# Some problems of geophysical works for line construction

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***Některé problémy geofyzikálních prací pro liniové stavby***

*Obecně známý logický požadavek na to, aby inženýrskogeologický průzkum předcházel vypracování projektové přípravy liniových staveb, není v praxi často respektován. Dodatečné úpravy trasy, které jsou nutné podle výsledků provedených průzkumů, si následně vyžadují podstatné prodloužení přípravy stavby, budování monitorovacích systémů, další finanční náklady i prodloučení času. V článku jsou uvedeny některé příklady dodatečných inženýrskogeologických (včetně geofyzikálních) průzkumů pro liniové stavby.*

***Klíčová slova**: liniové stavby (vysokotlaký plynovod, silnice), geofyzikální průzkum.*

## Introduction

The article is not intended to cover all problems of geophysical works for line constructions, it merely wants to present some examples of successful applications of even a simple complex of geophysical methods for the given purpose.

## Investigation of gas high-pressure pipeline

What is a well-known logical requirement presented in basic textbooks is that engineering-geological exploration should precede the project design of construction. It is usually far from being respected in practice, even in the case of structures situated in areas dislocated and full of conflict up to areas endangered by slides, as can be supported by an example from the construction of a gas high-pressure pipeline (GHPP) leading from Třinec to Jablunkov. After the alignment of the line it was found that the pipeline should run, among other matters, even through erosive valleys of local rivers, where activation of landslides could occur as a result of building. Therefore, geophysical exploration was supplementarily carried out in these risky zones with a view to judge the preconditions for possibilities of generation and activation of slope deformations (to assess a thickness of the gravel-sand complex, depths and courses of shear planes and the depth range of the slope deformation). The method of resistivity profiling with a symmetrical layout of electrodes, two depth ranges (5 and 12m theoretically) and a 5m spacing as well as the method of vertical electrical sounding was applied. Besides, emanometric exploration was made to a limited extent. The areas of exploration and the localization of geophysical profiles themselves were designed by a geological engineer after detailed geological reconnaissance of the terrain and were modified depending upon terrain accessibility and possibilities of entry to private lands. The interpretation of geological exploration, that unfortunately could not rest upon any direct works, pointed out the necessity of both partial changes in the pipeline alignment and some building measures. Although in the given area, it is largely the case of potential slope deformations, those can be revived or their movement velocity can be increased within the periods of excessive rains, at scouring the river banks, at terrain improvements, etc. In the sections where the suggested line went obliquely or normally to a possible direction of slope movements, the change in the line was designed to the dip direction. Moreover, the drainage of trenches, or the building of a stabillizing fill at the base of the slope was recommended. In places, where the trenches for the pipeline would undercut the accumulative part of the slide, a shift of the alignment was suggested.

In Fig. 1 an example of interpreting a part of the profile in Lyžbice is shown. In the profile direction, the suggested gas line went up to the 110m footage, where is declined southwards. According to the results of resistivity profiling and VES 2 (vertical electric sounding) interpreting, a 5-6m thick layer of probably loamy gravel-sand (according to the samples of rock material on the surface) occurs in the roof of a low-resistivity layer up to the footage of about 80m. However, from the 80m footage the results of resistivity measurements indicate the existence of shear, markedly low-resistivity zones. The base of the slope deformation is situated approximately at the depth of 10m. Here, a shift of the gas line to a lower footage of the profile was designed.

Fig.2 illustrates a typical manifestation of the block slope deformation in an erosive valley. On the surface, manifestations of creeping to sliding movements can be observed (tilted trees, terrain steps). The gas pipeline ought to have been led transversally through the slope in the NE-SW direction. We suggested to lay the line

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through an erosion furrow of the left bank along the slope dip direction, to diminish its dip with ensuring permanent drainage and to lay the line across the brook in the stabillizing fill.

