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# A PRELIMINARY ASSESSMENT OF THE RECENT INCREASE IN EARTHQUAKE ACTIVITY IN THE LOS ANGELES REGION

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# A Preliminarly Assessment of the Recent Increase in Earthquake Activity in the Los Angeles Region

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Recently, the Los Angeles metropolitan region has experienced numerous felt earthquakes (Table 1, Figure 1). This increase has prompted us to focus attention on the detailed nature of the seismicity variations in the Los Angeles region. We have analyzed the Caltech/USGS earthquake catalog for the region within 25 miles of Los Angeles and for the time period 1975 to the present (3 February, 1989). This preliminary study addresses two questions: 1) Has there been a significant change in the seismicity under Los Angeles?, and 2) What do such changes, when they occur, tell us about the present regional earthquake hazard? We found that a 2.9-year interval of significantly high seismicity rate, relative to the long-term rate for the region, began approximately March, 1986, and has continued to the present time. The implications of this increased activity for the regional earthquake hazard were considered from two perspectives.

First, we considered the possibility that the observed seismicity rate increase may be a precursor to a strong earthquake. A strain softening model (Stuart, 1986) predicts an increase in seismicity rate before a strong earthquake. Accordingly, we would consider the present interval of elevated rate in the Los Angeles area as a potential candidate for a strain softening precursor if a large earthquake were to occur there soon. However, there does not currently exist in the recent literature an established or widespread *observational* basis for interpreting such a seismicity increase as an earthquake precursor. Therefore, at this time we do not interpret the current observation as a precursor.

Secondly, we consider a stochastic model that provides an estimate of the probability gain for a strong earthquake associated with the observed rate increase in Los Angeles. The model suggests that the current daily probability for a damaging earthquake in the Los Angeles area has increased from its historical level of $1.5 \cdot 10^{-4}$ to $2.6 \cdot 10^{-4}$.

The catalog used in the study included 563 earthquakes with magnitude 2.3 and larger. Many of these events are aftershocks of larger earthquakes (such as the $M5.9$, 1987 Whittier Narrows earthquake and the $M5.0$, 1979 and 1989 Malibu earthquakes). We identified and removed the aftershocks using a clustering algorithm (Reasenberg, 1985), leaving a residual catalog consisting of 314 ($M \geq 2.3$) events. The statistical significance of variations in the seismicity rate in the residual catalog was measured with the $\beta$-statistic (Matthews and Reasenberg, 1988).

During the entire study period, the average rate of magnitude 2.3 or greater earthquakes in the Los Angeles region (excluding aftershocks) was 22 per year, with variations in the rate for individual years ranging from 14 to 60 per year (Figures 2, 3). The most significant rate fluctuation found in the study began in March, 1986, and has continued to the present (3 February, 1989). Over this interval, the rate averaged 33 events per year, 1.7 times the average rate for the interval 1975 through 1985. The statistical significance of a change in average seismicity rate during an interval (relative to a constant background rate) depends on both the rate and the duration of the interval. Short intervals of high (or low) rate are, in general, expected from random fluctuation in a constant-rate process, while longer intervals of sustained high or low rate are less likely. The 2.9-year interval of sustained high seismicity rate observed in the Los Angeles region represents a very significant departure from the pre-1986 levels. The probability that it is a random fluctuation in a constant-rate process is less than 1%.

The increase in activity is neither concentrated at a single site nor associated with a single fault. It is, however, confined to the area around Los Angeles, and does not extend to the San Andreas fault.

In addition, the average rate for the interval from August, 1988 to February, 1989 was 60 events per year, 3.2 times the average rate for the 1975-1985 base period. However, because rate fluctuations over such a short time scale (5 months) are common, this latest increase in rate is not, in itself, considered significant.

Scientists do not agree about how to interpret changes in the regional rate of earthquake activity. Some scientists believe that a strong and sustained *decrease* in seismicity rate signals the coming of a strong earthquake. This is known as the seismic quiescence hypothesis (Wyss and Habermann, 1988). Other investigators believe that a strong and sudden *increase* in seismicity rate may mean increased hazard (Wesson and Nicholson, 1988; Heaton, 1987). Both viewpoints are partially supported by theoretical or observational considerations.

