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# INTERPRETATION OF ROCKBURSTS RECORDED BY THE LOCAL SEISMIC STATION KLADNO–VINAŘICE DURING THE YEAR 1994

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ABSTRACT. During the year 1994, seismic station Vinařice recorded a total of 3201 rockburst events (brittle fracturing) with foci located in the volume of the safety shaft–pillar Kladno–2. Liquidation of this pillar continued by new drifts and by coal extraction at several stopes. Evaluation of the site, size and time of rockburst events resulted in: a) seismic energy flow (seismic power) does correlate with drifting rate of new galleries and with the coal extracting rate, b) distribution of foci depths shows maximum in the overlying sandstone bed, c) estimate of seismic source zone dimensions being within tens to one hundred meters.

KEYWORDS: rockburst, rock fracturing, distribution, prediction, safety shaft pillar, covariance, mine drift, coal extraction.

## 1. INTRODUCTION

Having started exploitation in the safety shaft pillar the local seismic station Vinařice 1300 rockbursts were recorded during the year 1993. Evaluation of data obtained resulted in statistically significant covariance between rockburst frequency, rate of coal extraction, and amount of exploitation blasts. Variations in rockburst occurrence (frequency and seismic power) has shown both trend as well as periodical character. Such correlations are valid for the whole pillar area.

An increase in daily frequency of very weak rockburst events, which was registered at local seismic network Kladno–2 only, could have been a precursor for the three of the strongest rockbursts recorded on the seismograph station Vinařice [Brož, Buben 1995; Růžek 1995].

Liquidation of the shaft safety pillar continued during the year 1994 by extraction as well as by driving new galleries at several separate working places. There were variations in intensity of the work at different places and time periods. In contrast to the year 1993, data about driving and extraction rates specific to individual working places, could be identified. An improved mine seismic array allowed for a more reliable location of rockburst foci and their delimitation to source zones around individual mine galleries and stopes. The whole area of the shaft–pillar could have been divided into, where mining activities were concentrated. Such data were used to investigate specified relations between rockburst occurrence and mining activity.

The correlation of blasting and rockburst occurrence, which came out of 1993 data, was not investigated any more, as the evidence of blasts was no more available.

## 2. INPUT DATA

During the year 1994, station Vinařice (50.158° N 14.095° E) registered 3201 rockburst events with foci within the safety shaft pillar, i.e. at epicentral distances of 1500 ± 200 m.

Looking at the stope distribution, the shaft pillar was divided into three zones, marked No 1, No 2, and No 3. (Fig. 1).

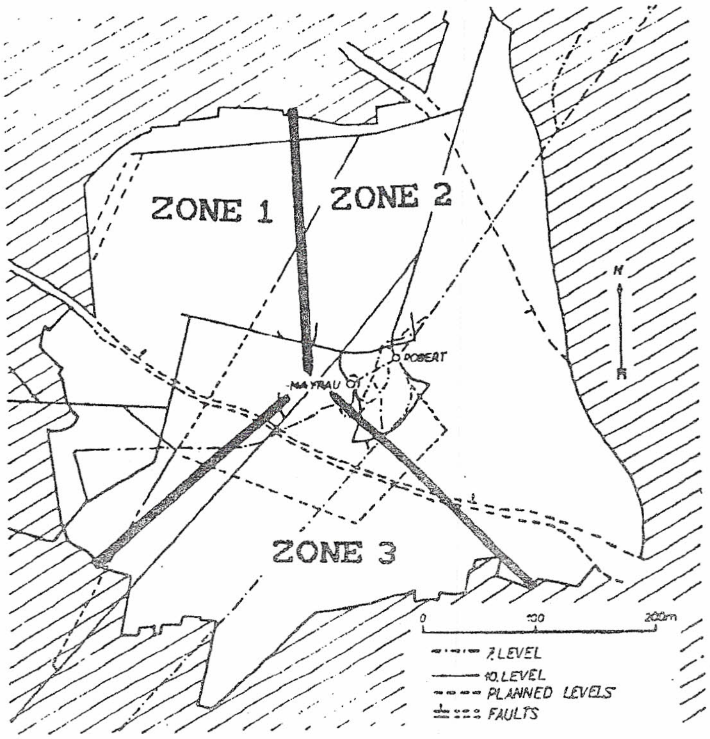

FIG. 1. Schematic map of the safety shaft pillar and delimitation the zones of mining activity concentration

The input data are specified for the zones No 1, No 2 and No 3, see Figs 2, 3 and 4. The data are given in graphs marked A, B, C:

Graphs A show cumulative increments in length of all driven galleries per month.

Graphs B show cumulative volume of extraction per month.

Graphs C show daily cumulative trace amplitudes of maximum seismic ground motion 2Y, recorded by the vertical – component seismograph in the Vinařice station.

