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RECENT TECTONIC MICRODISPLACEMENTS REGISTERED IN BEDŘICHOV TUNNEL „A“ IN THE JIZERSKÉ HORY MTS. (N BOHEMIA)

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ABSTRACT

Three year monitoring of micro-displacements on four tectonic fracture planes in a tunnel driven by a milling cutter into granitoids of Bohemian Massif revealed micro-movements that develop in certain trends and impulses. Two investigated fractures are of the Krušné Hory Mts. orientation (NE – SW), other two of Sudeten orientation (NW – SE). These have been found the two prevailing fracture orientations in the massif. Results from all the four fractures indicate trends in overfaulting of southern blocks over the northern ones and a stress state model characteristic of approximate N-S compression with overthrust vergence to N. Besides, some impulses were indicated with abrupt occurrence that dominates the development of movements. The first most significant impulse occurred by the end of the year 2004, the second one at the break of 2005/6. The coincidence of the impulses with earthquake events is discussed.

KEYWORDS: present tectonic movements; monitoring; Bohemian Massif

1. INTRODUCTION

Bedřichov A tunnel was driven into Jizera granite formation in the left slope of Desná River Valley in 1981 to a total length of 2593 m and diameter 3.1 m. A steel pipeline was installed in it to draw drinking water from water reservoir Josefův Důl to the nearby town of Liberec (Fig. 1). The tunnel is exceptional in being drifted in its total entrance length of about 900 m by a milling cutter rather than by shooting which was accepted further on. It was in 2004 when the tunnel was investigated to prepare possible precise movement measurements on tectonic structures in the massif here. In a number of places in the walls there were structures cutting through the tunnel and found suitable for such measurements. Such places were marked and evaluation has shown two prevailing tectonic systems. The first oriented to 310 – 330° and known as the Sudeten system and the second oriented to 30° and known as the system of the Krušné Hory Mts. Then, in July and August 2004, two fractures stationing 792 and 881 m from the portal, and representing the two fracture systems, were instrumented with crack gauges TM71. Thus, long-time measurement has been started in the tunnel, regular registration taking place since August 27, 2004. Later, in November 2005, two other gauges were set on structures stationing 235 and 278 m, where again the two important structure systems were found. Regular registration of these two gauges has taken place since November 30, 2005. All gauges were placed into northern side of the tunnel.

2. GEOLOGY AND TECTONICS

The tunnel is situated in the western section of Krkonoše-Jizera Massif formed by Jizera granite. A wider surrounding of the tunnel bears signs of three principal primary fracture systems. Two of them are sub-vertical and oriented to NW-SE and NE-SW. The third one is sub-horizontal showing mostly EW orientation and inclination to S; at places to N also. Faults of the NW (Sudeten) orientation reach lengths of more than 10 km. They are formed by individual sub-parallel fractures usually filled with tectonic breccia and tectonic clay. Structures of NW-SE orientation are evaluated by Klomínský et al. (2005) as of tensional character and of more pronounced hydraulic conductivity that those of NE-SW orientation.

NW-SE faults, i.e. of the Sudeten orientation, were founded in the final phases of the Variscan tectonogenesis. They came through periodical revivals during Mesozoic and Tertiary (Coubal, 1990). They belong to a wide zone of Lužice Fault. The tectonic activity in Tertiary is documented by formation of the Zittau basin W of the tunnel. Movements continue even during Quaternary with relative lifting of Ještěd Ridge, which can be documented by accumulations of alluvial cones on the NE slope of Mt. Ještěd (Chaloupský et al., 1989).

NE-SW faults, i.e. those of the Krušné Hory Mts. orientation disturb the faults of the Sudeten system. The Krušné Hory Mts. faults experience outcome of mineral springs with high content of juvenile CO_2.

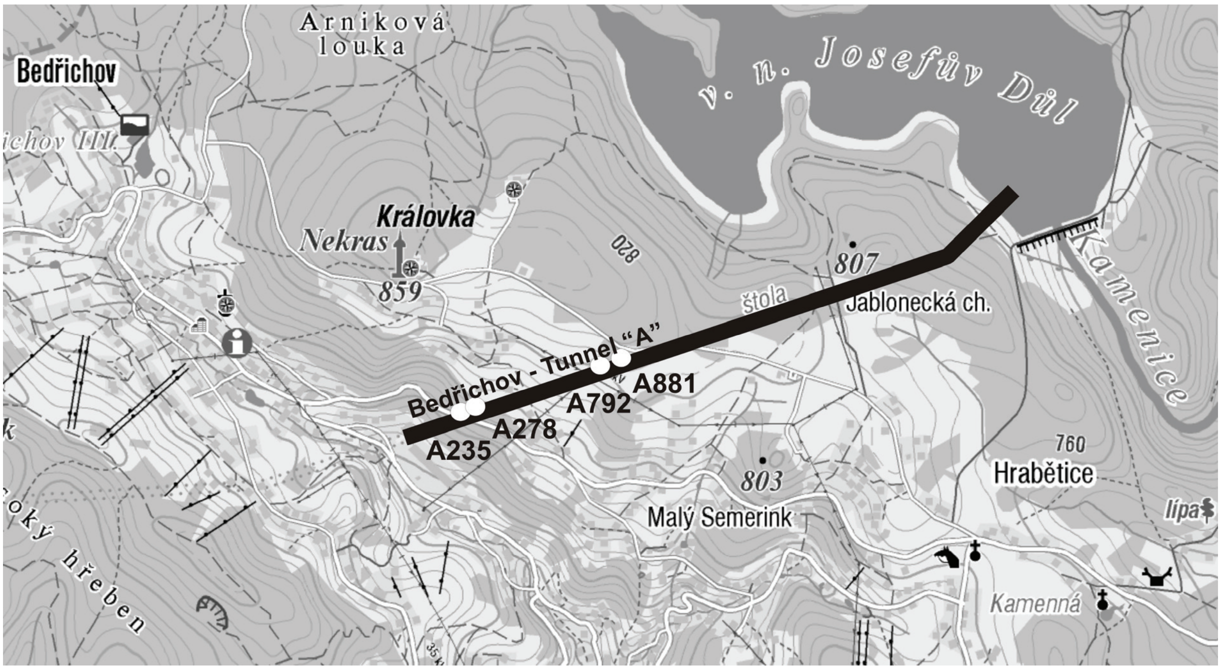


Fig. 1 Position of the Bedřichov Tunnel „A" and monitoring points inside the tunnel.

