Spatial-temporal variability of seismic hazard in peninsular India

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This paper examines the variability of seismic activity observed in the case of different geological zones of peninsular India (10°N–26°N; 68°E–90°E) based on earthquake catalog between the period 1842 and 2002 and estimates earthquake hazard for the region. With compilation of earthquake catalog in terms of moment magnitude and establishing broad completeness criteria, we derive the seismicity parameters for each geologic zone of peninsular India using maximum likelihood procedure. The estimated parameters provide the basis for understanding the historical seismicity associated with different geological zones of peninsular India and also provide important inputs for future seismic hazard estimation studies in the region. Based on present investigation, it is clear that earthquake recurrence activity in various geologic zones of peninsular India is distinct and varies considerably between its cratonic and rifting zones. The study identifies the likely hazards due to the possibility of moderate to large earthquakes in peninsular India and also presents the influence of spatial rate variation in the seismic activity of this region. This paper presents the influence of source zone characterization and recurrence rate variation pattern on the maximum earthquake magnitude estimation. The results presented in the paper provide a useful basis for probabilistic seismic hazard studies and microzonation studies in peninsular India.

1. Introduction

India has experienced several devastating earthquakes in the past few centuries that have resulted in severe destruction in terms of loss of lives and property. Minimization of the devastating effects of earthquakes in India certainly requires better understanding of the seismic hazards in different parts of the country and adopting better earthquake preparedness measures. Earthquake activity in India is attributed mainly to two distinct tectonic environments namely seismically active Himalayan frontal arc which covers most of northern parts of the country and intraplate seismic activity within the Indian shield which accommodates central and southern India. The Himalayan seismicity has caused several damaging earthquakes in the last few centuries (such as Shillong 1897; Kangra 1905; Nepal 1934; Assam 1950; Uttarkashi 1991; Chamoli 1999 and Kashmir 2005) and intraplate seismicity within the continental shield mass of India has caused intermittent heterogeneous seismic activity (Koyna 1967; Latur 1993; Jabalpur 1997; Bhuj 2001). The intra-plate seismic activity in peninsular India (10°N–26°N; 68°E–90°E) arises largely out of the sudden release of strain energy that has been accumulated over a long time due to the north and northeastward movement of the Indian plate. Most of the historical earthquakes in peninsular India have been concentrated near the weak rifting zones (Rann of Kuchchh, Narmada lineament) or in the passive continental margins (both eastern and western) whereas the cratonic zones (northern and eastern) and inactive grabens are generally free from large earthquake activity and thus form stable shields of

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the Indian plate. The seismic hazard estimation in peninsular India for different levels of exceedance hence requires understanding of the variability in seismogenic characteristics of different source zones.

The seismic hazard has been quantified for most of the active tectonic environments of the world whereas for regions of low to moderate seismicity such as the Stable Continental Regions (SCRs), it still remains an important task to accurately estimate the likelihood of future seismic activity for predefined exceedance levels. The seismic hazard estimation procedure has been broadly categorized into two broad categories namely deductive and historic (McGuire 1993). Cornell (1968) pioneered the theoretical basis of the deductive method which is primarily based on deducing the causative sources (zones), seismicity and earthquake ground motion characteristics in the region. Historic methods rely completely on past earthquake catalog data and do not require specification of seismogenic zones. For each historic earthquake of certain magnitude, distance and assumed ground motion prediction equation, the empirical distribution of the required seismic hazard parameter is computed (Veneziano *et al* 1984). By normalizing the empirical distribution for the duration of earthquake catalog, an annual rate of exceedance of ground motion parameter is estimated. However, historic procedures generally work only in active tectonic regions which are characterized by frequent earthquakes and where the record of past seismicity is reasonably complete (Boschi *et al* 1996).

The deductive methods have several advantages in terms of its applicability in variable seismotectonic regions and its ability to account for aleatory and epistemic uncertainties mainly because the procedure is parametric in nature. It requires accurate identification and characterization of different earthquake sources that can result in damaging earthquakes. Earthquake sources may be identified on the basis of geologic (paleoseismic), tectonic, historical, and instrumental evidence. Better estimation of seismic hazards of peninsular India especially due to large damaging earthquakes which tend to have higher return periods require the use of more accurate assessment of $M_{\max}$ and its recurrence for each seismogenic zone. The assumption of single $M_{\max}$ and single b-value for the entire peninsular India as used in previous PSHA studies (Khatri *et al* 1984; Bhatia *et al* 1999) provides only a macroscopic picture of seismic hazard associated with the entire region without incorporating spatial variability of earthquake recurrence.

