Tôhoku Geophys. Journ. (Sci. Rep. Tôhoku Univ., Ser. 5), Vol. 36, No. 2, pp. 260–262, 2001

Testing the Hypothesis that Asperities of Subduction Earthquakes may be Mapped Based on Minima in Local Recurrence Time : Examples from Mexico and the Kanto-Tokai Areas, Japan (Extended Abstract)

MAX WYSS[1], F. RAMÓN ZÚÑIGA[2] and SHOZO MATSUMURA[3]

[1] Geophysical Institute, University of Alaska, Fairbanks, AK 99775, USA
[2] Unidad de Ciencias de la Tierra-Instituto de Geofisica, UNAM, Juriquilla, Querëtaro, CP 76230, Mexico
[3] National Research Institute for Earth Science and Disaster Prevention, Tsukuba

(Received November 14, 2000)

The b-value in the frequency-magnitude distribution

$$\log N = a - bM \tag{1}$$

is not a universal constant of $b=1$, as believed by some, but varies from approximately 0.5 to 2. 0, sometimes over distances of just a few kilometers. For example, active magma chambers can be mapped by anomalies of high b-values that surround them, embedded within a crust of normal to low b-values [Murru *et al.*, 1999 ; Wiemer and McNutt, 1997 ; Wiemer *et al.*, 1998 ; Wyss *et al.*, 1997].

Along the San Andreas fault, the creeping segment exhibits an anomalously high b-value [Amelung and King, 1997], strongly contrasting with the minimum in b observed in the volume that is know as the asperity of the Parkfield earthquake [Wiemer and Wyss, 1997]. Based on this observation, we propose that minima in the b-value, or possibly more clearly in local recurrence time (T_L), map major asperities. T_L is defined as the probabilistic recurrence time for the target earthquake of magnitude M_{targ}, estimated from a and b, using the nearest 100 earthquakes to any location in the crust, measured during the observation period ΔT.

$$T_L = \Delta T / (10^{(a - bMtarg)}) \tag{2}$$

Testing the hypothesis in southern California along strike slip faults of the San Andreas system, we found that 5 out of 6 target shocks of typically M 6.5 correlated with the asperities mapped by our method [Wyss *et al.*, 2000]. Here, we wish to test the hypothesis in the case of a compressional regime of the Kanto-Tokai district in Japan and the subduction plate boundary in Mexico. The target events in subduction zones of Mexico and Japan are the shallow earthquakes of $M7+$class.

The method we use for mapping these parameters was introduced and programmed by Wiemer [1996]. We place a grid with node spacing of one to a few kilometers over the study area and calculate the parameter of interest based on the data within a constant radius from each point.

In the case of the plate margin of the Pacific coast of Mexico, we used the catalog of the Mexican Seismological Survey with magnitudes transformed to the M_s scale, in which the minimum magnitude of completeness is 3.6, for on- as well as offshore seismicity. We mapped parameters b and T_L ($M_{\max}=7.2$) and compared these results with observed recurrence times for events with $M \geq 7.0$. The following regions stand out as likely locations for large earthquakes: the coast of Guerrero between longitude 100.5° and 101.5°, and the area off the coast of southern Chiapas show the shortest T_L, estimated as about 20 years; the location at longitude 98.5° (near the boundary of Guerrero and Oaxaca, the Ometepec segment) follows with estimates of about 30 years as the next shortest T_L; along the coast of Guerrero, between 99° and 100.5° longitude, T_L is estimated as about 40 years; and finally in the segments off the Oaxacan coast near 95.7° and 97.7° longitude, T_L ranges from 40 to 60 years. Long local recurrence times (locations not likely to produce large earthquakes) are observed offshore from the isthmus of Tehuantepec; on the Pacific plate off the coast of Guerrero; on land along the coast of most of Oaxaca; and along the northern-most 40 km of the Guerrero coast. Comparing T_L with historical recurrence times for the different regions yields a good correlation.

