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FRENŠTÁT SEISMIC NETWORK AND ITS CONTRIBUTION TO OBSERVATIONS OF THE NATURAL AND INDUCED SEISMICITY ON THE TERRITORY OF NORTHERN MORAVIA AND SILESIA

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ABSTRACT
We present comprehensive information on the Frenštát seismic network operated in 1992-2002 by the Institute of Geonics AS CR in Ostrava. The proposed regional diagnostic polygon in the Ostrava-Karviná Coal Basin consisting of 15 observation points was later divided into two parts. The first part (10 stations) surrounded the mining area of the Karviná partial basin, the other (5 stations), denoted as SPF, was distributed in the wide outskirts of Frenštát p. Radh. where a new mine was under construction. Special attention in this paper is paid on the description of developed instrumentation and methodical approaches in the data interpretation.
The regular continuous operation started on January 1992. The network consisted of 5 three-component short period stations. Data from individual seismic stations were transmitted by telemetry to the recording centre via a relay station.
The primary seismic digital data were sorted into the following groups: earthquakes, induced seismic events from Ostrava-Karviná coal mines as well as from Polish ore and coal mines, quarry blasts and other unidentified sources.
Quarry blasts were used for the construction of travel-time curves and for deriving Pg- and Sg- waves velocities. The SPF network significantly contributed to the detection of seismic events , foci localization and seismic regime investigation in the mines Paskov and Staříč situated in the southern part of the Ostrava-Karviná Coal Basin.
The operation of the SPF monitoring system discontinued in December 2002.

KEYWORDS: Ostrava-Karviná Coal Basin, seismological monitoring, seismic network, instrumental equipment, data acquisition and data processing

1. INTRODUCTION

After the strong rockburst which occurred in April 1983 in the eastern part of the Ostrava-Karviná Coal Basin it was proved that analogue seismic stations operated here were not able to record such intensive geomechanical events within the whole dynamic range. This finding led to a proposal to erect a regional seismic diagnostic polygon, stations of which would be able to detect and record all seismic events within a broad span of energies. It was obvious that investigation into seismic activity development within the region under investigation and monitoring of all seismic events in space and time were impossible without modern digital instrumentation. Hence, a proposal of regional seismological network, Regional Diagnostic Polygon (RDP), was elaborated (see Klíma et al. 1984; Konečný et al. 1986).

The originally proposed RDP consisting of 15 seismic station was later modified and divided into two part. One part surrounding the Karviná partial coal basin (10 stations) and the other situated in the broader environs of newly driven shafts of the mine Frenštát (5 stations). One of the crucial demands for the realization of the diagnostic polygon was the centralization of acquisition data. The construction of RDP started in January 1987 and 5 surface stations were erected by December 1988. After the completion of the network construction in January 1991, 10 stations (7 on the surface and 3 underground) with telemetric data transmission to the recording centre were in operation.

Monitoring of the southern part of the coal mine district, i.e. in the Frenštát region, was carried out by a network (denoted SPF) consisting of 5 surface seismological stations with autonomous data acquisition and transmission system and their evaluation. While the instrumentation for the network operating around the eastern part of the Ostrava-Karviná Coal Basin, whose instrumentation was obtained from abroad, the SPF network required only import of telemetry and seismometers. The rest of instrumentation was developed in the Mining Institute CSAS (at present Institute of Geonics AS CR) (see Knejzlík and Zamazal 1992 and 1992a).

The distribution of seismic stations of both networks is given in Fig. 1.

