

Earthquake pattern in Central Europe

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ABSTRACT : The paper gives a survey of the typical character of earthquake activity of a region with low seismicity and of the relations of earthquake epicenters with current tectonic movements. It summarizes the author's results of the systematic study of the region has been carried out since 1972.

1 GEOLOGICAL CHARACTERISTICS AND TECTONIC HISTORY

From the geological point of view, the territory of Central Europe (45°-53°, 5°-23°) is mainly formed by the Hercynides and Alpides. Central European Hercynides lie mostly on the outer margin of the Alpine-Carpathian foredeep. This area is composed of several different geological units of the first order of different age and different histories of the geological development which is reflected in the structure and thickness of the Earth's crust and in the differences of geophysical fields (Procházková, Roth 1992).

The development in the Upper Tertiary shaped the tectonic skeleton of the present Central European relief. According to the current assumptions, the events that produced the present orographic units, involve tectonic processes excited by the continuing collision between the continental block of Africa and the Proterozoic continental core of Europe (Fennosarmatia), it has been lasting about last 200 Ma years with a generally stable rate of about 25 mm per year (Roth 1987). The character of endogenic tectonic movements in the area under study in the last 5-10 Ma have a considerable time and regional stability (Procházková, Roth 1992).

2 SEISMOTECTONIC RELATIONS

The specific feature of the region under study is low seismic activity on its greater part, which means that the study has to involve also analyses of historical earthquakes since instrumental data only include a short time interval, the last 50-80 years. The map of the earthquake epicenters (see annex) with epicentral intensity $I \geq 5$ MSK-64 (Procházková 1991) documents that

the earthquake epicenters in the study area are unevenly distributed. This map point to clustering of shocks into regions. The focal regions are usually connected with faults that separate units characterized by different geologico-tectonic processes in the recent time (Procházková, Roth 1992).

A comparison of the geologically and geomorphologically established young movements of the Earth's surface with historical and recent seismicity allows the geophysical definition of the focal regions :

- Earthquake epicenters often concentrate along lines, where neotectonic movements take place (only some parts of these boundaries are seismoactive; in the region under investigation six units with different tectonic movement trends in the last 5-10 Ma were found).
- Foci of earthquakes originate in the dynamic system consisting of the African Plate and the Alpides and in the platform forefield of the Alpides.
- Foci of strong earthquakes originate in the platform only where it is coupled with the Alpides, i.e. in Central Europe in a belt about 300 km wide.
- Strong shocks do not occur in the domains of purely subsidence tectonics. (Procházková, Roth 1992).

The foci of stronger shocks frequently lie on the points of intersection of faults, sometimes a shock connected with one fault system is followed by a shock connected with other fault system. Usually, one fault system is predominant in respect of earthquake occurrence (Procházková et al. 1986).

3 EARTHQUAKE PATTERN

The shapes of macroseismic fields of earthquakes depend on the focal region and on

the focal depth; there are great differences between individual focal regions (Procházková, Dudek 1982). While the elongation of isoseismals in the near zone points to a system of faults in the focal region and to the focal mechanism that triggers the motion of the system of blocks under an earthquake, the elongation of distant isoseismals (the radii of which are greater than 2.5 h, where h is the focal depth in km) depends on the structure of the Earth's crust and the upper mantle, through which seismic waves propagate. The size of macroseismic fields depends in direct proportion on the earthquake magnitude, the focal depth, and in indirect proportion on the attenuation coefficient (Procházková 1990 a).

Earthquakes originating in a particular area differ in the size, the focal depth, the focal mechanisms and the dimension of the focus. In greater part of the study area, earthquake foci occur in the upper parts of the Earth's crust, i.e. $h \leq 10$ km; characteristic focal depths range between 5 and 8 km. In the south of the study area, the seismoactive layer is thicker, reaching a depth of as much as 25 km; two highly seismoactive parts were identified here round in depths of 5 and 17 km (Procházková 1984, 1990 a).

The differences in the focal mechanisms are documented e.g. in the Semmering region (47.65° N, 15.85° E) in 1984 by fault plane solutions given in Table 1 (data are in Procházková 1990 b),

Table 1. Fault-plane solutions of earthquakes : (1) - 15.4.1984, 10h56m52.4s, (2) - 22.5.1984, 19h33m32.2s, (3) - 24.5.1984, 19h56m05.9s.

	(1)	(2)	(3)
ML	4.7	3.8	4.6
h/km/	5	8	12
X - A	19°	311°	68°
i	43°	20°	62°
Y - A	115°	125°	282°
i	55°	59°	48°
Z - A	264°	229°	161°
i	56°	75°	33°

X, Y - the nodal planes, Z - the auxiliary plane, A - the azimuth, i - the angle of emergence.