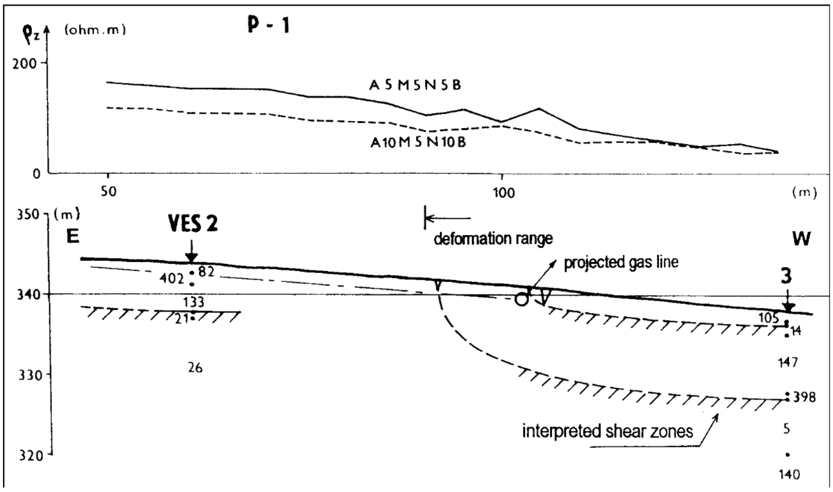


*Fig.1. GHPP Jablunkov, locality 1 km 8,5.*

By check observing the movements with bar extensometers built in risky places of the gas line, a shift of even 25mm (between the VES 3 and the VES 4) was verified within the spring thawing in 1995.

Additional improvements in the line required a considerable extension of the stage of construction preparation for the reason of new negotiations with land owners, the creation of a monitoring system, i.e. extra time and financial demands (million in order) that might have been avoided during the stage of gas line alignment.( Műller, K. et al., 1994).