Estimation of maximum magnitude potential for each seismotectonic zone of peninsular India is useful for future regional PSHA studies, seismic microzonation studies and also for application in building codes. Most of the building codes used for earthquake resistant design generally specify Maximum Considered Earthquake (MCE) and Design Basis Earthquake (DBE) to help to estimate potential design forces. Similarly design of large engineering facilities such as dams and nuclear power plants require accurate estimation of maximum magnitude earthquake potential in a region.

The main focus of this article is to understand the spatial variability of seismic activity in peninsular India and to estimate seismic zone-specific parameters which can be used for future PSHA studies. It is worth noting that currently, there is no established or generally accepted method available for the estimation of $M_{\max}$ especially for SCRs such as peninsular India. The most commonly used deterministic procedure consists of using knowledge of various tectonic and fault specific parameters and combining it with historical earthquake data associated with each seismogenic feature to empirically estimate the maximum earthquake potential. Such an approach may not be always applicable to SCRs due to limited knowledge regional faults, its activity and accurate delineation. Secondly, empirical magnitude fault-length relationships for SCR regions are not well-established and can contribute significantly to the uncertainty of PSHA results.

One of the well-known approaches proposed by Kijko and Sellevoll (1989) is parametric and it allows application of historical earthquake information (that can be both extreme and complete parts of the region's earthquake catalog) to statistically predict region specific maximum magnitude and earthquake recurrence characteristics. The present investigation makes use of Kijko's approach (Kijko and Sellevoll 1989; Kijko 2004) to incorporate the uncertainties associated with catalog information due to its incompleteness while estimating the seismicity parameters and finally estimate the seismic hazard for each identified seismotectonic zones of peninsular India. Similar approach has been used in earlier studies by Sharma *et al* (2003) for hazard estimation for Delhi and surrounding region and by Shankar and Sharma (1998) for the entire Himalayan belt. Due to the paucity of data and relatively shorter catalog history, we utilize both extreme and complete parts of the catalog to estimate seismicity parameters of nine source zones of peninsular India.

The application of Gutenberg–Richter (GR) relationship derived from earthquake catalog data helps in determining the earthquake recurrence characteristics and this approach is similar to flood and wind hazard analyses in civil engineering (Wang and Ormsbee 2005) and is appropriate for seismic hazard assessment (Wang 2006, 2007). In

