Acta Montanistica Slovaca Ročník **13** (2008), číslo **1**, 58-65

Influence of Mining Activity on Selected Landslide in the Ostrava-Karviná Coalfield

Marian Marschalko[1], Matěj Fuka *and* ***Lubomír Třeslín***

Vliv hornické činnosti na vybraný sesuv v Ostravsko-karvinském revíru

The paper deals with the impact of undermining on the slope deformation Doubrava Vrchovec. For the evaluation of the impact, isocatabase maps, terrain deformation parameters calculated for slope deformation, length measuring by zone extensometry and dilatometric measuring in the cracks of an asphalt road have been used. The length and dilatometric measuring identified the direction of slope deformation movement corresponding to the direction of rock mass movement as the consequence of undermining. With regard to the fact a change in the longitudinal relative deformation values in the direction of the subsidence slope gradient was evaluated (in the direction of the slope deformation movement). During the monitored period, terrain surface compression occurred, which manifests the position of the slope deformation in the concave portion of the subsidence slope. This fact probably induces additional strain from undermining in the slope deformation, which may worsen its stability conditions.

Key words: *engineering geology, slope deformations, mining, undermine*

Introduction

The landslide Doubrava Vrchovec lies in the cadastral district of the municipality of Doubrava, approximately 20 km from Ostrava in the Moravia-Silesian Region (Fig. 1). It is situated in the working district of Doubrava Mine on an area affected by the impact of undermining. Doubrava Mine makes part of OKD a.s. company, which co-operated by providing all the necessary data. The slope deformation is examined from the point how it is affected by the progress of the subsidence trough as well as the surface demonstration of the underground mining.

Fig. 1. Localization of Doubrava Vrchovec landslide.

The geological structure of the locality (wider area) can be characterized by Brunovistulicum rock basement, which is overlapped with Devonian and Carbonian sediments. In the Upper-Silesian Basin, the Upper-Carbonian deposits are stratigraphically divided into Ostrava (paralic coal molase) and overlying Karviná strata series (continental coal molase). The roof is formed by Badenian deposits, the sedimentation of which was caused by the formation of the Carpathian Foredeep in the foreland of the Outer Flysch Carpathians. Especially those Miocene (Badenian) sediments form a large part of the slope deformation Doubrava Vrchovec. In the surface sections there are Quaternary deposits of various types and thicknesses.

A geological survey in the locality determined Miocene sediments of a high plasticity character of calcareous, fine silty claystone of a greenish grey colour with weathered surfaces in places and rusty brown colour. On the surface of the Miocene sediments there is their eluvium, which has the form of a greenish grey to rusty streaked clay, decalcified to calcareous. The slope and fluvial sediments mainly represent the stream deposits of the Kotlinský Stream. They are predominantly represented by blue-grey and brown-grey high-plastic clays with abundant wooden chips and isolated boulders of a glacigenous origin. Coarse-grained sands badly sorted out, of a grey-yellow colour mainly formed by Nordic materials and silica

[1] *doc. Ing., Marian Marschalko, Ph.D., Ing. Matej Fuka, Ing. Lubomír Třeslín,* Hornicko geologická fakulta, VŠB-Technická univerzita Ostrava, tř. 17. listopadu, 708 33 Ostrava-Poruba, Tel: +420/596993505, Česká republika, marian.marschalko@vsb.cz
(Recenzovaná a revidovaná verzia dodaná 25. 2. 2008)

grains, and in a smaller extent present sandy clays and positions of fine-grained gravels of a grey, reddish or blue-grey colour represent glacigenous sediments of salic glacial age. The sediments of the Elster glacial have the form of greenish-grey silty non-calcareous clay with the position of medium-grained to coarse-grained clayey sands with fine quartz pebbles and Nordic materials. Humic soils on the majority of the interest area enclose the succession of Quaternary sediments, which are refilled in places by embankments of spoil, ash and materials used for partial improvement of the landslide (waste rock, slag).

Methodically, the impact of undermining on the slope deformation was evaluated on the basis of correlation of the subsidence trough development along the direction of gradient and slide location by means of isocatabase maps, changes in the terrain deformation parameters in time monitored on the slope deformation and regular dilatometric and extensometric measuring on the slide-prone slope surface. In the year of monitoring in the vicinity of the locality in question, possible accelerators of slope movements in the form of rainfall were examined, as a general, frequent starting mechanism of slope movements (see Terrain deformation parameters).