In California, both increases and decreases in the regional rate of small earthquakes have been observed prior to strong earthquakes, as have periods of normal rate (Reasenberg and Matthews, 1988). Indeed, rate fluctuations are a common feature of California seismicity. In some instances, moderate or large earthquakes have occured during times of increased seismicity, while in others, the rate of seismic activity returned to normal without the occurence of a large earthquake. In general, no simple pattern consistently relates observed fluctuations in seismicity rate to future strong earthquakes. In this context, the increased level of earthquake activity in the Los Angeles region over the past 2.9 years, while very unusual, cannot be considered a precursor to a large earthquake.

An estimate of the hazard increase associated with the current high-rate interval may be derived from a stochastic model. We model the regional seismicity as a non-

homogeneous (varying rate) Poisson process in time, with a magnitude distribution that is stationary in time. In fact, the $b$-value in the Los Angeles region has remained nearly constant over the 14-year study period (Figure 3). In our model, the daily probability for a strong earthquake varies continuously in time from its long-term historic value, in proportion to the current average seismicity rate. The background rate of damaging earthquakes in the Los Angeles area is 10 earthquakes in past 180 years (Yerkes, 1985), corresponding to a background daily probability of $1.5 \cdot 10^{-4}$. We assume that the observed seismicity rate during the interval 1975-1985 represents the long-term background rate. Then, we infer that the current daily probability for a damaging earthquake in Los Angeles has risen (in proportion to the rate increase observed since March, 1986) to $2.6 \cdot 10^{-4}$.

In summary, a statistically significant increase in the rate of $M \geq 2.3$ earthquakes in the Los Angeles region began approximately March, 1986, and continues to the present time. The implications of this elevated activity for the regional earthquake hazard were considered from two perspectives. First, we noted that a strain softening model is consistent with an increase in seismicity before a strong earthquake. However, we do not interpret the current period of elevated activity in Los Angeles as a precursor to a strong earthquake because of the absence of a general observational pattern relating such seismicity changes to strong earthquakes. Secondly, we infer from a stochastic model of seismicity that the probability for a damaging earthquake in the Los Angeles region has risen slightly during the period of elevated seismicity from a daily background probability of $1.5 \cdot 10^{-4}$ to $2.6 \cdot 10^{-4}$.

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## FIGURE CAPTIONS

Figure 1. Map showing the locations of earthquakes with magnitude 2.3 and larger in the greater Los Angeles area for the period 1975 - 1989. The area for which the seismicity rate was evaluated in this study is indicated by the 40-km radius circle.

Figure 2. Cumulative number of ($M \geq 2.3$) earthquakes in the Los Angeles study area since 1 January, 1975. The change in rate that appears to begin approximately March, 1986 is a statistically significant departure from the 1975-1985 activity level.

Figure 3. (a) Rate of ($M \geq 2.3$) earthquakes in the Los Angeles area for the period 1975 to the present (3 February, 1989). Solid line indicates the smoothed seismicity rate calculated with a running averaging kernel with a width of 1 year. Broken line is the average rate for the entire 14-year study period. (b) Smoothed b-value variations (solid line) for the same data set calculated with the same averaging kernel as in (a). Upper and lower broken lines are $\pm 1$ standard deviation. The b-value is essentially constant, except for a possible decrease during the last few months of the study period.

