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REGIONAL EARTHQUAKE CATALOGUE AND FOCAL REGIONS IN CENTRAL EUROPE

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CONTENTS

FOREWORD

The present work consists of four chapters. It summarizes the input data for the determination of seismic hazard of localities in the Central Europe. Above all it deals with:

- the compilation of a catalogue of strong earthquakes,
- the delimitation of regions in which earthquakes can originate, including the estimation of the maximum size that they can reach in a 10 000 year interval.

The sets of data are valid for the whole region under consideration. The seismic risk depends on the seismic hazard and on the seismic vulnerability of real structures, taking into account the local ground conditions, the type of structures and the technologies located there.

The earthquake catalogue, the atlas of earthquake isoseismals and the atlas of seismograms of earthquakes create, in hierarchical order, the primary data sets. All other data (frequency graphs, the space distribution of earthquake foci, and the time distribution of strong earthquakes) are derived from these primary (basic) data (e.g. Procházková 1984). Because the seismic hazard of localities is chiefly determined by strong earthquakes, the present work concentrates on these earthquakes exclusively. For the last ten years (as a consequence of the availability of recording technology) we have also followed the effects of weaker shocks in the close vicinity of real localities at which important structures might be located (IAEA, 50-SG-S1).

The authors know all the works of Zátopek, Kárník, Drimmel, Schenk, Schenková etc. (which are listed e.g. in Procházková 1984, 1993), dealing with the earthquakes in the region under consideration, and they know that the earthquake parameters determined by the individual authors of published works are not the same. Because they are presenting data sets that are used for real assessments in practice, they use the conservative approach for the sake of safety. The conservative approach, according to the guidelines of the IAEA and the US NRC is usually understood as follows:

- realistic upper estimates of the size of earthquakes have priority over lower values that were determined on the basis of assumptions that are not fully verified;
- the greater size of focal regions has priority over lower ones if there are doubts following from the present knowledge on earthquakes, geological structure and tectonic manifestations.

The most elaborated assessment of seismic safety of constructions is presented and codified for nuclear installations. The present work is orientated in this direction. The assessments of strong earthquakes in Mexico 1986, Spitak 1988, Loma Prieta 1989, Northridge 1994, Kobe 1995, etc. in the last ten years has in many countries resulted in the establishment of practices which were originally stipulated only for nuclear installations, also for the assessment of bridges, chemical plants, military constructions, smelting works, oil and chemical storage facilities, etc. (Procházková 1997).

1. INTRODUCTION TO SEISMIC HAZARD AND SEISMIC RISK

1.1. Legal Requirements

Every technical solution (i.e. including nuclear power plants or other nuclear installations) corresponds by its level to the knowledge at the time of its creation, and to the financial and technical possibilities of the creator, so that it has advantages and weaknesses that are then enhanced or weakened by the conditions in the vicinity in which the technical solution is located. From the view of the protection of the population and the environment it is necessary, during the design, construction and operation of the technical work, to solve not only technical questions but also the legal questions that guarantee the safety of the work for the population.

The safety of nuclear installations is determined both by technical parameters of the work and by external conditions. Earthquakes are among the external factors that are hazardous for the nuclear installations.

The building law (Law No. 50/1976 Sb.), the technical standard ČSN 73 0036, and the set of Regulations and Decrees (e.g. by the Czechoslovak Commission for Atomic Energy, and the State Office for Nuclear Safety) codifies that important installations must be resistant against external hazards (wind, earthquakes, precipitation, snow, extreme temperatures, missiles, floods, explosions). The following considerations in the present work are connected with earthquakes, because these represents the greatest hazard in the conditions of Central Europe.

Since the end of the 70s the guidelines of the International Atomic Energy Agency (further on "the IAEA"), e.g. IAEA 50–C–S, IAEA 50–SG–S7, IAEA 50–SG–S8, and IAEA 50–SG–S9, have required the synthesis of data from the Earth sciences with the aim of assessing a potential nuclear installation (i.e. an installation with nuclear technologies or with nuclear materials), taking into consideration the stability of the area, the moveability of faults, the frequency of earthquakes, their sizes and the maximum possible effects on the planned installation. Scenarios of movements in the region and in time (so called development trends of regions) are created, and the possible impact of these on the planned nuclear installations are evaluated. On the basis of these data decisions are made concerning the nuclear installation's siting and final design, on the construction procedure, on the equipment, and on measures to ensure both the optimal functioning of constructions and technologies, and nuclear safety in the case of the occurrence of an extreme event.

The IAEA recommendations of the 90s (e.g. the Safety Guide IAEA 50–SG–S1 of 1991) require the creation of seismic and geological databases. For nuclear safety procedures were also stipulated which are recommended by the IAEA for the assessment of the seismic resistance of present nuclear installations. These address:

- the determination of the marginal seismic resistance of the constructions, components and systems of each existing nuclear installation, that are relevant to safety; and
- the comparison of this marginal value with the value for the given locality.

In adverse cases, i.e. if the marginal resistance of some items under consideration (e.g. constructions, components, systems) is lower than the locality value, there should be carried out the appropriate seismic upgrading. The above-mentioned procedures are called the seismic PSA (Probabilistic Safety Assessment); their methodology is contained in the material (IAEA 1994).

1.2. Definition of Terms

Seismic Hazard

For the assessment of seismic hazard we must take into account (for reasons following from the reality of earthquake occurrence) both uncertainties (following from the causality of phenomena) and indefiniteness (following from the insufficient knowledge of the phenomena under consideration). By the application of probabilistic methods we can evaluate the uncertainties. The elimination of the influence of indefiniteness (that is in the definition of the boundaries of seismogenic structures and focal regions, in the parameters of earthquake foci, in the determination of seismic activity, in the definition of attenuation functions, in the selection of a stochastic model for earthquake occurrence, in the calculation of magnitudes for the intensities and in the determination the acceleration) is very complicated. This influence may only be diminished — by an assessment of the indefiniteness of all input parameters, by the calculation of the probabilities of all possible variants of input parameters, and by the consideration of several methodologies.

To determine the seismic hazard (and the seismic risk) there are used as a minimum two basic procedures (IAEA 50–SG–S1), namely:

1. A probabilistic procedure, determined through statistical evaluation and the processing of the observed earthquakes in the region under consideration. For localities in Central Europe we use an area delimited by a circle with the centre in the locality to be considered and with a radius of 200 – 400 km.
2. A seismotectonic (deterministic) procedure, that consists in the assessment of seismic hazard on the basis of geological and tectonic data that predetermines the possible seismoactivity of faults. The basis of this method is the assessment of the maximum possible earthquake that can be generated by the fault. For this purpose we use empirical functional dependencies (in the USA e.g. the magnitude of the maximum historical earthquake + half of a magnitude unit), statistical estimates (different relations between the fault length and magnitude) or expert judgements (based on the classification of selected features of faults). The last mentioned method tends to gain the upper hand, because by the use of an expert's experience it is possible to compensate for the incompleteness of our knowledge.

In the conservative approach, that is necessary for the assessment of a locality for a nuclear installation from the viewpoint of nuclear safety, the results of both the above-mentioned methods are considered. A real example is in Procházková (1995 c).

Probabilistic Assessment of Seismic Hazard

The methodology of the probabilistic assessment of seismic hazard of a given locality consists of four steps:

- the identification of seismic zones (focal regions),
- the determination of parameters of magnitude and frequency relationship for each focal region,
- the determination of a model describing the expected changes of parameters characterizing the ground movement (intensity, acceleration) as a function of a magnitude and an epicentral distance,
- the synthesis of data for all focal regions and the determination of the hazard curve.

For the appropriate determination of seismic hazard a theoretical statistical model of earthquake occurrence is used. Kijko (1985) has derived a model suitable for Central Europe. In the application of such theoretical models it is assumed that:

- the present model of earthquake occurrence (the spatial and time distribution of earthquakes and the occurrence of strong earthquakes) will be conserved in the future,
- there is a homogeneous distribution of earthquake foci in each zone,
- there is a random occurrence of earthquakes in space and time,
- there is independence among the shocks of individual focal regions,
- there is the same attenuation of ground movement in the broad region, i.e. in a region with a 5 km radius around the locality.

The hazard curves are determined for annual probabilities 0.95 and 0.85, the mean (of 0.05 and 0.95), the median and 0.05, taking the local geological conditions into consideration (Budnitz 1995a).

In making real calculations (introduction of numerical data into theoretical models) it is necessary to take into account that the results do not only depend on the model used but also on the model's calibration, i.e. on the determination of maximum possible earthquake and on the boundaries of focal regions. For the calculation of seismic hazard we consider that earthquake foci with a size up to the size of the maximum possible earthquake may occur at any point in each focal region. For safety purposes the least favourable case is used, taking into account the sizes of maximum possible earthquakes in individual focal regions, the shortest epicentral distance between the boundaries of focal regions, locality, and the smallest attenuation of earthquake intensity (IAEA – TECDOC–724, 1993, Budnitz et al. 1995 a,b).

The Seismotectonic Determination of Seismic Hazard

The seismotectonic method consists of two steps, namely:

- the collection of geological and seismic data. These are summarized and évaluated according to seismic and geological expert opinions on the tectonic moveability of the region, by the determination of active tectonic zones (i.e. zones in which movements occur, or can occur, or occurred in the Quartenary) and the level of their activity, and according to the maximum possible magnitude that can be generated by the real geological structure through its movement. The method of evaluation of geological data with regard to seismogeneration has been processed in many variants; all have the common feature that they consist in the evaluation of a set of multidisciplinary data and their empirical relation with regard to seismogeneration.
- the estimation of maximum possible earthquake (a magnitude $M_{\max}$ or an intensity $I_{\max}$) that can be generated by each tectonic zone. This either uses expert methods or deterministic relations (e.g. relations based on the fault length, particularly on the length of active part of the fault, and on the proportional increase of the observed value). This approach is feasible in regions of young, tectonically active regions. For the conditions in Central Europe it does not give reliable results (e.g. because in the literature there are no reliable relations derived for this region). Similar methods also use other characteristics of faults (e.g. Borisov, Rejsner, Šolpo 1975).

The method of evaluation of faults in Central Europe was established by Šimůnek (1989). The detail description of the method mentioned is in the paper (Procházková, Šimůnek 1998)

Moscow, but it has been adapted to the geological structure of the considered region and to its intense investigation.

The Duration of the Maximum Phase of Ground Movements

The basic characteristic of the focal region and each real locality is the duration of the maximum phase of ground motion. From the literature it follows that:

- it directly depends on the size of the earthquake (JENA 1980, Kato 1994),
- it increases with the epicentral distance (JENA 1980).

Its determination for localities in Central Europe is difficult, because there are no accelerograms recorded in this region. It is therefore necessary to use working estimates (JENA 1980). Taking into account the data (JENA 1980) for the sizes of maximum possible earthquakes in the focal regions of Central Europe (9 – 10 °MSK–64) and the shortest epicentral distances of localities on the territory of the Czech Republic from these focal regions (i.e. up to 300 km), the resulting value reaches several seconds.

Influence of Local Geological Structure

The real surface manifestation of an earthquake depends on the structure and on the arrangement of the upper parts of the local (geological) basement. Resonance effects come into play in a given place (Procházková, Drimmel 1983), when the basement is formed by a thin sedimentary layer over a rock base, and when the resonance period of the sedimentary layer (depending on the thickness of this layer) has a value that coincides with the prevailing period of seismic waves at a given place. The prevailing period of waves at a given place depends on the earthquake's size, on the focal depth, and on the hypocentral distance. It means that at a given place the resonance phenomena can only appear when certain conditions exist.

From the viewpoint of geological structure a role is played not only by the thickness of sedimentary cover, but also by the structural geometry, the level of ground water and the specific manifestation of geomechanical properties of rocks and soils creating the basement. The phenomena that can adversely influence the safety of nuclear installations are:

- the liquefaction of soil under the foundations of constructions,
- the failure of slope stability,
- the additional subsidence of the rock base under the constructions, induced by the change of the ground water regime,
- the collapse of underground cavities (caverns and mines).

For safety purposes, and according to the guidelines, (Šimůnek 1981) all nuclear power plant constructions falling into category 1 of seismic resistance (i.e. those constructions ensuring the safe shut–down of the reactor) shall be located on one geological block with a minimal size 500 × 500 m. The selection of this block is one of the main tasks of the geological and seismological survey of potential building site.

The Protection of Nuclear Installations against Earthquakes

The protection of nuclear installations against earthquakes issues from the known experience of what primary damage earthquakes cause, and also from the consideration of the secondary damage (even though this is the result of subsequent phenomena), which sometimes has the worst impact.

Seismic Risk

The risk to nuclear installations with regard to the earthquakes is determined by the consideration of the seismic hazard of the locality and of the vulnerability of the nuclear installation with regard to earthquake size and to the earthquake's other properties. The modelling of the vulnerability of components and systems (seismic fragility) of a nuclear installation is carried out during the design phase. An important role is played by the links in the nuclear installation systems that are designed, i.e. they are desirable. As a consequence of seismic oscillations (or processes that they have caused) there may also come into existence undesirable links that may have an influence on nuclear safety. The input data are made up on the one hand by the data on seismic hazard and on the other hand by the data on the seismic fragility of components and systems, that were obtained by monitoring (and in the USA also by analogy, taking into account the data of the experience database and of expert estimation). These data are processed by the methods of system analysis, most frequently by the logic tree method (Barosh et al. 1995). On the basis of the results obtained, preventive measures (technical and organizational) are applied. Their aim is to reduce the vulnerability of nuclear installations against earthquakes and to ensure preparedness to solve failures induced by the damage caused by the earthquakes.

The ability of safety and safety related systems to mitigate the damage caused by earthquakes (e.g. mechanical damage), i.e. to prevent the origin and the development of chains of phenomena that can affect the functioning of a nuclear power plant (NPP), depends on the size of primary damage and on its position. The probability of component damage is derived from the seismic fragility with specified characteristics. These questions are treated in detail in the standards NUREG/CR–2300 and NUREG/CR–2815.

Design and Maximum Calculated Earthquake

The design earthquake (level SL–1 according to the IAEA Safety Guide 50–SG–S1, design basis earthquake in the USA literature) is determined on the basis of historical data on earthquakes that have affected the given locality. In the case of a low data set, with uncertain and indefinite values, the value of 0.5 – 1 °MSK–64 is added to the intensity of maximum observed shock in the historical time at the given locality. The nuclear installation is constructed or upgraded so that it would be capable of safe operation after the occurrence of such a design earthquake.

The maximum calculated earthquake (level SL–2 according to IAEA Safety Guide 50–SG–S1, safe shutdown earthquake in the USA literature) is determined through the consideration of maximum possible earthquakes in the focal regions, the earthquakes of which can significantly influence the given locality by macroseismic effects, taking into account the seismotectonic regime in the region under interest. The following assumptions are used:

- the occurrence of maximum possible earthquake at each seismically active structure is considered at the point of active structure that is the nearest to the given locality,

- the occurrence of maximum possible earthquake that is not connected with the tectonic structures is considered at the point that is the least favourable for the given locality (mostly the nearest point),
- the occurrence of maximum possible earthquake in neighbouring focal regions is considered on the boundary that is the nearest to the locality,
- for the determination there is used the least favourable model of attenuation of macroseismic intensities (or accelerations) with the epicentral distance in the azimuth focus–site.

With regard to nuclear safety, the nuclear installation is designed, constructed or upgraded so that the equipment ensuring the safe shut down of the NPP remains functional after an earthquake of a size equal to the maximum calculated earthquake. For the determination of seismic load (i.e. strain induced by seismic waves) of constructions and their equipment, the ground acceleration is important for designers. Therefore, the values of design and maximum calculated earthquakes are given in the values of acceleration. According to the IAEA guidance NPPs must be designed for the maximum calculated earthquake characterized by a minimal ground acceleration equal to 0.1 g.

According to present knowledge (see the analysis in Procházková, 1984), it holds that:

- the ground acceleration caused by an earthquake is proportional to the earthquake stress drop, i.e. the higher stress drop the higher the ground acceleration,
- the earthquake stress drop is proportional to the corner frequency, i.e. in the case of high corner frequencies (so called short period earthquakes), the accelerations, and also the resultant damage, are higher,
- the size of an earthquake is not fully described by one parameter. At least two parameters are necessary, , e.g. the magnitude or the seismic moment and the stress drop or the focal dimension. In one focal zone there can occur earthquakes with the same magnitude but with different stress drop, i.e. with different ground acceleration.

For the assessment of the response of constructions and their equipment accelerograms are used: i.e. records of ground acceleration. These can be obtained in the following ways:

- by the direct measurement of ground acceleration at the given place,
- by the derivation of records of velocity or displacement at the given place,
- by estimation based on analogy, provided that the ground acceleration and the macroseismic effects are the same at all places with the same local geological structure from shocks with the same size, originating in a similar geological unit, with the same focal depth and in the same epicentral distance, if the seismic waves spread through a similar regional structure,
- by theoretical calculation (so called theoretical accelerograms), that considers the same aspects as those quoted for the estimation based on analogy.

In the territory of Central Europe there have not been recorded accelerograms, and so we use methods based on the use of the accelerograms of the World Database of Accelerograms. For this purpose we can take into account the knowledge specifying the transfer of results (see ČSN 73 0036) that has been presented in the professional literature.

The relationship between the macroseismic intensity and the ground acceleration depends on the local conditions and on the earthquake parameters.

The further empirical relationship (the vertical component of acceleration is equal to two thirds of the horizontal component) will require in future deep analysis (ČSN 73 0036). The earthquake records at Northridge 17.1.1994 and Kobe 17.1.1995 showed that this relation has no general validity (Procházková 1995 a,b).

Response Spectra

For the design of nuclear installations the seismic hazard must be expressed either in the form of response spectra or in the form of the accelerogram set.

The seismic waves propagating through the medium from the earthquake focus contain information on the one hand on the focus (i.e on its size, on the mechanics, and on the physical process taking place in time) and on the other hand on the medium through which the seismic waves are propagated. The occurrence of different mechanisms of earthquake origin and the complicated structure of the Earth's interior cause great variability of wave groups on seismograms, even in the case of earthquakes of nearly similar epicentral distances with the same focal mechanisms and the same size.

The above mentioned experience shows that not only the seismic waves but also their Fourier spectra depend on the azimuth between the seismic station and the fault (the manifestation of focal mechanisms), on the geological structure in the focal region and under the seismic station, on the properties of medium through which the seismic waves are propagated, and on the transmission function of the instrument by which the seismic waves are recorded.

The calculations of seismic vulnerability of NPPs are performed in the frequency domain. For the expression of seismic vulnerability design response spectra are used. These can be obtained through evaluation of the measurements (if the maximum effects are recorded at the locality) or by estimation, if the spectra of real waves are not available. Estimation consists in the use of data from another locality with the same focal characteristics and similar geological structure (see the methodology in revised standard ČSN 73 0036).

The influence of local geological structure is also expressed in the frequency domain, i.e. the determined spectrum of seismic hazard is modified by the so–called transmission function of the ground. The transmission function of the ground characterizes the ability of the medium to amplify or to reduce seismic waves. A distinction is made between the rate of spectra of waves striking the surface geological layer and that of spectra of waves recorded on the surface.

According to the ASCE standard (1986) the influence of local geological structure of locality need not be considered in the case of a rock fundament, i.e a fundament in which the S wave velocity is greater than $1100\,\mathrm{m\,s^{-1}}$.

In actual technical computations in the building (construction) dynamics floor response spectra are used, taking into account the different attenuation coefficients that are modified for the local geological structure. From the physical viewpoint the response of the construction is expressed by the size of movement, strain or stress that is caused by the seismic movements.

The seismic response of constructions and their equipment to the seismic load depends not only on the size of acceleration at the given place, but also on the duration of the maximum phase of ground movements and on the prevailing period of acceleration at the given place. In cases when the resonance properties of the upper parts of the Earth's crust, buildings and equipment come into existence, extra strong macroseismic effects are observed. For this reason, the Japanese nuclear legislation (JEAG 4601–1987) requires that the eigen frequencies of buildings, equipment and fundament should be different. For dynamic computations, the response spectra and the time record are used (IAEA, 50–SG–D15).

The USA Regulations (RG 1.60) contain the standard response spectra for damping of 0.5, 2, 5, 7 and 10 %. It issues from the theoretical and experimental papers of Newmark at al. (1973 a,b). In (Stevenson 1990) there is the recommendation that it is necessary to use the 5 % damping and that the response spectra peaks can be cut if the standard response spectra are used (RG 1.60) or (Newmark, Hall 1978). The 5 % damping is also used in Japan. The Regulatory Guide 1.60 specifies the acceleration response spectra for the value 0.25 g. NUREG/CR–0098 (Newmark. Hall 1978) specifies the median acceleration response spectra for the acceleration 0.3 g. In US practice the priority is given to real spectra (obtained as the median of a set of spectra), rather than to the very conservative spectra defined by RG 1.60.

For the evaluation of deflections (amplitudes) of real response spectra in the frequency interval corresponding to the resonance frequencies of a construction, the following strategy is used: the uncertainty in the determination of the eigen frequency of the construction is better removed by the shift of frequencies containing these deflections than by the extension of the amplitude spectrum. It is assumed that these deflections will not be amplified in the real construction during strong ground motions in the way predicted by linear elastic mathematical models. For each technological equipment of the NPP there are created the GERS (Generic Equipment Ruggedness Spectra) spectra that correspond to large ground movements at the seismic design terms of references for the given locality (Budnitz et al. 1995 a,b).

The standard spectrum according to the RG 1.60 was derived with the help of accelerograms from regions with a high level of seismic activity. The application of this spectrum in regions with small near earthquakes (e.g. in the ER and in the whole Central Europe) results in the overestimation of response spectra in the frequency domain $f < 3$ Hz.

The IAEA project "Benchmark Study for the Seismic Analysis and Testing of VVER Type Nuclear Power Plants" (Gürpinar 1995) was started in 1993. 23 institutions of 14 countries have participated in it. The project is divided into 17 tasks, and as NPP models there were selected the NPP Paks (VVER 440/213) and the NPP Kozloduj (VVER 1000). The main aim of the project is the transfer of know–how and the upgrading of the seismic safety of NPPs with VVER reactors for middle term and long term time intervals.

Owing to the highly individual character of earthquakes and to the great diversification of earthquake manifestations at any given places, an approach based on the introduction of standard spectra, calibrated to the acceleration in the given locality and to the local geological condition (with 5 % damping), is codified in many countries of the World and of Europe (Eibl, Keintzel 1992).

According to the IAEA guidance (IAEA 50–SG–S1) it is possible to use three methods for the determination of response spectra, namely:

- standard response spectra — the envelope created on the basis of existing data (no direct relation to the locality),
- specific (locality) response spectra, compiled as the envelope of response spectra of earthquakes that manifested in the locality (in the case when there are no data for the given locality it is only possible to use data from places with similar geological, seismological and geomechanical characteristics),
- reliably computed (theoretically constructed) response spectra.

Because there are a lot of uncertainties and indeterminacy in the specification of accelerograms and response spectra, in the IAEA member states a special procedure is used for the determination of response spectra. This is called "median plus σ (standard deviation)", and is based on the spectra of real earthquakes (selected from the accelerograms database or measured at the site).

The purposes of studies of earthquakes in nuclear engineering are the following:

- to define the relevant seismic terms of reference for the constructions, systems and components of nuclear installations,
- to delimit the frequency range that must be followed during equipment exchange with regard to the eigen frequencies of equipment with which the seismic instrumentation is put in tune,
- to determine the strategy for the case of occurrence of an earthquake of hazard proportions.

Firstly, there is performed the determination of the real seismic hazard of the given locality at the level of maximum computed earthquake, i.e. the long term prediction of the maximum effects of an earthquake of the given level at the given place (at the siting of the NPP constructions estimations for 10 000 years are determined, and for the final disposal of high level radioactive waste, for 100 000 years).

This is followed by the determination of the three components of ground response spectra and the three components of accelerograms for the site that are used for the computation of floor response spectra and floor accelerograms. These are compiled by help of a suitable model of the constructions of nuclear installation or its parts. From these data there are determined the response spectra for the selected pieces of equipment that are to be evaluated in the safety analyses.

Further aims are the determination of parameters of the seismic instrumentation that is located according to the IAEA guidance (IAEA 50–SG–D15) at the NPP (it usually works in the trigger regime and its signals are on the NPP control desk), and the stipulation of organizational and technical regimes for the case of strong earthquake occurrence (the conditions for shut–down of the NPP as a consequence of earthquake, the conditions for re–starting the NPP after a shut–down as a consequence of earthquake occurrence, and principles for inspection of the NPP after a strong earthquake occurrence).

1.3. Input Data

To ensure the safety of important technological and civil constructions it is necessary to determine the real seismic hazard for the given locality and on the basis of geological and geotechnical parameters of the locality the seismic risk that follows from it.

For the seismic hazard assessment we need:

- the data of the seismic database for the given locality, i.e. the earthquake catalogues and other data that describe the earthquakes in the region under consideration,
- the map of focal zones and the map of seismoactive parts of faults,
- the values of maximum possible earthquakes max I_0 for the individual focal zones and for the individual seismoactive parts of faults,
- the attenuation of intensities of earthquakes in the azimuth focal zone (fault) — locality,
- the geotechnical parameters of the locality and its vicinity.

The last mentioned data are not the subject of this work because they will depend on the results of a complex geological and seismological survey of the locality and its vicinity.

2. REGIONAL CATALOGUE OF EARTHQUAKES WITH $I_0 \geq 6\,°$MSK–64 ($M \geq 4$)

2.1. Introduction

The catalogue of earthquakes summarizes the primary data on earthquakes, i.e. the place of origin, time of origin and the size of the earthquake. The catalogue of historical earthquakes can only be complete for strong earthquakes (Procházková 1984). From the evaluation of completeness of data on earthquakes by help of frequency graphs it follows that in the whole of Central Europe there have only been recorded with sufficient reliability all earthquakes with the following epicentral intensities I_0 (MSK–64) in these periods:

- $I_0 \geq 8°$ since about the 13th century,
- $I_0 \geq 7°$ since about the 14th century,
- $I_0 \geq 6°$ since about the beginning the 16th century,
- $I_0 \geq 5°$ since the middle of the 19th century,
- $I_0 \geq 4°$ in the 20th century.