This tectonic system is considered to origin during the pre-rift developing period of Ohře River Rift being one of its main marginal fault systems (Coubal and Klein, 1992).

As to the regional scale view of the territory in question, fractures oriented NW-SE outnumber fractures oriented NE-SW. Paleostress analysis has shown that the orientation of paleostress field changed repeatedly during the fracturing process of the granite body and NE-SW fractures were probably reactivated later by horizontal displacements during NEE-WSW compression. Regarding striations that characterise shear movements, statistical fracture analysis provided a heterogeneous group of fractures originating not only in one single stress field (Havíř, 2007).

3. METHODICAL APPROACH

Long-term investigations of deformations in rock massifs are carried out with the use of the crack gauge TM71, a device working on the principal of mechanical interference between optical grids (Košťák, 1991) which can register displacements on discontinuities or fractures disturbing rock (Photo 1). This instrument is deviced as a very stable 3D indicator to be installed permanently in the field under the most severe environmental conditions, notably in mountains, caves, galleries, and tunnels. Its sensitivity is appropriate to used grids, i.e. derived from the density of grid lines. The types in current use reach 0.05 to 0.0125 mm in all the three Cartesian co-ordinates x, y, z in space, and the type is to be selected in respect to expected movement range and

Photo 1 Gauge TM–71 installed across fracture of Krušné Hory Mts. orientation (120°/75°).

acceleration. New types of the instrument are also equipped with special grids to register angular deviations between fracture flanks in contact. The deviations are registered in two planes xy and xz, horizontal and vertical usually, with prospect sensitivity 3.2 . 10^{-4} rad.

At present, this gauge is in use of research groups recording movements under very different situations and different origin of movement including the tectonic one. Let us mention sites in Czech Rep., Germany, Italy, Greece, Poland, Slovakia, Bulgaria, Slovenia, Kyrgyzstan, Peru, and Canada. The research includes sites of active tectonic movements set on contacts between hard and sedimentary rocks (Stemberk and Košťák, 2007).

Operations in the tunnel Bedřichov A, deep in the massif, has got to apply gauges equipped with the highest sensitivity, i.e. ±0.0125 mm. Registration of obtained gauge interference patterns takes place by digital photography, the patterns being analysed in laboratory by computer picture analysis software.

As to the gauge system in use, one should understand that it is set for long-term measurements, so records can be taken manually with frequency of several days, weeks, or even months. Therefore, individual readings express differential positions due to total changes that occurred in the given intervals, which may cause difficulties to interpret effects of individual earthquakes. Synchronisation of effects with individual earthquakes may be then doubtful sometimes. Such trials may then call for increasing registration frequency or exceptional registrations on call. In any case the conception of the gauge has not been set for registration of vibrations and does not compete with seismographs. Contrary to that, it can register irreversible displacements of even aseismic origin and provide data about trends of movements developing slowly during decades. These are often data missing in geological investigations and widely demanded by geologists.

Results of measurements carried out with this method are often confronted with a widely accepted view that tectonic movements are resulting almost exclusively from earthquakes. Therefore, many scientists call us to find earthquake events that would be behind individual movement deviations. There are obvious limits to do that and to set timing of the observed displacement. In any case, only displacements recorded at the end of the interval in which any particular earthquake may occur can be considered resulting directly from its dynamical performance. Other situations should be interpreted more specifically, and coincidence must be well specified. Some situations will show aftereffects or even precursors, if not pure tectonic pressure.

4. ANALYSIS OF RESULTS

Four crack gauges TM71 were installed in Bedřichov A tunnel. Two of them set on Sudeten Fault structures, other two on structures that belong to the Krušné Hory Mts. system.

Graphs that follow are presented in a *Cartesian co-ordination system xyz* that coincide with gallery orientation: *x oriented into gallery azimuth*, *y horizontal* and *z vertical*. All the instruments are set to the NW gallery wall and oriented in the same manner. Therefore, results represent displacements of the NE structural flank with respect of the SW flank as relatively stable. *Axis x* is oriented toward the portal, and its positive value represents the *effect of compression* between the structural flanks in the gallery wall. The gallery azimuth 250^0 is oriented toward the portal of stationing 0 m. *Values +y* in the graphs represent *sinistral slips*, i.e. relative slips of SW flanks out or NE flanks into the wall. *Values +z* represent *relative subsidence* of NE wall flanks in respect of SW flanks. The interpretation of results must be always carried out in respect to the relativity of movements between the two respective separate structural flanks.

Gallery temperature is registered and varies between 4 and 10 ^{0}C. Limits are found only exceptionally and the variation reduces with distance from the portal. The temperature effect to the instrumentation is numerically compensated in the results while the effect to the rock is not compensated. One can also observe a serious retardation of temperature cycles in the gallery under the surface. In the gallery, the highest temperature comes out in October, the lowest in April. The temperature reaction in the graphs would be noticed by cyclic variations parallel with seasonal cycles but one can see that the effect is low and becomes suppressed with observed tectonic effects. The only temperature interference comes out partially with the results observed near the portal.

Generally, displacement records show long-time movement trends, as well as short-time or even abrupt deviations from such trends.

4.1. *THE KRUŠNÉ HORY MTS. ORIENTATION FRACTURES*

The Krušné Hory Mts. orientation fractures are monitored at stationing 792 and 278 m from the portal.

4.1.1. GAUGE A792 (THE KRUŠNÉ HORY MTS. FRACTURE, 120°/75°)

Regular measurements started in August 2004. Registered displacements are given in the graph of Figure 2.