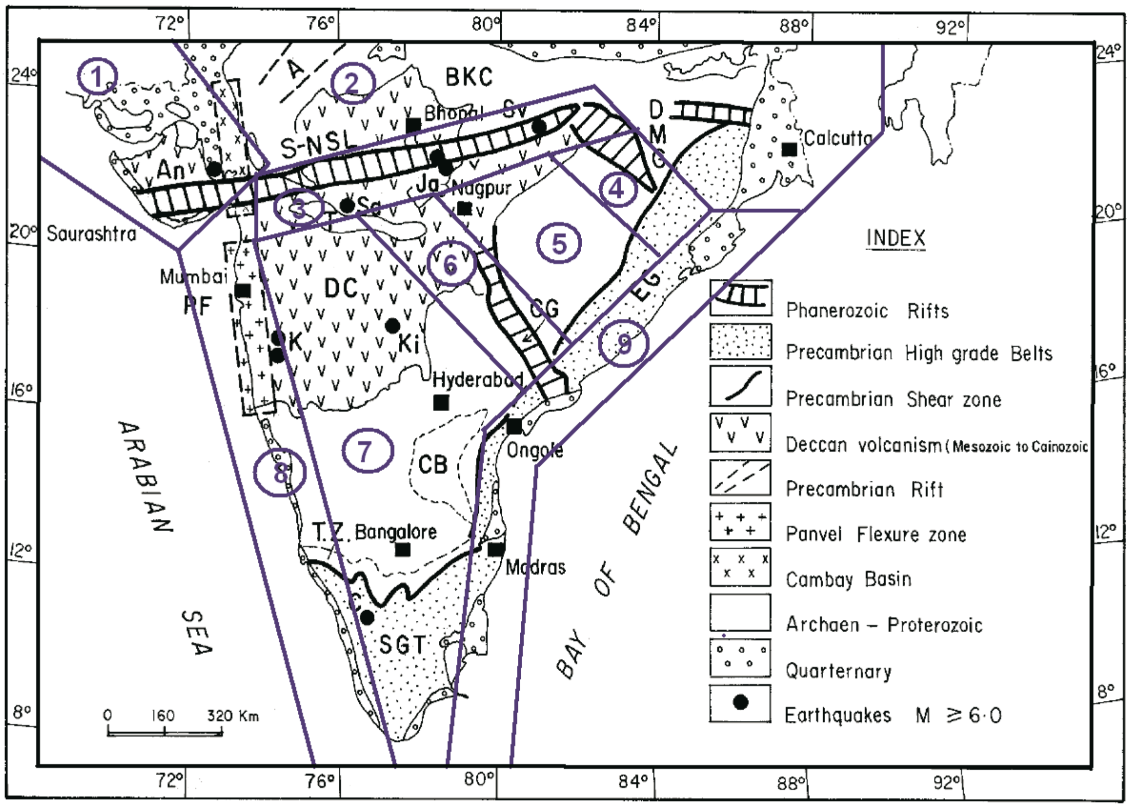

Figure 1. Various geological and seismotectonic units of peninsular India resketched from Rao (2000) along with geological zonation used in the present study for seismic hazard analysis of peninsular India. ① Rann of Kuchchh (ROK), ② Northern Craton (NC), ③ Narmada Lineament (NL), ④ Mahanadi Graben (MG), ⑤ Eastern Craton (EC), ⑥ Godavari Graben (GG), ⑦ Southern Craton (SC), ⑧ Western Passive Margin (WPM), and ⑨ Eastern Passive Margin (EPM).

the absence of sufficient earthquake data as is in the case of peninsular India, Kijko's approach (Kijko and Sellevoll 1989; Kijko 2004) provides an opportunity to examine and combine extreme and complete parts of catalog to compute the seismicity parameters and to estimate the seismic hazard of different geologic zones of peninsular India. However this approach is fundamentally different from probabilistic seismic hazard analysis (PSHA) carried out by Jaiswal and Sinha (2007) to develop a seismic zoning map of the region.

The annual exceedance probability of ground motion in most of the PSHA studies is a numerical extrapolation of the annual exceedance probability of earthquake occurrence defined by GR curve and exceedance probability of ground motion uncertainty at a site (Cornell 1968; Frankel 2004). For this reason, the PSHA can derive ground motions with an annual exceedance probability less than 10^{-8} or a return period greater than 100 millions of years from a few hundred years' historical and geological data. It may be noted that a fundamental problem with PSHA is that the mathematical formulation is not valid (Wang and Zhou 2007) and the results from PSHA are nearly impossible to test (Bozkurt *et al* 2007). Nevertheless, PSHA still remains one of the most useful tools to estimate the future seismic hazards both in stable as well as active tectonic regions. It is also due to its ability to include all kinds of variation (such as spatial temporal variation, seismicity gaps and non-stationarity) and incorporation of the aleatory and epistemic uncertainties in the modeling process.

2. Seismotectonics and earthquake catalog

The Indian peninsular shield is one of the oldest landmasses on earth with over one-third of its region covered by basaltic lava flows and the rest of peninsula consists of Precambrian crystalline rocks and sedimentary formations. Most of the shield is characterized by complex structures of rifting and thrust zones as shown in figure 1. Some of the prominent tectonic features of the shield are massive deccan volcanic province, Narmada lineament, southern and eastern cratons and grabens of mainly Godavari and Mahanadi as discussed by Rao (2000). Rifting zones such as Rann of Kuchchh and Narmada have experienced severe earthquakes in the last two centuries (Kuchchh 1819; Anjar

1958; Jabalpur 1997; Bhuj 2001); however most of southern peninsular shield have experienced diffused seismic activity except regions of so called triggered or induced seismicity on the Western Ghats. Chandra (1977) described the broad tectonic regions of Indian shield in detail and Khatri *et al* (1984) took it forward to propose broad geologic zones in the region to be used for probabilistic seismic hazard analysis. Bhatia *et al* (1999) in the Global Seismic Hazard Assessment Program (GSHAP) study confined the earthquake zonation scheme in Indian shield to only small and limited pockets of the shield delineated based on either locations of past earthquake epicenters and prominent seismotectonics.