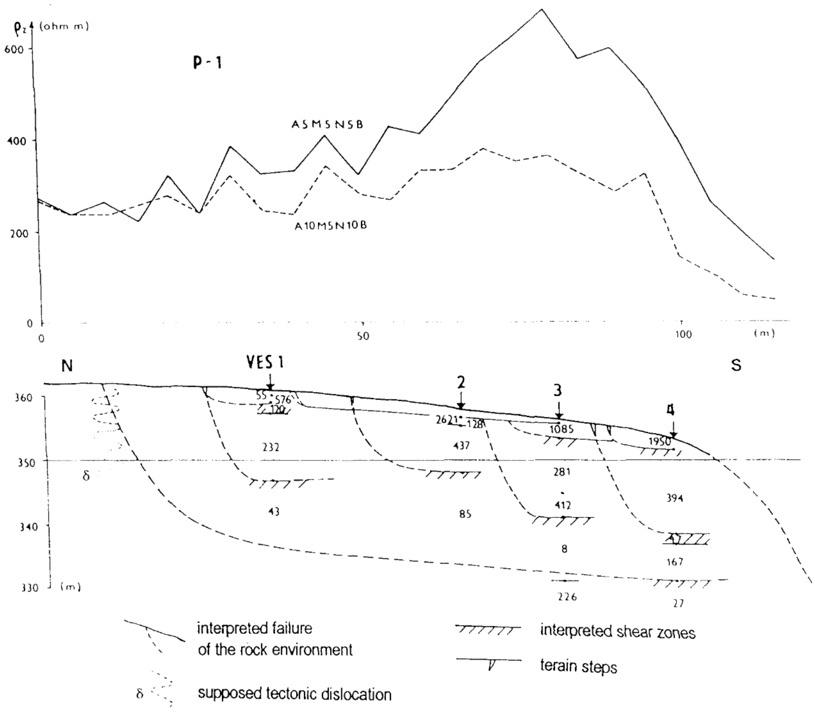


*Fig.2. GHPP Jablunkov, locality 3 km 10.*

**Investigation of roads**

Another example showing an insufficient advance of proper studying the geological situation over the given phase of project documentation, is projecting and exploration for the purpose of a by-pass road in the town of Mosty u Jablunkova. It is laid out in the zone of contact between the Silesian and the Magurian nappes, the zone of the complicated tectonic structure and superficial manifestations of slope deformations. The road alignment is designed along embankments and, in places, along the trench even 14m deep. Evaluation of geological conditions for building was made only on the basis of results from the shallow drilling exploration that had not provided any information for necessary stability calculations. Therefore, geophysical exploration was required later with the aim of defining, in virtue of physical, more specifically, resistivity manifestations, the extent of slope deformations and lithological boundaries, namely merely in seven profiles aligned by an engineering geologist in a part of the route. The profiles were situated in places of supposed slope deformations with reference to terrain accessibility. From the standpoint of time, we confined ourselves again to a complex of methods consisting of the resistivity profiling method with a symmetrical lay-out of electrodes, two or three depth ranges (theoretically approx.5,12 and 17m), a 5m spacing and the electrical sounding method. Sondes were chosen according to the results from resistivity profiling with an expansion in the direction of contour lines with the usual maximum spacing of current electrodes of 164.6m; 276m being the maximum.

