Proceedings of Ninth World Conference on Earthquake Engineering
August 2-9, 1988, Tokyo-Kyoto, JAPAN (Vol.II)

2-1-3

MINOR SEISMIC HAZARD FROM SWARM EARTHQUAKES

Gottfried GRÜNTHAL and Peter KNOLL

Central Institute for Physics of the Earth,
Academy of Siences of the GDR, Potsdam, GDR

SUMMARY

The upper bound earthquake has been assessed for the typical focal zone of swarm quakes in the border region between the GDR and Czechoslovakia. Therefore, both statistical and seismotectonic approaches were applied. The latter one is based on a seismotectonic model for the focal process especially derived for the swarm in 1985/86. Both approaches result in an upper bound value of about M = 4.8. This maximum expected magnitude and also the seismic hazard for this region is relatively low in comparison with the fact that this focal zone is the seismically most active one in that part of Central Europe.

EARTHQUAKE SWARM ACTIVITY

An intensive earthquake swarm occurred 1985/86 in the narrow focal area well known for swarm quakes (see Fig. 1) in the border region of the German Democratic Republic (GDR) and Czechoslovakia (CSSR). By local seismic networks more than 8000 events have been recorded during this swarm. The activity maxima occurred in Dec. 1985 and in Jan. 1986 with a maximum event on Dec. 21, 10:16 UT, having a local magnitude of 4.6 which corresponds to a macroseismic intensity of 6.5 - 7 degrees (MSK-scale). The magnitude of the second largest event on Jan. 20, 20:38 UT, was 4.2.

All the tremendous number of this swarm events occurred in a relatively small focal volume of 3.5 km length, 1.5 km width, and in a depth of 6-8 km (Ref. 2, 3). A local seismic network is operating in that focal region since 1962. During the last 500 years peaks of swarm activity were repeating with a mean return period of 74 years and a standard deviation σ = 10 years (Ref. 4).

UPPER BOUND EARTHQUAKE (UBE) OF THE FOCAL ZONE OF SWARMS

<u>Statistical Approach</u> An essential step in the procedure of seismic hazard assessment is the estimate of the UBE for respective seismic source regions. Different approaches have been proposed for such an estimate, only a few of them could succesfully be applied in areas of relatively low seismic activity as in Central Europe.

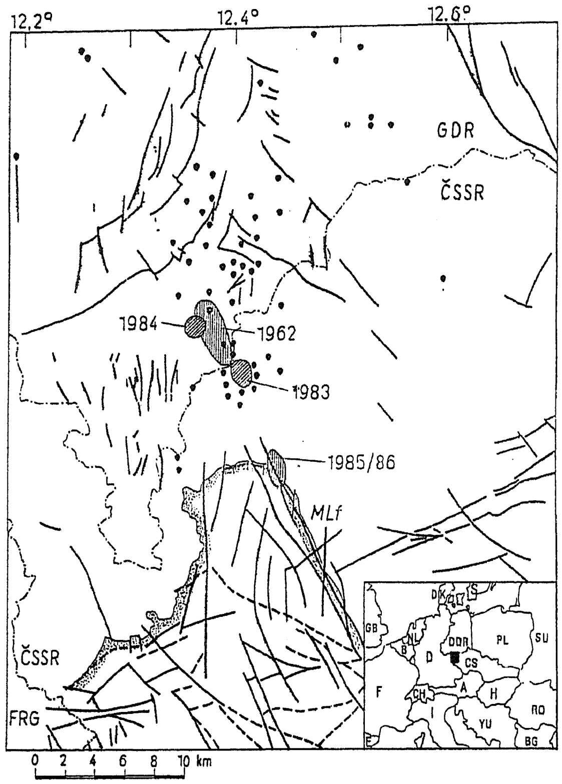

Fig. 1 Location of seismic activity in the focal area of swarms since 1962 and fault tectonics (Ref. 1). Dots - single event activity ($0.5 < M \leq 2.5$). Hatched areas - focal zones of swarms. MLf - N153°E striking dominating Marianske Lazne fault. Dotted strip - bound of a Tertiary/Quarternary basin.

Because this problem is not free of personal judgement we follow the principle that there is some guarantee for a proper estimate of the UBE if different independent approaches result in similar upper bound values.