Slope deformation related to the subsidence

The formation of a subsidence trough on an undermined area can trigger a new slope deformations or changes in the gradient, slope state of stress, structure, physical-mechanical properties of the slope material, ground water levels, etc. may cause the reactivation of alleviated slope deformations. Vertical and horizontal spread of a subsidence trough as well as its own formation and related terrain deformations are direct manifestations of mining of one or more faces not only within Ostrava-Karviná District (OKR).

The least positive area of the subsidence trough is its slope, on which deformations caused by the rock movements into the centre of the mined out area show the most. The subsidence slope has a characteristic shape and its parts are generally labelled (from the slope crest) as convex portion, point of inflection and concave portion (Fig. 2). At the localization of the slope deformation in the point of the subsidence slope two critical situations can appear in dependence on their mutual surface areas. I f the landslide takes up a larger area than the subsidence slope, deformations characteristic for the convex portion, point of inflection as well as the concave portion of the subsidence slope will show. In the opposite case the overall slope deformation is situated in one part of the subsidence slope.

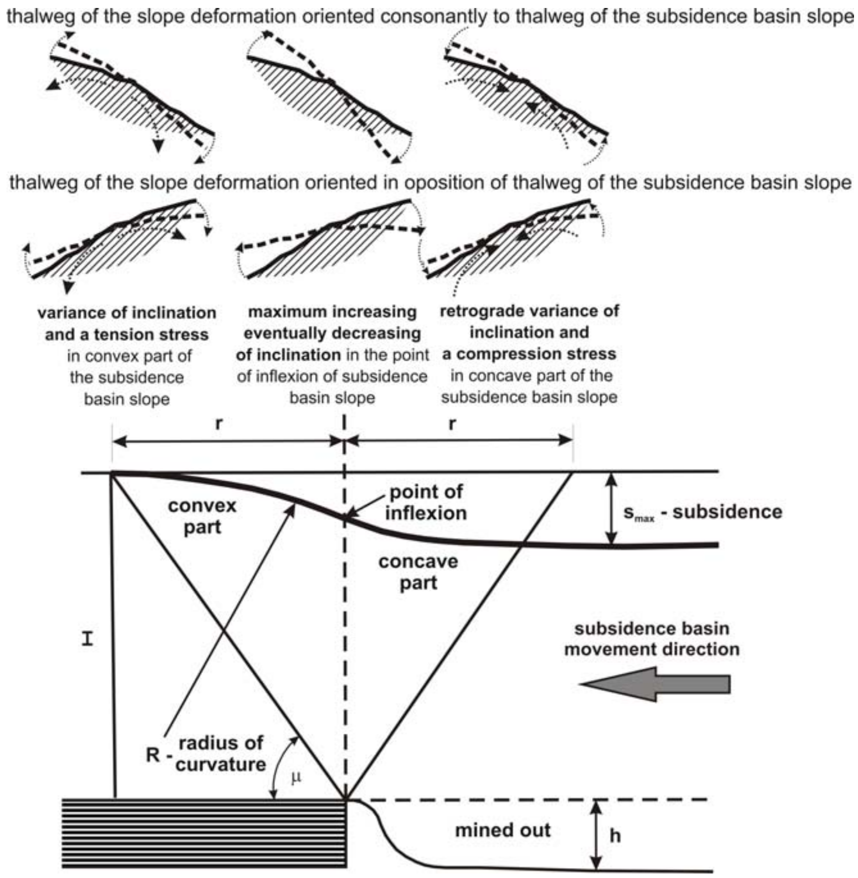


Fig. 2. Schematic representation of influenced slope deformation by the subsidence slope at analogous and inverse orientation of their thalwegs.

From the point of the mutual position of the slide thalweg and the subsidence slope thalweg four situations can be theoretically determined. The first will occur when both thalwegs are analogous; the second when they are inverse to one another, while those two situations can be labelled as extreme with regard to the maximum enlargement or reduction of the gradient. The third situation corresponds to the state when the thalweg of the slope deformation perpendicularly faces the subsidence slope thalweg and the fourth when they are in a general angle to one another.