In the area of exploration, it was not possible to rest upon the results of direct works at greater depths and thus to use possibilities of interpretor's intervening in the process of automatic interpreting the sondes (e.g. fixation of resistivities or a thickness of the last layer, changes in a so-called "shift-factor"), which, on the other hand, was possible thanks to the applied interpretable program. In this case, the program by A.R.Zohdy and R.J.Bisdorf (1989) from the U.S. Geological Survey was used. In the locations of six boreholes suggested by geologists, we carried out the interpretation of sondes both by means of theoretical curves (see Fig.3, which is an example of interpretation of one of the sondes marked with a letter a) and by using the already mentioned program (b letter in Fig.3) and by the PC VES interpreter from the firm DATA SLUŽBA (author Gűrtler, 1993). Here, either the result of graphic interpretation (d letter) or of the American program (c letter) was chosen as a starting model in Fig.3.

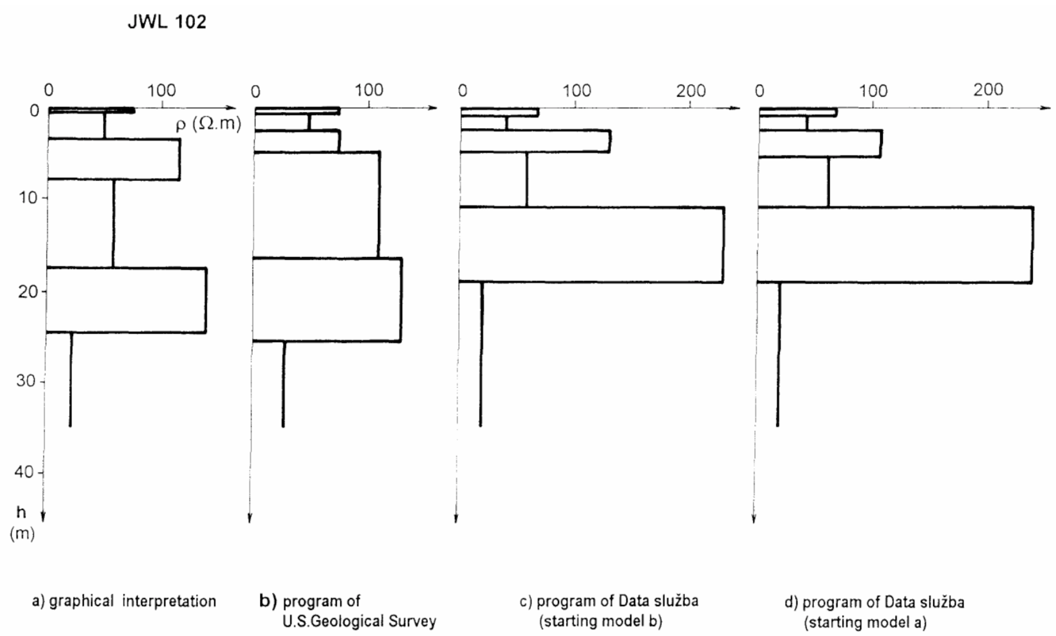


*Fig.3. Results of interpretation – sonde JWL 102.*

Discrepancies in results of interpretation exist that can be probably explained partly by a validity of the equivalence principle and the manner of decision-making concerning the accordance of a sonde curve calculated according to the resistivity model with the measured curve. I would like to express once more that no possibility of existed intervening in the interpretation on the basis of parametric measurements of values of resistivity and boundary depths found in rather deep boreholes.