Seeber *et al* (1999) studied the seismic hazard assessment of Maharashtra for developing probabilistic seismic hazard map to be used by the Government of Maharashtra. In this unpublished report, the authors proposed nine broad seismic zones based on geology, key tectonic features and observed seismic activity. Seismic zone characterization proposed by Seeber *et al* (1999) were primarily based on various evolutionary geologic and seismotectonic units identified by researchers in the past (Valdiya 1973; Naqvi *et al* 1974; Chandra 1977; Rao and Rao 1984) and classifying them broadly into cratonic and paleorifting zones. Cratons are primarily a stable interior of peninsular shield namely northern, eastern and southern cratons and paleorifting zones (a region containing large faults and has experienced extensional deformations in their most active phase) which are Narmada, Cambay and Mahanadi grabens and passive continental margins as shown in figure 1. More details about classification, zonation boundary and spatial extent have been discussed in Jaiswal (2006). Table 1 provides a concise summary of the geologic and seismotectonic characteristics of Indian shield along with significant earthquakes in each region.

A working catalog has been prepared based on the available information of the earthquake data from various sources. It includes the published catalog ($M_w \geq 3.0$) after equivalent moment magnitude conversion up to 1997 from Rao and Rao (1984) and Seeber *et al* (1999). The Preliminary Determination of Epicenters (PDE) bulletin of the US Geological Survey's National Earthquake Information Center (NEIC) has been used to include most recent events up to May 2003 (NEIC 2003) within the study area. The events are in terms of body wave magnitude and hence converted to equivalent moment magnitude using the relation proposed by Johnston (1996). Details of the earthquake catalog development process which includes magnitude conversion criteria, removal of duplicate events and application of declustering algorithm for removing foreshock and aftershocks can be found at Jaiswal (2006), and final catalog data can be easily downloaded from EarthquakeInfo.org website (Jaiswal and Sinha 2005).

3. Spatial-temporal variability in seismicity

This section focuses on evaluating the spatial-temporal variability of seismic activity observed for peninsular India based on past earthquake catalog. Estimation of the seismicity parameters using the past earthquake catalog data without modeling such variability may lead to erroneous results. The recent increase in seismic activity for peninsular India has been discussed in detail by Seeber *et al* (1999). It indicates the association of a large number of earthquakes in the marginal areas along with a few regional conglomeration or hotspots near some of the reservoirs. Figure 2 shows a plot of decadal variation of seismic activity in peninsular India clearly indicating the rapid increase in the activity since 1960s. One of the reasons of rapid increase is due to remarkable increase in seismic activity of Koyna belt after being constant for more than one century. This increase is rapid and drastic in the 1960s which is commonly termed as triggered seismicity and is described in detail in earlier studies (Gupta and Rastogi 1976; Gupta 1992).

It is important to study such increase in terms of different magnitude ranges to understand the possible rate variation in terms of seismic activity in the region. For this, earthquakes in different magnitude ranges are shown in figure 3 which indicates that a large number of earthquakes during recent times are in the magnitude range of 3.0 to 4.5. It is obvious due to increase in the capability of detecting such low to moderate earthquakes precisely through better instrumentation in the shield region. Since a very small portion of data in this magnitude range is available for period prior to 1960s, it is likely that several low to moderate earthquake events may be missing due to sparse instrumentation in the region.