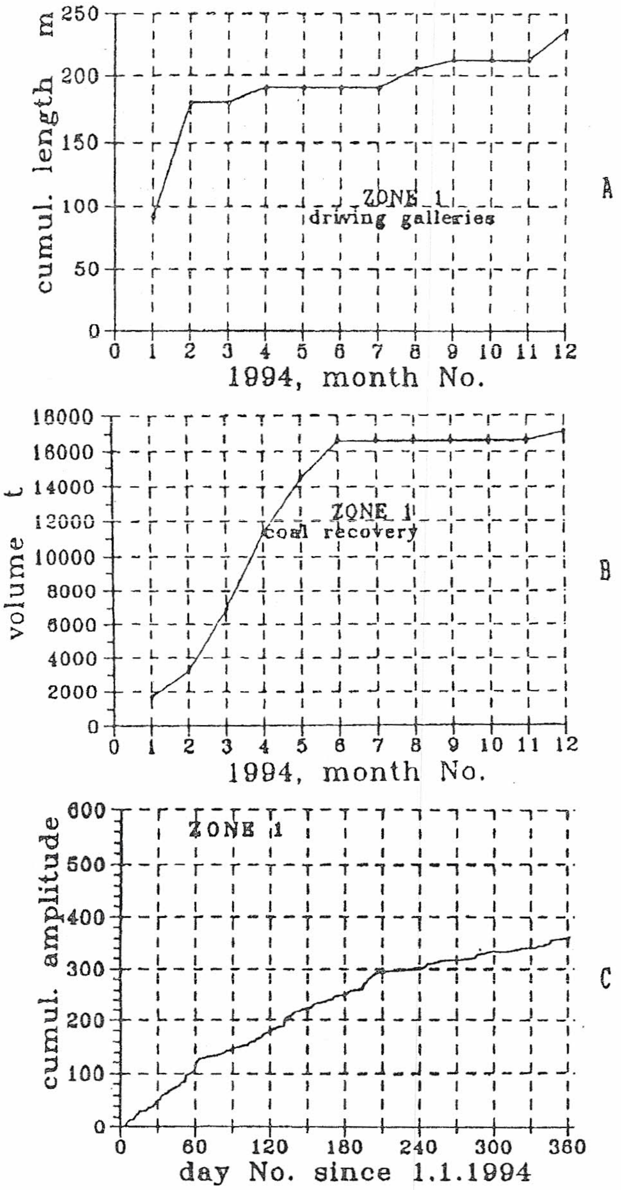

FIG. 2. Presentation of data observed within Zone 1. A – cumulative length of newly driven galleries, B – cumulative volume of excavation, C – cumulative amplitudes od seismic records of rockbursts

Data about time and size of rockbursts located in the Zone No 1 are given in Tab. 1. Each event in a day is defined by maximum peak to peak trace amplitude 2Y followed by the values of time (hour, minute).

Depths of rockburst foci are given in Fig. 5A (Zone No 1), Fig. 5B (Zone No 2), and Fig. 5C (Zone No 3). Horizontal axis bears the serial number of rockburst, vertical axis gives the vertical coordinates of foci in meters above sea level. The

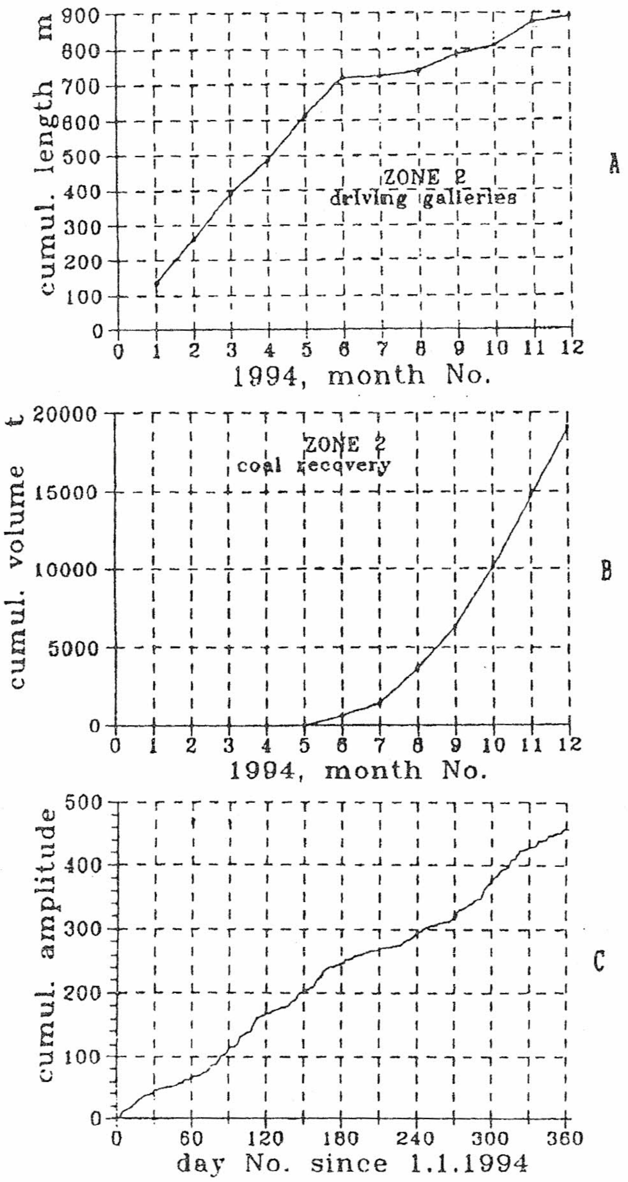

FIG. 3. Presentation of data observed within Zone 2. A – cumulative length of newly driven galleries, B – cumulative volume of excavation, C – cumulative amplitudes of seismic records of rockbursts

coal seam, depicted by a dash line, lies in the depth of – 160 m a.s.l. The level of the pit bank of Kladno–2 shafts (Mayrau and Robert) is 353 m a.s.l. Vertical lines separate events in individual months of the year 1994.

