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SEISMIC ACTIVITY OF KOYNA REGION FOR THE PERIOD SEPT., 1993 - AUG., 1996

Sushil Gupta, B. K. Bansal and Sanjeev Kumar
Seismology Group, Nuclear Power Corporation, Vikram Sarabhai Bhavan,
Anushaktinagar, Mumbai - 400 094

ABSTRACT

This paper deals with the seismic activity of Koyna region during the period Sept., 93 to Aug., 96. The data was recorded by a single component seismograph installed at Vikram Sarabhai Bhavan, Anushaktinagar, Mumbai. A coda-duration magnitude scale has been developed through regression analysis of data set comprising 49 earthquakes for which M_L were reported by India Meteorological department. An empirical relationship, $\mathrm{Log}_{10}E_D = 13.18 + 1.2332\,M_D$, to estimate energy release has also been developed. The total amount of energy released during this period was estimated to be 1.7×10^{20} ergs. Half-yearly variation of b- value has been discussed in the end.

INTRODUCTION

Koyna lies in one of the most seismically active regions of Peninsular India, having experienced the largest earthquake of magnitude 6.3 on Dec. 10, 1967 attributed to reservoir impoundment. Since then the region has experienced over a thousand earthquakes of magnitude ≥ 3.0 (AERB, 1993). Figure-1 shows the recordings of some earthquakes from Koyna region by a simple seismograph consisting of a vertical component short period (L-4C, Mark product) seismometer and a paper chart recorder. This equipment is kept in a room in the neighbourhood of Vikram Sarabhai Bhavan at Anushaktinagar, Mumbai (Bansal et al., 1994) and the station is operational since August 27, 1993. Earthquakes of magnitude as low as 2.5 originating in the Koyna region were detected by this instrument. A total of 103 earthquakes were recorded in a period of 3 years from Sept., 1993 to Aug., 1996. Most of the events were cross-examined from the seismological bulletins of National Geophysical Research Institute (NGRI), Hyderabad and India Meteorological Department (IMD). The number of earthquakes recorded per month is shown by a histogram in Figure-2.

