GNSS OBSERVATIONS IN THE GABRIELA LOCALITY

GNSS OBSERVACE NA LOKALITĚ GABRIELA

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Abstract

GNSS method was selected as the most suitable one for monitoring the surface after-effects from undermining in the Gabriela locality in the Karviná region. An observation network was built, whose points were repeatedly surveyed by this method. Evaluation of the obtained spatial coordinates allows analyzing not only the vertical movement, subsidence, as usual, but also the horizontal movement, horizontal displacement. This comprehensive approach would allow a better evaluation of the character of the creating subsidence depression. The extraction of the mining panel caused sizable surface changes in a short time due to a significant exploited thickness of the mining panel together with considerable failure of the overlaying strata from previous exploitations. The analysis of subsidence and horizontal displacement proved that the subsidence depression is creating in a symmetric way and the current centre of the subsidence depression is created above the exploited part of the mining panel.

Abstrakt

Metoda GNSS byla vybrána jako nejvhodnější pro sledování povrchových projevů poddolování na lokalitě Gabriela na Karvinsku. Byla vybudována pozorovací stanice, jejíž body byly touto metodou opakovaně zaměřovány. Vyhodnocení získaných prostorových souřadnic umožnilo analyzovat nejen vertikální pohyby, tedy poklesy, jak bývá obvyklé, ale také horizontální pohyby, tedy posuny. Tento komplexnější přístup umožnil lépe posoudit charakter vznikající poklesové kotliny. Těžba porubu způsobila v krátkém čase výrazné povrchové změny vlivem velké dobývané mocnosti porubu spolu se značným porušením nadložních vrstev z předchozích dobývacích prací. Analýza poklesů a horizontálních posunů prokázala, že poklesová kotlina se vytváří symetricky a její současný střed je nad vydobytou částí porubu.

Keywords

undermining, GNSS, surface changes

Klíčová slova

poddolování, GNSS, povrchové změny

1 Introduction

Geodetic methods are traditionally used for monitoring of surface changes in undermined areas. The advantage of using GNSS method repeatedly to observe these changes rests in allowing quick connection to the stable, not undermined areas and in providing 3D coordinates of points, and thus providing a surface change not only in elevation, but also in the horizontal position of the point. Research shows that this surveying is more complex and allows a better understanding of the processes caused by underground mining.

The Institute of Geonics uses GNSS method to observe the surface changes caused by underground exploitation of the hard coal in the Karviná region. An observation point network was built in the area of interest to allow repeated GNSS surveying on points that are changing their position due to undermining. Space coordinates of the points enable to analyze both vertical and horizontal movements of the undermined surface.

