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May 13, 2000, Bratislava, SLOVAKIA

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LANDSLIDES SYMPOSIUM

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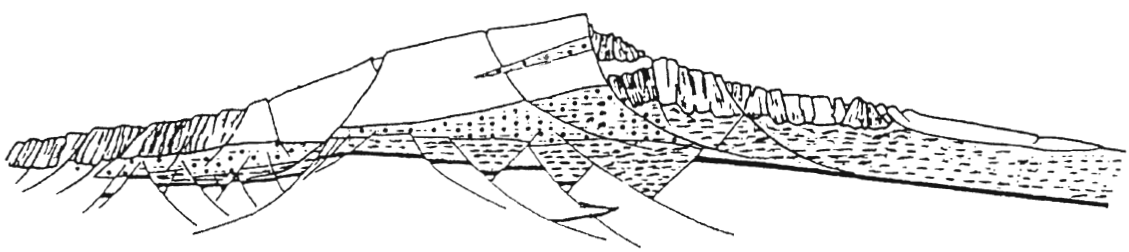

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History and perspectives of landslide studies in Slovakia

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Abstract

Due to its uneven morphology and complicated geological structure the Slovak Republic suffers from many types of slope deformation, especially landslides. Slope movements negatively affect the development of entire areas and regions and cause imeasurable economic loss. The origin and development of landslides is either a natural phenomenon, or, more often, they are caused by human activity. The increasing number of destructive landslides gave rise to systematic study of the phenomenon including identification and monitoring. The authors present a short history of the study of slope movements in Slovakia; the current situation is noted, together with suggestion for further methods of study with the ultimate aim of limiting the destructive effects of slope movements and contribute to the safe development of land areas.

Key words: slope movements, history, landslide inventory, systematic research

Introduction

The relative density of slope deformations in Slovakia is due to several specific features – first of all there are geological structures predisposing to the origin and development of slope movements; complicated hydrogeological and climatic conditions and intensive differentiation of mountains and lowlands as a result of relatively fast neotectonic movements. This all leads to the presence of large areas damaged by slope movements. Natural activation of these movements continues and occurs especially in seasons with precipitation anomalies. Increased human activity causing an impact on the environment, has led to an increasing the number of slope movements, directly caused by human interference. Damage caused by slope movements increased, and study of methods of preventing landslide damage developed into systematic study of the frequency and development of the phenomenon. Especially after the catastrophic landslide in the town of Handlová, it was realised, not only specialists, but also by responsible state officials, that the evaluation of stability is an essential part of urban planning and technical projects in the development of individual regions. The basis of systematic study of slope movements was thereby formed. The study was coordinated by the central state authority – the Slovak Geological Bureau, later by the Department of Geology and Geofactors of Environment, which is part of the Ministry of Environment of Slovakia. Paralelly with investigation of active landslides various forms of systematic landslide research are also ongoing.

The history of slope movement study in Slovakia is in various ways an expression of widely varying opinions in society with regards to the best method for elimination this undesirable geodynamic phenomenon.

Early approaches to solving problems in slope movement

In the period before engineering geology developed as a independent scientific discipline, problems of slope movements were studied only occasionally by specialists as part of the process of basic geological and geomorphological map compilation. The attention of experts and public, alike, focussed on slope movements, caused by building and construction work. These problems were usually connected with the construction of transport routes (roads, railroads), which crossed complicated geological terrain. Since 1920, much well-known work on landslide problems connected with the construction of railway network, connecting Slovakia with Czech lands. A special map of landslide regions (Kettner and Záruba, 1922 in Malgot and Baliak, 1999) was to make the decision on proposed railway routes. Stability problems arose frequently in the ensuing period, especially during communications construction in Carpathian Flysch (Záruba and Myslivec, 1942), but also during the laying of new rail routes in complicated geological conditions (e.g. the Diviaky – Banská Bystrica line, frequently exposed to landslides and creep deformation of rock massifs). Besides transport communications (including tunnels) the problems of slo-

pe movements were pronounced during the preparation process for important hydrotechnical constructions. During the preparation of the Upper – Váh hydro-cascade in the section between the villages of Krpeľany and Lipovec a series of well known stability evaluations were made (Záruba, 1954; Záruba and Mencl, 1958). A lot of experience gained in solving stability problems connected with hydrotechnical construction work was summarized in individual papers (Záruba, 1957 and others).

Though in this period stability problems were solved usually in connection with actual construction problems, thanks to much analysis of available scientific expertise provided by two of the leading figures of the Czechoslovak landslide school – Q. Záruba and V. Mencl, the base for systematic study of slope movements arose.

Catastrophic landslide near Handlová town in 1960–1961

The Handlová landslide, which started in December, 1960 and was active till May, 1961, is an example of natural catastrophe, initiated by a precipitation anomaly. The volume of moving mass was estimated to be about 20 mil. m^3. Approximately 150 houses, 2 km of road, water supply system and several power lines were completely destroyed. The Handlová landslide is considered to be the greatest natural catastrophe, caused by slope movement, in Slovakia, to this day.

The origin, development and consequences of landslide catastrophe in the mining town of Handlová was a turning point in the attitude to the importance of slope movements and their study. This change in attitude was typical not only for experts, but also for the responsible state authorities, as well. The development and consequences of the slide clearly show the danger to people and the threat to general development of some areas.

A short time after the Handlová catastrophe, a landslide station was set up in the town. The station was part of the Dionýz Štúr Institute of Geology and about 7 specialists were employed there. Besides continual monitoring of the Handlová landslide they prepared basic materials for a general inventory of slope movements. After three years the landslide station closed down.

The change, initiated by the Handlová landslide gave rise to systematic research into slope movements in Slovakia. This research took form as a result of Handlová landslide and other landslides at the beginning of the 60's (for example the landslide catastrophe near Riečnica village in 1962, etc.) and was coordinated by the central state authority (Slovak Geological Bureau, later the Department of Geology and Geofactors of Environment at the Ministry of Environment of Slovak Republic).

Systematic research into slope movements

The Handlová landslide shows, that in certain geological structures in Slovakia (especially in territories of Carpathian Flysch and on the borders of Neogene Volcanites) slope movements may activate, and they were rarely monitored with serious consequences for the area. Experience of that time indicates, that stabilization of active slope movement is substantially more complicated and expensive than prevention measures (including issuing warnings during building construction). Moreover, the assumption that the activation of new slope movements occur mainly on old landslide areas, turned out to be right.

In the light of the above, the first logical step in systematic research into slope deformation was their general registration. The aim of registration was to create a base for area forecast of the degree of probability new movements, and at the same time, to limit ill-conceived urban planning projects. Slope deformations were registered first of all in areas with an investment interest – especially around roads, railways, rivers, villages and towns (Matula and Nemčok, 1966).

Evaluation of the first stages of registration showed, that the occurrence of slope deformations is usually concentrated in certain areas. In line with urban development, a study project on the most important landslides in Slovakia was prepared. The project was gradually changed into evaluation of important landslide areas, in urban district, which attracted investment interest. In the framework of this project new methods of investigation and research were tested in selected landslide localities.

Despite continuous systematic research and investigation of slope movements, unforeseen cases of catastrophic landslides occurred during the entire period. These landslides had to be solved and stabilized immediately. The information gained, was used to expand the database of systematic research into slope movements.

We may say, that systematic research into slope movement has been in progress on a regional level (inventory) and area level (research and investigation of selected landslide areas) since sixty years. Data obtained is supplemented by the results of local investigation of catastrophic slope movements.

Regional level of study – inventory of slope deformations

An inventory of slope deformations in Slovak Republic territory was done in several stages. During these stages the method of inventory of individual slope deformations was improved (types of inventory cards, maps). A description of method of compiling the inventory was dealt with in an individual paper (Kováčik and Suchánková, 1993).

In the first stage of inventory (from 1962 to 1964), carried out by several scientific and University institutions in the former Czechoslovakia, about 4800 slope deformations were recorded on a map on the scale of 1:25 000 (Matula and Nemčok, 1966). Inventory cards were stored in the central geological archive – Geofond (in Prague and in Bratislava). Thanks to obtained information, extensive regional studies on the occurence of slope deformation in Slovakia and their connection to geomorphological and geological conditions, were worked out. In connection urban planning the areas most exposed to the threat of slope movement origin and activation were

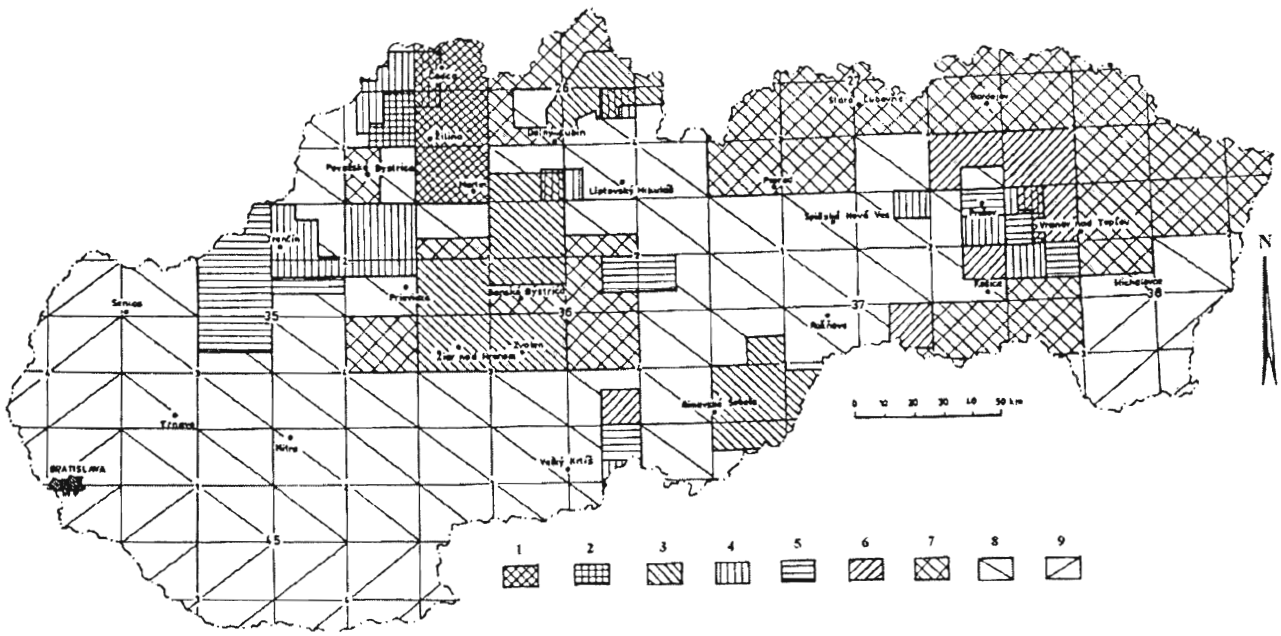

Fig. 1. Inventory of slope deformations in Slovakia (according to Liščák and Caudt, 1997). 1–7 realized by Dionýz Štúr Institute of Geology (1 – in 1981, 2 – 1982, 3 – 1983, 4 – 1985, 5 – 1986, 6 – 1987, 7 – 1989–1992), 8 – realized by other organizations, 9 – territory without registered slope deformations.

identified (Malgot, 1980; Malgot, Baliak and Andor, 1994).

The register of slope deformations was continually updated by data from engineering geological reports, but contained relatively little information about slope movements, affected areas without human activity (e.g. arable land, pastures, meadows etc.). The second stage of inventory development took place from 1974 to 1978, and concentrated especially on high mountain areas. This stage was realized by geologists from the Department of Geotechnics of the Slovak Technical University in Bratislava (Nemčok et al., 1977, 1979). The result was an important contribution to knowledge about slope movement occurence in West Carpathians and verify a new classification system for slope movements (Nemčok, Pašek and Rybář, 1974). The total number of registered slope movements rose to about 10 000 after completing this stage of the inventory. An important contribution at this stage was methodical revision of the inventory (including the inventory cards), to make it computer compliant.

The third stage of inventory from 1981 to 1991, was realized by geologists from the Department of Engineering Geology of the Dionýz Štúr Institute of Geology. The work was based on previous data, and stereoscopic interpretation of aerial photographs, but mainly on new field mapping (Kováčik and Suchánková, 1993). Obtained information made a valuable contribution to knowledge about the principles of origin, development and regional distribution of slope movements. The study was regional in scope, and the aims were: a) to completion of slope deformation records, b) to create a basis for long-term monitoring of slope deformations in Slovakia (Modlitba and Klukanová, 1996). In this stage, about 5000 new slope deformations were registered and the total number of recorded slope deformations rose to ca 15 000 (Modlitba et al., 1992). Map sheets with the inventory of slope deformations are summarized in Fig. 1.

Area level – research and investigation of selected slope deformation areas

At the area level of research, basic maps (in scales 1:25 000 and 1:10 000) of slope failures were compiled. The selection of areas was based on general knowledge about the geology of Slovakia, on the data in the slope deformation inventory and on urban planning in Slovakia. Several areas with frequently occurring slope movements were identified, e.g. Handlovská Kotlina Basin, Liptovská Kotlina Basin, Vtáčnik Mountain, Slanské Vrchy Hills, Kremnické Vrchy Hills, Pokoradzská Tabuľa Plateau, etc. Several areas have been completed, or are being worked on at present.

In each map area representative localities of active slope movements are selected. These localities are studied in more detail. In the past new methods of investigation were verified for such selected localities (for example the landslide near the village of Turany), or new stabilization measures were used experimentally. This trend is continuing. Based on the results of investigation work and methods, the stability of each representative locality is evaluated by computing methods. Where actual endangering of important structures by slope movement is involved, the proposal is being considered to include the locality in the set of long-term monitored localities of slope movements.

Local level – investigation of destructive active slope movements

Detailed engineering geological investigation of destructive slope movements involves the optimal stabilization of a slope followed by the institution of corrective measures. Success in slope movement stabilization is usually verified by long-term monitoring of slope stability state.

Present state and perspectives of research and investigation into slope movements

Since the completion of third stage of the inventory, the database of slope deformation is updated by information from engineering geological investigation for various purposes, as well as by data from systematic study of slope movements areas. At present there are ca. 15 000 slope deformations, covering an area of 1820 km^2, in the database. This means, that about 3.7 % of Slovakia is covered by slope deformations (Liščák and Caudt, 1997). In some areas slope deformations affect more than 60 % of the total area.

According to Nemčok (1982), 548 residential areas, 5730 houses, 127 sections of railroad (total length ca. 46 km), 200 sections of I. and II. category roads (length ca. 90 km) and 600 sections of III. cathegory roads (total length ca. 180 km), are under threat from slope movements in Slovakia. The total area of devastated land and forests is ca. 1483.6 km^2. All this information is continually updated.

At present processing of selected slope deformations areas is continuing with systematic study at the area level (Kysucká vrchovina Upland, Ľubovnianska vrchovina Upland, Orava River Basin). Completion the slope deformations inventory for the whole of Slovakia is part of the long-term plan for landslide studies, which is coordinated by the Ministry of Environment.

Research into the data in the inventory of slope deformations monitoring of landslides and other slope deformations has been in progress since 1993, as part of the monitoring system of geological environmental factors. In this project, the state of selected slope deformations in Slovakia is observed. Methodology and partial results of this project are summarized in an individual paper published in this issue (Wagner et al., 2000).

An important project, now underway, involves compilation of an Atlas of maps of slope stability in Slovakia on the scale of 1:50 000. The first phase of this project is connected with the data in the slope deformations inventory. These results will be supplemented by new information about the occurence of the phenomenon. Inadequate and controversial data will be assessed in the next stage of field studies. The final version will conform to modern standards for presentation of a work in map and digital form.

Conclusion

The principal aim of systematic study of slope movements in Slovakia is to obtain as much information as possible about their occurrence and principles of development. This information, should in all probability, make it possible to forecast slope instability in areas with projected construction and development activity. Distribution of this valuable information to central and local authorities, and dealing with urban planning, is the basic practical result of the work.

