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SEISMOTECTONICS OF THE INDOBURMAN ARCUATE SYSTEM - A SUBDUCTION -COLLISION RELATED PROCESS

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ABSTRACT

The Indoburman arcuate system represents a conspicuous boundary between the Indian and the Burmese plates and are characterised by frequent occurrences of shallow and intermediate depth earthquakes. NOAA data file from 1906 to 1987 are used for the present study. The geologic features and seismic activity suggest a strikingly analogous environment of island arc system. A well defined Benioff zone dipping approximately 45°E upto a depth of about 150 km is well illustrated by the depth sections perpendicular to the arc. The seismic activity below and above 25°N Lat. exhibits striking difference. Increased seismic activity of both shallow and intermediate foci earthquake in the Manipur sector suggest active subduction processes. Reduced seismic activity in the Nagaland sector is a manifestation of a gradual attainment of maturity after collision. An increased occurrence of intermediate foci earthquakes within the Lat. 24.8°-25.2°N points to unusual condition over there. More or less aseismic nature of the Arakan Yoma sector needs further investigation. A complex pattern of focal mechanism is typical of a collision zone. However, predominance of strikeslip mechanism bear the imprints of northward movement of the Indian plate with a drag of the slab in the process. A complex geometry of the slab is also evident from the probable HTS analysis.

INTRODUCTION

The Indoburman seismic zone coincides with the Indoburman orogenic belt having a submeridional trend nearly over the entire length. The seismic activity within the Indoburman orogenic belt can be grouped into two classes. One group is associated with the Naga-Patkai-Arakan-Yoma ranges, while the other group follow the line from Moulmein to Myitkina. The most important earthquakes originating along the line are Mandalaya earthquake (1839), Taungyi earthquake (1912), Pegu earthquake (1930), Pyu earthquake (1930) and Myitkina earthquake (1931). They probably have their origin in the boundary fault extending from Rangoon to Mandalaya (Eiby, 1973). On the other hand, large number of shallow and intermediate depth earthquakes occurring along the Western part of the orogenic belt is of interest in understanding the upper mantle activity and their application in plate tectonic interpretation on the evolution of the orogenic belt. The occurrence of intermediate earthquakes in a continental environment is a unique feature outside the present day island arc system. Such belts are only observed in the Betic mountain belt of Spain, the Carpathian arc of Romania and the Hindukush. Manifestation of this type of activity can be linked with lithospheric understanding.

DATA SELECTION

The data base consists of the NOAA data file from 1906 to 1987. It is integrated with the information derived from the Bulletin of the International Seismological Centre and the catalogue prepared by Gupta and Singh (1986). The data file contains 332 events (1906-1987), which lie between Lat. 15° to 28°N and Long. 90° to 98°E. The following criteria have been used for data selection:

(i) events with magnitude 3.8 and above were used,

(ii) events shallower than 35 km were excluded to avoid mixing of intercontinental events,

(iii) events recorded by more than 15 stations have been used for hypocentral trend surface (HTS) analysis. As a result, the total number of events in this investigation has been considerably reduced,

(iv) for shallow and intermediate depth earthquakes (1963-1987) the body wave magnitude are used for 'b' value estimation,

(v) available focal mechanism solutions have been used to determine direction/ nature of plate movements and subduction polarity.

DATA ANALYSIS AND DISCUSSION

The entire data were plotted with the help of computer to determine the spatial distribution of epicenters (Fig. 1).

Figure 2 shows the depthwise spatial distribution with gradual increase of depth to the east as expected for an easterly descending plate under the Eurasian (Burmese) plate.

Figure 3 consists of a number of depth sections perpendicular to the orogenic belt, where each section is a composite of events occurring within a vertical slab of one degree latitudional thickness. Since the trend of the orogenic belt is north-south upto Lat. 25°N, the sections are therefore latitudional. As the trend of the belt is NE above this latitude the sections are therefore, drawn at an azimuth of 135° to bring perpendicularity to the orogenic trend. Previously this procedure was usually not followed by many workers leading to different dips for most identical sections. This also led to different thickness of the subducting slab. In the northern section of the studied area the dip is approximately 45°E. In the southern half the dip ranges between 27° to 30° due east. These sections indicate a thickness of about 30 to 40 km of the slab. Therefore, when a composite section is drawn combining the narrow sections the composite section show more thickness compared to the narrow sections. No depth section is possible between Lat. 15° to 20°N because this sector is virtually devoid of intermediate foci earthquakes. The spatial distribution of the epicenters reveals that the earthquakes follow the tectonic trend of the orogenic belt. One very interesting observation is that between Latitudes 24.8°N to 25.2°N the earthquake activity bulges out into the interior of the Indian plate. For instance, the entire Manipur state and the southern part of Nagaland and Cachar-Tripura belt show very high seismic activity. This sector also shows increased upper-mantle activity.