Table 2. The numerical values of the stress drop of earthquakes : (1) - 6.5.1976, (2) - 15.9.1976.

	(1)	(2)
M	6.4	6.1
$\Delta\sigma$ /MPa/	0.1	2.4
Remark	many after-shocks	rapid drop of aftershock activity

The differences in the source dimension, which is indirectly proportional to the stress drop $\Delta\sigma$, are documented e.g. in the Friuli region in 1976, Table 2 (Procházková 1984).

As regard the seismicity character, the study area is greatly differentiated. Seismicity is a function of space and time. Individual focal regions differ by the numerical values of the parameters of the magnitude - frequency relationship; the examples are in Table 3.

Table 3. The numerical values of the parameters of the cumulative frequency in the last 80-130 years; (1) - The Bohemian Massif, (2) - the Western Carpathians + the Pannonian Basin, (3) - the Mur - Muerz-Leitha region, (4) - the Southern Alps.

	(1)	(2)	(3)	(4)
a	5.85+	4.62	5.28	5.52
b	0.74+	0.48	0.62	0.56

+Here is a big influence of the activity of the swarm region in Western Bohemia.

The seismic regime in focal regions is variable with time; there occur either active periods or gaps, see e.g. the Benioff's graph for the Verona - Padua region, Figure 1; periods of quiescence and active periods last hundreds, even thousands of years.

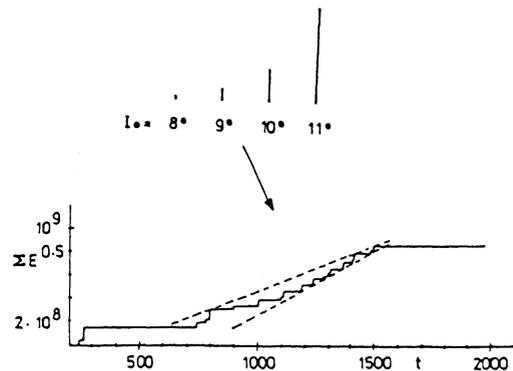


Figure 1. Benioff's graph for the Verona-Padua region; ΣE /J/ - the seismic energy, t /years/ - the time.

The short-term character of seismic activity is represented by sequences main shock - aftershocks, foreshocks - main shock - aftershocks, multiple earthquake

sequences in the case of the stronger earthquakes and earthquake swarms. Weak earthquakes and microearthquakes occur single or in groups of the swarm type. The form of the quantitative and qualitative characteristics describing the earthquake sequences is the same as in the seismic active regions, but there are differences in the values of numerical parameters. Detailed analysis of the earthquake sequences revealed :

- The detailed character of the swarm regime ; the seismic activity varies in time by the defined way - Figure 2.

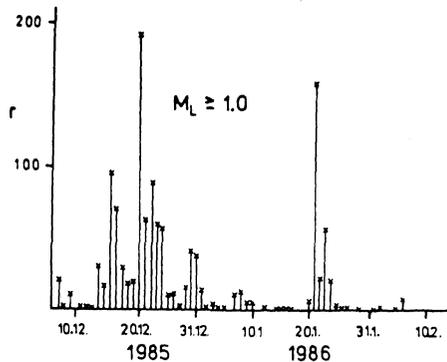


Figure 2. Daily number of shocks with $M_L \geq 1.0$ during the 1985-86 earthquake swarm in Western Bohemia (details see in Procházková 1988 b).

- The existence of two types of aftershock groups in one focal region, e.g. in the Semmering region (Procházková 1984, 1987). The results given in the literature and in Table 2 lead to the hypotheses that the character of the aftershock group is predetermined by the value of the stress drop of the main shock.

In some focal regions there are indications of the existence of space - and - time tendencies in the strong earthquake occurrence (Procházková 1984, 1988 a).

4 CONCLUSIONS

The paper shows that earthquake foci do not occur everywhere, but are controlled by specific global, regional and local structural situations. Earthquakes in Central Europe thus are shown (Amex) to be controlled by neotectonic movements (last 5 - 10 Ma years). Thus understanding the causative relation of earthquakes to neotectonic deformation and structure allows the earthquake hazard to be assessed on a higher level.