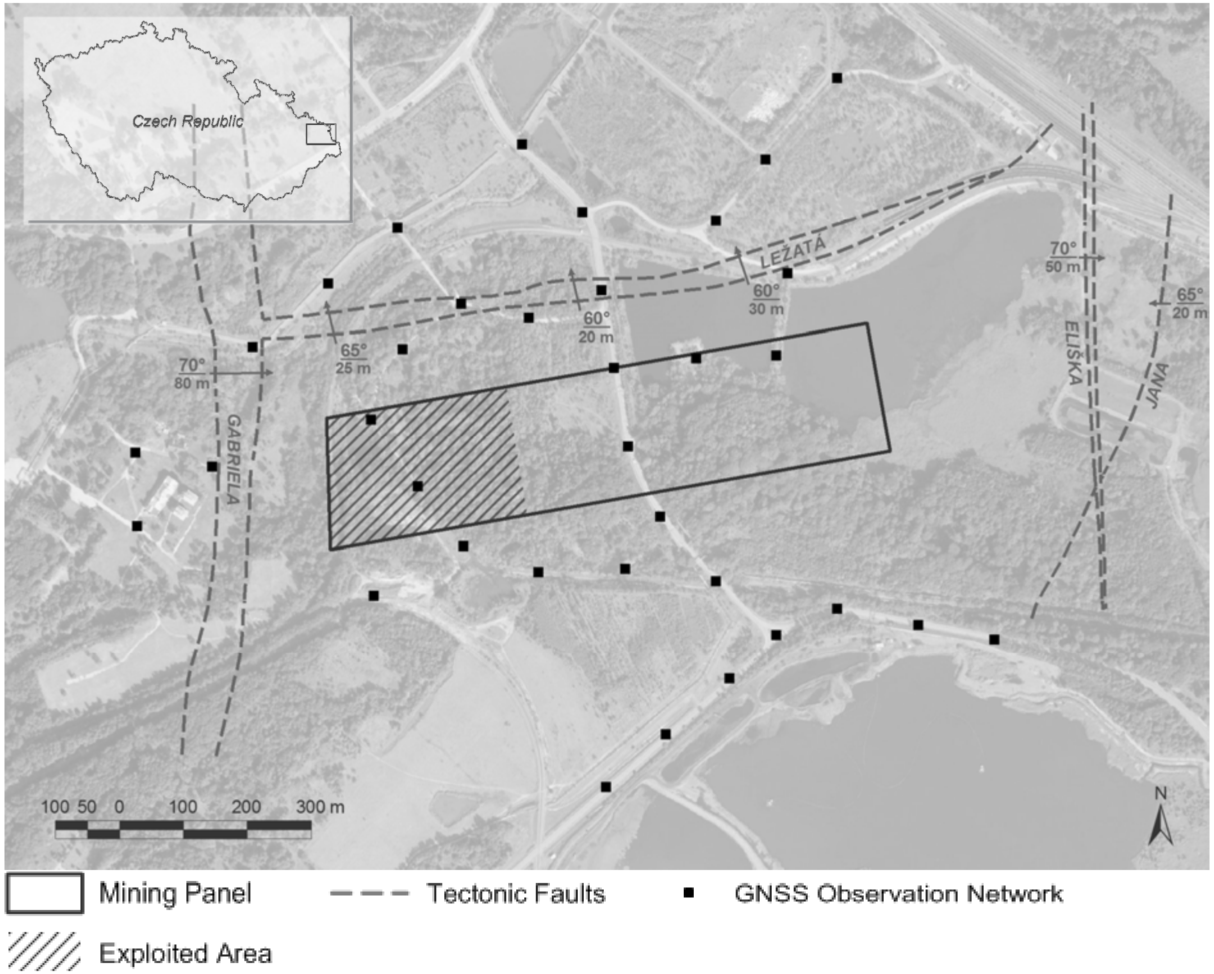

Fig. 1 Observation network in the Gabriela locality (Kajzar et al. 2012)

2 Mining Locality

The area of interest is situated in the Darkov mining area in the Upper Silesian Coal Basin near the town Karviná (see Fig. 1). The locality occupying an area of c. 3 km^2 is called Gabriela after the former mine that was founded here in 1850s. Two mine towers are left here as a memory of the mine that was productive until 2004 when it was closed. The nearby village Karvinna was destroyed due to undermining, its buildings were demolished and only a church was left here, reinforced and reconstructed. Through the decades, many mining panels were extracted from many coal seams in the locality and in some of its parts; the surface subsided of several tens of meters.

In the Gabriela locality, the exploitation of the last mining panel started in July 2011. This mining panel is situated beneath the previously extracted mining panels and its exploited thickness is very high on local conditions. It is situated in coal seam that has a total thickness about 6 – 7 m. The depth of this coal seam varied from c. 790 m to 820 m and the seam has an average inclination of 5° to 8° in north-north eastward direction. The face length of the mining panel is 200 m and the lateral length of longwall advance is up to 900 m. The average thickness of extraction is 5.5 m and the longwall method with controlled caving was used as a mining method of this panel, proceeding from west to east. The rock mass consists of typical for the Upper Silesian Coal Basin upper carboniferous molasse sediments consisting mostly of coal-bearing siliciclastic continental deposits. The Upper Silesian Coal Basin is divided into tectonic blocks by a set of normal faults of tens to hundreds of meters amplitude (Dopita, 1997). There are two main tectonic faults in the Gabriela locality (see Fig. 1). The mining panel is located east of an important tectonic fault called "Gabriela" which intersects in the north-southward direction the above mentioned safety shaft pillar. The "Gabriela" fault has the thickness of deformation zone of several tens of meters with the amplitude of 80 m, with dip of approx. 70° to the east. Another important tectonic fault called "Ležatá" of the east west direction creates a north border of the mining block. The "Ležatá" fault has the fault amplitude of approx. 20 – 30 m and dip of 50° to the north. Two other faults are worth mentioning: "Jana" and "Eliška" bounding the area of interest on the eastern side (Kajzar et al. 2012).

3 Surveying

The Institute of Geonics prepared an observation point network that was fixed on the surface of the Gabriela locality in July 2011, prior to the exploitation of the last mining panel. The points were fixed in profiles and also scattered on the surface, with nails in the roads and metal bars in the ground (a total of 35 points; see Fig. 1). As GNSS was selected as an observation method, the position of individual points was suited to the limitations of the GNSS surveying.