It is side slips y and vertical z in a range of 0.3 mm which characterise results. On the other hand development along x axis is relatively indifferent within a range of 0.05 mm only. There were about three major and abrupt deflections recorded in the development of displacements during the period of three years from the start of measurements and all

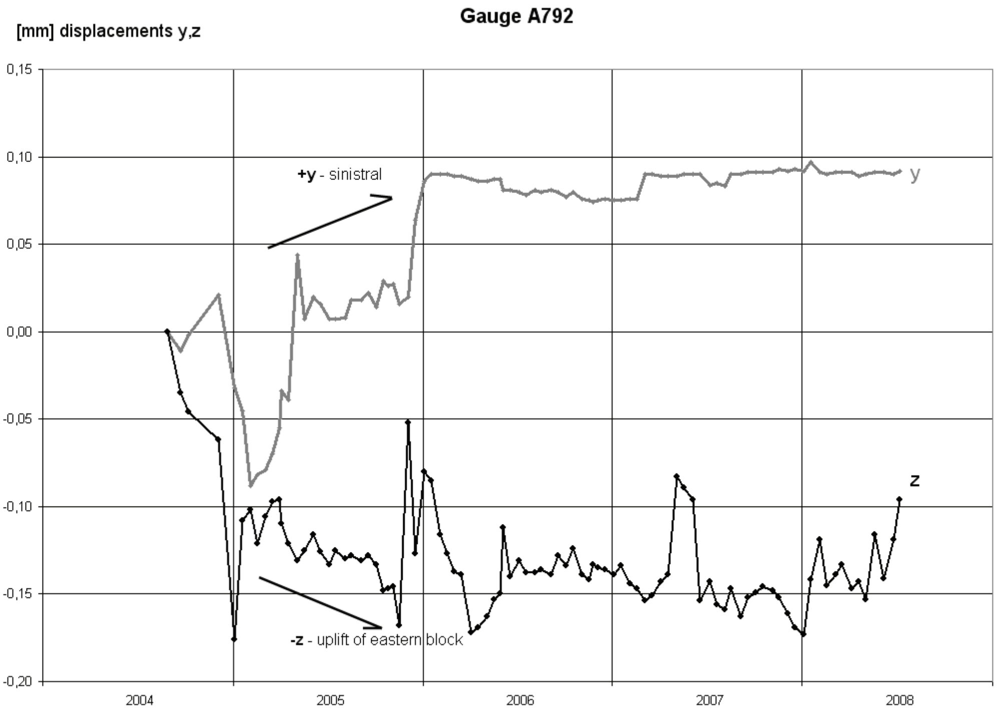


Fig. 2 3-D displacements registered on the failure of Krušné Hory Mts. orientation at 792 m.

of them occurred in the slips. The first occurred at the break of years 2004/5, reached about 0.1 mm and has been interpreted by Stemberk and Košťák (in Klomínský et al., 2008) as an effect of global reaction to Sumatra catastrophic earthquake of December 26, 2004 (M = 9.3). This movement reaction occurred in both the co-ordinates y and z. Then in z a reverse reaction appeared without delay. In y a reverse reaction appeared with a serious delay of about four months so that it could not be really a reverse reaction but rather a renew slip function of this period. Regarding the sense of the movement, the December 2004 deflection was negative in y and z, which means that it was dextral and combined with a lift on the NE. wall flank of the fracture. Early in February 2005 horizontal slip y changed to a sinistral one.

Deflections that appeared after December 2004 represent a totally reverse development in time comparing with the previous one. They start with an abrupt sinistral impulse in y combined with subsidence on the NE fracture wall flank. Such a deflection occurred at the break of years 2005/6 and reached amplitude of about 0.10 mm in z and 0.06 mm in y. Displacement in y took place in December 2005 abruptly and was completely irreversible. Since then no similar effects occurred and movement in y almost stabilised. The main displacement in z started also abruptly in November/December 2005 with an oscillatory effect and developed later reversibly. The main reversible deflection took five months – from November 2005 to March 2006, and in a broader point of view it leaves an impression of several oscillations originating in September 2005 and ending only in June 2006. A similar deflection but shorter one occurred in the first half of 2007 representing an amplitude between April and June and reaching 0.05 mm. Reversal deflections of this type characterise an impulse which is of a temporary character and dissipates later.

Now, let us consider the orientation of the facture – the Krušné Hory Mts. orientation. The graph shows a certain general trend of movement. While the deflections in z start into positive figures and thus express impulses showing subsidence in SE in respect to NW block, the general trend suggests an overthrust fault of the SE fracture block in the wall to NW.

Resulting slips on the fracture during the first three year period 2004/7 are sinistral reaching about +0.09 mm in horizontal slips y, and about -0.15 mm in vertical z. These can be understood as a three year trend. Regarding fracture orientation this represents an oblique overthrusting movement with SE block lifted over the block in NW. Not considering the exceptional effect of December 2004, the overthrusting movement is regarded as a result of an overall pressure effect of 2005 which was generally unilateral and irreversible.