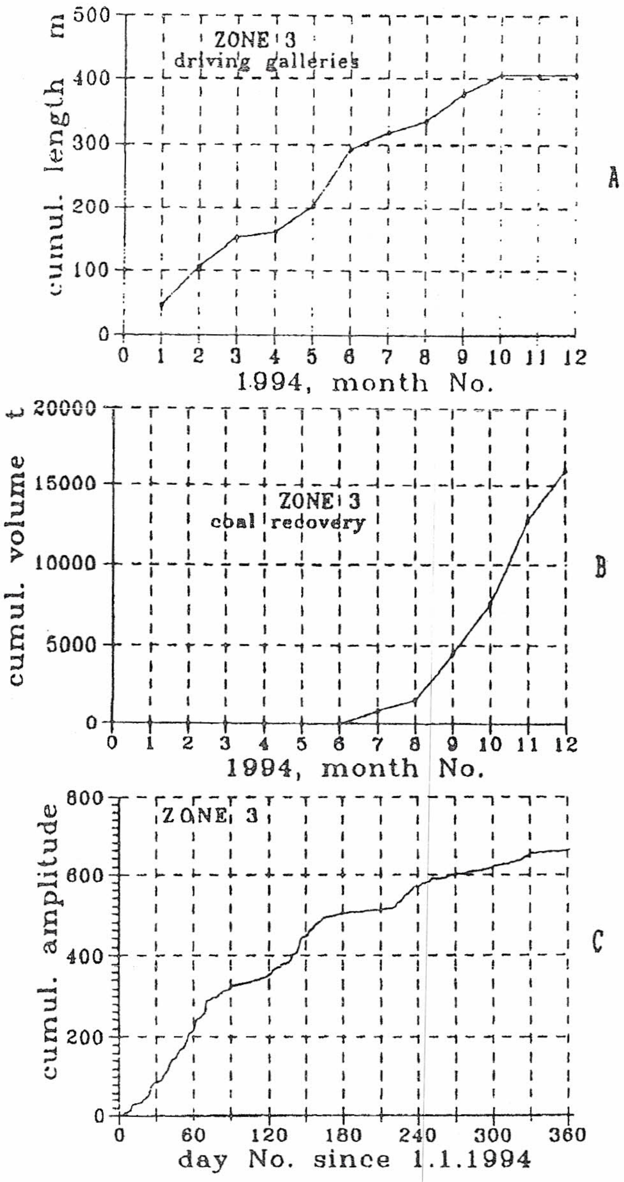

FIG. 4. Presentation of data observed within Zone 3. A – cumulative length of newly driven galleries, B – cumulative volume of excavation, C – cumulative amplitudes of seismic records of rockbursts

TABLE 4. Rockbursts within the ZONE 1 in the year 1994.

**January**

| | |
|---|---|
| 1 | 25[4 22], |
| 2 | 14[14 55], |
| 3 | 90[14 17], |
| 4 | |
| 5 | 58[7 0], 85[11 39], 20[12 27], 25[12 27], 13[1235], 20[12 59], 375[12 59], 11[13 0], 16[17 22], 15[18 45], 11[19 4], 22[19 12], 20[20 16], 15[20 40], 15[20 41], |
| 6 | 50[01 36], 15[7 22], 30[8 52], 36[8 52], 31[10 39], 100[15 1], 15[15 39], [16 59], 65[17 47], 15[21 4], |
| 7 | 26[0 33], 10[0 4], 19[2 39], 15[4 58], 23[8 6], 33[8 35], 55[17 2], 43[17 21], 10[17 59], 12[19 42], |
| 8 | |
| 9 | |
| 10 | 60[12 48], |
| 11 | 80[0 33], 20[2 1], 36[8 20], 50[9 25], 29[17 27], 30[17 28], 20[18 53], 100[18 53], 32[23 26], |
| 12 | 190[4 7], 20[9 20], 20[9 20], 72[9 20], |
| 13 | 20[1 26], 25[1 35], 28[12 4], 49[12 53], 12[15 27], 34[17 19], 43[17 28], 18[18 58], 67[19 2], |
| 14 | 8[17 09], 30[21 50], |
| 15 | 21[3 2], 390[20 59], |
| 16 | 30[17 56], |
| 17 | |
| 18 | |
| 19 | 12[16 54], 50[17 3], |
| 20 | 5[3 46], 14[6 20], 14[15 49], 20[15 49], 10[17 12], 25[17 39], |
| 21 | 20[1 5], 190[4 6], 62[13 49], 15[13 50], |
| 22 | 110[3 19], 20[19 24], |
| 23 | 15[6 38], |
| 24 | |
| 25 | 31[0 30], 50[15024], 43[20 14], |
| 26 | 52[0 1], 35[2 27], 21[2 49], |
| 27 | 100[5 12], 35[7 29], 60[11 54], 55[17 2], |
| 28 | 770[12 18], 30[22 47], |
| 29 | 30[11 34], |
| 30 | 90[1 22], 12[1 51], 25[8 32], |
| 31 | 18[10 31], 25[17 9], 46[22 28], |