The mining activities can cause a relative increase in the groundwater level (terrain surface depression), which can in the largest extent be observed on the bottom of the subsidence trough. This usually causes saturation or waterlogging of the slope, which can worsen the stability situation of the slope. In certain cases the terrain depression can lead to the formation of drainless depressions (lakes or small lakes).

The investigation of a slope deformation is carried out only in the case when a failure in its stability can cause damage to the structural engineering. Similarly, terrain subsidence and follow-up terrain surface deformation is evaluated in terms of the impact on the structural engineering. According to ČSN 73 0039 Standard – Design of premises on undermined areas, the impact of undermining on the structural engineering is characterized by groups of building sites. On the basis of the terrain deformation parameter values (horizontal relative deformation, curve radius, inclination or maximum subsidence and horizontal advance) five groups of building sites are determined (the fifth degree represents minimum influence), while the relevant classification is decided on the basis of the least favourable value of all the examined parameters.

Impact of undermining on the Doubrava slope deformation

On the basis of isocatabase maps and four time intervals since the beginning of surface levelling in 1983 (provided by the company of OKD a.s.) a general **subsidence trough advance direction** can be interpreted in the vicinity of the slope deformation Vrchovec and changes in the subsidence trough gradient can be localized and described.

The gradient of the slope deformation Doubrava Vrchovec is oriented north-north-eastwards, while the subsidence slope thalweg has a northwards direction in its maximum point in the first period 1983 – 1990. In the region of the slope deformation the subsidence slope is gentler with the north-western thalweg. The maximum subsidence of 200 cm can be observed westwards of the slope deformation. In the lower part of the slope deformation there is an apparent drop of 125 cm and of only 75 cm in the upper part, which manifests an increase in the gradient (Fig. 3).

