ACTA MONTANA IRSM AS CR (1994)
Series A7, No (96), 65–74

DISJUNCTIVE STRUCTURES WITHIN THE SHAFT PILLAR – KLADNO MINE NO. 2

Robert BROŽ

Institute of Structure and Rock Mechanics, Academy of Sciences of Czech Republic
V Holešovičkách 41, 182 09 Prague 8, Czech Republic

Abstract. The acquaintance with parameters of disjunctive structures in the shaft pillar is an indispensable condition for controlling the expected deformations of the rock mass. Some geometric elements of the studied discontinuity planes, such as strikes (directions), sense and angles of slope and, above all, frequency values have been defined. In fault structures, the relative displacement has been mentioned. The results have been processed both in rosette diagrams

Disjunctive structures are considered as important geological factors, which together with other (e.g. mechanical) ones, occurring during the mining operations, adversely affect the original equilibrium within the rock mass and are a frequent cause of rock pressure phenomena (detonations and rock bursts) in burst–prone areas, where this mine belongs. According to the own classification of the Kladno–2 mine, 1768 rock bursts of various intensities have been recorded within the shaft pillar during the year 1993.

Introduction

The investigation of disjunctive structures within the shaft pillar of shafts Mayrau and Robert was aimed at the determination of characteristics of both the fault and joint structure with special reference to geometric elements in connection with the rock–bursting properties of some rock mass parts. The analysis of these discontinuity planes revealed their distribution within the studied rock mass part. The obtained results were used for different parametric measurements in situ and later as input data for the constructed shaft pillar model.Mine maps were used in the investigation of fault structures and measurements of the joint structures were made within the main Kladno seam (MKS).

Situation of the Deposit

The investigated part of the pillar is situated within the catastral territory of communities Vinařice, Švermov and Libušín [Horný et al. (1963)]. The main Kladno seam, where the measurement of discontinuities took place, belongs to the Radnice strata series (lower Radnice strata) and has been encountered at the depth of 515 m. The stratigraphy of the investigated area has been described in detail by R. Živor [Živor (1993)] and is therefore not reproduced here. The pillar has the diameter of about 400 m and MKS attains here the thickness of 699 to 870 cm. The claritic–vitrinitic coal component prevails in this seam. The dip of MKS within the pillar is subhorizontal (6–8°) and the prevailing slope strike is towards NNE to NE with minor deviations. Stratigraphically important tuffogenic partings and arenaceous marl maintain here about the same thickness and, in the same time, also the distance each from the other. Within the investigated area, situated in the lower part of the MKS, the thickness of the "big" arenaceous marl varies from 12 to 15 cm, above it there are "small" marls of 4 to 6 cm and the roof marls are 10 to 15 cm thick. Between the roof and "small" marls there are three more marl positions with a relatively small thickness (1–3 cm). The roof marl (slate), which developed everywhere, proves that the eventual erosion did not reach up to the highest positions of this seam, which had the possibility to be formed in full thickness during the sedimentation.

In the hanging wall of the MKS, there occur mostly dark grey claystones or even grey–black siltstones (soapstones). The main substance of these mostly siltstonic rocks is formed by irregularly arranged flocks or aggregates of kaolinite and sericite. A small quantity of siderite acts as bonding agent. The coal substance then impregnates this rock quite intensively. The overlying rock of these claystone–siltstonic rocks is formed by thick banks of bright–grey to grey sandstones and conglomerates. The structure of these sandstones is psamitic, medium to coarse–grained, with small quantity of siderite as bonding agent. In conglomerates, the quartz boulders with size 0,4 to 2–3 cm prevail. Under the MKS there occur dark–grey to grey–black claystones. Their thickness varies within several tens of cm and they contain residues of stigmarian roots. Their bedrock contains, at places, bright–grey to grey, strong laminated siltstones ("whetstones") and under them again white–grey tuffogenic sandstones, called "whitestones" (bělka). The thickness of tuffogenic siltstones ("whetstones")is not the same within a broader shaft area (being 0,7 to 2,6 m thick), but attains mainly 1,0 to 1,5 m. The whitestones of the whetstones horizon are less thick (50–70 cm), but elsewhere (e.g. SE from the Mayrau shaft and in the mine field Robert) they use to be thicker (up to 1,6 m). The subsoil of the whetstone horizon is formed by the low–grade basic Kladno seam with thickness of about 1 m, which has never been mined; about 32 m below this seam, phyllitic slates (upper Proterozoic) can be found.