Earthquakes with intensity equal to $2-3\,°$MSK–64 are thus recorded only in the 20th century. The complete data on these shocks are available since the 60 s, from those areas in which the seismic network was thickened. The data on weak shocks are not processed at the international centres, because the location of weak shocks is only performed for special purposes. The present catalogue only includes strong earthquakes with the intensities $I_0 \geq 6\,°$MSK–64, for which there is a sufficiently long observation series.

In the used source catalogues the macroseismic data predominate over the instrumental data. For ranking the earthquakes by intensity the macroseismic scales MCS and MSK–64 are used. Both scales have twelve degrees. To each degree corresponds a list of macroseismic effects that are characteristic for it. The dissimilarity of the two scales consists in two features (Medvedev, Sponheuer, Kárník 1965):

- the MSK–64 scale has more detailed discrimination of building types, number of observations and description of damage,
- the values of acceleration arranged in the MCS scale are 4 – 5 units lower than the values of acceleration arranged in the $5^{th} - 10^{th}$ ° of the MSK–64 scale.

2.2. Data Sources

The sources of the catalogue given below are the national catalogues and the following publications: (Brouček 1991, Grünthal 1988, Juhásová 1994, Leydecker 1981, Labák 1996 a,b, Labák, Brouček 1995, Labák et al. 1996, Labák, Moczo 1996, Kárník, Michal, Molnár 1958, Kárník, Procházková, Brouček 1984, Drimmel, Procházková 1985, Procházková, Drimmel 1983, 1989, Procházková 1984, 1988, 1993a, Procházková, Dudek 1982, Zátopek 1939, 1940, 1948, Pagaczewski 1972, Slejko 1982, Ribarič 1982, Cvijanovič 1969, Brouček 1969, 1991, Kárník 1968, 1971, Drimmel 1980, Drimmel, Gangl, Trapp 1971, Trapp 1973, Drimmel, Trapp 1982, Gangl 1969, Réthly 1952, Csomor 1973, 1978, Zsíros, Monus, Toth 1983, 1988, 1993, Shebalin, Kárník, Hadžievski 1974, Zsíros 1983 a,b, Radu et al. 1979, Procházková, Kárník, Brouček 1980, Procházková, Brouček 1989, Kondorskaya, Shebalin 1982, Sponheuer 1952, Procházková et al. 1979).

The data on some shocks are given at several sources in a different way. In the case of great deviations in the position of epicentre, epicentral intensity, focal depth and magnitude among the individual sources, the values were checked on the basis of primary materials, both macroseismic (isoseismal maps, original descriptions of macroseismic effects) and instrumental (national seismic bulletins, the ISS, later ISC bulletins, bulletins of BCIS, CSEM and NEIS). The comparison of data showed that the differences in the geographical coordinates of earthquake epicentre among the individual sources only exceptionally exceeded the parameter uncertainty limits (±5 – 10 km, ±0.5 °MSK–64).

The comparison of given data sets (including the catalogues) showed that the authors do not always use suitable methodology for the determination of parameters of earthquakes. E.g.:

- some authors locate the earthquake epicentre at the centre of gravity of the isoseismal with the highest intensity, or at the centre of gravity of the area delimited by the highest observed intensities,
- other authors locate the epicentre at the place in which the strongest macroseismic effects were observed,
- other authors prefer the instrumental epicentre over the macroseismic (namely in the cases when there is no certainty that the model of medium used is adequate for the given area), etc.

The source catalogues mostly compiled several approaches that are not accurately distinguished. They usually apply the so-called "case by case" method.

2.3. Method of Catalogue Compilation

The catalogue is compiled in chronological order. The assessment of data on earthquakes is performed in the work of Procházková (1984). In Central Europe, for historical earthquakes documented by one data source or by several dispersed data sources, the accuracy of the epicentre determination is equal to ±50 – 100 km and the accuracy of intensity determination is ±1 – 2 °MSK-64. Procházková, Dudek (1982), Procházková, Drimmel (1983), Procházková, Kárník (1978) documented that for earthquakes for which the reliable maps of isoseismals are available, the upper boundary of the accuracy of epicentre determination is equal to ±5 km and the upper boundary of the accuracy of size determination ±0.5 °MSK-64. From works in which the evaluation of macroseismic observations is described, it follows that the accuracy of evaluation of individual macroseismic observations is as a rule not higher than ±0.5 °MSK-64. It is necessary to take into account the existence of local anomalies in the spatial intensity distribution documented by the isoseismal maps and by the microzoning (Procházková 1984), and that it was not possible to determine the origin time of an earthquake (hour, minute, second) before the existence of instrumental records (i.e. not before this century). The regional catalogue is compiled in the following way:

In cases where the parameters of one event occurred in several sources, the data incorporated into the regional catalogue are determined according to the following order:

- the earthquake parameters, determined on the basis of the isoseismal map in the way described in (Procházková, Dudek 1982). For the determination of earthquake parameters in cases with a small quantity of data, several combinations of values I_0, h, α, k frequently complied with the used formula. For the determination of earthquake parameters the following rule was applied: to select from the possible combinations of values the combination that best complied with the typical values of parameters h, α, k that were determined for the region on the basis of reliable parameters,
- the earthquake parameters determined from the isoseismal map in another way than that described above,
- the earthquake parameters of national catalogues,
- other sources.

In cases when it is not possible to decide which version should have priority, a conservative value is used, for the sake of the safety of nuclear installations and other installations. For this reason there are also included in the catalogue several earthquakes for which the authors give a magnitude higher or equal to 4 and an intensity of only 5.5 °MSK-64. By the determination of the magnitude from the epicentral intensity and the focal depth there are as a rule two suitable two, namely smaller I_0+higher h or higher I_0+smaller h. In the catalogue there is included the version for which the focal depth belongs to the depth interval determined on the basis of reliable data and the magnitude is higher than or equal to 4.

2.4. Catalogue

The catalogue contains the data on earthquakes from the territory delimited by the coordinates (46.7 – 51.5°N, 11 – 24°E), that is extended with regard to the shape of focal regions in the region of the Swabian Jura, Friuli and Southern Hungary. The data are arranged in the following order:

- the origin time, depending on the accuracy of determination (date + origin time in the world time UT (h – hour, m – minute, s – second), if it is known, or only the year of earthquake origin),
- the epicentral coordinates,
- the focal depth if it is possible to determine it,
- the epicentral intensity, the earthquake magnitude (the determined magnitude of the surface waves, or its equivalent determined on the basis of empirical formulae for individual regions (Procházková 1984)).

The catalogue consists of the following data:

- 456, 47.23° N, 16.62° E, I_0 9° MSK–64, M 6.2,
- 518, 47° N, 19° E, I_0 9° MSK–64, M 6.2,
- 823, 51.1° N, 12.8° E, I_0 7° MSK–64,
- 827, 51.1° N, 12.8° E, I_0 7.5° MSK–64,
- 984, 47° N, 19° E, I_0 8° MSK–64, M 5.6,
- 12.5.1022, 47° N, 19° E, I_0 8° MSK–64, M 5.6,
- 15.8.1038, 47° N, 19° E, I_0 8° MSK–64, M 5.6,
- 8.2.1062, 49° N, 12° E, I_0 8° MSK–64,
- 12.5.1088, 51.1° N, 13.1° E, I_0 7.5° MSK–64,
- 6.7.1092, 48° N, 21° E, I_0 8° MSK–64, M 5.6,
- 1100, 47° N, 18° E, I_0 8° MSK–64, M 5.6,
- 1170, 47° N, 19° E, I_0 8° MSK–64,
- 4.5.1201, 47.1° N, 14.2° E, I_0 9° MSK–64, M 6,
- 1230, 47.68° N, 16.58° E, I_0 7° MSK–64,
- 1250, 47° N, 19° E, I_0 9° MSK–64,
- 1258, 47° N, 19° E, I_0 9° MSK–64, M 6.2,
- 7.2.1258, 01h, 49° N, 19° E, I_0 7° MSK–64,
- 31.1.1259, 49.7° N, 20° E, I_0 8° MSK–64, M 5.2,
- 8.5.1267, 02h, 47.5° N, 15.4° E, I_0 8° MSK–64, M 5.5,
- 1323, 51.18° N, 12.56° E, I_0 6.5° MSK–64, M 4.2,
- 1326, 50.8° N, 12.2° E, I_0 6.5° MSK–64, M 4.2,
- 1342, 47° N, 19° E, I_0 7° MSK–64, M 5.0,
- 1346, 50.8° N, 12.2° E, I_0 8° MSK–64, M 5.2,
- 25.1.1348, 16h, 46.6° N, 13.8° E, h 7 km, I_0 10° MSK–64, M 6.5,
- 24.5.1366, 50.8° N, 12.2° E, I_0 7.5° MSK–64, M 4.8,
- 1410, 47° N, 19° E, I_0 8° MSK–64, M 5.6,
- 1433, 50.7° N, 16.5° E, I_0 6.5° MSK–64, M 4.6,

- 1441, 48.9° N, 20.6° E, I_0 6° MSK–64,
- 25.5.1443, 47.5° N, 16.3° E, I_0 8° MSK–64, M 5.6,
- 5.6.1443, 08h, 48.71° N, 18.94° E, h 25 km, I_0 8° MSK–64, M 5.9,
- 4.8.1444, 46.25° N, 20.15° E, I_0 8° MSK–64, M 5.6,
- 1453, 49° N, 20.5° E, I_0 8° MSK–64, M 5.6,
- May 1471, 48.5° N, 10.3° E, I_0 7° MSK–64,
- 1.6.1485, 47.5° N, 16.3° E, I_0 7° MSK–64, M 5,
- 26.3.1511, 13–14h, 46.1° N, 14° E, h 15–20 km, I_0 10° MSK–64, M 6.9,
- 26.3.1511, 19–19h30m, 46.2° N, 13.4° E, h 20 km, I_0 10.5° MSK–64, M 7–7.2,
- 26.2.1515, 48.37° N, 17.56° E, I_0 6° MSK–64,
- 26.5.1540, 19h, 51.1° N, 12.9° E, I_0 6.5° MSK–64,
- 6.3.1552, 50.58° N, 13.08° E, I_0 6° MSK–64,
- 12.2.1561, 47.53° N, 19.01° E, I_0 8° MSK–64, M 5.6,
- 10.2.1562, 50.5° N, 16.7° E, I_0 6.5° MSK–64, M 4.6,
- 1.11.1571, 47.3° N, 11.4° E, I_0 7° MSK–64, M 4.6,
- 4.1.1572, 19h45m, 47.3° N, 11.4° E, I_0 8° MSK–64, M 5.3,
- 27.4.1578, 11h, 50.88° N, 12.23° E, I_0 6.5° MSK–64, M 4.2,
- 1.1.1585, 47.5° N, 16.3° E, I_0 8° MSK–64, M 5.6,
- 1586, 48.37° N, 17.56° E, I_0 7° MSK–64, M 4.6,
- 29.6.1590, 47.95° N, 16.4° E, I_0 6° MSK–64, M 4.2,
- 15.9.1590, 17h, 48.2° N, 15.91° E, I_0 8° MSK–64, M 4.7,
- 15.9.1590, 23h50m, 48.2° N, 15.91° E, h 5 km, I_0 9° MSK–64, M 6,
- 1.10.1590, 48.14° N, 16.12° E, I_0 6° MSK–64, M 4.4,
- 12.7.1595, 47.3° N, 11.5° E, I_0 6° MSK–64,
- 16.12.1598, 50.87° N, 12.18° E, I_0 6.5° MSK–64, M 4.2,
- 1.10.1599, 8h30m, 47.76° N, 18.14° E, I_0 7° MSK–64, M 4.6,
- 21.9.1600, 19h, 49.23° N, 18.73° E, I_0 6° MSK–64,
- 7.9.1601, 47.5° N, 16.3° E, I_0 7° MSK–64, M 5,
- 27.11.1607, 18h, 49.06° N, 18.29° E, I_0 6° MSK–64, M 4.1,
- 16.11.1613, 11h, 49.25° N, 18.75° E, I_0 8° MSK–64, M 5.2,
- 12.2.1614, 10h, 47.02° N, 21.95° E, I_0 6° MSK–64, M 4.4,
- 5.1.1615, 47.98° N, 18.18° E, I_0 6° MSK–64, M 4.1,
- 20.2.1615, 02h, 47.5° N, 16.3° E, I_0 6° MSK–64, M 4.4,
- 5.6.1643, 11h, 49.23° N, 20.37° E, I_0 6° MSK–64, M 4.1,
- 7.3.1652, 48.8° N, 20° E, I_0 6° MSK–64, M 4.4,
- 30.11.1660, 08h30m, 48.37° N, 17.56° E, I_0 6° MSK–64, M 4.4,
- 26.4.1662, 06h, 46.67° N, 23.58° E, I_0 6° MSK–64, M 4.1,
- 9.8.1662, 23h, 49.0° N, 20.3° E, I_0 6° MSK–64, M 4.4,
- 27.8.1668, 06h, 47.8° N, 16.2° E, I_0 7° MSK–64, M 4.8,
- 4.8.1669, 15h15m, 48.5° N, 10.35° E, I_0 7° MSK–64,
- 12.4.1670, 01h30m, 49.05° N, 10.15° E, I_0 7° MSK–64,
- 17.7.1670, 47.3° N, 11.5° E, I_0 8° MSK–64, M 5.3,
- 3.8.1670, 49.9° N, 23.6° E, I_0 6° MSK–64, M 4.5,
- 26.3.1676, 48.5° N, 21.0° E, I_0 6° MSK–64, M 4.4,
- 22.12.1689, 47.3° N, 11.4° E, I_0 8° MSK–64, M 5.3,

- 4.12.1690, 46.6° N, 13.8° E, h 6 km, I_0 9° MSK–64, M 6.2,
- Dec. 1691, 47.1° N, 13.7° E, I_0 6.5° MSK–64, M 5,
- 23.12.1693, 12h, 49.4° N, 10.1° E, I_0 7° MSK–64,
- 1700, 48.14° N, 17.12° E, I_0 7° MSK–64, M 4.6,
- 28.7.1703, 48.86° N, 20.97° E, I_0 8° MSK–64, M 5.2,
- 28.3.1706, 47.3° N, 11.4° E, I_0 6° MSK–64, M 3.8,
- 2.12.1706, 47.3° N, 11.5° E, I_0 6.5° MSK–64,
- 25.10.1711, 19h15m, 51.18° N, 12.56° E, I_0 6.5° MSK–64, M 4.2,
- 10.4.1712, 11h, 47.82° N, 16.24° E, I_0 7° MSK–64, M 4.8,
- 1.7.1720, 17h, 50.56° N, 12.4° E, I_0 6° MSK–64, M 4,
- 29.1.1724, 19h45m, 49.13° N, 20.44° E, I_0 7° MSK–64, M 4.6,
- 12.4.1724, 12h, 48.9° N, 20.6° E, I_0 6° MSK–64,
- 13.6.1724, 48.9° N, 20.6° E, I_0 6° MSK–64,
- 18.8.1727, 47.3° N, 11.4° E, I_0 6.5° MSK–64, M 4.2,
- 6.1.1734, 02h, 48.01° N, 16.24° E, I_0 6° MSK–64, M 4.1,
- 1736, 47.8° N, 16.3° E, I_0 7° MSK–64, M 5,
- 30.6.1751, 50.8° N, 15.6° E, I_0 6° MSK–64, M 4.3,
- 9.12.1755, 8h30m, 48.45° N, 10.4° E, I_0 7° MSK–64,
- 28.6.1763, 04h22m, 47.75° N, 18.16°E, I_0 8.5° MSK–64, M 5.8
- 9.8.1763, 47.7° N, 17.6° E, I_0 6° MSK–64,
- 5.2.1765, 22h45m, 47.76° N, 18.14° E, I_0 6° MSK–64, M 4.1,
- 5.8.1766, 05h30m, 47.8° N, 16.61° E, I_0 7° MSK–64, M 4.6,
- 16.8.1766, 47.8° N, 16.61° E, I_0 7° MSK–64, M 4.6,
- 17.3.1767, 47.76° N, 18.14° E, I_0 6° MSK–64, M 4.1,
- 13.4.1767, 50.95° N, 9.72° E, I_0 6.5° MSK–64, M 4.2,
- 21.11.1767, 46.9° N, 14.3° E, I_0 7° MSK–64, M 4.6,
- 8.12.1767, 10h, 47.52° N, 19.73° E, I_0 6° MSK–64, M 4.4,
- 27.2.1768, 01h45m, 47.83° N, 16.17° E, h 12 km, I_0 8° MSK–64, M 5.5,
- 4.8.1769, 15h15m, 48.45° N, 10.4° E, I_0 7° MSK–64,
- 6.1.1771, 16h, 50.25° N, 12.43° E, I_0 6° MSK–64, M 4,
- 26.1.1774, 50.1° N, 18.2° E, I_0 6° MSK–64, M 4.3,
- 28.1.1778, 47.2° N, 9.6° E, I_0 6° MSK–64,
- 22.5.1778, 1h30m, 48.48° N, 10.42° E, I_0 6° MSK–64,
- 19.12.1778, 08h, 48.9° N, 21.8° E, h 8 km, I_0 8° MSK–64,
- 23.12.1778, 05h45m, 48.9° N, 21.8° E, h 8 km, I_0 8° MSK–64, M 5.4,
- 6.4.1779, 13h15m, 48.9° N, 21.8° E, I_0 7° MSK–64, M 4.6,
- 26.6.1780, 21h20m, 47.8° N, 18.1° E, I_0 6° MSK–64, M 4.1,
- 9.12.1781, 23h, 48° N, 23.5° E, I_0 6° MSK–64, M 4.1,
- 22.4.1783, 02h30m, 47.75° N, 18.08° E, h 18 km, I_0 8° MSK–64, M 5.3,
- 31.5.1783, 11h, 47.75° N, 18.16° E, I_0 6° MSK–64,
- 10.12.1783, 16h, 47.76° N, 18.14° E, I_0 6° MSK–64, M 4.3,
- 23.1.1784, 21h, 47.9° N, 23.9° E, I_0 6.5° MSK–64, M 4.6,
- 20.3.1784, 50.6° N, 13.7° E, I_0 7° MSK–64,
- 15.6.1784, 47.76° N, 18.14° E, I_0 6° MSK–64, M 4.3,
- 7.8.1784, 03h40m, 47.76° N, 18.14° E, I_0 6° MSK–64, M 4.3,

- 22.8.1785, 06h, 49.7° N, 19° E, h 10 km, I_0 6.5° MSK–64,
- 12.2.1786, 23h, 50.4° N, 16.6° E, I_0 6° MSK–64, M 4,
- 26.2.1786, 23h45m, 50° N, 18° E, I_0 6° MSK–64,
- 27.2.1786, 03h, 49.7° N, 18.5° E, h 30 km, I_0 7.5° MSK–64,
- 3.12.1786, 16h, 49.7° N, 20° E, h 20 km, I_0 7.5° MSK–64,
- 6.2.1788, 07h, 49.88° N, 12.75° E, I_0 6° MSK–64,
- 26.8.1789, 09h30m, 50.55° N, 12.12° E, I_0 6° MSK–64, M 4,
- 11.12.1789, 50.8° N, 15.6° E, I_0 6° MSK–64, M 4,
- 6.2.1794, 12h18m, 47.4° N, 15.1° E, I_0 8° MSK–64, M 5.3,
- 12.5.1794, 47.3° N, 11.4° E, I_0 6° MSK–64,
- 3.3.1796, 23h, 48.36° N, 10.24° E, I_0 6° MSK–64,
- 31.1.1797, 0h, 48.5° N, 22.6° E, I_0 6° MSK–64, M 4,
- 11.12.1799, 14h45m, 50.5° N, 16.1° E, h 5 km, I_0 7° MSK–64,
- 1805, 48.58° N, 17.68° E, I_0 6° MSK–64, M 4.3,
- 22.9.1806, 19h45m, 47.76° N, 18.14° E, I_0 7.5° MSK–64, M 5.1,
- 17.11.1809, 21h40m, 49° N, 21.2° E, I_0 7° MSK–64,
- 14.1.1810, 17h09m, 47.38° N, 18.2° E, h 6 km, I_0 8.5° MSK–64, M 5.3,
- 21.1.1810, 02h, 47.38° N, 18.2° E, I_0 6° MSK–64, M 4.4,
- 27.5.1810, 08h, 47.38° N, 18.2° E, I_0 7° MSK–64, M 5.0,
- 3.6.1810, 47.38° N, 18.2° E, I_0 6° MSK–64, M 4.1,
- 24.6.1810, 14h, 47.38° N, 18.2° E, I_0 6° MSK–64, M 4.4,
- 18.7.1810, 47.6° N, 14.5° E, I_0 7° MSK–64,
- 21.12.1810, 16h30m, 47.38° N, 18.2° E, I_0 6° MSK–64, M 4.4,
- 6.9.1811, 01h, 47.38° N, 18.2° E, I_0 6° MSK–64, M 4.1,
- 4.10.1811, 20h50m, 47.55° N, 15.56° E, I_0 6.5° MSK–64, M 4.3,
- 28.4.1814, 47.3° N, 11.4° E, I_0 6° MSK–64,
- 7.5.1814, 16h15m, 47.38° N, 18.2° E, I_0 6° MSK–64, M 4.4,
- 1815, 47.73° N, 18.33° E, I_0 6° MSK–64, M 4.4,
- 15.6.1815, 8h, 48.6° N, 17.68° E, I_0 6° MSK–64,
- 17.7.1820, 47.35° N, 11.7° E, I_0 7° MSK–64, M 4.2,
- 6.2.1822, 8h, 48.75° N, 18.16° E, I_0 6.5° MSK–64,
- 18.2.1822, 16h15m, 47.75° N, 18.25° E, I_0 8° MSK–64, M 5.4,
- 5.1.1823, 02h, 47.9° N, 23.9° E, I_0 6.5° MSK–64, M 4,
- 19.1.1824, 15h30m, 50.2° N, 12.4° E, h 7 km, I_0 6.5° MSK–64,
- 1.2.1824, 05h, 50.2° N, 12.6° E, I_0 6° MSK–64,
- 21.2.1825, 46.8° N, 14.4° E, I_0 6° MSK–64,
- 15.5.1826, 47.6° N, 14.5° E, I_0 6° MSK–64,
- 1.7.1829, 19h30m, 47.5° N, 22.2° E, h 15 km, I_0 8° MSK–64, M 5.9,
- 8.6.1830, 07h10m, 47.61° N, 15.67° E, I_0 6.5° MSK–64, M 4.3,
- 26.6.1830, 47.4° N, 15.1° E, I_0 6.5° MSK–64, M 4.3,
- 1.7.1830, 04h, 48° N, 23.6° E, I_0 6° MSK–64, M 4.3,
- 11.7.1830, 09h15m, 48.75° N, 19.35° E, I_0 7° MSK–64, M 4.6,
- 11.8.1830, 46.5° N, 14.3° E, I_0 6° MSK–64,
- 15.10.1834, 06h30m, 47.6° N, 22.3° E, h 25 km, I_0 8.5° MSK–64, M 5.9,
- 12.7.1836, 46° N, 17.5° E, M 5.3,

- 14.3.1837, 15h40m, 47.61° N, 15.67° E, h 9 km, I_0 7° MSK–64, M 5,
- 11.7.1839, 12h, 47.45° N, 19.68° E, I_0 6° MSK–64, M 4.1,
- 23.4.1840, 49.38° N, 20.37° E, I_0 7° MSK–64, M 4.8,
- 26.6.1840, 49.4° N, 20.37° E, I_0 6° MSK–64, M 4.4,
- 13.7.1841, 12h30m, 47.82° N, 16.24° E, I_0 7° MSK–64, M 4.8,
- 24.10.1841, 12h10m, 47.76° N, 18.14° E, I_0 7° MSK–64, M 4.6,
- 31.8.1842, 09h30m, 46.47° N, 17.0° E, I_0 6° MSK–64, M 4.4,
- 5.11.1844, 08h30m, 47.9° N, 23.9° E, I_0 6° MSK–64, M 4,
- 9.5.1845, 13h, 47.76° N, 18.14° E, I_0 6° MSK–64, M 4.3,
- 7.4.1847, 19h30m, 50.31° N, 10.77° E, I_0 6.5° MSK–64, M 4.2,
- 30.8.1847, 47.51° N, 15.45° E, I_0 6° MSK–64, M 4,
- 14.7.1850, 50.2° N, 12.8° E, I_0 6° MSK–64,
- 1.7.1851, 21h15m, 47.74° N, 18.15° E, I_0 7.5° MSK–64, M 5.1,
- 16.2.1852, 48.1°N, 19.3°E, I_0 6° MSK–64,
- 15.11.1852, 22h30m, 48.64° N, 17.16° E, I_0 6° MSK–64, M 4.3,
- 15.11.1852, 48.63° N, 19.15° E, I_0 6° MSK–64, M 4.1,
- 2.10.1854, 02h14m, 47.78° N, 19.13° E, I_0 6° MSK–64, M 4.1,
- 31.1.1855, 12h35m, 48.46° N, 18.96° E, I_0 6.5° MSK–64, M 4.5,
- 18.3.1855, 46.5° N, 13.8° E, I_0 6° MSK–64, M 4,
- 30.9.1855, 20h, 48.46° N, 18.96° E, I_0 6° MSK–64, M 4.3,
- 7.3.1857, 46.6° N, 14° E, I_0 6° MSK–64, M 4,
- 9.6.1857, 15h47m, 47.76° N, 18.14° E, I_0 6° MSK–64, M 4.3,
- 24.12.1857, 47.6° N, 14.4° E, I_0 6° MSK–64,
- 25.12.1857, 46.6° N, 14° E, I_0 7° MSK–64, M 4.8,
- 15.1.1858, 19h15m, 49.22° N, 18.76° E, h 7 km, I_0 7.5° MSK–64, M 5.1,
- 24.10.1858, 15h14m, 49.22° N, 18.76° E, I_0 6° MSK–64, M 4.3,
- 28.4.1859, 47.4° N, 11.8° E, I_0 6° MSK–64,
- 8.11.1861, 48.71° N, 18.97° E, I_0 6° MSK–64,
- 13.1.1862, 00h55m, 48.65° N, 19.05° E, h 6 km, I_0 6° MSK–64, M 4.3,
- 25.1.1862, 46.5° N, 14.4° E, I_0 6° MSK–64, M 4,
- 27.5.1862, 46.75° N, 12.4° E, I_0 6.5° MSK–64, M 4.4,
- 1.9.1864, 11h05m, 48.91° N, 18.18° E, I_0 6° MSK–64, M 4.3,
- 27.1.1865, 47.5° N, 12.0° E, I_0 6° MSK–64,
- 16.5.1865, 48.5° N, 16.6° E, I_0 6.5° MSK–64,
- 13.7.1865, 47.05° N, 16.18° E, I_0 6° MSK–64, M 4.3,
- 10.12.1865, 47.5° N, 12° E, I_0 6° MSK–64,
- 1866, 48.1° N, 19.9° E, I_0 6° MSK–64,
- 3.9.1867, 01h, 48.4° N, 23.3° E, I_0 6° MSK–64, M 4.2,
- 22.9.1867, 05h, 48° N, 20.1° E, I_0 6.5° MSK–64,
- 21.6.1868, 05h30m, 47.5° N, 20.07° E, I_0 7.5° MSK–64, M 5.3,
- 20.8.1868, 19h20m, 47.5° N, 20.07° E, I_0 6° MSK–64, M 4.4,
- 22.8.1868, 15h30m, 47.5° N, 20.07° E, I_0 6° MSK–64, M 4.4,
- 29.5.1869, 20h37m, 48.73° N, 19.16° E, h 7 km, I_0 6.5° MSK–64, M 4.3,
- 8.8.1869, 13h, 47.8° N, 18.1° E, I_0 6° MSK–64,
- 5.1.1870, 04h, 48.37° N, 17.16° E, I_0 6° MSK–64, M 4.3,