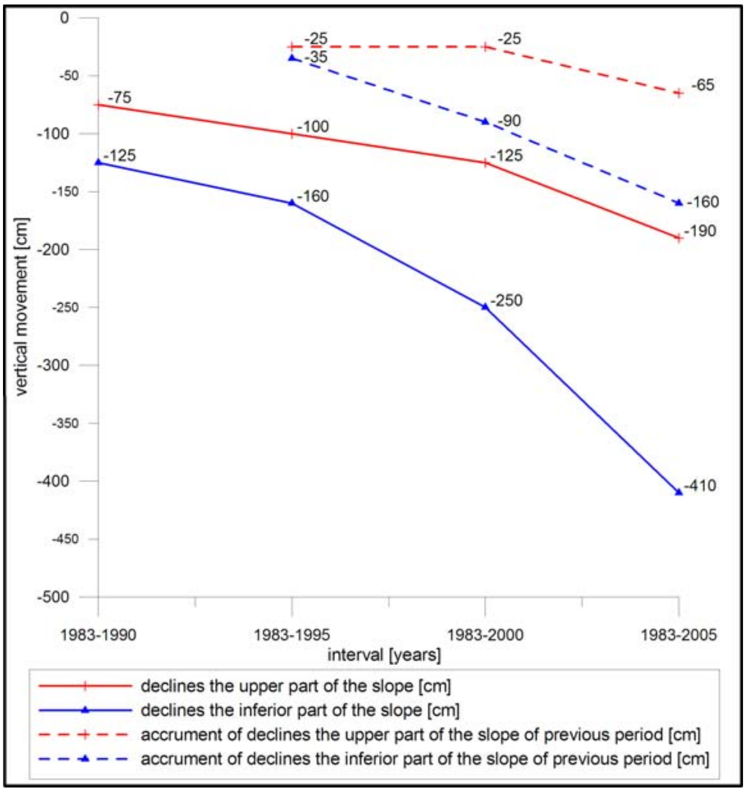
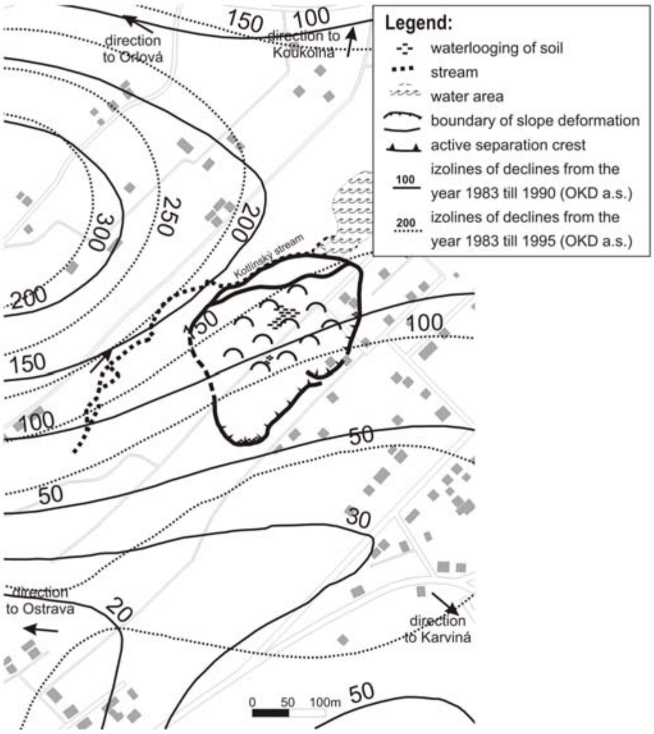
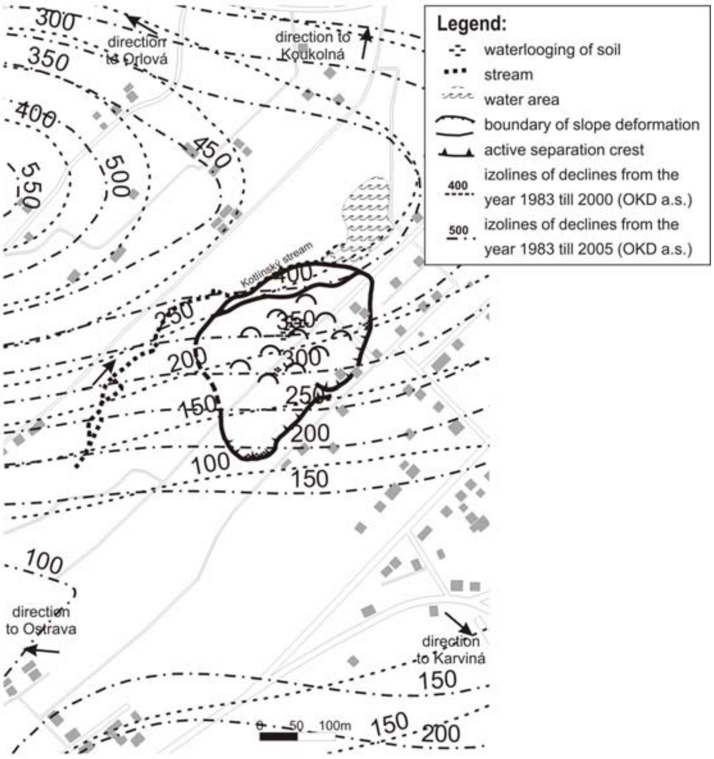


Fig. 3. Subsidence caused by undermining in the upper and lower parts of the slope deformation Doubrava Vrchovec.



In the course of the next five years till 1995 (Fig. 4) there is an apparent, similar shape of the subsidence trough and the subsidence slope gradient in the point of the slope deformation corresponds to the approximate ratio 1:240. The steepest slope of the subsidence trough can be observed in the vicinity of the slope deformation; the maximum subsidence is similarly situated as in the previous period.

Fig. 4. Subsidence caused by undermining in the periods of 1983 - 1990 and 1983 - 1995 with marked positions of the slope deformation.



Subsidence caused by undermining between 1983 and 2000 reach higher values again (about 125 cm in the upper and 250 cm in the lower part of the slope); the subsidence slope gradient in the point of the slope deformation rises (approx. 1:180) and its thalweg direction faces north-north-west. Thus there is an apparent approximation in the direction of the slope deformation thalweg (Fig. 5).

Fig. 5. Subsidence caused by undermining in the periods of 1983 - 2000 and 1983 - 2005 with marked positions of the slope deformation.