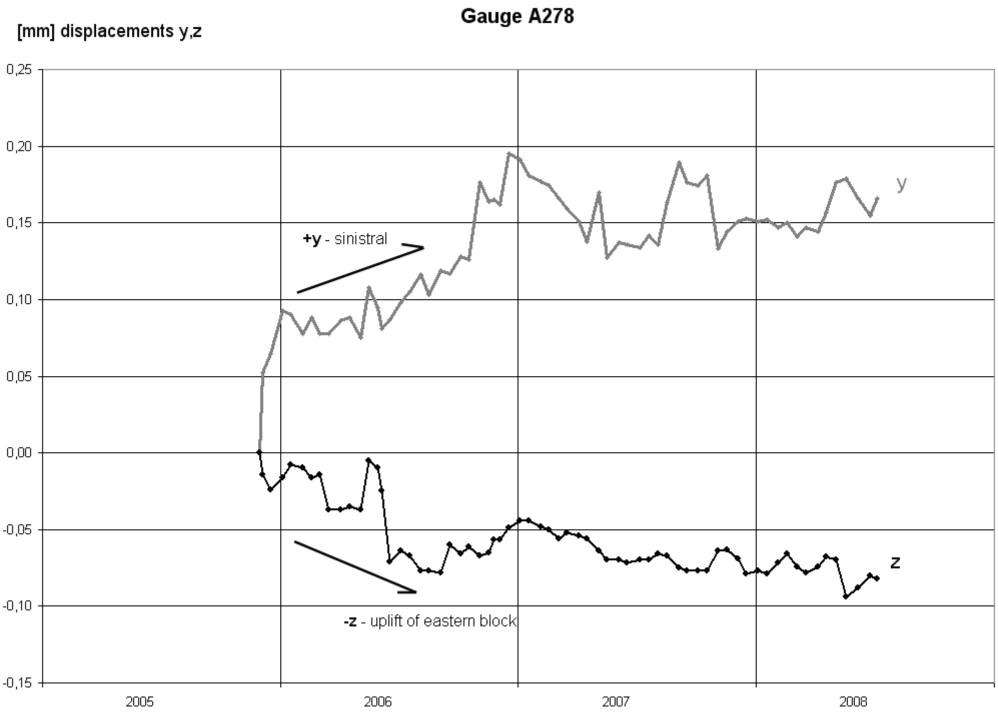


Fig. 3 3-D displacements registered on the failure of Krušné Hory Mts. orientation at 278 m.

4.1.2. GAUGE A278 (THE KRUŠNÉ HORY MTS. FRACTURE, 120°/83°)

Regular measurements started in November 2005. Registered displacements are given in Figure 3. A significant unilateral trend in y can be noticed. It starts with an abrupt movement right at the beginning of measurements by the end of 2005 which represents coincidence with the result of the gauge A792 in sense and magnitude and gets on during the whole year 2006 representing sinistral slips. Such a trend later in 2007 reversed for a time, being generally unstable. Trend can be observed even in vertical displacements z, as development into negative figures, i.e. lift in SE against subsidence in NW. Again, this means coincidence with A792. The main portion of vertical displacement was centered into a period April – June 2006, then reversed till the end of the year and continued. Meanwhile, the trend is observable also in x co-ordinate, representing a minor opening of the fracture. Obviously, this fracture closer to the terrain displays a lower stability than A792.

The year 2007 displays certain y - deflections from the trend. One developed in May which, as compared with A792, is delayed to y and premature regarding z. Then another in September/November is again delayed to y in A792 as if certain reciprocal effects have developed. This can be preliminarily but easily explained due to the distance between the two fractures, as well as due to possible passing of the impulse from point to point.

A total shift on the fracture reached 0.2 mm horizontally and about 0.08 mm vertically, as well as in x - fracture opening. The figures could be considered as a two-year trend of 2006/7.

As for the effects that concern the Krušné Hory Mts. fracture orientation, A278 observation represents a sinistral shift, i.e. again an oblique overthrusting movement combined with a small fracture extension. This is a good coincidence with A792. Moreover, by the end of 2005 both the points registered simultaneously a significant irreversible horizontal deflection of about 0.1 mm. Regarding the considerable distance between the two points which reads 514 m, one can conclude that observed displacements were of natural tectonic origin.

4.2. SUDETEN ORIENTATION FRACTURES

Sudeten orientation fractures are monitored at stationing 881 and 235 m from the portal.

4.2.1. GAUGE A881 (SUDETEN ORIENTATION FRACTURE, 204°/86°)

Regular measurements started in August 2004. Registered displacements are given in the graph of Figure 4.

There were two major and abrupt deflections recorded in the development of displacements during the period of three years from the start of measurements. The first is evident in y and later also in z and occurred at the break of years 2004/5. It has

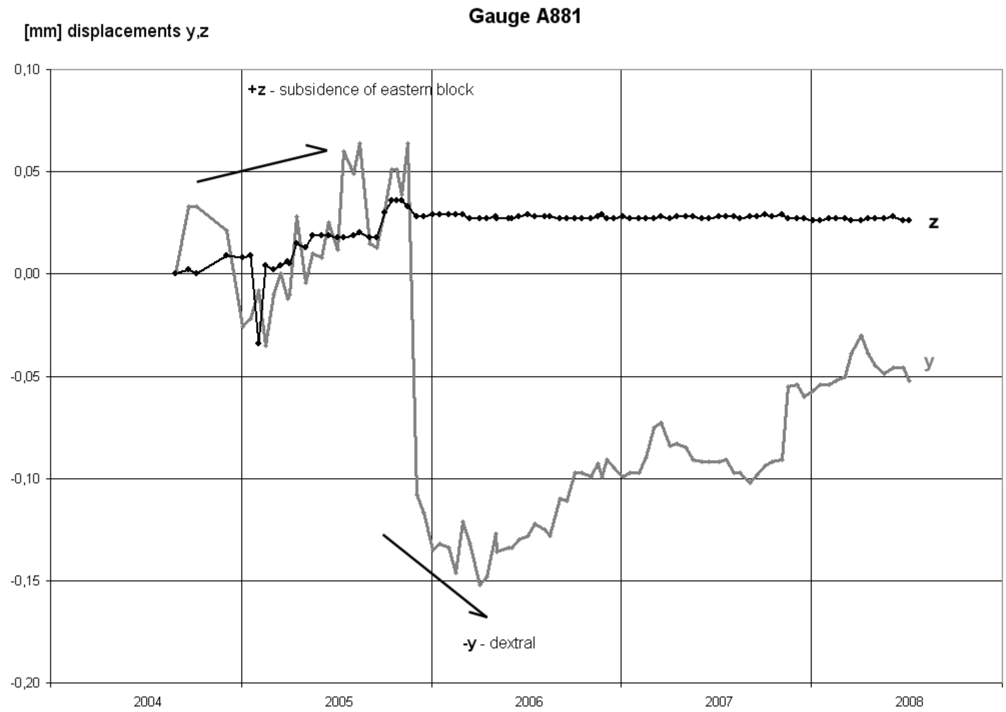


Fig. 4 3-D displacements registered on the failure of Sudeten orientation at 881 m.

been interpreted by Stemberk and Košťák (in Klomínský et al., 2008) as an effect of global reaction to Sumatra catastrophic earthquake of December 26, 2004 (M = 9.3). The reaction represents quite opposite development than that observed later and is similar to reactions on the Krušné Hory Mts. orientation fractures.