- 18.1.1870, 15h, 47.65° N, 15.92° E, I_0 6° MSK-64, M 4.2,
- 21.12.1870, 16h, 48.0° N, 23.6° E, I_0 6.5° MSK-64, M 4.3,
- 6.3.1872, 14h55m, 50.86° N, 12.28° E, I_0 7.5° MSK-64, M 5.1,
- 8.8.1872, 47.3° N, 11.4° E, I_0 6° MSK-64,
- 26.12.1872, 13h40m, 48.4° N, 23.3° E, I_0 7° MSK-64, M 4.3,
- 3.1.1873, 18h, 48.25° N, 15.96° E, I_0 6.5° MSK-64, M 4.4,
- 2.12.1874, 06h, 48.7° N, 17.5° E, I_0 6° MSK-64,
- 17.8.1875, 15h45m, 50.3° N, 24.2° E, h 10 km, I_0 7° MSK-64, M 5.3,
- 18.3.1876, 03h, 49.1° N, 20.4° E, I_0 6° MSK-64,
- 17.7.1876, 12h15m, 48° N, 15.17° E, h 6 km, I_0 7.5° MSK-64, M 5.1,
- 1.12.1876, 47.51° N, 15.45° E, I_0 6° MSK-64, M 4,
- 28.12.1877, 47.1° N, 14.4° E, I_0 6° MSK-64, M 4,
- 31.12.1878, 5h30m, 47.8° N, 19.9° E, I_0 6° MSK-64,
- 11.1.1879, 46.5° N, 14.6° E, I_0 6° MSK-64, M 4,
- 18.5.1879, 23h, 48° N, 23.3° E, I_0 6° MSK-64, M 4.6,
- 13.12.1879, 18h30m, 49.06° N, 10.18° E, I_0 6° MSK-64,
- 17.1.1880, 14h15m, 48.1° N, 23.8° E, I_0 6° MSK-64, M 4,
- 6.10.1880, 46.97° N, 22.82° E, I_0 6° MSK-64, M 4.4,
- 14.11.1880, 47.4° N, 11.3° E, I_0 6° MSK-64, M 4,
- 5.11.1881, 46.9° N, 13.5° E, I_0 6° MSK-64, M 4.2,
- 23.1.1882, 47.5° N, 10.55° E, I_0 6° MSK-64, M 4,
- 31.1.1883, 13h43m, 50.5° N, 15.9° E, h 6 km, I_0 6.5° MSK-64,
- 27.3.1883, 23h28m, 48.1° N, 20.8° E, I_0 6° MSK-64,
- 30.4.1885, 23h15m, 47.51° N, 15.45° E, h 8 km, I_0 8° MSK-64, M 5.4,
- 26.5.1885, 08h45m, 47.27° N, 23.25° E, I_0 6° MSK-64, M 4.1,
- 17.8.1885, 18h35m, 48.9° N, 21.7° E, h 6 km, I_0 6.5° MSK-64, M 4.1,
- 26.8.1885, 47.51° N, 15.45° E, I_0 6° MSK-64, M 4,
- 22.9.1885, 02h45m, 47.68° N, 15.94° E, I_0 6.5° MSK-64, M 4.2,
- 28.11.1886, 47.3° N, 10.8° E, I_0 7.5° MSK-64, M 5.2,
- 12.4.1888, 05h30m, 47.78° N, 16.54° E, I_0 7° MSK-64, M 4.6,
- 12.4.1888, 19h20m, 47.78° N, 16.54° E, I_0 6.5° MSK-64, M 4.3,
- 28.1.1890, 08h11m, 48.76° N, 19.4°E, h 7 km, I_0 6° MSK-64, M 4.1,
- 25.11.1890, 09h56m, 48.34° N, 17.11° E, h 10 km, I_0 6° MSK-64, M 4.5,
- 28.11.1890, 01h37m, 48.25° N, 17.04° E, h 12 km, I_0 7° MSK-64, M 4.5,
- 28.12.1890, 11h32m, 48.9° N, 21.8° E, h 5 km, I_0 6.5° MSK-64, M 4.1,
- 22.6.1892, 01h35m, 46.68° N, 18.45° E, h 5 km, I_0 7.5° MSK-64, M 4.3,
- 11.3.1893, 09h25m, 47.98° N, 23.05° E, h 3 km, I_0 7° MSK-64, M 4.4,
- 24.3.1893, 17h35m, 48.6° N, 17.8° E, h 4 km, I_0 6° MSK-64, M 4,
- 15.4.1893, 04h48m, 49.2° N, 21.8° E, h 6 km, I_0 6.5° MSK-64, M 4,
- 7.10.1894, 02h, 48.05° N, 23.47° E, I_0 6.5° MSK-64, M 4.4,
- 11.6.1895, 08h27m, 50.7° N, 16.9° E, h 8 km, I_0 7° MSK-64, M 4.9,
- 16.5.1896, 20h50m, 50.5° N, 12.1° E, I_0 6° MSK-64, M 4,
- 20.2.1897, 47.3° N, 11.4° E, I_0 6° MSK-64,
- 24.10.1897, 50.3° N, 12.5° E, I_0 6.5° MSK-64,
- 25.10.1897, 20h, 50.3° N, 12.4° E, h 5 km, I_0 6° MSK-64,

- 29.10.1897, 19h45m, 50.35° N, 12.48° E, h 5 km, I_0 6.5° MSK–64, M 4,
- 3.11.1897, 50.3° N, 12.5° E, I_0 6.5° MSK–64,
- 7.11.1897, 03h58m, 50.35° N, 12.48° E, h 6 km, I_0 6.5° MSK–64,
- 7.11.1897, 04h45m, 50.3° N, 12.5° E, I_0 6° MSK–64, M 4,
- 7.11.1897, 04h58m, 50.35° N, 12.48° E, I_0 6.5° MSK–64, M 4.2,
- 17.11.1897, 05h30m, 50.22° N, 12.32° E, h 9 km, I_0 6° MSK–64,
- 17.11.1897, 06h45m, 50.2° N, 12.3° E, h 5 km, I_0 6° MSK–64,
- 29.4.1899, 47.3° N, 15° E, I_0 6° MSK–64,
- 5.8.1899, 46.6° N, 14.6° E, I_0 6.5° MSK–64, M 4.2,
- 10.1.1901, 02h30m, 50.5° N, 16.1° E, h 5 km, I_0 7.5° MSK–64,
- 21.10.1901, 01h20m, 49.45° N, 20.4° E, I_0 6.5° MSK–64, M 4.5,
- 12.12.1901, 10h28m, 47.9° N, 23.1° E, I_0 6° MSK–64,
- 19.6.1902, 09h23m, 46.9° N, 11.3° E, I_0 6° MSK–64,
- 26.11.1902, 12h15m, 49.7° N, 12.8° E, h 5 km, I_0 6.5° MSK–64,
- 21.2.1903, 21h09m06s, 50.3° N, 12.2° E, h 5 km, I_0 6.5° MSK–64, M 4.3,
- 25.2.1903, 23h11m 58s, 50.27° N, 12.33° E, h 8 km, I_0 6° MSK–64, M 4,
- 5.3.1903, 20h37m06s, 50.37° N, 12.42° E, h 6 km, I_0 7° MSK–64, M 4.5,
- 5.3.1903, 20h55m32s, 50.37° N, 12.42° E, I_0 6.5° MSK–64, M 4.5,
- 6.3.1903, 04h57m29s, 50.34° N, 12.47° E, h 7 km, I_0 7° MSK–64, M 4.3,
- 7.3.1903, 05h01m, 50.3° N, 12.6° E, h 8 km, I_0 6° MSK–64,
- 27.4.1903, 16h08m04s, 50.27° N, 12.29° E, I_0 6° MSK–64, M 4,
- 26.6.1903, 04h28m, 47.9° N, 20.38° E, h 3 km, I_0 6.5° MSK–64, M 4.5,
- 12.2.1904, 04h, 46.45° N, 17.98° E, I_0 6° MSK–64, M 4.2,
- 20.4.1904, 14h03m,15s, 48.62°N, 17.46°E, I_0 6.5° MSK–64, M 4.5,
- 9.6.1904, 17h30m, 46° N, 13.5° E, I_0 6° MSK–64,
- 12.10.1904, 03h, 48.68° N, 17.39° E, I_0 6° MSK–64, M 4.3,
- 2.2.1905, 22h55m, 47.15° N, 14.4° E, I_0 6° MSK–64,
- 24.2.1905, 05h25m, 47.3° N, 11.7° E, I_0 6° MSK–64,
- 9.1.1906, 23h07m, 48.58° N, 17.46° E, h 10 km, I_0 8.5° MSK–64, M 5.7,
- 16.1.1906, 02h52m, 48.62° N, 17.56° E, h 8 km, I_0 7.5° MSK–64, M 5.1,
- 15.4.1906, 23h20m, 48.6° N, 17.6° E, I_0 6° MSK–64,
- 19.4.1906, 23h55m, 48.6° N, 17.6° E, I_0 6° MSK–64,
- 29.4.1906, 9h15m, 47.32° N, 22.18° E, I_0 7° MSK–64, M 5,
- 15.6.1906, 01h45m, 48.6° N, 17.6° E, I_0 6° MSK–64,
- 12.8.1906, 47.45° N, 19.7° E, I_0 6° MSK–64, M 4.1,
- 22.3.1907, 19h10m, 47.6° N, 14.5° E, h 9 km, I_0 6° MSK–64, M 4.2,
- 13.5.1907, 04h23m, 47.51° N, 15.45° E, I_0 6.5° MSK–64, M 4.4,
- 5.1.1908, 14h40m, 48.55° N, 23.03° E, h 5 km, I_0 7° MSK–64, M 4.7,
- 19.2.1908, 21h11m, 47.94° N, 16.74° E, h 7 km, I_0 6.75° MSK–64, M 4.8,
- 15.3.1908, 17h38m, 47.38° N, 19.53° E, I_0 6° MSK–64, M 4.3,
- 28.5.1908, 08h27m, 46.9° N, 19.68° E, h 6 km, I_0 7.5° MSK–64, M 4.4,
- 21.10.1908, 14h04m23s, 50.3° N, 12.3° E, h 5 km, I_0 6° MSK–64,
- 21.10.1908, 20h39m48s, 50.28° N, 12.29° E, h 5 km, I_0 6° MSK–64, M 4.3,
- 3.11.1908, 13h25m02s, 50.3° N, 12.31° E, h 9 km, I_0 6° MSK–64,
- 3.11.1908, 17h21m42s, 50.34° N, 12.47° E, h 10 km, I_0 6.5° MSK–64, M 4.7,

- 4.11.1908, 03h33m09s, 50.36° N, 12.49° E, h 3 km, I_0 6.5° MSK–64, M 4.3,
- 4.11.1908, 10h55m, 50.34° N, 12.3° E, h 9 km, I_0 6.5° MSK–64,
- 4.11.1908, 13h10m, 50.34° N, 12.3° E, h 10 km, I_0 6.5° MSK–64,
- 4.11.1908, 20h41m57s, 50.28° N, 12.37° E, h 9 km, I_0 6.5° MSK–64,
- 6.11.1908, 04h36m11s, 50.4° N, 12.4° E, h 7 km, I_0 6.5° MSK–64, M 4.5,
- 29.5.1909, 05h53m, 46.1° N, 18.3° E, h 5 km, I_0 6° MSK–64,
- 24.3.1910, 14h37m, 47.2° N, 14.3° E, I_0 6.5° MSK–64, M 4.2,
- 11.5.1910, 20h18m, 47.74° N, 15.99° E, h 5 km, I_0 6.5° MSK–64, M 4.5,
- 13.7.1910, 08h32m, 47.3° N, 10.9° E, h 5 km, I_0 7.5° MSK–64, M 4.8,
- 24.4.1911, 17h19m, 47.2° N, 10.3° E, I_0 6° MSK–64,
- 19.6.1911, 03h21m, 46.9° N, 19.68° E, I_0 6.5° MSK–64, M 4.5,
- 8.7.1911, 01h02m, 46.9° N, 19.68° E, h 7 km, I_0 9.5° MSK–64, M 5.6,
- 16.11.1911, 21h30m, 48.3° N, 9° E, h 10 km, I_0 9.25° MSK–64, M 5.4,
- 22.1.1912, 20h08m, 47.3° N, 15.3° E, I_0 6° MSK–64,
- 19.9.1912, 21h, 46.2° N, 16.9° E, M 4.2,
- 18.4.1914, 05h15m, 48.32° N, 17.22° E, h 9 km, I_0 7.5° MSK–64, M 5.1,
- 13.5.1914, 19h07m, 47.37° N, 19.53° E, h 6 km, I_0 6.5° MSK–64, M 4.0,
- 26.5.1914, 20h28m48s 49.1° N, 21.53° E, h 10 km, I_0 7° MSK–64, M 5.2,
- 27.6.1914, 01h44m50s, 51.36° N, 12.43° E, I_0 6° MSK–64, M 4.3,
- 30.8.1914, 11h22m, 47.3° N, 9.65° E, I_0 6° MSK–64,
- 31.8.1914, 13h26m, 47.3° N, 11.5° E, I_0 6.5° MSK–64,
- 1.10.1914, 20h31m, 48.9° N, 11.4° E, h 16 km, I_0 6° MSK–64,
- 25.11.1914, 16h12m, 47.3° N, 18.2° E, h 6 km, I_0 6° MSK–64,
- 31.1.1915, 07h05m, 47.9° N, 20.4° E, I_0 7° MSK–64,
- 2.6.1915, 02h33m, 48.9° N, 11.4° E, h 20 km, I_0 6.5° MSK–64,
- 10.10.1915, 03h50m, 48.8° N, 11.6° E, h 12 km, I_0 7° MSK–64,
- 6.1.1916, 03h45m, 47.4° N, 16.8° E, I_0 6° MSK–64,
- 1.5.1916, 10h24m, 47.2° N, 14.65° E, h 8 km, I_0 7° MSK–64, M 4.7,
- 30.7.1917, 01h30m, 48.27° N, 22.05° E, h 7 km, I_0 6° MSK–64,
- 26.9.1918, 0h16m, 47.18° N, 10.18° E, I_0 6° MSK–64,
- 22.2.1919, 14h, 46.97° N, 16.46° E, I_0 6° MSK–64, M 4.2,
- 22.12.1920, 22h14m, 47.61° N, 15.99° E, I_0 6° MSK–64, M 4.1,
- 24.10.1921, 02h06m, 47.5° N, 12.6° E, I_0 6.5° MSK–64,
- 24.11.1922, 02h15m40s, 45.7° N, 18.75° E, I_0 7.5° MSK–64, M 5.3,
- 28.11.1923, 06h07m, 47.1° N, 13.8° E, I_0 6° MSK–64, M 4.8,
- 18.1.1924, 01h30m, 48.41° N, 22.58° E, I_0 6° MSK–64, M 4.1,
- 26.3.1924, 17h08m, 46.9° N, 11.4° E, I_0 6° MSK–64,
- 28.7.1924, 20h, 48.02° N, 23.71° E, I_0 6° MSK–64, M 4,
- 31.1.1925, 07h05m, 47.86° N, 20.42° E, h 5 km, I_0 8.5° MSK–64, M 5,
- 27.6.1925, 08h15m, 46.47° N, 17.0° E, I_0 6.5° MSK–64, M 4.5,
- 28.1.1926, 16h57m, 50.88° N, 11.76° E, I_0 6° MSK–64,
- 28.7.1926, 20h00m, 48.02° N, 23.7° E, h 4 km, I_0 6° MSK–64, M 4,
- 6.7.1926, 07h39m, 47.61° N, 15.67° E, I_0 6.5° MSK–64, M 4.4,
- 10.8.1926, 01h10m, 48.02° N, 23.7° E, h 5 km, I_0 7° MSK–64, M 4,
- 28.9.1926, 15h41m, 47.72° N, 16.04° E, h 7 km, I_0 6.75° MSK–64, M 4.7,

- 4.3.1927, 06h22m37s, 47.2° N, 18.13° E, h 2 km, I_0 7° MSK–64, M 4,
- 8.6.1927, 06h09m37s, 47.2° N, 18.13° E, h 2 km, I_0 7° MSK–64, M 4,
- 25.7.1927, 20h35m, 47.53° N, 15.49° E, h 8 km, I_0 7.5° MSK–64, M 5.1,
- 8.10.1927, 19h49m, 48.07° N, 16.58° E, h 11 km, I_0 8° MSK–64, M 5.2,
- 27.3.1928, 02h33m, 46.4° N, 13° E, h 7 km, I_0 8.5° MSK–64,
- 2.9.1929, 05h52m, 46.4° N, 14.3° E, I_0 6° MSK–64,
- 5.3.1930, 23h55m44s, 48.58° N, 17.62° E, h 6 km, I_0 7.5° MSK–64, M 5,
- 6.3.1930, 05h13m, 48.55° N, 17.63° E, h 7 km, I_0 6.5° MSK–64, M 4.6,
- 14.5.1930, 00h01m, 46.6° N, 12.4° E, I_0 6° MSK–64,
- 18.5.1930, 04h14m, 47.5° N, 13.4° E, I_0 6° MSK–64, M 4.1,
- 22.8.1930, 05h49m, 47.98° N, 19.43° E, h 8 km, I_0 6.5° MSK–64, M 4.2,
- 7.10.1930, 23h27m, 47.35° N, 10.7° E, h 6 km, I_0 7.5° MSK–64, M 5.3,
- 7.4.1931, 01h35m, 48.17° N, 22.53° E, h 4 km, I_0 6.5° MSK–64, M 4.2,
- 7.4.1931, 01h42m, 48.22° N, 22.69° E, h 5 km, I_0 6.5° MSK–64,
- 12.4.1931, 21h25m, 49.9° N, 17.9° E, h 7 km, I_0 6.5° MSK–64, M 4,
- 21.4.1931, 14h22m, 47.2° N, 18.13° E, I_0 6° MSK–64, M 4,
- 24.7.1933, 46.6° N, 16.7° E, I_0 6° MSK–64, M 4,
- 8.11.1933, 00h51m, 47.35° N, 10.7° E, I_0 6.5° MSK–64, M 4.6,
- 26.4.1934, 16h55m30s, 47.72° N, 18.7° E, I_0 6° MSK–64, M 4.1,
- 31.8.1934, 23h29m30s, 46.79° N, 16.93° E, h 10 km, I_0 6.5° MSK–64, M 4.7,
- 4.9.1934, 01h26m, 47.4° N, 11.8° E, I_0 6.5° MSK–64, M 4.7,
- 23.3.1935, 22h46m, 49.45° N, 19.85° E, I_0 6° MSK–64, M 4.3,
- 27.6.1935, 17h19m, 48.0° N, 9.5° E, h 20 km, I_0 7.5° MSK–64,
- 4.3.1936, 04h45m, 48.0° N, 21.1° E, h 6 km, I_0 6° MSK–64,
- 2.8.1936, 20h27m, 48.61° N, 22.53° E, h 3 km, I_0 7° MSK–64, M 4.1,
- 3.10.1936, 15h48m, 47.1° N, 14.7° E, I_0 7.5° MSK–64, M 5.1,
- 10.6.1937, 01h43m, 48.12° N, 21.35° E, h 8 km, I_0 6° MSK–64, M 4.2,
- 14.9.1937, 08h58m, 48.21°N, 23.54°E, h 3 km, I_0 6.5° MSK–64, M 4.3,
- 8.11.1938, 03h11m35s, 47.95° N, 16.4° E, h 9 km, I_0 7° MSK–64, M 5,
- 23.3.1939, 02h00m, 47.3° N, 21.8° E, h 13 km, I_0 6° MSK–64, M 5,
- 18.9.1939, 00h14m37s, 47.8° N, 15.91° E, h 9 km, I_0 7° MSK–64, M 5,
- 5.6.1941, 02h49m57s, 48.7° N, 21.82° E, h 3 km, I_0 7° MSK–64, M 4.8,
- 12.4.1942, 00h01m, 46.3° N, 13.8° E, I_0 6° MSK–64,
- 14.5.1942, 08h28m, 47.25° N, 17.73° E, h 4 km, I_0 6° MSK–64, M 4,
- 30.9.1942, 02h30m, 47.45° N, 19.6° E, h 7 km, I_0 6° MSK–64, M 4.2,
- 21.12.1947, 09h43m, 49.23°N, 18.76°E, I_0 6° MSK–64, M 4.4,
- 24.10.1950, 11h48m, 47° N, 14.7° E, I_0 6° MSK–64, M 4.1,
- 20.2.1951, 00h14m12s, 47.97° N, 19.13° E, h 5 km, I_0 7° MSK–64, M 5.1,
- 7.6.1951, 04h07m, 47.3° N, 11° E, I_0 6° MSK–64,
- 22.2.1953, 20h15m47s, 50.92° N, 10.0° E, I_0 7.5° MSK–64, M 5.2,
- 2.5.1953, 12h37m, 48.08° N, 16.75° E, I_0 6° MSK–64, M 4.1,
- 13.9.1953, 08h01m50.9s, 47.03° N, 17.17° E, h 7 km, I_0 6.5° MSK–64, M 4.2,
- 22.5.1955, 04h58m, 47.3° N, 11.4° E, I_0 7° MSK–64, M 4.6,
- 12.1.1956, 05h46m08s, 47.35° N, 19.09° E, h 6 km, I_0 8° MSK–64, M 5.6,
- 31.3.1956, 14h07m, 46.98° N, 17.0° E, h 10 km, I_0 6.5° MSK–64, M 4.2,

- 4.12.1956, 06h21m47s, 46.8° N, 16.2° E, I_0 6° MSK–64, M 4.2,
- 14.12.1956, 00h12m, 47.92° N, 20.27° E, I_0 6° MSK–64, M 4.5,
- 13.1.1958, 07h36m, 47.61° N, 15.67° E, I_0 6° MSK–64, M 4.4,
- 8.7.1958, 5h02m, 50.82° N, 10.11° E, I_0 7° MSK–64, M 4.7,
- 30.9.1958, 08h45m, 47.2° N, 10.6° E, I_0 6.5° MSK–64, M 4.5,
- 13.11.1958, 07h36m, 47.6° N, 15.7° E, I_0 6° MSK–64,
- 17.2.1959, 01h54m, 48.45° N, 15.56° E, I_0 6° MSK–64, M 4,
- 29.6.1961, 11h52m49s, 50.82° N, 10.11° E, I_0 6° MSK–64, M 4,
- 4.10.1961, 12h21m, 47.6° N, 12.7° E, I_0 6° MSK–64,
- 29.11.1962, 04h57m34s, 47.48° N, 11.06° E, I_0 6° MSK–64,
- 2.12.1963, 06h46m09s, 47.85° N, 16.37° E, h 7 km, I_0 6.5° MSK–64, M 4.5,
- 27.10.1964, 19h46m09.1m, 47.63° N, 15.81° E, h 7 km, I_0 7° MSK–64, M 5.3,
- 30.12.1964, 03h10m08s, 48.33° , 17.13° E, h 7 km, I_0 6° MSK–64, M 4.2,
- 8.7.1965, 23h20m, 47.3° N, 11.4° E, I_0 6° MSK–64,
- 24.10.1965, 06h26m51s, 48.22° N, 22.65° E, h 2 km, I_0 7° MSK–64, M 4,
- 29.1.1967, 00h12m11.7s, 47.9° N, 14.3° E, h 7 km, I_0 7° MSK–64, M 4.6,
- 3.12.1967, 22h10m53.4s, 48.57° N, 17.39° E, h 6 km, I_0 6.5° MSK–64, M 4.3
- 9.2.1969, 23h08m27s, 47.45° N, 18.1° E, h 12 km, I_0 6° MSK–64, M 4.3,
- 1.6.1969, 23h21m, 47° N, 14.2° E, I_0 6° MSK–64, M 4.4,
- 10.5.1970, 01h49m, 47.2° N, 9.6° E, I_0 6° MSK–64,
- 5.1.1972, 04h57m41.3s, 47.8° N, 16.2° E, h 6 km, I_0 6.25° MSK–64, M 4.1,
- 16.4.1972, 10h00m04.8s, 47.75° N, 16.2° E, h 7 km, I_0 8° MSK–64, M 5.3,
- 16.4.1972, 11h04m46.6s, 47.71° N, 16.18° E, h 6 km, I_0 6.5° MSK–64, M 4.3,
- 17.6.1972, 09h03m, 48.35° N, 14.5° E, I_0 7° MSK–64,
- 12.6.1973, 21h02m56.7s, 47.54° N, 15.51° E, I_0 6.25° MSK–64, M 4.1,
- 12.12.1973, 00h03m, 47.05° N, 14.1° E, I_0 6° MSK–64, M 4.5,
- 23.6.1975, 13h17m36s, 50.48° N, 10° E, I_0 7.5° MSK–64,
- 14.1.1976, 11h53m56s, 49.05° N, 24.02° E, h 5 km, I_0 6° MSK–64, M 4,
- 7.2.1976, 20h46m40s, 49.01° N, 24.02° E, h 5 km, I_0 6° MSK–64, M 4.1,
- 6.5.1976, 20h00m09s, 46.3° N, 13.1° E, h 6 km, I_0 10° MSK–64, M 6.5,
- 24.8.1976, 23h23m, 48.57° N, 17.36° E, I_0 5.5° MSK–64, M 4,
- 11.9.1976, 16h34m57.2s, 46.3° N, 13.2° E, h 10 km, I_0 7° MSK–64,
- 15.9.1976, 03h15m17s, 46.3° N, 13.2° E, h 7 km, I_0 8.5° MSK–64,
- 15.9.1976, 09h21m16s, 46.3° N, 13.2° E, h 5 km, I_0 9.5° MSK–64,
- 15.9.1976, 11h11m07.7s, 46.4° N, 13.2° E, I_0 6° MSK–64,
- 26.12.1976, 09h, 47.3° N, 9.6° E, I_0 6° MSK–64,
- 22.6.1978, 02h33m24s, 46.75° N, 21.13° E, I_0 6° MSK–64, M 4.6,
- 30.6.1978, 01h15m29s, 47.68° N, 23.27° E, I_0 6° MSK–64, M 4.3,
- 19.8.1978, 18h43m, 48.8° N, 19.2° E, I_0 6° MSK–64, M 4,
- 3.9.1978, 05h03m31.8s, 48.29° N, 8.94° E, h 10 km, I_0 8.5° MSK–64, M 5.4,
- 26.9.1978, 16h47m34s, 47.26° N, 19.05° E, I_0 6° MSK–64, M 4.3,
- 28.3.1979, 13h02m43s, 47.67° N, 23.35° E, I_0 6° MSK–64, M 4.7,
- 30.3.1979, 15h56m15s, 47.68° N, 23.3° E, I_0 6.5° MSK–64, M 4.7,
- 18.4.1979, 15h19m19s, 46.3° N, 13.3° E, h 11 km, I_0 7° MSK–64,
- 12.5.1979, 21h34m, 47.3° N, 15.2° E, I_0 6° MSK–64,