**February**

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|---|---|
| 32 | 52[0 29], 25[1 32], 55[3 42], 14[5 6], 31[10 48], 29[16 51], 80[22 38], |
| 33 | 210[1 46], 8[3 36], 10[3 41], 15[9 4], 43[10 7], 24[14 0], 150[17 22], |
| 34 | 9[1 12], 8[1 42], 12[1 59], 15[3 9], 43[11 33], 30[19 0], 28[20 5], 63[23 43], 14[23 50], |
| 35 | 20[0 57], 15[2 57], 38[5 27], 30[10 20], 29[13 7], |
| 36 | 45[9 13], 35[9 19], 25[20 3], |
| 37 | 30[16 27], |
| 38 | 32[14 59], 42[15 29], 35[23 48], |
| 39 | 15[2 57], 15[3 42], 49[4 42], 53[7 19], 60[16 23], 210[18 59], |
| 40 | 10[2 27], |
| 41 | 60[8 30], 15[21 49], |
| 42 | 35[2 28], 11[2 59], 41[2 59], 110[3 8], 32[15 13], |
| 43 | 100[5 59], 55[16 16], |
| 44 | |

45 43 [17 13],
46 22[1 21], 45[1 21], 22[1 21], 10[15 25], 80[15 25],
47 23[9 6], 56[9 24], 21[9 24], 73[18 55],
48 15[0 34], 45[0 59], 30[1 23], 8[1 44],
49 10[0 32], 9[3 21], 48[3 35], 310[13 51], 85[17 34],
50 5[0 58], 55[8 6], 10[14 42],
51 10[3 57], 9[21 39],
52 50[1 11], 42[16 46], 40[18 25], 25[23 47],
53 12[0 39], 25[0 52], 1100[6 57], 70[17 22], 11[18 0], 10[18 27], 12[18 27],
54 15[0 22], 10[0 40], 17[1 26], 16[1 47], 13[3 47], 22[6 29], 15[11 25], 15[20 52],
55 9[20 42],
56 58[0 59], 18[4 22], 13[4 22], 20[6 44], 75[14 12],
57 14[12 47], 180[14 30],
58 15[13 15], 10[19 53],
59 130[9 38],

## March

60 10[1 59), 20[2 4], 27[2 35], 100[7 28], 30[7 44], 200[15 40], 19[15 56], 16[17 19],
61 20[0 54], 6[1 38], 400[5 5], 62[10 43], 630[10 43], 11[19 45], 20[21 5], 20[22 5],
62 100[2 44], 12[6 41], 48[16 24], 62[17 5],
63 85[0 24], 8[1 5], 16[2 6], 19[2 50], 120[12 33], 90[16 21],
64 20[0 4], 7[3 3],
65 55[18 4],
66 15[16 13],
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68 8[17 3], 75[17 47],
69 140[3 47],
70 73[22 24],
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72 36[7 49],
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74 55[17 6], 14[21 7],
75 6[2 28], 7[4 14], 58[18 44], 55[23 38],
76 11[3 32],
77 48[3 42], 65[16 1], 16[20 52],
78 20[0 49], 20[2 54],
79 40[2 19],
80 12[1 0], 20[15 22],
81 10[3 54], 21[9 59], 23[19 46],
82 68[8 29], 40[13 36], 180[22 14],
83 14[3 28], 10[17 50],
84 90[19 39], 9[20 42], 18[22 54],
85 53[10 22], 20[13 28], 26[21 7], 48[21 7],
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87 79[7 4], 22[13 53], 7[20 17], 8[23 50],
88 17[4 28], 33[6 4], 13[7 1],
89 55[4 35], 11[9 53], 32[12 49], 41[22 25],
90 12[0 28], 10[7 58], 22[18 13], 35[23 2],

## April

91 30[2 40], 22[4 36], 22[15 12], 15[20 37],
92 23[4 3],

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|---|---|
| 93 | 10[19 25], |
| 94 | 9[2 19], 21[7 19], 52[15 34], 50[20 53], |
| 95 | |
| 96 | 55[13 48], |
| 97 | 24[18 8], 39[23 23], |
| 98 | 160[9 20], 29[15 53], |
| 99 | 5[1 44], 14[2 28], 4[3 2], 6[3 20], 11[18 38], |
| 100 | 28[15 55], |
| 101 | 19[17 44], |
| 102 | 6[2 34], 11[17 11], 17[17 11], 22[23 57], |
| 103 | 30[0 19], 21[11 18], 90[14 12], 42[20 55], 10[21 39], 13[20 56], 75[26 45], |
| 104 | 29[3 1], 100[13 40], 15[18 55], |
| 105 | 9[1 26], 35[2 51], 30[13 8], 11[14 28], 70[15 30], |
| 106 | 7[1 56], 5[4 43], 6[18 40], 14[22 53], |
| 107 | 21[2 11], 42[9 35], |
| 108 | 31[7 42], 10[16 4], 61[18 4], 13[18 52], |
| 109 | 270[1 42], 27[4 43], 21[12 9], 14[18 28], |
| 110 | 9[0 55], 12[3 48], 18[20 47], |
| 111 | 22[2 53], 12[9 0], 14[21 53], |
| 112 | 11[1 27], 22[3 15], 8[9 21], 14[11 16], 15[12 27], 22[21 5], |
| 113 | 100[4 39], |
| 114 | 19[17 34], |
| 115 | 22[0 21], 7[0 53], 40[13 52], 55[20 43], 160[20 43], 330[21 50] |
| 116 | 14[11 29], |
| 117 | 17[10 8], 140[12 44], |
| 118 | 12[9 3], 12[14 8], 14[21 7], 36[22 20], |
| 119 | 6[3 50], 7[8 11], 26[12 27], 150[13 23], 22[15 37], 10[16 17], |
| 120 | 15[2 45], |