The simplest but non the less relatively reliable procedure is based on the largest earthquake observed up to now in a region. From the 7 previous intensive swarms since 1552 there is no evidence that maximum magnitudes have exceeded values of about 4.7 or intensities of 6.5-7 degrees, respectively (Ref. 4, 5). This observational fact of repeated occurrence of events of more or less the same strength indicates that the UBE should be near to the observed maximum. According to the IAEA Safety Guide 50-SG-S1 (Vienna, 1979) it is recommended to add one degree of intensity to the maximum observed value in order to get the UBE. This recommendation concerns especially "normal" focal regions, i. e. such ones with non-swarm activity. The special characteristics of the focal area of swarms seem to justify the addition of probably 0.5 degrees to the maximum observed earthquake to get an appropriate conservative estimate.

Another approach is the extreme value statistics (type III distribution after GUMBEL) to determine the asymptotic maximum value. From the catalogued data (Ref. 5) extrema within consecutive time intervals of 8 years since 1890 have been used (Fig. 2). As the asymptotic maximum follows an intensity of 7.4 degrees (Ref. 6) which corresponds with a local magnitude of 4.8.

Seismotectonic Approach Very precise localizations and fault plane solutions of 17 events of the swarm 1985/86 provided the basis for *seismotectonic modeling* (Ref. 1, Fig. 3) in connection with detailed fault tectonic data, photolineations after satellite images, fault structures after geophysical data indicating conditions in the seismogenetic depth, studies of recent horizontal crustal movements and crustal stress data. 14 fault plane solutions show strikes in an azimuth of N187°E ($\sigma = 10^{\circ}$), the others are striking along the N153°E fault (c.f. Fig. 1). Fig. 1 shows the

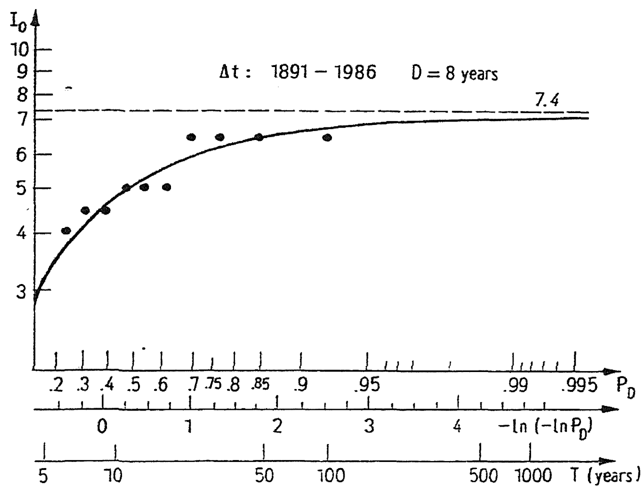

Fig. 2 Distribution of extrema (I_0-values) from 1980 to 1986 within D = 8 year intervals and the appropriate GUMBEL-type-III approximation with the asymptotic maximum $I_0 = 7.4^{\circ}$. (P_D - occurrence probability within D, T - mean return period).

locations of swarms and of single events since 1962. All epicentral areas of swarms are aligned along the N153°E striking fault system approximately trending in the azimuth of the maximum horizontal stress component (N136°E, $\sigma = 13^{\circ}$). This fault system is intersected by a bundle of recent active lamellar N-S to NNE-SSW striking fault elements. Both the N153°E fault system and the N-S fault elements show dextral creep tendency (Fig. 3a) while for the focal process of the swarm generally sinistral elastic rebound has been derived on the N-S fault splits. This means that the faulting process reflects a local compensation of the observed creep tendency. Moreover, a splay structure along the N153°E fault immeditaly S of the epicentral area 1985/86 connected with a right-stepping offset along a N-S fault element substantiates the proneness to the occurrence of swarm-like seismic activity (Ref. 7). Assuming the extension of this splay structure to the seismogenetic depth and its coincidence with the focal volume there follows from the fault plane solutions the seismotectonic model shown in Fig. 3.