The next deflection occurred at the break of years 2005/6, reached amplitude of about -0.2 mm representing a dextral slip on the respecting fracture in horizontal y co-ordinate. This was an extreme slip as compared with other movements. Sometime in March 2006 a return to the previous sinistral trend can be observed and vertical movements stopped.

From the spatial point of view a total displacement during the three year period of observation on the monitored fracture A881 reads about -0.2 mm horizontally and about +0.04 mm vertically, which represents lift in SW over the block in NE combined with a dextral fracture slip. Evidently, however, a slow-movement trend was opposite, i.e. sinistral, yet overcome by the abrupt extreme reversal slip of November 2005.

4.2.2. GAUGE A235 (SUDETEN ORIENTATION FRACTURE, 204°/86°)

Regular measurements started in November 2005. Registered displacements are given in the graph of Figure 5.

Horizontal co-ordinate y shows first at the break of years 2004/5 a short-time abrupt reversible dextral displacement which is soon repeated in spring 2006. Then a sinistral movement develops culminating in May 2006. It is also reversible. In the next development y component oscillates near zero with the exception of summer 2007 when a negative deflection developed.

Vertical co-ordinate z is also quite variable. A significant deflection developed between November 2006 and March 2007. The amplitude reaches 0.1 mm and represents a temporal lift of the NE block. Generally, resulting trends in y, as well as in z are indifferent. Co-ordinate x seems to copy z during the winter 2006/7 including its amplitude of 0.1 mm and its trend is more or less compressional.

The graph is very unstable, in which it differs from the other three. Out of the four investigated fractures in Bedřichov tunnel, this fracture is the closest to the portal and to the surface. Some interference with superficial events cannot be excluded here. Variations in x show certain signs of climatic cycles although reverse than usual, therefore improbable.

Our experience says also that fast cyclic variations sometimes represent step by step progressive unidirectional movements in which step movements of opposite fracture sides sum up. In such a case total movements would be able to reach up to

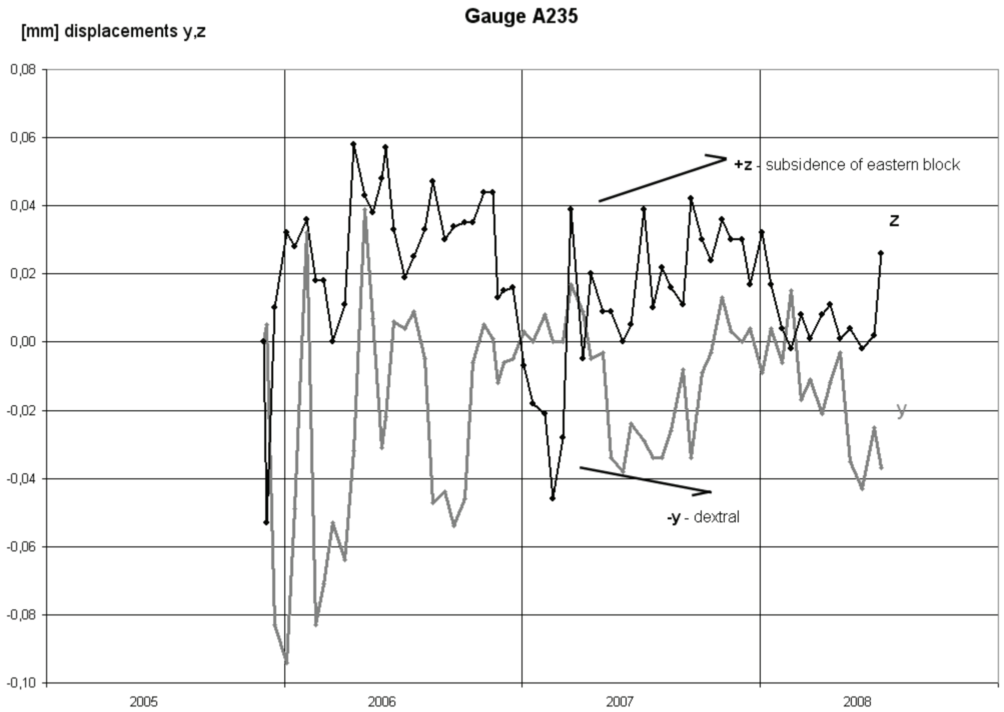


Fig. 5 3-D displacements registered on the failure of Sudeten orientation at 235 m.

0.4 mm here. This shows that results from A235 cannot be easily interpreted.

In spite of that, there are some similarities between A235 and other investigated fractures. It is first the timing of more significant deflections: winter 2005 and March/April 2007. It is to be mentioned that this two periods were coincidently verified as anomalous even at other numerous measurement points in Bohemian Massif (Stemberk et al., 2008a). Therefore, even the point A235 is to be considered principally effective in tectonic investigations carried out in Bedřichov tunnel.

5. DISCUSSION

The first important observation concerns the method used in the tunnel with respect to the research aims. Regarding that one can see that the selected sensitivity and stability of the instrumentation, as well as the registration frequency and analysis of registered displacements proved satisfactory to indicate tectonic movements. Indicated trends of tectonic movements are several times higher than the limit given for sensitivity of the installed instrumentation which reads 0.0125 mm. Besides, short-term deflections in movement development were successfully registered which are by figure of ten to one hundred higher than the instrumentation sensitivity. Therefore, as for displacements registered, results are quite reliable and conclusive.