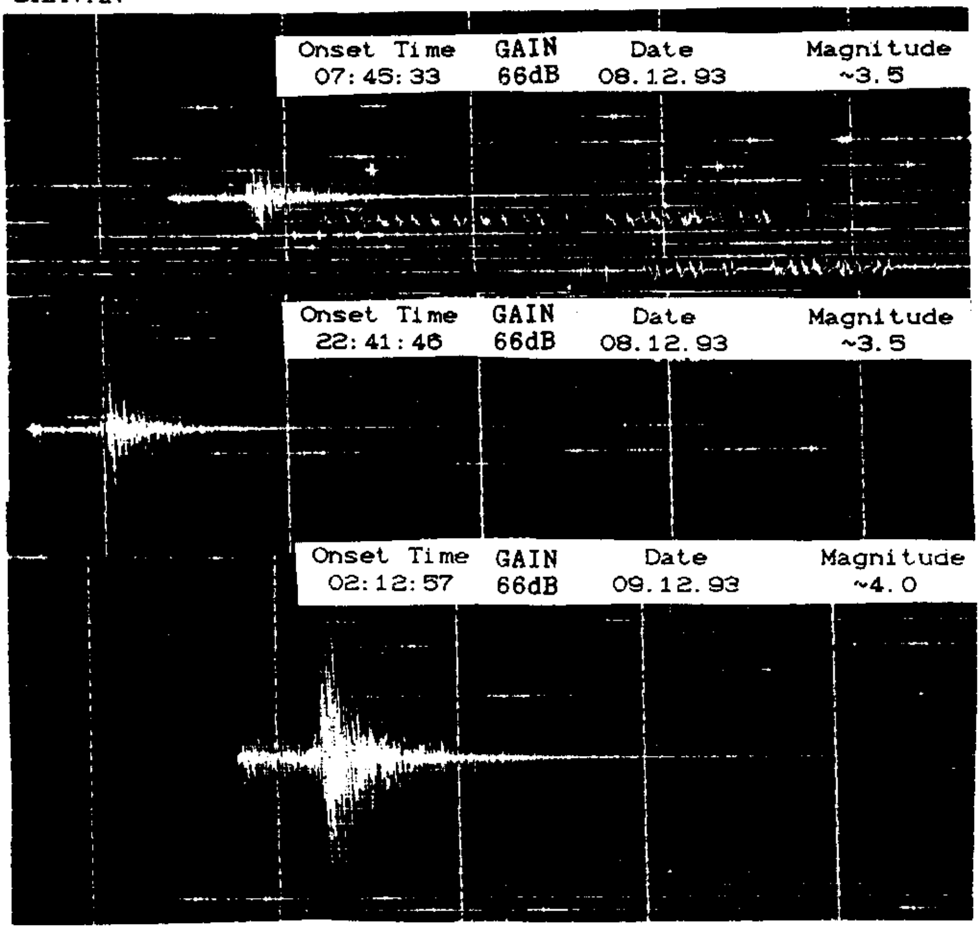
LOCATION OF EARTHQUAKE SOURCE

Using the S - P time difference and velocity of Primary and Shear waves, the approximate distance of earthquake source from the recording station can be estimated using the well known relationship,

$$\Delta = T_{S-P} \cdot V_S \cdot V_P / (V_P - V_S) \qquad (1)$$

where, Δ is the epicentral distance in km, T_{S-P} is time difference in sec between P and S wave arrivals and V_P and V_S are the primary and shear wave velocities in km/sec. The T_{S-P} time of most of these events ranges between 24 - 26 sec (see Figure-3). Assuming the average