- 31.1.1981, 12h49m, 47.1° N, 14.7° E, I_0 6° MSK–64,
- 15.6.1981, 10h17m, 47° N, 14.7° E, I_0 6.5° MSK–64,
- 1.7.1982, 05h50m, 48.48° N, 22.23°E, I_0 6.5° MSK–64, M 4.6,
- 14.4.1983, 14h52m14.14s, 47.67° N, 15.14° E, h 10 km, I_0 6.5° MSK–64, M 4.4,
- 15.4.1984, 10h57m53s, 47.65° N, 15.85° E, h 7 km, I_0 6.5° MSK–64, M 4.9,
- 24.5.1984, 19h56m08.5s, 47.68° N, 15.84° E, h 10 km, I_0 6° MSK–64, M 4.6,
- 15.8.1985, 04h28m46.9s, 47.06° N, 18.01° E, h 10 km, I_0 6.5° MSK–64, M 4.7,
- 15.8.1985, 05h29m17.9s. 47.04° N, 18.01° E, I_0 6° MSK–64, M 4,
- 15.8.1985, 10h53m17s, 47.14° N, 18.05° E, I_0 6° MSK–64, M 4,
- 6.12.1985, 05h00m28.8s, 50.22° N, 12.37° E, h 6 km, I_0 6° MSK–64,
- 14.12.1985, 05h38m01.8s, 50.2° N, 12.29° E, h 5 km, I_0 6.5° MSK–64,
- 20.12.1985, 16h36m27.4s, 50.16° N, 12.48° E, h 9 km, I_0 6° MSK–64,
- 21.12.1985, 10h16m19.8s, 50.14° N, 12.44° E, h 11 km, I_0 7° MSK–64,
- 23.12.1985, 03h24m46.6s, 50.24° N, 12.56° E, h 9 km, I_0 6° MSK–64,
- 23.12.1985, 04h27m07.5s, 50.26° N, 12.42° E, h 9 km, I_0 6.5° MSK–64,
- 24.12.1985, 00h04m17.6s, 50.26° N, 12.34° E, h 8 km, I_0 6° MSK–64,
- 20.1.1986, 23h38m27.8s, 50.27° N, 12.42° E, h 12 km, I_0 6.5° MSK–64,
- 23.1.1986, 02h21m59.6s, 50.09° N, 12.55° E, h 9 km, I_0 6° MSK–64,
- 27.1.1988, 47.0° N, 17.0° E, I_0 6° MSK–64, M 4.3,
- 28.4.1988, 21h22m26s, 48.92° N, 18.36° E, 5 km, I_0 6° MSK–64, M 4.1,
- 11.2.1989, 02h46m11.5s, 47.94° N, 17.02° E, I_0 6° MSK–64, M 4.1,
- 7.6.1989, 00h18m18.4s, 48.72° N, 19.29° E, I_0 6° MSK–64, M 4.1,
- 15.11.1989, 02h54m33s, 48.75° N, 19.36° E, I_0 6° MSK–64, M 4,
- 2.5.1991, 10h15m19.1s, 47.91° N, 16.42° E, I_0 6° MSK–64, M 4.3,
- 18.9.1995, 08h26m10.5s, 47.87° N, 18.83° E, I_0 6° MSK–64, M 4.2,
- 9.1.1996, 01h07m22.7s, 47.96 ° N, 16.49° E, I_0 6° MSK–64, M 4.3,

2.5. Evaluation

The present catalogue is used as the fundamental data for the seismic hazard assessment of localities on the territories of Czech and Slovak Republics. According to the IAEA guidance (IAEA, 50–SG–S1) it is necessary for each locality in the Czech Republic to take into account data from the territory delimited by a circle around the locality with a radius of 200 – 400 km and in the Slovak Republic with a radius of 200 km. The difference is caused by the fact that the Bohemian Massif, predominantly creating the basement of the Czech Republic, is characterized by a small attenuation of macroseismic effects with distance (Procházková 1984, Zátopek 1948). It is evident that for the seismic hazard determination it is not possible to take into account only the parts of focal regions that are denoted by the geometrical circle: it is necessary to consider the whole of the focal regions.

3. Focal Regions and Regions with Diffuse Seismicity in Central Europe

3.1. Introduction

An earthquake originates by the sudden release of mechanical energy. It is necessary to characterize each earthquake by the geographical coordinates of focus, the focal depth, the origin time, the size, the orientation of forces acting in the focus (predominant force multipole), the stress drop as a consequence of failure, the size of irreversible strain of focal region and its time course, the shape of the fractured region and its size and by the distribution of earthquake effects on the ground, on constructions and on people.

Earthquakes, which are the manifestation of tectonic activity, originate under conditions varying in their degree of dependence on the tectonic zone. They are consequences of long term tectonic movements, the velocity of which is in comparison with the human life–span, i.e. with our observation possibilities, very low. For the comparison of seismic activity with the geological structure of the region, it is necessary to consider that the accuracy of earthquake foci positions is not always the same, and that from the whole process of earthquake origin we only have data concerning a part of the process, in a limited time interval. The period of a few centuries for which we have data on earthquakes may be too short for an assessment of the dynamics of processes of increased and diminished earthquake activity.

Earthquakes originate in the lithosphere, i.e. in the Earth's crust and in the upper mantle. The lithosphere (a layer 100 – 120 km thick) consists of blocks and plates the size of continents and oceans. As a consequence of passing tectonic processes (i.e. of processes passing within the Earth's body) the blocks and the plates are constantly moving. Earthquakes originate from brittle instability or rough sliding, mainly at the plate boundaries. The earthquake foci as a rule reach a depth of from several km up to several tens of km; on the boundaries of continental and oceanic plates they can reach a depth of 700 km.

Earthquake foci are not uniformly distributed. They are concentrated in some regions that we call focal regions or focal zones or focal provinces. The individual focal regions we describe by the predominant focal mechanisms, the typical focal depth, the typical isoseismals, the typical value of intensity attenuation or by the typical value of seismic energy attenuation, the frequency graphs, the Benioff graphs, maximum observed earthquake, typical earthquake sequences and where appropriate by the foci migration (Procházková 1984, 1988, 1990, 1993). When we discuss typical quantities, we understand a determined mode of frequency distribution of values of quantity.

Apart from the focal zones there are areas (continental shields), on which sporadic, scattered earthquake foci occur. They are not connected with the fault structures of regional significance, but only with structures of local significance, in which from time to time the strength of the rock mass can be exceeded (Procházková, Roth 1993, 1996). Since these local structures are not extensive, they can only accumulate small energies, that correspond to their dimensions. Therefore, the earthquakes in these structures are small. In the sense of the IAEA guidance

(IAEA 50–SG–S1) and the US NRC Regulations (Budnitz 1995b) we define them as regions with diffuse seismicity.

We are assured of the existence of local stresses in seismic regions by earthquakes induced by special human activities, e.g. rockbursts, earthquakes induced by dams, explosions, injection of liquids into the rock massifs, and withdrawing liquids from the rock massifs (Procházková 1995).

In our considerations we assume that earthquake foci are connected with the origin of fractures or with the block movements along living (active) tectonic faults. Deep drill holes (Kola peninsula – Russian Federation, Weiden – Germany) show that only minimally do we see seismic activity in the interval of shallow earthquakes (i.e. up to 12 km) that does not involve the change of physical properties of rocks: so that the earthquake foci cannot originate without the existence of deep faults.

In the investigation of genetic connections of earthquake foci with the horizontal and vertical fault structures in the medium we do not assume that each fault must continually be active. We take into account the existence of gaps in time and space. We do not consider the fault as a thin linear dislocation but as a set of roughly parallel fractures that create the fault structure, belt, or zone.

In the delineation of focal regions that we call "seismic zoning" we do not consider the frequent assumption of geologists (e.g. Reisner 1976), that any fault can generate an earthquake. We only delineate the focal regions with faults that have been able to generate earthquakes in the historical period.

From seismological practice (e.g. Niklová, Kárník 1969) we know that the determination of a boundary between two neighbouring regions is difficult. By the application of statistical methods based on the determination of inflexion points on the summation curves, constructed for selected azimuths either for the number of shocks or for seismic energy released, it is possible (incorrectly) to locate the boundary in a place in which there is at present no seismic activity, i.e. in a gap that will be filled in the future by the occurrence of earthquakes. Therefore, in agreement with Grin and Kauf (1978) we define the boundaries of regions as frontiers that separate regions with different space–time dependencies of number of earthquakes on the earthquake size, valid for earthquake occurrence. We take into account not only the seismological data, but also geological data and data of further geophysical, tectonic, geodetic and geomechanical disciplines.

At the limits of focal regions we find small clumps of foci that are as a rule connected with the movements along one fault or along a system of several parallel faults. We take into account the fact that of the earthquake foci, the strongest are mainly situated at fault crossings, because these places create the weakest parts of the region that is affected by tectonic motions. We define greater focal regions on the basis of the similarity of quantitative and qualitative seismic characteristics of individual small regions. We consider the assumption that partial regions create seismotectonic units, which are characterized by the same process of earthquake origin and by the same geomechanical properties.

3.2. Focal Regions

3.2.1. Definition of Terms

The focal region is a region containing existing or possible earthquake foci, generated by the same tectonic movements. According to our purpose we can use a more or less detailed distribution. In the case where in one region there are several seismoactive layers that occur at different depths, we divide the given region into appropriate seismoactive layers.

We characterize focal regions by the size of the maximum possible earthquake that has occurred in the region in historical time, by the parameters of macroseismic fields, by the slope of the empirical frequency graph and eventually by the further characteristics of earthquake activity (Procházková 1984, 1993), if we have enough data to construct these.

The macroseismic field of the earthquake is the part of the Earth's surface that surrounds the earthquake epicentre on which are or can be observed the macroseismic effects (Procházková 1981, 1984).

The frequency graphs describe the distribution of a number of earthquakes according to size. They compare the number of strong and weak shocks (the number of weak shocks is substantially more than the number of strong shocks) in the given region. They are the basic empirical characteristics of focal regions (Procházková 1984, 1990, 1993).

The cumulative frequency of earthquakes N_c (I_0) is the number of earthquakes in a given focal region with the intensity equal or greater than I_0. The sum curve starts at high intensities and in the coordinates $[I_0, \log N_c]$ it gets closer to the straight line, and therefore it is usually replaces by a straight line, i.e. $\log N_c = a - b \cdot I_0$, where a and b are numerical parameters. The comparison of parameters of simple and cumulative frequencies is e.g. in (Procházková 1984).

The other terms used in the seismological practice are defined in (Procházková 1984, 1988, 1993). They are not given here because they are not used hereafter.

3.2.2. Basic Seismological Characteristics of Central Europe

For the study of earthquakes in Central Europe, there were used the regional catalogue (Chapter 2), the national catalogues, and national seismic bulletins, which also contain data on weak earthquakes that are not processed by the regional centres or the and World Data Centres. All accessible data, summarized in about 50 publications, the list of which is given in (Procházková 1984) and its supplements in (Procházková 1993a,b) were processed according to uniform methodology.

The methods used for the data processing serve for the selection and evaluation of heterogeneous and often non–homogeneous data sets that are objectively burdened by considerable dispersion. Because the data are incomplete, non–homogeneous (i.e. their accuracy depends on the size of an earthquake or on the time of its occurrence), non–stationary and in addition to that burdened by random errors, the distribution functions of which are not usually possible to determine, we can only derive certain trends.

Further seismological characteristics of Central Europe are found in the results given or quoted in the papers of Procházková (1981, 1984, 1988, 1990, 1993, 1995). We can make the following summary:

The earthquakes in the investigated region usually have a tectonic origin and are connected with present tectonic movements. The earthquake foci are usually connected with faults (the foci of most earthquakes are located on fault crossings). At present only some parts of faults are seismoactive. In the case of focal regions connected with fault crossings we often observe that the foci are connected either with the first fault or with the second one; as a rule one of the faults predominates from the viewpoint of earthquake occurrence. Sometimes after a shock connected with the one fault system, there is also observed a shock connected with the second one, e.g. in the Friuli region (Procházková 1984).

The earthquake foci on the boundary of the Bohemian Massif are mostly connected with the fault zones of the Bohemian Massif, that may be characterized, according to the direction and the sense of motion, as in essence a Hercynian couple system of horizontal shifts of the Great Glenn type (Blanice, Boskovice, Jihlava furrow) and of the San Andreas type (Sudetian faults, Elbe lineament, Jáchymov fault) — according to (Roth 1972, Jaroš, Mísař 1967). In the Neoidic era the boundary zones of the Bohemian Massif have a tendency to rise, while its core keeps a tendency to sink, and on the faults the vertical component of movement predominates (Mísař et al. 1983). The foci of weak shallow earthquakes in the inner parts of the massif can be connected with the disintegration of the massif into a great amount of small structures, that is according to Kopecký and Vyskočil (1972) the main characteristic feature of the neotectonic development of the Bohemian Massif.

The contact of the Bohemian Massif and the Eastern Alps is created by the Alpine foredeep, that has a mean activity (see the earthquake foci near Linz, Pregarten and Neulengbach). The boundary between the East European platform and the Hercynides is created by the Oder lineament, that is in great part seismically inactive; the exceptions are the region Wittenberg – Hamburg, located to the NW from Berlin and the region Wroclaw – Legnice, where there are reports of several earthquake foci in historical time.

The boundary between the East European platform and the Carpathians is created by the Eastern branch of peri–Pieninian lineament, and it is seismically active. The most important boundary in Central Europe is the boundary between the Bohemian Massif and the Western Carpathians, the so–called peri–Pieninian lineament, that is considered as a deep zone of the highest order giving the basic geotectonic sense to the structure and the geological development of the whole of Central Europe and a large part of Southern Europe. It already separated regions with different geotectonic development in the pre–Alpine period (Dudek 1981). Its recent activity is documented by the earthquake foci in the Western Carpathians.

The earthquake foci in the Western Carpathians along the western part of the great Carpathian arc, that originated as a consequence of Alpine folding, run along to the Central Slovakian fault system and along to the deep faults of the Sudetian direction. This fact is also, apart from anything else, evidence of the development of a block structure, that started in the Miocene (Fusán et al. 1981). The characteristic feature of the Western Carpathians is the napped structure. The elongation of macroseismic fields of stronger shocks in far fields shows that this structure is relatively shallow (Procházková et al. 1986).

The earthquake foci in other parts of the Central European Alpines (the Eastern Alps, the Pannonian basin, the Eastern Carpathians and the northern part of the Dinarides) are connected with the important deep faults that create the boundaries of great blocks and for which the moveability is geologically and geodetically evidenced (Procházková et al. 1986).

The earthquake foci in the investigated region are usually in the upper part of the Earth's crust, i.e. $h \leq 10$ km. In several focal regions (e.g. in the southern part of region considered) two seismoactive floors (layers) occur in the Earth's crust.

Among the focal regions on the considered territory there are considerable differences in the shape and the size of macroseismic fields (Procházková, Dudek 1982). The size (surface) of macroseismic fields is directly proportional to the earthquake size and the focal depth and indirectly proportional to the attenuation coefficient of intensities with distance (Procházková 1981). While the elongation of isoseismals of earthquakes in the epicentral area depends on the fault system in the focal region and on the earthquake mechanisms by which the fault system is put into motion, this is not as a rule observed at more distant parts (in the far fields) of macroseismic fields. In the distant zone the intensity distribution is also determined by the properties of the medium through which the seismic waves are propagated. The boundary between the near–field and far–field zones in the macroseismic fields is roughly created by the isoseismal, the mean radius of which is equal to $r \approx 2.5h$, where h is the focal depth in km. The size of surfaces of individual isoseismals and the whole macroseismic field is directly proportional to the earthquake size and the focal depth and indirectly proportional to the attenuation coefficient of intensities (Procházková 1984).

It is noticeable that the Bohemian Massif has small attenuation of intensities with distance. This is confirmed by the isoseismal map of earthquakes in South and South–Western Germany, in the Alpine region, in Poland, in Slavonia, in Friuli and even in the region of Vrancea; and similarly for earthquakes with foci in the marginal parts of the massif. The elongation of isoseismals of earthquakes, especially intermediate ones with foci in the Vrancea region running into the East European and Moesian platforms shows that small attenuation is usually observed in older geological units. On the other hand greater attenuation is observed in younger geological units, mainly in the vicinity of a boundary with the older units (Western Carpathians, Pannonian basin). This attenuation may be explained by the marked change of the thickness of the Earth's crust (breaching the course of the MOHO), the thickness of which is substantially greater in the Alpine region and in the Bohemian Massif than in the western part of the Pannonian basin and in the Western Carpathians (Beránek, Zátopek 1981).

In the case of deeper shocks in the region of the Alps and Carpathians smaller values of the attenuation coefficient are observed than in the case of shallower ones in the same region. On the basis of this fact, we assume that the deeper structure under the napes of the Eastern Alps and Carpathians are connected by position and by direction with the old deeper structures of Moldanubicum and Brunovistullicum, and especially with the directions of Moravicum, finalized in the Variscan period. This interpretation is confirmed by the results of data from bore holes.

The analysis of the numerical values of focal parameters (such as seismic moment, focal dimensions, stress drop and displacement over the fault) shows that earthquakes cannot be compared according to the magnitude or the seismic moment alone; it is necessary to use two parameters, namely on one side the seismic moment or the magnitude (or the epicentral intensity) and on the other side the focal dimension or the stress drop: because there are earthquakes that have nearly the same magnitude but very different focal dimensions (Procházková 1984). After such different earthquakes we also observe great differences in the character of subsequent earthquake activity, i.e. in the case of relatively small stress drop we observe a great number of aftershocks and vice versa, and similarly for the duration of maximum ground movements.

The relationships among earthquakes are not the same in the whole region under account. The regions differ by the different values of parameters of frequency relationship, by the number of shocks, by the values of maximum observed earthquake, sometimes by the types of earthquakes sequences that occur in the individual regions, and often by the direction of foci migration (Procházková 1984).

The comparison of values of standard deviations and of correlation coefficient (Procházková 1984) showed that according to cumulative frequency the points are closer to the straight line than in the case of simple frequency. For this reason the focal regions are compared according to the values of parameters of cumulative frequency ($\log N_c = a - b \cdot I_0$, where N_c is the cumulative frequency) calculated for the period of last 80 – 130 years. From comparison we see (Procházková 1984):

- In the Bohemian Massif, with the exception of the region Aš – Skalná – Kraslice – Bad Elster, where $b = 0.76$ (a high value of this parameter is typical for regions characterized by earthquake swarms), there is $b = 0.34 - 0.51$, the typical value (mode) being $b = 0.43$.
- In the Western Carpathians there is $b = 0.24 - 0.66$; typical value (mode) is $b = 0.40$.
- In the Pannonian basin there is $b = 0.27 - 0.45$; typical value (mode) $b = 0.36$.
- In the Eastern Alps there is $b = 0.47 - 0.67$; typical value (mode) $b = 0.58$.

The Benioff graphs (Procházková 1984, 1988) show that the tectonic stresses are always released after a long period of calm, namely either in the form of one stronger shock or in the form of a group of several stronger shocks, often of comparable size. In one focal region we often observe both forms. The lengths of the active period are not the same in all focal regions (e.g. in the Eastern Alps the active and calm periods last several centuries), and they do not occur simultaneously, in the case of neighbouring focal regions.

The investigation of earthquake groups on the territory of Central Europe (Procházková 1984) confirmed the results that were obtained by the investigation of stronger earthquakes (magnitude $M > 4$) in Europe and in adjacent regions. There are usually observed the following two groups:

- Earthquake swarms represent groups of weaker and stronger shocks in which no shocks of predominant size occur. In the region under investigation these are typical for the regions of Opava, Aš – Skalná – Kraslice, Kunějov, etc.
- The second group is a group with a main shock and aftershocks. It represents a group of shocks in which the first one considerable exceeds the subsequent shocks. It occurs e.g. in the region Hronov – Poříčí. Only in some cases are there also foreshocks, i.e. weak shocks before the main shock (it is possible that the foreshocks are in many cases under the sensitivity threshold of the recording instruments used). In the region Mur – Mürz – Leitha two types of aftershocks have occurred in the same place, namely mostly the aftershocks that are described by the mean regularities but also sometimes the aftershocks in which a strong aftershock follows the main shock after a relatively long time, and is relatively weaker than in the first case. The strong shocks sometimes occur in multiple shock groups (Procházková 1984, 1990).

In several focal regions in the region under investigation it is possible to observe with different conclusiveness certain space–time tendencies in the occurrence of stronger earthquakes, which indicate that the earthquake occurrence does not always represent a pure random process in space and time. By this fact it is possible to explain the deviations (e.g. sudden occurrence of strong earthquake at places that were calm for a long time) from the mean dependencies that were derived. These mean dependencies are based on the assumption that general regularities of the seismicity, or of wider geological–geophysical processes causing the seismicity, do not change with time (i.e. the seismic regime is stationary).

In agreement with the space–time tendencies in the occurrence of foci of strong earthquakes we also observe in several cases in the region under investigation the shift of active periods in time in one direction. Though the activity of weaker shocks in a certain place still continues, a strong shock occurs further off, where it causes the origin of an active period in the first place, etc. E.g. in the year 1876 an active period started in the region Leoben – Wiener Neustadt; in the year 1885 an active period started in the region Wiener Neustadt – Schwadorf and in the year 1890 an active period started in the region Malé and Bielé Karpaty Mts.

The region of origin of strong earthquake is marked by peculiarities in the course of tectonic forces that caused it (Džibladze, Bolkvadze, Džidžejšvili 1975). The causes of strong earthquakes are determined by tectonic processes that are characteristic for substantially greater units than is the case for weaker shocks (see the results for Caucasus, Kamchatka, Central Asia).

The use of strong earthquakes for study is advantageous because a great amount of macroseismic and instrumental material is available, that enables us to investigate the earthquake process from many viewpoints. Some properties are substantially more distinct in the case of strong shocks than in the case of weak shocks, in which they disappear in the noise. The effects of strong shocks are in comparison with the weak shocks substantially greater and observable in a substantially greater region, and therefore, they are under greater attention from seismologists and the public.

From the study of strong earthquakes (Procházková 1984) there followed findings on the detailed distribution of macroseismic effects of earthquakes and on the values of focal parameters of several strong earthquakes, and knowledge about the time intervals between strong earthquakes. The comparison of time intervals between strong earthquakes in individual focal regions clearly documents the differences in the time regime of their seismic activities. Apart from other things it also shows that the intervals between strong shocks in the older geological units of the region under investigation are substantially greater than in the case of earthquake foci in younger geological units.

Both earthquakes with their foci in close vicinity to the locality, and earthquakes the foci of which are outside the vicinity of the locality, but which are manifested there by macroseismic effects, contribute to the seismicity of that locality. For the territory of the Czech Republic there are earthquakes the foci of which are the Alpine foothills, in the Eastern, Western and Southern Alps, in the region of the Frankian and Swabian Jura, in Saxony, Poland, the Western Carpathians, the Pannonian massif and even in Slavonia, Yugoslavia and in the Vrancea region in Romania on the bend of the Southern Carpathians. The strongest earthquakes (Procházková 1984) with the foci:

- in Central Germany (6.3.1872, $I_0 = 7.5°$ MSK–64) reach to the territory of Western Bohemia with the 4 °MSK.–64 isoseismal,
- in the Swabian Jura (16.11.1911, $I_0 = 9.25°$ MSK–64 and 3.9.1978, $I_0 = 8.5°$ MSK–64) reach to the territory of Western Bohemia with the 4 °MSK.–64 isoseismal,
- in the Frankian Jura (10.10.1915, $I_0 = 7°$ MSK–64) reach to the territory of Western Bohemia with the 5 and 4 °MSK.–64 isoseismals,
- in the Lechtal Alps (vicinity of Inn, 13.7.1910, $I_0 = 7.5°$ MSK–64) reach to the territory of South–western Bohemia with the 4 °MSK.-64 isoseismal,
- in the Eastern Alps (River Mur and continuation to Semmering and Wiener Neustadt, 8.10.1927, $I_0 = 8°$ MSK–64) reach to the territory of the Czech Republic with the 5 and 4 °MSK.–64 isoseismals,
- in the Alpine foredeep (on the crossings with the lines parallel to line River Mur and continuation to the NE (15.9.1590, $I_0 = 9°$ MSK–64)) reach to the territory of the Czech Republic with the 6, 5 and 4 °MSK.–64 isoseismals,
- in the region Friuli – Villach (25.1. 1348, 6.5.1976, $I_0 = 10°$ MSK–64) reach to the territory of the Czech Republic with the 5 and 4 °MSK.–64 isoseismals,
- in the Monte Negro (15.4.1979, $I_0 = 10.5°$ MSK–64) reach to the territory of the Czech Republic with the 3.5 °MSK.–64 isoseismal,
- in the region of Strzelin (11.6.1895, $I_0 = 7°$ MSK–64) reach to the territory of North Bohemia and North Moravia with the 4 °MSK.–64 isoseismal,
- in the region of Krakow (3.12.1786, $I_0 = 7.5°$ MSK–64) reach to the territory of Moravia with the 5 and 4 °MSK.–64 isoseismals (to the territory of Slovakia with the 7, 6, 5 and 4 °MSK.–64 isoseismals),
- in the region of Žilina (15.1.1858, $I_0 = 7.5°$ MSK–64) reach to the territory of the Czech Republic with the 5 and 4 °MSK.–64 isoseismals,
- in the region of Komárno (28.6.1763, $I_0 = 8.5°$ MSK–64) reach to the territory of the Czech Republic with the 4 °MSK.–64 isoseismal,

- in the region of Malé Karpaty Mts. (9.1.1906, I_0 = 8.5° MSK–64) reach to the territory of the Eastern Moravia with the 4 °MSK.–64 isoseismal,
- in the Pannonian basin (12.1.1956, I_0 = 8° MSK–64) reach to the territory of Eastern Moravia by the margin of the macroseismic field, i.e. with the 3 °MSK.–64 isoseismal,
- in Ruthenia (24.10.1965, I_0 = 7° MSK–64) reach to the Eastern Slovakia with the 5 and 4 °MSK.–64 isoseismals,
- in Vrancea (4.3.1977 – $M = 7.2$, 30.8.1986 – $m = 6.4$) reach to the territory of the Czech Republic only by margin of macroseismic field, i.e. with the 3 and 2 °MSK.–64 isoseismals and to the territory of Slovakia with the 3.5° MSK–64 isoseismal.