During the period 1970–1999 more than 100 projects were run connected with long-term direction of geological investigation of landslides, which were coordinated by Ministry of Environment of Slovak Republic. The total cost of these projects was more than 450 millions crowns (for the area of Horná Nitra, which includes Handlová area, it was ca.200 million crowns). It should, however, be stressed that activization new slope movements result in damage, amounting to some millions of crowns a year. Stabilization of active movements is always technically, economically and time demanding and complicated (Andor and Spusta, 1996). Advance warning, and reliable forecasts of possible slope movements requires considerable investment. The actual amount of money which could be saved by advance warning procedures is normally accorded too little consideration.

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História a perspektívy štúdia svahových pohybov na Slovensku

Svahové deformácie sú najvýznamnejším geodynamickým javom ovplyvňujúcim optimálne využívanie územia a prevádzku technických diel na Slovensku. Vznikajú alebo sa aktivizujú prirodzene (zvyčajne pri zrážkových anomáliách) alebo ako dôsledok technickej činnosti človeka. Štúdium svahových pohybov prešlo niekoľkými vývojovými štádiami. Prvé analýzy vzniku a vývoja svahových pohybov, ako aj návrhy sanačných opatrení (z 20. a 30. rokov 20. stor.) súviseli s úlohami pri realizácii rozličných stavieb, najmä dopravných a hydrotechnických. Vo väčšine prípadov ich riešili zakladatelia modernej inžinierskej geológie – akad. Záruba a prof. Mencl, ktorí praktické poznatky syntetizovali, a tak vytvorili základ na ich klasifikáciu. Prelom znamenali poznatky z katastrofálneho zosuvu v Handlovej na prelome rokov 1960 a 1961, ktorého priebeh a dôsledky boli také varovné, že vzbudili nielen záujem odbornej i laickej verejnosti, ale iniciovali aj praktické opatrenia organizované štátnou správou. Možno konštatovať, že sa po handlovskom zosuve začal na Slovensku systematický výskum svahových pohybov, ktorý prebieha na niekoľkých úrovniach – regionálnej (registrácia svahových deformácií) a oblastnej (tvorba máp oblastí s významným rozšírením svahových deformácií). Získané poznatky sa dopĺňajú výsledkami lokálneho prieskumu (riešenie havarijných stabilitných stavov). V súčasnom období sa okrem stáleho dopĺňania registra svahových pohybov a tvorby máp svahových deformácií vybraných oblastí rieši celoplošný monitoring zosuvov a iných svahových deformácií na vybraných lokalitách a začal sa zostavovať Atlas máp stability svahov SR v mierke 1:50 000. Celá činnosť je zameraná na získavanie komplexných informácií o výskyte a zákonitostiach vývoja svahových pohybov umožňujúcich prognózovať narušenie stability v územiach s plánovanou inžinierskou a hospodárskou činnosťou a včas ich odovzdávať orgánom a organizáciám územného plánovania.

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Landslides in Slovakia, their effects on the environment and on important engineering structures

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Abstract

The landslides are an important factor in geological endangering of environment in Slovakia. The present regional investigation has registered in Slovakia more then 15.000 old potential landslides, which cover an area of about 1.620 km^2. The landslides are concentrated in the flysch highlands, intramountain basins and on the margins of young volcanic mountains. The landslides damage the forests, the arable soils, meadows and pastures. They endanger railways and roads on 1300 sectors. They limit extension of towns and villages into unstable surrounding. The slope stability is a limiting factor in an optimum landscape use. About 90 % of new landslides take place by reactivization of potential landslides due to man's negative intervention.

Antropogeneous interventions act on the stability of old, dormant landslides differently. The landslides are either artificialy loaded or undercut. Man's activity induces changes in the regime of groundwaters or causes dynamic effects on the landslides. The lecture will analyze cases of activization old landslide due to the construction of civil or industrial structures, bridges, roads, tunels, pipe-lines and water artifitial reservoires. Numerous landslide were induced by deforestation of land, incorrect agricultural melioration works, worsening of flow - off surface and underground waters and failures of the underground pipe-lines.

The high number of artificially activized dormant landslides in the areas with an intense economic activity in Slovakia is alarming. With the constantly increasing urbanization of Slovakia it can be expected that this trend will be maintained even in the future, if we do not take an advice from the present mistakes.

Man's activity in the densely populated areas is becoming the most important geological factor. By its influence is activizing the landslides of bigger dimensions, vhich are usually causing the biggest damages. From these findings, however, results the fact that the risk of renewing movements of old landslides may be decreased to the minimum, when we know the degree of danger, which threatens all the planned and existing structures in the sliding areas.

Key words: landslides, types of slope deformations, environment, urban planning, landslides reactivation

1. Introduction

Landslides represent the most hazardous geodynamic phenomenon in Slovakia. Their study has a longlasting tradition. A systematic regional research of the area of the former Czechoslovakia began in 1962 - 1963. The results of this registration were followed by the investigation of the principles of the formations and the development of slope deformations in Slovakia by scientific workers of Slovak Technical University, Comenius University, Dionýz Štúr Institute of Geology and other research organizations. The investigation was financed from the state budget, and was organized by Slovak Geological Office – now by the Ministry of Environment (Nemčok, 1982; Modlitba, Klukanová, 1996; Kováčik and Suchánková, 1993).

On the basis of evaluation of the results of systematic regional investigation of landslides and the local investigation of the most hazardous landslides an outline of their regional distribution in Slovakia was made.

2. Slope deformation types

Nemčok, Pašek, Rybář (1974), created the slope movements classification, which is, in an modified form, still used in Slovakia. According to their classification the slope gravitational movements are divided into 4 essential groups – creep, sliding, flowing, falling. Each type of movement results in certain group of slope gravitation failure – deformation. Taking into account the fact that this classification is rather complicated and comprises types of slope deformation which do not occur in Slovakia, we have modified it in the form presented in Fig. 1.

Creep is a long-continued downslope movement of the rock material due to gravitational forces, and represents the initial phase of all other types of slope movements. The movement occurs in relatively thick shear zones. The result of this type of movement is loosening and disruption of mountainous massifs and gravitational folding on slopes composed of rigid or relatively plastic rocks. De-

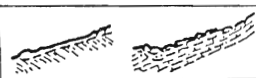
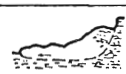
NAME OF DEFORMATION				SCHEME	OCCURRENCE
		LOOSENING OF MOUNTAINOUS MASSIFS	1		ROCK SLOPES IN THE DEEP VALLEYS IN THE HIGH MOUNTAINS AREAS
CREEP MOVEMENTS	CREEP DEFORMATIONS	DISRUPTION OF MONTAINOUS CRESTS	2		SLOPES OF THE HIGH MOUNTAINS FORMED BY GRANITS
		GRAVITATIONAL FOLDS	3		SLOPES OF THE HIGH MOUNTAINS FORMED BY METAMORPHIC ROCKS
		DEFORMATIONS OF BLOCK TYPE CAMBERING — BLOCK DISLACE-MENTS	4		FLYSCH HIGHLANDS
		DEFORMATIONS OF BLOCK TYPE CAMBERING — BLOCK RIFTS BLOCK FIELDS	5		FLYSCH UPLANDS, MARGINS OF NEOGENE VOLCANITES AND TRA-VERTINE BODIES
SLIDING	LANDSLIDES	ROTATIONAL	6		INTRAMOUNTANE BASINS, BANKS OF RIVERS IN LOWLANDS AND BASINS
		PLANAR	7		FLYSCH, HIGHLANDS FOR-MED BY MESOZOIC ROCKS
		COMBINED	8		OCCURRENCE IN ALL UNITS
FLOWING	SLOPE FLOWS	EARTH FLOWS	9		FLYSCH, BASINS, MARGINS OF NEOGENE VOLCANITES MTS.
		DEBRIS FLOWS	10		CORE MOUNTAINS FORMED BY MAGMATIC AND META-MORPHIC ROCKS
FALLING	ROCK FALLS	ROCK TOPPLES	11		CORE MOUNTAINS, NEO-GENE VOLCANIC MTS.
		PLANAR ROCK FALLS	12		CORE MOUNTAINS

Fig. 1. Basic types of slope deformations in Slovakia (adopted after Nemčok, Pašek and Rybář, 1974).

formations of block type represent an important group, which develop on slopes of rigid rocks (limestones, sandstones, volcanics) lying on relatively plastic, softer bedrock (clay, shales, tuffs). If this plastic substratum is thin, the development of the block displacements is typical. In the case of the thicker plastic bedrock the initial state of block rift occurs, in which the vertical movement of blocks is dominant. Block fields are made up of systems of blocks sunk into the bedrock and displaced downslope.

Sliding is a relatively rapid, short-lasting gliding movement of the rock mass along one or several shear planes. According to the shape of the shear plane we distinguish rotational, planar and combined landslides.

Flowing represents a short-lasting movement of rock mass in the viscid phase. During the movement the influence of water present in soil reaching up to 50% of the total mass volume plays a prominent role. According to the granular distribution of soils we can distinguish the earth flows and debris flows (mures).

Falling represents a sudden short-term movement of rock mass down steep slopes, whereby the rock is at least partially displaced by the fall. Resultant forms of this movement are rock topples or planar rock falls.

According to the degree of activity, we distinguish stabilized slope failures, which may be triggered only by anthropogeneous impact, calm - potential slope failures which may be activated by the influence of natural fac-

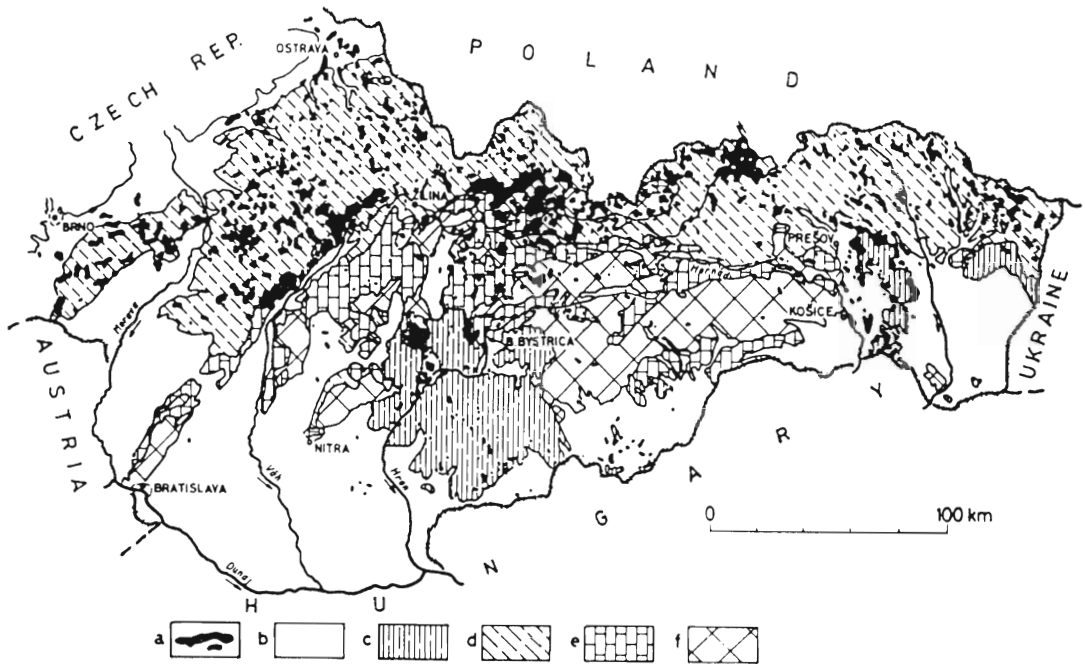


Fig. 2. Areas of slope deformation in the Carpathians: a – slope deformations, b – unconsolidated and weakly consolidated sediments of Quaternary and Tertiary, c – neovolcanites, d – weakly consolidated flyschoid sediments of Cretaceous - Paleogene age, e – consolidated sediments and volcanites of Mesozoic-Lower-Paleogene age, volcanites of Proterozoic and Paleozoic age.

tors. Indisputably active failures display present movements as a single sliding mass or at least of some parts of a landslide mass.

3. Principles of the regional extent of slope deformations

In the Slovak Carpathians slope failures are found mainly in the regions of High Mountains, e.g. Flysch Belt, Neovolcanics of the Middle and East Slovakia and Intramontane basins (Fig. 2).

3.1 Mountainous and high mountain areas of core mountains

In the region of core mountains slope failures are mainly found in areas of the highest altitudes of the West Carpathians Mts., and are composed of Variscian granitoids and metamorphites of Paleozoic age, or consolidated sedimentary rocks (limestone, dolomite, marly shales) of Mesozoic age.

In the high mountains (Tatry, Malá Fatra, Nízke Tatry) creep deformations reaching up to 250–300 m are prevalent. These deep-seated creep deformations occur in three basic forms (Nemčok, 1972):

1. Slope deformation in granitoid rocks, revealed by disintegration of mountain massifs. A typical example which demonstrates the mechanism of their formation using the dilatant – contractant model of behaviour of granitoid rocks, represents the slope failure of the Chabenec slopes in Nízke Tatry Mts. studied by Mahr and Baliak (1973) and Nemčok (1972). A typical profile of this deformation is presented in Fig. 3.

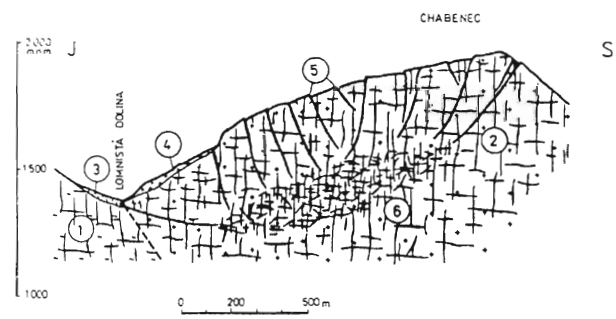


Fig. 3. A profile through the ridge of Chabenec Mt. (Mahr, 1997): 1 – orthogneisses (Proterozoic), 2 – granitoids (Paleozoic), 3 – slope debris, 4 – accumulation of rockfall (3-4 – Quaternary), 5 – dilatant shear planes, 6 – contracting shear zone.

2. Slope failure in relatively plastic metamorphic rocks, demonstrated by the occurrence of gravitational folds and by the loosening of mountain massifs.

3. Slope failure in Mesozoic rocks with the character of loosened mountain ridges and slopes with systems of block rifts and block fields are identified by hard limestone or dolomite overlaying relatively plastic bedrock composed of marl and marly shales (Nemčok and Baliak, 1977). A typical example of this type of failure frequently encountered in Slovakia is shown in Fig. 4. As these types of slope deformation represent the first introductory stage of rock fall and landslide development, they represent a potential risk to all kinds of constructions. In the

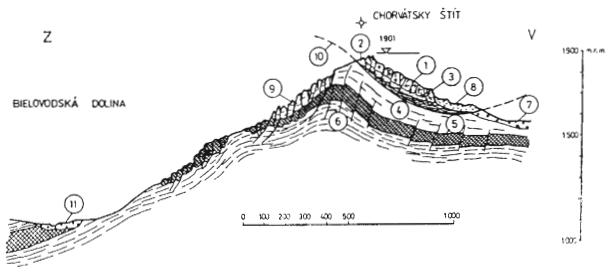


Fig. 4. A profile through the ridge of the Chorvátsky štít Mt. (Nemčok and Baliak, 1977): 1 – granitoids (Paleozoic), 2 – quarzites (Lower Triassic), 3 – coloured shales (Werfenian, 1–3 the Široká subunit disintegrated in blocks), 4 – limestones and dolomites (Middle Triassic), 5 – limestones (Doggerian, Malmian, Urgonian), 6 – shales and sandstones (Albian, 4–6 – the Tatry unit), 7 – accumulations of a rock glacier, 8 – an accumulation of rockfall, 9 – block rifts and a block field, 10 – an overthrust fault, 11 – fluvial deposits.

high mountains 691 larger failures have been found (Baliak and Mahr, 1979). Most of them are concentrated in the Západné Tatry Mts., along the border with Poland.