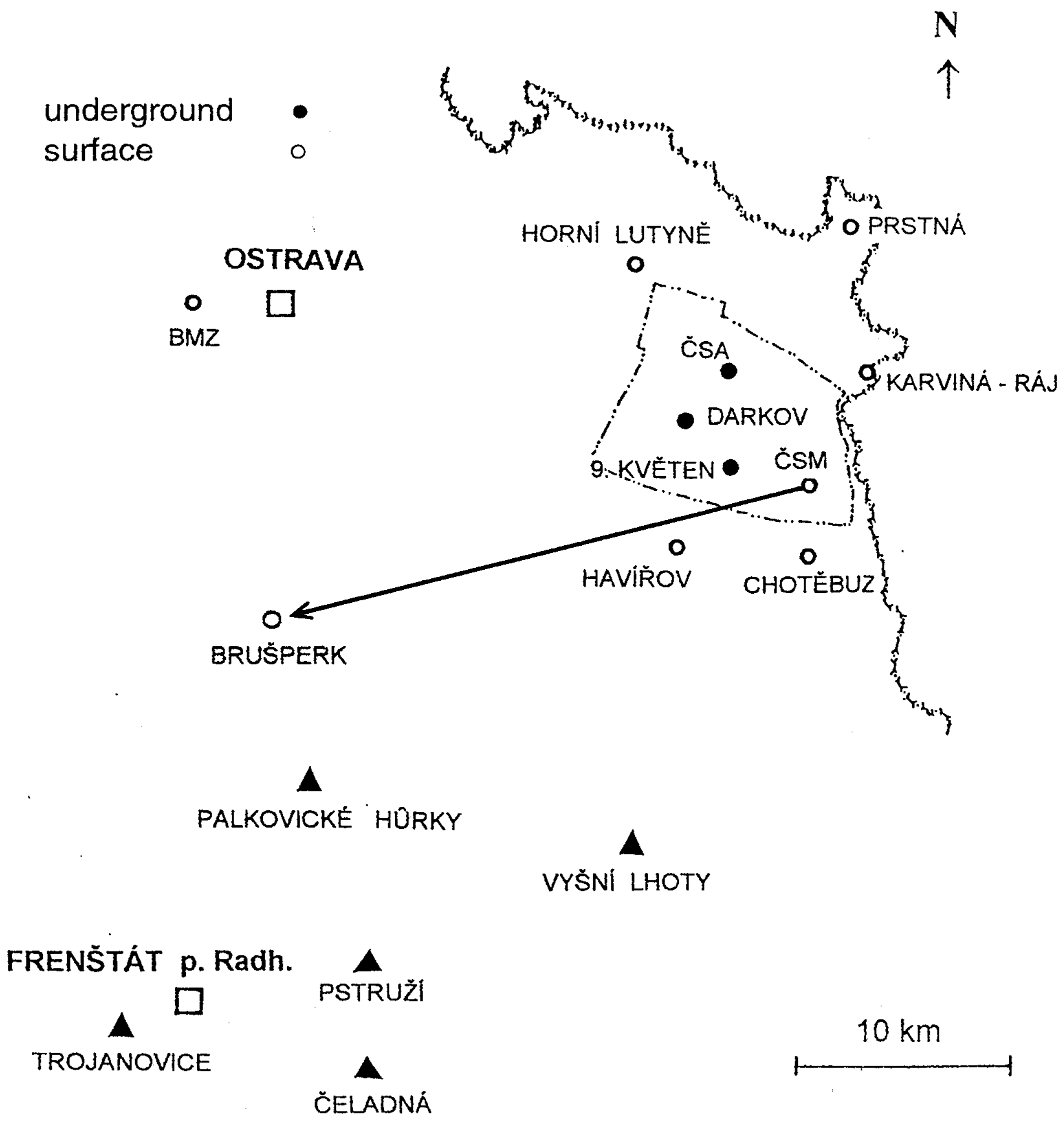

Fig. 1 Distribution of stations of the seismic polygon DPB Paskov around the Ostrava-Karviná coalfield (○ and ●) and sites of the Frenštát network (▲), —.. — mine take demarcations.

2. BRIEF GEOLOGICAL CHARACTERISTIC OF THE AREA

The present geological surface structure of the pre-Quaternary formations of the Moravo-Silesian Beskid, where individual observation sites of the SPF were located, belong to the Subsilesian and Silesian units of the flysh thrust nappes of the Outer Carpathians. The wider environs of the SPF are characterized by their close contact between the Outer Carpathians and the Bohemian Massif. The margin of the Outer Carpathians overfault to the Miocene foredeep follows the southern margin of the Ostrava Quaternary basin.

The pre-Quaternary structure of the Subsilesian and Silesian units represents a neiodal tectonic level of Alpine type subhorizontally translated overthrusts. This tectonic allochton covers as part of Miocene foredeep, as older, Variscan consolidated tectonic level, which represents a submerged continuation of the Epivariscan platform of the Bohemian Massif. Its prevailing part is also the southern offspur of the Upper Silesian Basin, which reaches in the autochtonous bottom even to the region of Frenštát p. Radh. and Trojanovice (Bouček a Kodym 1963).

The crystalline basement of the autochtonous Paleozoic is created by regionally metamorphosed paragneisses and migmatites in the roof of which some Devonian carbonate series were discovered which break into the Lower Carboniferous. At the beginning of the Upper Carboniferous the former marine sedimentation was passing into the paralic sedimentation of Ostrava-Karviná coal-bearing groups of strata. At the end of the sedimentation within the Karviná partial basin the paralic sedimentation was being changed into the continental one. The productive Carboniferous at individual sites of the SPF is situated at the depths within the interval of 300-1500 m (Kaláb 1992).

In the flysh series of Subsilesian unit sediments from the Upper Cretaceous to the Oligocene are preserved, while in the Silesian unit sediments of the time period from the Jurassic to the Oligocene are characteristic whose cover is built by Quaternary sediments. Both units mentioned above are represented by claystones, sandstones and partly also by limestones, on the other hand the surface layer consists of sands, clays and claystones.

3. INSTRUMENTATION

The chain of instrumental equipment for the SPF network consisting of three basic parts is described below. More details can be found also in (Knejzlík and Zamazal 1991, 1992 and 1992a). These individual parts are as follows: seismic station, relay station and recording centre.

3.1. *SEISMIC STATIONS*

The SPF network consisted of 5 stations where a probe with 3-component seismometers WDS-202 ($f_0 =$ 2 Hz) was placed in a shallow borehole (h ≈ 30 m). Coordinates of these stations are given in Table 1.

The analogue signals were converted to a floating point code (10 bits mantissa and 4 bits exponent) which made the dynamic range of 120 dB (MSB/LSB) possible. The sampling frequency was 125 Hz, the sampling shift between the channels was 500 μs. Code words containing the code of the amplitude of the seismic signal sample, a service bit and a synchronization bit were compiled to the serial form for PCM telemetric transmission. For the radio data transmission within the frequency band of 430 MHz Miller´s code modulation was used. The mains supply function and the safety circuit of the station were checked by the service bits. The input of analogue seismic signals and the output of the radio transmitter were protected by lightning protectors. The apparatus PCM3-T was powered by mains and supplemented by automatically charged backup batteries.

3.2. *RELAY STATION*

The relay station, which was situated at the top of the Beskyds at a communication tower, was equipped with a data concentrator based on microcomputer SAPI-1 as seen in Fig. 2. The signals received from individual seismic stations by radio receivers (Rx) were conducted to the decoders of Miller´s code (DMC). In DMC the PCM frames were decoded and then stored in buffer memories of SAPI-1. The SAPI-1 combined individual PCM frames into one common PCM frame. If discrepancies of number

Table 1 Coordinates of stations of the SPF network.

station	φ_N	λ_E	h (m)
Trojanovice	49°31′23″	18°10′28″	435
Pstruží	49°34′30″	18°19′34″	461
Palkovické Hůrky	49°38′27″	18°16′25″	517
Čeladná	49°31′14″	18°19′59″	454
Vyšní Lhoty	49°38′15″	18°28′34″	456