Until 2005 it is possible to notice the maximum subsidence of 550 cm westwards of the slope deformation, while the subsidence increase was about 100 cm in that period. The subsidence slope thalweg direction is to the north and therefore there is again an apparent approximation to the direction of the slope deformation thalweg. The gradient is approximately 1:100. The bottom edge of the slope deformation has dropped by 410 cm since 1983, while the top edge in the region of the tear edge dropped by 190 cm (Fig. 3, Fig. 5).

Figure 6 shows the subsidence between 1985 and 2002 and a prediction of the rise in the surface subsidence due to undermining between 2003 and 2010, which documents the fact of persistent impact of undermining and its significant growth. It implies spread of the partial subsidence trough affecting the slope deformation to the east and the maximum rise in the subsidence to the north-east, i.e. in the lower part of the slope deformation, which will probably cause an acceleration of its movement (due to increased gradient).

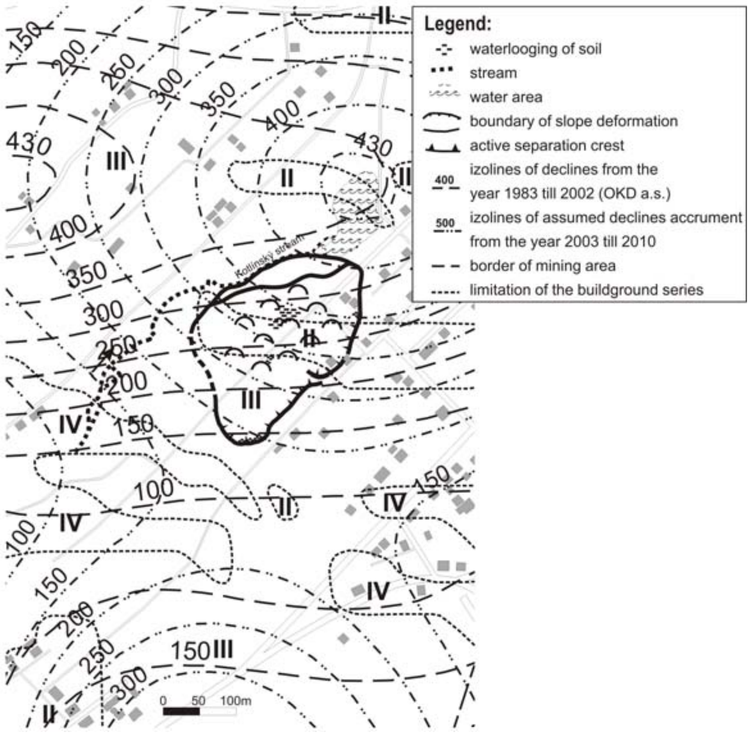


Fig. 6. Subsidence caused by undermining between 1983 and 2002 and a subsidence increase forecast for 2003 – 2010.

Terrain deformation parameters

On the surface of the slope deformation Doubrava Vrchovec a point was selected (with regard to a large areal extent of undermining in relation to small extent of the slope deformation the discussed terrain deformation parameters do not change within this landslide), with which terrain deformation parameters change, namely inclination, longitudinal relative deformation in the direction and perpendicular to the subsidence slope gradient direction, curve radius and subsidence, were monitored on the basis of extrapolated values in the above mentioned time intervals. It is necessary to point out that despite the above mentioned information being related to one point, they express a spatial evaluation. This fact is also confirmed by the definition of the individual parameters. The terrain inclination can be specified as the proportion of subsidence differences of two points in a subsidence trough to their mutual distance. The horizontal proportional deformation represents a proportional lengthwise change of a subsidence trough part in the horizontal direction. The terrain curve radius is given by the radius of an osculating circle of terrain surface curvature in the given point and vertical section trough the subsidence trough. The terrain subsidence characterizes the vertical component of spatial movement of a point in the subsidence trough. As apparent from Figure 7, there is a deterioration in all the parameters of the terrain deformation values, which shows by a gradual transition of the given point from the building site group IV to III (subject to ČSN 73 0039 Standard).