Figure 4 shows the frequency of earthquakes of different magnitude ranges in different cratonic and rifting zones of peninsular India. Though for low to moderate magnitude ranges, the observed frequency of earthquakes in both the zones is similar; the variation is quite high for larger size earthquakes. The sudden rise in terms of frequency in high magnitude ranges is a peculiar characteristic of these rifting zones which have experienced some of the largest earthquakes with short recurrence duration. Rajendran (2000) obtained similar results based on the classification of recent

Table 1. *Seismogenic zones of peninsular India and their associated characteristics.*

Name of the source zone	Geographical location boundary	Seismotectonics and geological settings from Chandra (1977); Khatri *et al* (1984)	Previous significant earthquakes (M_w)
1. Rann of Kuchchh (ROK)	22.0, 68.0; 26.0, 68.0; 26.0 69.9; 22.4, 73.6; 20.0, 71.0.	West-northwest seismically active striking faults and associated block faulting. Southern aseismic Girnar consists of extension of Narmada fault.	June 16, 1819 (7.7); July 21, 1956 (6.5); January 26, 2001 (7.6)
2. Northern Craton (NC)	30.0, 68.0; 30.0, 70.0; 30.0, 73.6; 33.0, 75.0; 28.5, 80.0; 27.0, 85.0; 26.0, 89.9; 26.0, 90.0; 22.0, 90.0; 21.0, 88.85; 21.0, 86.3; 23.95, 82.4; 22.2, 73.8; 22.4, 73.6; 26.0, 70.0; 26.0, 68.0.	North-east trending zone of Singhbhoom merges with Himalyan and Burmese mountain ranges in the northeast. Earthquake activity in the eastern portion is correlated with northern margin of Sausar series. In western part, Aravalli ranges trending northeast direction.	December 15, 1882 (6.1); May 20, 1935 (6.0); June 12, 1989 (5.8)
3. Naramada lineament (NL)	20.4, 73.2; 22.05, 73.2; 23.95, 82.4; 22.75, 84.05.	The 800 km straight course of Narmada river may be due to the fault which joins with Son fault to the east. It is a prominent tectonic feature of the Indian shield trending ENE-WSWdirection.	March 31, 1852 (6.0); November 18, 1863 (5.2); June 2, 1927 (6.4); March 14, 1938 (6.3); May 22, 1997 (6.0)
4. Mahanadi Graben (MG)	22.15, 81.5; 22.75, 84.05; 21.0, 86.3; 19.8, 84.8.	Presence of seismically active tectonic graben trending in NW-SE direction.	May 8, 1963 (5.1); June 12, 2001 (4.8)
5. Eastern Craton (EC)	21.5, 78.1; 22.15, 81.5; 19.8, 84.8; 17.7, 82.0.	No specific known seismotectonic structure has been identified in this region and can be termed as one of the most stable cratonic zone.	No significant earthquake in the extreme and complete part of catalog above cut-off threshold used in the study.
6. Godavari Graben (GG)	21.5, 78.1; 21.0, 76.05; 16.5, 80.3; 17.7, 82.0.	Long and narrow graben trending in northwest direction. Trend in northeast direction indicates conjugate set of faults transverse to the graben.	November 22, 1872 (4.7); April 13, 1969 (5.8)
7. Southern Craton (SC)	21.0, 76.05; 20.4, 73.2; 16.0, 74.1; 10.0, 76.8; 10.0, 79.0; 16.0, 79.5; 16.5, 80.3.	The southern portion of the zone consists of block faulted mountains such as Nilgiri and Annamalai and graben structure. No known surface geological structure is associated with the observed seismic activity in the region.	February 28, 1882 (5.6); February 7, 1900 (5.7); September 29, 1993 (6.2); September 5, 2000 (5.4)

Table 1. *(Continued)*

Name of the source zone	Geographical location boundary	Seismotectonics and geological settings from Chandra (1977); Khatri *et al* (1984)	Previous significant earthquakes (M_w)
8. Western Passive Margin (WPC)	10.0, 74.0; 20.0, 71.0; 22.05, 73.2; 20.4, 73.2; 16.0, 74.1; 10.0, 76.8.	A large vertical fault of north-northwest strike exposed in the middle part of the Western Ghats in Belgaum, Vengurla region. However, earthquake activity of Koyna suggests activity of fault with north-northeast strike. Presence of major tectonic feature called Panvel flexure parallel to the west coast and runs in northerly direction.	December 10, 1967 (6.3); June 4, 1965 (5.4)
9. Eastern Passive Margin (EPC)	21.0, 86.3; 16.0, 79.5; 10.0, 79.0; 10.0, 81.0; 15.0, 81.0; 21.0, 88.85.	Northeast trending zone from Kakinada to Midnapore in the eastern coast of India. The south central portion of Ongole trends in the northeast direction. The southern east margin consists of Tamil Nadu with north-easterly alignment in the area south of Madras.	July 3, 1867 (5.6); April 17, 1917 (5.3); October 12, 1959 (5.2); January 14, 1980 (5.9); September 25, 2001 (5.5)

damaging earthquakes in terms of tectonic environment, recurrence period, maximum magnitude and style of deformation.