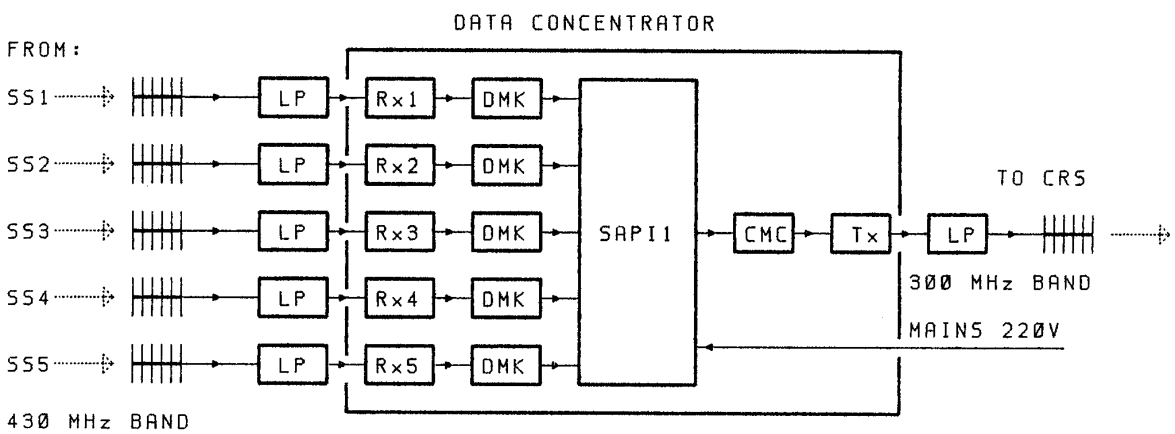

Fig. 2 Block diagram of the relay station.

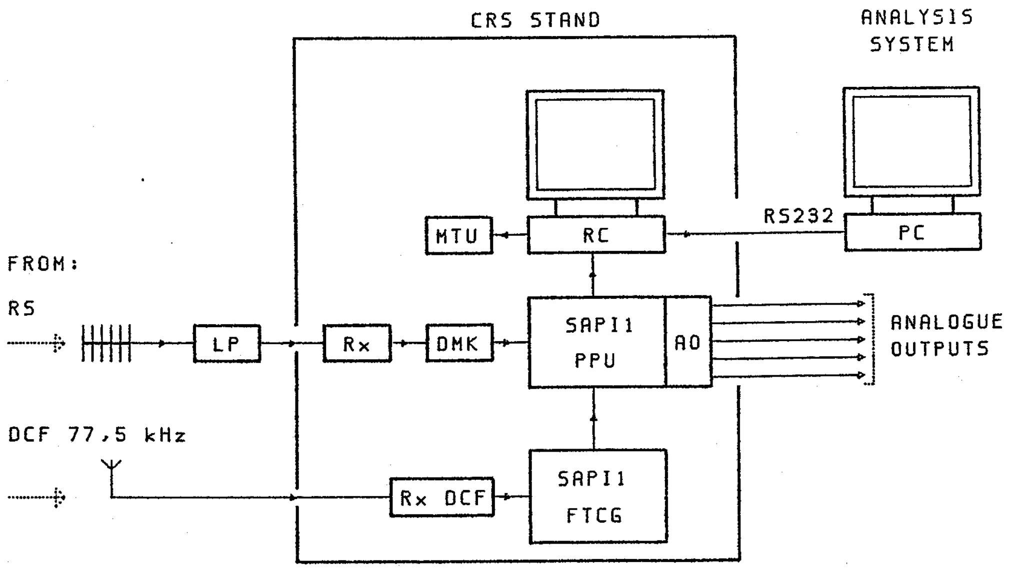

Fig. 3 Block diagram of the recording centre.

of the samples from individual stations due to inaccuracy of their sampling frequencies occurred, then superfluous samples were omitted and missing samples were substituted by copies of the preceding ones. The synchronization of data from individual stations was therefore ensured up to the accuracy of ±1 sampling interval. The resulting accuracy of allocation of the time information to seismic data was better than ± 2 sampling intervals, i.e. ± 16 ms.

Combined frame was transmitted by radio transmitter (Tx), using Miller's code modulation, within the 300 MHz frequency band to the recording centre. Inputs of radio receivers and transmitter were protected using lighting protectors (LP).

3.3. RECORDING CENTRE

According to the block scheme given in Fig.3 the following devices were included in the recording centre: radio receiver (Rx) with the lighting protection (LP), decoders of the Miller´s code (DMK) preprocessing unit (PPU), fast time code generator (FTCG) with the DCF signals receiver (Rx DCF), data acquisition system (RC), magnetic tape unit (MTU) and system for seismic signal analysis (PC).

In the central recording station, data received by Rx were decoded again in DMK. Afterwards, by means of the direct memory access (DMA) data were transmitted into the buffer which was created in the RAM memory of the microcomputer SAPI-1 in data acquisition RC. The signals stored in the buffer were evaluated by means of the STA/LTA algorithm. A weighted coefficient within the interval 1-100 was attributed to each 15 seismic channels. Recording on the hard disc was switched on in case the sum of individual weights exceeded the value of 100. The individual records contained a defined pre-event time. The STA/LTA algorithm made possible operative changes of switching parameters directly in the PC. To check input data, obligatory coincidence predefined bites in PCM frames was applied. PCM data frames were recorded directly to the data file. At the end of this data file time information was added.

The FTCG operated like a precise clock synchronized by the DCF 77.5 kHz time signal. Generated fast time information from the FTCG was supplemented into data frames.

The PPU was also equipped with digital/analogue convertors, which generated analogue signals from the selected channels to display them on the screen of a low-speed oscilloscope.

Recorded data files were converted into the ESTF/2 format, which was proposed and has been used for data of seismic polygon DPB Paskov. The ESTF/2 format was modified from the standard ESTF format by transferring 4 byte signal amplitude information into 2 byte form. Thus it was possible to reduce the recorded data volume by a half was enabled. It also enabled the interpretation of records using analyzing system SAP 580000 Lennartz Electronic on the one hand, and a direct data exchange at the level of the whole RDP, on the other. Data recording on the magnetic tape has never been used.

4. SOFTWARE FOR THE INTERPRETATION CENTRE

A conception of the software was based on the possibility of interactive data processing. Individual program packages work interactively and make the following options possible:

- selection of the station
- choice and displaying of channels (selected component, number of channels)

- choice of decimation
- setting up of magnification
- determination of arrival times of the individual groups of seimic waves
- possibilities of displaying wave trains on the screen by a printer and/or by a plotter.