To understand the geometry of the subducting slab an attempt has been made to determine the hypocentral trend surface (HTS) following Choudhury and Whiteman (1987) by using computer programming of P.M. Mether (1973). A comparison of the trend surface analyses from 1st to 6th degree equations has been made. F-test is used to test the statistical significance of HTS.

$$F(q, n-p-1) = \frac{(ESS - ESS(p))\,/\,q}{(100 - ESS)\,/\,(n-p-q-1)} \qquad (1)$$

where 'n' is the number of events, ESS(p) is percentage of explained sum of squares for 'p' variables in the regression and ESS applies to (p+q) variables. If the calculated F value is less than the tabled F-value for a given step it may be concluded that the additional group of terms should not be added. For the present study we obtain

F (5, 130) = 1.21796 which is less than the tabled F 0.95 (5, 130) = 2.2141 value while going from 3rd order to 4th order surface adding five additional terms (Fig. 4). Therefore, the 3rd order HTS provides the best fit and indicate a complex geometry.

COMPARISON BETWEEN INTERMEDIATE VERUS SHALLOW EARTHQUAKES

From a statistical comparison between the intermediate and shallow earthquakes (Fig. 5) it has been observed that the two activities might be interrelated and must be the result of subduction/collision processes. With the different stages of collision uppermantle activity exhibits significant variations. The segment below Lat. 25°N upto Lat. 21°N shows very intense seismic activity both of intermediate and shallow earthquakes. This segment had also been the site of many large earthquakes in the recent past. The strongly felt earthquakes which occurred along the plate boundary are the 1954 Manipur Burma Earthquake ($M = 7.3$); 1957 Manipur Earthquake ($M = 7.0$); 1970 India-Burma Earthquake ($m_b = 6.5$) and 1988 India-Burma Border Earthquake ($m_b = 6.8$). Furthermore, in the shallow dipping western part of this segment some significant earthquakes have occurred. For example, the 1984 - Cachar Earthquake ($m_b = 5.6$); the 1987 South Kohima Earthquake ($m_b = 5.8$) and the 1988 Sylhet Earthquake ($m_b = 5.8$). Another very significant observation is that in this segment the interior part is also quite active, showing a bulging out of the seismogenic zone. Such activity suggest that sector is in great distress with increased intermediate foci earthquakes. This may contribute towards identifying active seismogenic zones and sites of future large earthquakes. The increase in deep seismic acitivity prior to great shallow earthquakes have been very well observed along the trenches in eastern Japan (Mogi, 1973).

Another observation which needs elucidation is the pattern of seismicity in the Naga Hills segment. Very minor activities are seen in the interior part of Nagaland. Only along its boundary with Burma large number of earthquakes do occur. There again, the intermediate depth earthquakes are comparatively low (25%) in comparison to that of the Chin Hill segment (75%). The dip of the underthrusting slab is also more compared to the lower segments. From the pattern of seismicity it may be argued that the thrust fault occurring within the Nagaland belt might be a group of decollement flat lying thrust faults. This has also been corroborated by the noninvolvement of the basement in the thrusts. Furthermore, the high dip of the remnant lithospheric slab indicates blocking of subduction to an advanced stage of collision.

The morphological and structural features might be the manifestation of a collision process. Due to the continent/continent collision within the Naga Hills segment a major structural configuration of high rise mountain chains, developed, but not in the south (Graham et al., 1975). It has been observed that the Chin Hills and Arakan-Yoma segments continent/continent collision had not occurred to the fullest extent and perhaps involved only subduction of oceanic crust covered by thick turbidite sequence. It is opined that in the southern part of the Indoburman ranges continental crust is probably absent beneath the Arakan-Yoma and Western trough (Mitchell and McKerrow, 1975). The low height and more width of the hills and the decrease in the size of the folded turbidite compared to the northern half could be a reflection of collision.