Contemporary results show two characteristic features. First, movement trends can be registered, which indicates periods in which the movement is of a uniform character, i.e. of a uniform rate and orientation. Second, relatively short-time deflections in movements, often with abrupt acceleration, so called impulses, can be registered. These take place often several weeks to months and may develop even in a sense reverse to general trends at the given observation point. Registered movements on the Sudeten fracture, gauge A881, may serve as a clear example for such a result. Originally, movements on this fracture could be characterised with a relatively clear sinistral trend in horizontal movement. However, this development was interrupted abruptly at the break of years 2005/6 with an abrupt horizontal dextral shift so high that it reversed even the general character of its resulting orientation, becoming thus dextral.

Such two basic features of movements are not just local features of Bedřichov A Tunnel. They were observed by the authors widely, even at many other points of investigation in Bohemian Massif. The points are typically found underground, e.g. in the cave Pustožlebská Zazděná in Moravian Karst where movements on Macocha Fault are controlled, or in the cave Pod Šeptouchovem near the town of Ledeč nad Sázavou in Central Bohemia where monitoring of movements on a fault of Sudeten orientation is taking place in the valley of Sázava River (Stemberk et al., 2008a), or in the cave Na Špičáku, N of spa town of Jeseník.

Present results from Bedřichov A Tunnel show overthrusting movements that were registered with all of the gauges. Individual fracture movements proved to reach about 0.1 mm horizontally and vertically. Considering progressive movements as totals of step-like displacements of local blocks in space, calculated rates in movement trends during the investigated three-year period, read 0.22 mm per year on a deep overburden fracture with the Krušné Hory Mts. orientation, and 0.16 mm per year on such a fracture of Sudeten orientation.

There is an obvious difference resulting from the position of gauges. Two gauges are placed in the frontal section (stationing 235 m and 278 m), two in the rear section of the tunnel (stationing 791 m and 881 m). Records from the frontal section are of a more toothed form and the value of total movements recorded per one year of measurement is higher than in the rear section. Also, reached movement accelerations may be up to three-times higher. Fracture monitored with gauge A235 got even a character of extension. This is explainable by the fact that the massif is more loose near the surface, therefore it sustains even higher shifts between blocks, as well as some temperature dilatations, possibly, as noticed at A235.

There is an important finding in the fact that gauges monitoring parallel fractures provide results showing similar development in movements, as well as general coincidence in registered impulses. Regarding the considerable distance between the gauges (646 m for Sudeten orientation and 514 m for that of the Krušné Hory Mts. orientation) it is to be assumed that registered movements originate in the depth and reflect stress state changes representative for the present tectonic development of the region.

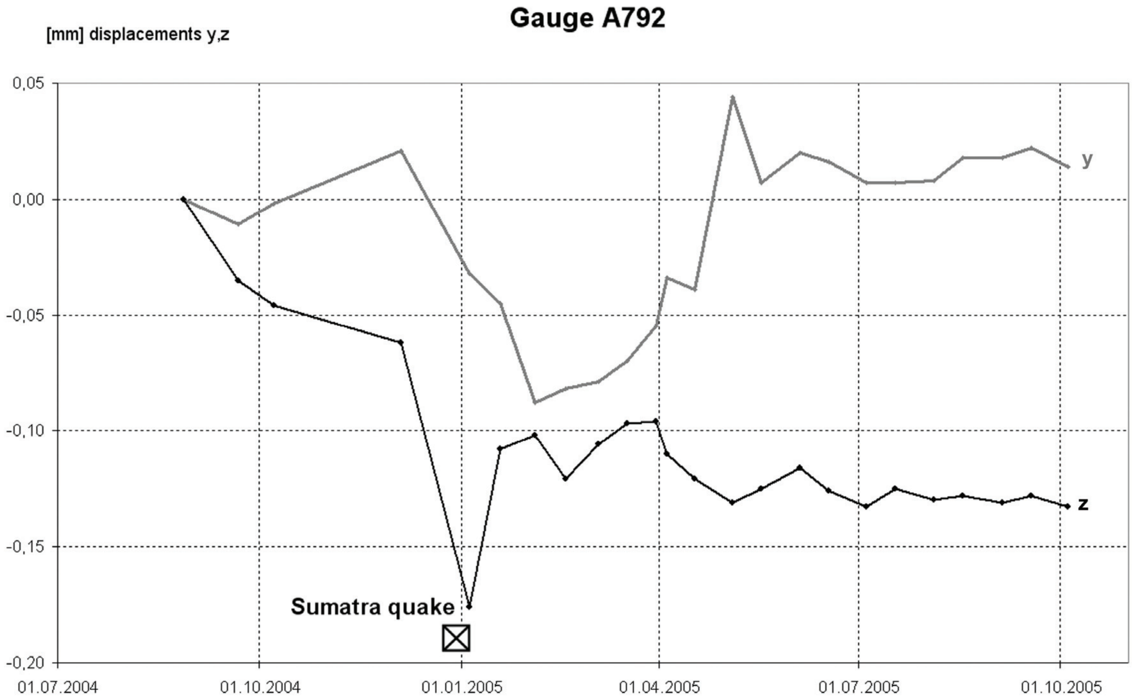
Monitoring period encountered two significant impulses producing accelerated micro-movements. The first (see Figs. 2 and 4) was registered soon after beginning of the monitoring, i.e. at the break of 2004/5. The effect was attributed to Sumatra earthquake that occurred by the end of 2004. The impulse evidently originated as a reaction to stress changes of global propagation that produced even the earthquake (M_W = 9.3) that also caused effects of global character. The record is well evidenced in detail (Figs. 6a,b). This impulse from 2004/5 is typically different from the impulses that originated later, i.e. up to November 2007.