For seismological interpretation of processed digital data a compilation of special program packages was performed which are as follows:

- localization
- spectral analysis
- polarization analysis
- focal mechanism determination.

The first versions of the programs were aimed at the interactive processing of the wave trains (arrival times determination) needed for localization procedures. In this stage the programs operated under the MS OS using an IBM PC, later OS Win 3.0 was used. The inputs and outputs of the programs were compatible with the system of the DPB Paskov polygon. The format of output data for further data processing (arrival times of various wave groups, localization, determination of periods and/or frequencies average etc.) is compatible with the system Dbase IV.

The essential advantage of the system based on the PC was a possibility to extend basic software by further programs moduli, which were compiled for filtration, differentiation, integration and rotation of signals. At present a package seismic interpretation system WAVE is utilized for digital data processing, for details see Toth (1992).

5. DIGITAL DATA PROCESSING

The original data recorded in the recording centre in the Institute of Geonics AS CR were always primarily sorted. In the course of this procedure useless recordings, e.g. various drops out of the apparatus and interference during data transmission, were separated from the useful records. From the beginning of the SPF network operation individual seismic events were sorted according to the type analysis into following categories:

- earthquakes (e.g. regional or distant)
- rockbursts and mining shocks originated in the Ostrava-Karviná Coal Basin
- mining induced seismic events from Polish coal mines in the regions of Katowice, Rybnik and others
- mining induced seismic events from the Lubin region
- quarry blasts.

Preliminary categorization of seismic events for the summary of events into categories mentioned above was carried out according to the type analysis of wave trains, each of them having characteristic features. Location of foci of the mining induced seismic events from the Ostrava-Karviná coal mine district, from the Polish part of the Upper Silesian Basin and regional and distant earthquakes were established using the arrival times of P and S waves at various stations (HYPO71 family). Onsets of individual waves were set with the accuracy of ± 2 samples, i.e. ± 2/125 sec. The accuracy of the determination of foci was tested by means of data from quarry and mine blasts. An average location error, which of course depends on the quality of seismic models, was set up to 1.5 km for the central part of the Karviná area. It is necessary to say, however, that the location of mining induced events was not the goal of monitoring of SPF and was not performed for all recorded events.

Sporadic local earthquakes, quarry blasts and induced seismic events from the coal fields of Paskov and Staříč mines were regularly located. A special 1-D layered velocity-depth model derived from the SPF data, which is given in Fig. 4, was used in the locating procedure (Kaláb and Knejzlík 1995). In questionable cases the records were compared with those of seismic stations of the regional seismic network (DPB Paskov), seismic stations Ostrava-Krásné Pole (OKC), Moravský Beroun (MORC) and Vranov near Brno (VRAC).

5.1. LOCAL TECTONIC EARTHQUAKES IN THE MORAVO-SILESIAN REGION

The SPF seismic network, which was put in operation in January 1992 was considered as a new source information on local tectonic earthquakes. Nevertheless, according to the current experience, the level of seismic activity on the territory of Morava and Silesia is relatively low (swarms in Jeseníky in 1986 and Opava region in 1993).

On the basis of long-term foci localization of earthquakes recorded by the SPF network 3 focal regions at a minimum have been proven. During the SPF operation lasting almost 11 years, higher concentration of earthquakes occurred in the regions as follows:

Opava region – 12 swarm earthquakes appeared in the surroundings of Opava in 1993 (Kaláb and Holub 1995, Častová a Kaláb 1999). The only earthquake of this series, on June 13, 1993, was also observed macroseismically (Holub a Müller 1997). Further solitary earthquakes were recorded: July 1997 (2 events), February 1999 (3), October 2000 (2) and January 2001(1). Epicentres were located to the northern margin of Culm facies of the Lower Jeseník near the Jesenice fault (Kaláb a Skácelová 1999).

Odry Hills – 1 earthquake in February 1997, which was followed by further events in July and August 2001 (2) and in March and June 2002 (2).