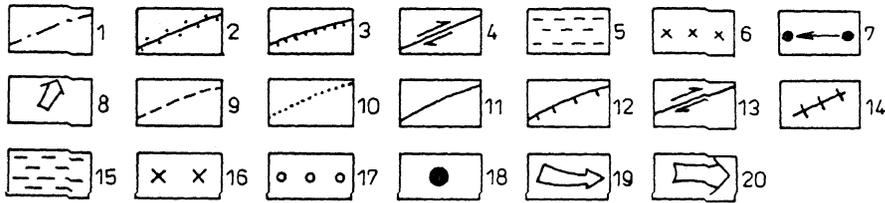
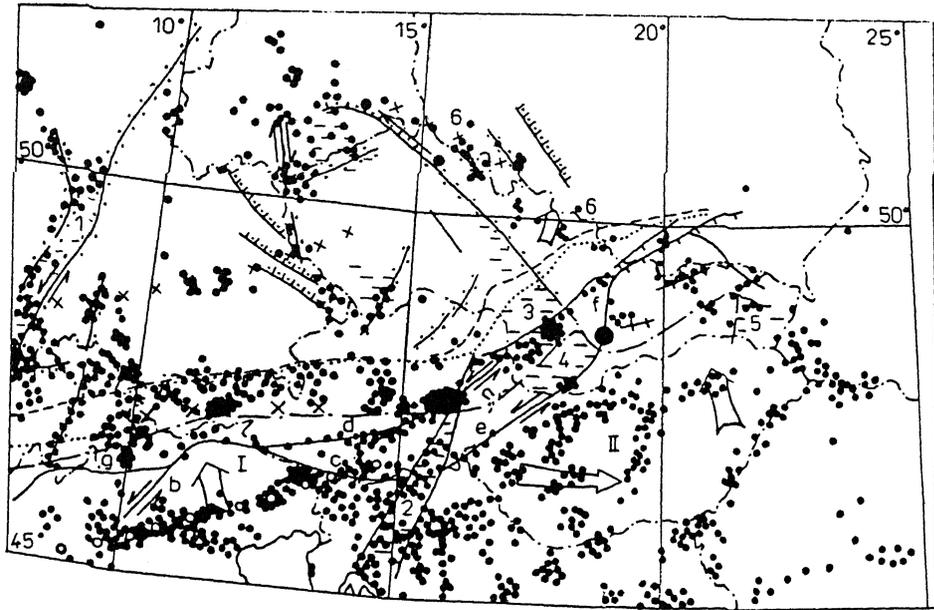
The physical processes taking place in earthquake foci are not identical, even in

one focal region. The nature of seismicity of a region with low seismicity does not qualitatively differ from those of a region with high seismic activity; there are considerable quantitative differences, first of all in the sizes of focal regions, the magnitude of strong earthquakes, the time intervals between strong earthquakes, etc. It seems that in region with weak seismicity, the tectonic processes leading to the earthquake origin were less intensive and slower in the recent time, than those in the regions with high seismicity.

In order to acquire further knowledge, it is necessary to study changes in the dynamic focal parameters, reflecting variability of the focal processes with time in individual focal regions.

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ANNEX

Connection of earthquake epicenters and geological structure elements and recent movement tendencies of the Earth's crust in Central Europe (details see in Procházková, Roth 1992).

Explanation:

Epi-paleozoic platform (1-8):

1 - S margin of the platform concealed below the northward overthrust Alpine chain, 2 - steep fractures, 3 - upthrust, 4 - strike-slip, 5 - extension areas, 6 - linear doming of the platform, 7 - approximate center of the sinistral twist of the Sudetian - Maleník platform block under the attack of the Carpathians, 8 - sense of the sinistral twist of the Sudetian - Maleník block.

Alpides (i.e. the Alps and the Carpathians, 9-20):

9 - frontal boundary of the Alpides (margin of the parautochthone platform cover), 10 - frontal margin of the geosynclinal Alpine structure, 11 - steep fractures, 12 - principal Cenozoic upthrusts, 13 - strike-slip, 14 - recent longitudinal roll-over faults separating the West Carpathian core-mountains, 15 - extension area, 16 - doming axis, 17 - down-warping axis, 18 - centre of the recent sinistral twisting of the Pannonian-Carpathian crustal block, 19 - direction of the

recent excentric sinistral twisting of the Pannonian block, 20 - sites and directions of the principal stress of the Alpides in Central Europe.

Ciphers :

I - the Cenozoic megablock of the Alps, II - the Cenozoic megablock of the Dinarides - Carpathians;

1 - Rhine Graben, 2 - Vienna - Kvarnerski Bay fault zone, 3 - Vienna Basin, 4 - Danube Basin, 5 - Trans - Carpathian Basin, 6 - Sudetian - Maleník block;

Letters :

a - Insubric - Drava Line, b - Judicaria Line, c - Gailtal Line, d - Mur-Muerz-Leitha-Žilina Line; e - Raaba Line, f - Revúca Line, g - Basel-Luzern Line.

- - earthquake epicenters, with epicentral intensity greater or equal to 5⁺ MSK-64.