Table I

Earthquakes M $\geq$3.5 within 40 km of 34° 0′N, 118° 20′W, 1975–February 7, 1989

| Date | Time | Second | Latitude | Longitude | Depth | Magnitude |
|---|---|---|---|---|---|---|
| 1975 1 13 | 11:21 | 50.32 | 33° 48.70′ | 118° 2.23′ | 8.00 | 3.8 |
| 1979 1 1 | 23:14 | 38.94 | 33° 56.66′ | 118° 40.88′ | 11.28 | 5.0 |
| 1981 2 27 | 15:11 | 12.60 | 34° 10.08′ | 118° 36.13′ | 16.21 | 3.5 |
| 1982 7 29 | 5:50 | 8.55 | 33° 56.71′ | 118° 42.71′ | 11.07 | 3.6 |
| 1982 10 15 | 9:57 | 20.47 | 34° 11.91′ | 118° 38.57′ | 3.31 | 3.5 |
| 1983 1 28 | 14:54 | 8.98 | 33° 56.47′ | 118° 42.33′ | 11.97 | 3.8 |
| 1983 3 1 | 20:18 | 35.80 | 33° 56.78′ | 118° 18.94′ | 5.00 | 3.6 |
| 1984 10 15 | 17:44 | 4.35 | 33° 41.86′ | 118° 9.57′ | 2.15 | 3.7 |
| 1987 7 8 | 16:55 | 59.46 | 33° 41.95′ | 118° 16.34′ | 7.75 | 3.6 |
| 1987 10 1 | 14:42 | 20.02 | 34° 3.68′ | 118° 4.71′ | 9.50 | 5.9 |
| 1988 3 26 | 14:54 | 20.44 | 33° 59.78′ | 118° 42.63′ | 13.85 | 3.7 |
| 1988 9 12 | 13:24 | 34.21 | 33° 51.99′ | 118° 27.42′ | 3.37 | 3.9 |
| 1988 12 3 | 11:38 | 26.43 | 34° 8.98′ | 118° 8.12′ | 13.50 | 5.0 |
| 1989 1 19 | 6:53 | 28.84 | 33° 55.12′ | 118° 37.64′ | 11.85 | 5.0 |
| 1989 2 2 | 4:51 | 54.65 | 33° 56.78′ | 118° 48.56′ | 6.00 | 3.8 |