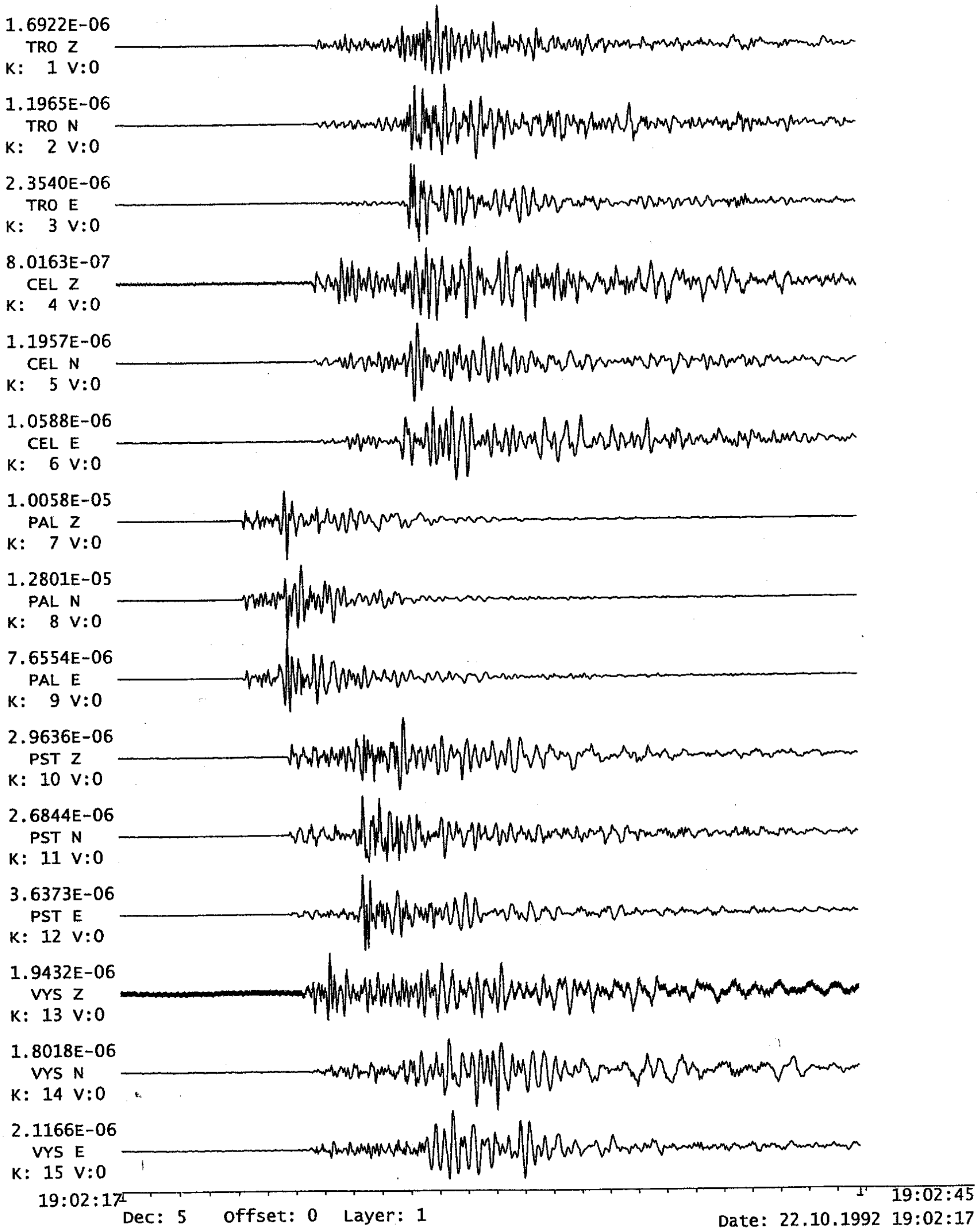

Fig. 4 Seismograms of the induced seismic event from the mine Staříč recorded at seismic stations of SPF network.

Valašské Meziříčí – Hranice – Vsetín – 2 weak earthquakes in August 1994, which were localized to the region westward of Valašské Meziříčí (Firbas et al. 1995). A comparison of foci positions with the geological-tectonic structure show that these earthquakes were closely connected with the Račanská and the Silesian units of the Outer Carpathians (Kaláb 1994 – Current supplement). Weak earthquakes, from May 1997 and May 1998, very likely originated in the same area.

It must be stressed that the number of local tectonic earthquakes in the Moravo-Silesian region was higher than the actual number recorded by the SPF network. The seismic stations operated by the Institute of Physics of the Earth of Brno in the region, detected new, seismically active focal areas, however, the respective earthquakes were below the detectability level of the SPF network (see Skácelová 1997, Havíř et al. 2001).

5.2. MINING INDUCED SEISMIC EVENTS AND BLASTING OPERATIONS IN MINES

As stated in the introductory chapter, the main reason for establishing the SPF network in the Frenštát region was monitoring the seismic activity expected in the area of the Frenštát mine after its opening. Nevertheless, monitoring the seismic activity in the mines in the eastern part of the Ostrava-Karviná

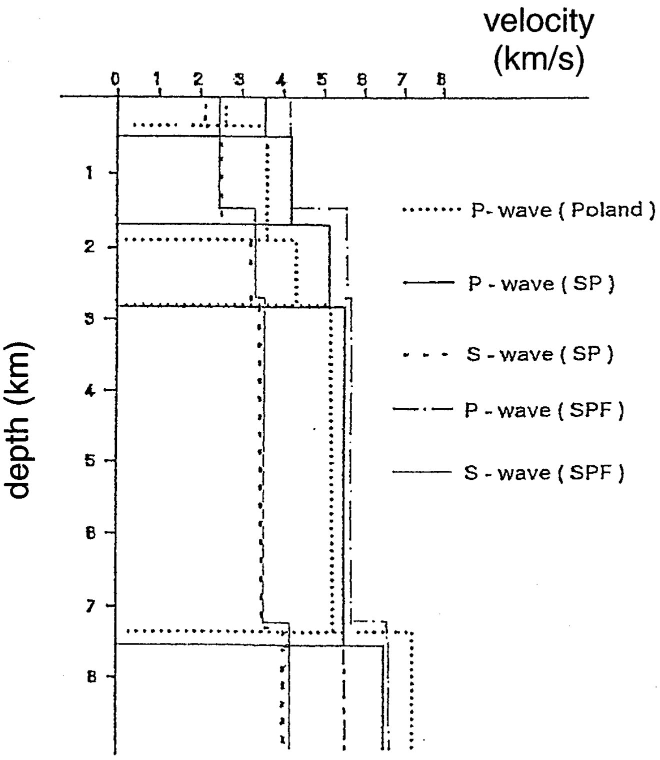

Fig. 5 Regional seismic models used during location procedures.

Coal Basin, which prevails in the region, was also included into the tasks of this network when the local seismological network was unable to record them reliably. In addition the SPF network together with the stations of the seismic polygon DPB Paskov could provide important information on the development and character of the wave trains, determination of physical properties of seismic waves and physical parameters of the foci of more intensive seismic events. The determination of focal mechanisms was also tested for a selected set of the most intensive shocks. Calculated results documented a higher portion of the volumetric component. A very complicated geological pattern and situation of worked out areas do not make it possible to intepret the obtained results from the geomechanical viewpoint.

During the day, the SPF network reliably recorded the seismic events with energy $E = 3x10^4$ J (Kaláb et al. 1999), while during the night and public holidays even events with energy $E \approx 5x10^3$ J were recorded owing to the lower level of the industrial noise. The eccentric position of the network towards the central part of the coal mine district influenced the location accuracy of the foci. Therefore, events from the eastern part of the Ostrava-Karviná Coal Basin were not located, nor seismic energy released was estimated. These parameters were determined by the local seismological network operated in individual mines and also by the seismic polygon DPB Paskov and were later implemented into the local bulletin of seismic events of the SPF network.