The average value of apparent resistivity in all the profiles differed only little at various depth ranges. This is also valid for the range of values - see Tab.1. As for differences between profiles, they were shown only in two profiles - one in higher values and the other, on the contrary, in generally lower values.

Tab.1.

| *Lay-out of electrodes* | *Value number* | *Arithmetic mean (Ωm)* | *Minimum value (Ωm)* | *Maximum value (Ωm)* |
|---|---|---|---|---|
| A5M5N5B | 605 | 65 | 17 | 314 |
| A10M5N10B | 604 | 62 | 14 | 217 |
| A15M5N15B | 190 | 70 | 2 | 283 |

In all the profiles, wholes could be defined vertically and horizontally, different in lithology - complexes of rocks with a prevalence of psammites or pelites, and many more or less marked vertical and inclined low-resistivity areas that are probably manifestations of the zones of weakening the rock massif reaching the deeper underlying rocks (wavy lines in Fig.4,5). Some of these disconti-nuities seem to condition the origin of slope deformations, mainly in upper or lower parts of the slopes.

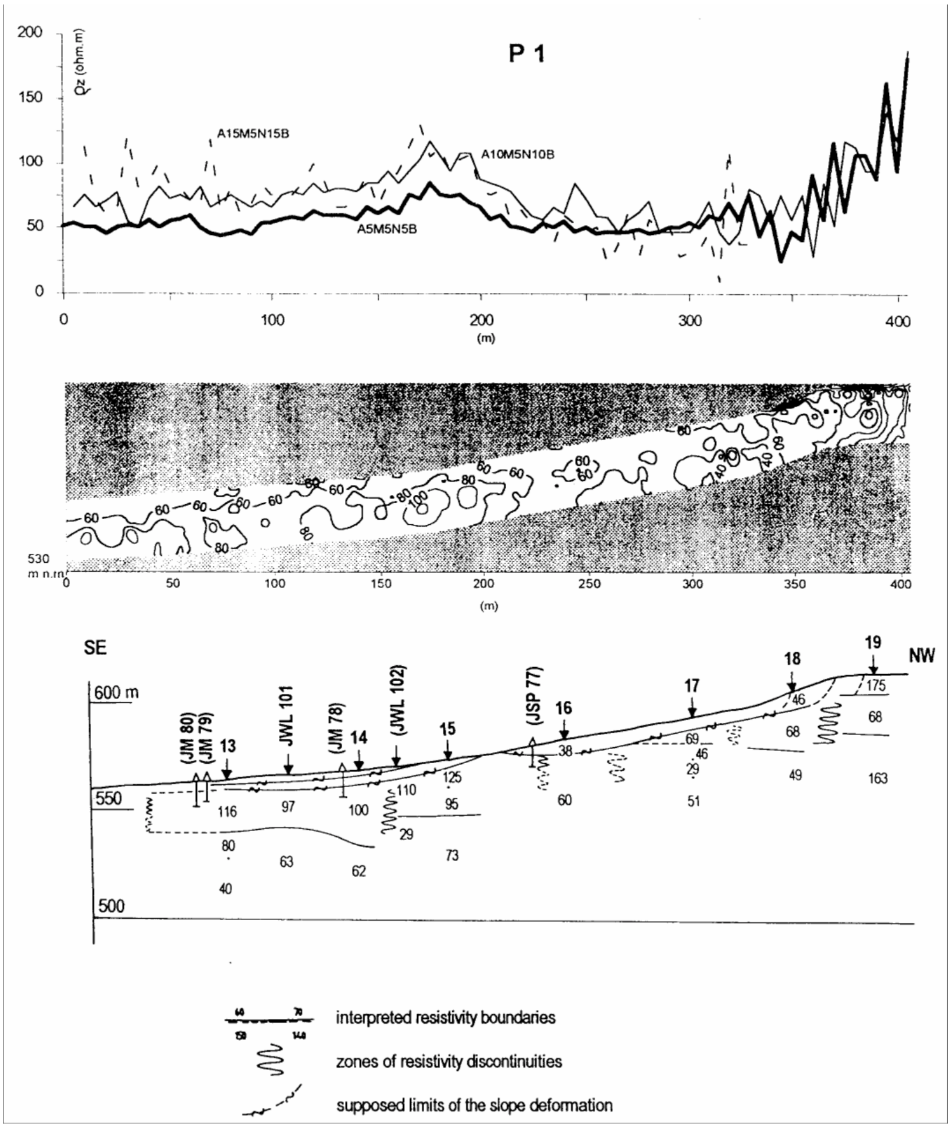


*Fig.4. Mosty u Jablunkova, profile No. 1.*

In Fig.4 an example of results of both the processing the measurements and the inter-preting one of the profiles is given. Up to the footage of 200m, it was possible to correlate a layer of weathered rocks with a zone of intensive weathering of the bedrock with a thickness of 5-8m and resistivity values of approx.60-70 m that could be a cause of stability problems at building rather deep trenches. The third geoelectric layer of a thickness less than 20m and of resistivity values of approx.100 m seems to correspond either to a pelitic environment with inter-calations and layers of psammites or, with an increasing depth, an environment of a predominantly pelitic character. A vertical shift of the lower boundary of this layer between the VES 14 and VES 15 sondes as well as the occurrence of a low-resistivity layer in the VES JWL 102 at the depth of 24m can indicate a tectonic deformation of the massif. In addition, in another part of the profile between the footages of 310 and 400m characterized by rapid changes in the curves of resistivity profiling and change in isoohm character in the vertical isoohmic section, it can probably be a case of manifestations of deeper loosening of the rock massif and, maybe, even changes in the geological structure. The impossibility to correlate geoelectric layers between the sondes VES 18 and 19 can be a result of a slope deformation of the block type, to which a subsequent gravitational movement of overlying weathered rocks and also the block itself could be linked.

By a borehole drilled subsequently in one of the profile (about 500m from the P1 profile to the south), which was situated in the place of similar marked changes in resistivity conditions, a zone of an intensive deep deformation has been verified. It requires an expensive stability measures regarding the slope of the trench. A pile wall up to 22m deep is being considered.