The map of seismic zoning for the Czech and Slovak Republics (Kárník et al. 1988) is a part of the revised standard ČSN 73 0036.

3.2.3. Methodology of Compilation of Focal Regions

The determination of focal regions must be performed on the basis of seismological, geological, tectonical and geodetic data. Only the synthesis of knowledge from these different branches can reduce the uncertainty that is objectively caused by the indefiniteness of input data sets, something that cannot be removed by statistical data processing.

As was stated in Section 1.2, in agreement with Grin and Knauf (1978) we define the boundaries so that they separate regions with different space–time dependencies in the occurrence of earthquakes. In the case of greater depth capacity we have divided the active regions into several floors (layers) that we investigate separately, because the characteristics of seismic activity depend on depth (Procházková 1984, 1993).

At the limits of focal regions we pass from small clumps of foci that are as a rule connected with movements along one fault or along a system of several parallel faults. We take into account the fact that the earthquake foci, especially the stronger ones, are situated on fault crossings, because these places create the weakest parts of a region that is under the same tectonic forces.

We define the greater focal regions on the basis of the similarity of quantitative and qualitative seismic characteristics of individual small regions, because we consider the assumption that partial regions create seismotectonic units when they are characterized by the same process of earthquake origin and by the same geomechanical properties.

The used method of determination of focal regions starts with individual clumps of earthquake foci. These are connected in the frame of one geological and tectonic structure into greater units on the basis of similarity of earthquake parameters and similarity of seismic regime parameters (Procházková 1990).

We define the boundary of a focal region as a boundary that surrounds (Bune, Vvedenskaja, Gzovskij 1968, Budnitz 1995b, Hays 1980, Gelfand et al. 1973):

- all known earthquake foci occurring in historical time and in the case where there is reliable evidence on pre–historical foci from the research of paleoseismicity, so that the boundary also includes those foci,

- a region in which earthquakes with the same characteristics of seismic regime occur,
- a region with the same geological, tectonic and recent movements characteristics (Procházková, Dudek 1982, Procházková, Roth 1993).

3.3. Data Used

3.3.1. Earthquake Catalogues

For the investigation of earthquakes, the derivation of quantitative and qualitative characteristics of seismic activity, and the delimitation of focal regions it is necessary to use all sources of information and summarized data (Kárník, Michal, Molnár 1958, Kárník, Procházková, Brouček 1984, Procházková, Drimmel 1983, Procházková 1984, 1988 a,b, 1990, 1993 a,b, 1994, 1996, Procházková, Dudek 1982, Zátopek 1939, 1940, 1948, Pagaczewski 1972, Slejko 1982, Ribarič 1982, Cvijanovič 1969, Brouček 1969, Kárník 1968, 1971, Drimmel 1980, Drimmel, Gangl, Trapp 1971, Trapp 1973, Drimmel, Trapp 1982, Gangl 1969, Réthly 1952, Csomor 1973, 1978, Zsíros, Monus, Tóth 1983, 1988, 1990, 1993, Shebalin, Kárník, Hadžievski 1974, Zsíros 1983b a, Grünthal 1988, Sieberg 1940, Sponheuer 1952, Kunze, Sponheuer 1981, Leydecker 1986, Radu 1974, Radu, Apopei, Utale 1980, Evseev et al. 1980, Labák 1996a).

3.3.2. Epicentre Maps

Maps of earthquake epicentre are discrete maps; each epicentre is represented by a point. With the aim of quantitative expression of the size of the earthquake to which a given epicentre belongs, we introduce different symbols for the size of the earthquake, e.g. circles with different radii. The maps show the distribution of earthquake foci if different symbols are also used for the different intervals of depth. On the basis of epicentre maps we perform the first stage of delimitation of focal regions. For the delimitation of focal regions there were used the epicentre maps in (Procházková 1984, 1993, Kárník, Procházková, Schenková 1981, Labák 1996a).

3.3.3. Seismic Zoning Maps

Seismic zoning maps are created by the further generalization of maps of maximum observed earthquake intensities (Procházková 1984) and they are used for the first estimation of seismic hazard of a real locality. In general they record the distribution of foci of strong earthquakes and maximum observed intensities, the influence of focal depth on the size and the shape of isoseismals, the anomaly propagation of seismic energy (in Central Europe and its vicinity this anomaly propagation is observed in the Bohemian Massif, in the East European platform and in the Moesian platform (Procházková 1985)) and the anomalies of higher intensities along the boundaries of tectonic structures.

For the analysis of distribution of earthquake foci with the aim of delimiting the focal regions it is suitable to use the summary characteristics of seismic activity, because these emphasize many anomalies that are not distinct in the investigation of individual earthquakes, but which reflect certain physical properties of the fundament that can be important for the delimitation of boundaries of focal regions (Mísař, Procházková 1981, Procházková, Zeman 1982). Therefore, in this study there are used the seismic zoning maps or maps of maximum observed intensities from (Csomor 1981, Bistriczany, Csomor, Kiss 1990, Procházková Brouček 1981, Kárník et al. 1988, Procházková 1981, Grünthal, Sponheuer, Kunze 1981, Radu, Apopei, Utale 1981, Kostyuk, Sagalova 1981, Procházková et al. 1977, Ahorner, Murawski, Schneider 1971, Sponheuer 1962, Guterch, Lewandowska 1981, Pavoni, Mayer-Rosa 1980).

The analysis of available seismic zoning maps allows us to delimit the area in which the strongest macroseismic effects of earthquakes were observed and in which strong earthquakes have mostly occurred. Because the distinctive delimitation of macroseismic effects is the manifestation of distinctive changes of structure in the Earth's crust or upper mantle (Mísař, Procházková 1981, Procházková, Dudek 1982, Procházková, Zeman 1982, Procházková et al. 1986), it is possible to use the course of isoseismals as auxiliary information for the identification of the boundary between such regions as the Komárno region and Central Slovakia.

3.3.4. Results of Seismic Data Processing

On the basis of co–operation of seismologists in Central and Eastern Europe in the 70s and 80s uniformly processed data on earthquakes. Therefore, it is possible to find the characteristic features of earthquakes in individual focal regions and to compare the seismic activity of different geological units. In Central Europe partial focal regions were defined as the regions characterized by the same regime of seismic activity, as delimited in (Procházková 1984, 1990, 1993).

The focal regions on the territory under investigation are characterized by the focal depth $h \leq 10\,\mathrm{km}$, apart from the regions: Nový Jičín – Těšín, Krakow, Štiavnica and Komárno, where the focal depths reach to 20 and more km. The marked difference in focal depths, in the Western and Eastern Beskides (20 km and more) and in the vicinity of Žilina (only at depths up to 10 km) shows in the tectonic activity of two different floors of the Earth's crust (Procházková, Zeman 1982).

As was given in Section 3.2.2, the analysis of macroseismic fields (Procházková 1984, 1987) shows that:

- Among the individual macroseismic fields on the territory under investigation there are differences in the shape and the size of macroseismic fields.
- The elongation of isoseismals in the near–field depends on the fault set in the focal region and on the earthquake mechanisms by which this set is put into motion.
- For the elongation of isoseismals of earthquakes in the distant zone (the far field) the intensity distribution is also determined by the properties of the medium through which the seismic waves are propagated. The boundary between the near–field and far–field zones in the macroseismic fields is roughly created by the isoseismal, the mean radius of which is equal to $r \approx 2.5h$, where h is the focal depth in km.

- The boundary between the Bohemian Massif and the Western Carpathians is characterized by a distinct increase of attenuation, and the same holds true for the boundary between the zone Mur – Mürz – Leitha and the Pannonian basin; it is connected with the distinct change of thickness of the Earth's crust (also the MOHO course). Only earthquakes in Western Carpathians with focal depth > 10 km have an attenuation comparable with the attenuation in the Bohemian Massif and in the zone Mur – Mürz – Leitha. Because the values of attenuation for deep shocks are comparable with those in the Bohemian Massif, so on the basis of results from boreholes Bärendorf–1, Urmansau–1 we assume the continuity of deeper floors of the Earth's crust under the Alpides with the Moldanubicum and Brunovistulicum.

The different elongation of macroseismic fields indicates the different structural zoning of shallower and deeper parts of the Earth's crust in different directions (Procházková, Zeman 1982).

The analysis of frequency graphs $\log N_c = a - b \cdot I_0$ (N_c is the cumulative frequency) in the region under consideration on the basis of data from the last 80 – 130 years (Procházková 1984) is given in section 2.1. If we directly do the computation for larger regions, we obtain different values of the b parameter, as:

- the Bohemian Massif: $b = 0.74 \pm 0.04$,
- the Western Carpathians: $b = 0.49 \pm 0.04$,
- the Pannonian basin: $b = 0.44 \pm 0.01$,
- the Western Carpathians + the Pannonian basin: $b = 0.48 \pm 0.01$,
- the Mur – Mürz – Leitha zone: $b = 0.62 \pm 0.03$.

The given fact is the consequence of the physical essence of the aggregation of data, i.e. the earthquake activity of individual focal regions is not the same, and within the computation for the region taken as a whole there are distinctively manifested regions with a great number of shocks (e.g. the region Aš – Skalná – Kraslice – Bad Elster in the frame of the Bohemian Massif) than other regions, with a smaller number of events. Therefore, for tasks that are based on physical regularities (and among these the delimitation of focal regions indisputably belongs), it is important to proceed carefully from small units to larger ones on the basis of similarity of selected representative characteristics, even though it is a time consuming method.

The focal regions differ not only by parameters of relation $N_c(I_0)$, but also by the length of active and calm periods (found from the Benioff graphs), by the types and properties of earthquake groups that occurred within them, and eventually by the migration of earthquake foci (Procházková 1984, 1988, 1990, 1993).

3.3.5. Geophysical and Geodetic Data

Central Europe has been geologically and geophysically, on the surface and in depth, fairly well (even though methodologically not completely homogeneously) investigated. It is geologically, gravimetrically, magnetometrically, radiometrically mapped, it has been subject to several national and international profiles of the deep seismic sounding, and its shallower structure in the basins has been investigated by many profiles of explosive seismic and by several thousands of boreholes, many of which, in the central part of the territory (Linz – Graz – Gliwice – Krakow) reached the crystalline basement at the depth of 3 – 6 km. The deepest borehole (Zistersdorf UT 2A in Austria) reached the depth of 8553 m in 1983 and is among the deepest ones in Europe. It has been investigated in detail geothermically, geomorphologically and by repeated levelling. In the region of the Outer Carpathians on the distinct fault belts the ground horizontal movements have been measured by three expert geological groups for more than 15 years (Zátopek et al. 1981, Roth, Procházková 1988 a,b, Procházková, Roth 1993, 1996). The summary data processing is e.g. in the works of Zátopek et al. (1981) and Bucha and Blížkovský (1994).

3.3.5.1. Geological Characteristics of Central Europe

The territory of Central Europe is in essence created by the Hercynides and Alpides. The Central European Hercynides are situated on the margin of the Alpine – Carpathian foredeep. Their main partial units are the Bohemian Massif, the Schwarzwald (the Black Forest), the Vosges, the Rheinisches Schiefergebirge Mts. and the territory covered by the platform sediments between Munich and Berlin and partly between the Oder and Wisla lines. To the Central European Alpides the region to the South from the Alpine – Carpathian foredeep belongs. The foredeep passes through the rim of Swiss Alps between Bern and Zurich, passes along the Donau in Austria up to Krems a.d. Donau and further to the NE through Znojmo to Ostrava and to the territory of Poland in the vicinity of Krakow, and terminates in an arch in the eastern rim of the Eastern Carpathians at the Donau River.

The Alpides are divided into: Alps (Western, Eastern, Southern), Carpathians (Western, Eastern and Southern) and Dinarides. The central massifs also form part of the Alpides, e.g. the Pannonian central massif.

The investigated region, therefore, consists of several different geological units of the first order, of different age and with different histories of geological development (Adam, Beránek, Weiss 1979, Aubouin 1980, Beránek, Zátopek 1981, Dudek 1981, Chain, Leonov 1979, Kodym, Fusán, Matějka 1966, Maheľ 1973, 1979, Matějka et al. 1966), as is reflected in the structure and in the thickness of the Earth's crust and in the differences in the geophysical fields. These geological units also differ by the level and character of earthquake activity.

Historically and structurally, Central Europe contains in its geology complicated, young and tectonically still living (active) contact between both basic geological parts of Europe, i.e. between the present (Saxonian) form of the North European platform (including the Tertiary elevation of the Bohemian Massif) and the European Alpides (the Alps and the Carpathians). The deep contact of the Alpides with their platform forefield is flat. It is represented by the flat overthrust of napes and blocks of the Alps and the Carpathians onto the south margin of the platform. The platform crust reaches, according to the geological and geophysical evidence, as confirmed by boreholes, up to a distance 30 – 40 km from the forehead of the Alpides under the Alps, up to the upper, E – W part of the valley of rivers Salzach and Enns, to the feet of the Litava Hills and Malé Karpaty Mts. and to Trenčín, where it reaches up to a distance of 60 – 70 km (Roth, Procházková 1988 a,b).

3.3.5.2. Bohemian Massif

The Bohemian Massif is a morphologically distinct unit of Central Europe. It is an epivariscan, consolidated platform, with the structure of megahorst and with certain features of an epi–platform orogenic zone (block arching, fault activity). It has a rhombic shape, with the spur of the Thüringen Wald Mts. running to the NW (Mísař et al. 1983). The oldest structural element of the Bohemian Massif is the Brunovistulicum (Dudek 1980), the deeper structural floor of Moravia, consolidated during the Cadomian folding, i.e. about 600 Ma ago. This unit was the forefield of the Variscan mountain chain on our territory and it was united with the Bohemian Massif in the period of the lower Carboniferous (about 330 Ma ago). Since this time the Bohemian Massif is a consolidated block, that was for a short time partly flooded by the sea.

The Bohemia Massif is created by structural belts predominantly of the SW – NE strike, that are divided by faults of the NW – SE strike into crustal blocks having similar development. The oldest development stadia of the Bohemian Massif are not reliably known, and the rocks building the bottom structural layer were several times folded and metamorphosed (by the Variscan, Caledonian and Cadomian an may be also by older orogenesis), so their original links were not preserved. Reliably there is only known the Upper Proterozoicum (about 800 – 600 Ma ago), the sediments and volcanoes of which build the Teplá – Barrandien region and parts of the Krušné hory Mts, the Krkonoše Mts. and the Orlické hory Mts. (so called Saxothuringicum). These are partly covered by the Barrandien, the classic region of older Paleozoicum between Plzeň and Praha, and partly by the basic world stratotypes, especially from the Silurian and Devonian periods. This lower part, formed by metamorphosed rocks, by the rocks of the Upper Proterozoicum and Lower Paleozoicum, and by the vast granitoide massifs, was consolidated and united with the Brunovistulicum in the East in the period of the Variscan orogeny (330 Ma ago). In the younger period the Bohemian Massif was not intensively folded and was in some places covered by the sediments of the Permo–Carboniferous with significant black coal beds (especially the Kladno – Rakovník basin and the Ostrava – Karviná basin). The uppermost floor is created by the Upper Cretaceous sediments of the North Bohemian basin and of smaller basins such as those at Budějovice and Třeboň. Of smaller extent are the Tertiary fresh–water basins in the Ohře graben with the brown coal beds, the origin of which was accompanied by volcanic activity of the České středohoří Mts. and Doupovské hory Mts. (Procházková 1991).

From the hydrogeological viewpoint, according to (Mísař et al. 1983), the most significant feature in the Bohemian Massif is the North Bohemian basin, that is our most significant reservoir of drinking water. Less significant are the South Bohemian basins. The other regions are less important for the fresh water supply, even though the fissure waters of these regions can be significant for the local supply. The sources of mineral and thermal waters are connected with the NW and NE part of the Bohemian Massif, especially with the Krušné hory graben and the structures joined with it (Western Bohemian Spas, Jáchymov, Teplice, etc.), with the Krkonoše region (Jánské Lázně) and the deepest parts of the North Bohemian Cretaceous basin (Poděbrady, etc.).

3.3.5.3. Western Carpathians

The Western Carpathians folded in the Mesozoic and in the Tertiary (100 – 15 Ma ago); they form a set of sub–horizontal napes thrust on to the Bohemian Massif and the Polish Paleozoic platform. The different structure of the Bohemian Massif and the Western Carpathians is reflected in the different structure of the deeper part of Earth's crust for both units and apparently also of the upper mantle; the MOHO discontinuity in the region under consideration is in (Mísař et. al. 1983).

The boundary with the Bohemian Massif passes on the surface through the outer margin of the flysch napes, in the basement structure it is farther to the East with three kinds of interpretation:

a) the Lednice zone,
b) the peri–Pieninian lineament (interpretation of geophysical measurements);
c) further to the East the line Stupava – Trenčín – Krupina – Medzilaborce.

The Western Carpathians had a considerably different development in comparison with the Bohemian Massif. Though they adjoin the Bohemian Massif today, they were originally far away from it (several hundreds, perhaps thousand km) and were shifted to it and joined with it during the folding in the Mesozoic and the Tertiary eras. The Western Carpathians are formed of a set of arching, elongated belts. They are divided into the Outer, Central and Inner Carpathians. The characteristic feature of the Western Carpathians is the nappe structure. The block structure has been developed since the Miocene. The elongation of macroseismic fields of deeper inner shocks ($h > 10\,\mathrm{km}$) and far strong shocks (e.g. from the Vrancea region) give evidence of the fact that the block structure is relatively shallow (Procházková 1988).

The Inner Carpathians only reach to the SE part of Slovakia, where they build the region of the Slovenský kras, that is mainly formed by Mesozoic units (Mahel' 1986).

The Central Carpathians build the main part of Slovakia, and they are mainly composed of Mesozoic sedimentary complexes, that cover as napes the older cores, made of crystalline slates and granitoid massifs. The Central Carpathians were formed by folding in the Middle Cretaceous (90 Ma ago). They are separated from the Outer Flysch Carpathians by the complicated klippen belt passing from the Malé Karpaty Mts through the valley of River Váh, the Orava region to the Eastern Slovakia (is mainly made of Jurassic and cretaceous sediments).

The Outer Flysch Carpathians are built by the belt of Cretaceous and lower Tertiary sediments passing from Eastern Moravia through the Polish territory to Eastern Slovakia. They were thrust on their forefield as napes about 25 – 17 Ma ago. The fault structure of the Carpathians is described e.g. in (Fusán et al. 1981, Fusán, Ibrmajer, Plančár 1979).

The outermost part of the Carpathians is created by the Carpathian foredeep filled by the Upper Tertiary unfolded sediments lying on the Brunovistulicum of the Bohemian Massif. The upper structural floor of the Western Carpathians forms the Upper Tertiary basins (especially Donau, South Slovakian and East Slovakian) and the young volcanics of Central and Eastern Slovakia (Dudek 1981).

Significant ore deposits are linked to the Central Carpathians and to the young volcanics there. The regions of the Outer Carpathians and the Upper Tertiary basins are known by the occurrence of liquid and gaseous carbohydrogens, brown coal and several non–metallic raw materials. Hydrogeologically, the regions built by the Mesozoic and Carboniferous complexes, that have large reservoirs of ground water, are the most significant. Sometimes these waters have a very deep circulation, so they spring up at the surface as significant thermal or mineral sources (Piešťany, Teplice, Bojnice, Kováčová, etc.). The regions of Flysch and Neogene have a smaller significance from the viewpoint of fresh–water supply. Also important, but easily threatened by contamination, are the ground waters of the Quartenary on the Žitný ostrov and in other basinal regions (Mahel' et. al. 1967).

3.3.5.4. Eastern Alps

The Alpine orogeny creates an expressive mountain arch between the coast of the Adriatic Bay and the Pannonian basin. In the fundament of the Vienna basin it is linked to the Carpathian arch. For the tectonic position of the Alps and the origin of the arch structure the basic influence was the position of the Adriatic Plate and its shift in the direction of the NW. A movement in the opposite direction, i.e. to the SE, was performed by the other part of the Mediterranean, including Sardinia and part of Corsica. For the further division of the Alps two structures are important. The first one (a roughly directional structure) is denoted as the root zone, or the Alpine – Dinaric scar. It divides the Alps into Northern and Southern parts. The Northern branch is further divided into the Western and Eastern Alps, and the southern branch creates the Southern Alps. The second significant structure is transversal. It passes roughly from the lake Lago di Como to the upper course of the River Rhine. By this line the Alps are subdivided into Western and Eastern parts. These units are differentiated by the paleogeographic development, by the character of the fundament, by the depth of denudation and also by the preservation of different groups of napes.

The outer marginal part is the flysch belt, built by the nappe units, that pass to the flysch belt of the Western Carpathians. Its southern margin is a narrow belt, the main klippen zone, that is the equivalent of the inner klippen belt of the Western Carpathians. Further to the South there is the unit of Oberostalpine, represented by the massif of the Northern Limestone Alps. In the most southward part of the structure, there is the Unterostalpine unit, with a link to the Malé Karpaty Mts. in the complex of core mountains of the Central Carpathians.

The Eastern Alps, to which the SW part of the region under investigation reaches, are limited on the West by the transversal Alpine flexure, on the South by the Alpine – Dinaric scar, on the East by the Vienna basin and to the North they neighbour the units of the Bohemian Massif and are partly thrust over it. Unlike the Western Alps, the Eastern Alps only negligibly contain Pennine napes, emerging on the surface. The most substantial part there are Austrian (eastern Alpine) napes.

From the morphological viewpoint, with regard to the geotectonic development of the Eastern Alps the following units are selected:

- The Eastern Alpine central Penninicum,
- The Eastern Alpine napes (Ostalpinicum),
- The North marginal zone with the Helveticum, Ultrahelveticum and Flysch belt.

The central Penninicum of the Eastern Alps emerges in the windows of the Lower Engadine, of the Tauern and of the Wechsel near Vienna. The Lower Engadine window emerges from the fundament of the Silvreta Mt. and Otztal napes. On the basement units there are layers of Triassic to Cretaceous age (Champat zone) and the Tasna nappe with crystalline complexes and Mesozoicum, eventually also with the Lower Tertiary flysch.

The Tauern window is submerged according to the results of Tollmann (1965) to the W, S and E under the Upper Ostalpinicum. The lowest core is of pre–Hercynian and Hercynian age, and it is formed by granite gneiss and granite. Both passed through the Tauric crystallisation of the Alpine age. The remaining two zones are marked as Lower and Upper slate cover. The whole inner structure of the Tauern window is formed by napes.

The Weschel window and the metamorphic island emerge below the base of the Ostalpinicum of the Semmering nappe. The central gneiss is of pre–Hercynian age, the cover units are Upper Paleozoic.

The East Alpine napes (Ostalpinicum) form the main massif of the Eastern Alps. To the south they are closely connected with the root zone, to the north they were shifted over the marginal zone in the final stage in the Miocene. The development of this unit passed through two stages of tectonic transport. In the first stage there originated the basic napes of the Middle Cretaceous age. In the second stage, in the Miocene, there was the Ostalpinicum shifted far to the North, up to the foredeep margin.

The Ostalpinicum is divided into three units. The central crystalline Ostalpinicum belongs according to its age to Hercynian and pre–Hercynian crystalline complexes. The unit is formed by granitoids and Upper Palaeozoic phyllites. Further on it follows the lower plus middle Ostalpinicum of the central crystalline zone, and on the uppermost part there is the upper Ostalpinicum. The Permo – Mesozoic formation is deposited on this.

The central crystalline zone borders with the northern graywacke zone. Their contact is tectonic, even though of a different nature (shift displacements, reverse faults, transversal dislocations). On the northern margin of this zone there begin the North Limestone Alps. They represents an up to 2000 m thick complex, prevailingly of limestone Mesozoicum. They are linked with the Malé Karpaty Mts. in the complex of core mountains of the Central Carpathians.

The northern marginal zone dips under the North Limestone Alps and simultaneously it is shifted as a whole over the molasse of the Alpine foredeep. Along the

Salzburg line it is divided into the East Alpine zone and the Helvetic unit. On the Salzburg line there terminates the continuation of the Vienna – Carpathian flysch in the direction of the west and further to the west the development of the Penninic flysch begins.

In the fundament of the marginal zone and of the foredeep between Krems and Vienna there passes the boundary between Moldanubicum and Moravicum (Mísař 1987).

The overthrust of North Limestone Alps in the marginal zone began during the Upper Eocene. The overthrust of the marginal zone over the foredeep and the origin of the Helvetic klippen occurred in the Upper Miocene.