3.2 Carpathian Flysch region

The area composing the Carpathian Flysch (Fig. 2-d) is characterized by extraordinarily frequent occurrence of slope failure with a total area of ca.900 km².

Block displacements and block fields develop in places where, in the upper parts of slopes, heavy-bedded sandstone prevails. A typical example of this type of deformation is an extensive failure in Levočské vrchy Mts. of East Slovakia (Fig. 5).

The most numerous and most extensive landslides originate in areas consisting of fine-rhythmical flysch sediments or of prevailingly claystone flysch rocks. The principles of the landslide development in the flysch region where described in minute detail by Nemčok (1982).

Sliding and flowing is generated by much precipitation and deep vertical erosion, caused by young neotectonic uplift of flysch highlands and uplands. Most of landslides have a planar or flow form. Their thickness occasionally exceeds 10–15 m. Shear planes are usually planar or combined.

Fig. 6. Typical geological cross-sections through the margins of the Kremnické Hory Mts at Handlová, Malachov and Kordíky (Malgot, 1977): 1 – limestones (Mesozoic), 2 – sandstones (Paleogene), 3 – flysch complex (Paleogene), 4 – clays, 5 – tuffites, 6 – coal seam, 7 – overlaying clays (4–7 Badenian), 8 – gravels, 9 – andesites and agglomerate tuffs (8–9 Sarmatian), 10 – block in block fields, 11 – slope debris, 12 – creep zones, 13 – alluvial sediments, 14 – sliding material, 15 – springs, 16 – tectonic faults, 17 – boreholes.

Fig. 7. A map of slope failures on the margins of the Slanské vrchy Mts (Malgot, 1975): 1 – marl shales with interpolated of sandstones (Paleogene of Central Carpathian Flysch), 2 – clay beds with interlayers of gravel-sand tuffites and coal seams (Burdigalian – Sarmatian), 3 – andesites agglomerates and ash tuffs, sporadic bodies of rhyolites (Sarmatian – Panonian), 4 – replaced pyroclastic sediments, 5 – coloured clays with interlayers of gravels (Pliocene), 6 – proluvial cones, 7 – fluvial deposits (6–7 Quaternary), 8 – block rifts, block fields, 9 – landslides.

3.3 Neogene volcanics

Most of Middle and East Slovakia is formed by neovolcanic rocks (andesites, basalts, rhyolites and tuff), which originated during the Miocene volcanic activity. In many places the slopes of volcanic mountains are characterized by a geological structure of hard volcanic rocks resting upon substratum, either of plastic tuff and tuffits or older claystone sedimentary series of marine origin of Neogene or Paleogene age. Such structures are very liable to generate slope movement.

a) The most extensive slope failures in a neovolcanic region were studied in Middle Slovakia around Handlová, and westwards from B. Bystrica near Malachov and Kordíky (Fig. 6), in East Slovakia, on the edge of the Slanské vrchy Mts. (Fig. 7).

Various types of slope failures are found in disrupted areas. They are formed by coarse blocks of volcanic rocks (50–300 m), which have sunk into the bedrock and displaced downslope. The movements of blocks are relatively fast with average movement of 2 cm per year.

b) A continuous circle of landslides with total thickness up to 40 m originates on the margin of the block fields. Planar landslides dominate, less frequent are the flow and the frontal types. According to their activity stabilized, potential and active landslides occur.

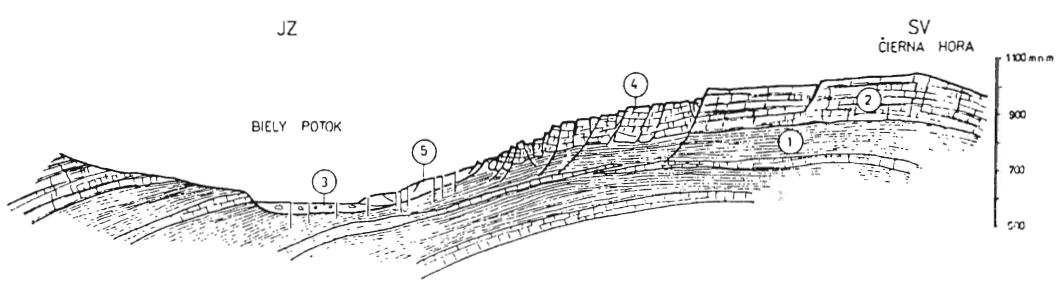
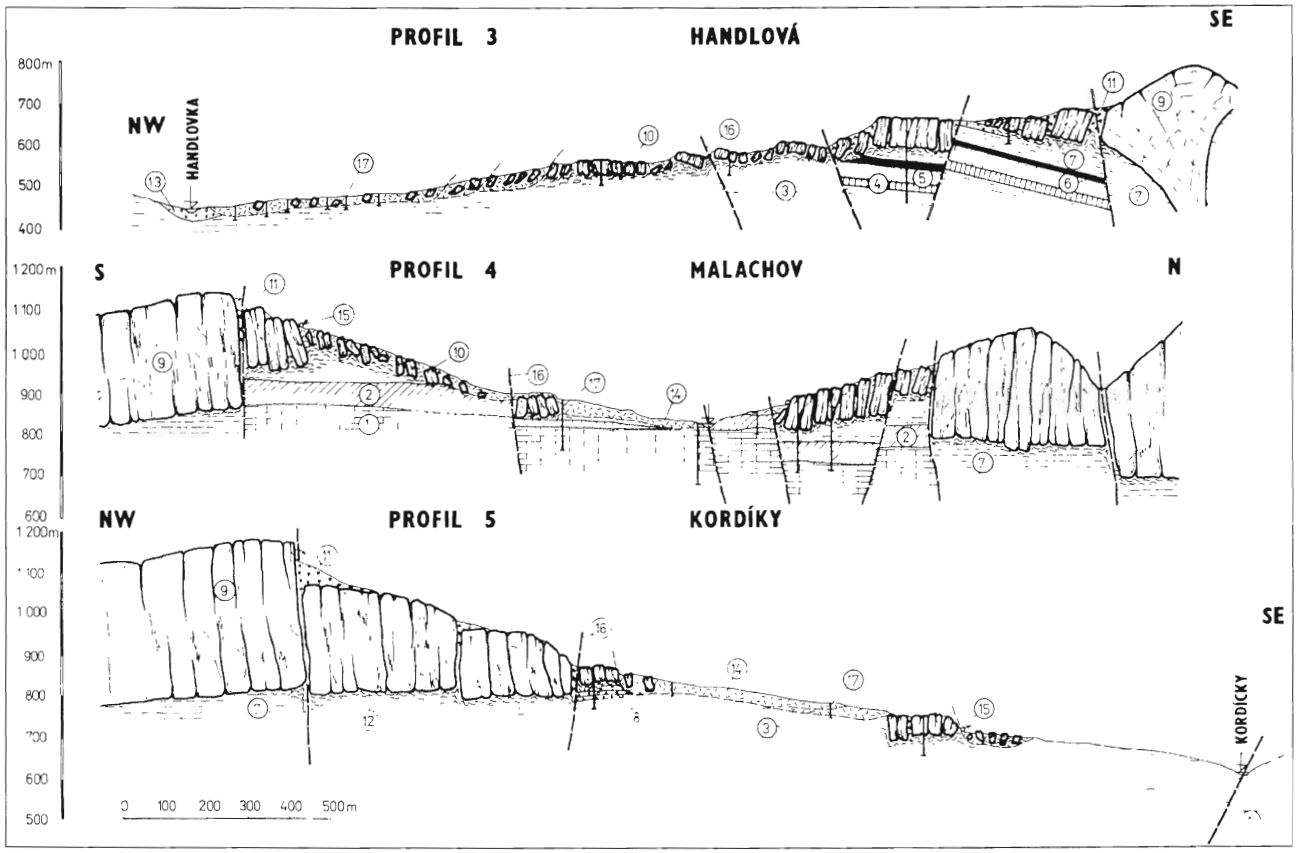


Fig. 5. A profile through the ridge of the Čierna Hora Mt. near Tichý Potok village (Nemčok, 1982): 1 – claystones with interlayers of sandstones, 2 – sandstones with interlayers of claystones (1–2 – Central Carpathian Flysch, Paleogene), 3 – fluvial deposits, 4 – block rifts and block field, 5 – landslides.


PROFIL 3
HANDLOVÁ
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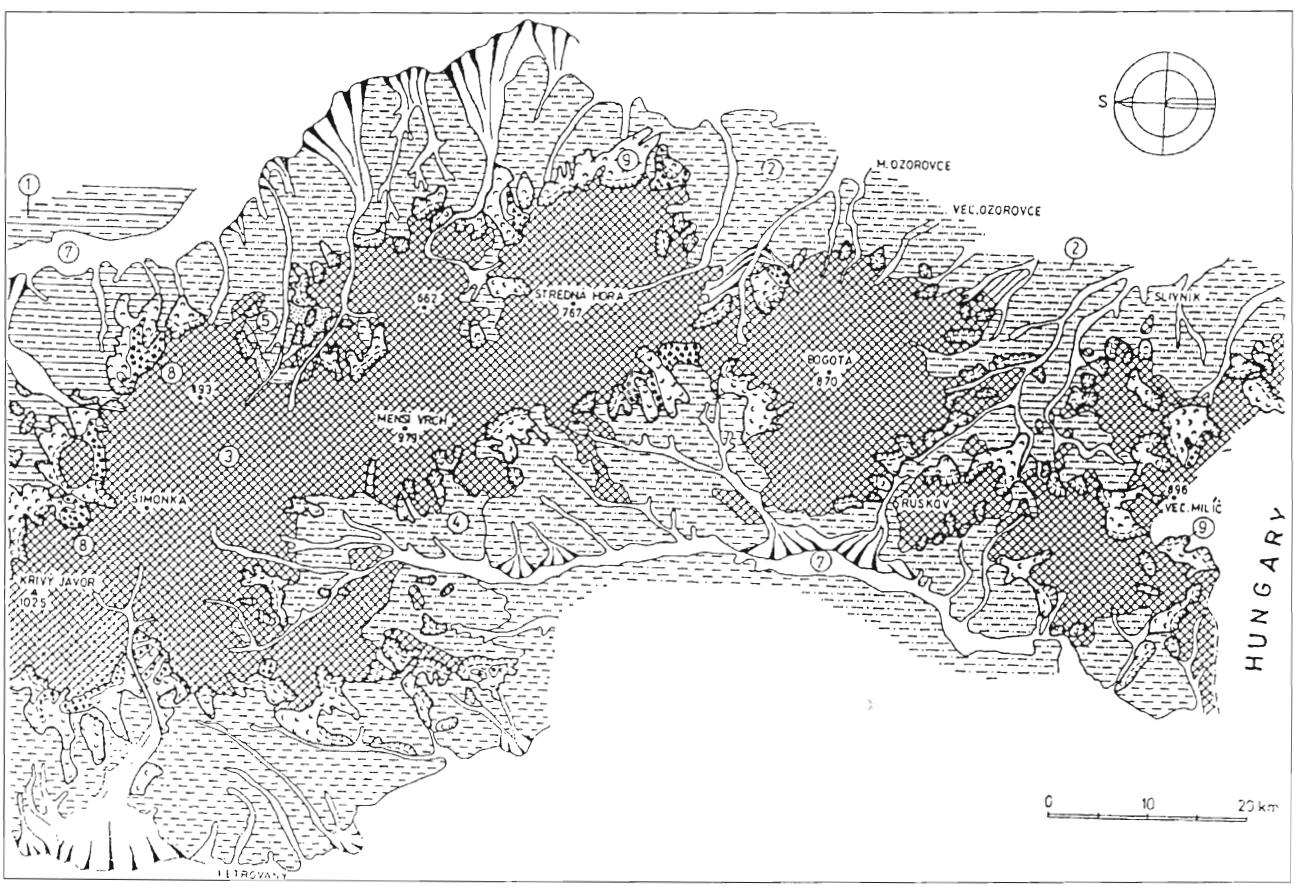
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H. OZOROVCE
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KRIVÝ JAVOR
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0 10 20 km

Formation of landslides on the margin of volcanic mountains is in distinctly influenced by the unfavourable physical and mechanical properties of substratum rocks and of the landslide material itself. We have demonstrated the results of the statistical evaluation of a great many laboratory tests of substratum rocks and associated colluvial soils, investigated by Mahr and Malgot (1978) in the Handlovská kotlina basin.

The average angle of slopes recorded in more then 100 landslides range form 60 to 80°.

c) Earth flows are an inherent part of landslides areas. They most frequently develop in depressions on slopes in the places with concentrated runoff of ground and surface waters. They may be over 200 m in length, 100–200 m in width.

d) On predisposed rock walls rockfalls caused by collapse are the most frequent.

3.4 Basins and lowlands of Slovakia

In single core and volcanic mountains in Slovakia there are numerous intramontane basins. They represent typical tectonic depressions (grabens). They are filled, either with flyschoid sediments of Paleogene age, or with sands and clays of Neogene age. The topography of basins is hilly and is dissected by river activity, which has created a system of river terraces.

The most common type of slope failure in the intramontane basins and lowlands of Slovakia are landslides. They develop mainly as a result of rainfall anomalies in the depressions and shallow valleys on slopes. Most are formed on slopes with geological structure favourable to their development, and consist of beds of terrace gravels resting upon Tertiary flyschoid rocks or Neogene sand-clay substratum.

4. Influence of landslides on the environment in Slovakia

On deformed slopes landslides are of a varied age, at various stages of development and degree of activity. The most frequent are landslides which we classify as potential and stabilized. Potential landslides are activated usually by natural factors (weathering, erosion, rainfalls).

Stabilized landslides are activated solely by anthropogenic activities (construction activity, etc.). Based on slope investigation in Slovakia, we found that 90% of all landslides taking in inhabited areas during the last 30 years and which caused the greatest damage, were either wholely or partly brought about by human activity in the sensible stability regime of old landslides.

Among the man made intrusions on unstable slopes formed by old landslides, the most frequent are the loading of slopes (buildings, embankments), undercutting of slopes (cuttings, excavations) and artificial vibrations. Particularly dangerous are the man made intrusions which induce groundwater regime changes. The groundwater regime change induces instability by changing the stress state in the slope and by gradual degrading the rock properties supporting the slope (Fig. 8).

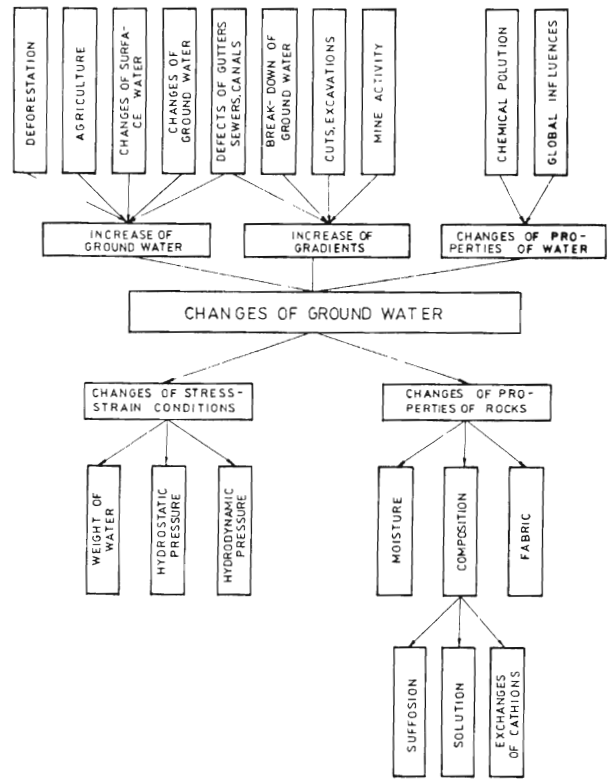


Fig. 8. Influence of changes in the groundwater regime on landslide development.

Slope sliding causes substantial reduction in the utility value of the affected area. Landslides cause different types of direct and indirect damage. They represent a potential hazard not only to the existing structures, but also to further construction in the affected area. They have a negative influence on further development of the area and on the environment in general.