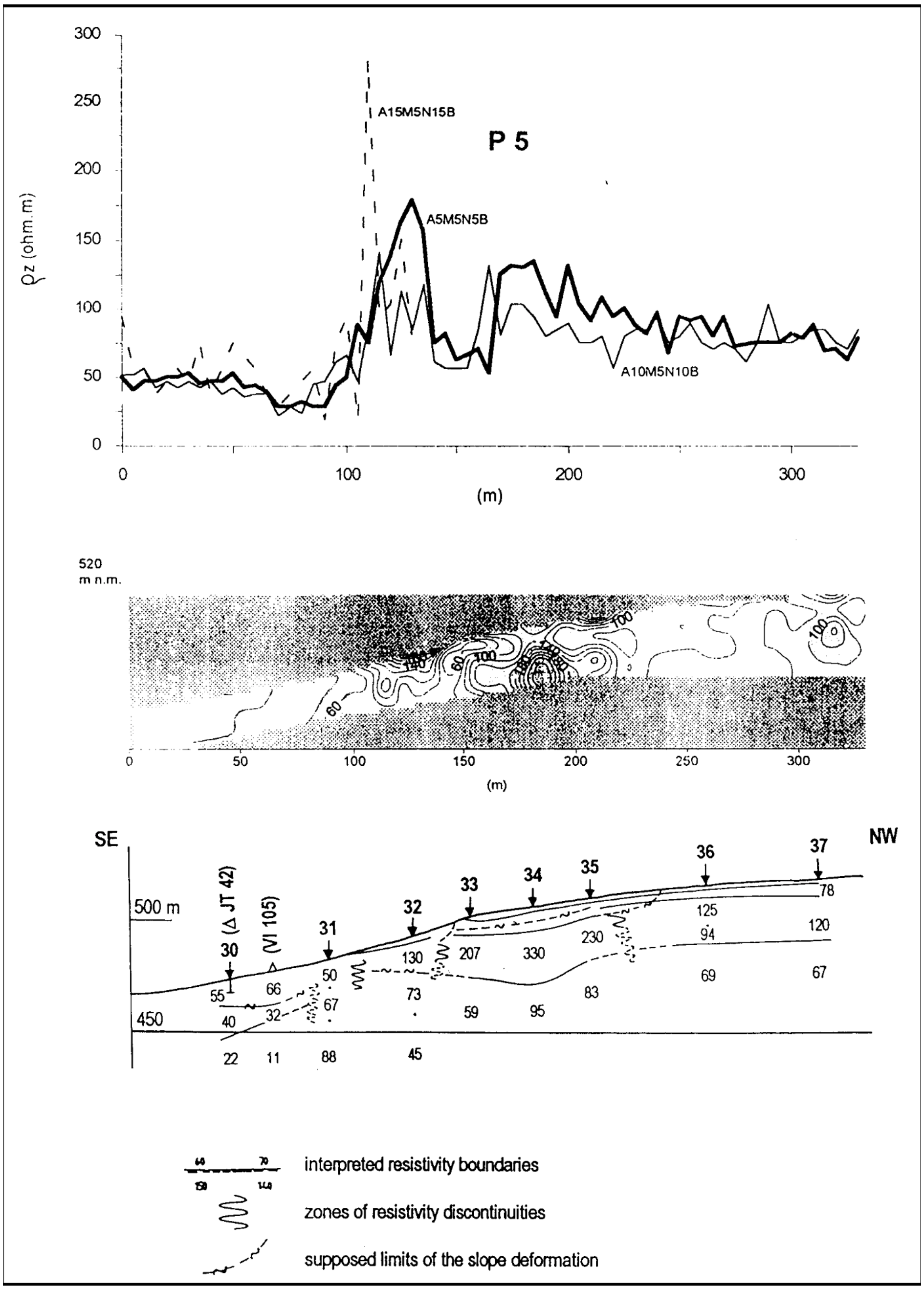


*Fig.5. Mosty u Jablunkova, profile Né. 5.*

In Fig.5, an example of processing the measurements and interpreting with another profile is illustrated. A rock massif consists here of two environments, differing the in resistivity with a boundary at the footage of about 110m. A lower part of the profile can be affected by slope movements. In the upper part of the profile (especially between the sondes VES 33-VES35), the rock environment is characterized, from the standpoint of resistivity, by higher values up to the depth of approx. 45m. Two weakened zones, characterized by lower resistivities in the footages of 140-160m and 220-230m, limit also a block of higher resistivities that is more or less compact. Their subsurfacial manifestation is probably shaded with a gravitational deformation of the weathered crust that reaches the depth of up to 8-10m, contingently 15m and more (surroundings of the VES 32 sonde), ( Műllerová, J. et al., 1995).

By results of geophysical exploration that were interpreted in a close co-operation of a geophysicist and an engineering geologist, it has been possible to define more marked low-resistivity discontinuities in the area of the planned by-pass road as manifestations of weakened zones. They condition or can condition the origin of slope deformations.