FIG-1 : TYPICAL RECORDS OF KOYNA EARTHQUAKES RECORDED AT V.S. BHAVAN



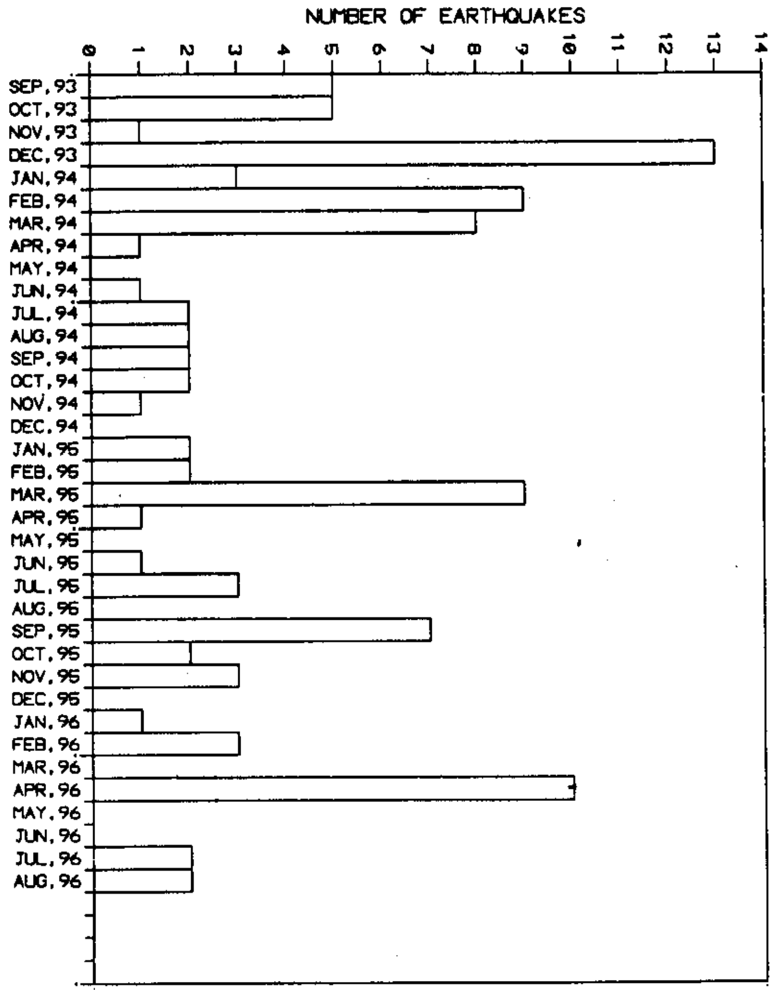


FIG-2 : HISTOGRAM SHOWING NO. OF EVENTS RECORDED PER MONTH AT V.S. BHAVAN FROM KOYNA REGION

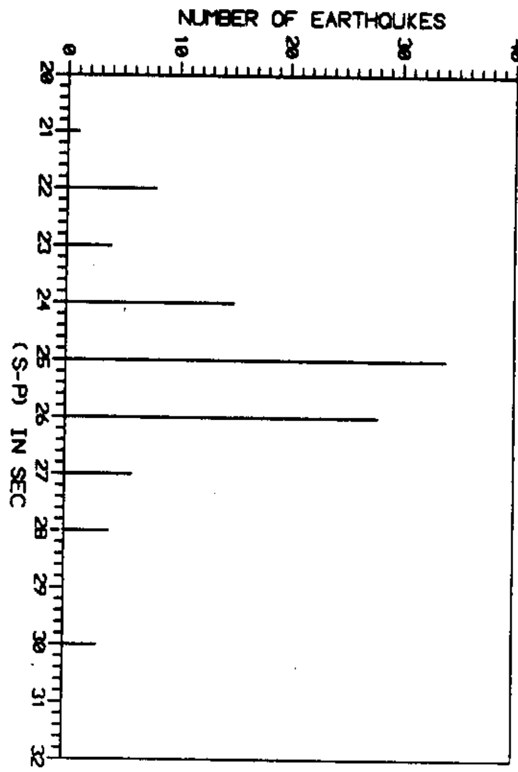


FIG-3 :NO. OF EVENTS VERSUS T_{S-P} TIME velocity V_P as 6.19 km/sec and V_P/V_S ratio as 1.706 (Srivastava, 1988) the epicentral distance of most of the events (~ 75 %) lies in the range of 210 to 228 km from the recording station.

CODA-DURATION MAGNITUDE

Magnitude of an earthquake is a widely used parameter in evaluating its size or total energy released at the source. It is generally estimated by measuring the trace amplitude of seismic signal as recorded on the seismogram. While most of the formulae for estimation of magnitude depend upon instrument constants, duration magnitude is one which is independent of these constants.

For earthquakes recorded at the Anushaktinagar station, following model has been used for estimation of duration magnitude (Lee & Stewart, 1981),

$$M_D = a_0 + a_1 \text{Log}_{10} T + a_2 \Delta \qquad (2)$$

where, T is signal duration in sec., Δ is the epicentral distance in km and a_0, a_1 and a_2 are the constants which vary from region to region. A set of 49 events with M_L ranging from 2.7 to 5.1 (personal communication - IMD, Mumbai) was used in the analysis. Parameters a_0, a_1 and a_2 were determined through regression analysis. The estimated values of these constants were found to be -0.2161, 1.7798 and 0.00084 respectively with standard error of 0.33 and correlation coefficient of 81%. In order to improve upon the applicability of the model, the data set was passed through a 1-Standard Deviation filter. The Parameters thus determined show a significant improvement over the earlier ones reducing standard error to 0.25 and improving correlation coefficient to 89.7%. Substituting values of a_0, a_1 and a_2 in equation (2) M_D can be written as:

$$M_D = -1.450269 + 2.226551 \text{Log}_{10} T + 0.001957 \Delta \qquad (3)$$

ENERGY RELEASE & ITS TEMPORAL DISTRIBUTION

Seismic activity of a region can be characterized by the total seismic energy-release within the region during the period of observation. Several empirical relations (using Body wave; Surface wave or local magnitude) are available to estimate the strain energy-release. The most commonly used one as given by Gutenberg and Richter (1956) has the form,

$$\text{Log}_{10} E = a_1 + a_2 M_S \qquad (4)$$

where, E is the strain energy-release in ergs, M_S is the surface wave magnitude and a_1, a_2 are constants with respective values of 11.8 and 1.5. The M_S values of 19 events reported by NGRI were first transformed to duration magnitude by way of linear fitting and constants were determined through regression analysis. The computed values of constants exihibt a standard error of 0.3 and correlation coefficient of 88%. Relation between energy release and M_D was then written by substituting the values of a_1 and a_2 in equation (4) :

$$\mathrm{Log}_{10}E = 13.18 + 1.2332\, M_D \quad (5)$$

Half-yearly release of seismic energy computed using the above relationship is shown in Figure-4. It is evident from this figure that there are two distinct periods of strain energy-release, i.e., Sept., 93 - Feb., 94 and March, 95 - Aug., 95. The amount of energy released during the above periods is 1.07×10^{20} ergs and 0.55×10^{20} ergs respectively. Also the cumulative energy computed for all the events using the relationship as given by equation (5) for the 3 year period is shown in Figure-5. A power - law fit between cumulative-energy release and time is given by :

$$E_t = 21 \times (t)^{0.62} \times 10^{18} \text{ ergs} \quad (6)$$

where E_t is average cumulative energy released in time t, measured in months from Sept., 1993. The above relation shows that the rate of energy-release is decreasing slowely and can be represented by :

$$dE_t / dt \quad \propto \quad t^{-0.38} \quad (7)$$

The Total amount of energy released during this period is estimated to be 1.7×10^{20} ergs.