4.1 Influence of landslides on agricultural land and forests

Agricultural land and forests are basic natural assets of every country. Agriculture and forests occupy to 90% of the area of Slovakia. This amounts to 0.49 ha of agricultural land and 0.40 ha of forests per capita. Agricultural and forest areas, apart from erosion and emissions from the industry, are seriously endangered by landslides.

Sliding causes total devastation of the surface area. A slide-area is excluded for decades from the possibility of agricultural use. The costs involved in reclaiming active or even dormant landslides for agricultural or forest use are usually too high and as they represent an unacceptable investment. Stabilized (old) landslides in Slovakia are used for meadows, pasture, gardens or afforestation.

Stabilized landslides can be reclaimed at reasonable cost for the purposes of agricultural production, but they will require a careful maintenance.

Experience has shown that devastation of agricultural land was caused in many cases by the activation of

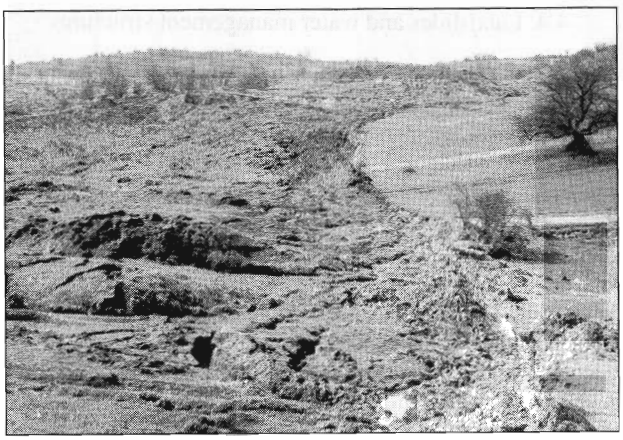


Fig. 9. View of a part of an activated landslide in Ľubietová.

Fig. 10. Devastated forest caused by the stream-like landslides Orava).

landslides due to neglect of the old surface and underground drainage.

Periodic ploughing of a slope is not recommended. Ploughing destroys grassy cover and enables the infiltration of rain waters. The present methods of agricultural production require thorough preparation of land areas. Such preparation of landslide areas is unlikely to be successful. Unsuitable reclamation of sliding slope, was of the reasons for reactivization of the landslide in Ľubietová (Fig. 9) in 1977 (Malgot, 1978). During the years 1974 to 1976, extensive terrain adaptations were made in the landslide scar. The sliding slope was deprived of humus for a long period over a considerable area and a substantial increase of rain water infiltration into the body of the landslides. When in December 1976, January and February 1977, rain fall anomalies arose, exceeding the rain fall normal by 50%, the landslide was activated. It passed from the creep stage to a sliding movement at a velocity of 2.5 m/day. The length of the sliding flow was 1200m, the width 450 to 500m, and the height difference 160m, the depth of the sliding surface in places reached 35m. The volume of the slide reached 4.5 mil. m^3. 5 dwelling houses were destroyed in the lower part of the landslide together with about 50 ha of agricultural land.

The activated landslide was solely a part of the wide sliding area, situated on the margin of a volcanic mountain range. The geological structure of slopes is exemplified here by the fact that hard volcanic rocks lie on soft clays, leading to typical failure of blocks types, rock falls and landslides at various stages of development took place.

Of particular significance are landslides on forested areas. Presently about 40% of the area of Slovakia is covered by forest. Together with the negative effects of industrial pollution, landslides play a considerable part in the deterioration of forest growth, since about 45% of the area of all landslides in Slovakia are covered by trees. Landslides are destroying the tree species and change of forest areas into devastated landscapes (Fig. 10). However, experience of tree planting on stabilized landslides is good. Particular attention, however, has to be paid to the selection of suitable types of trees.

4.2. Effects of landslides on urban planning of Slovakia

Slope movements are an important factor affecting urban planning in Slovakia. In Slovakia are 548 villages and towns, built either entirely or partly on the bodies of old landslides, are under threat.

Damage to houses in threatened villages occur frequently due to activation of part of a landslide area. Similar cases take place every year. They are caused either by activation of old landslides due to natural factors, or are brought about by human intervention. The activation of landslides is caused by the neglect of drainage systems, which had previously been carefully maintained through generations. Landslides are often activated loading the active part or by undercutting their accumulations (Fig. 11).

Fig. 11. View of the landslide caused by undercutting of slope in Košice.

4.3. Landslides and communication structures

Most geotechnical problems arise in building structures – roads, highways and railways. Their construction often necessitates undercutting of landslides (release of the accumulation part) or loading of the upper part of landslides

Fig. 12. View of the landslide caused by undercutting of dormant landslide on the highway near Prešov (Široké).

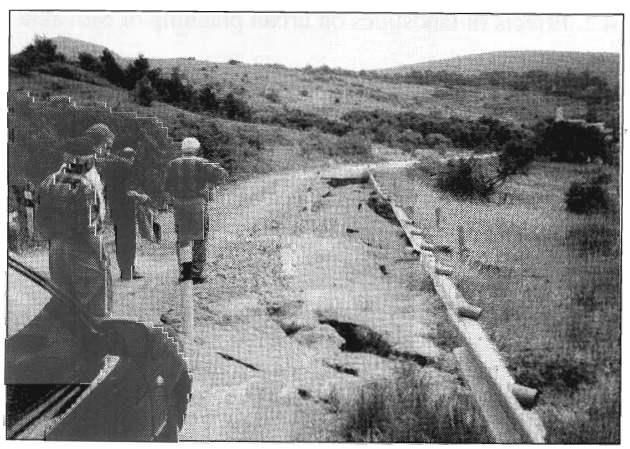


Fig. 13. View of the damage to a highway caused by overloading (March, 2000) – Gregorovce.

(Fig. 12, 13). According to investigations carried out to date the slope movements in Slovakia threaten the railways in 145, and roads in 1085 sections. The major part of the deformed sections is found in the area of flysch uplands, but also in basins and in the neovolcanic mountain ranges of Slovakia. They created suitable conditions for the occurrence of slope movements based on geological – tectonic structure, properties of rocks and the geomorphological development of the area.

Several sections of roads and railways, which run through slope deformation areas have been successfully corrected. The correction measures which are gradually being perfected remain as temporary raised areas, which, from time to time, usually in spring, are repaired and adjusted. This state of affairs, however, is not acceptable, with regard to maintaining safety on the roads and railways.

With regard to the frequent occurrence of landslides in some areas of Slovakia, it is not possible to by pass landslides when laying out new communication routes, so a great deal of attention should be paid to the stability of the lay-out at the beginning of project preparation.

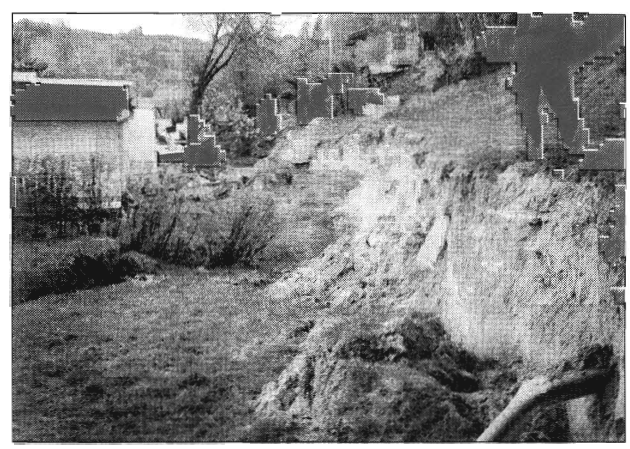
4.4. Landslides and water management structures

Construction of dams and artificial water reservoirs in Slovakia acts markedly on the environment and on the activation of landslides along the periphery of water reservoirs. The activated landslides reduce the accumulation space of the water reservoirs, damage the objects in the reservoir vicinity and may bring about the failure of the dam itself. The activation of landslides has usually two causes.

The first is the fact that flooding of the landslides lower part disturbs the static equilibrium, since the load of the accumulation part decreases due to upward pressure, meanwhile load above the level does not decrease. Simultaneously the rock shear strength decreases. In rapid water level decrease the rock is strained by flow pressure or the effect of water pressure appears in the pores. All these factors decrease seriously the degree of stability of the slope and cause activation of landslides.

The second cause is the wave motion inducing abrasion of the banks. When abrasion is taking place in the lower part of the accumulation part of the landslide its instability increases till its activation takes place.

The problems with the slope stability occurred in building of almost all the dams in Slovakia. Mainly along



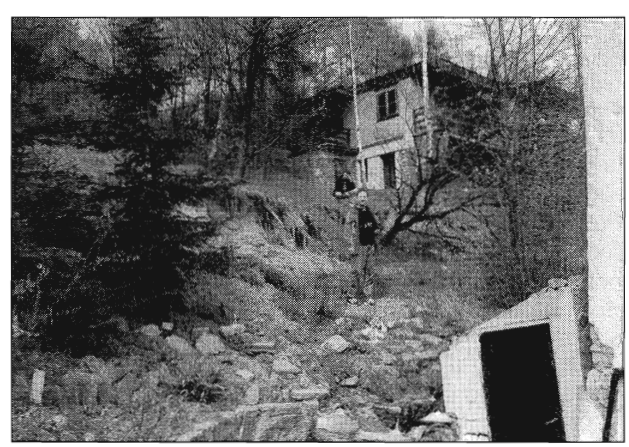


Fig. 14, 15. View of landslides in the year 1999 on the banks of Domaša water reservoir (East Slovakia).

banks of reservoirs built in flysch areas landslides are activated in a great number, which endanger or directly damage numerous technical objects (Fig. 14, 15).

A detailed verification of endangered sections is made as part of an engineering geological investigation. In the first place, maps are prepared on scales 1 : 1000, 1 : 2000, which afford a precise illustration of the geological-tectonic structure, which may also be found by tectonic investigation work. Detailed maps of landslides served as a record for sitting investigation works for geophysical measurements, as well as for suggesting correction measures. Besides investigation using boreholes, which helped to verify the line of the basal shear surface in the investigation of the landslide, we set up a network for observation of geodetic points, on which the velocity of landslide movement was measured by microtrigonometric methods. The geoeletric resistance method offered the best results in the detection of the shear surface position. From the exploratory borings we took undisturbed samples, which served for the detection of the physical–mechanical properties of sliding soils. The result of the engineering geological analysis was a calculation of the sliding slope stability (F = 1.1) and assessment of the effects of undercutting the landslide of water works Žilina (Fig. 16).

Fig. 16. Remedial works on the landslide at Žilina, water works (anchored-pile underground wall).

5. Conclusion

Experience shows that money spent on regional investigations into slope failures and to experimental-correction works, were not spent in vain, on the contrary, they are high effective. The regional engineering geological investigation detected in the studied areas of Slovakia the area distribution and the degree of activity of old gravitational deformations, which represent a potential (hidden) threat to existing and planned structures. Taking account of such deformations in planning and preventive stabilization substantially reduces the consequential damage. The costs of prevention works are five times lower than those required for correction measures and damage caused by reactivated landslides.

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Zosuvy na Slovensku, ich vplyv na životné prostredie a na dôležitejšie inžinierske stavby

Zosuvy a iné typy gravitačných svahových porúch sú veľkým geotechnickým problémom, lebo významne ovplyvňujú výstavbu a prevádzku dôležitých inžinierskych stavieb a životné prostredie na Slovensku.

Pri doterajšom výskume svahových deformácií sa v báze dát Geofondu zaregistrovalo vyše 15 000 starých potenciálnych zosuvov, ktoré pokrývajú územie veľké okolo 1620 km^2.

Zosuvné územia sú najmä vo flyšových horninách, vnútrokarpatských depresiách a na okrajoch neovulkanických pohorí Slovenska.

Zosuvy porušujú lesný porast, poľnohospodársku pôdu, lúky a pastviny, ohrozujú železnice a cesty a na 1300 úsekoch obmedzujú rozvoj mnohých miest a obcí. Stabilita svahov je limitujúcim faktorom optimálneho využívania krajiny. Asi 90 % zosuvov v súčasnosti vzniká reaktivizáciou starých, potenciálnych zosuvov ako dôsledok negatívnej antropogénnej činnosti.

Antropogénna činnosť pôsobí na stabilitu potenciálnych zosuvov rozmanitým spôsobom. Zosuvné telesá bývajú alebo umelo priťažené, alebo podrezané. Ľudská činnosť vyvoláva zmeny režimu povrchových a podzemných vôd alebo dynamicky pôsobí na zosuvy.

Príspevok analyzuje prípady aktivizácie pohybov starých, potenciálnych zosuvov vyvolaných výstavbou pozemných alebo priemyselných stavieb, mostov, ciest, tunelov, podzemných diaľkovodov a umelých vodných nádrží. Mnohé zosuvy spôsobilo odlesnenie územia, nesprávne poľnohospodárske meliorácie, zhoršenie odtokových pomerov povrchových a podzemných vôd a poruchy vodovodných privádzačov.

Vysoký počet umelo aktivizovaných zosuvov v oblastiach s intenzívnou stavebnou aktivitou je alarmujúci a bude rásť, ak sa z doterajších chýb nevyvodí poučenie a neurobia potrebné opatrenia.

Zo získaných poznatkov vychodí, že riziko obnovenia pohybov starých zosuvov možno minimalizovať, ak bude známy stupeň nebezpečenstva, ktoré hrozí jestvujúcim aj plánovaným stavbám v zosuvných územiach.

Aby sa predišlo devastácii prírodného prostredia a veľkým hospodárskym škodám, pripravujú sa špeciálne inžinierskogeologické mapy svahových porúch a z nich sa odvodzujú mapy stabilitného rajónovania a mapy zosuvného rizika. Tieto mapy sú zdrojom nevyhnutných informácií z hľadiska urbanistického využívania oblastí potenciálnych zosuvov a iných gravitačných svahových porúch.

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The application of hydrogeological expertise in the correction of landslide movements

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Abstract

Due information obtained by the study of the regularity of groundwater circuit and regime in area influenced by the gravity movements it is possible to improve the knowledge about the mode of the groundwater flow in this kind of the environment. Gravity slope movements cause deformation and loosening of the rock what generates more favourable conditions for recharge, accumulation and concentrated outflow of groundwater Detailed knowledge about groundwater circulation mode enables more efficient lateral and vertical positioning of the corrective drainage measures into area of the natural concentration of the groundwater and to more effectively and economically solve correction and monitoring of the slope movements.

Key words: geology, engineering geology, engineering hydrogeology, landslide, monitoring of landslide, landslide correction

Introduction

Gravity slope movements cause deformation and loosening of the rock, thereby creating conditions favourable to recharge, accumulation and concentrated outflow of groundwater. Detailed knowledge about the modes of groundwater circulation enables more effective lateral and vertical positioning of a corrective drainage system into the area of natural concentration of groundwater and to deal with corrections and monitoring of slope movements more effectively and economically. The presence of groundwater causes changes in the physico-mechanical properties of rock slopes, changes in uplift conditions and changes in groundwater pressure. The more rapid the changes, the more intensive the effect, and the development of slope deformations. The groundwater's effect is a dynamic process depending mainly on intensity and the frequency of precipitation and degree of evaporation.

Thus, the goal of corrective monitoring is lowering of the dynamic resources of groundwater and minimization of the spreading velocity of groundwater effects. The lowering of groundwater dynamic resources in a given structure could be achieved by i) evapotranspiration increase, ii) surface runoff increase and iii) artificial runoff of accumulated groundwater reserves via horizontal drainage wells. The present paper deals with the optimalization of horizontal drainage well location.