Fault Structure within the Shaft Pillar Area

The faults found out are mostly of the post–Permian age, mostly of the Saxonian tectogenesis. At the same time, also younger faults, most probably of the Pliocene age, take part in the structure of this mining district. The prevailing majority of the occurring fault structures is oriented diagonally to the direction of the alpine folding and of the main pressure within the rock mass of this area,which acted from S to SE [Přibyl, Rudajev (1969); Přibyl et al. (1972)]. Faults of the "Sudetian" or NW direction (NW–SE), resp., created, within the entire Kladno coal basin, a system , which divides the basin into partial floes, where the dip–slip faults and liftings formed grabens and elevations [Collective of authors].

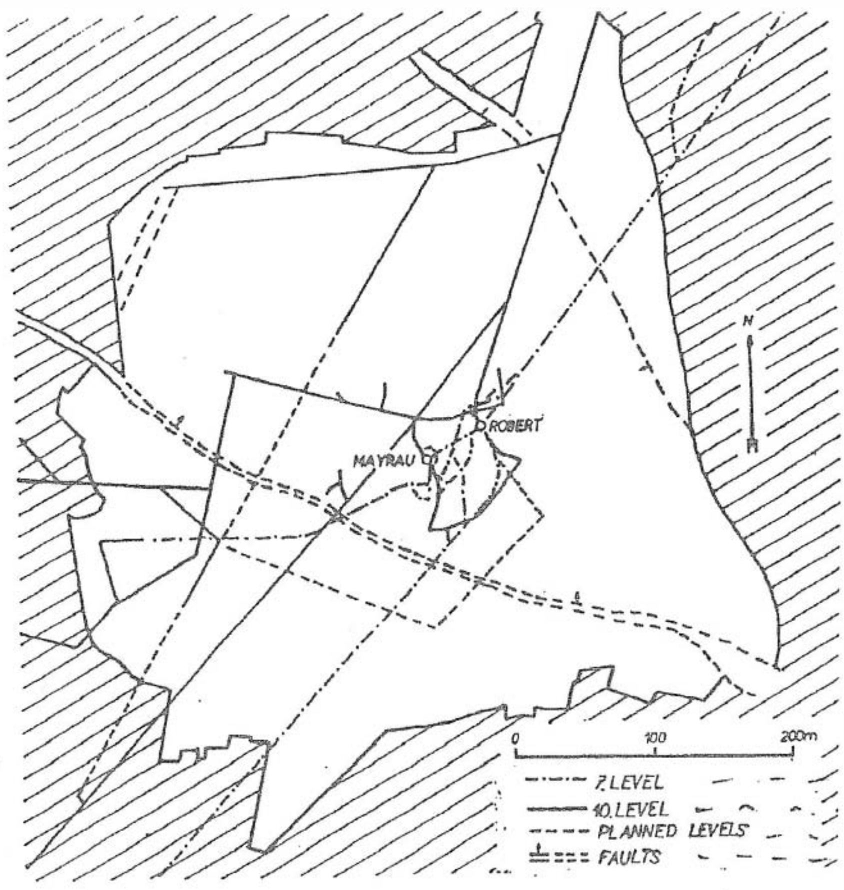

FIG. 1. Situation of the shaft pillar

From the genetic point of view, the recorded faults can be classified, in most cases, as shear faults, i.e. dip–slip faults, horizontal displacements, and to a lesser extent as tension faults, which illustrates their function as feed paths for deep melts (Vinařická hora and Slánská hora) [Brož (1990)]. Within the shaft pillar, there runs, to the W from the Mayrau shaft, an important fault structure of first order in the direction about NW to SE, with a dip sense towards NE, under the angle of about 70° [Přibyl, Matějovský (1977)]. In this direction, the northeastern tectonic floe subsided by 11 to +15 m lower and displaced thus the coal seam. This was the reason why on the part of an crossing gateway, the sandstone hanging wall of the main Kladno coal seam has been discovered there. This fault,which is accompanied by a series of partial faults, is designated as Mayrau fault.