The previous section implies that there is a rise of the gradient, which makes it felt by the increased inclination in this chart. Approximation of the monitored point towards the point of inflection of the subsidence trough can be assumed from the shape of the curve. The shape of the curve of the horizontal relative deformation in the subsidence slope gradient direction manifests a general growth in negative values, i.e. rising compression, which occurs in the concave portion of the subsidence slope. The values of the horizontal relative deformation perpendicular to the subsidence slope gradient direction range in the positive values till 1995 (elongation) and in the negative values between 1995 and 2005 (compression). Before 1995 the curve radius fluctuates in the negative values, which can be interpreted as an occurrence of the monitored point either in the vicinity of the point of inflection or near the foot of the concave portion of the subsidence slope, with regard to the longitudinal relative deformation values. Approximation of the monitored point towards the point of the maximum curve of the concave portion of the subsidence slope can be deduced from the following development.

The slope deformation Doubrava Vrchovec is an active landslide influenced by combined impacts of undermining, while the local maximum movements are caused by extreme rainfall or melting of snow. A similar situation occurred also in the year of interest, 2006. The **landslide movement** in that year amounted to 45 cm. However, it was not documented by inclinometric measurements, as these are not installed in the locality of interest. The movement was intercepted by surface measu-ring of zone

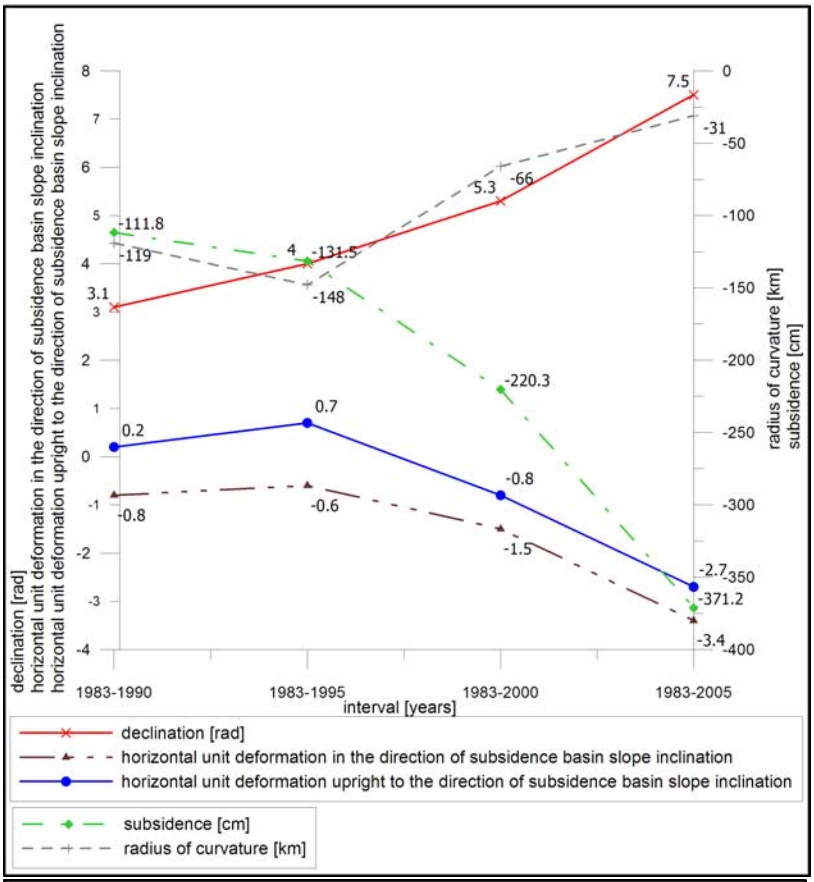


Fig. 7. Chart of terrain deformation parameter changes on the slope deformation Doubrava Vrchovec in the selected time periods.