At the Department of Hydrogeology and Geothermal Energy of the Geological Survey of Slovak Republic, the hydrogeological conditions of slope deformations have been studied particularly closely in the last few years. This paper is based on the results of evaluation of hydrogeological background of landslides in Okoličné, Veľká Čausa and Dolná Mičiná, as part of the project "Landslide Monitoring in Slovakia" (Scherer in Klukanová et al., 1998, 2000). At these landslides sites, long-term monitoring of the volume (discharge) of drainage elements and groundwater level depth (below benchmark) in selected vertical wells is conducted. Information about the above landslides can also be found in the following papers: (Scherer and Wagner 1997; Kordík and Scherer, 1999; Scherer, 1998; Scherer, 1999). During hydrogeological mapping in the eastern part of the Veľká Fatra Mts. significant results were obtained on relations between slope movements and springs (Malík and Kordík, 1999). Results of the engineering-geological research for individual landslides are in following papers: Okoličné landslide – Fussgänger et al. (1976) and Jadroň (1980), Veľká Čausa landslide – Mesko et al. (1985), Jadroň et al. (1999) and Dolná Mičiná landslide – Fussgänger and Jadroň (1985).

Methods

Current methodology focuses on complexity of the geological environment, the amount and time dependent variation in the source waters and runoff properties of the local rock environment. In evaluating the hydrogeological circumstances the entire area affected by slope movements was assessed as one unit and secondary detail (point) data were analysed. The area affected by slope movements is regarded as one unit as is also its probable recharge area as well. As point data we understand measurements of individual horizontal (volume – yield) and vertical (groundwater level) in drainage wells. By delineating the recharge

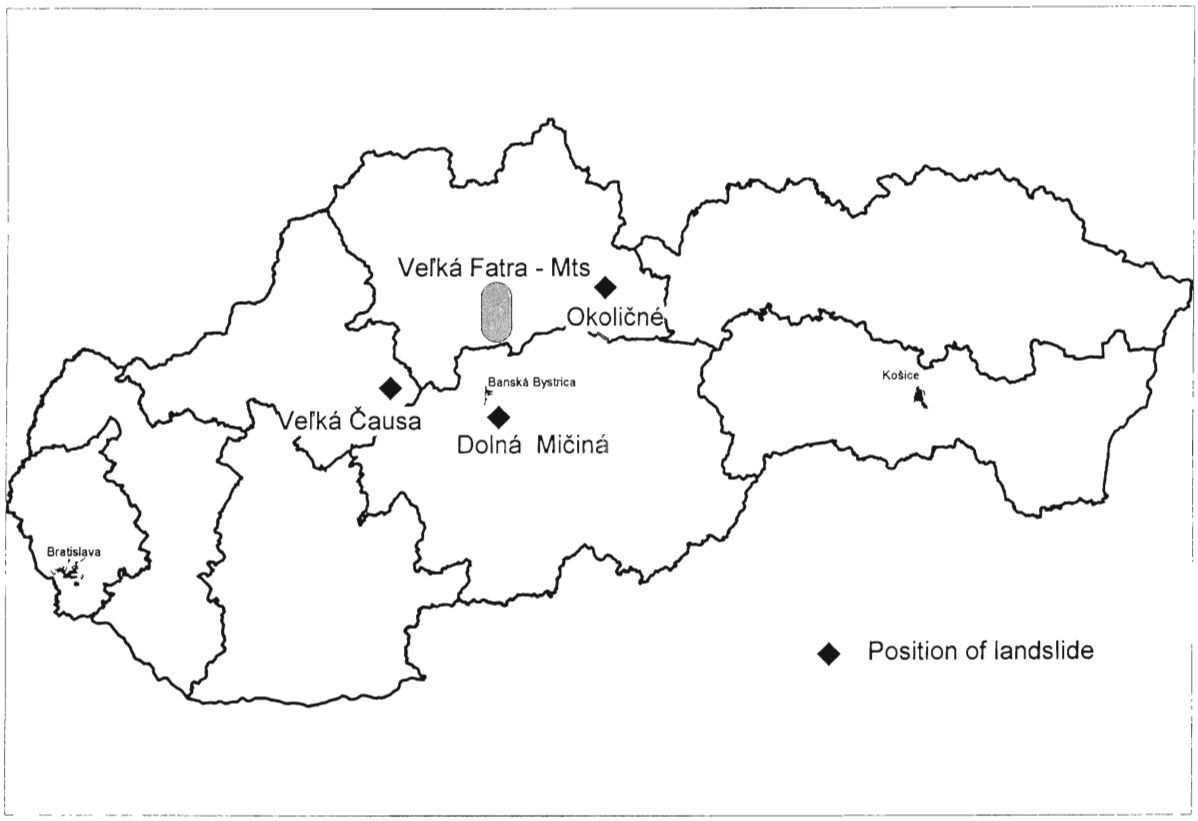

Fig. 1. Description of localisation of studied landslides.

area of the slope deformation area, i.e. *limited hydrogeological structure*, it is possible to find the water balance and to establish direct and indirect criteria that enable quantification of observed phenomena. Quantification of the observed phenomena enables comparison of landslide characteristics in time and comparison of different landslides. This methodology is given in detail by Scherer (1999).

Results

Rock environment

Different lithologic, at composition of rocks form the rock environment by which gravity slope movements are confined, principally rocks with relatively low permeability, low accumulation ability and low ability of groundwater concentration. Groundwater circuit is concentrated mainly in the near-surface zone and in fissure zones and constitutes the typical hydrogeological feature – type of structure so-called "hydrogeological massif". Near-surface zone in the geo-climatic conditions of Slovakia is situated some 20–40 m (Jetel, 1990) bellow the surface. The zone of near-surface loosening – subsidence includes the upper part of the bedrock and weathered cover. In the area formed by rocks with low primary permeability, the near-surface zone forms the main aquifer. *Rock environment deformed by gravity movements could be characterised as an environment with extreme subsidence increased thickness of the subsidence zone.*

A rock environment affected by sliding could be formed by a lithologic composition of rock with relatively higher permeability and accumulation potential, but sliding processes cause the splitting of more permeable layers into smaller blocks, isolated one from the other, by the clay layers, so their hydraulic connection is limited. At the same time clay particles clog fissures in the more permeable rocks.

Hydraulic properties of the rock environment are influenced by heterogeneities:

– subsidence of rock environment due to sliding
– tectonic deformation
– lithological and granulometric properties of rock and weathering cover
– position and nature of shear planes

Tab. 1
Rock environment of studied landslides

Landslide:	Veľká Čausa	Okoličné	Dolná Mičiná
Rock environment:	Neogene clays and marles, andesite tuff bloks	Claystone, less sandstone and claystone formation of Paleogene	Clayey tufittes, sandy tuffs and carbonates (NE part)

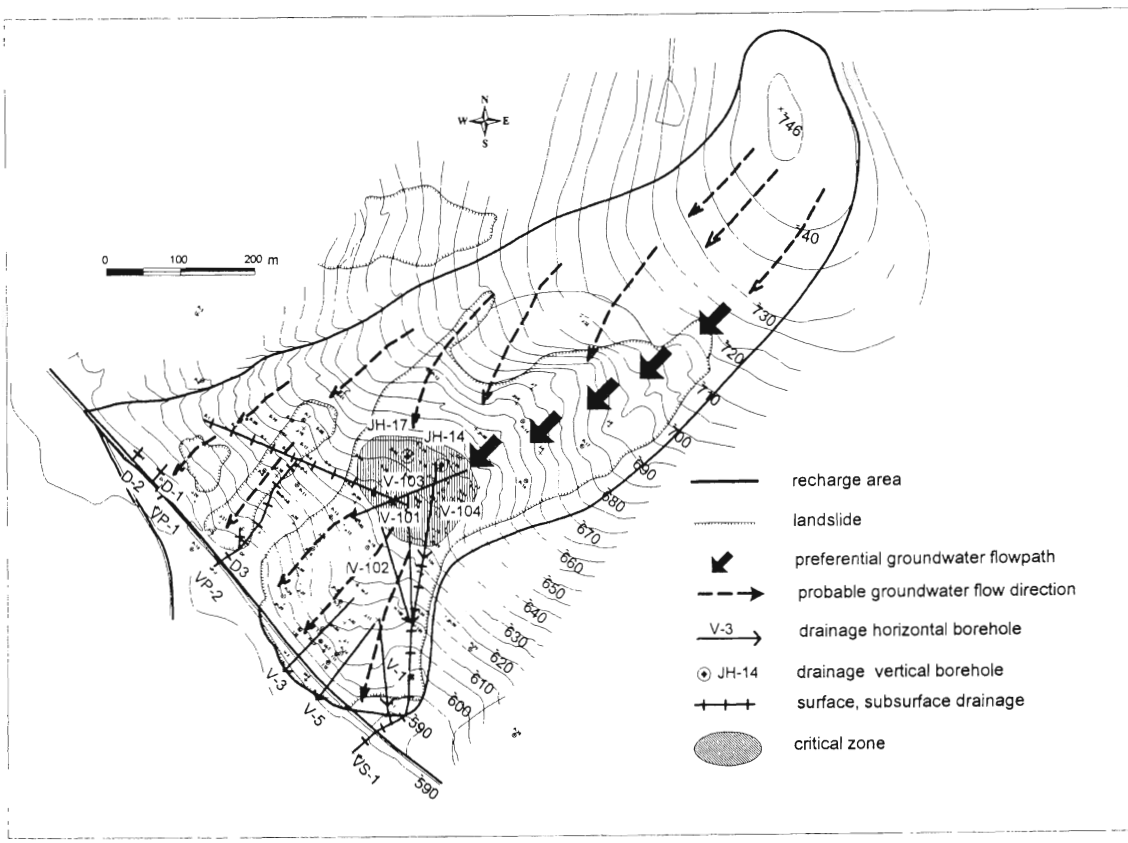

Fig. 2. Landslide in Okoličné.

Based on observations mentioned it can be assumed that in rock environment deformed by slope movements, the character and extent, due to slope movement, has the most influence on hydraulic properties. Influence of lithology is secondary. Very important are shear zones. If they are not deformed they represent a relatively impermeable barrier. Brief lithologic characterisation of the landslides studied is given in Tab. 1.

Recharge area

The surface of the slope deformation recharge area comprises the area affected by slope deformations and the adjacent area, so that surface and subsurface inflow to the recharge area is zero in value.

The characteristic of the recharge areas of the landslides is in Tab. 2. Parameters of the recharge area include size, shape and maximum height difference between base of slope deformation and the highest part in the recharge area. The volume of source waters ready for infiltration rises with the size of recharge area. The hydrodynamic pressure potential rises with the height difference between the base of deformation and the highest elevation. The smaller the width of the deformation, the easier it is to observe the potential for groundwater concentration. The depth of subsidence and the slope angle of relatively impermeable bedrock, influence the potential for groundwater accumulation. The shape of the recharge area is significant when considering the preconditioning character of the geology and properties of slope deformation. After assigning a recharge area to the respective landslide area it is possible to estimate average annual natural sources of groundwater based on long-term average of precipitation totals and potential evaporation. Calculated value of the average annual natural sources of the groundwater is only an estimate, but is nonetheless important for a comparison with the benefits of corrective drainage measures.

Tab. 2
Characteristics of infiltration area of the landslides

Lanslide	unit	V Čausa	Okoličné	D. Mičiná
Area	[km^2]	0.288	0.404	0.097
Average inclination (dip) slope angle	[°]	7.4	8.3	7.5
Altitude	a. s. l.	305–388	590–746	393–450
Maximum height difference	[m]	83	156	57
Maximum length	[m]	558	1105	435
Maximum width	[m]	692	563	338
Shape index (length/width)		0.81	1.96	1.29

Source waters

Rock environment influenced by the slope deformations is affected mainly by water recharge in the recharge area, by infiltration from surface streams, by secondary

Tab. 3
Characteristics of the long-term precipitation amount and evapotranspiration according to SHMÚ (Slovak Hydrometeorological Institute) measurements at weather stations near the landslides

Mean	Veľká Čausa	Okoličné	Dolná Mičiná	Veľká Čausa	Okoličné	Dolná Mičiná	Veľká Čausa	Okoličné	Dolná Mičiná
1950–1980 (SHMÚ weather station)	(Prievidza)	(Okoličné)	(Banská Bystrica)	(Prievidza)	(Okoličné)	(Banská Bystrica)	(Prievidza)	(Okoličné)	(Banská Bystrica)
	Precipitation total [mm]			Evapotranspiration total [mm]			Effective rainfall [mm]		
Year (100%)	672 (100%)	688 (100%)	786 (72,5%)	487 (71,5%)	492 (63,1%)	496 (27,5%)	185 (28,5%)	196 (36,9%)	290
Summer period (60%)	405 (63%)	435 (53,7%)	422 (58,%)	393 (59%)	405 (50,3%)	395 (2%)	12 (4%)	30 (3,4%)	27
Winter period (40%)	267 (37%)	253 (46,3%)	364 (14%)	94 (13%)	87 (12.9%)	101 (26%)	173 (25%)	166 (33,4%)	263
	Precipitation total $[l.s^{-1}.km^{-2}]$			Evapotranspiration total $[l.s^{-1}.km^{-2}]$			Effective rainfall = Total runoff $[l.s^{-1}.km^{-2}]$		
Annual average	21.3	21.8	24.9	15.4	15.6	15.7	5.9	6.2	9.2

infiltration from corrective drainage measures, and eventually by transfer from neighbouring hydrogeological structures.

Mean long-term year effective rainfall (Slovak Hydrometeorological Institute, SHMÚ) at weather stations near landslides is shown in Tab. 3. The largest potential source of infiltration water is at landslide Dolná Mičiná. In the lower part of Tab. 3, there are precipitation totals recalculated from "mm" to average annual amount of source water in litres per second per square kilometre.

Natural surface streams do not exist in the area of the landslides. In the area of all landslides corrective drainage measures have been installed and consequently surface water is led out of the recharge area. Poorly built drains and more often lack of maintenance of drains, cause secondary infiltration of the primary drainage water into the rocks in the slope deformation. For example we can take the landslide Okoličné, where secondary infiltration into landslide body represents about 50–60% of total drained water. Substantial improvement could be obtained at relatively little costs. Secondary infiltration at the Veľká Čausa and Dolná Mičiná landslides is very low, however.

Rock environment affected by slope deformation could be charged via transfer of ground water from neighbouring hydrogeological structures. The body mass of the landslide at Dolná Mičiná is charged by groundwater coming from carbonates. The volume of groundwater based on recharge area surface and estimation of groundwater runoff is shown in Tab. 4.

Tab. 4
Estimation of volume of natural sources of groundwater in infiltration area of the landslides

Landslide		Veľká Čausa	Okoličné	Dolná Mičiná
Total runoff (tr)	$[l.s^{-1}.km^{-2}]$	5.9	6.2	9.2
Total runoff estimation (= 26 % of tr)	$[l.s^{-1}.km^{-2}]$	1.54	1.61	2.39
Infiltration area (IA) surface	$[km^2]$	0.288	0.404	0.099
Estimation of groundwater natural sources in IA	$[l.min^{-1}]$	27	39	14

Runoff properties of rock environment

A large part of precipitation evaporates and the rest (= effective rainfall) forms surface runoff, subsurface runoff and groundwater flow. Division of total runoff individual components is controlled mainly by geologic-tectonic and geomorphologic circumstances and by precipitation intensity as well. The quantitative separation of single components is difficult and in the landslide reviewed here a qualified estimation was made.