## May

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| 122 | 250[10 50], 10[14 54], 14[16 31], 22[21 54], |
| 123 | 22[10 34], |
| 124 | 13 [7 16], 9[20 23], |
| 125 | 22[6 42], 37[18 4], |
| 126 | 160[14 26], 7[18 4], |
| 127 | |
| 128 | |
| 129 | 8[5 9], 9[8 44], 33[11 40], 33[15 57], |
| 130 | 28[8 40], 105[15 41], |
| 131 | 25[9 46], 8[18 13], |
| 132 | 180[5 11], 850[6 46], 500[18 29], |
| 133 | 10[8 48], 9[22 22], |
| 134 | 120[7 51], 130[20 17], 23[22 2], |
| 135 | 10[5 28], 31[14 25], 48[20 26], |
| 136 | 145[14 48], |
| 137 | 15[12 17], 11[18 10], 22[20 28], 15[20 34], |
| 138 | 70[3 32], 11[6 43], 12[10 38], 355[20 40], 9[23 16], |
| 139 | 66[16 2], |
| 140 | 19[6 28], 90[13 6], 25[18 30], 340[22 57], |
| 141 | 27[6 25], |
| 142 | 9[4 43], 6[8 17], 5[23 54], |
| 143 | 8[14 29], 17[21 5], |

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| 144 | 90[0 49], 12[2 38], |
| 145 | 37[2 18], 11[3 54], 135[12 27], 16[12 43], |
| 146 | |
| 147 | 60[20 14], 8[20 16], 38[23 29], |
| 148 | 21[5 3], 7[21 25], |
| 149 | 12[0 42], 6[5 4], 14[11 16], |
| 150 | 8[19 25], 10[21 49], |
| 151 | 31[1 38], 41[4 49], 7[23 43], |

### June

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|---|---|
| 152 | 9[0 42], 8[18 9], |
| 153 | 65[21 54], 10[22 14], |
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| 156 | 480[2 1], 50[9 49], |
| 157 | 35[6 17], 24[17 17], |
| 158 | |
| 159 | 24[7 12], 190[20 36], 38[21 37], |
| 160 | |
| 161 | 15[7 7], 43[18 21], |
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| 164 | 31[21 39], |
| 165 | 14[2 33], 16[9 42], 10[18 29], 300[21 37], |
| 166 | 15[7 11], 49[18 11], |
| 167 | 22[1 42], 43[16 2], 43[20 20], |
| 168 | 16[11 43], |
| 169 | 8[1 46], |
| 170 | 9[2 5], |
| 171 | 290[2 11], 260[17 40], |
| 172 | 35[4 36], 14[7 48], |
| 173 | 20[11 3], 11[13 57], |
| 174 | 30[17 22], |
| 175 | 62[12 34], 18[22 28], |
| 176 | 19[3 51], 12[6 6], 18[6 41], |
| 177 | 12[1 51], 35[2 46], 12[7 42], |
| 178 | 12[15 4], 6[15 45], 7[20 21], |
| 179 | 13[16 38], 10[18 59], |
| 180 | 10[7 40], 30[13 43], 110[18 54], |
| 181 | 5[16 27], 11[22 18], |

### July

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|---|---|
| 182 | 11[15 57], 16[22 22], 76[22 27], |
| 183 | 270[2 1], 30[20 5], 155[20 39], 11[23 37], |
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| 188 | 7[18 40], 14[26 59], |
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205 140[10 47], 340[12 29],
206 25[21 51],
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208 10[10 54],
209 30[7 5],
210 42[4 51],
211 25[12 13],
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## August

213 12[2 50],
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243 19[15 50],

### September

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256 27[5 59],
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261 31[9 5], 95[11 13],
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264 43[17 39],
265 14[0 47],
266 14[6 5], 15[22 57],
267 78[21 3],
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270
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272
273 17[17 59],

### October

274 44[4 30], 16[16 22],
275 10[5 46],
276 63[4 47],
277 14[6 26],
278 25[7 52],
279 11[0 33],
280
281 49[2 14], 110[16 54], 18[21 48],
282 16[6 58],
283
284 6[14 36],
285 85[4 57], 180[4 57],
286 170[0 11], 150[4 48], 4[22 53],
287 150[10 53],
288 22[20 52],
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294 41[9 15], 17[12 8], 67[17 6],
295 43[5 45], 14[12 3],
296 23[10 15],
297
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299 6[0 19],
300 22[11 47],
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302 25[11 41], 17[17 43],
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## November

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311 90[5 54],
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313 43[11 5], 10[16 25],
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317 210[20 48],
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319 23[21 48],
320 18[7 17],
321 110[8 19],
322 18[7 8], 185[10 35],
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324 20[5 59],
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326 11[11 54],
327 7[16 11], 8[18 1],
328 10[9 38],
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## December

335 210[4 28], 110[17 52],
336
337 12[18 29],
338 15[1 35],

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| 339 | 18[1 36], |
| 340 | 11[6 50], |
| 341 | 56[2 34], 43[5 52], |
| 342 | 120[7 38], |
| 343 | 12[19 49], |
| 344 | 6[17 1], |
| 345 | 6[6 13], |
| 346 | 820[6 14], |
| 347 | 26[11 56], |
| 348 | |
| 349 | 8[1 28], 8[1 28], 7[6 7], 19[16 17], |
| 350 | |
| 351 | 9[13 41], 7[16 28], |
| 352 | 9[1 3], 11[10 3], 85[23 34], 60[23 34], |
| 353 | 68[8 39], |
| 354 | 12[10 56], |
| 355 | 27[3 47], 7[11 22], 20[12 25], |
| 356 | 6[6 18], 23[17 14], |
| 357 | 11[2 4], 11[23 2], |
| 358 | 9[20 23], |
| 359 | 15[10 7], |
| 360 | 11[6 39], 10[9 57], 51[15 59], |
| 361 | 31[14 57], |
| 362 | 10[5 55], 17[5 56], 12[16 48], |
| 363 | 31[3 27], 15[8 1], 9[13 2], |
| 364 | |
| 365 | |