The regional earthquake recurrence activity is commonly expressed in terms of the Gutenberg–Richter magnitude frequency relationship (Gutenberg and Richter 1944) represented by the following exponential magnitude distribution function:

$$\mathrm{Log}_{10} N\,(\geq M\,\text{per year}) = a - b\,M, \qquad (1)$$

where N is the number of events per year with magnitude greater than or equal to M. The a-value is rate per unit area per year of M earthquakes and the b-value is the slope of log-linear fit that represents the relative likelihood of larger and smaller earthquakes. To evaluate the effect of increase in seismicity, the pre- and post-1960 earthquake catalog data are shown in figure 5. It can be seen that the increase in seismicity after 1960 is also in terms of increase in recurrence rate of moderate earthquakes giving higher b-value of 0.90 compared with 0.77 as observed for pre-1960 data. According to Seeber *et al* (1999), this increase is not due to statistical fluctuation or due to catalog incompleteness. There is considerable increase in the observed seismic activity especially within certain pockets of peninsular India namely in passive continental margins (mainly in Koyna–Warna region) and in rifting zones (Narmada and Kuchchh region). However, the increase cannot be attributed to reservoir-induced seismicity alone. It should also be noted that most of the earthquakes (between magnitude 4 and 5) near Koyna region have been identified only after relatively better instrumentation in the area which took place in late 1960s whereas most such earlier earthquakes in the rest of peninsular India may have remained unrecorded in the time span of catalog data (Mohan *et al* 1981). In addition, the spatial variation in seismicity needs to be studied with respect to each geological source zone for accurate estimation of seismicity parameters.

4. Uncertainty modeling using extreme and complete data

4.1 *Earthquake database completeness*

Rao and Rao (1984) estimated b-value of 0.85 using single threshold of magnitude level of 4.5 for the entire catalog data of peninsular India during 1840–1980. Jaiswal (2006) studied the earthquake catalog developed in terms of moment magnitude using Stepp's procedures (Stepp 1973)

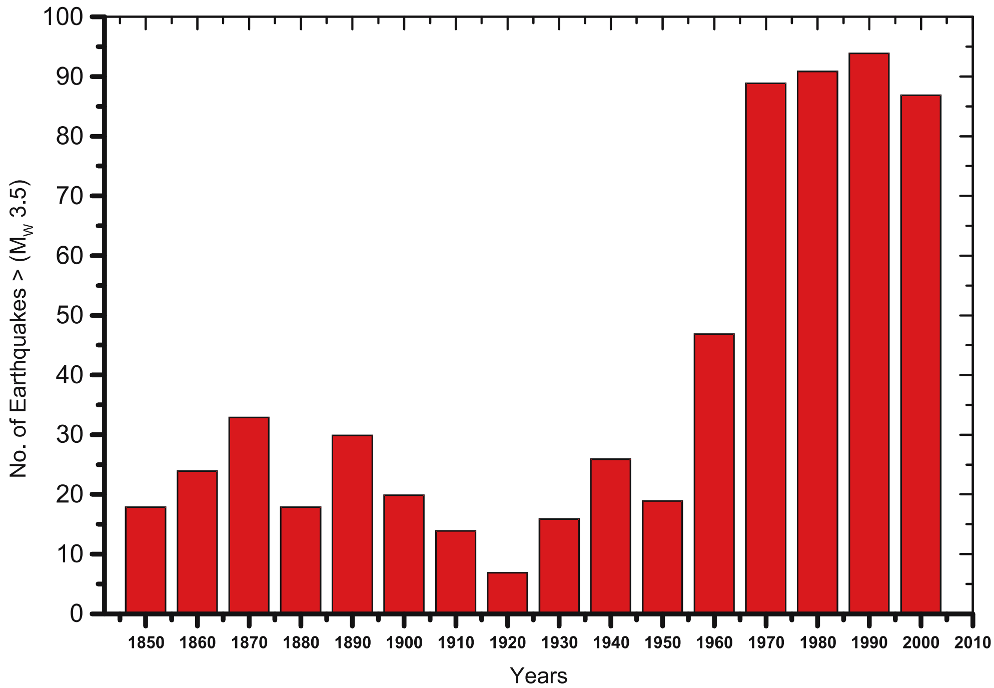

Figure 2. Plot showing rapid increase in seismic activity observed during last few decades in peninsular India.