Groundwater flow in recharge area

Most of the recharged surface water concentrates and flows in areas with lower hydraulic resistivity in relatively more permeable "channels". The presence of the double conductivity and presence of several aquifers in supraposition (one over another) with differing pressure of confined aquifers shows that groundwater level (under benchmark) even in piezometers close by its position, can be diametrically different at the same time. More permeable "channels" are bound to subsidence zones, while impermeable shear (slide) planes control direction of groundwater flow. System of shear zones creates suitable conditions for the formation of a few groundwater bodies in supraposition. By measuring the drainage elements volume it was found

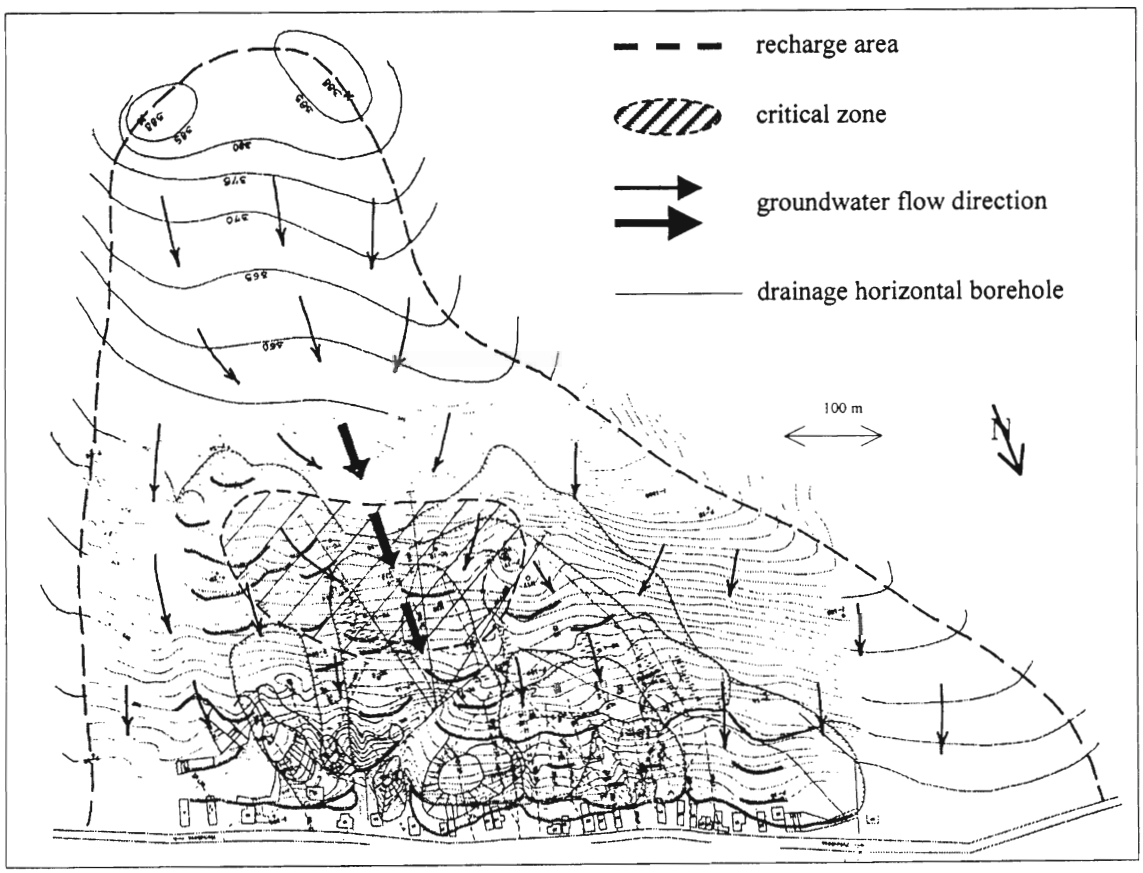

Fig. 3. Landslide in Veľká Čausa.

Tab. 5
Characteristic of critical zone (CZ) of studied landslides

Landslide		Veľká Čausa	Okoličné	Dolná Mičiná
Estimated height of CZ	a. s. l.	337	636	409
Height difference between CZ and the highest point IA	[m]	49	110	41
Depth of critical aquifer under surface	[m]	9.5–11.5	15	12–15
Maximum proven aquifer confidence pressure	[MPa]	0.074+	0.18	0.052
Ability of the drainage elements concentration in the CZ*	[%]	228**	78	82
Natural sources of groundwater of recharge area over the CZ	[l.min^{-1}]	14	20.8	9.9
Drainage elements yield in CZ*	[l.min^{-1}]	32	16.3	8.1

* Period monitored as in Tab. 6
** Ability of concentration is overestimated due to lowering groundwater resources after drilling VV-110 well
\+ Maximum difference of the piezometric level

that ability to concentrate groundwater is increased in aquifers with high artesian pressure of groundwater level (Scherer, 1998).

With regard to ability to concentrate groundwater we can define the "critical zone" in the recharge area. This "critical zone" is situated in the area where the flow of groundwater acquires local energy and the force of groundwater artesian level pressure is so high that resistance of the rock environment is reduced. Aquifer with the highest artesian pressure is called "critical aquifer". The levels of the groundwater with higher artesian pressure are obviously located nearby or below the critical zone in the landslide area. Critical zone can be delineated by geomorphology of terrain, artesian pressure of groundwater level, drainage elements volume and by the assumed shape of shear zones.

Optimal proposal for drainage elements

One of the main results of landslide hydrogeological monitoring was found to be that drains situated in the critical zone and critical aquifer of the landslide had high volume. By estimating the natural resources of groundwater from recharge area in the critical zone a large amount of the recharged water is concentrated in the critical aquifer. Horizontal drains situated bellow the critical zone and

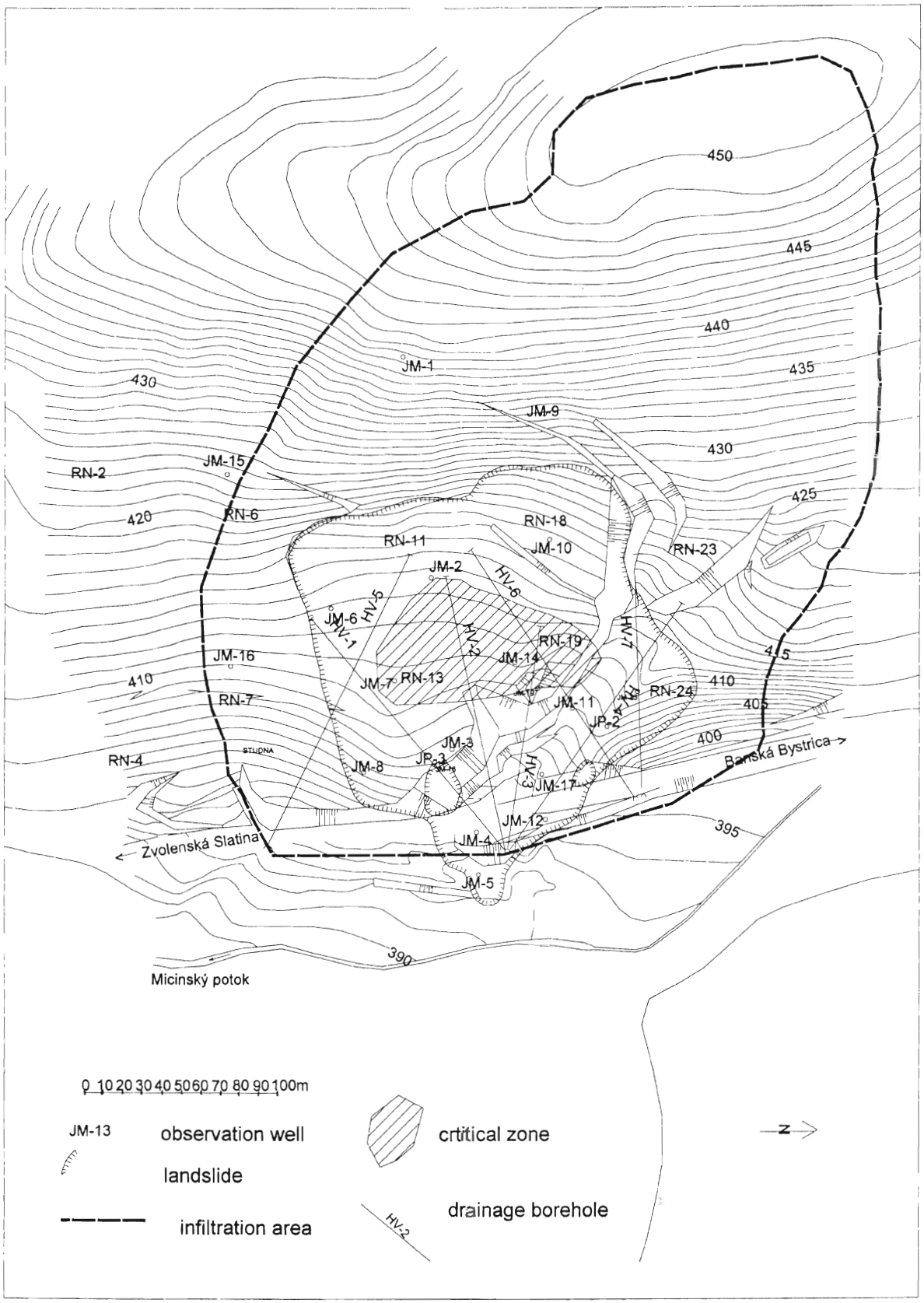

Fig. 4. Landslide in Dolná Mičiná.

Tab. 6
Characteristic of drainage elements

Landslide	V Čausa	Okoličné	D. Mičiná
Period measured	X.98–X.1999*	1995–1999	1997–1999
Number of drains	12	12	8
Number of drains with the mean discharge over 1 l.min^{-1}	4	9	3
Total average discharge [l.min^{-1}]	40	45	16.8
Total minimum discharge [l.min^{-1}]	14.4	9.7	12
Total maximum discharge [l.min^{-1}]	90	106	40.1
Mean specific discharge of drainage units [l.s^{-1}]	2.3	1.86	2.83

* monitored period is characterised by unsteady state after drilling horizontal drain VV-110. This drain reached critical aquifer (with high mean discharge = 24 l.min^{-1}). A reduction of this high discharge is assumed in steady state conditions.

above the critical aquifer, drain groundwater only during periods with high groundwater levels in the landslide. Horizontal drains situated bellow the critical zone and in critical aquifer, have relatively greater discharge, but due to lower concentration ability, the discharge is lower than in drains in critical zone. Crossing of shear zones of different age influences reduced concentration ability. Such crossing lowers the permeability of preferred flow paths. Accumulation parts of landslides are often moved above alluvial sediments, which function as a drainage medium. Discharge of horizontal channels situated in the accumulation part of the landslide is less (Okoličné), or negligible (Veľká Čausa) (Scherer, 1998). A brief characteristic of drain units in the landslides is given in Tab. 6.

Results from hydrogeological mapping in the Veľká Fatra Mts. area

In the Veľká Fatra Mts. area more rockslides are present. The size of these rockslides and their recharge areas is significantly larger then the previously mentioned landslides. The Krížna – Turecká landslide for example is 1500 x 1200 m plus the adjacent recharge area. Rockslides in the Veľká Fatra Mts. are conditioned by geology (Nemčok, 1982), consisting of softer Keuper schists superimposed solid Upper Jurassic and Lower Cretaceous marly limestone. During the mapping and documentation of springs for the hydrogeological map (Malík and Kordík, 1999) many springs were recorded with irregular water flow in the areas deformed by rockslide (landslide Krížna – Turecká, landslide in Blatná dolina valley and nearby landslide Suchý hrad). Relatively high discharges of these springs clearly suggest that the environment has greater potential to accumulate groundwater from a larger area. Springs alone are mainly connected to more permeable Triassic or Jurassic carbonates; these rocks function as a drain for water accumulated in marly limestone. It is possible that the relatively very low permeable rock environment of marly limestone due to the effects of slope deformation acquires markedly increased potential for recharge, accumulation and groundwater flow concentration. Considering the presence and nature of slope deformation in such an area it should be easier to describe the circuit and flow of groundwater, and eventually, to recommend using spring water as a drinking water source.

Discussion

Investigation of hydrogeological settings in areas affected by slope deformation and gravity movement is quite complicated. This involves drawing up a chart for each mentioned feature. In the contemporary state of knowledge obtaining exact parameters is not possible, but from the point of view of understanding the basic principle, it is possible to use approximate values, or qualified estimations. Both will be gradually specified and improved in the future.

The deformations studied in Okoličné, Veľká Čausa and Dolná Mičiná, belong to (Nemčok, Pašek and Rybář, 1984, classification by movement mechanism) one type of deformation – sliding. Deformations in the Veľká Fatra Mts. belong to the rockslide type. Slope movements are geodynamic processes with different mechanisms of movement, in lithologically different environments and with different depth and volume (area) of deformation. Nonetheless, we assume that some of the resulting knowledge could be applied to other types of slope movement.

Conclusions

For several years, landslide monitoring concentrated on drainage element yields and groundwater level measuring. The results, together with meteorological data evolution, show that slope deformation creates favourable conditions for infiltration, accumulation and groundwater flow concentration. Based on rock environment charts and data a conceptual model of the groundwater circulation was created. Variability of groundwater flow concentration was demonstrated. Interpretation of groundwater circulation figures in the recharge areas of landslides was carried out in a relatively short period and more time is required for development.

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Využitie hydrogeologických poznatkov na sanáciu svahových pohybov

Poznanie vlastností obehu povrchovej i podzemnej vody umožňuje efektívnejšie a ekonomickejšie riešiť sanáciu a monitoring svahových pohybov. Monitoring hydrogeologických pomerov zosuvu v Okoličnom, Veľkej Čause v Dolnej Mičinej, ako aj pri hydrogeologickom mapovaní prameňov vo Veľkej Fatre umožnil získať nasledujúce nové poznatky.

Horninové prostredie, na ktoré svahové pohyby zväčša viažu, je relatívne málo priepustné. Hydrogeologické vlastnosti zosuvných území ovplyvňuje najmä charakter a rozsah porušenia vyvolaný svahovými pohybmi, kým litologické zloženie má až druhotný význam.

Priradením plochy infiltračného územia do svahovej deformácie možno získať dlhodobý odhad veľkosti prírodných zdrojov podzemnej vody v zosuvnom území. Na inžiniersko-geologické vlastnosti horninového prostredia ovplyvneného zosuvnými procesmi má podstatný význam veľkosť, tvar a sklon infiltračného územia zosuvu.

Porovnávaním dlhodobého odhadu veľkosti prírodných zdrojov s výdatnosťou z jednotlivých drenážnych prvkov, resp. so spoločnou výdatnosťou drenážnych prvkov možno získať poznatky o preferovaných cestách prúdenia podzemnej vody a o schopnosti podzemnej vody sústreďovať sa v jednotlivých častiach infiltračného územia.

Z hľadiska schopnosti sústredenia podzemnej vody možno v infiltračnom území vyčleniť kritickú zónu a kritický zvodnenec, kde je najväčšia schopnosť sústredenia podzemnej vody. Situovaním drenážneho prvku do miesta kritického zvodnenca vzniká podstatne vyššia pravdepodobnosť vytvoriť dlhodobý drén s relatívne vysokou výdatnosťou.

Získané poznatky umožňujú kvantifikovať niektoré hydrogeologické vlastnosti zosuvných území, a tak možno tieto vlastnosti porovnávať v čase, resp. aj s vlastnosťami iných svahových deformácií.

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Methodology and some results of slope movement monitoring in Slovakia

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Abstract

Slope movements are the most wide-spread geological hazard in Slovakia negatively influencing the quality of the environment. Systematic monitoring of slope movements has been carried out since 1993. The main goals are the selection of representative localities (according to the type of slope movement, its location in the basic types of geological structures and economic significance), creation of the monitoring system and monitoring data processing in the initial stage of the project process.In the advanced stage, the obtained and worked-out information will be extrapolated as for areas with similar stability conditions. The paper deals with the problems connected with the initial stage of the project process and brings some practical results of monitoring observations.

Key words: monitoring, slope movements, landslide, falling, creep, data collection and processing

Introduction

Systematic monitoring of slope movements in Slovakia is realized through a project of geological hazard monitoring, which is a part of the general project "Monitoring System of the Environment of the Slovak Republic". The project (underway since 1993), is funded by The Ministry of the Environment of the Slovak Republic and is carried out by the Geological Survey of Slovak Republic in cooperation with other organizations (Klukanová and Liščák, 1998).

Main goals of systematic monitoring

According to the progress of the project, the main goals of systematic monitoring may be divided into two main stages:

– In the initial stage of the project the most interest is concentrated on selection and monitoring of representative slope movement localities, where the collection of data was obtained. On the basis of this information the development of the slope movements in various geological structures is evaluated, which is the main theoretical aim of this stage of the study. From the practical point of view, the results of monitoring help to select optimal corrective measures and to control their precise functioning in the localities of active slope movement. The critical warning levels are defined for the long-term monitoring of selected important localities. Methodology and some results of this stage of the project are summarized in the paper.