3.3.5.5. Pannonian Basin

The Pannonian basin represents the wide tectonic depression between the Alps and the Carpathians, that originated in the Neocene and in the Quaternary. It is subdivided by the deep faults of the SW – NE direction (Raab, Balaton – Darnó, Zagreb – Zemplín, Szolnok – Ebes) into blocks (Körössy 1981). The following zones are distinguished: Western Hungarian belt, Köszeg – Mihalyi belt, Central Hungarian belt, Igal – Bükk belt, Kapostö – Magocs belt, Meczek – Kiskörös belt, Moragy – Central Hungarian plain (the crystalline complex of the River Tisa) and Villány – South Hungarian plain. Some of these blocks have the same structure as the blocks in the Western Carpathians.

3.3.6. Seismotectonic Characteristics of the Region

The analysis of neotectonic movements in Central Europe (Procházková, Roth 1993, 1996) reveals that during the last 5 Ma on the territory of Central Europe there have developed more or less independently six units, namely: the region Burgundy – Vosges, the region of the Dauphinese Folds and Jura Mts., the Central European mountain region (divided into sub–regions: the Schwarzwald Mts. (the Black Forest), the Germany – Czech triangle, the Central European mountain range, the Brunovistulicum), the region of Donau and South–western Pannonian basins, the tectonically active region, with a northward–moving nappe structure, of the Flysch Western Carpathians, and the central Alpine – Carpathian neotectonic region. In the historical period only some of the fault margins of region are seismogenic. The region of the Donau basin and the Malé Karpaty Mts. is characterized by subsidence, that is accompanied by intermittently horizontal shifts, especially on the western and eastern margins of the basin.

The comparison of the positions of earthquake epicentres and the positions of faults with the consideration of earthquake mechanisms and observed movements of the faults (Procházková, Dudek 1982, Procházková et al. 1986) have enabled us to delimit the recent seismoactive faults in Central Europe. It has been shown that:

- seismoactive are mainly some parts of fault structures that have either NW – SE or NE – SW direction;

- some distinct geological structures (e.g. the Odra lineament) are at least to a great extent seismically inactive (Procházková et al. 1986).

The finding that only parts of the structure are seismoactive corresponds to the idea of Jaroš and Vachtl (1980), formulated on the basis of investigation of the rheologic behaviour of rock massifs.

The mutual comparison of regional findings on the geologically recent changes of orientation, on the relative sizes of main stresses in the crust, on the geologically and geomorphologically determined young movements of the Earth's surface, on the geodetically determined recent movements and on the historical seismicity (Procházková, Roth 1993, 1996) results in the following conclusions on the generation of focal regions in which the stronger earthquakes occur:

- the earthquake epicentres on the territory under investigation are concentrated into regions along the lines that separate individually developing tectonic units (neotectonic regions or provinces). The greatest mutual movements at present take place along these lines. Only some parts of these are seismoactive;
- the foci of stronger earthquakes originate not only in the dynamic system that consists of the African plate and the Alpides but also in the Saxonian forefield of the Alpides, i.e. in the Epi–Hercynian platform;
- in the platform there only originate the foci of stronger earthquakes in the places in which the platform is mechanically coupled with the Alpides, i.e. in Central Europe, in a belt about 300 km broad. Here we observe the movements in the last 5 – 10 Ma and the distinct historical seismicity;
- the dominant present stress, without which stronger shocks in this part of the platform cannot originate, is the sub–horizontal, near–meridian stress transferred by the Alpides from Africa.

In the region under investigation the foci of these shocks are usually situated in the brittle lithosphere, i.e. at depths of 3 – 20 km (mostly 5 – 8 km), namely mostly on the pre–existing (Hercynian and older) fracture zones, in the dilatation and compression parts of the Earth's crust, as far as their position is close to the highest shear stresses of the "African" shear stress.

The strongest shocks in the region of the Eastern Alps and the Western Carpathians occur in the places where the vertical, shear, diagonal zones (with vertical σ_2) pass laterally into the shear zones diagonal (i.e. with sub–horizontal σ_2), e.g. in the region of Friuli, Žilina and Komárno.

The foci of stronger shocks in the saxonically activated platform are concentrated on one hand in the zones of horizontal shifts (e.g. the Rhine Graben), and on the other hand in regions in which by lateral (horizontal) bending the direction of steep lineament has recently changed with regard to the direction of shear stress of African stress; e.g. in the region of the Sudetian – Malenice horst. In Central Europe, both types of zones influence the transfer of "African" stress from the Alpides into the platform. Stronger shocks do not occur in the fields of clear subsidence tectonics, i.e. where the subsidence tectonics is not accompanied by the horizontal shifts. From this viewpoint there is e.g. a great difference between the subsidence tectonics of the (aseismic) Vienna basin (being out of the region of transfer of Alpine stress, i.e.

to the NW of the Mur – Mürz – Leitha – Žilina zone) and the subsidence tectonics of the Donau basin, that is enclosed on the NW and on the SE by active seismogenic zones (Roth a Procházková 1988 a,b).

3.4. Focal Regions in Central Europe

On the basis of the methodology described in the section 2.3, the epicentre maps (Procházková 1984, Schenková, Kárník 1981, Labák 1996a, Zsíros et al. 1990), the epicentre map of Central Europe (Procházková 1993), the data given above in Chapter 3, and from the evaluation of the accuracy of the data on earthquakes (Procházková 1984) there was compiled a map that contains the focal regions of earthquakes, and the regions with diffuse seismicity, Fig. 1.

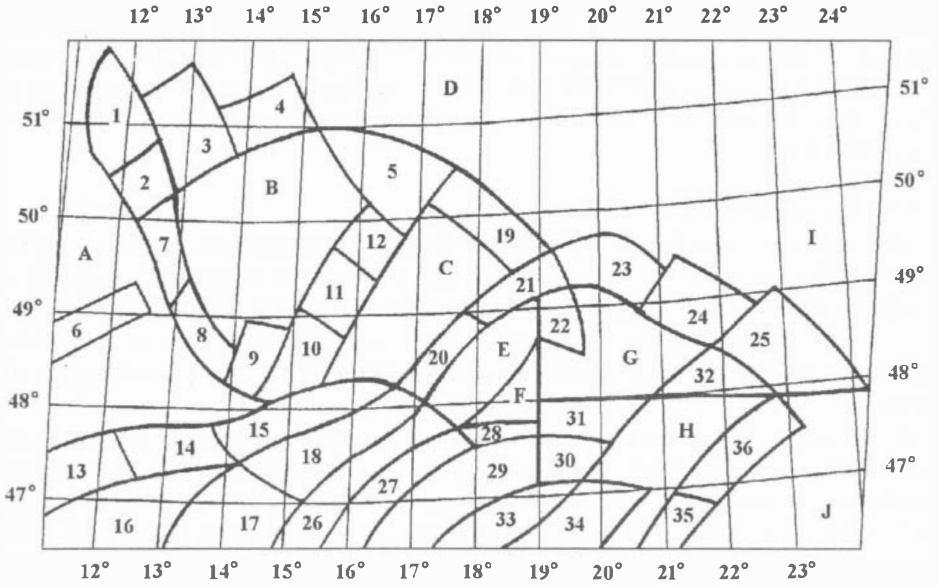

FIG. 1. Map of the focal zones in Central Europe

Altogether there were delimited 36 focal regions of earthquakes (denotation 1 – 36) and ten regions with diffuse seismicity (denotation A – J).

3.4.1. Characteristics of Focal Regions

The individual focal regions are briefly characterized by:

- brief geological characteristics (Dudek 1997),
- typical parameters (determined as a mode of values obtained for the given region (Procházková 1981, 1984, 1993, Procházková, Dudek 1982)) for the earthquakes and their macroseismic fields,
- the parameters describing the seismic activity of a given region (in particular the slope of a graph of cumulative frequency *b* for the period of the last 80 – 130 years)

that were derived in (Procházková 1984, 1988, 1990, 1993) and other works that are independently quoted

Region 1 — Thüringer Wald - Gera

The region occupies the Thüringen basin to the NE of the Thüringer Wald Mts., whose upper Proterozoic fundament is created by complexes of epi-zonal metamorphites of the Vogtland synclinorium and by the Thüringen anticlinorium and by the zone of the Central crystalline rise. The units of the basement are covered by folded and weakly metamorphosed Palaeozoic reclay (up to the Lower Carboniferous inclusive) and further by the younger platform cover of the Permian and the Mesozoic. The region reaches to the Eastern margin of the Harz Mts. and it is disturbed by significant faults of the NW - SE strike.

There have usually occurred single earthquakes, and the stronger shocks are accompanied by the aftershocks. The strongest shocks occurred close to Gera. The intensity of the strongest earthquake so far recorded ($I_{\max}$) of March 6, 1872 close to Gera, did not exceed 8 °MSK.-64. The focal depth of shocks is small (up to 6 km). The attenuation of intensities with distance is low, i.e. $\alpha = 0.001$, $k = 3$, $b = 0.76 \pm 0.03$.

Region 2 — Kraslice - Aš - Plauen

The region is built by the crystalline schists of the Krušné Hory Mts. and the Smrčiny Mts. with the Smrčiny and Nejdek - Eibenstock granitoid massifs. It is roughly limited by the Krušné Hory fault on the SE, by the Central Saxony deep fault on the NW and by the Jáchymov fault on the NE. The system of the Cheb - Domažlice graben with the active Mariánské Lázně fault also pass through the region.

In the region there have occurred earthquake swarms. Records of shocks are available from the year 1198. For 198 shocks isoseismal maps have been constructed. Earthquake swarms were recorded in the years 1198, 1522, 1674, 1701, 1770, 1771, 1824, 1850, 1896, 1897, 1900, 1901, 1903, 1908, 1911, 1929, 1936, 1962, 1973, 1983, 1985 - 86.

Stronger earthquakes, that do not belong to earthquake swarms, have their foci on the boundary of the focal region (Plauen 1875, 1888, 1896, Hof 1883).

The region of foci of earthquake swarms roughly occupies the area delimited by the geographical coordinates 50.2 - 50.4° N, 12.2 - 12.6° E. It is among the deep faults of Jáchymov, Litoměřice and Krušné Hory. The shocks are connected with the Mariánské Lázně fault (roughly in the NNW - SSE direction), with the continuation of the Tachov fault and with the Krušné Hory fault. The weak swarms only attack a part of the delimited region, and during strong swarms the earthquake foci occur in the whole region.

The shocks in the earthquake swarms are accompanied by underground rumbling. Both the upgrading and weakening of the capacity of the mineral sources has occurred, and sometimes the water of sources is made muddy. The intensity of maximum observed earthquake ($I_{\max}$) did not exceed 7 °MSK.-64. The foci of shocks are shallow, in the interval 3 - 11 km (typical focal depth is 5 km).

For stronger shocks there are isoseismals elongated in the direction into the Bohemian Massif and often also to the N and NNE. The local decrease of intensity (in comparison with the vicinity) has occurred in the region of Doupovské Hory Mts. (Procházková 1990). The attenuation of intensities is small, i.e. $\alpha = 0.001$, $k = 3$, $b = 0.76 \pm 0.03$.

The last swarm affected Western Bohemia and the adjacent region at the turn of the years 1985 and 1986 (Procházková 1989). Most foci were connected with the Mariánské Lázně fault in the area between the localities of Nový Kostel and Křižovatka. The swarm consisted of 4 main active periods lasting 4–6 days, and between these active periods the occurrence of earthquakes was very low. The active periods concentrated around the strongest shocks of the swarm. The character of the swarm in the different swarm stages was not the same. At one stage there was a great number of weak shocks (e.g. after 20.1.1986) and at other stages more and stronger shocks (e.g. 20.–25.12.1985).

Stronger earthquake swarms (containing tens of shocks) consist of two or more active periods, and between them the activity is low. The active periods concentrate around the strongest shocks of the swarm. They last as a rule 3–6 days and during them there occur hundreds of shocks per day. During some swarms there were also observed short term migrations of stronger shocks in the vertical and horizontal planes.

Region 3 — Komořany – Leipzig

The region, having a NW–SE elongation, is formed by the crystalline complex of the Krušné Hory Mts. and of the Saxony granulite mountain range, that dip to the NW under the sedimentary cover of Palaeozoic sediments, and further under the sediments of the Mesozoicum – mainly Triassic. To the NE the region is limited by the Elbe lineament, and to the SW by the Jáchymov deep fault. On the NW the region reaches to the Central German crystalline rise. In the middle of this region runs the Central Saxony deep fault (Central Saxony lineament), in a NE–SW direction.

The strongest shocks occur on the crossing of faults of the NNW–SSE direction with the Central Saxony lineament and with the Krušné Hory fault, that were active in the Neogene and in the Quaternary.

Stronger shocks (up to the intensity 8 °MSK.–64) are connected with the first one, because it has greater deep range.

In the southern part of the region (where we have records of 81 shocks since the year 1505) the intensity of the greatest observed earthquakes ($I_{\max}$) did not exceed 7strongest shock, of 20.3.1784, close to Duchcov, had the epicentral intensity $I_0 = 7°$ MSK–64. The further reports are only for the earthquakes of 4. and 5.10.1877 close to Teplice and on the earthquake swarm in 1896 (there were only recorded five shocks). The foci of shocks are shallow (6–9 km, the typical focal depth is 8 km). The attenuation of intensities with the distance is small, i.e. $\alpha = 0.001$, $k = 3$, $b = 0.50 \pm 0.04$.

Region 4 — Zittau - Bautzen (Upper Lausicz)

The region is limited to the SE by the continuation of the Krušné Hory fault and to the NW by the continuation of the Central Saxony deep fault. In the greatest part it is formed by the Cadomian Lusatian pluton with the remains of its mantle, that dips to the N under the sediments of the Polish Palaeozoic platform. The SW limit of the region is formed by the system of faults of the Elbe lineament.

Here there have only occurred single weak shocks. The intensity of the strongest earthquake so far recorded ($I_{\max}$) did not exceed 4°MSK.–64. There is not enough data for the compilation of a frequency graph.

Region 5 — Trutnov - Klodzsko - Strzelin - Šumperk

This extensive region is built by the crystalline complex of Lugicum from the eastern part of the Krkonoše Mts. up to the Hrubý Jeseník Mts. inclusive. There are metamorphic complexes of the Proterozoic, and partly of the Lower Palaeozoic age that are penetrated by Variscan plutons. On the crystalline basement there are sediments of the Inner Sudetian basin (Carboniferous to Triassic). The crystalline basement gradually dips to the NE under the sediments of the Polish Palaeozoic platform. The SW boundary of the region is formed by the active Hronov - Poříčí fault system, and the SE one by the Moravia - Silesian lineament. On the NE the marginal fault of Lugicum is significant.

Shocks occur in the region of:

- the Hronov - Poříčí fault (e.g. 11.12.1799, 31.1.1883, 10.1.1901),
- the marginal Sudetian fault (e.g. in the vicinity of towns Görlitz and Klodzko, 10.2.1562),
- the fault parallel with the Odra lineament (e.g. Strzelin 11.6.1895),
- the deep fault of the Červená hora saddle (Šumperk - Kouty n. Des., e.g. 4.5.1616, 26.11.1878, 24.7.1935, 10.9.1986),
- the Lusatian fault (e.g. 30.4.1908, 4.7.1980),
- the Stráž fault (e.g. in the vicinity of Polubný 5.10.1877)
- the town Frýdlant (e.g. 14.1.1804, 7.3.1915, 30.6.1979),
- the town Žamberk (14.6.1945, 28.6.1982).

The strongest shocks are connected with the Hronov - Poříčí fault. The systematic local increase of intensities in the case of strong shocks is observed in the vicinity of Jablonec and Tanvald. During earthquakes there are observed expressive sound effects, and changes in the regime of the ground water. The intensity of the strongest observed earthquake ($I_{\max}$) did not exceed 7.5°MSK.–64. The focal depths of shocks are in the range 5 to 9 km (typical value 7 km). The attenuation of intensities with distance is characterized by the parameters $\alpha = 0.001$ and $k = 3.1$, $b = 0.38 \pm 0.03$.

A shock in the vicinity of Strzelin (11.6.1895, $I_0 = 7°$ MSK–64) had the focal depth $h = 8$ km, $\alpha = 0.003$, $k = 3.1$.

Shocks in the region Šumperk - Kouty n. Des. had $h \leq 10$ km, $I_0 \leq 5.5°$ MSK–64, $\alpha = 0.003$, $k = 3.1$.

Region 6 — Regensburg – Augsburg

The region, of NE – SW orientation, is at the SW elongation of the Krušné Hory fault belt. It is formed by the platform sediments of the Mesozoic, that are dipping in the S under the Neogene Alpine molasse. On the NE the region terminates on the fault boundary of Western Germany Mesozoic table against the moldanubian crystalline complex (the continuation of the Frankian faults). On the SE margin of the region there is the famous Ries astroblem.

Shocks have been recorded since 1062. The foci of shocks occur along the Donau fault. The strongest shock was in 1062 in the vicinity of Regensburg. The intensity of the strongest observed earthquake ($I_{\max}$) did not exceed 8 °MSK.–64. The foci of shocks are not close to the Earth's surface: their focal depth is between 12 and 20 km (the typical depth is 16 km). The attenuation of intensities with distance is characterized by the parameters $\alpha = 0.002$ a $k = 3.4$. The slope of the frequency graph is $b = 0.42 \pm 0.04$.

Comment:

To the W from this region there is the focal region along to the Swabian Jura Mts. that lays on the continuation of the deep fault from Lago di Como – upper course of the River Rhine. The intensity of the strongest shocks reaches to 9 1/4 °MSK.–64 (16.11.1911). The macroseismic fields of the strongest shocks (16.11.1911, 1943, 3.9.1978) reached far to the E into the Bohemian Massif. The focal depth $h = 8 - 10$ km. The attenuation of intensities with the distance is expressed by the parameters $\alpha = 0.008$, $k = 3.2$. The local increase of macroseismic effects is observed in the Thuringian basin, that shows expressive subsidence tendencies at present.

Region 7 — Domažlice – Tachov

The region is formed by moldanubian metamorphites with small granitoid massifs. It is situated between the Saxothuringicum on the NW and the Kdyně basic massif on the SE. On the E it is connected with the metamorphites of the Bohemicum in the Cheb – Domažlice graben, in which there are preserved small relicts of Miocene sediments. The SE limit coincides with the Central Bohemian deep fault, that is not seismically active.

Since 1197 there have been recorded 71 local shocks. The shocks occur near Planá (e.g. 6.2.1788, 22.7.1915), Přimda (e.g. 26.11.1902), Stráž u Tachova, Vítkov, Studánka, Domažlice and Horšovský Týn (e.g. 18.10.1688, 24.4.1858). The intensity of the strongest recorded earthquake so far ($I_{\max}$) of 26.11.1902 near Přimda did not exceed 6.5 °MSK–64. The foci of shocks are shallow (up to 5 km). The attenuation of intensities with distance is small, i.e. $\alpha = 0.001$, $k = 3$. The slope of the frequency graph $b = 0.51 \pm 0.04$.

Region 8 — Šumava – Grafenau – Thalberg

The fundament of the region is created by the metamorphites of the Šumava branch of the Moldanubicum, with smaller granitoid massifs and with bodies of granulites. Its Eastern boundary is formed by the fault belt of the Lhenice graben, in a N – S direction. On the SW it borders with the Alpine foredeep filled with

Tertiary sediments. The region is cut by the Donau fault, the Bavarian Quartz lode (Pfahl) and on our territory by the so far not so precisely defined Šumava fault, being generally a NW – SE strike.

The shocks occur in the vicinity of localities:

- Lenora, Horní Vltavice and Boubín (e.g. 28.5.1929, 20.8.1978, their connection with the Šumava fault is assumed),
- Grafenau and Thalberg (e.g. 5.1.1897),
- Nýrsko (e.g. 9.10.1915).

The intensity of the strongest observed earthquake ($I_{\max}$) did not exceed 5.5 °MSK-64. The shocks are shallow (up to 8 km), and the attenuation of intensity with distance is small ($\alpha = 0.001$, $k = 3$). There is not enough data for the construction of an empirical frequency graph.

Region 9 — Kaplice – Freistadt

The region is formed by a moldanubian crystalline complex (metamorphites with the granulite massifs and a part of the moldanubian pluton) along both sides of the significant Rodel fault belt. On the S the crystalline complex is covered by Neogene sediments of the Alpine molasse. On the N there are deposited on the crystalline complex the South Bohemian basins, limited by faults, with Upper Cretaceous and Tertiary sediments (the southern parts of the Budějovice and the Třeboň basins). The faults limiting the basins belong to the system of the Jáchymov fault (NW – SE) and to the system of the Blanice furrow (N – S).

Shocks occur:

- near Třeboň, where their connection with the Blanice furrow (e.g. 8.12.1877) is assumed,
- near Nové Hrady (6.2.1796, 17.7.1875), where their connection with the Jáchymov deep fault is assumed,
- on the Kaplice fault belonging to the fault system of the Blanice furrow and the Rodel line (České Budějovice, Český Krumlov, Vyšší Brod),
- near Chvalšiny and Bavorov (e.g. 1.2.1880, 27.5.1882, 20.10.1909, 11.2.1900, 29.4.1983), where their connection with the Lhenice graben is assumed,
- along the River Krems (e.g. 6.6.1982, 22.11.1862, 5.1.1865, 10.3.1971).

The intensity of the strongest observed earthquake ($I_{\max}$) did not exceed 5 °MSK-64. The focal depths are within the first km, about up to 4 km, and the attenuation of intensities with the distance is small, i.e. $\alpha = 0.001$, $k = 3$. The slope of the frequency graph $b = 0.35 \pm 0.15$.

Region 10 — Waidhofen – Jindřichův Hradec

The W part of the region is formed of granitoids of the moldanubian pluton, and the E part by the metamorphites of the Moravian branch of the Moldanubicum up to the moldanubian overthrust (the Moldanubicum thrust over the Moravicum). In the W part there is the important Vitis fault, linking in the N to the Přibyslav deep fault. With its SW part the region reaches to the Alpine foredeep, and the northern boundary is formal (it is created on the basis of a boundary between regions with different properties of earthquakes).

Shocks occur near Jindřichův Hradec, Rajchéřov (1932), Stráž n. Než. (1860), Kunějov (1924–25) and Lišov (1854–59). For these sound effects (detonations) are characteristic. Most often the shocks occur in the form of earthquake swarms, and some swarms have lasted up to 2 years. The intensity of the strongest observed earthquake ($I_{\max}$) did not exceed 5 °MSK–64.

From the fact that there are mainly recorded sound effects in a small area (one village) we suppose that the shocks are not only weak but also shallow. There are not enough data for the construction of a frequency graph.

Region 11 — Jihlava and vicinity

The region is formed by the moravian branch of the Moldanubicum, that is rimmed on the W by the granitoid moldanubian pluton and on the E by the Třebíč durbachite massif. The NNE boundary is the Sázava deep fault. The region is cut by the Přibyslav deep fault (inactive) and by the young fault system of the Jihlava furrow, with rare relicts of sediments of the Youngest Tertiary and the Quaternary.

For earthquakes with foci on the Českomoravská Highland there are described distinct sound effects. Since 1329 we have records of 18 shocks, mostly of the vicinity of Jihlava, where we may assume a connection of shocks with the mines that were here in the middle ages. Shocks also occur in the vicinity of Křemešník (22.10.1877) and of Želiv (1927), where they are probably connected with the Sázava deep fault; some local shocks are connected with the Přibyslav deep fault. The intensity of the strongest observed earthquake ($I_{\max}$) did not exceed 5 °MSK–64. The macroseismic fields of earthquakes mostly include several localities, which means that the foci of shocks are very shallow, i.e. within the first km (up to 4 km). The attenuation of intensities with distance is small ($\alpha = 0.002$, $k = 3$). The slope of the frequency graph $b = 0.43 \pm 0.04$.

Region 12 — Vysoké Mýto – Litomyšl – Svitavy

The region is essentially located between the Sázava deep fault and the Elbe lineament (where it borders with region 5). It is formed by the Strážec Moldanubicum, that is separated on the NE by a fault from the crystalline complex of the Svratka anticlinorium and from the Polička crystalline complex (faults of NW – SE strike). The Polička crystalline complex is mostly covered by the Upper Cretaceous sediments of the North Bohemian basin. The E boundary is roughly the line of the moldanubian overthrust and of the Bíteš dislocation.

Only single shocks have occurred (e.g. 31.3.1908 Svitavy). Their foci are probably connected with the Elbe fault. The intensity of shocks only exceptionally reaches to 5 °MSK–64. The macroseismic fields are small. They include one or two villages, and sound effects have been described that give evidence for small focal depths. The slope of the frequency graph $b = 0.34 \pm 0.03$.

Region 13 — Innsbruck and vicinity

The region includes a large part of the nappe units of the Eastern Alps, from the Helveticum and the Ultrahelveticum through the flysch, the North Limestone Alps, the Northern graywacke zone and the Ötztal nappe up to the N part of the crystalline of the Tauern window. The significant fault structures in the region are faults of the WSW – ENE strike, passing the valley of River Salzach at the N margin of the Tauern window. The region on the W reaches to the Engadine window, and on the E it includes the western half of the Tauern window. In the basement of alpide napes there are complexes of the epi–Variscan platform. At its SW tip the region touches the significant transversal Judicaria fault, and the Insubric line already passes on the S from the region.

The foci of shocks are connected with the Central Alpine scar (the Insubric line). The intensity of the strongest earthquake recorded so far ($I_{\max}$) did not exceed 8 °MSK–64. The macroseismic fields of strong shocks (with $I_0 \geq 7.5$ °MSK–64) are anomalously in the far field elongated into the Bohemian Massif (Procházková, Kárník 1978).

The characteristics of earthquake activity of the region are:

- max $I_0 = 8$ °MSK–64,
- $b = 0.65 \pm 0.04$,
- the focal depth interval: 4 – 7 km,
- typical focal depth: 6 km,
- typical values of attenuation coefficients of intensity with the distance: $\alpha = 0.002$, $k = 3.4$.

Region 14 — Salzach – St. Martin

The region is situated on the N part of the Eastern Alps and it includes all main nappe units from the flysch up to the crystalline of the Upper Austroalpide napes and up to the core of the Tauern tectonic window. In the E – W direction it includes the area from the E part of the Tauern window up to the transversal faults on the E margin of the Niedere Tauern Mts. The significant transversal fault (N – S) follows the valley of the River Salzach.

The focal region is located along to the River Salzach. There have usually only occurred weak shallow earthquakes. The intensity of the strongest observed earthquake ($I_{\max}$) did not reach 7 °MSK–64. The attenuation of intensities of earthquakes with distance is characterized by the parameters $\alpha = 0.002$, $k = 3.3$. The slope of the frequency graph $b = 0.54 \pm 0.05$.