## 3. RELATIONS BETWEEN MINING AND ROCKBURST ACTIVITIES

### *3.1. Depth of Foci*

In the Zone No. 1 (Fig. 5A) appears an effect of a time change in the depth distribution. In initial months there is a larger scattering in depth, and relatively large number of foci is located under the coal seam. During later months the activity is concentrated in higher levels of the hanging wall. At levels up to 50 m above the seam there is very small number of events. Their maximum concentration at the level of about 70 m above the seam coincides with the location of a sandstone bed having relatively high strength [Živor 1995].

In the Zone No 2 (Fig. 5B) there is no evidence of changes in the distribution of foci with time. The concentration in the strong sandstone hanging bed is also evident, although a significant number of foci appears also at higher levels up to 200 m above the seam. Migration of foci with time cannot be noticed at this reviewing graph, but could not be noticed even at graphs of higher resolution. Similarly, no significant correlations between depth and magnitude of events was noticed. Foci do not show any tendency to cluster around a tectonic fault cutting through the shaft–pillar. Their time and space distribution seems to be random.

In the Zone No 3 (Fig. 5C) the scattering of depth distribution is even higher than in the Zone No 2. There are much more foci lying under the seam up to depths

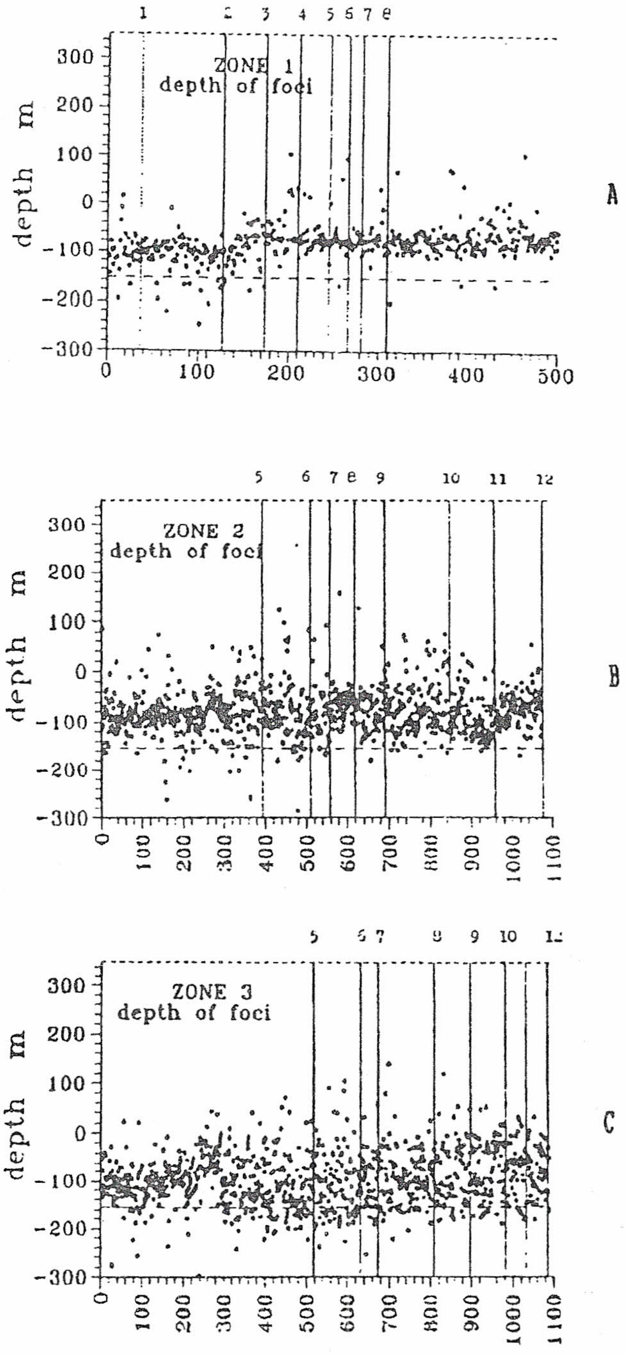

FIG. 5. Distribution of rockbursts foci with depth. A – within Zone 1, B – within Zone 2, C – within Zone 3

of about 50 m, where a contact between Carboniferous and Algonkian bedrock can be found.

### *3.2. Seismic Power*

Seismic power can be characterized by the course of cumulative amplitude graphs

2Y in time [Brož, Buben 1995]. The mean value of seismic power for a source zone is given by the slope of regression lines of these graphs.

In the Zone No 1 (Fig. 2C) there appears to be three time segments of stationary seismic power. The first segment with the highest power covers first 60 days of the year. The second time period with relatively lower power ends by the 130th day, and the third period, where the seismic power is at the lowest level, covers the rest of the year 1994.