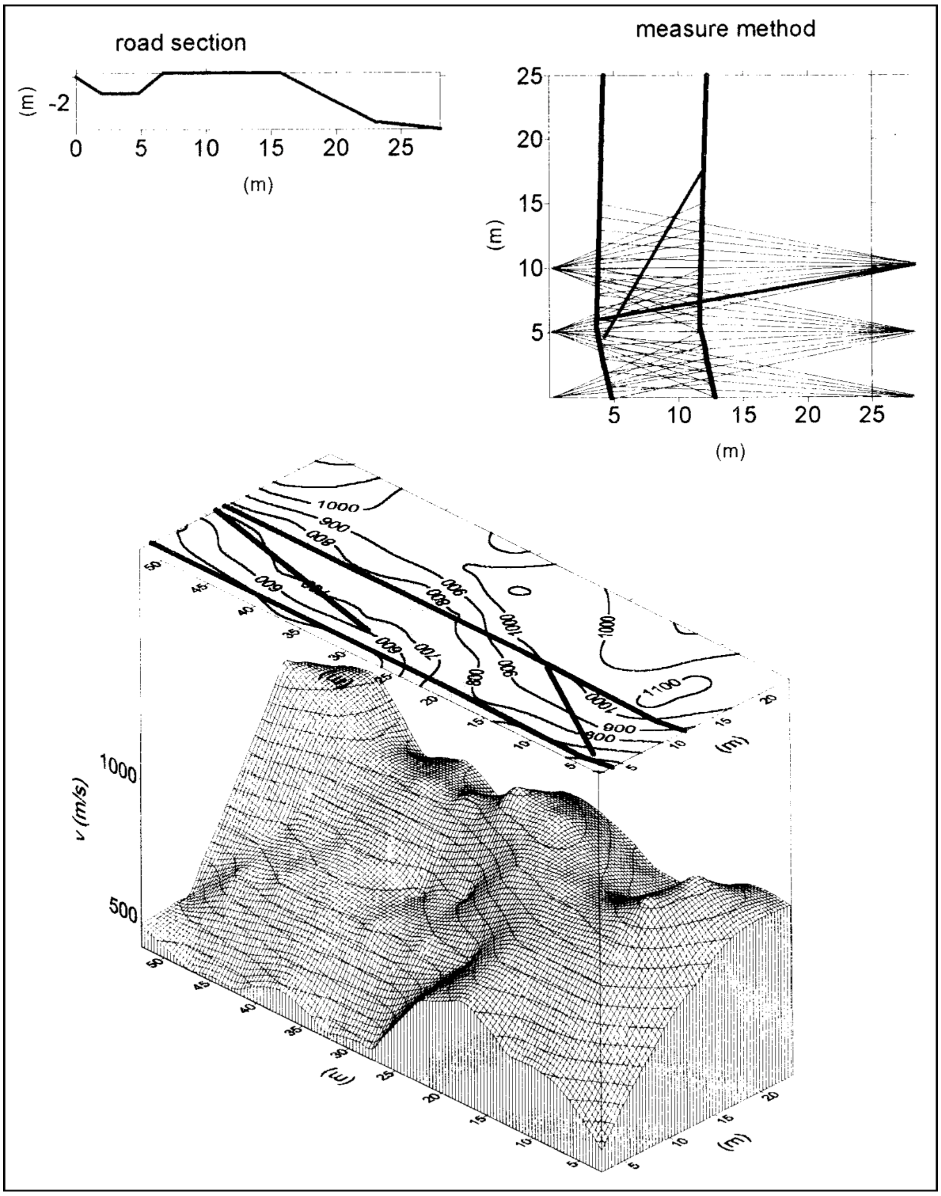


*Fig.6. Bartovice – seismic measurement.*

In the village of Bartovice, a new road was built along the embankment of compacted cinder. Tension cracks appeared in the asphalt topping soon. The designer as well as the producer were accused of wrong foundations of the road along the embankment and insufficient compaction and sliding. The road with a considerably heavy traffic is situated in the risky area (sliding structure). We intended to apply the method of seismic shooting to the embankment but it was not succesull. It was too wet weather, ground was soft and the damping of seismic waves was considerable. For this reason, we choose the following measuring method: points of seismic initiation - hammer blows - were located along both the sides of the road at a 1m spacing, geophones were placed on the embankment slope across the road at a 5m spacing - see the top of Fig.6. A fivefold overlap of measurements was used with a lap of 1m. At the classic processing, the values of the velocity of elastic wave propagation (first arrival was taken) were related to the middle of the distance between a point of seismic initiation and the geophone location in the profiles designated as AA'(to the depth of about 0.5m) and BB' (depth of about 2m) in Fig.7. It followed from the mere statistical processing of results of the measurements that sets of $v_p$ values are mixed - in Fig.7, the arithmetic mean of $v_p$ values is plotted on the profile as a full line and median values as dashed lines. For the beginning part of the profile - block I - median values are plotted again as dashed lines. For the second block, these values are equal to those for the total set. Differences in velocities in the profiles are rather small - from -11 to +16% with the AA' profile and from -14 to +33% with the