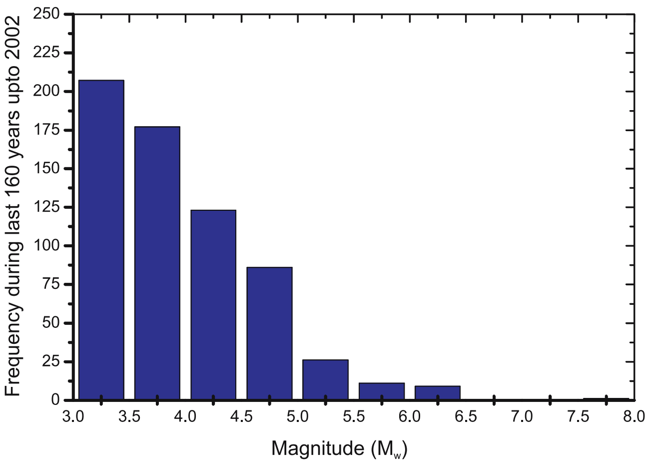

Figure 3. Frequency plot for different magnitudes range in peninsular India.

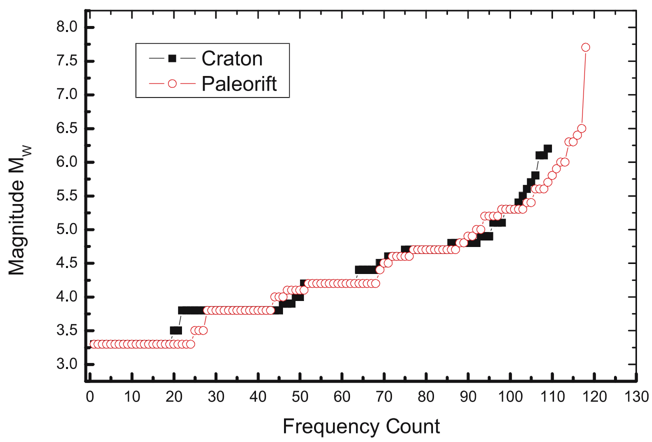

Figure 4. Frequency plot of craton and paleorift data for different magnitudes in peninsular India.

and established four levels of completeness as discussed in Jaiswal and Sinha (2007). However, in the present investigation, it was necessary to establish broad completeness level to model both extreme and complete parts of earthquake catalog separately using Kijko's approach (Kijko and Sellevoll 1989; Kijko 2004). Based on the analysis of processed catalog, two different cut-off levels were assumed for the entire catalog for the present investigation. Earthquake data with $M_w \geq 4.2$ prior to 1960 have been assumed to be well-documented in terms of shaking intensities in peninsular India and this level also helps to retain most of the earthquakes in the region and model them using extreme magnitude distribution. Similarly events above $M_w \geq 3.8$ that have occurred after 1960 (including most recent events from PDE catalog) are assumed to be well-documented in the catalog. It is also based on the fact that the region is well instrumented after 1960s and more precisely after the 1967 Koyna earthquake. This level is slightly lower than the level of $M_w \geq 4.0$ derived for post-1960 seismicity as obtained by Jaiswal (2006) for PSHA study. This is mainly due to the fact that PSHA procedure was based on application of GR model for earthquake occurrence modeling and hence requires establishment of completeness interval for each magnitude interval whereas Kijko's approach (1989, 2004) is fundamentally different