In addition to the induced seismic events occurring in the central part of the Karviná basin, sporadic induced seismic events generated in the southern part, i.e. in the mines Paskov and Staříč were also observed. Both mines were situated closer to the SPF network, and therefore more intensive attention was paid to these events afterwards. The first seismic event from this region was recorded by the seismic polygon DPB Paskov (former Regional Diagnostic Polygon) in February 1990. From the onset of the operation of the SPF network (January 1992), induced seismic events from both mines mentioned above were also recorded by this monitoring system. Based on the assessment of these recordings it was proven that during the period January 1990 – December 2002 98 events in total were recorded. Out of this number, 67 events were detected by the SPF network only, while seismic polygon DPB Paskov detected separately 12 events and only 19 events were observed simultaneously at both networks (Holub et al. 2002, Holub and Rušajová 2003). An example of seismograms of a seismic induced event from mine Staříč recorded at seismic stations of the SPF network is shown in Fig. 4.

The different seismogeological conditions in the area of SPF network and seismic polygon DPB Paskov and their different space distribution with respect to the focal region influenced the accuracy of

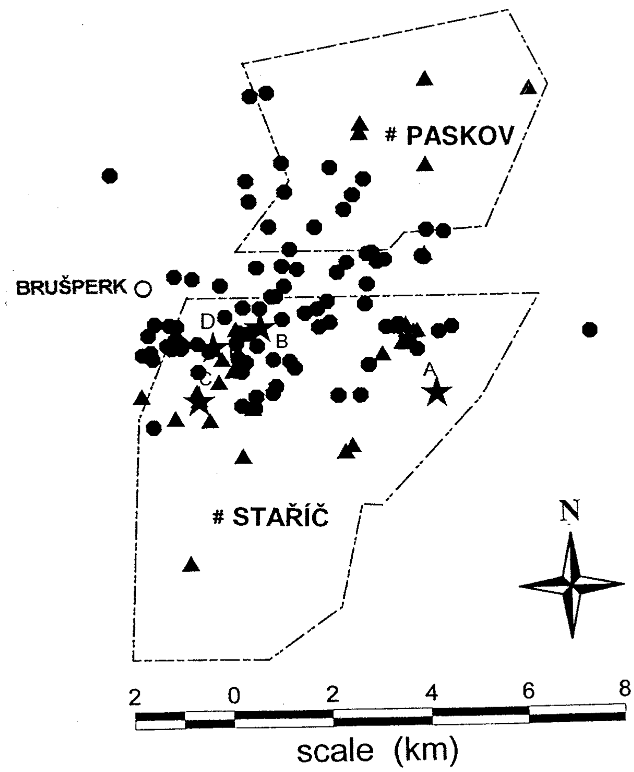

Fig. 6 Foci located by SPF network (●) or by seismic polygon DPB Paskov (▲) within the time interval 1992-2002, ★ focal regions A, B, C and D, —.. — mine take demarcations.

focus coordinates determination. By comparison of 19 couples of calculated foci of common events by means of the SPF and DPB Paskov data it was found that distances between both corresponding foci varied from 0.6 to 4.5 km. The differences in foci coordinates were also influenced by different velocity-depth models used in the location procedures in the SPF and DPB Paskov interpretation centres (see Fig.5). The resulting plot of 98 foci is presented in Fig.6. On this plot four probable focal regions (A,B, C and D) according to the acoustic observations of miners are given as well, though the seismic events originated there were relatively weak and no visible consequences in the mine were observed. To improve the localization accuracy of events from Paskov and Staříč mines, a surface seismic station from the ČSM mine was transferred to site Brušperk situated closely to the focal region. Besides the triggering conditions of the monitoring system within the Ostrava-Karviná coal mine district were changed.

Further type of induced seismic events were blasts in mines. There are two types of blasts; the first is large scale torpedo blasting and the other is destressing blasting. These blastings are usually carried out for preventive measures of rockbursts.. For the disintegration of the main roof, torpedo blastings having charges up to several tons were used, while for destressing blasts, performed in the coal seams, charges of a dozen kg were usually fired.

5.3. ROCKBURSTS FROM THE POLISH COAL MINES

Rockbursts, which originated in the mines of the Upper Silesian Coal Basin, were often recorded at the seismic stations of the SPF network and their frequency was almost comparable to the frequency of induced seismic events from the eastern part of the Ostrava-Karviná Coal Basin.

Depending on the intensity of individual seismic events, different features of wave trains were usually observed. Either the entire wave train, including group a of P and S wave groups or only a group of S waves were recorded. One of the rockbursts originating in the Halemba mine with energy $E = 3x10^9$ J was analyzed in detail (Kaláb and Knejzlík 1995). Mostly rockbursts from the Katowice and Rybnik regions were recorded during the SPF network operation, in addition, a lot of seismic events from the Polish mine Morcinek nearby the ČSM mine were detected.

5.4. ROCKBURSTS FROM THE REGION OF COPPER MINES NEAR LUBIN

The copper deposit is situated in the Lubin Basin in the area of Fore-Sudetic Monocline (Gibowicz et al. 1980) approximately 80-90 km westwards of the