GNSS is a method that can be successfully used in the undermined area. Its advantage over other common geodetic methods lies not only in providing space coordinates of a surveyed point but also in ability of a quick connection to the stable area not affected by undermining. This ability is very important because common geodetic methods of surveying may take time to connect the large undermined area to the non-affected stable area which means that these methods are not only time consuming but they may also bring inaccuracy to the surveying as the points in the undermined area may move meanwhile, due to undermining. The ability to provide space coordinates of points is also important. As subsidence is the main after-effect from undermining, repeated geodetic levelling is the most common way to survey the undermined areas. But it only provides the information about the vertical changes of the surface points or profiles while the information about the horizontal displacements, i.e. the direction of the surface movements is absent. But GNSS provides both these information. Our previous research of the undermined areas proved that the analysis of both vertical and horizontal movements enables more complex and precise evaluation of surface changes and their causes in the rock massif (Doležalová et al. 2009, Doležalová et al. 2010, Doležalová et al. 2011, Doležalová et al. 2012, Kajzar et al. 2011, Staš et al. 2009).

For the surveying in the Gabriela locality, a static way of GNSS surveying was chosen, with the observation of at least 11 minutes on each point with the Leica GPS system 1200. While GNSS field receiver was surveying in the observation network, a GNSS reference station was surveying on a trigonometric point situated in Karviná, outside the assumed undermining effects, at a distance of several kilometres from the observation network, near the state border on Poland. It is a point inside the national network with the defined coordinates in S-JTSK and in ETRS-89 system. For the used GNSS equipment, the stated accuracy for static surveying with subsequent post-processing is 0.005 m + 0.5 ppm in horizontal position of a point and 0.010 m + 0.5 ppm in vertical position of a point. Since the surveyed points were only few kilometres far from the reference point, constellation geometry was controlled during the whole observation and precise ephemeris were input into post-processing, the obtained accuracy of a spatial position of surveyed points may be estimated within interval from 0.01 to 0.03 m. Tests that were done in given locality confirmed this presumption. In order to record an incremental development of undermining effects, the interval of roughly 1 month was chosen for repeated GNSS surveying. Afterwards, the data from field surveying was processed on computer. Spatial coordinates of the surveyed points in the WGS-84 and S-JTSK systems are the results obtained from the post-processing. Thanks to the stabilization of the points of the observation network in the form of lines and scattered points, it is possible to express subsidence and horizontal displacements of individual points as well as over the entire observed area.

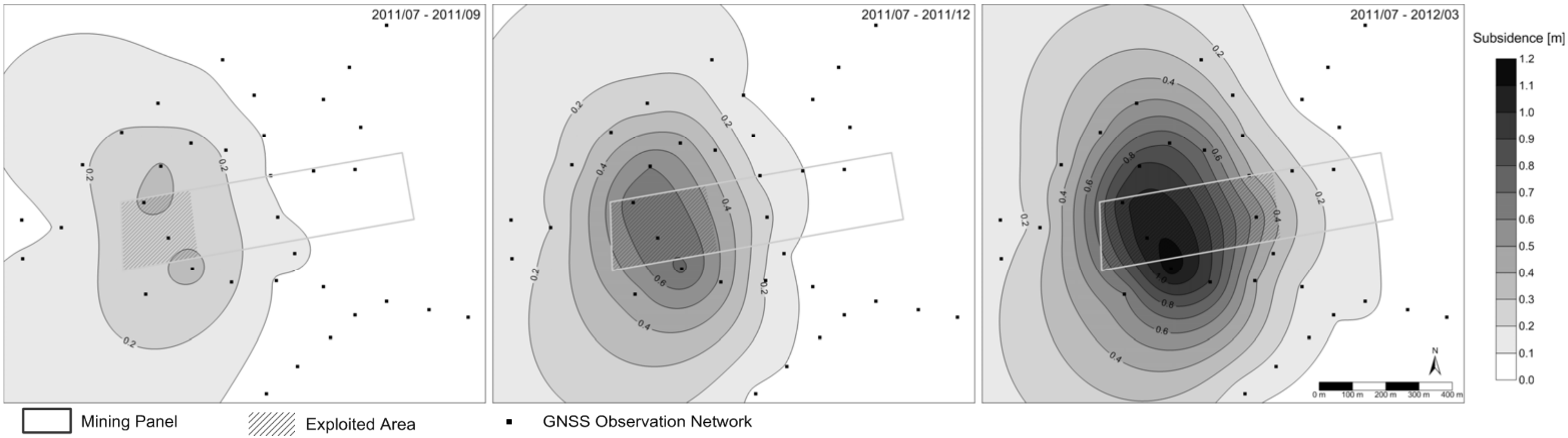

Fig. 2 Progress of the subsidence depression

4 Surface changes

The GNSS surveying provided space coordinates of each point in each surveying campaign. So far, 8 GNSS surveying campaigns were realized so we can analyze the change of the position of individual points in time. Vertical and horizontal changes in the point's position can be analysed. Fig. 2 shows the progress of the creating subsidence depression in time. There are three subsidence maps of the observed locality made from GNSS data that were surveyed on fixed points of the observation network. The contour maps are prepared from the point data of an irregular network using the geo-statistical kriging interpolation method with linear variogram model. The maps show the gradual development of the subsidence depression from 07/2011 to 09/2011, 12/2011 and 03/2012. It is almost symmetric and it is creating according to theoretical assumptions of the behaviour of the undermined area. The current centre of the subsidence depression is created above the exploited part of the mining panel and the subsidence reached 1.15 m here in the period 07/2011 – 03/2012. So far, the tectonic faults seem to have little influence on the surface changes.