– In the advanced stage of the project the obtained and worked-out information will be extrapolated for areas with similar stability conditions. Problems of regional application of monitoring results are, still being analyzed, so they are not discussed in this paper.

Methodology of monitoring – introductory stage

The methodology of the first stage of systematic monitoring consists of the following stages:

– selection of representative localities according to various criteria,

– creation of a monitoring system, i.e. selection of monitoring methods and frequency of data collection,

– monitoring data processing (i.e. methods of presenting monitoring results).

Selection of representative localities according to various criteria

The selection of representative localities is based on the following criteria:

– type of slope movement,

– location of slope failures in basic geological structures according to regional engineering geological zoning of Slovakia (Matula and Pašek, 1986), and

– economic significance of the locality.

The type of slope movement (creep, sliding, flowing and falling – according to Nemčok et al., 1974) is the leading criterion, but only movements like creep and sliding can be long-term monitored. Monitoring of road cuttings is concerned with prevention of rock falls.

Another criterion is location of selected slope failures in basic geological structures in Slovakia (Pre-tertiary rocks of the Central Carpathians, so-called Core Moun-

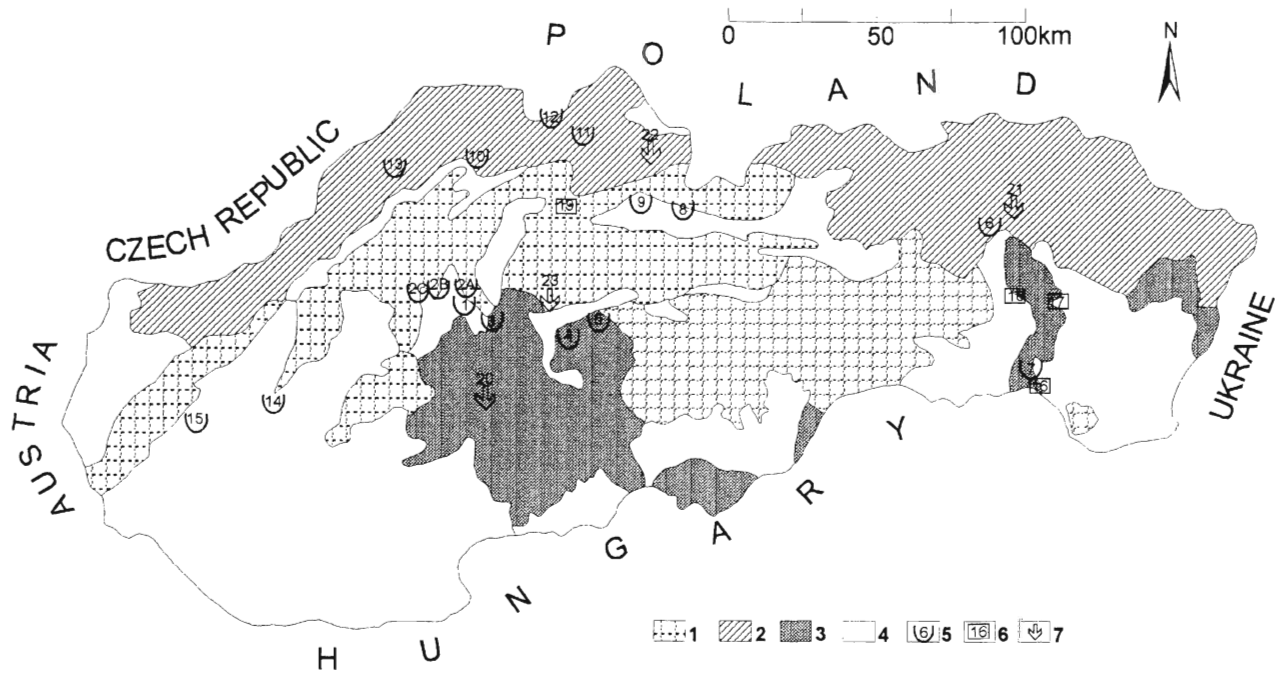


Fig. 1. Situation of monitored localities. 1 – region of core mountains, 2 – region of Carpathian Flysch, 3 – region of Neogene volcanics, 4 – region of Neogene tectonic depressions, 5 – landslides, 6 – creep, 7 – road's rock cutting (compiled by P. Liščák and P. Wagner).

tains, Carpathian Flysch, Neogene Volcanics or Neogene Tectonic Depressions). In a way, selected localities are like "guide fossils" for various geological units.

Recently, the economic necessities of locality have prevailed selection. The active landslides, endangering important structures (residential areas, roads, railroads, water-works etc.) have been included in the collection of monitored localities.

The distribution of monitored localities in the period from 1993 to 2000 is given the Fig. 1. Representative localities are spread across the whole of Slovakia in all geological structures. It is important to add, that the collection of representative localities is open – new, important slope movements are being added to and monitoring of some stabilized localities has been finished.

Creation of monitoring system

The creation of a monitoring system includes two main problems – selection of suitable monitoring methods and the frequency of data collection.

The methods of monitoring, based on our conditions, are summarized in Tab. 1 and some of them are described in this chapter in greater detail. The frequency of monitoring observations depends on economic importance and stage of activity of monitored slope failure. The frequency

Tab. 1
The methods of slope movements monitoring

Type of slope movement	Methods of monitoring	
Falling (rock cuts stability)	– documentation – photogrammetry – slope stability analysis	
Creep	– crack gauge TM-71	
Sliding	– regime measurements	– measurements of ground water level (including the automatic water stage indicators) – discharge, temperature and chemical composition of water
	– surface measurements	– detailed mapping – geodetic measuring – measuring of surface residual stresses
	– subsurface measurements	– inclinometric drill logging – PEE method

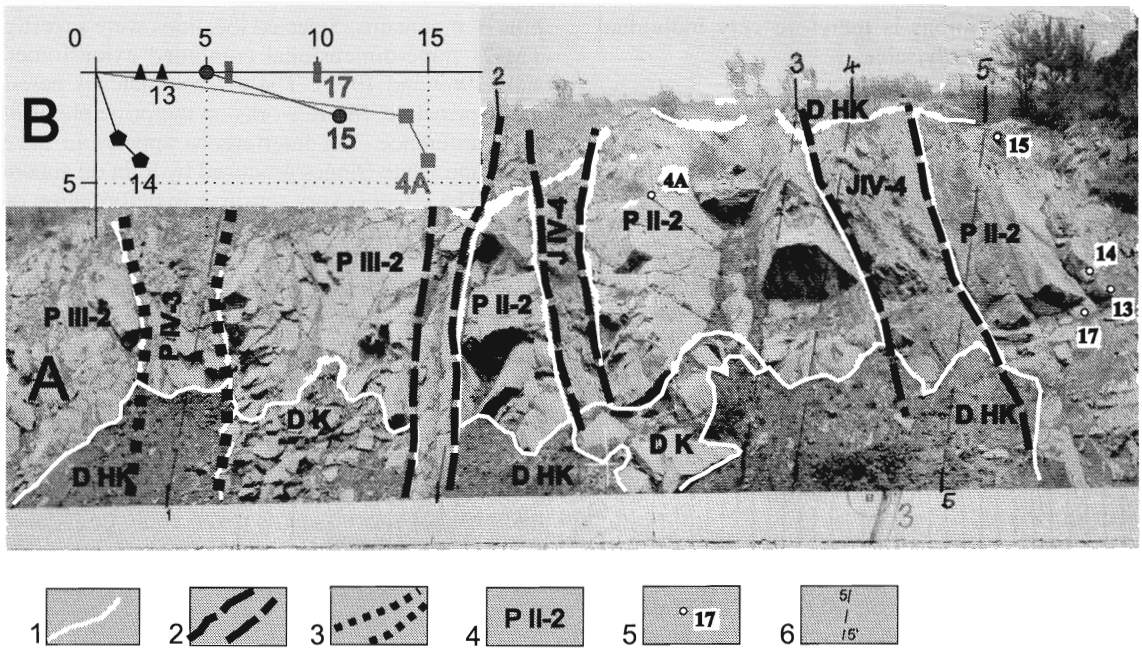


Fig. 2. Monitoring of the rock cutting at the site Demjata. A – Engineering geological homogeneous units. 1 – borders of engineering geological quasi-homogeneous units, 2 – zones of intensive weathering, 3 – zones of tectonic failures, 4 – method of indication of engineering geological quasi-homogeneous units (P- sandstones, J-claystones, D HK-loamy-stony scree, D K-stony scree, II-IV-blockiness of rock massif expressed by the representative size of blocks according to the Slovak Technical Standard STN 72 1001, 2–4 – classes of compressive strength according to the same standard), 5 – designation of several observed blocks, 6 – representative profiles; B – Graph of the horizontal and vertical displacements of blocks at the quasi-homogeneous units P II-2 observed during the years 1998 and 1999 (compiled by Iglárová).

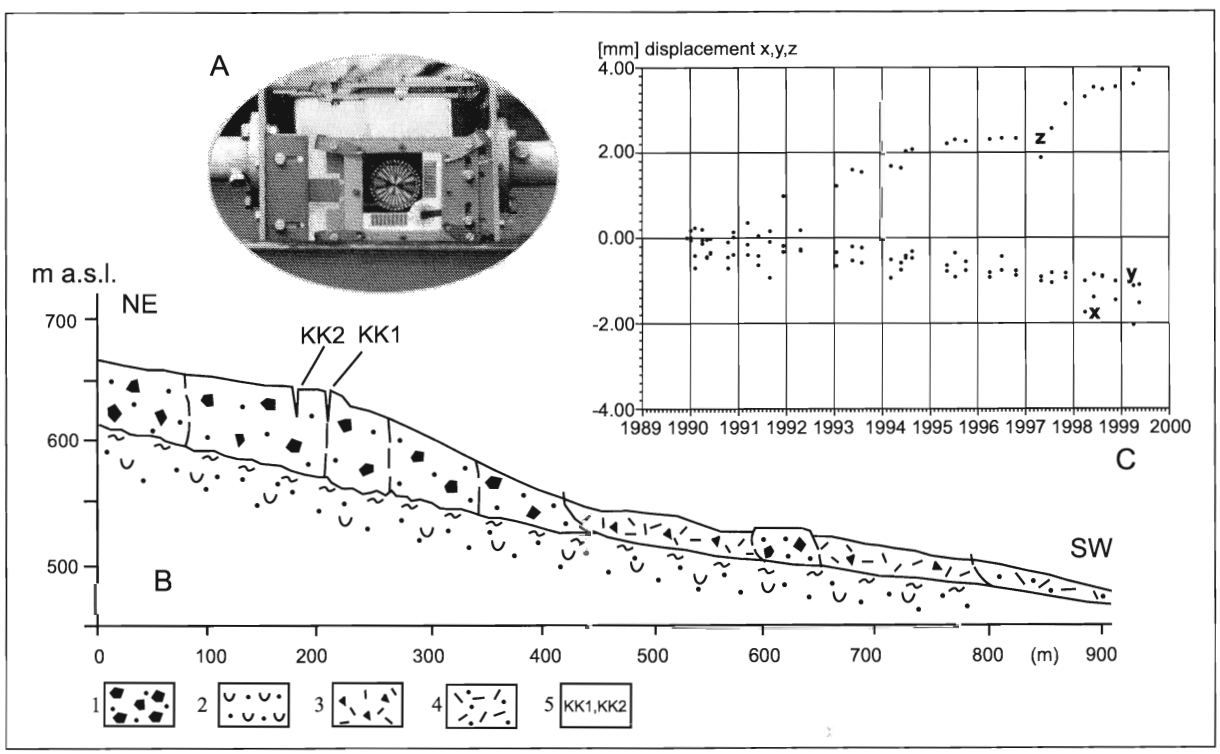


Fig. 3. Monitoring of the creep slope failures. A – Installation of the TM-71 three-dimensional combined extensiometer; B – Engineering geological cross-section of the slope deformation at site Košický Klečenov with location of installed extensiometers KK-1 and KK-2. 1 – alternation of andesites and breccias of lava flows, 2 – redeposited pyroclastics and tuffs, 3 – predominantly slope sediments (talus) with boulders, 4 – stony-clayey slope sediments (talus), 5 – location of extensiometers TM-71 (KK-1 and KK-2), C – Results of block movements monitoring at Košický Klečenov (KK-1 and KK-2) during the period 1990 – 1999 (compiled by Petro and Polaščinová).

of monitoring observations is therefore very individual and generalization is unadvisable.

Falling

Monitoring of rock cutting stability is based on regularly maintained documentation of rock walls and the use of photogrammetry.

Initial work aims at reconnaissance of geological, tectonic and structural conditions. Field works has determined the parameters of discontinuities, which defined the main systems and their orientation. The overall stability conditions of the rock massif were estimated, together with its blockiness and loosening.

Field and laboratory evaluation of rock material aimed at determining strength properties by Schmidt's rebound hammer, and observation of rock erodibility and estimation of rock durability.

After estimating the basic stages of rock massif quality, the monitoring of deformation was realized by aerial photogrammetry (Bartoš and Gregor, 1999). Repeated photogrammetric measurements comprise changes in the representative slope profiles and make it possible to determine the movement of partial units in selected profiles. Moreover, photogrammetric methods make it possible to compile a discontinuity model for inaccessible parts of a wall; to identify and quantitatively express the volume of failed parts of the cutting, or individual blocks, which, by loosening and falling endanger the vicinity. Finally, the information makes it possible to compile a model of blockiness and identify units of homogeneous stability within the rock massif (Fig. 2).

Creep

Creep slope failures are very slow (a few mm/year). They do not usually act as an endangering factor, but give information about the movement of blocks or the foot hills of mountains. Selected localities were investigated by TM-71 three-dimensional combined extensiometer (Košťák, 1969 and 1991). The extensiometer is based on the moiré principle. Moiré works on the principle of mechanical interference. The interference appears in the form of black and white fringes produced by light on superimposed grids. The effect is very sensitive to deformation or displacement. The change in the moiré pattern indicates displacement which can then be used to define quantity. The inaccuracy of such measurements is less than 0.1 mm/year.

The extensiometer is placed in a crack from 0.5 to 2 m wide, the rods being anchored in both blocks of the crack. The glass plates of the extensiometer are arranged in horizontal and vertical planes (Fig. 3a). An example of regular measurements realised since 1990, is shown in Fig. 3b, c. The displacement in axis z indicates the vertical movement of the block on that side. Petro et al. (1999) interpret this movement as neotectonic uplift of the periphery of the neovolcanic mountain of observation area.

Sliding

Most monitoring measurements are connected with monitoring of landslides. Since hydrogeological conditions are usually the main cause of landslide activation, monitoring of a water regime is the most wide spread method used for slope stability evaluation. The methods and results of hydrogeological monitoring of landslides are summarized in individual paper included in this issue (Scherer, 2000).

The methods of geodetic and inclinometric measurement are well-known and used in investigation and monitoring practice all over the world. The method of surface residual stress measurement was developed and described by Mencl (1996) and is used by the investigation organization, INGEO Ltd., Žilina. The geophysical method of pulsed electromagnetic emissions (PEE) is a relatively new and promising method for monitoring of landslides.