Another big fault of the first order runs through the northern part of this mining district, that means NNE from the Mayrau shaft. This fault runs also in the direction from about NW to SE (300–315°) with the dip sense towards SW, with dip angle within the range from 40° (in the neighbourhood of the Robert shaft) to 60° (in the northern part of the entry No. 2175), displacing the main Kladno seam mostly by 7,5 m – this in the northern part. In the neighbourhood of the Robert shaft, the skip height does not exceed 1,8 m (Fig. 1).

For the determination of the fault frequency (relative fault number – RFN), the relation of their number per unit area of 10 000 m^2 [Brož (1982)], given by the coordinate network, has been used.

The whole pillar area was then divided into 24 fields of the mentioned area. Altogether 34 faults were recorded and their directional data were processed into Table 1. and graphically into the rosette diagram (Fig. 2). Values of RFN are plotted as average values in semicircular rose (rosette) diagrams, which include all recorded faults and are there illustrated in the respective directions.

Their relative abundance can be read on the horizontal scale of faults numbers (RFN) from 0 to 2. The total value RFN in this pillar zone is expressed also by a single number, which is given by the sum of RFN in individual directions of the rosette diagram (pillar – RFN = 1,5).

TABLE 1. Fault structures within individual directions (strikes)

	direction [°]					
	0–15	16–30	31–45	46–60	61–75	76–90
n	—	—	—	—	1	—
RFN	—	—	—	—	0,07	—
%	—	—	—	—	2,9	—

	direction [°]					
	91–105	106–120	121–135	136–150	151–165	166–180
n	3	7	12	9	2	—
RFN	0,13	0,30	0,50	0,40	0,10	—
%	8,8	20,6	35,3	26,5	5,9	—

In this Table, the following faults directions can be specified as most expressive:

1 – Direction NW–SE (121°–135°), with the dip sense mostly towards NE (⊣) and dip angles from 35° to 70°. The displacement amplitude (skip height) in this direction with the dip sense towards NE varied within 1,6 m to 15,0 m. It should be pointed to the fact that a higher displacement amplitude was established only at the big faults of the first order, i.e.at the Mayrau fault, which runs SW from the shaft (15,0 m) and then at the fault intercepted NE from the mentioned shaft (7,0 m). The inverse dip sense (⊢) of faults in this direction, i.e. towards SW, was characterized by the displacement amplitude from 1,2 m to 2,7 m. This fault direction was represented by 35,3 % within the pillar.

2 – Direction about NNW–SSE (136°–150°), almost exclusively with dip sense towards SW. The dip angle varied from 29° to 60° and the displacement amplitude from 1,0 to 12,0 m, where the higher amplitude was bound to both the above mentioned outstanding faults. The percentual representation of this direction was 26,5 %.

3 – Direction WNW–ESE (106°–120°), where the dip sense was exclusively towards NNE (⊣) and the dip angle varied from 22° to 70°. The displacement amplitude varied from 1,1 m to 11,2 m, the maximum being bound to the fault of first order. The percentual share of this direction was 20,6 %.

The displacement amplitude (skip height) varied within the investigated shaft pillar from 1 m to 15 m, and the highest values were bound again to first order faults. Most frequently represented were the ranges of up to 2,0 m (33,3 %) and 6,1 to 8,0 m (33,3 %). The remaining amplitude ranges were less expressive.

When the fault direction NW–SE (121°–135°) including the dispersion variance (106°–120°) is considered dominant, the prevailing dip towards NE (⊣) is evident, attaining, within the investigated structures, 73,7 %. In remaining directions of these discontinuity faces the reverse dip (⊢) prevails.

Another investigated geometrical parameter concerned the angular values of fault structures. From 34 recorded faults, the angular values were checked in 24 of them, for remaining ones these values are not mentioned.

Steeper dip angles were found at the Mayrau fault, in the NW part of the pillar. In the direction towards SE, the dip angle of this fault decreased below 60°. Generally, the faults occurring within the pillar can be characterized as faults with dip angles of up to 60°, the occurrence of wider angles being limited to 29,2 %. Most frequent were angle values within the range of 51°–60° (33,3 %). The distribution of angle values of recorded faults is given by Table 2.