VARIATION IN b-VALUE

Gutenberg and Richter (1949) introduced the concept of earthquake recurrence using frequency - magnitude relationship :

$$\mathrm{Log}_{10}N(M) = a - bM \quad (8)$$

where. N(M) is the number of earthquakes of magnitude $\geq$ M in a given area during a specified time interval. and a and b are constants called seismicity parameters. Parameter a is a measure of seismicity and depends upon the region and the period of observation. b is a measure of relative abundance of large and small earthquakes. If b is large, smaller earthquakes dominate the earthquake population and vice versa. Globally the value of parameter b is close to 1 but varies between 0.5 and 1.5 from region to region.

b- value estimates were made for half-yearly intervals and are plotted in Figure-6. This shows that during the period from Sept.,93 - Feb.,94 and March,95 - Aug.,95 the b- value is much smaller than the average value (0.83) for the entire period which indicates occurrence of large magnitude events. b- value for the period from Sept.,94 - Feb.,95 and March,96 - Aug.,96 is higher than the average value, indicating the occurrence of small magnitude events.

RESULTS AND DISCUSSION

The study highlights findings based on single component seismographic station data. An empirical relationship between energy-release and coda-duration magnitude has been developed. The coda-duration magnitude relationship developed through regression analysis is suitable for earthquakes occurring in Koyna region. Estimated model parameters have the low