Quite interestingly the Arkan-Yoma belt between 20°N to 15°N Lat. shows low seismic activity. It is opined that this segment forms the transition zone between island arc to mountain arc system (Mukhapaddhaya, 1984). However, the question still remains open as to why this segment exhibits relative quietness compared to the sectors north and south of it. At this segment subduction ceased after the formation of the Arakan-Yoma ranges during Mio-Pliocene time. The causes of cessation of subduction activity may be attributed to the incorporation of the aseismic ridge connected with the 90°E ridge and thereby introducing nonsubductible material into the area, change in the angle of convergence and finally to the rifting of the volcanic arc to form the interarc Central Burman basin. The events like the outpouring of basaltic and rhyolitic magma through the opening at Swebo (Mitchell, 1974) and occurrence of basaltic plug indicative of such a development have been reported from Ramree region (Brunnschweiler, 1966).

'B' VALUES

Figure 6 shows the plot of log-cumulative number of earthquake vs magnitude for the region (1963 to 1987) and b-value derived for shallow and intermediate earthquakes.

Depth	'b' value m_b
$\leqslant$ 70 km	1.20682 (± 0.0387)
> 70 km	0.88645 (± 0.027)

The higher 'b' value suggest a lower strength of the lithospheric plate having higher temperature regime characteristic of subduction zone.

FOCAL MECHANISM

The available focal mechanism solutions of this region (Lat. 15°N to Lat. 28°N) show mixed FM (normal, thrust and strikeslip) with a dominance of strikeslip mechanisms (32.6%) probably associated with the drag of the subducted lithosphere (Le Daine et al., 1984). A subordinate amount of thrust (22.4%) and normal (12.2%) faulting associated with the strikeslip component are significant.

CONCLUSIONS

1. Spatial distributions of earthquakes follow the geological trend of the orogenic belt.
2. Seismic activity clearly exhibits segmented nature of the orogenic belt. Three distinct segments can be observed. The Lat. 25°N may be considered as dividing line between the Naga Hill and Chin Hill segments. Lat. 20°N delineates the Arakan-Yoma segment from Chin Hill segment.
3. The depth sections reveal that the subduction/collision processes are still active with variable degrees. Sector between Lat. 24° - 25°N needs close investigation.
4. HTS analyses suggest complex geometry of the subducted lithosphere.
5. Higher 'b' value might indicate low strength of the lithosphere and higher temperature regime.
6. The subducting slab is still attached to the Indian plate, a complex FMS is typical of collision zone, while on northward movement a drag of the slab is envisaged, predominance of strikeslip mechanism may be the result of such a drag.

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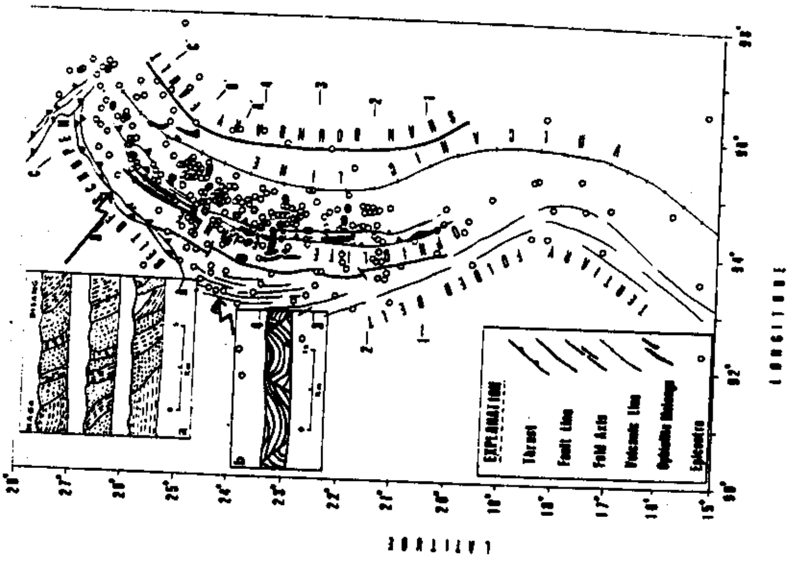

Fig.1 Spatial distribution of epicenters.