TABLE 2. Dip angles of fault structures

	Dip angle [°]								
n/%	0–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80	81–90
n	—	—	3	2	4	8	7	—	—
%	—	—	12,5	8,3	16,7	33,3	29,2	—	—

The prevalence of dip angles below 60° corresponds with the classification of this shaft pillar into the "burst–prone areas" on the basis of the dip angle values. Dip angle data belong to important geometric characteristics of fault structures due to the dissimilarity of their values in burst–free and burst–prone areas [Brož (1982)].

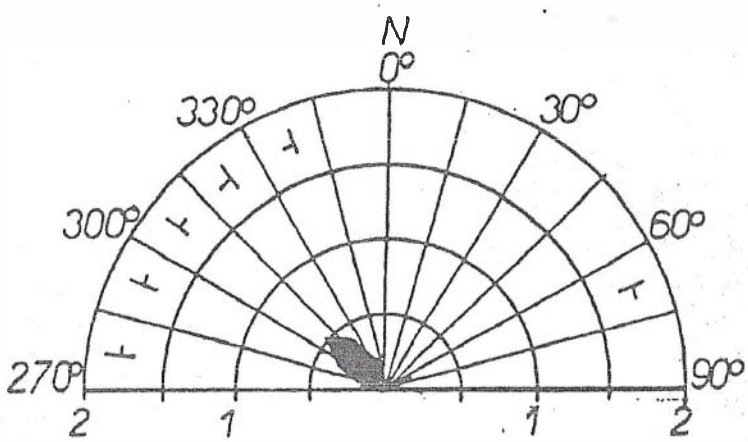

FIG. 2. Fault structures. RFN = 1,5

The frequency of fault structures is another important geological factor in categorization of burst–prone and non–bursting areas of the Kladno coal district. It should be pointed out, from the viewpoint of faultiness of the investigated shaft pillar, that the relative fault number (RFN) for the mine district Mayrau, whose part is the mentioned pillar, had the value of 4,8, while the pillar itself 1,5. The comparison of these RFN values illustrates the lower faulted condition (by $\leq$ 64,3 %) of the shaft pillar. This fact confirms the risk of the occurrence of rock bumps on the basis of the evaluation of fault frequency within the non–bursting and burst–prone zones of this district. The boundary value between the non–bursting and burst–prone areas varies within 5,0 to 5,9 RFN. Lower values determine the area as the burst–prone one.

Joint Structure within the Studied Area of the Mayrau Pillar and in its Wider Neighbourhood

The joint (fracture, crack) structures belong to the most wide–spread structures of the mezoscopic category and they are distinguished from the fault structures by the displacement measure. The extent of displacements on individual joints is from geological standpoint negligible and, so far it is perceptible or even significant, it concerns rather small fault surfaces. As joint (fracture, crack) structures only such of them are denoted, which are clustered more densely and have the same orientation, approximately the same frequency and plane surface quality.

Within the coal seam, there occur two kinds of join structures, the primary ones and – as more pronounced – the secondary structures.

As primary structures, the endogenic joints can be specified, as they are connected with the coalification process and are denoted as contraction joints, bound to glossy coal positions. Further, there are joints connected with tectonic origin, which occur within the coal seam and both in its bedrock and hanging wall, are differently oriented and have a variable dip angle. At places, these joints are filled with a white substance, mostly kaolinite, and due to banded condition of coal substance they are continuous. Further joints, which may be denoted as secondary, originated within the fields of increased pressures, are connected with the surrounding of mine openings and their occurrence is due to mining activities. They use to be open and are denoted either as cracks (fissures) or genetically as tension joints. Often they do not follow a linear course.

Among all these discontinuity planes, at the measured sites of the coal seam, joints of the tectonic type were particularly investigated in order to establish the faulted condition of this special part of the rock mass. As some mine working both in the shaft pillar and in its neighbourhood are actually inaccessible, some information from precedent years (Chňáře entry – 1985), completed by values from actual measurements, were used for the evaluation of joint structures.

Strikes (Directions) of Joint Structure

This geometric element of joint was studied, within the pillar, mainly as far as the variability of directions and formation of zoned are concerned. Directions of these zones were plotted in a semicircular rosette diagram, which is easier to take in than other charts and gives better information not only on prevailing directions, but also on dip senses of these discontinuity surfaces. In an aggregative semicircular rosette diagram, we see on the Y–axis values of the relative joint number (RJN) from 2 to 8, which characterize the average frequency of individual joint strikes (directions) pro 1 linear meter (1 ℓm) calculated from all measured sites within the investigated area. The total relative joint frequency (RJF) of the area, which is given by the sum of RJF of individual joint strikes, is mentioned to the right of the rosette diagram.