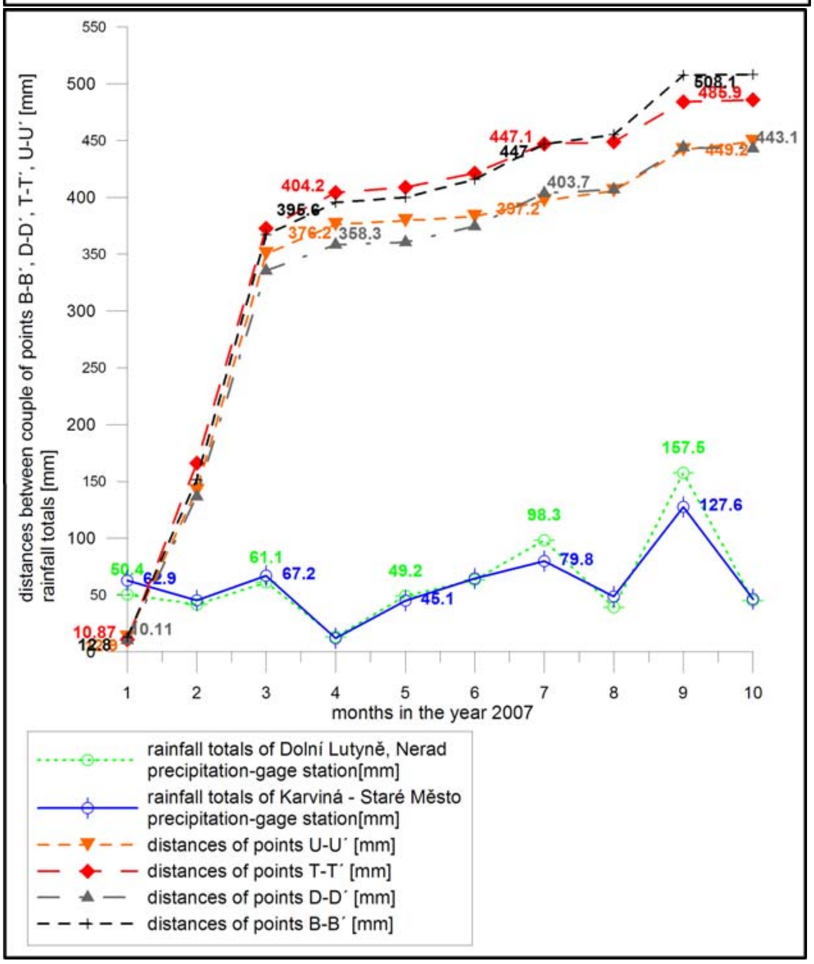


Fig. 8. Chart of measured mass movements and monthly precipitation depth from two rain gauging stations closest to the slope deformation Doubrava Vrchovec for 2006 and 2007

extensometric lengths as well as dilatometric measurements of the cracks in the asphalt road running across the slope deformation. From the time point of view, the most intense movement was identi-fied in February and March, when its average size reached 36 cm. The shift was evenly divided in the rest of the year.

It is apparent from the following chart (Fig. 8) that the above mentioned movement in the 2nd and 3rd months of 2007 has not been set off by rainfall as this did not reach over-limit values comparable to the precipitation depth in 1997 (approx. 300 mm). The slope move-ment observed in that period may unambi-guously be attributed to undermining.

Conclusion

The changes in the slope state of stress, structure and physical-mechanical properties of the slope material, ground water level, etc. are important statements trough movement impact on a slope deformation. Though, the subject of the investigation was not the evaluation of those factor changes as from the practical point of view it is useful to identify the cause of the arising deformations.

The formation and development of the subsidence trough due to mining as well as the slope movements have a negative impact on the stability conditions of the area. In case of separate action it is possible to clearly specify the direction and size of movement and the surface deformation caused by this movement. In case of mutual action for the purposes of identification of a terrain deformation cause it is necessary to separate the individual influences, which can be achieved by the correlation of changes in the terrain deformation and the overall development of a subsidence trough with slope deformation movement measurements. These correlations helped to identify or verify the below mentioned dependences and facts in the Doubrava Vrchovec locality.

By means of measuring the zone extensometric lengths and dilatometric measurements of the cracks in the asphalt road a movement in the slope deformation thalweg direction was identified. From the course of isocatabases in the region of the slope deformation the direction of the subsidence slope gradient can be deduced, which almost agrees with the slide-prone slope inclination direction. This interference is an example of a substantial negative impact of undermining on the slope deformation.

On the basis of isocatabase maps a considerable change in the subsidence of the upper and lower parts of the slope was identified in three consecutive five-year intervals. This dependence implies a rise in the slide-prone slope gradient, which significantly contributes to worsening of its stability conditions.