BB' profile, which indicates rather small differences in composition or physical state of the embankment in the area of both the profiles, because seismic waves propagated mainly through the embankment material. Results of measuring made it possible, at certain simplification of measuring situation, even it was possible to use tomographic processing when considering curved seismic rays. This part was carried out by RNDr.Bláha. Results of this processing in a form of a block diagram and a map of isolines of velocities of wave propagation on an oblique plane laid through the point of seismic initiation are presented in Fig.7 and in the central part of Fig.7. Dimensions of particular cells at the processing were rather great - (5*5.2m). The results of both the cases of processing show a very good congruency. Rather high values of velocity of wave propagation along the side of the higher embankment slope prove that the deformation is rather of a nature of remodelling clayey soils under a cinder embankment of the slope. A subsequent reducing of concentration in the surface part of the cinder embankment along the left side of the road in the direction of its rise was probably initiated by an insufficient compaction of the edge of the embankment. (Hofrichterová, L., 1995)

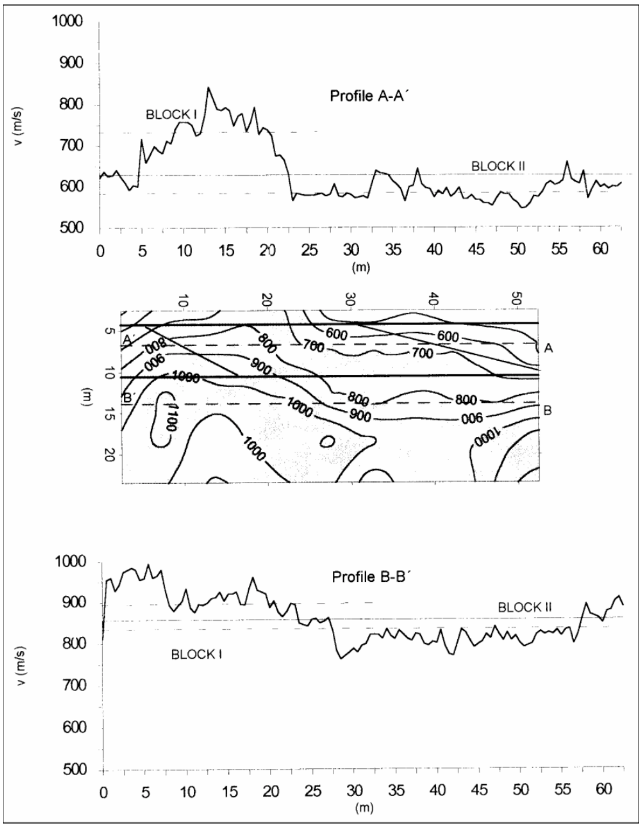


*Fig.7. Bartovice – results of seismic measurement*

## Conclusions

The given examples support the suitability of geophysical methods utilisation in the stage of selection of line constructions alignments, especially in the areas of a possible slope stability disturbance. This practise will contribute to the early warning of possible complications during the construction and operation of construction work, which will result in the financial and time savings.

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