Region 15 — Linz – Pregarten – Molln – Neulengbach

The region includes the E part of the Eastern Alps, from the Niedere Tauern Mts. up to the margin of the transversal Vienna basin. It includes the Alpine foredeep filled by Miocene sediments, flysch napes and the napes of the North Limestone Alps. The N boundary of the region, however, passes into the most southern part of the Bohemian Massif, that is built by the moldanubian metamorphites and by plutonites. The Bohemian Massif certainly reaches far to the S under the foredeep and the Alpine napes.

The region belongs to the Alpine foredeep that has in this part the W – E direction, The foci of stronger shocks occur in the vicinity of Linz (1.10.1785, 26.10.1865, 17.6.1972), Molln (27.10.964) and Neulengbach. (15.9.1590).

The intensity of the strongest earthquake ($I_{\max}$) of 15.9.1590 near Neulengbach reached the value 9 °MSK–64. The focal depth was determined at 15 km, which means that the foci were placed in the basement (epi–Variscan platform) of the Bohemian Massif, because the Alpine napes are very thin there. The coefficients of attenuation of intensities with the distance are $\alpha = 0.002$, $k = 3.4$.

The foci of other known shocks are shallow, i.e. $h = 4 - 10\,\mathrm{km}$. The attenuation of intensities with the distance is small, i.e. $\alpha = 0.001$, $k = 3.2$. The slope of frequency graph is $b = 0.43 \pm 0.03$.

Region 16 — Bolzano – Lienz

The region includes the most important tectonic lines of the Eastern Alps, the Insubric fault and the Judicarian transversal fault. It is created by the crystalline schists of the Ötztal graben and by the Upper Austroalpine napes, by the Penninicum and by part of the crystalline complex of the Tauern window. In the N it almost reaches to the fault in the valley of the River Salzach.

The intensity of the strongest observed earthquake ($I_{\max}$) did not exceed 6.5 ° MSK–64. The region was not specially followed, neither from the viewpoint of macroseismic fields nor from the viewpoint of the empirical relationship between the number of earthquakes and their size, because none of the recorded shocks has manifested itself by macroseismic effects on the territory of the Czech Republic or in its close vicinity.

Region 17 — Friuli

The region includes the central part of the Eastern Alps up to the Insubric line and up to the Periadriatic lineament on the S. Its eastern limit is the margin of the Pannonian basin and the western limit is the margin of the Tauern window. There are significant systems of faults limiting the W – E stripe of the Gailtal Alps (Dráva valley). The region is mainly formed by units of the Upper Austroalpine napes and of the Southern graywacke zone. In the N the region reaches to the North Limestone Alps.

The foci of shocks are situated in the vicinity of the lake Lago di Garda, in the Friuli – Villach region, and in the Verona – Padova belt. The intensity of maximum observed earthquake ($I_{\max}$) reached 11 °MSK–64.

The characteristics of earthquake activity of the region are the following:
- max $I_0 = 11$ °MSK–64,
- $b = 0.45 \pm 0.03$,
- interval of focal depth: 5 – 10 km,
- typical focal depth: 6 km,
- typical values of attenuation coefficients: $\alpha = 0.001$, $k = 3.0$.

A systematic local intensity increase of 0.5 – 1 °MSK–64 is observed in the Southern Bohemian basins (Procházková, Kárník 1978, Kárník et al. 1979).

Region 18 — Eastern Alps

This wide region is formed from the eastern part of the Eastern Alps and continues far to the NE across to the Neogene Vienna basin (Neogene pull–apart basin) up to the Malé Karpaty Mts. It includes the Alpine units on the NW from the Pannonian basin, that are built by the Upper Austroalpine napes, methamorphised

Paleozoicum and by the Southern graywacke zone, by the Northern graywacke zone and by the marginal part of the North Limestone Alps. The significant fault belts of the SW – NE directions are seismoactive (the line Mur – Mürz – Leitha).

The analysis of the spatial distribution of earthquakes, macroseismic fields and earthquake mechanism shows that many earthquakes are connected with the Mur – Mürz – Leitha line. We consider this line, following (Čekunov, Kučma 1979, Dobrev, Ščukin 1974, Procházková, Roth 1993), as a manifestation of the developing hidden deep fault. The strongest earthquake, of 4.5.1201 in the vicinity of Murrau had epicentral intensity $I_0 = 9$ °MSK–64. Since 1201 there were 5 earthquakes recorded in the region with $I_0 \geq 8$ °MSK–64, and 21 earthquakes with $I_0 \geq 7$ °MSK–64.

The eastern–alpine earthquakes are marked by the anomalous shapes of the macroseismic fields, i.e. they are strongly felt far in the Bohemian Massif, while in the direction to the Pannonian basin and to the Western Carpathians there is a fast decrease of intensities. The elongation of macroseismic fields into the Bohemian Massif we explain as a consequence of the shallow nappe structure of the Alps. According to data from boreholes:

- Bärendorf 1 – the epi–Variscan platform continuing from the Bohemian Massif has a depth of 5 945 m,
- Urmansau 1 – the epi–Variscan platform continuing from the Bohemian Massif has a depth of 3 015 m.

The stronger shocks, with intensities around 8 °MSK–64, are macroseismically felt up to Dresden, and distinctly in the mobile zones, the positions of which are connected with the main fault belts of the Bohemian Massif, with gravimetric and geomagnetic anomalies, and with anomalies in the deviations of plumb lines (Zátopek 1948, Zátopek, Beránek 1975). The systematic local increase of intensity is also observed in regions of the Bohemian Massif where the sedimentary Quaternary cover reaches a thickness of 30 – 50 m (Procházková, Drimmel 1983).

Shocks with $I_0 \geq 8$ °MSK–64 only occur in periods of increased activity. They are in multiple groups of shocks (either main shock + aftershocks + main shock + aftershocks or foreshocks + main shock + aftershocks + main shock + aftershocks). In the region under investigation two types of aftershocks were observed:

groups of aftershocks, when the strongest aftershock follows the main shock after several hours up to 1 day (e.g. 2.12.1963 near Wiener Neustadt, 30.6.1964 near Semmering, 2.6.1969 near Murrau, 16.4.1972 near Schwadorf, 14.1.1978 near Semmering),

groups of aftershocks, for which the strongest aftershock follows the main shock after several days (e.g. 24.5.1984 near Semmering), and is relatively weak in comparison with the strongest aftershock that is observed in the first group for the same size of main shock.

With regard to the fact that both types of aftershocks occur at the same places (e.g. Semmering, Wiener Neustadt), it is not possible to explain this fact by the structure of the region, but it is necessary to search for another explanation. The results of study of dynamic focal parameters (Procházková 1984) indicate the existence of focal processes of different character in one focal region in different time intervals, which cause the different character of aftershocks (e.g. different sizes and asperity distributions). Therefore we think that in the vicinity of Semmering we have observed the results of two different physical processes in earthquake foci. The investigation of three strong shocks (15.4., 22.5., 24.5.) in 1984 in the vicinity of Semmering have revealed in one place, lying on the crossing of three fault systems, the occurrence of shocks in the different layers of the Earth's crust, with different earthquake mechanism and with different elongation of isoseismals in dependence on the earthquake mechanism (Procházková, Drimmel 1989).

The most active part of the region under investigation is the section Leoben – Wiener Neustadt. The active periods in the individual parts (Murrau – Strassburg; Strassburg – Judenburg; Leoben – Wiener Neustadt; Schwadorf) do not occur simultaneously, and they have not as a rule had the same character. E.g. in 1876, an active period began in the region of Leoben – Wiener Neustadt (strong shocks near to Kindberg, $I_0 = 8\,°$MSK–64); in 1885 there began an active period near Schwadorf; and in 1890 in the Malé Karpaty Mts.

The characteristics of seismic activity are the following:

- max $I_0 = 9\,°$MSK–64,
- $b = 0.62 \pm 0.03$,
- interval of focal depths: $h = 5 - 18\,\mathrm{km}$,
- typical focal depth: 7 km,
- typical values of attenuation coefficients: $\alpha = 0.001$, $k = 3.3$,

Comment:
The region of Semmering has a complicated fault structure (Procházková, Drimmel 1989).

Region 19 — Český Těšín – Opava

The region includes the NE margin of the Bohemian Massif where there are units of Silesicum (to the E from the Kouty fault system that belongs to the Moravia – Silesia lineament) and further the whole sequence of the Devonian and the Lower Carboniferous, so called Sudeticum, the Carpathian foredeep and the flysch napes of the Outer Carpathians up to the Biele Karpaty unit of the Magura group. The N margin of the region passes parallel with the Odra lineament (but to the S from it). The southern margin of the region is the Bělá fault, which is the continuation of the marginal fault of Lugicum, with occurrences of Quaternary basic volcanics (inter alia the remains of the volcanoes Velký and Malý Roudný).

The strongest shocks have occurred in the vicinity of:

- Zlaté Hory and Hlubčice (e.g. 13.2.1786),
- Opava (e.g. 1591, 14.1.1827, 1931, 3.9.1934),
- Nový Jičín, Ostrava and Bohumín (e.g. 18.11.1014, 1.5.1715, 22.8.1785, 27.2.1786, 15.1.1855, 9.1.1936, 23.3.1977, 3.3.1982). Some of the shocks in the vicinity of Ostrava may be connected with mining activities.

In the vicinity of Opava there have occurred shocks at the crossing of the Sudetic fault with the Zlatov – Krnov fault. Their focal depths are in the interval 4 – 10 km (the typical one is 6 km). The attenuation of intensity with distance is characterized by the parameters $\alpha = 0.001$ and $k = 3.2$. The intensity of the strongest observed earthquake ($I_{\max}$) did not exceed 6.5 °MSK–64.

In the vicinity of Český Těšín there are shocks in the deeper levels of the Earth's crust (the shock of 27.2.1786 had a focal depth of 30 km), i.e. the focal depth varies between 10 and 30 km (the average is 20 km). The attenuation of intensity with distance is characterized by the parameters $\alpha = 0.006$ and $k = 3.4$, which explains why the macroseismic fields of the strongest shocks are relatively great. The intensity of the strongest observed earthquake ($I_{\max}$) did not exceed 7.5 °MSK–64. The strongest shocks were on 22.8.1785 $I_0 = 6.5$ °MSK–64, $h = 10$ km) and on 27.2.1786 ($I_0 = 7.5$ °MSK–64, $h = 30$ km).

The foci of strong earthquakes in the W part of Beskides are in a place where the Carpathian arch turns within a small area from the SW – NE direction to the W – E direction. They are situated on the crossing of the Hercynian structures (NW – SE) and the Alpine ones (SW – NE). From the analysis of focal depths it follows that foci are in the Bohemian Massif, because in this place the Bohemian Massif is under the Carpathians napes at a small depth, which is evidenced by the data from the borehole Krásná–1 near the Lysá hora Mts. (Mísař, Procházková 1981). According to the classic theory the foci are connected with the underthrusting of the Bohemian Massif under the Western Carpathians. According to the plate tectonics the foci are connected with the overthrusting of the Western Carpathians (flysch) to the NW on the Bohemian Massif. The analysis of macroseismic fields indicates the existence of a deep fault in the NW – SE direction (sudetian direction) in the region under investigation. Due to the small number of shocks it is impossible to study the earthquake regime of this region.

The characteristics of earthquake activity of the lower level are the following:

- max $I_0 = 7.5$ °MSK–64,
- interval of focal depths: $h = 10 - 30$ km,
- typical focal depth: 20 km,
- typical values of attenuation coefficients: $\alpha = 0.006$, $k = 3.4$,

Region 20 — Malé and Biele Karpaty Mts.

The region is linked with the margin of the Carpathian arch and includes the core mountains of the Malé Karpaty Mts. (the granite massifs with their mantle and sedimentary cover of the Mesozoicum and by the Mesozoicum of napes of the Fatricum and of the Hronicum - mainly Triassic and Lower Cretaceous, mainly carbonate limestones), the important tectonic scar of the klippen belt (mainly carbonate rocks of the Jurassic and of the Cretaceous) and in the NW marginal part also the flysch napes of the Magura group. The klippen zone is identical with the Záhorie – Humenné deep fault. The region is also cut by transversal faults in the NW – SE direction.

Since 1515 there are records of 236 shocks, with $I_0 \leq 8.5$ °MSK–64. The analysis of macroseismic and instrumental data shows that the earthquake foci are connected with the deep boundary of the Bohemian Massif and the Slovakian block, i.e. they are mostly connected with movements along the Záhorie – Humenné deep fault. There are also shocks connected with the Dobrá Voda fault, e.g. 6.9.1929 with epicentral intensity $I_0 = 4.5\,^\circ$MSK–64. The strongest shocks are situated on the crossing of the two faults mentioned. The Dobrá Voda fault belongs to the system of the Nesvačily graben and limits the NE margin of the Malé Karpaty Mts. The next parallel fault crosses the fault Záhorie – Humenné in the region Stupava – Pernek – Modra, and the foci of the stronger shocks are also on this crossing.

The elongation of the far isoseismals of earthquakes to the Donau basin is connected with the deeper structure of the basement. It may be caused by the elevating crystalline block, that was indicated by a positive gravimetric anomaly (Buday, Dudek, Ibrmajer 1969).

The strongest known earthquake of 9.1.1906 in the vicinity of Dobrá Voda had epicentral intensity $I_0 = 8.5\,^\circ$MSK–64. In the last four hundred years we have reports of 8 earthquakes with $I_0 \geq 7\,^\circ$MSK–64. The analysis of shocks after 1700 shows that every 50 years there has occurred at least one shock with intensity $\geq 6\,^\circ$MSK–64.

The analysis of the time aspect shows that the increase of frequency of stronger earthquakes appeared after 1850. This active period had two peaks, namely in 1906 and in 1930. The highest activity was in the period 1890 – 1906; the most seismic energy was released in the period 1904 – 1906. Since 1930 there has not occurred a shock with $I_0 \geq 7\,^\circ$MSK–64. There was a local increase of earthquake activity in the period 1964 – 1967, when there occurred two stronger shocks, with intensities 6 and 6.5 °MSK–64. In the 20th century the vicinity of Dobrá Voda has been more active than the neighbouring focal region of Stupava – Pernek – Modra.

The group of earthquakes in 1906 had the character of a multiple group of shocks, with the main shocks of 8.5° and 7.5 °MSK–64; the aftershocks lasted about one year, and increased seismic activity was observed up to 1908. The group of earthquakes in 1930 had the character of foreshocks + main shock + aftershocks. The main shock had the intensity $I_0 = 7.5\,^\circ$MSK–64, the strongest aftershock had the intensity $I_0 = 6\,^\circ$MSK–64 and the strongest foreshock had the intensity $I_0 = 5\,^\circ$MSK–64. The aftershocks lasted for 14 days. With regard to the fact that we only have reports on the foreshocks and aftershocks of stronger earthquakes after 1890, it is impossible to determine the quantitative dependencies describing the properties of foreshocks and aftershocks. Qualitatively the obtained data do not differ from the dependencies determined for other focal regions.

The analysis of space–time dependencies shows that every shock with $I_0 \geq 7\,^\circ$MSK–64 near Pernek is followed by a strong shock near Dobrá Voda; the migration of foci of strong shocks has a SW – NE direction.

The characteristics of earthquake activity are the following:

- max $I_0 = 8.5\,^\circ$MSK–64,
- $b = 0.36 \pm 0.02$,
- the interval of focal depths: $h = 4 - 12$ km,
- the typical focal depth: 8 km,
- the typical values of coefficients of attenuation of intensity: $\alpha = 0.026$, $k = 4.1$.

Region 21 — Trenčín - Žilina

The axis of the region is the klippen zone (Záhorie - Humenné deep fault), with fragments of Jurassic and Cretaceous limestones. The napes of the Magura group of flysch on the NW and the units of the Central Carpathians on the SE also belong to the region. There are the so-called core mountains, in which the crystalline basement is covered by the napes of the Mesozoic complexes of the Fatricum and of the Hronicum (mainly Malá Magura Mts. and Malá Fatra Mts.). Also significant are the faults of the N - S direction, being in the W from Ružomberok, linking to the Central Slovakian fault system.

Since 1600 there are 53 shocks recorded in the catalogues, e.g. 21.9. 1600, 1613, 15.1.1858. The elongation of isoseismals in the epicentral region of both earthquakes for which isoseismal maps exist (15.1.1858, $I_0 = 7.5\,^\circ$MSK-64, $h = 7\,$km a 23.9. 1930, $I_0 = 4.5\,^\circ$MSK-64, $h = 9\,$km) shows the link of these shocks with the Záhorie - Humenné deep fault. The foci of shocks in the vicinity of Trenčín and Trenčanské Teplice are probably on the crossing of the deep faults of Záhorie - Humenné and Štiavnica - Přerov.

The macroseismic field of the earthquake of 15.1.1858 in the vicinity of Žilina is in the far field elongated in the direction of the Bohemian Massif; this is possible to interpret as the consequence of shallow structure of the Carpathian napes in this region.

Since 1850 there were two earthquakes with $I_0 \geq 6\,^\circ$MSK-64 in the region under investigation (15.1.1858 in vicinity of Žilina and 1.9.1864 in vicinity of Trenčanské Teplice); the shift of epicentre of these strong shocks is in the NE - SW direction. After the strong earthquake of 15.1.1858, the increased seismic activity lasted about one year.

The different directions of the migration of the earthquake foci in the Malé Karpaty Mts. and in the vicinity of Žilina could be connected with the fact that the course of the MOHO isolines is substantially different in the region of the Malé Karpaty Mts. from that in the vicinity of Žilina, which is located to the NE of the Štiavnica - Přerov deep fault (Fusán et al. 1981), and also by the fact that the two regions are distinguished by different directions of their recent crustal movements (Kvitkovič, Plančár 1979).

The characteristics of the earthquake activity of the region are the following:

- max $I_0 = 7.5\,^\circ$MSK-64,
- $b = 0.40 \pm 0.07$,
- interval of focal depths: $h = 7 - 9\,$km,
- typical focal depth: 8 km,
- typical values of coefficients of attenuation: $\alpha = 0.0055$, $k = 3.3$,

Region 22 — Martin - Prievidza - Banská Bystrica - Dolný Kubín

This smaller region is mainly formed from the core mountains of the Velká Fatra Mts. and the western Nízké Tatry Mts. It reaches to the boundary of the Veporicum. The cores are formed of granites and metamorphites and are covered by sediments (Upper Carboniferous up to Cretaceous) and by the system of napes of the Fatricum and of the Hronicum, mainly formed by Mesozoic carbonate rocks of considerable thickness. In the S the given units dip under the Miocene volcanites of the Central Slovakian volcanic region.

The upper layer of the Earth's crust – h up to 10 km:

We have data on 30 shocks, e.g. 11.7.1830. The region is situated to the N from the Central Slovakian block that is limited on the N by the Štiavnica – Přerov deep fault (Fusán, Ibrmajer, Plančár 1979).

The characteristics of earthquake activity are the following:

- max $I_0 = 5.5$ °MSK–64,
- $b = 0.66 \pm 0.02$,
- interval of focal depths: $h = 3 - 10$ km,
- typical focal depth: 7 km,
- typical values of coefficients of attenuation: $\alpha = 0.029$, $k = 3.9$.

The lower layer of the Earth's crust – $h > 10$ km:

The shock of 5.6.1443 is exceptional. The expert team Labák, Brouček, Gutdeutsch and Hammerl (1996), that studied the earthquake of 5.6.1443 in Central Slovakia, evaluated the given earthquake in the framework of an evaluation of strong historical earthquakes on the basis of original sources on their effects. The parameters they issued were the same as were derived in (Procházková, Dudek 1982). The macroseismic field of the shock was extensive and corresponded to the energy propagation in the deeper parts of the Earth's crust, that has a different structure than the upper Carpathian structures. The given shock determines the characteristics of the region as follows:

- max $I_0 = 8.5$ °MSK–64,
- focal depth: 20 km,
- values of the attenuation coefficients: $\alpha = 0.001$, $k = 3.1$.

Region 23 — Kežmarok – Zakopané – Krakow

The region follows the arch of the Western Carpathians. It includes the core mountain range of the Vysoké Tatry Mts. (mainly of granitoids), surrounded by the extensive and thick sequence of sediments of the inner Carpathian Palaeocene (up to 4 km). On the E it is terminated by the transversal tectonic horst of the Branisko Mts. The axis of the area is the Klippen belt (Jurassic and Cretaceous limestones), and to the N there are the flysch complexes of the Magura group napes.

Since 1016 we have data on seven shocks from the region to the S of Krakow, e.g. 31.1.1259, 3.12.1786, 8.3.1942 (the earthquake foci are located in the region in contact with the Hercynides, the Eastern European platform and the Alpine – Carpathian system; the strongest known shock of 3.12.1786 occurred 9 months after the strong shocks in the vicinity of Těšín). In the region Zakopané – Kežmarok, since 1453 we have data on 29 shocks, e.g. 5.6.1643, 28.5.1966. From the region of the Vysoké Tatry Mts. we know about such shocks as e.g. 9.8.1662, 7.2.1839. Several shocks occurred in the vicinity of Spišská Nová Ves – Levoča (e.g. 12.4.1724, 23.4.1840).

The characteristics of earthquake activity of the region are the following:

- max $I_0 = 7.5$ °MSK–64,
- $b = 0.24 \pm 0.00$,
- interval of focal depths: to 20 km,
- mean value of attenuation coefficients: $\alpha = 0.004$, $k = 3.7$.

Region 24 — Prešov – Košice – Humenné

The axis of the region is the Klippen belt that has a WNW – WSE direction; a small part, to the N of it, is formed by the flysch napes of the Magura group. The S part of the region consists of thick sedimentary sequences of the Eastern Slovakian basin with the Miocene volcanics of the Slanské vrchy Mts. and of the Vihorlat Mts. Through the region there passes a sequence of important N – S faults (the Hornád fault, the deep fault of the Slanské Vrchy Mts.) with a clear relation to the volcanic and seismic activities.

We have data on earthquakes in Eastern Slovakia since 1605; altogether we have records of 64 shocks. The most shocks occur in the region of Giraltovce – Humenné – Koliabovce. The foci of the strongest shocks are situated in the vicinity of Vranov n. Top., on the crossing of the N – S line of earthquake foci with the Záhorie – Humenné deep fault. The N – S row of earthquake foci, roughly around the Ondava river, has the same direction as the deep fault of the Slánské Vrchy Mts., that is located about 35 km to the W. This N – S row cuts across the Carpathian units, the Eastern Slovakian basin and the Pannonian basin. The faults of the given direction in the region under investigation are described in (Mahel' et al. 1973). Further, the shocks occur in the vicinity of Prešov and Košice (e.g. 26.3.1676, 17.11.1809, 29.4.1974), Šáriš (e.g. 17.11.1809), near Gelnice and Krompachy (e.g. 28.7.1703, 10.3.1724). The size of the strongest shocks did not exceed 8.5 °MSK–64.

The characteristics of earthquake activity are the following:

- max $I_0 = 8.5$ °MSK–64,
- $b = 0.27 \pm 0.04$,
- interval of focal depths: do 3 – 13 km,
- typical focal depth: 7 km,
- typical attenuation coefficients: $\alpha = 0.028$, $k = 3.8$.

Region 25 — Užgorod – Mukačevo – Beregovo

The axis of the region forms a tectonic zone of the first order, i.e. the Klippen zone. The marginal part of the region on the NE is formed by the flysch complexes of the Magura group napes, and especially by the Dukla unit. The S part of the region is formed by the sediments of the Eastern Slovakian basin (they reach a thickness of over 6 km) and by the volcanics of the Vihorlat Mts. and of the Popričný Mts.

The shocks are connected with the Záhorie – Humenné deep fault (Perečin – Svaljava – Siget), the Számos deep fault (Užgorod – Mukačevo – Beregovo), the Teisseyre – Tornquist line (Lvov – Zaleščiki – Červnovcy) and the fault of the River Tisa. The size of the strongest earthquakes did not exceed the intensity 7.5 °MSK–64. According to Zátopek (1940) the investigated region is made up of a mosaic, the blocks of which in many places adapt relatively easily to the changes in the force systems that affect them. Earthquakes are of tectonic origin, and the prevailing movements of the blocks have a dominant vertical component. The earthquakes are shallow, and their macroseismic fields correspond to this fact, i.e. they only affect a small area.

The characteristics of earthquake activity of the region are the following:

- max $I_0 = 7.5\,°$MSK–64,
- $b = 0.44 \pm 0.04$,
- interval of focal depths: 2 – 5 km,
- typical focal depth: 3.5 km,
- typical attenuation coefficients: $\alpha = 0.025$, $k = 3.7$.

Region 26 — Graz – Maribor – Oberschuetzen – Sopron – Kapuvár

The region is situated on the W margin of the Pannonian basin, and so of course in its basement units of the Eastern Alps continue to the NE. The thickness of the Neogene sediments in this part reaches to 2 km. It is crossed by the important Osapod fault in the SW – NE direction.

Only single, weak, shallow earthquakes occur here. The intensity of the strongest observed earthquake ($I_{\max}$) did not exceed 5 °MSK–64. The western Hungarian belt (Ascalág – Kapuvár) is limited by the Osapod fault. There are not enough data for the study of the properties of the macroseismic fields. The slope of the frequency graph is $b = 0.36 \pm 0.02$.

Comment:

To the S from this region there is located the seismoactive region Ljubljana – Zagreb – Slavonski Brod, which is situated along the fault line of the River Sáva and which has two seismoactive levels.

The characteristics of the seismic activity of the 1st level are the following:

- max $I_0 = 10\,°$MSK–64,
- $b = 0.60 \pm 0.01$,
- interval of focal depths: to 10 km,
- typical focal depth: 5 km,
- typical attenuation coefficients: $\alpha = 0.003$, $k = 3.2$.

The characteristics of the seismic activity of the 2nd level are the following:

- max $I_0 = 10\,°$MSK–64,
- interval of focal depths: 11 – 20 km,
- typical focal depth: 17 km,
- typical attenuation coefficients: $\alpha = 0.017$, $k = 4.8$.

Region 27 — Kőrmand – Győr

The region, elongated in the SW - NE direction, is structurally dependent on the row of parallel faults that limit the structural units in the basement of the Pannonian basin. The Raaba fault is dominant in the region, on which there have also emerged small bodies of basaltoid volcanites (from the Miocene).