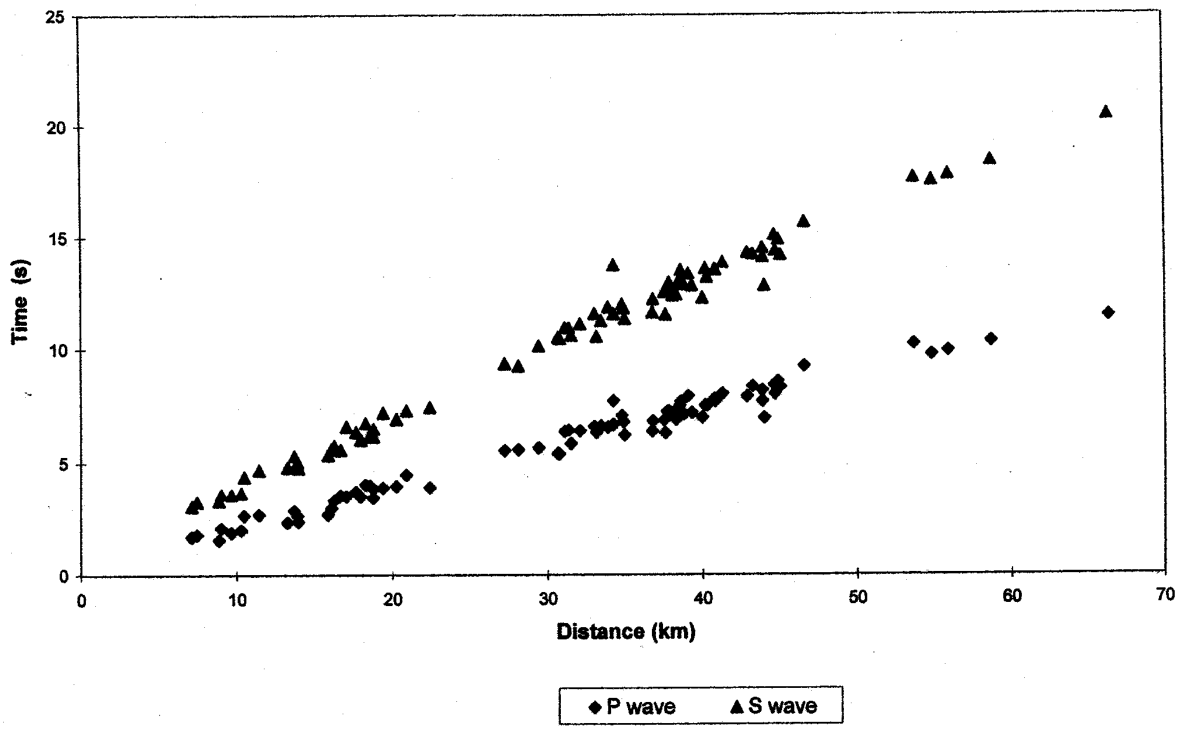

Fig. 7 Travel time curves based on quarry blasts recorded at seismic stations of SPF network.

Giant Mountains. The first rockbursts occurred here in 1972 and their frequency has been increasing as a result of the increasing ore production. Due to the high amount of seismic energy released during the most intensive rockbursts ($E = 10^6$-10^8 J) these events are usually detected and recorded at many seismic stations in Central Europe. The strongest of them were recorded at the stations of the SPF network at distances of about 300-350 km, having distinct P and S wave onsets.

5.5. QUARRY BLASTING

Besides earthquakes and mining induced seismic events, some quarry blasts on the territory of northern Moravia and Silesia were recorded. Individual quarries had to be gradually identified by means of approximative localization. Afterwards, the approximate determination of the quarry position was compared with the information on the position, date and time of the performed quarry blast from the respective professional mining companies. On the basis of the quarry blast data the P- and S- travel time curves were constructed (see Fig. 7) and the apparent Pg and Sg wave velocities were calculated, they were as follows: v_{Pg} = 5.7-5.9 km/s and v_{Sg} = 3.3-3.5 km/s (Kaláb a Kunčický 1996).

All seismic events recorded at the seismic stations of the SPF network which were mentioned in paragraphs 5.1 – 5.5 were assessed also statistically; total numbers of events belonging to individual groups are presented in Table 2, Figs 8 and 9.

6. CONTRIBUTION OF THE FRENŠTÁT SEISMIC NETWORK TO THE LONG- TERM OBSERVATION OF SEISMIC ACTIVITY IN THE MORAVO-SILESIAN REGION

(a) Special instrumentation for acquisition, transmission and data processing of SPF network was developed. An original concept, different from the system Lennartz Electronic, was utilized for the transmission and data recording formats, for the controlling of records triggering as well as the construction of hardware. However, at the level of data interpretation the compatibility of both parts of seismic polygon was guaranteed.

(b) The operation of the SPF network proved that during the entire period of observation any seismic event was observed, whose origins could be unquestionably attributed to the existence of local seismicity (neither natural, nor induced) in the environs of the coal mine Frenštát.

(c) For data processing original software packages were compiled, namely program WAVE.

(d) Using the SPF network only the weak local earthquakes on the territory of Moravia and Silesia were observed. In addition to the induced seismic events from the Ostrava-Karviná Coal Basin and Polish coal and copper mines, quarry blasts were also recorded.

(e) The SPF network contributed significicantly to the detection, localization and seismic regime investigation in the coal fields of mines Paskov

Table 2 Statistical distribution of all seismic events recorded at seismic stations of SPF network during the years 1992-2002.

year	Lubin	Poland	OKCB	earthquake	local earthquake	Staříč	quarry Kotouč	quarry blasts	other	total
1992	9	354	154	194	0	3	18	9	16	777
1993	86	638	301	179	12	4	45	18	36	1319
1994	80	577	325	258	2	8	53	23	2	1328
1995	77	507	241	284	0	1	36	16	1	1163
1996	162	580	383	266	0	2	48	21	3	1465
1997	194	552	571	239	2	0	34	29	3	1624
1998	118	544	483	162	2	2	37	17	1	1366
1999	130	790	629	221	3	3	40	29	2	1847
2000	154	835	897	287	2	10	40	23	11	2259
2001	180	772	889	214	3	7	32	18	10	2125
2002	145	792	886	184	2	49	36	17	0	2111
total	1355	6941	5759	2488	28	89	419	220	85	17384

and Staříč. The shift of one station from the mine ČSM to a new locality near Brušperk (close to mines Staříč and Paskov which was closed in 1993) considerably improved the location accuracy for events from these mines.

(f) A more precise depth-velocity model of the upper crust of the region under investigation was derived based on velocities of the P and S waves generated by quarry blasts.

(g) Some shots fired during the international seismic experiment CELEBRATION 2000 were also recorded by the SPF network. Based on these observations, preliminary values of apparent velocities of the Pn-, Pg-, Sx- and Sg- waves were derived within the region of northern Moravia (Holub a Rušajová 2002).