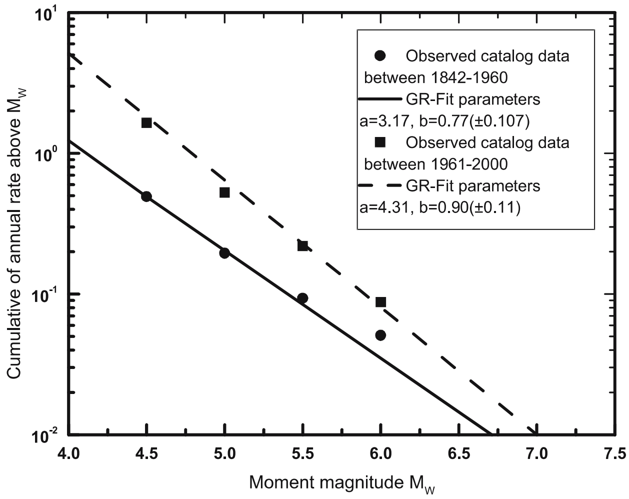

Figure 5. Completeness plot for different magnitude ranges based on earthquake catalog for pre-1960 and for post-1960 of peninsular India.

and it allows incorporation of significant events prior to 1960 using extreme value distribution along with the standard estimation error in its estimation.

4.2 *Seismicity parameter estimation*

To estimate the maximum earthquake magnitude for different seismogenic zones of peninsular India, the well-known approach proposed by Kijko and Sellevoll (1989, 1992) has been used. It is based on modified Gutenberg–Richter relation after introducing the lower and upper truncation in terms of minimum and maximum bound of earthquake occurrence as:

$$F_M(m) = \begin{cases} 0, & \text{for } m < m_{\min} \\ \frac{1-\exp[-\beta(m-m_{\min})]}{1-\exp[-\beta(m_{\max}^{\text{obs}}-m_{\min})]} & \text{for } m_{\min} \le m \le m_{\max}, \\ 1 & \text{for } m > m_{\max} \end{cases} \quad (2)$$

where $\beta = b\ln(10)$, and b is the Gutenberg–Richter parameter indicating the seismicity rate. Kijko *et al* (2001) and Kijko (2004) have provided two separate estimates of $M_{\max}$ using Cramer's approximation and non-parametric Gaussian estimation. Page (1968) presented the maximum likelihood procedure for estimation of parameter β. This approach is very useful for regions with limited data such as stable shield regions and has been widely used by researchers in the past (Shankar and Sharma 1998; Sharma *et al* 2003; Kijko 2004; Raghukanth and Iyengar 2006). The earthquake magnitudes compiled in earthquake catalogs are never accurately estimated and the error in its estimation becomes even larger from complete (instrumentally recorded data) to extreme part of earthquake catalog (which are derived from shaking intensities). The standard error of 0.2 magnitude units has been considered for complete parts of catalog and 0.5 units for extreme parts of earthquake catalog. We have applied both the estimators to statistically evaluate maximum possible magnitude that can occur in each of the nine zones of the peninsular India region. Table 2 shows estimated values of seismicity parameters for each geological zonation.

4.3 *Comparative analysis and significance*

It is interesting to note that the *b*-value and the activity rate are found to be highest in the Southern Craton though this region has not experienced a large earthquake during last few hundred years. The seismicity rate from the statistical consideration is an indication of the previous observed activity in terms of magnitude of different sizes of past earthquakes and not just due to observed maximum magnitude in that region. The values of computed maximum magnitude of different seismogenic zones and different observed magnitude based on the catalog data reflect their different tectonic behaviour. The observed maximum magnitude is located in ROK ($M_w = 7.7$), which is the highest observed magnitude in the entire catalog. The expected maximum magnitudes in each zone along with error in the estimation procedure are shown in table 2. It is important to note that no earthquake records of magnitude more than the cut-off magnitude in the extreme and complete parts was available in the Eastern Craton region. Only two earthquake events of Eastern Craton were identified in the catalog period which were less than or equal to magnitude 5.0 but higher than 3.2. Since both events occurred outside the cut-off threshold of extreme and complete parts of earthquake catalog, they could not be included in estimation of earthquake parameters. However, it is seen that Eastern Craton is surrounded by different seismogenic zones which have experienced moderate earthquakes in the last hundred years. Even though the observed seismicity of the Eastern Craton region is not indicative of the severity of future possible earthquakes, it is imperative to consider the seismicity rate of this region closely associated with the neighbouring active seismogenic zones either due to the proximity or due to similar tectonic conditions with respect to other cratons. The seismicity parameters of Eastern Craton has been evaluated (shown