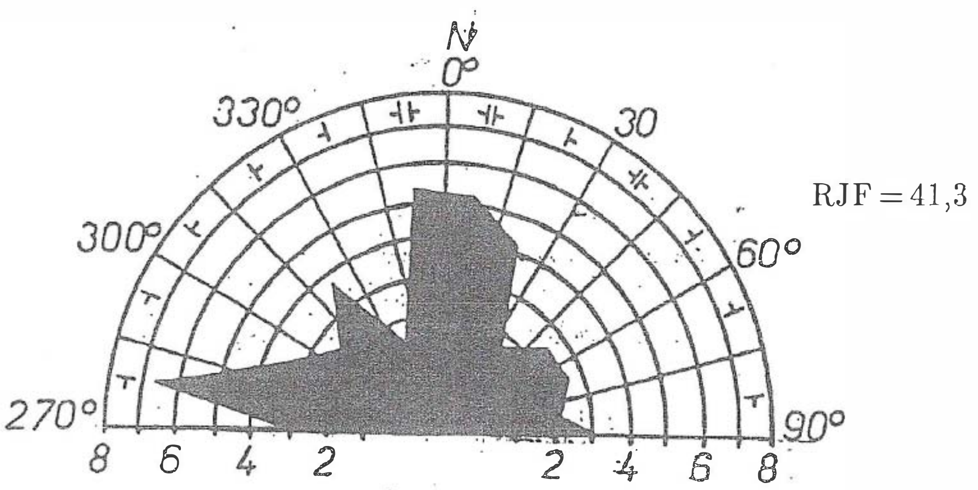

FIG. 3. Joint structure

Within the shaft pillar area, the following outstanding strikes (directions) of joint structures can be specified (Fig. 3):

1 – Direction about W–E (270°–285°) with dip sense towards S and dip angle 70° to 90°. The relative joint frequency of this strike is 6,9.

2 – Direction about N–S (range from 0° to 15° and from 165° to 180°. RJF of this strike is 5,4.

3 – Direction about NW–SE (315°–330°), mostly with dip sense to NE and dip angle of 70°–90°. The RJF of this strike is 3,8. This strike is not very expressive, bur copies the main strike of faults occurring within this area of our interest.

FREQUENCY OF JOINT STRUCTURE

This element of joint structures is one of the most important for the evaluation of burst–prone and non–burst areas. Assuming that a rock mass less affected by discontinuity planes creates favourable conditions for the possible occurrence of rock bursts (rock bumps), sites with a higher frequency of joint could be considered non–bursting [Buben, Rudajev (1976)]. The frequency was evaluated by means of the relative joint frequency (RJF), which meant the number of joints pro linear meter (ℓm), measured perpendicularly to the joint system.

The frequency of joints within the broader area of the shaft pillar had the value of RJF = 41,3. This low number ranges this area among burst–prone ones, differing from the other non–bursting areas by lower frequency of joints. In non–bursting areas is the frequency of joints much higher (by 40 % to 100 %), varying within the range of 60 to 80 [Brož (1985)]. Although the shaft pillar has the diameter of the order of 400 m, the frequency of joints within the main Kladno seam is not distributed uniformly. In the northern part, the RJF varies within 32 to 40 and in the southern part it increases to 45–52 joints/m. For the investigated area, it is possible, basing on measured elements of joint structures and using data from previous reports from actually inaccessible regions (Chňáře entry – 1985), to specify their relative representation.

Table 3. Occurrence of joints in individual strikes RJF = 41,3

	direction (strike) [°]					
	0–15	16–30	31–45	46–60	61–75	76–90
n	5,1	4,2	1,7	2,4	2,6	2,1
%	12,3	10,2	4,1	5,8	6,3	5,1
	direction [°]					
	91–105	106–120	121–135	136–150	151–165	166–180
n	6,9	3,3	2,3	3,8	1,5	5,4
%	16,7	8,0	5,6	9,2	3,6	13,1

When evaluating the values of joint dip angles, the main share was established for the range 80°to 89°. The other, through less frequent range of dip angles was 76° to 80°. The right angle (90°) does not occur at all and is therefore not considered important for this evaluation. Mentioned values hold the joint length, which has also been followed in the main Kladno seam, reveals the highest frequency from 10 cm to 15 cm. The occurrence of longer joints, i.e. up to 40 cm and more was also established, but this maximum length was relatively rare. Generally, the joint lengths from 5 cm to 30 cm can be considered dominant.