(h) The data from the stations of the SPF network were used to solve special tasks as follows:
- spectral analysis (Kaláb 1997)
- polarization analysis (Kaláb et al. 1999)
- attenuation of seismic waves amplitudes (Holub and Veselá 1996)
- foci mechanism determination and source parameters investigation (Kaláb and Knejzlík 1995)
- verifying approaches and properties of wavelets (Častová a Kaláb 1999).

(i) The data of the primary seismogram interpretation (data level one) were collected in the monthly local seismic bulletins.

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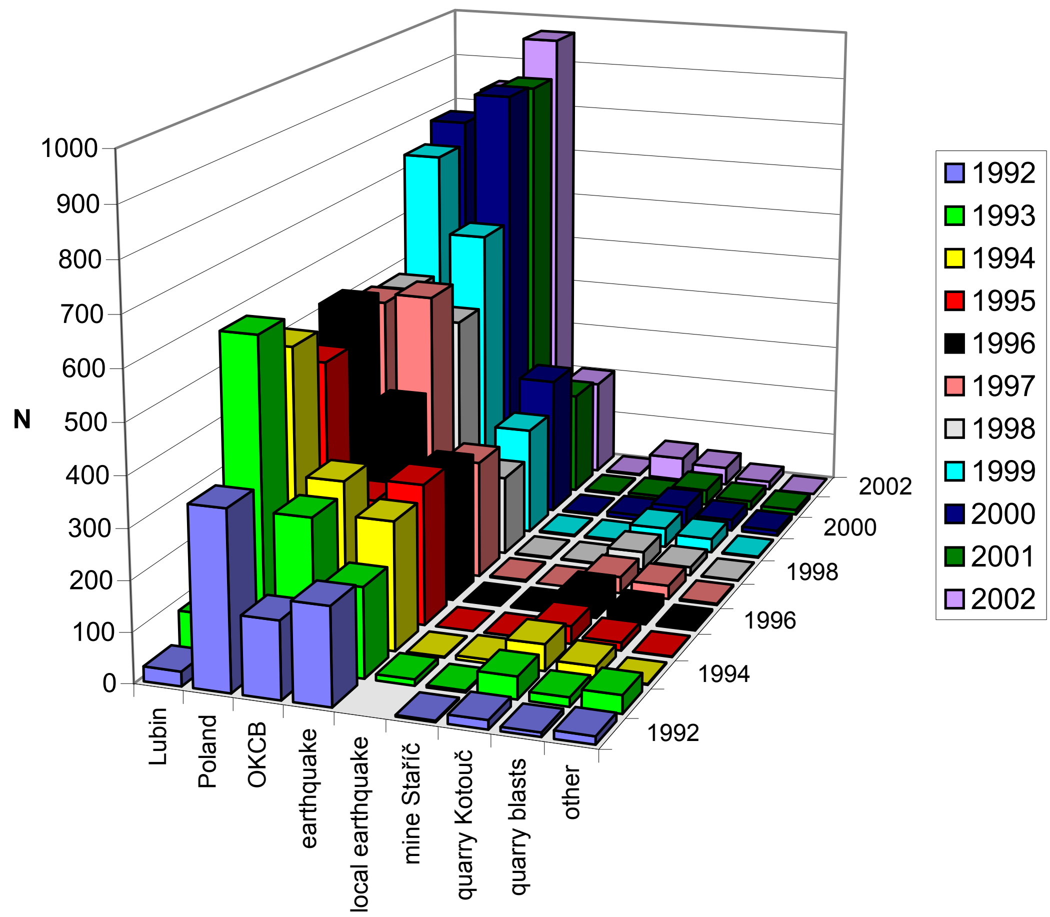

Fig. 8 Statistical distribution of seismic events according to frequency N recorded in separate years.

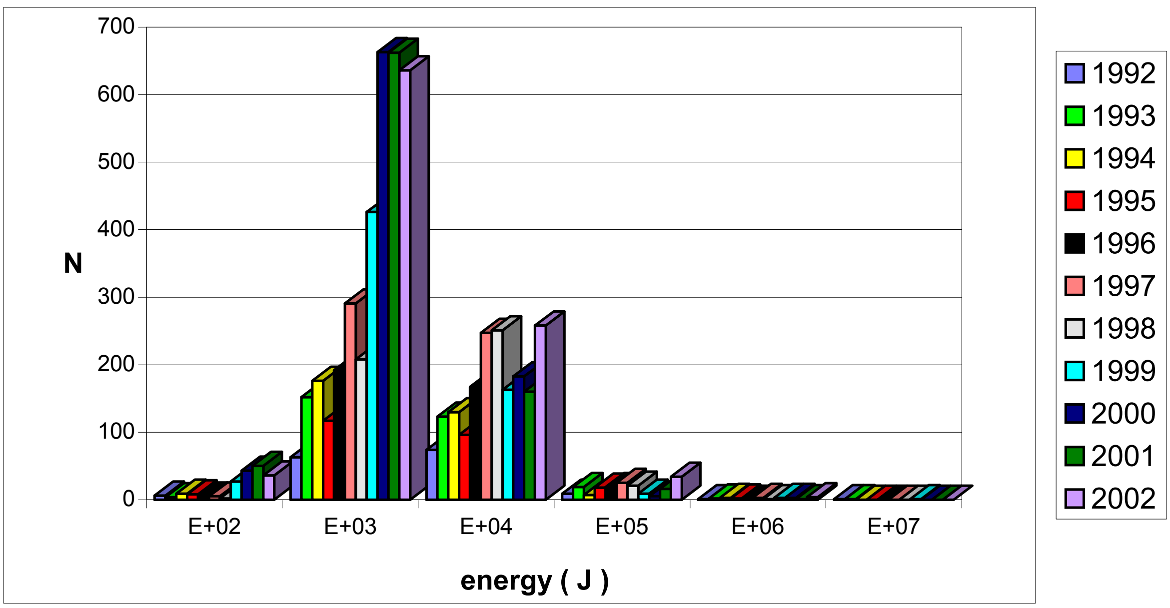

Fig. 9 Statistical distribution of mining induced seismic events according to frequency N and energy classes recorded during individual years.