FIGURE 1

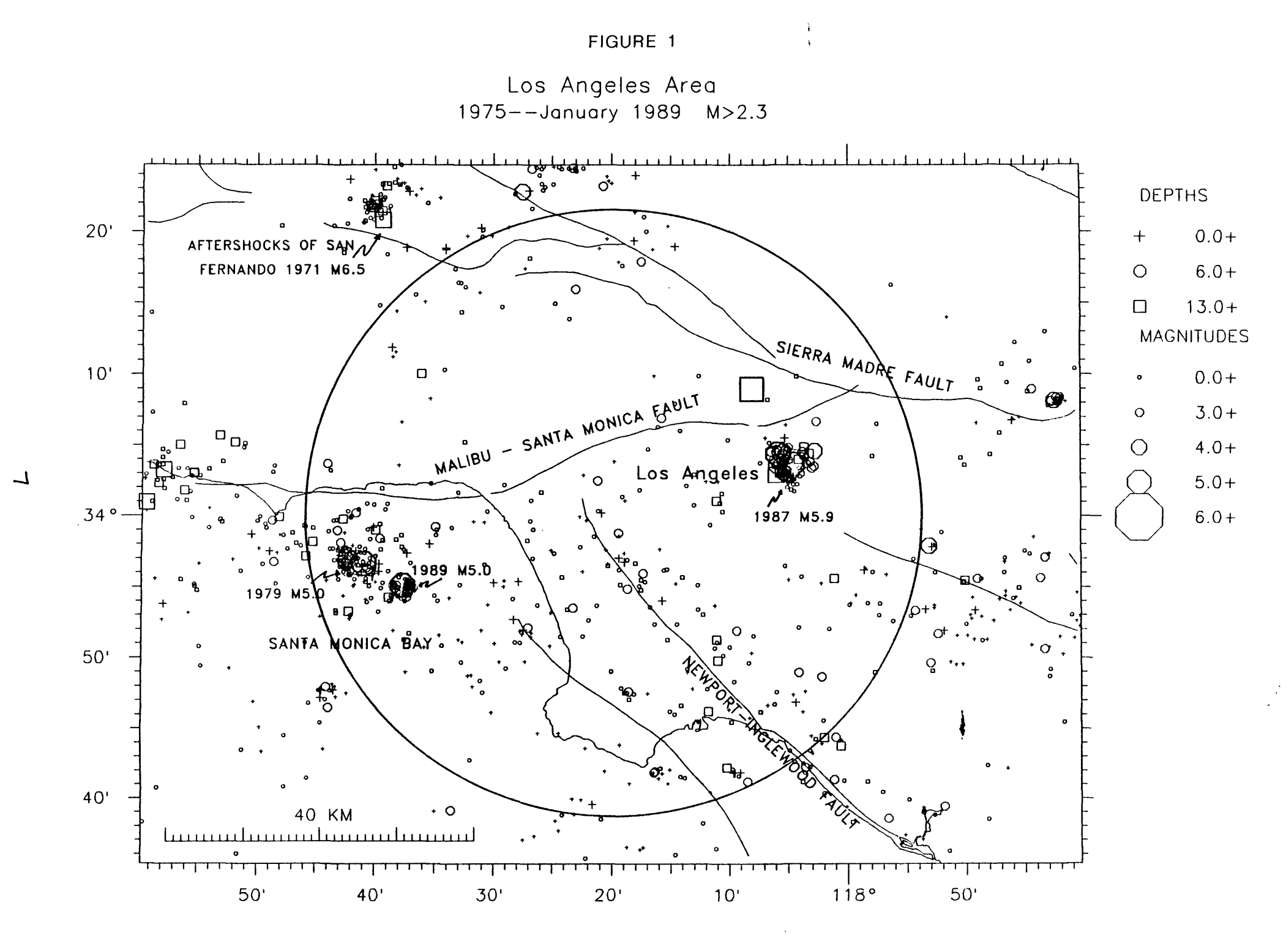

Los Angeles Area
1975--January 1989 M>2.3
DEPTHS
+ 0.0+
○ 6.0+
□ 13.0+
MAGNITUDES
0.0+
3.0+
4.0+
5.0+
6.0+
AFTERSHOCKS OF SAN FERNANDO 1971 M6.5
SIERRA MADRE FAULT
MALIBU - SANTA MONICA FAULT
Los Angeles
1987 M5.9
1989 M5.0
1979 M5.0
SANTA MONICA BAY
NEWPORT-INGLEWOOD FAULT
40 KM
20'
10'
34°
50'
40'
50'
40'
30'
20'
10'
118°
50'

