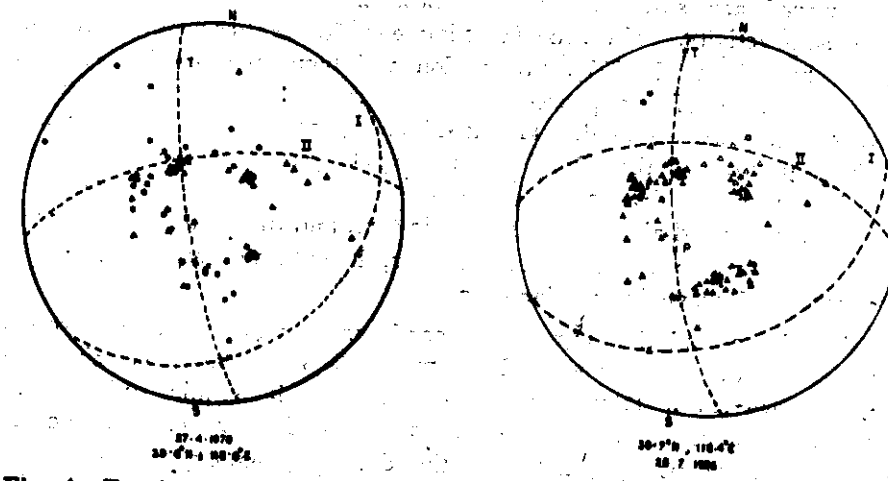

Fig. 4 Focal mechanism of (a) Main Tangshan earthquake (b) Its largest aftershock. Compressions denoted by circles, dilatations by triangles (Equal) area projection of lower half of hemisphere)

Both the mechanism solutions show that the nature of faulting is normal and predominantly dip slip. Tapponier and Molnar (1977) have determined fault plane solutions of some earthquakes lying at distances from 150 to 300 Km from Tangshan earthquake on similar feature and found them predominantly strike slip (Table 1).

TABLE 1

Source mechanism of some earthquakes in eastern China (after Molnar)

Date	Epicentra		Pressure		Tension		Nature of faulting
	ON	OE	Az	Plunge	Az	Pl.	
27.3.1963	37.70	115.12	281	07	171	07	Strike slip
22.3.1966	37.49	115.06	241	10	050	04	Strike slip
18.7.1969	38.43	119.47	069	12	335	16	Strike slip

One of the two nodal planes in the new solutions is showing an eastnorth easterly/easterly strike and is dipping at angles of 55 to 65° towards north easterly directions. The other nodal plane shows a north-easterly strike dipping towards southeast at angles ranging from 30 to 40°. One way of distinguishing the fault plane from the auxiliary plane is based on the spatial distribution of aftershocks (Fig. 5) with respect to their focal depths. It may be noticed that the direction of dipping of the fault plane cannot be unambiguously determined, but considering the spread of aftershocks to larger distances in northeasterly direction, the fault dipping at angles of 55 to 65° in that direction may be tentatively selected as the fault plane.

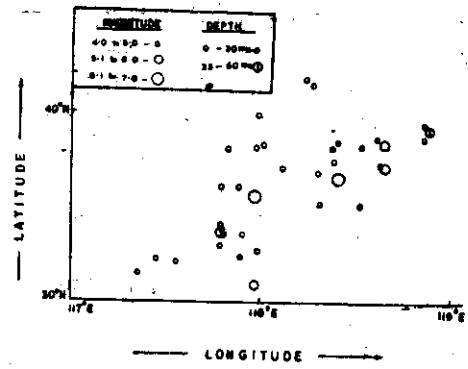

Fig. 5 Aftershocks of Tangshan earthquake (till 1977)

Pressures are acting from southwesterly direction and are rather steeply dipping, while shallow dipping tensions are acting from northerly direction.

Aftershock characteristics

The sample data for aftershocks as collected from U.S. Geological Survey was used for applying maximum likelyhood method to estimate 'b' value in the Gutenberg's frequency magnitude relationship. The value of 'b' was found to be 0.85 $\pm$ .08.

The aftershock area works out to be approximately 6000 Km^2.

New Indian plate boundary

The opinion that boundary of the Indian plate lies in the vicinity of the foot hills of the

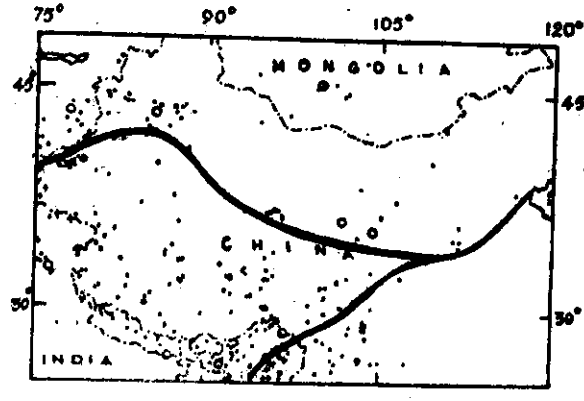

Fig. 6 Near India plate boundary versus more accepted plate boundary (Kaila and Narain, 1976). Solid thick lines denote the new plate boundary (by Kaila and Narain, 1976). Epicentre of earthquakes equal to or greater than magnitude 4.5 have been shown by block dots while for earthquakes equal to or greater than 8.0 by bigger circle. The symbol + (plus) shows the deeper earthquakes in the focal depth zone of 71 to 300 km

Himalayas is more widely accepted by the seismologists. Kaila and Narain (1976) have however, postulated a new Indian plate boundary (Fig. 6) north of Tibet, which coincides with the southern margin of Tien Shan-Nan mobile fold belt, passing south of the Ordos and Shansi blocks, finally turning north eastwards reaching southeast of Peking. Tangshan earthquake of July 1976 occurred in the vicinity of the new plate boundary and showed normal faulting. The great Assam earthquake of 1950 (Tandon, 1955) near the syntaxial bend close to the more accepted plate boundary also showed normal faulting. However, the diffused seismicity and the fault plane solutions in the zone of continental type of collisions do not provide sufficient data to demarcate the plate boundaries. Further data from deep seismic sounding methods at both these possible locations of plate boundaries mentioned above may throw more light of the subject.

Conclusions

Tangshan earthquake of July, 1978 occurred in a region where no earthquake of mangnitude 4.5 or more had occurred in 11 years and could be described as 'seismic gap'. The focal mechanism of this earthquake as well as that of its largest aftershock showed normal faulting. The pressures are acting from southwest and are rather steeply dipping. The occurrence of this earthquake close to the new Indian plate boundary as postulated by Kaila and Narain (1976) is significant but does not offer a conclusive evidence in view of the nature of faulting of this earthquake.

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