The focal region is located along the River Raab. The foci of shocks are connected with the Raaba deep fault. The strongest earthquake, with $I_0 = 8.5\,°$MSK–64, was on 10.7.455 near Szombathely Aquinicum. In the last thousand years there have only occurred earthquakes with intensity $I_0 \leq 6.5\,°$MSK–64. The relatively high attenuation of intensity is caused by the relatively thick layer of Tertiary sediments, the thickness of which here reaches 1000 – 6000 m.

The characteristics of earthquake activity are the following:

- max $I_0 = 8.5\,°$MSK–64,
- $b = 0.27 \pm 0.02$,
- interval of focal depths: 4 – 10 km,
- typical focal depth: 7 km,
- typical attenuation coefficients: $\alpha = 0.050$, $k = 4.7$.

Region 28 — vicinity of Komárno

This very small region round the town of Komárno has a W – E direction that coincides with the direction of the Donau fault in this region. It is formed by a thick set of Tertiary and Quaternary sediments, mostly only slightly consolidated, the thickness of which reaches to 4 km. To the E of the region there are also the Miocene volcanics of the Bőrzsőny Highland, and the southern promontory of the Central Slovakian volcanic region. In this region the Donau fault crosses the Raaba fault and the N – S faults of the Central Carpathian lineament.

The region of Komárno is located on the SE boundary of the subsiding region of the Donau basin in the Neogene and the Quaternary. It is located on the crossing of the Donau fault (W – E) and the Vepor deep fault (SW – NE), which probably continues to the SW. Since 1599, there have been recorded 824 shocks. The strongest shocks have their macroseismic fields in the far field elongated as far as the Bohemian Massif. The strongest shock was on 28.6.1763. The increased seismic activity after the shock of 1763 lasted more than hundred years.

The characteristics of the seismic activity are the following:

- max $I_0 = 9\,°$MSK–64,
- $b = 0.62 \pm 0.01$,
- interval of focal depths: to 18 km,
- typical attenuation coefficients: $\alpha = 0.008$, $k = 4$.

Region 29 — Nagykanisza – Mór

The region occupies a part of the Pannonian basin, in which there is situated the horst of the Bakony Forest Mts., formed of a complex of carbonate rocks, belonging by their development already to the Southern Alps, and to a small extent also by the Variscan metamorphosed complexes and plutonites (Velence). The Alpine units are cut by the bodies of Neoidic basalt (the NW coast of the Balaton lake). On the SW of the Bakony Forest Mts. the thickness of the Neogene reaches to 3 km. In the region of the Bakony Forest Mts. there is also the Palaeocene. Also significant there is the Balaton – Darnó fault on the SE part of the region and also the faults situated on the E margin of the Bakony Forest Mts. The NE boundary is formed by transversal faults of NW – SE direction that separate the Bakony Forest Mts. and the Vertes Mts.

The foci of shocks are connected with the deep Balaton – Darnó fault. Strong earthquakes have occurred near Mór (e.g. 14.1.1810). The relatively high attenuation of intensity with distance is caused by a thick layer of Tertiary sediments.

The characteristics of the seismic activity are the following:

- max $I_0 = 8.5\,^\circ$MSK–64,
- $b = 0.39 \pm 0.05$,
- interval of focal depths: $h = 1 - 12$ km,
- typical focal depth: 5 km,
- typical attenuation coefficients: $\alpha = 0.015$, $k = 3.8$.

Region 30 — Budapest – Monór – Jászbereny

The region extends in the E – W direction, and is located in the N part of the Pannonian basin, being to the S of the Carpathian volcanic arc, where the thickness of the sedimentary cover (Paleogene, Neogene) is about 3 km. In the W part of the region there have emerged from the Paleogene fundament Mesozoic complexes of Alpides (in the Vertes Mts.), while in the E the region reaches to the N – S faults separating the Matra Mts. and the Bükk Mts. and continues far to the S into the Pannonian basin.

The focal region is located in Central Hungary along the deep Balaton – Darnó fault. The strongest shocks (up to $I_0 = 8.5\,^\circ$MSK–64) had foci near Monór and Jászbereny.

The characteristics of the seismic activity are the following:

- max $I_0 = 8.5\,^\circ$MSK–64,
- $b = 0.33 \pm 0.04$,
- interval of focal depths: 3 – 10 km,
- typical focal depth: 6.5 km,
- typical attenuation coefficients: $\alpha = 0.010$, $k = 3.7$.

Region 31 — Mátra Mts. and the vicinity

The region is limited by faults: on the W by the N – S faults of the Central Carpathian lineament, and on the E by the deep Balaton – Darnó fault of SW – NE direction. The region is mainly covered by Paleogene sediments with a thickness of up to 3 km (to the E of the Mátra Mts.); on its N margin there have emerged the Miocene volcanic mountain ranges as the Czerhát Mts. and the Mátra Mts., and on the NE the southern promontory of the Bükk Mts. with carbonates of the Mesozoic (Alpides).

The region includes such mountain ranges as the Novohradské Hory Mts., the Mátra Mts. and the Bükk Mts. (Balassagyarmat – Salgótarján – Eger – Miskolc); the tectonic movements are concentrated along the N branches of faults, such as the Balaton – Darnó fault and the Zagreb – Zemplín fault; the S boundary forms the Donau – Černovice lineament roughly of W – E strike (Šimůnek 1992) and the rift structure with reduced continental crust (Mísař 1987).

Shocks occur in the belt Diojenoe – Ersedvadken – Balassagyarmat – Štúrovo – Rimavská Sobota – Šafárikovo. Their intensity has not exceeded the value $I_0 =$

7 °MSK–64. The attenuation of intensity with distance is characterized by the parameters $\alpha = 0.016$, $k = 3.7$. The slope of the frequency graph is $b = 0.45 \pm 0.11$.

Region 32 — Zemplín - Tokaj

The sunken part of the Eastern Slovakian basin (the promontory of the Pannonian basin) is formed by thick, weakly consolidated sediments of the Younger Miocene and of the Pliocene, up to 3 km thick. The region is limited by faults of the first order, on the NW by the Balaton - Darnó deep fault, and on the NE by faults linking to the fault limits of the Gemericum in the Central Carpathians. The Miocene volcanic mountain ranges of the Carpathian volcanic have emerged to the N, i.e. apart from this region.

The region is characterized by weak shocks, that are probably connected with the Tisa River fault. The size of recorded shocks has not exceed an intensity $I_0 = 5$ °MSK–64. There are not sufficient data for the determination of the parameters characterizing the attenuation of intensity with distance or the slope of the frequency graph.

Region 33 — Kaposvár - Dunafoeldvár

The region lies in the central part of the Pannonian basin, being to the SE of the Balaton - Darnó deep fault up to the Zagreb - Zemplín fault on the SE. On the SW it borders with the elevation of the crystalline fundament and of the Mesozoic of the Alpine type in the Mecsek Mts. near Pecs. The thickness of the Neogene sediments is a little lower than in the adjacent regions, 1.5 - 2 km.

The region is linked with the Zagreb - Zemplín deep fault. The strongest shocks have occurred near Kaposvár.

The characteristics of the seismic activity are the following:

- max $I_0 = 7.5$ °MSK–64,
- $b = 0.36 \pm 0.04$,
- interval of focal depths: $h = 5 - 13$ km,
- typical focal depth: 6 km,
- typical attenuation coefficients: $\alpha = 0.023$, $k = 3.7$.

Region 34 — Keczkemet - Szolnok

The region is located in the central part of the Pannonian basin, to the SE of the Zagreb - Zemplín fault, along the Szolnok - Ebes fault. It is marked by the high thickness of Tertiary sediments, that reach over 3 km.

Shocks are linked with the Szolnok - Ebes deep fault (Pécs - Keczkemet - Szolnok). The vicinities of Pécs and Keczkemét are at present marked by fast subsidence (0.7 - 1 mm a year).

The characteristics of the seismic activity are the following:

- max $I_0 = 9.5$ °MSK–64,
- $b = 0.29 \pm 0.03$,
- interval of focal depths: $h = 6 - 9$ km,
- typical focal depth: 7 km,
- typical attenuation coefficients: $\alpha = 0.015$, $k = 3.9$.

Region 35 — Békés - Gyula

The region is located in the E part of the Pannonian basin. It is characterized by the high thickness of the Tertiary sediments.

The region is characterized by weak seismicity. The intensities of the strongest earthquakes have not exceeded $I_0 = 5\,°$MSK–64. There are not sufficient data for the determination of parameters characterizing the attenuation of intensity with distance or of the slope of the frequency graph.

Region 36 — Oradea - Satu Mare

The region occupies the SE part of the Pannonian basin, where the uplifted horst of the basement of SW - NE direction separates the proper Pannonian basin from the Transylvanian depression. The thickness of the Neogene decreases up to 1 km. In the uplifted belt (to the SE from the region) there have emerged Paleogene and islands of pre–Alpine metamorphic complexes, with granitoid massifs and with a sedimentary cover of Mesozoic rocks. In the region round the western marginal fault of the Apuseni Mts. there are two seismoactive levels, namely: 5 - 13 km and 15 - 25 km.

The characteristics of the seismic activity of the $1^{\rm st}$ level are the following:

- max $I_0 = 7.5\,°$MSK–64,
- $b = 0.38 \pm 0.09$,
- interval of focal depths: 5 - 13 km,
- typical focal depth: 9 km,
- typical attenuation coefficients: $\alpha = 0.001$, $k = 3.3$.

The characteristics of the seismic activity of the $2^{\rm nd}$ level are the following:

- max $I_0 = 8.5\,°$MSK–64,
- $b = 0.43 \pm 0.05$,
- interval of focal depths: 15 - 25 km,
- typical focal depth: 20 km,
- typical attenuation coefficients: $\alpha = 0.005$, $k = 4.0$.

3.4.2. Characteristics of Regions with Diffuse Seismicity

The analysis of data shows that regions with diffuse seismicity on the territory under investigation have earthquakes, the parameters of which are different. For these shocks there are usually only available macroseismic data, and only exceptionally instrumental data. On the basis of these data, it is impossible to determine the representative parameters of earthquakes and of earthquake activity.

Region A — Western margin of the Bohemian Massif

The region is formed of the Southern Germany basin of Mesozoic sediments (Triassic and Jurassic). With the Bohemian Massif it borders along the system of Frankian faults of NW - SE strike. To the S it dips under the Alpine molasse.

Weak shocks only sporadically occur. The intensity of the strongest observed earthquake ($I_{\rm max}$) did not exceed $4\,°$MSK–64.

Region B — Central part of the Bohemian Massif

The region consists of the central part of the Moldanubicum (metamorphites and Central Bohemian pluton) and of the Bohemicum – the Upper Proterozoicum with the Palaeozoic basin of the Barrandien. In the N the region is covered by the sediments of the Upper Cretaceous North Bohemian basin.

From this region we have data on 38 earthquakes since 1036. The earthquake of 8.4.1898 in the vicinity of Mělník was accompanied by distinct sound effects. The most shocks occurred in the vicinity of Kutná Hora, where they are probably connected with mining activities. Other shocks have occurred in the vicinity of Kladno and Příbram, where a connection with mining activity is also evident. The foci of shocks are also observed in the vicinity of the Litoměřice deep fault or its continuation – the Stráž fault (e.g. other shocks near Rovensko pod Troskami 30.3.1928, near Bělá pod Bezdězem 7.2.1949) and in the vicinity of the Jáchymov deep fault (e.g. shocks near Rožmitál pod Třemšínem 20.8.1978, near Plasy 17.4.1521, near Blovice 23.4.1881 and 16.9.1977) and on the SW part of the Kladno fault passing through Plzeň (e.g. 21.1.1909, 20.9.1973, 21.9.1978) and in the vicinity of Stříbro (e.g. 1.10.1822, where a connection with the Stříbro fault is assumed). The intensity of the strongest earthquake ($I_{\max}$) did not exceed 5 °MSK–64. The foci of shocks are very shallow, i.e. only the first km (the highest known focal depth is 6 km). The attenuation of intensities with distance is very low (ca $\alpha = 0.004$, $k = 3$).

Region C — Moravia and Vienna basin

The basement of the region is formed by the Pre–Cambrian consolidated block of the Brunovistulicum, with platform cover of sediments from the Cambrian up to the Neogene. At the W margin of the block there are thrust the Variscan complexes (Moravicum), and to the E margin the napes of the Outer (flysch) Carpathians. The block is cut by a set of fault belts of WNW – ESE strike.

From time to time there have occurred weak shocks. Since 1014 there are recorded 59 shocks. The foci are located in the vicinities of the towns of Litovel, Olomouc, Přerov (e.g. 1495, 2.7.1635, 30.11.1981, probably connected with the Bušín fault), Brumovice (e.g. 2.12.1874, 18.1.1886, probably connected with the Vranovice graben, i.e. with the Dyje fault), Jaroměřice, Brno, Znojmo (e.g. 15.4.1748, 21.3.1977, 11.6.1982), Dalešice and Krhov (10.10.1927, 5.2.1949). The intensity of the strongest observed earthquake with foci in this region ($I_{\max}$) did not exceed 5 °MSK–64.

Region D — Lower and Upper Silesia

The basement of the region is the Polish Palaeozoic platform, the fundament of which is formed by metamorphites and magmatites with complicated structure. It is covered by sediments of the Upper Palaeozoic to Quaternary ages. The significant faults have especially the NW – SE direction (the Baltic – Podolian lineament, the Odra lineament).

The region lies on the N margin of the Bohemian Massif. The foci of rarely occurring shocks were near Wroclav and Legnice (e.g. 24.1.1775, 13.3.1790, 1799). The foci are probably situated on the crossing of the Odra lineament with the Přibyslav deep fault. Their intensities did not exceed 4 °MSK–64.

In the mining region rockbursts have occurred. The intensity of the strongest rockbursts reached 7 °MSK–64. The foci of rockbursts are shallow and their macroseismic fields are small. The foci of the strongest rockbursts are on the faults that cross the mining region (Jech 1988).

Region E — Central Slovakia

The region includes the W part of the Danube basin with its N and NE embayment and the Turiec basin, in which sediments of the Tertiary age and of Miocene volcanites surround the core mountains of the Považský Inovec Mts. and of the Tríbeč Mts. (formed of granitoids and methamorphites with a cover of Mesozoic rocks and their napes). The thickness of the Neogene and the Quaternary sediments exceeds 4 km. In the region there have only occurred single shocks, the size of which only exceptionally reached the intensity of 4 °MSK–64.

Region F — Nové Zámky - Levice - Banská Štiavnica

The wedge–shaped region includes a part of the Kremnica - Štiavnica Hills, formed from volcanites (andesites, rhyolites) mainly from the Miocene age, and by their tuffs, and the E part of the Danube basin with the sediments of Neogene and Quaternary, up to 4 km thick.

In the region there have only occurred isolated shocks, the intensity of which only exceptionally reached the value $I_0 = 6$ °MSK–64. The shocks near Banská Štiavnica and Kremnica can be connected with mining activity. The analysis of macroseismic fields on the basis of existing data shows that the foci of shocks are shallow.

Region G — Revúca - Rožňava - Miskolc

This very wide–ranging region, with a complicated structure, is formed from units of the Veporicum and the Gemericum with their covers of Mesozoic rocks, and to the S by units of the Slanicum (mainly limestones of the Slovenský Kras) and of the Bükkicum. These units are in the S part covered by the sediments of the South Slovakian basin with basaltoid volcanites, and of the East Slovakian basin with volcanites of the Zemplín Hills (andesites, rhyolites). The region is cut by a set of faults and overthrusts, of which the most distinct is the Vepor deep fault of NE - SW direction (it links with the Raaba line).

Weak shocks, with the intensity under 5 °MSK–64, occur in isolation. The single shock near Rožňava (23.1.1855) could be connected with mining activity.

Region H — Debrecen - Szeged - Csongrád

The region occupies the greater part of the central and NE parts of the Pannonian basin, including its deepest part (up to 6 km) to the NE from Szeged.

The region is located in the Tisa basin. There have only rarely occurred single, weak shocks, the intensities of which are as a rule smaller than 5 °MSK–64. $b = 0.44 \pm 0.04$.

Region I — Russian Table

The Russian Table outside of the Carpathian arch is formed of Precambrian complexes, already consolidated in the Archaicum and in the Lowest Proterozoicum.

On the platform there are unfolded sediments in the rank from the Upper Proterozoicum up to the Quaternary (of course with a local hiatus). In some places the platform is cut by faults (Dněper – Don aulacogen), and of course these regions are very far from the region under investigation.

The old geological unit is aseismic. Isolated shocks only occur. Their intensity does not exceed the value $I_0 = 4\,^\circ$MSK–64.

Comment:
In the vicinity of crossing the 50th East – West line with the 24th meridian there is situated the Volyn – Podolie Highland in which from time to time the shocks have occurred. The strongest shock, of 17.8.1875, had intensity 7 °MSK–64, focal depth 10 km, attenuation coefficients $\alpha = 0.002$ and $k = 3.3$, and the distant isoseismals were elongated into the Russian Table.

Region J — NW Romania

The size of shocks known so far did not exceed the intensity $I_0 = 6\,^\circ$MSK–64. These shocks cannot influence the area of Central Europe by macroseismic effects.

3.4.3. Characteristics of the Vrancea Region

The Vrancea focal region is located on the Carpathian bend. In its broader vicinity there is contact between different tectonic units, namely the Eastern Carpathians, the Moesian platform and the East European platform. Though it is not located in Central Europe, its strong intermediate earthquakes are macroseismically felt there (e.g. 4.3.1977, 30.8.1986). The great attenuation of intensity with distance that we observe in the case of very shallow foci of earthquakes in the Pannonian basin is not observed here, which means that the properties of the deeper basement are different, and very significantly so. The region has two seismoactive levels, namely 30 – 45 km and 70 160 km.

The characteristics of the seismic activity of the 1st level are the following:

- max $I_0 = 6\,^\circ$MSK–64,
- interval of focal depths: 30 – 45 km,
- typical focal depth: 42 km,
- typical attenuation coefficients: $\alpha = 0.004$, $k = 4.1$.

The characteristics of the seismic activity of the 2nd level are the following:

- max $I_0 = 9\,^\circ$MSK–64,
- interval of focal depths: 70 – 160 km,
- typical focal depth: 128 km,
- typical attenuation coefficients: $\alpha = 0.008$, $k = 9.0$.

4. MAX I_0 FOR FOCAL REGIONS AND FOR REGIONS WITH DIFFUSE SEISMICITY IN CENTRAL EUROPE

4.1. Introduction

The character of the earthquake activity of the real focal regions determines the strongest possible earthquake that can be generated by the given focal region.

There are several methods for the determination of this value (Procházková 1976). Because the methods based on mathematical statistics often result in very high values (Procházková 1976), in practice pragmatic procedures are used, based either on adding safety corrections to the values obtained by observation, or on the complex geological–geophysical evaluation of the region and its vicinity.

Max I_0 is the intensity of the strongest earthquake that can be generated in the investigated focal region in the period, for which it is necessary to consider a given region as an earthquake source for the given locality. The value depends on one side on the structure and on the physical values of the real focal region and on the other side on the regional stress fields, which pre–determine the strain of the focal region under consideration (Borisov, Rejsner, Šolpo 1975). Therefore, it is not automatically equal to the greatest intensity observed in the historical period, but is corrected on the basis of the evaluation of other parameters, i.e. it is usually made greater (e.g. Budnitz 1995b).

4.2. Methodology

4.2.1. Determination of Max I_0 for Focal Region

Several methods are used for this determination (Procházková 1984). The simplest estimations are directly based on the set of macroseismic observations, collected in historical and present times (databases of macroseismic data and isoseismal maps (Procházková, Kárník 1978)), which are supplemented by estimations based on maps of maximum observed intensities (Kárník et al. 1988). The estimations made in this way include the non–expressed assumption that all focal regions, the manifestation of which can be observed in the given locality, have already been manifested in the maximum shocks observed. The uncertainty of such estimations is a demonstration of the validity of this assumption. Sometimes in this connections we must realise that earthquake safety has a historical limitation. This means that the greater the interval for which there are data, the greater is the probability that the obtained values will not be exceeded. With regard to the requirement of extreme safety, there are values, obtained empirically, which must be upgraded in nuclear engineering in the case of the application of simple estimations.

In the nuclear domain two methods are mainly used, namely:

- in the case of focal regions the value of maximum observed shock is increased by 0.5 – 1°MSK–64 (Budnitz 1995b, RSF),
- in the case of faults the value max I_0 is determined with the help of geodynamic factors (Borisov, Rejsner, Šolpo 1975, Šimůnek 1989, 1992).

In agreement with these facts we use the first given estimation, but respecting the following rules (Procházková et al. 1990):

- The value of the strongest earthquake that can be generated in the given focal region is equal to the intensity of the strongest earthquake observed in the given region in historical time if:
    - the intensity is not reliably documented (it might also be smaller),

  - for the region there is the typical occurrence of substantially weaker shocks, i.e. the value a/b (a, b are the parameters of the straight part of the frequency graph $\log N = a - b \cdot I_0$, where N is the simple frequency) is substantially lower (minimally on 1 °MSK–64) than the value of the maximum observed earthquake,
  - there are not any special geological data predetermining the occurrence of particular strong earthquakes with regard to the situation in the given region.
- The value of the strongest earthquake that can originate in the given focal region is equal to the intensity of the strongest earthquake observed in historical time plus 0.5 °MSK–64, if:
  - the data on earthquakes in the historical time are reliable (high quality),
  - the frequency graph for the given region is a straight line in the part of stronger and strong earthquakes respecting the situation in the region,
  - the value of the strongest observed earthquake is equal to a/b (for definition see above),
  - there are not any special geological data predetermining the occurrence of particularly strong earthquakes with regard to the situation in the given region.
- The value of the strongest earthquake that can originate in the given focal region is equal to the intensity of the strongest earthquake observed in the historical time plus 1 °MSK–64, if:
  - the data on earthquakes in historical time are not very reliable (not so high quality), i.e. the data set is not homogeneous and some data are uncertain,
  - the frequency graph is a straight line in the interval of stronger shocks with regard to the situation in the given region,
  - the value of the strongest observed earthquake is lower than a/b (for definition see above),
  - there are not any special geological data predetermining the occurrence of particularly strong earthquakes with regard to the situation in the given region.

4.2.2. Determination of Max I_0 for Region with the Diffuse Seismicity

In the case of a region with diffuse seismicity we consider max I_0 equal to the observed earthquake in the whole region. We assume that:

- an observation period around one thousand years represents a sufficient time interval for the occurrence of the strongest earthquake,
- from the geological analysis of the regions with diffuse seismicity it follows that there are not the extensive structures in which there could be accumulated the strain that is necessary for the origin of a strong earthquake.

4.3. Data Used

For the determination of the max I_0 there were used data on:

- the earthquake intensities given in the earthquake catalogues (see regional catalogue, Chap. 2 and the national catalogues, the overview of which is in Chap. 2),
- the values of parameters of frequency graphs (Procházková 1984, 1993),
- the sizes of earthquakes that can generate the seismoactive parts of faults in Central Europe (Šimůnek 1992),
- the geological data indicating the occurrence of earthquake (Procházková, Dudek 1982, Procházková, Roth 1993, Procházková et al. 1986, Šimůnek 1989, 1992).

4.4. Values of Max I_0 in Regions of Central Europe

On the basis of data described in the section 4.3 and on the basis of the methodology described in section 4.2 there were obtained the results given in Tables 1 and 2.

TABLE 2. Max I_0 for Regions with Diffuse Seismicity in Central Europe and its Vicinity

Region	Observed max I_0 [°MSK-64]
A	4
B	5
C	4
D	4.5
E	5
F	6
G	5
H	5
I	4
J	6

From Table 1 it follows that the strongest earthquakes can origin in the following regions:

- $I_0 = 11$ °MSK-64 in the Friuli region (17),
- $I_0 = 9.5$ °MSK-64 in the regions of the Eastern Alps (18), Budapest – Monor – Jaszberény (30) and Keczkemet – Szolnok (34),
- $I_0 = 9$ °MSK-64 in the regions of Innsbruck and its vicinity (13), Linz – Pregarten – Molln – Neulengbach (15), Eastern Slovakia (24) and Komárno (28),
- $I_0 = 8.5$ °MSK-64 in the regions of the Malé Karpaty Mts. (20), Martin – Prievidza – Banská Bystrica – Dolný Kubín (22), Užgorod – Mukačevo – Beregovo (25), Kőrmand – Győr (27), Nagykanisza – Mór (29), Kaposvár – Dunafoeldvár (33) and Oradea – Satu Mare (36),

TABLE 1. Max I_0 for Focal Regions in Central Europe and its Vicinity

Focal region	Observed maxI_0 value [°MSK–64]	Correction of max I [°MSK–64]	Result value max I_0 [°MSK–64]
1	8	—	8
2	7	0.5	7.5
3	8	—	8
4	4	0.5	4.5
5	7.5	—	7.5
6	8	—	8
7	6.5	0.5	7
8	5.5	0.5	6
9	5	0.5	5.5
10	5	—	5
11	5	—	5
12	5	0.5	5.5
13	8	1	9
14	7	0.5	7.5
15	9	—	9
16	6.5	0.5	7
17	11	—	11
18	9	0.5	9.5
19	7.5	—	7.5
20	8.5	—	8.5
21	7.5	—	7.5
22	8.5	—	8.5
23	7.5	—	7.5
24	8.5	0.5	9
25	7.5	1	8.5
26	5	0.5	5.5
27	8.5	—	8.5
28	9	—	9
29	8.5	—	8.5
30	8.5	1	9.5
31	7	0.5	7.5
32	5	0.5	5.5
33	7.5	1	8.5
34	9.5	—	9.5
35	5	0.5	5.5
36	8.5	—	8.5

- I_0 = 8 °MSK–64 in the regions of the Thüringen Wald Mts. – Gera (1), Komořany – Leipzig (3) and Regensburg – Augsburg (6),
- I_0 = 7.5 °MSK–64 in the regions of Kraslice – Aš – Plauen (2), Trutnov – Klodzsko – Strzelin – Šumperk (5), Salzach – St. Martin (14), Český Těšín – Opava (19), Trenčín – Žilina (21), Kežmarok – Zakopané – Krakow (23) and the Mátra Mts. and vicinity (31),
- I_0 = 7 °MSK–64 in the regions of Domažlice – Tachov (7) and Bolzáno – Lienz (16).

From Table 2 it follows that in regions with the diffuse seismicity there may only be generated earthquakes with intensity up to 6 °MSK–64 (regions F and J).

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