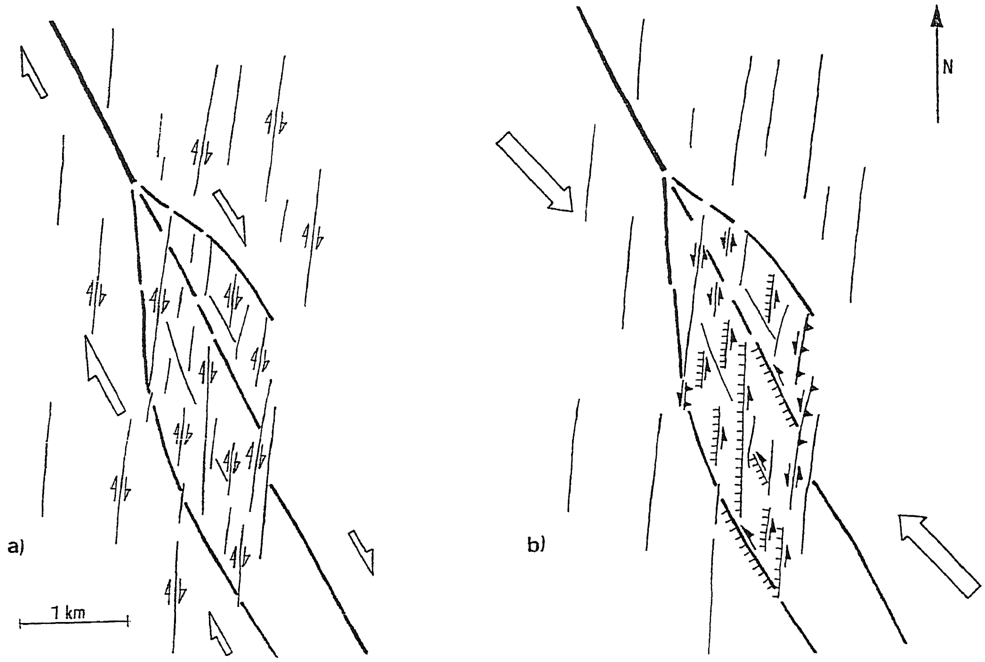

Fig. 3 Seismotectonic model for the focal area 1985/86 (Ref.1).
a - Strain accumulation phase. The N153°E striking main fault, respectively, the splay structure is intersected by NNE-SSE fault elements, both showing dextral creep tendency.
b - Focal process as sinistral rebound preferably on the lamellar NNE-SSW fault splits.

According to this model the maximum fault length would result in about L = 2.5 km. By means of the equation between fault length L and magnitude M for small earthquakes (Ref. 10)

$$M = 2 \log L /km/ + C \; ; \quad 3 < C < 4.2$$

one can estimate the UBE with C = 4.0 being about

$$M = 4.8.$$

On the other hand using the relation for the seismic moment M_o

$M_o = A \cdot \mu \cdot d,$ A - source area ($\approx l^2$)

μ - shear modulus ($\approx 3.10^4$ MPa)

$M_o \leq 1.5 \cdot 10^5$ Nm d - maximum source dislocation (≈ 10 mm, Ref. 3)

and the M_o-M-relation for the source area (Ref. 3)

$$\log M_o \approx 10.3 + M$$

the UBE results in

$$M = 4.9.$$

Thus, the estimated maximum magnitudes on the basis of the seismotectonic source model are in good agreement with the results of the statistical approach.

ATTEMPT OF SEISMIC HAZARD ASSESSMENT

A probabilistic calculation of seismic hazard will be given here for the town Klingenthal (about 12 km N of the source region 1985/86) which is most strongly affected by swarm earthquakes in the GDR. The special problem of seismic hazard assessment for sites highly influenced by earthquake swarms is the extreme non-Poissonian character of seismic activity. The generally used method after CORNELL (Ref. 8) requires strict Poissonian events. Therefore, a windowing routine has been applied to the initial data set (Ref. 1) for seperating the independent events (Ref. 9). This windowing results in the reduction of the initial data set to the appropriate main events of each swarm and the minor single event activity.

Fig. 4a shows the assessed seismic hazard for the site mentioned expressed as the probability that intensities will not be exceeded at the site during different periods D = 5, 10, 20,..., 2000 years, respectively. For small occurrence probabilities the hazard is strongly influenced by the UBE. This UBE is assumed as being larger by about one intensity degree in seismic active regions of the non-swarm type immediatly north of the focal area of swarms. Finally, Fig. 4b shows the percental influence of different focal regions on the seismic hazard of the site. The dominating influence of the focal region of swarms (sphere A) is obvious.