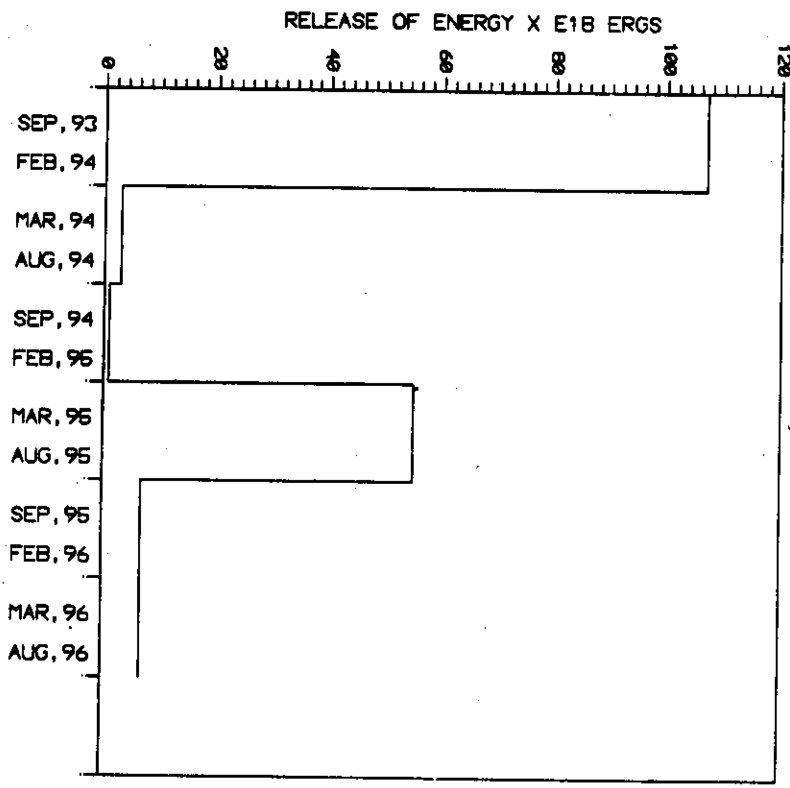


FIG-4 : HALF – YEARLY RELEASE OF SEISMIC ENERGY DURING SEPT., 93 – AUG., 96

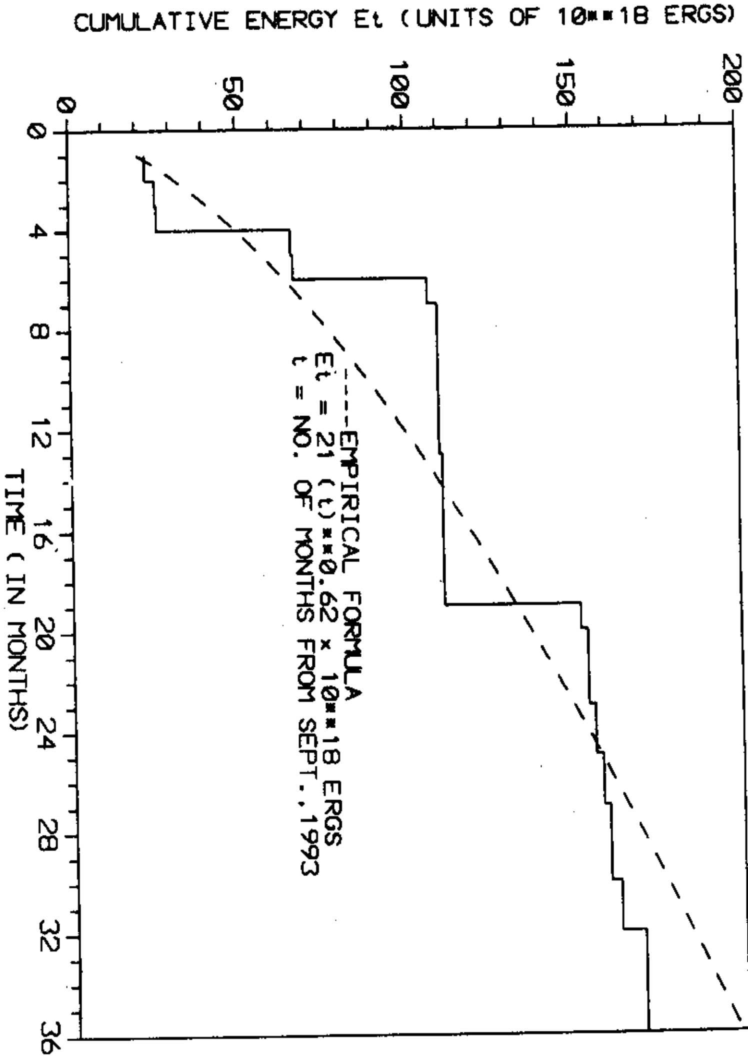


FIG-5 : CUMULATIVE ENERGY RELEASE OF KOYNA REGION AS A FUNCTION OF TIME

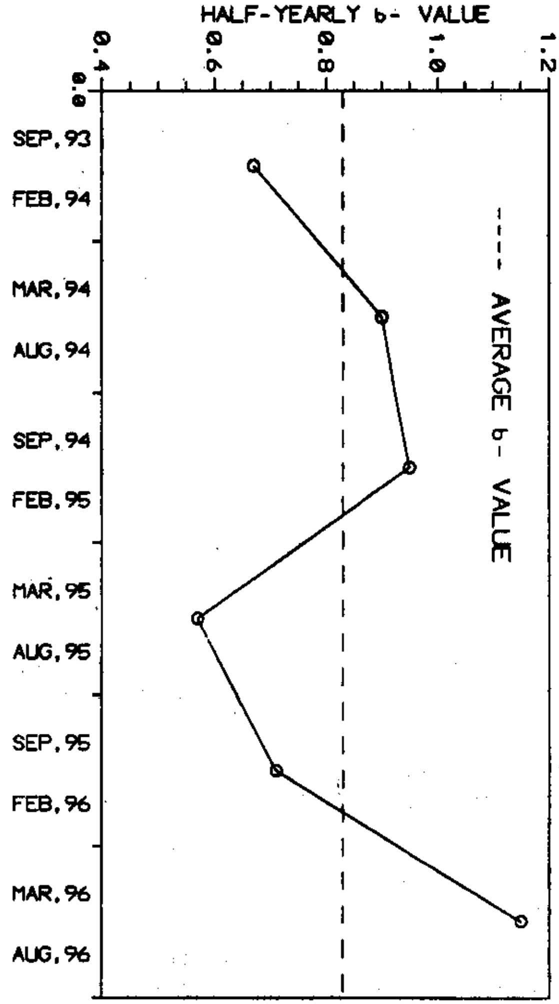


FIG-6. HALF-YEARLY TEMPORAL VARATION OF b- VALUE standard error and high correlation coefficient. The coda duration magnitude estimates using the developed relationship are quite close to local magnitude.

A total of 1.7×10^{20} ergs seismic energy was released during the period of study. However most of the energy was released during two distinct periods, i.e., Sept.,93 - Feb.,94 and March,95 - Aug.,95 (see Figure-4). Another interesting feature related to seismic energy is that rate of seismic energy release is decreasing slowly with time (see Figure-5). An average b- value of 0.83 was estimated using the half-yearly interval data. Similar estimates of b- value were given by other authors also. For instance, Guha et al. (1970) have found b- values varying from 0.75 to 0.95 for different periods between Dec., 1967 and Dec., 1969 and Chaudhury and Srivastava (1973) reported the b- value of 0.80 for the period 1970 to 1971. Thus the b-values obtained here are in good agreement with the reported b- values.

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