FIGURE 2

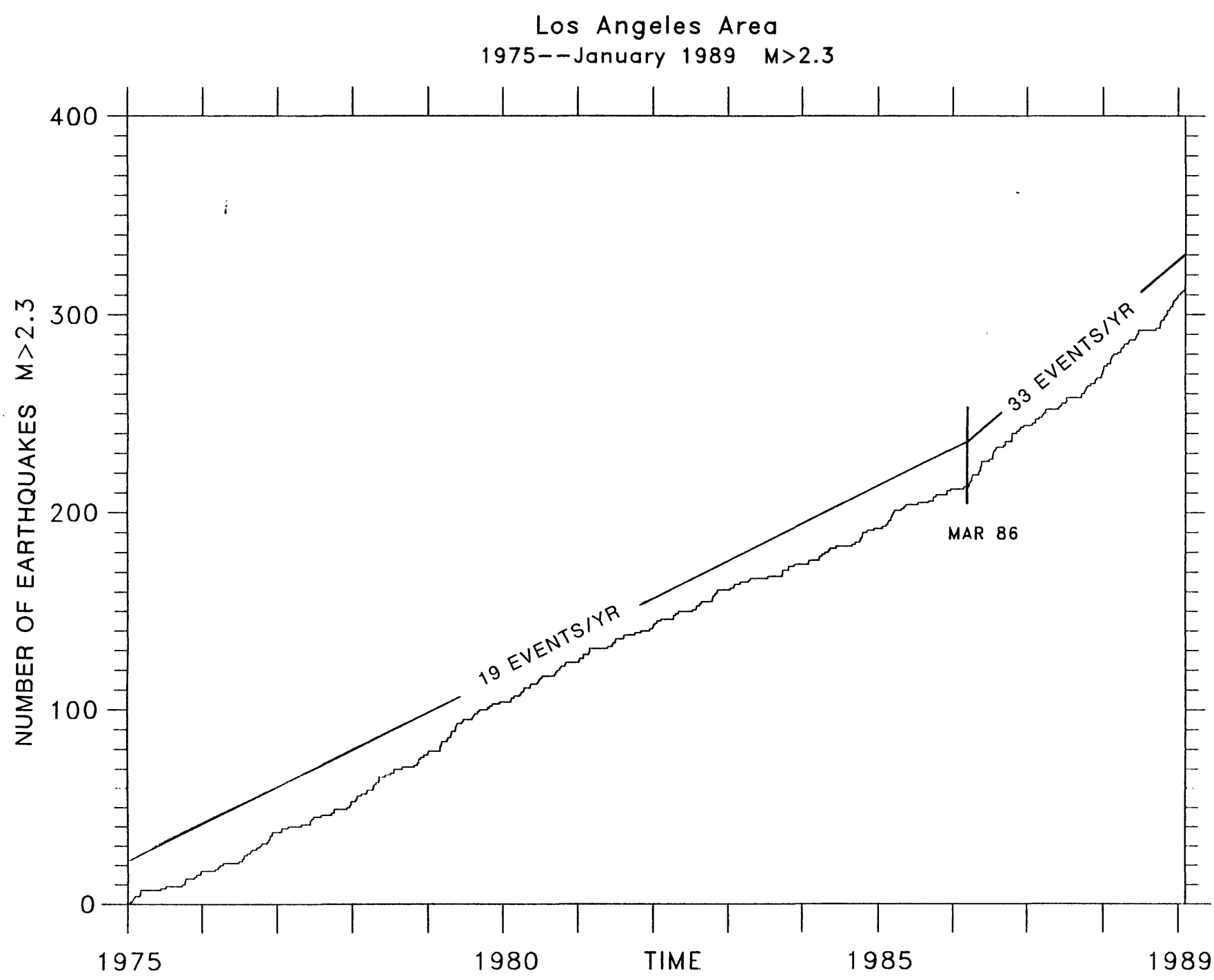
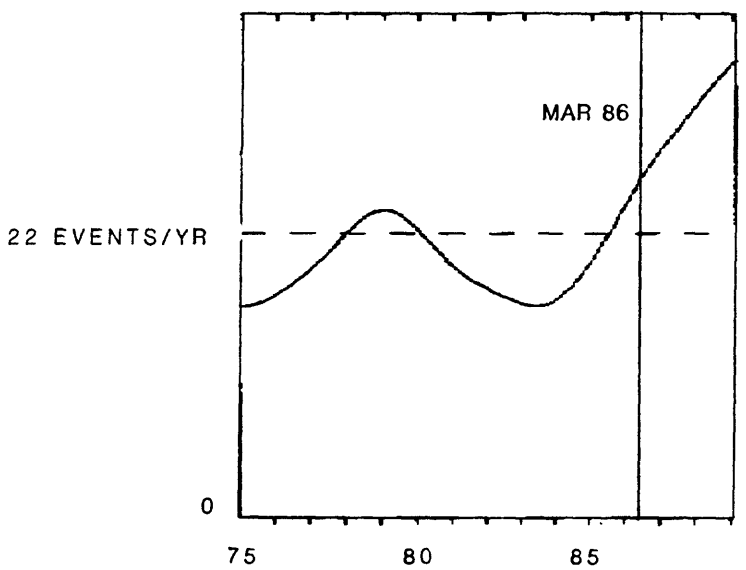

Los Angeles Area
1975--January 1989 M>2.3
NUMBER OF EARTHQUAKES M>2.3
400
300
200
100
0
19 EVENTS/YR
33 EVENTS/YR
MAR 86
1975
1980
TIME
1985
1989

FIGURE 3

a) RATE




b) B VALUE