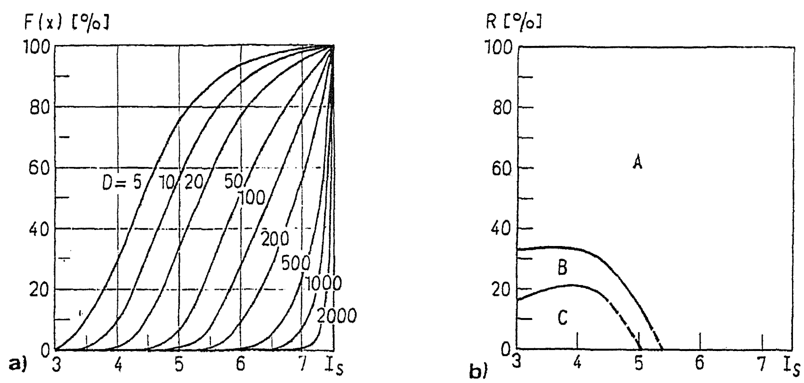

Fig. 4a Seismic hazard for a typical site expressed as the probability F(x) of non-exceeding of intensities I_S during time periods D.
Fig. 4b Influence R of different focal regions /in %/ on the seismic hazard depending on I_S for the site given in a). Spheres: A - focal region of swarms, B - northern adjacent region, C - others.

REFERENCES

1. Grünthal, G., Schenk, V., Zeman, A., and Schenková, Z., "Seismotectonic Model for the Earthquake Swarm 1985/86 in the Focal Area Vogtland/West Bohemia," submitted to Tectonophysics, (1988).
2. Horálek, J., Vavryčuk, V., Plešinger, A., Pšenčík, I., Jedlička, P., and Soukup, J., "Refined Localizations of Selected Jan. 5 - Feb. 6, 1986, Events of the West-Bohemian Earthquake Swarm," Proc. Workshop on Earthquake Swarm in Western Bohemia, Dec. 1985 - Feb. 1986, Mariánské Lázně, Dec. 1-5, 1986, 226 - 235, Prague (1987).
3. Neunhöfer, H., and Güth, D., "Detailed Investigations of the Great Earthquake Swarm in West Bohemia by the Local Vogtland Network," Monitoring and Analysis of the Earthquake Swarm 1985/86 in the Region Vogtland/Western Bohemia, Publ. Central Inst. for Physics of the Earth, in prepear., Potsdam (1989).
4. Grünthal, G. " About the History of Earthquake Activity in the Focal Region Vogtland/Western Bohemia," Monitoring and Analysis of the Earthquake Swarm 1985/86 in the Region Vogtland/Western Bohemia, Publ. Central Inst. for Physics of the Earth, in prepar., Potsdam (1989).
5. Grünthal, G., "Erdbebenkatalog des Territoriums der Deutschen Demokratischen Republik und angrenzender Gebiete von 823 bis 1984," Publ. Central Inst. for Physics of the Earth, No. 99, Potsdam (1988).
6. Schenk, V., Schenková, Z., and Grünthal, G., "Problems of Seismic Hazard Assessment for the Epicentral Area of Swarm Earthquakes in Western Bohemia/Vogtland," Proceed. Workshop on Earthquake Swarm in Western Bohemia Dec. 1985 - Jan. 1986, Mariánské Lázně, Dec. 1-5, 1986, 357-362, Prague (1987).
7. Segall, P., and Polland, D. D., " Mechanics of Discontinuous Faults," J. Geophys. Res. 85 (B8), 4337-4350, (1980).
8. Cornell, C. A., "Engineering Seismic Risk Analysis," Bull. Seismol. Soc. Am. 58, 1583-1606, (1968).
9. Grünthal, G., "The Up-dated Earthquake Catalogue of the GDR and Adjacent Areas - Statistical Data Characteristics and Conclusions for Seismic Hazard Assessment," Proc. 3rd Int. Symp. on the Analysis of Seismicity and Seismic Risk, Liblice Castle, Czechoslovakia, June 17-22, 1985, Vol. I, 19-25, Prague (1985).
10. Schick, R., "Untersuchungen über die Bruchausdehnung und Bruchgeschwindigkeit bei Erdbeben mit kleinen Magnituden (M < 4)," Z. f. Geophys. 34, 267-286, (1968).