In the Zone No 2 (Fig. 3C) there are no evident segments of stationary seismic power. One can see rather moderate and continuous fluctuations of the flow. The segments between days No 10, 90, 160, 230, and 320 show relatively constant power.

In the Zone No 3 (Fig. 4C) variations of the seismic power are very conspicuous. From the 70th day on, appears alteration of relatively short periods of rather increased seismic power with longer periods of low power. There is a general tendency of the power decrease with time.

Comparing the graphs, one can observe that seismic power variations in the individual zones are mutually independent. This is why any presence of external geodynamical processes (i.e. beyond the safety shaft–pillar), which could obvious by affect the rockburst activity, cannot be assumed. The mutual independence of activity in individual zones where the deformation energy is cumulated and released, implies that their dimensions can be assessed as tens to one hundred meters, which follows from the distances between foci localized in adjacent zones.

### *3.3. Seismic Power and Mining Intensity*

Covariance between seismic power and mining intensity variations in specified zones can be followed on a comparison between Graph A (the length of drifts driven per month) or Graph B (monthly volume of extraction) and Graph C (cumulative amplitude per month), given in Figs 1, 2 and 3. Unfortunately, daily reports about mining activities for individual mining places (drifts, stopes) are not at hand and therefore it is impossible to use shorter than monthly intervals. Conclusions are following:

Zone No 1. During first two months the drifting rate is high, while coal excavation is relatively low. Seismic power of the zone is high. From the second to the sixth months, the seismic power is high as well, however, it is connected with very great coal extraction rate, while drifting is at the minimum. The second half of the year shows low seismic power, which can be related to practically zero extraction and to very limited drifting. It is difficult to decide which of the two mining activities may have higher impact on the rockburst activity.

Zone No 2. Stationary seismic power during the first half of the year can be correlated with fast drifting but practically zero extraction rate. The situation in the second half of the year is vice versa: high extraction, and very limited drifting. Both mining activities seem therefore to be effective for the rockburst activity. A slight decrease of seismic power during July and August can be caused by minimum mining activities in the vacation period. Evaluation of time lags using monthly intervals does not allow to find shorter time delay in reaction of seismic to mining activities. It only can be concluded that it is shorter than one month.

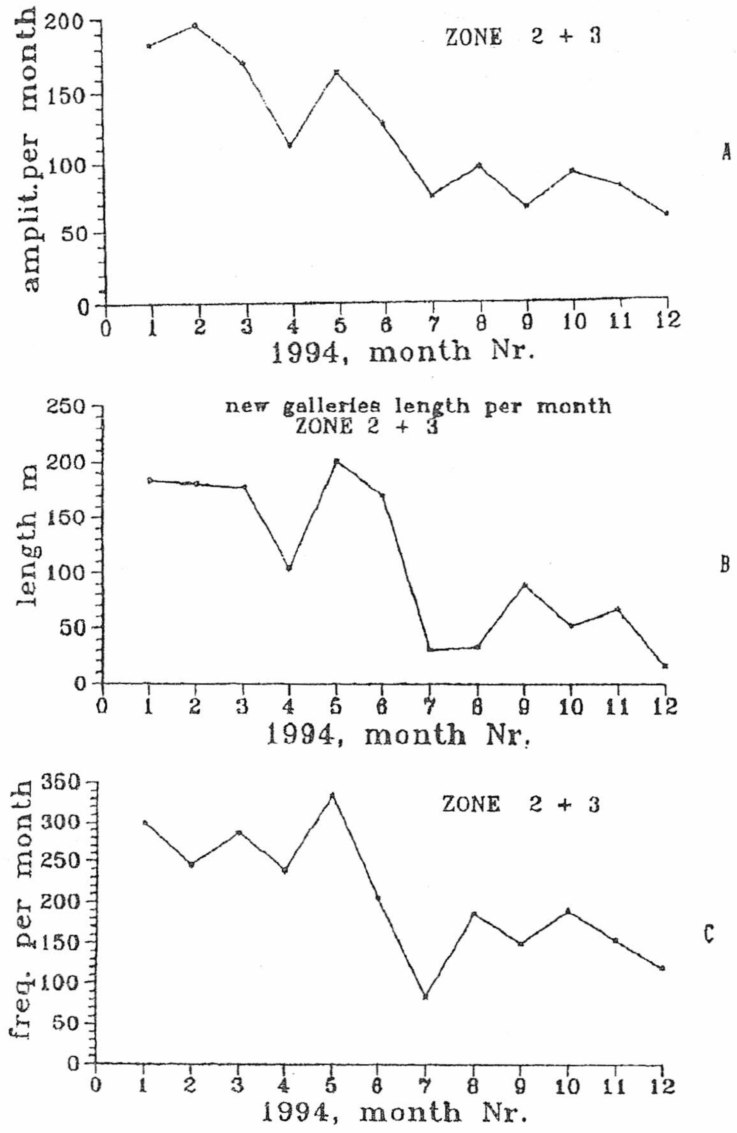

FIG. 6. Comparison of variations of the driving velocity and frequency of rockbursts within united zones 1 and 2, A – length of newly driven galleries per month, B – frequency of rockbursts

Zone No 3. In contrast with Zone No 1 and No 2, the correlation between seismic power and drifting rate is more pronounced. This can be mostly observed in the first half of the year, when the extraction was at a very low level. High increase of the extraction rate in the second half of the year did not affect the value of seismic power.