Conclusions

1 – Fault structures

a) Dominant faults are concentrated into the strike zone from WNW–ESE to NNW–SSW (106°–150°);
b) the dip sense towards NE prevails (73,7 %);
c) increased frequency of faults with the dip angle lower then 60° (70,8 %). This circumstance ranges the investigated part of the rock mass into the "burst–prone" areas – in agreement with the gathered experience and information with non–bursting and burst–prone areas of the Kladno coal district;
d) considerable reduction of the RFN (1,5) within the wider Mayrau range, by 31,3 %, this reduction increasing the risk of occurrence of rock burst;

e) most frequent displacement amplitudes (skip heights) are those of up to 2 m (33,3 %) and within the range from 6,1 m to 8,0 m (33,3 %).

2 – Joint structures

a) the following joint directions (strikes) are:
   - directions about W–E (270°–285°) with dip sense towards cca S a dip angle from 70° to 90°. RJF of the mentioned strike has the value of 6,9 %;
   - direction about N–S (range from 345° to 360° and 0° to 15°) with the dip angle to both sides and dip angles from 80° to 90°. RJF = 5,4;
   - direction about NW–SE (315°–330°), mostly with dip sense toward NE and dip angle of 70°–90°. This inexpressive direction is the same as the main strike of faults and has the value of RJF = 3,8;

b) Most frequent dip angle varied within 80° to 89° for both dip senses;

c) the join length varied mostly up to 30 cm and the lengths of 10–15 cm were most frequent;

d) from the genetical viewpoint, most joint can be considered shear joints, owing to the smooth character of surfaces. Less frequent are tension joints, which have a coarse (rough) character of joint walls and are frequently filled with bright to white kaolinite. In this case, the contraction joints in glossy coal substance positions are not taken into consideration.

The above described values of disjunctive structure will be completed later by further measured sites within the shaft pillar especially in the hanging wall, with the aim to follow the development of these discontinuity planes during the mining operations within the area.

REFERENCES

Brož R. (1982), *Geometric elements of fault structures within the non-bursting and burst-prone areas of the mine Kladno coal district*, Acta Montana **61**, 333–350. (in Czech)

Brož R. (1985), *Characteristics of the joint structures within the non-bursting and burst-prone areas of the Kladno coal district*, Acta Montana **71**, 93–102. (in Czech)

Brož R. (1990), *Characteristics of fault structure within the area of DP Kačice (KD Kladno)*, Acta Montana **83**, 7–20. (in Czech)

Buben J., Rudajev V. (1976), *Kinematic location method of rock-burst foci*, Research report HOÚ ČSAV, Praha.

Havlena V., Pešek J. (1975), *Lithostratigraphic zoning of the Central-Bohemian Carboniferous*, Sborník Západočeského musea v Plzni, Příroda **11**, 1–86. (in Czech)

Horný et al. (1963), *Explanation to the geological map of Czechoslovakia, 1 : 200 000, M33–XV*, Geofond Praha, Nakl. ČSAV. (in Czech)

Přibyl A., Rudajev V. (1969), *Location of rock-burst foci within the area of the Kladno mine Gottwald II*, Uhlí **11**, no. 3. (in Czech)

Přibyl A., Polák V., Buben J. (1972), *Geological, mechanical and seismic characteristics of rock samples obtained during the sinking of Nejedlý III shaft in Kladno–Libušín*, Research report HOÚ ČSAV, Praha. (in Czech)

Přibyl A., Matějovský J. (1977), *Effect of geological factors on the faulted condition of the rock mass in the neighbourhood of mine openings with view of the occurrence of rock bursts in the Kladno coal district*, Research report HOÚ ČSAV, Praha. (in Czech)

Collective of authors, *Tectonical development of Czechoslovakia*, Ústřední ústav geologický, Nakl. ČSAV, Praha 1961. (in Czech)

Živor R. (1993), *Geological conditions in the Vinařice allotment of the Kladno coal mine*, Acta Montana **A5**(92), 53–67.