In the Kanto and Tokai areas of Japan, where the earthquake catalog of the NIED is complete at the $M = 1.5$ level, we used the on land data only. We mapped T_L based on the a- and b-values of the nearest earthquakes within 20 km of every node of a grid spaced 0.01° for $M7$ main shocks. Only earthquakes within the top 33 km were used. The resulting T_L-map shows that approximately 12% of the total area shows anomalously short recurrence times. Out of six main shocks with $M \geq 6.5$ and which occurred since 1890, five are located within the anomalous areas with $T_L < 450$ years. We interpret this to mean that areas with anomalously short T_L map asperities, which are more likely than other areas to generate future main shocks. If we include historic earthquakes with uncertain depth in the range of 0 to 100 in our test, then only 6 out of 11 main shock epicenters fall into the anomalous areas.

Our interpretation of the physical process that perturbs the b-values is that high and low ambient stresses favor low and high b-values, respectively. This assumption is based on laboratory experiments [Scholz, 1968], earthquakes triggered by pore pressure [Wyss, 1973], events in underground mines [Urbancic *et al.*, 1992] and in a gas field [Lahaie and Grasso, 1999]. In the case of the contrast along the Parkfield segment of the San Andreas fault, this interpretation makes sense, because the creeping segment (high b) is understood to represent a low stress environment, whereas the asperity is believed to be under relatively high stresses. Nevertheless, other interpretations, such as differences in heterogeneity [Mogi, 1962], are also possible.

Taking all of these results together, builds a strong case for advocating that the contrast in b-values that exists between different volumes of the crust contains important information about local conditions. Combining these differences in b with the differences in a of equation (1) leads generally to maps in which 10% to 20% of the volumes show anomalously low local recurrence times. The observations in all areas studied show that these minima correlate with past main shocks, to a degree that has a very low probability to occur by chance. Therefore, we believe that it will be fruitful to test the hypothesis in additional areas to more firmly establish its usefulness.

References

Amelung, F. and G. King, 1997: Earthquake scaling laws for creeping and non-creeping faults, *Geophys. Res. Letts.*, **24**, 507–510.

Lahaie, F. and J.R. Grasso, 1999: Loading rate impact on fracturing pattern: lessons from hydrocarbon recovery, *Lacq gas field*, France, in preparation.

Mogi, K., 1962: Magnitude-frequency relation for elastic shocks accompanying fractures of various materials and some related problems in earthquakes, *Bull. Earthq. Res. Inst., Univ. of Tokyo*, **40**, 831-853.

Murru, M., C. Montuori, M. Wyss and E. Privitera, 1999 : The location of magma chambers at Mt. Etna, Italy, mapped by *b*-values, *Geophys. Res. Letts.*, **26**, 2553-2556.

Scholz, C.H., 1968 : The Frequency-Magnitude Relation of Microfracturing in Rock and its Relation to Earthquakes, *Bull. Seism. Soc. Am.*, **58**, 399-415.

Urbancic, T.I., C.I. Trifu, J.M. Long and R.P. Young, 1992 : Space-time correlations of b-values with stress release, *Pageoph*, **139**, 449-462.

Wiemer, S., 1996 : Analysis of seismicity : New techniques and case studies, Dissertation thesis, University of Alaska, Fairbanks, Alaska.

Wiemer, S. and S. McNutt, 1997 : Variations in frequency-magnitude distribution with depth in two volcanic areas: Mount St. Helens, Washington, and Mt. Spurr, Alaska, *Geophys. Res. Letts.*, **24**, 189-192.

Wiemer, S., S.R. McNutt and M. Wyss, 1998 : Temporal and three-dimensional spatial analysis of the frequency-magnitude distribution near Long Valley caldera, California, *Geophys. J. Int.*, **134**, 409-421.

Wiemer, S. and M. Wyss, 1997 : Mapping the frequency-magnitude distribution in asperities : An improved technique to calculate recurrence times ?, *J. Geophys. Res.*, **102**, 15115-15128.

Wyss, M., 1973 : Towards a physical understanding of the earthquake frequency distribution, *Geophys. J. Royal. astr. Soc.*, **31**, 341-359.

Wyss, M., D. Schorlemmer and S. Wiemer, 2000 : Mapping asperities by minima of local recurrence time : The San Jacinto-Elsinore fault zones, *J. Geophys. Res.*, **105**, 7829-7844.

Wyss, M., K. Shimazaki and S. Wiemer, 1997 : Mapping active magma chambers by *b*-value beneath the off-Ito volcano, Japan, *J. Geophys. Res.*, **102**, 20413-20422.