Covariation between drifting rates in new drifts (the monthly length of drifting) and the number of rockbursts comes from Fig. 6 and Tab. 2–4. In the Zones No 1

TAB. 2: Covariance length – frequency per month, Vin. 1994
$\frac{1}{n}\sum x_i^2 = 4514$, $\frac{1}{n}\sum y_i^2 = 5313$.

| $k$ | $F_{xy}(k)$ | $\frac{1}{n-k}\sum(x_i \cdot y_{i+k})$ |
|---|---|---|
| $-3$ | 0.12 | 623 |
| $-2$ | 0.19 | 964 |
| $-1$ | 0.60 | 2976 |
| 0 | 0.86 | 4228 |
| 1 | 0.28 | 1396 |
| 2 | 0.33 | 1620 |
| 3 | 0.31 | 1529 |

TAB. 3: Covariance length – amplitudes per month, Vin. 1994
$\frac{1}{n}\sum x_i^2 = 4514$, $\frac{1}{n}\sum y_i^2 = 2195$.

| $k$ | $F_{xy}(k)$ | $\frac{1}{n-k}\sum(x_i \cdot y_{i+k})$ |
|---|---|---|
| $-3$ | 0.32 | 1020 |
| $-2$ | 0.25 | 802 |
| $-1$ | 0.55 | 1748 |
| 0 | 0.90 | 2813 |
| 1 | 0.52 | 1647 |
| 2 | 0.36 | 1146 |
| 3 | 0.15 | 498 |

TAB. 4: Covariance frequency–cumul. amplitudes per month,
Vin. 1994; $\frac{1}{n}\sum(x_i^2) = 5313$, $\frac{1}{n}\sum(y_i^2) = 2159$

| $k$ | $F_{xy}(k)$ | $\frac{1}{n-k}\sum(x_i \cdot y_{i+k})$ |
|---|---|---|
| $-3$ | 0.34 | 1175 |
| $-2$ | 0.34 | 1174 |
| $-1$ | 0.36 | 1239 |
| 0 | 0.86 | 2940 |
| 1 | 0.55 | 1878 |
| 2 | 0.39 | 1336 |
| 3 | 0.17 | 592 |

and No 2 new drifts are driven 100 m to 250 m apart, which can result in mutual influence of corresponding seismic source zones. This is why the total length of new drifts (Graph A) and the total number of rockbursts (Graph B) is summarized in Fig. 6. The horizontal axis is divided into monthly intervals. Significant correlation between both graphs is very apparent. Drifting rate in mine design must therefore be considered as very important input data for rockburst prediction when using the optimum extrapolation of multichannel time series [Rudajev, Fučík 1982].

## 4. DISCUSSION

Foci of rockbursts are distributed at levels from 200 m above the seam to 100 m below it. Regarding the classification by [Knoll 1990], these rockburst events belong to the first type, being very closely connected with the mining face.

The mechanical model of the rockbursts is shear–implosional. The rockburst focus consists of a linear shear dislocation and of an implosive component assuming the case of mine openings subjected to compressive stress concentrations [Rudajev, Šílený 1985].

It is the operational short–time prediction of strong rockbursts which is most important regarding the safety in mining operations. Because of that, quite a time has been devoted to the experimental registration of seismoacoustic foreshocks in the operational mine drifts of Kladno mines. Up to now, simple and reliable enough precursors were not found.

Such a negative result may be partially due to the geophone location on the drift walls, i.e. at a distance of up to 200 m from rockburst foci, which occur in underlying as well as overlying beds of the drifts. Due to the attenuation of seismoacoustic waves (frequency about 600 Hz), the seismoacoustic emissions (from close vicinity of future rockburst foci) were probably covered by disturbing impulses of technical origin (loading of coal and muck, transport, drilling and blasting, ventilation buzz, etc.).

The main problem comes from the method of using seismoacoustic impulses as foreshocks. Generally it is known that foreshocks of natural tectonic earthquakes were not proved to be reliable precursors. On the other hand, it was proved that local stress concentrations in rockmass (reaching a level necessary for brittle fracturing) lead to the occurrence of aftershock sequences. They are caused by stress redistribution, that comes from the foregoing brittle fracturing in rockmass. A reliable precursor of strong rockbursts can therefore be expected to be the occurrence of seismoacoustic impulses (aftershocks) induced also by standard mine blasting works used for drifting or coal extraction. An important impact of such blasting (which can be easy characterized by proposed frequency of blasts or by the whole consumption of prepared explosives) on rockburst occurrence was newly proved in [Brož, Buben 1995].

The practical use of this prediction method needs the progress in developing a robust seismoacoustic equipment for computerized monitoring and automatic interpretation of seismoacoustic sequences in the overburden of coal seam induced by standard mining blasting. The solution of problem consists of the following steps:

1) High frequency geophones to be installed into the near–to vertical boreholes (length about 5 m) being bored near the face of a progressing drift or stope, in mutual distances of about 10 m.

2) Output signals from at least two geophones to be amplified, filtered and transmitted to the pithead mine observatory using current mine telephone lines.
3) Digital equipment for monitoring seismoacoustic impulses to be developed (e.g. on the basis of MARK GMA-15 KALENDA) complete with software for automatic triggering and evaluation of the characteristics of induced aftershock sequences. The monitoring period should last several tens of minutes after each blast, when the mining crew is not presented and the signal-to-noise level reaches its maximum possible value. Automatic evaluation of the sequence record must immediately provide the prediction of instantaneous rockburst hazard (warning message) before the crew comes back to its working place in the mine.

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