In order to assess the existence of extraordinary strain in the surface parts of the slide-prone slope, terrain deformation parameters were used, on the basis of which it is possible to interpret in which part of the subsidence slope the slope deformation is located in the given time moment. With regard to the analogous thalweg of the subsidence slope and of the slope deformation, a vital parameter is the longitudinal relative deformation in the direction of the subsidence slope gradient direction. Its values range in the negative figures, which means that the surface of the Doubrava Vrchovec slope deformation is being compressed in the area of landslide.

In the past, the movements of Miocene eluvium had affected the slope deformation Doubrava Vrchovec. The slope stability has been fundamentally influenced by the erosional activity of the Kolínský Stream. According to the archives, a considerable change in the stability was clearly brought by the impact of mining back in the 1960s, which caused slope movements. Then, these movements were disguised by land reclamation, while reactivation or acceleration of this action occurred in 1985 as a consequence of extreme rainfall. Despite the fact the landslide had been improved by 1997, it got reactivated in that year due to the extreme July rainfall (monthly precipitation depth about 300 mm). As for the current state, since the beginning of 2007 the movement has been approx. 45 cm and has most probably been caused by the impact of mining as no extreme rainfall occurred in the given period (confirmed by the Czech Institute for Hydrometeorology), i.e. rainfall whose intensity would correspond to the extreme rainfall back in 1997.

An optimal operation for the identification of the impact of undermining on a slope deformation is an implementation of inclinometric measurements inside and outside the body of the landslide correlated with isocatabases and parameters of terrain deformation. In this locality no inclinometric measurements were carried out, but from isocatabase maps in time chains and terrain deformation parameter changes the continuity of the impact of mining is quite apparent, and at the non-existence of extreme rainfall the mentioned slope movement can be attributed to undermining (mining activities) as the sole identified and proved geofactors active during the monitored period.

Acknowledgement: The publication was supported by the grant project GAČR - 105/07/1308.

References

[1] Černý, I.: Projevy dobývacích prací v karvinské části OKR. *Sborník konf. Hornická Ostrava, Hornická společnost, ČSVTS, s. 110 - 119, Ostrava, 1987*.

[2] Černý, I., Dopita, M., Jiřík, K., Klepek, O., Langr, L., Machač, J., Roček, A.: Uhelné hornictví v Ostravsko - karvinském revíru. *Anagram, 564 s, 2003*.

[3] Čurda, J., Drábková, E., Eliáš, M., Jinochová, J., Kašpárek, M., Manová, M., Müller, V., Nováková, D., Růžička, M., Šalanský, K., Tomášek, M., Veselý, J.: Vysvětlivky k souboru geologických a ekologických účelových map přírodních zdrojů v měřítku 1:50 000 (List 15-44 Karviná). *Český geologický ústav, Praha, 89 s, 1998*.
[4] ČSN 73 0039 Navrhování objektů na poddolovaném území. Základní ustanovení. *1989*.
[5] Hep, L.: Úkoly geotechniky v hornické oblasti (OKR). *Přírodovědecký sborník k 10. výročí založení Ostravského muzea. Ročník XXV. Vydalo Ostravské muzeum, Ostrava. s. 39 – 70, 1972*.
[6] Hulla, J., et al.: Mechanika zemín a zakladanie stavieb, *Alfa, Bratislava 1991*.
[7] Neset, K.: Vlivy poddolování. *SNTL, Praha, 344 s, 1984*.
[8] Novák, J., Sedlák, V.: K problematice určení mezního úhlu vlivu dobývání v poklesové kotlině. *Acta Montanistica Slovaca. 9/2 (2004), s. 85-89*.
[9] Pašek, J., Matula, M.: Inženýrská geologie I.,II. *SNTL, Praha 1995*.
[10] Schenk, J.: Časový faktor, důležitý prvek při zkoumání dynamiky vývoje poklesové kotliny. *Monografie, VŠB-Technická univerzita Ostrava 1997*.
[11] Seznam.cz a.s. [online], [cit. 5. 11. 2007] http://www.mapy.cz
[12] Ženč, M.: Některé zákonitosti pohybu pohoří při dobývání ploše uložených slojí v ostravsko-karvinském revíru. VVUÚ Radvanice, 1968.