The second impulse period (see Figs. 2, 3, 4 and 5) was registered from November 2005 to April 2006. Investigating other possible events that could be correlated with it, we find also earthquakes with epicentres within the territory of Bohemian Massif and its close neighbourhood, which produced macroseismic effects. The first occurred on October 25, 2005 near the town of Hronov nad Metují (NE Bohemia, M=3.2) and the second on March 13, 2006 near Vrbové in the Malé Karpaty Mts. (W Slovakia, M=3.2). Both the earthquakes represented locally the strongest natural events of last years. It must be mentioned, that day after, March 14, 2006, strong rockburst in Lubin coal mines was registered with M=3.7. It was felt also macro-seismically in N Bohemia (www.ig.cas.cz).

The authors registered this impulse not only in Bedřichov A Tunnel but in a series of other monitored points in Europe ranging from Upper Rhoinegraben (Stemberk et al., 2008b), Bohemian Massif (Stemberk et al., 2008a), to West Carpathians in Slovakia (Briestenský et al., 2007). As an example let us mention records from two caves: Pustožlebská Zazděná in Moravian Karst and the cave Na Špičáku in the Rychlebské Hory Mts. (Figs. 7 a,b). There is the second impulse there recorded with different intensity in different co-ordinates. Moreover, the record from Na Špičáku Cave displays also the first impulse of 2004/5. This is said to be the Sumatra impulse, although Pustožlebská Cave did not react to the first impulse.

To estimate relation between registered impulses and earthquakes either in local or global scale remains a problem. The fact that registered impulses come out often considerably in advance of the earthquakes in question leads to a conclusion that impulses cannot be considered as direct effects resulting from the energy released during the earthquake. The problem has been discussed recently by Košťák et al. (2007). We assume that the impulses registered in displacements result from extensive stress state transformations which afflict large areas from time to time. The changes provoke deformations on monitored structures, although in locally uneven intensity and character of movement. The process is extensive and affects eminently weak points with stress concentrations in the Earth Crust triggering earthquakes. Attention should be drawn also to the fact that the impulses are followed frequently by a calming period of movements or even with shift ending in a particular direction. Such is the case of movements having been observed horizontally in y with the gauge A792 and vertically with the gauge A881 since the beginning of 2006. Similar effects caused by earthquakes have been observed generally.

Attempts to define the situation of displacements registered in Bedřichov A Tunnel leads to a stress/strain model characteristic of compression inducing differential overthrust faulting. Comparison of our results with those obtained by brittle fracture rock analysis in Bedřichov A Tunnel made by Havíř (2007) comes to several deductions. First, it confirms that the decision to concentrate micro-displacement monitoring into the frontal section of the tunnel was right. Statistical analysis made in the frontal section driven by the milling cutter Demag shows overbalance of sub-vertical structures while further sections driven by shooting are seriously damaged



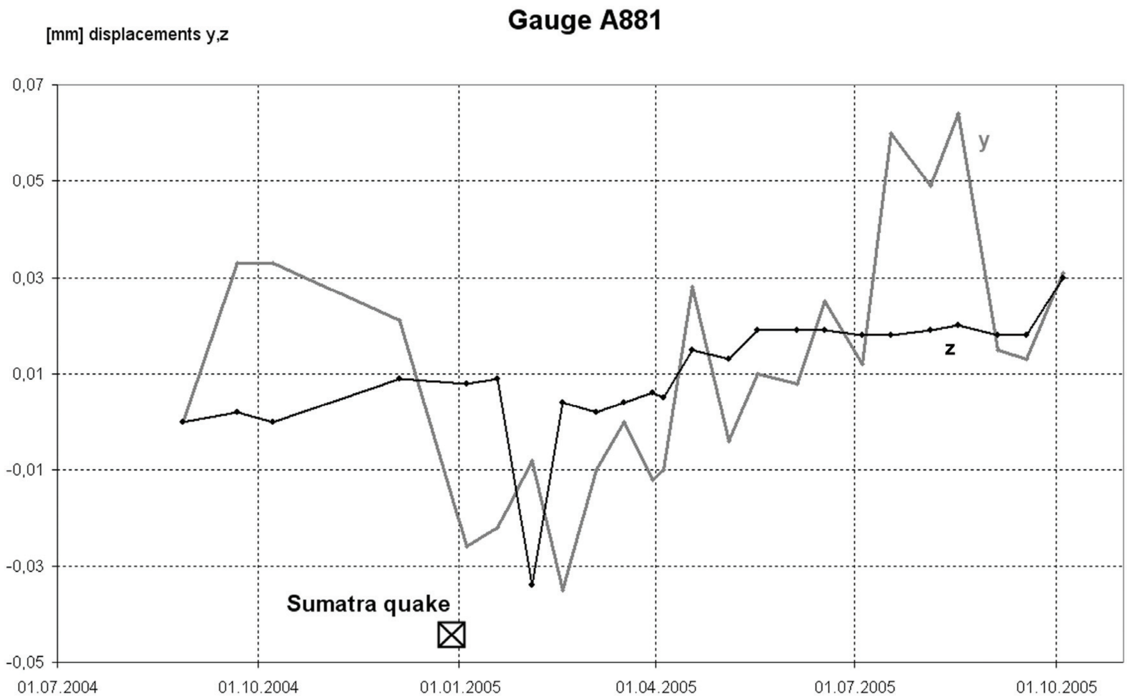


Fig. 6 Details of displacements registered around Sumatra earthquake (26.12.2004, M=9.3).