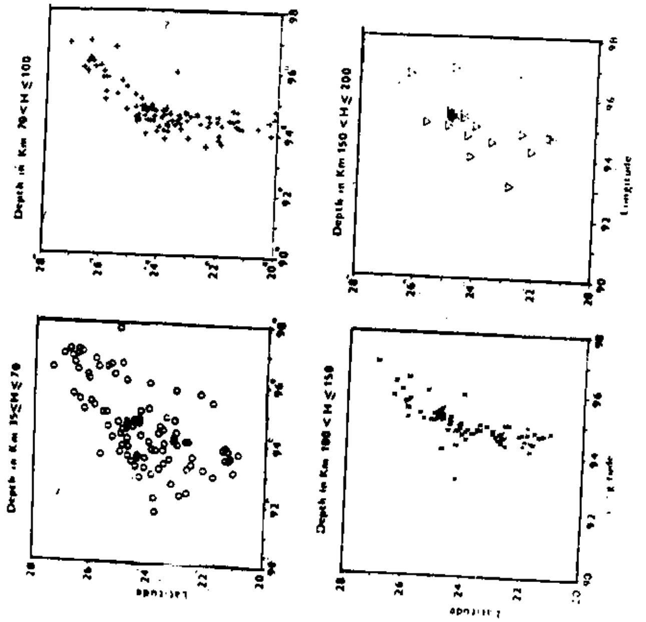

Fig.2 Depthwise spatial distribution of Epicenters.

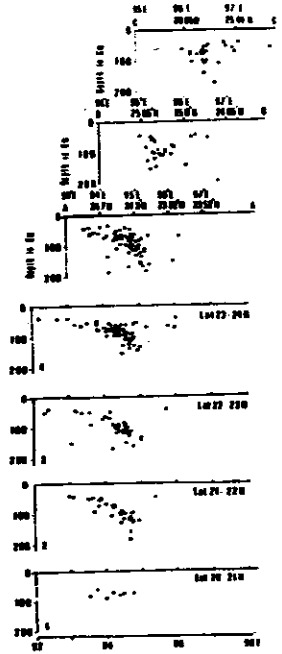

Fig.3 Depth sections perpendicular to the orogenic belt.

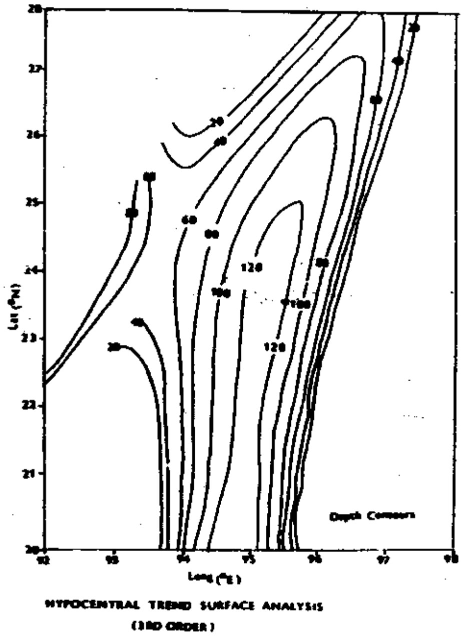

Fig.4 3rd Order Hypocentral Trend Surface Analysis

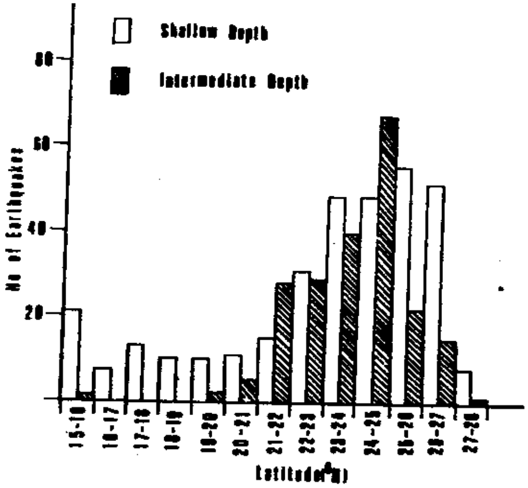

Fig.5 Comparison between Intermediate Versus Shallow Earthquakes.

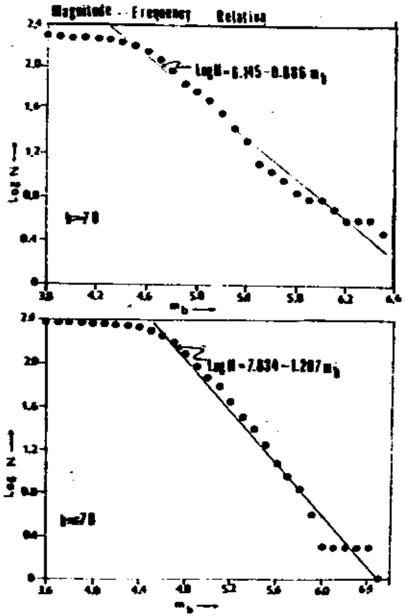

Fig.6 'b' Value for Indoburman Region.