Fig. 3 shows the progress of the horizontal displacements in the observation network. Not only the size of the displacements, but above all, the direction of the point's movements enable to understand the surface processes caused by undermining. Our 5-year research in the nearby locality Louky has proved the importance of the analysis of the horizontal displacements that proved the important influence of the tectonic faults in given locality (Doležalová et al. 2010, Doležalová et al. 2011). In the Gabriela locality, no extreme deviation from the theoretical behaviour has been discovered so far. The points of the observation network tend to the gravity centre of the exploited mass and the sizes of the horizontal displacements correspond with their position and distance from the direct overburden of the exploited mass. The maximum recorded horizontal displacement reached 0.45 m in the period 07/2011 – 03/2012. The surface reacts to the extraction progress in a short time. This is mainly due to the influence of the major rock mass failure caused by previous mining in many of the overlying strata (Kajzar et al. 2011).

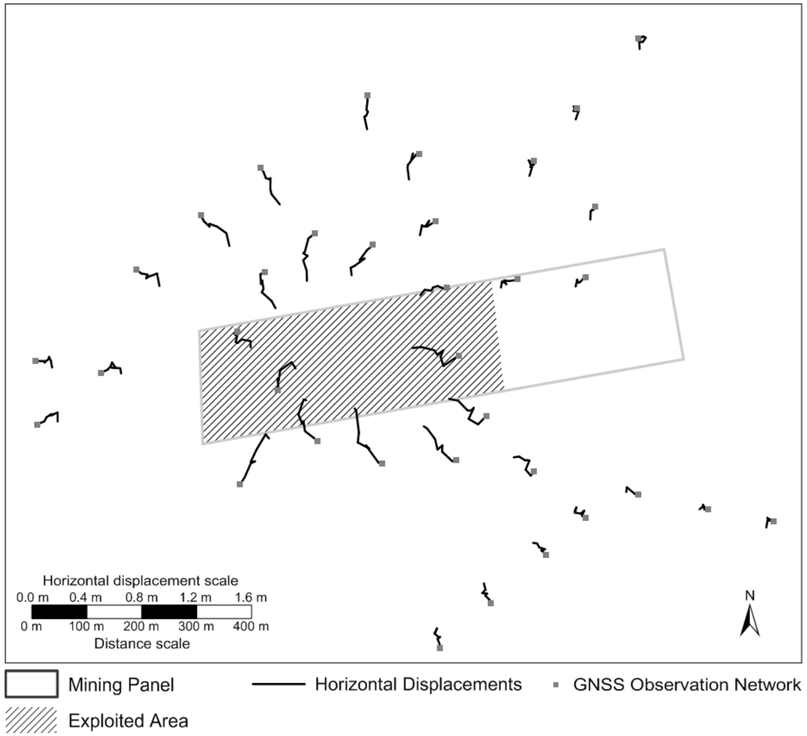

Fig. 3 Horizontal displacements from 07/2011 to 04/2012 (extended from Kajzar et al. 2012)

5 Conclusions

An observation network was built to observe the surface changes from undermining in the Gabriela locality near Karviná. A total of 35 points of the network were repeatedly geodetically surveyed by means of the GNSS method, using rapid static surveying with subsequent computer post-processing. Over other geodetic methods, this surveying method enables a quick connection of the undermined locality to the unaffected area several kilometres far and the repeatedly gained space coordinates allow analysis of both vertical and horizontal changes of the surface affected by underground mining.

Results of the GNSS surveying that was performed 8 times in the period from July 2011 to April 2012 detected the surface after-effects from underground mining of the last mining panel exploited in the Gabriela locality. The extraction of the mining panel caused sizable surface changes in a short time due to a significant exploited thickness of the mining panel together with considerable failure of the overlaying strata from previous exploitations. The analysis of areal subsidence proved that the subsidence depression is creating in a symmetric way and the current centre of the subsidence depression is created above the exploited part of the mining panel. Maximum subsidence reached 1.15 m. Also the analysis of horizontal displacements showed that the points behave according to the presumptions that come from the theory of the behaviour of the undermined area. The maximum recorded horizontal displacement reached 0.45 m. According to the analysis of both subsidence and horizontal displacements, the tectonic faults seem to have little influence on the surface changes so far.

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