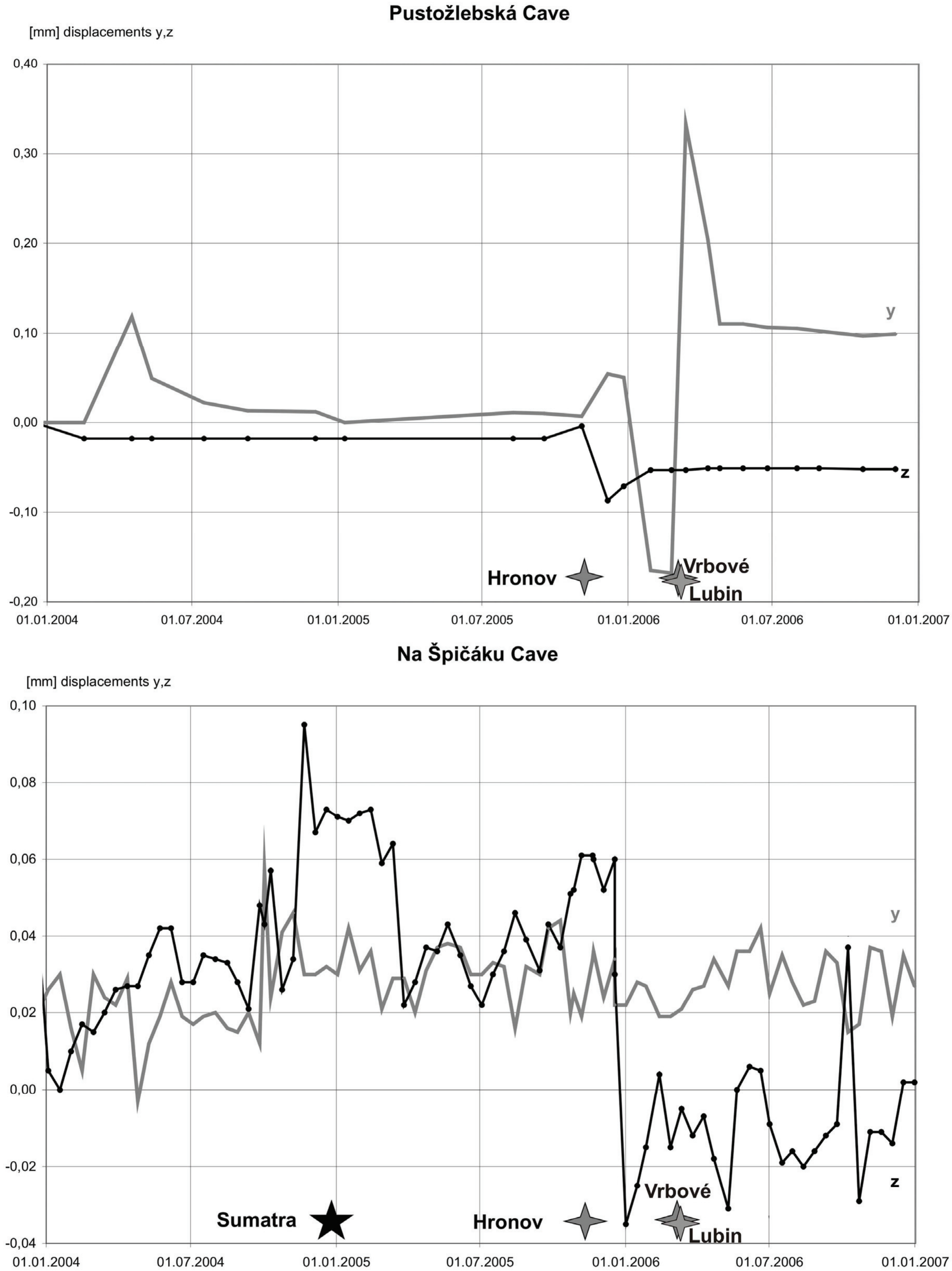


Fig. 7 Details of unusual displacements registered during the same time in Bedřichov Tunnel and in Pustožlebská zazděná Cave in the Moravian Karst and Na Špičáku Cave in the Rychlebské hory Mts. at the end of 2005 and beginning of 2006. Two events of local earthquakes occured in that time are marked – Hronov n./M. earthquake (NE Bohemia, 25.10. 2005, M=3.2) and Vrbové earthquake (W Slovakia, 13.3.2006, M=3.2). Strong rockburst in Lubin (SW Poland) was registered on March 14, 2006 with M=3.7.

structurally. Havíř´s report proves also two prevailing structural systems in the tunnel, marked by the authors as of the Krušné Hory Mts. and Sudeten which were selected for the monitoring. Then, analysis of striations which can be seen as characteristic for shear movements, proved the investigated set of fractures rather heterogeneous. This suggests the impression that the fractures originated or reactivated in more than one single stress state field (Havíř, 2007). One can make an important deduction therefore that striations originating in varied geological past due to varying slipping movements cannot be directly bound with present movements gauged and presented in our records to define present time state of deformation development.

All the gauges show overthrusting of southern blocks over the northern ones at present. It generally corresponds to result of older views upon the present stress state situation in Bohemian Massif published by Peška (1992) as well as to the newest analysis made by Jarosinski (2005) in Polish region N of Bohemian Massif. Stress $\underline{\sigma_1}$ should be found oriented approximately to N-S and stress $\underline{\sigma_3}$ to E-W.

6. CONCLUSIONS

Observation period is still too short to express conclusions that would define conclusively general character and origin of present movements registered on tectonic fractures in Bedřichov A Tunnel. This is a lesson for a long-term investigation. In spite of that some important findings summing up three years of the monitoring research can be given:

1. All the four gauges operating in the tunnel register displacements.
2. Individual displacements registered during 2004/7 period reach values close to 0.1 mm in slips, horizontal and vertical.
3. Displacements registered on fractures of the same tectonic orientation (two of the Krušné Hory Mts., other two of Sudeten orientation) are conformable. Registered data can be therefore with high probability identified as of tectonic origin.
4. Fracture slips analysed as progressive movements of local rock blocks in space give totals showing displacement rates of 0.22 mm per year along the Krušné Hory Mts. structures and rates of 0.16 mm per year, along the Sudeten structures. The figures belong to deep overburden blocks.
5. All the gauges have registered oblique overthrusting displacements appropriate to overfaulting of southern blocks over the northern ones.
6. Present character of displacements is conformable with a stress state model characteristic of approximate N-S compression with overthrust vergence to N.

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