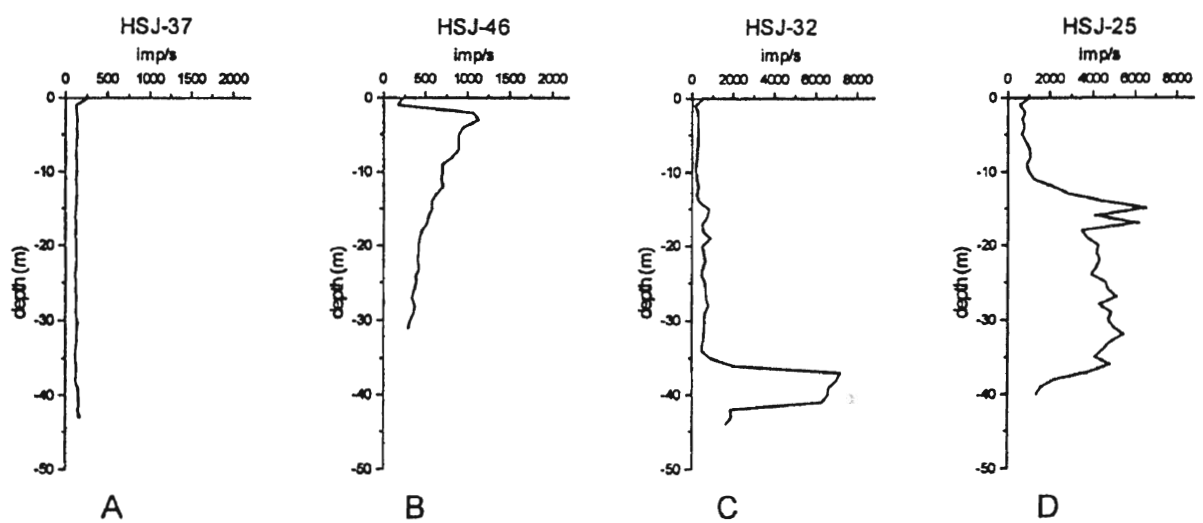


Fig. 4. Basic types of anomalies, recorded by the borehole variant of PEE method. HSJ-37 – mark of the borehole (according to Vybíral, 1997).

The PEE method is based on recording of the natural pulsed electromagnetic emission that is formed by changes in energy taking place during geodynamic processes. The state of the PEE field corresponds to a particular stage of the deformation process. Several basic types of anomaly, recorded by a drilling variant of the PEE method, are shown in Fig. 4. Type A is typical for the stabilized parts, free of any stress activity, in type B, relative activity values are high on the surface. This type is characteristic for the creep type of deformations of surface strata (e.g. in a zone influenced by seasonal climatic changes). Type C shows a horizon with permanent or local variations in values of relative activity. Stress activity is concentrated within a narrow zone, e.g. on a slide surface. Type D indicates two horizons with a varying degree of activity – stress activity is concentrated in the lower part. The curve expresses the situation, when high, the inactive horizon is "carried" on top of the lower, active horizon. Many results of the PEE method demonstrate the effectiveness of this method in monitoring landslides (Vybíral and Wagner, 1999; Vybíral, 1997).

Monitoring data processing

The results of monitoring can be presented in various ways. Most frequently used are the following:

– time course of values of observed data and their comparison with critical warning levels (usually critical levels of groundwater depth),

– graphical expression of selected monitoring observations in maps and cross-sections,

– complex evaluation of slope movement activity in the form of special zoning maps (according to semi-quantitative reclassification of the measured results).

Such expressed partial monitoring results can be used during the period of investigation with a choice of optimal corrective measures as well as in long-term control of the accuracy of the corrective measures.

All the above mentioned methods of monitoring data processing are illustrated by the results of monitoring the selected locality of the Okoličné landslide.

The landslide area Okoličné is situated in flysch rocks of the Central Carpathian Paleogene and constitutes a threat to the main railway line. The old landslide area was activated during the reconstruction work in 1949, when a cutting was excavated in the former accumulation part of the landslide. The front part of the landslide has threatened the railway line ever since. Its stabilisation demanded a number of corrective measures. Since the hydrogeological conditions of the slope are so complicated (confined groundwater level below the scarp of the landslide), surface (open ditch, drainage trenches) and subsurface (drainage shafts, subdrainage borings, rubble rib) drainage system was installed. Since the drainage system gradually ceased to work, the water has concentrated in the central part of the landslide, percolates into the landslide material and decreases its stability (Wagner et al., 1997).

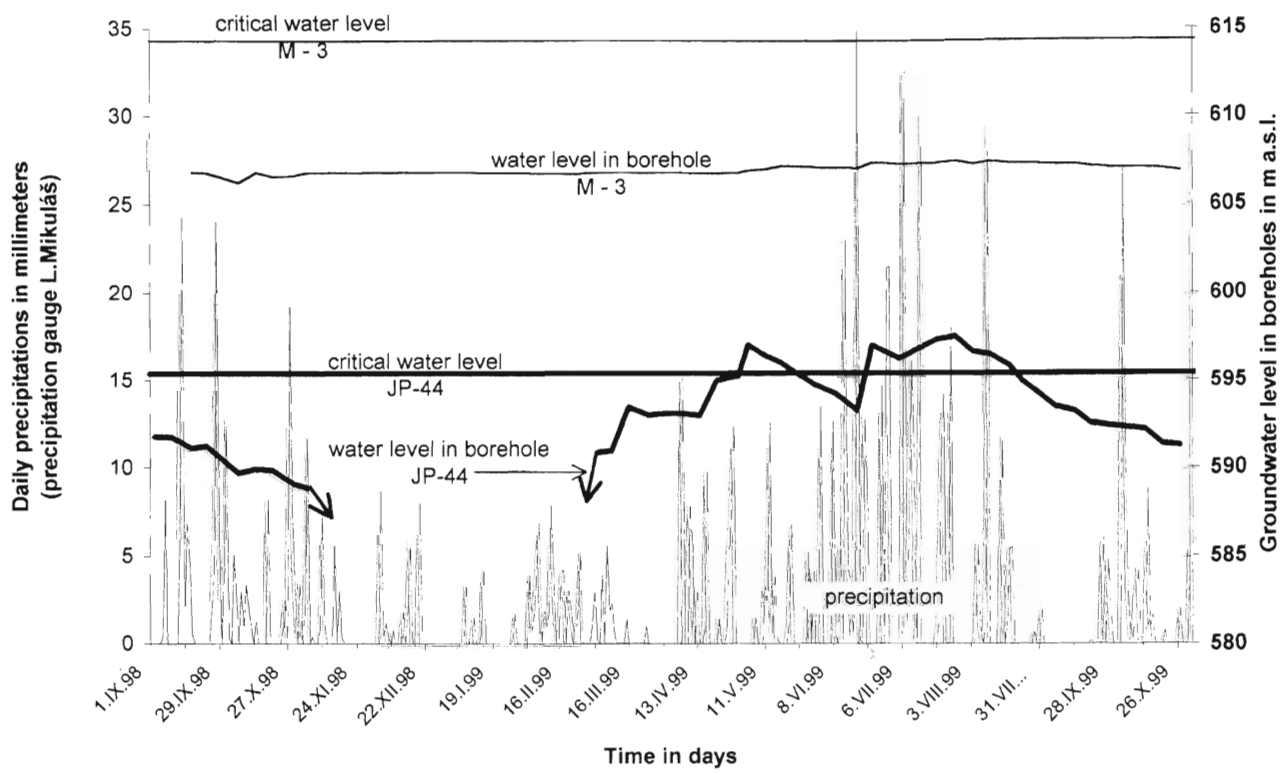


Fig. 5. Time course of ground water levels changes in selected boreholes (compiled by Wagner and Ondrášik).

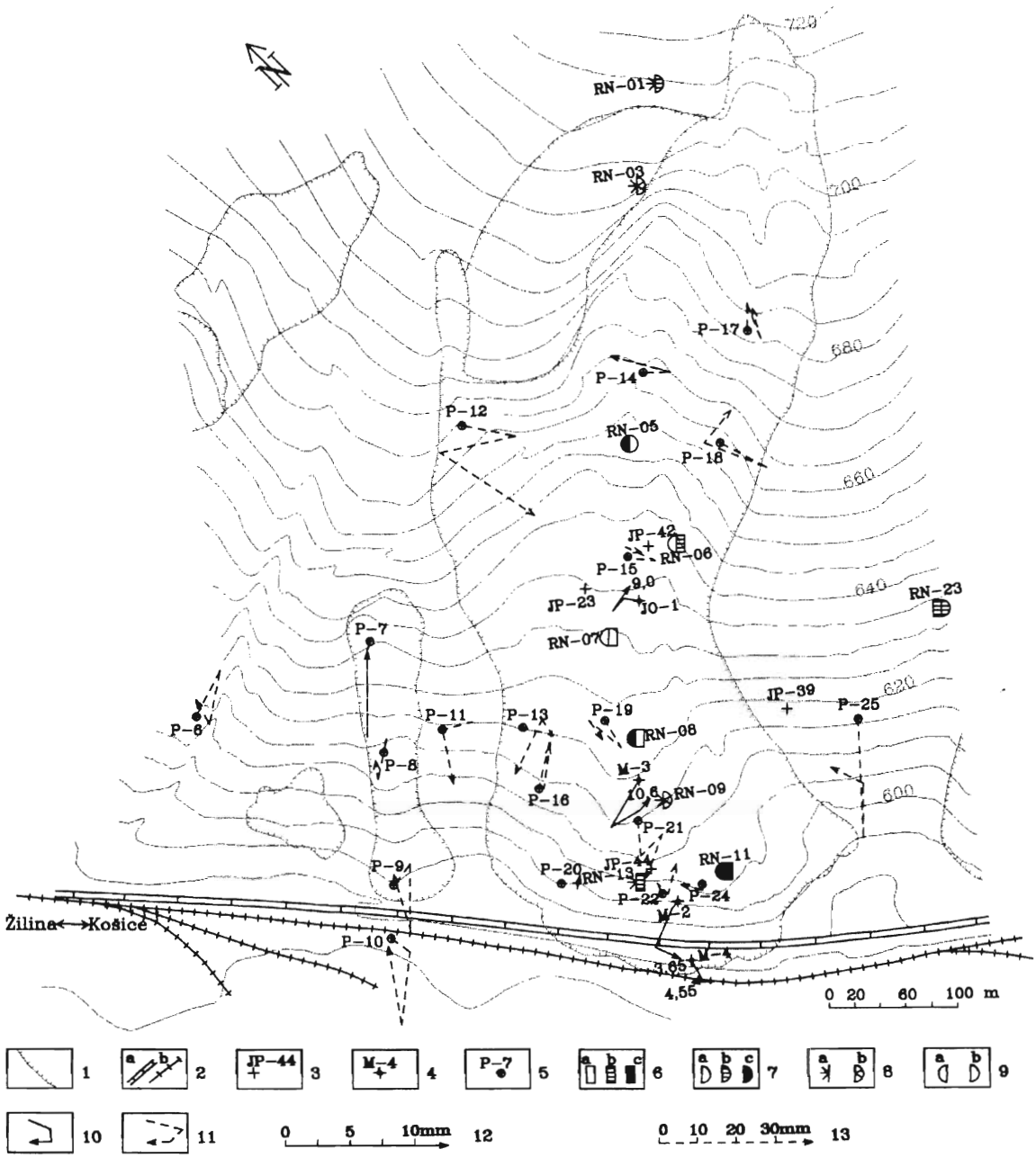
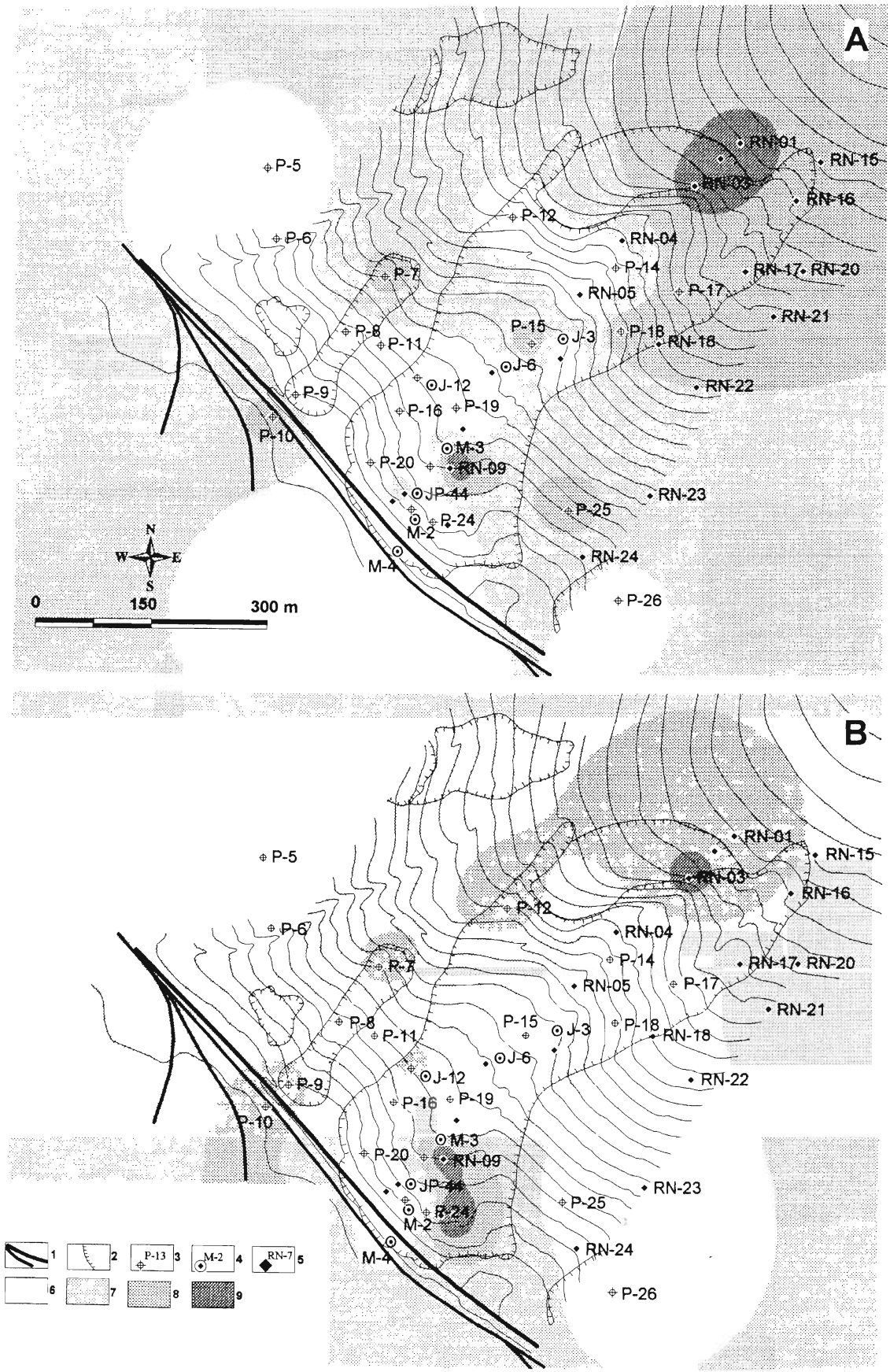


Fig. 6. The results of all monitoring observations on Okoličné landslide in period 1998 – 1999. 1 – morphologic borders of landslides, 2 – railway: main line, b) industry line, 3 – piezometric boreholes, 4 – inclinometric boreholes, 5 – geodetic points, 6 – surface residual stress - SRS (comparison with previous measurement): compression: a) slight increase, b) increase, c) expressive increase, 7 – SRS: compression: a) slight decrease, b) decrease, c) expressive decrease, 8 – SRS: a) change from tension to compression, b) from compression to tension, 9 – SRS- method of stresses development expressing: a) comparison of the stress state from XI. 1998 with the state from X. 1997, b) comparison of the stress state from XI. 1999 with the state from XI. 1998, 10 – inclinometric deformation vector in period XI.97 – XI.98 – VI.99 – XI. 99 (numbers mean a depth of deformation in m), 11 – geodetic points displacement vector in period X.97 – IV.98 – X.98 – X. 99, 12 – scale of the inclinometric deformations, 13 – scale of the geodetic displacements (compiled by Wagner and Iglárová).

Fig. 7. Complete evaluation of Okoličné landslide activity in 1998 (A) and 1999 (B). 1 – railway line, 2 – morphological border of landslides, 3 – geodetic points, 4 – boreholes, 5 – points of surface residual stress measurements, 6 – stable stage of landslide, 7 – activity indications, 8 – slightly active, 9 – active (compiled by Wagner and Pauditš).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RN-16
RN-17
RN-18
RN-20
RN-21
RN-22
RN-23
RN-24
J-3
J-6
J-12
JP-44
M-2
M-3
M-4
R-24
N
W
E
S
0
150
300 m
B
1
2
P-13
3
M-2
4
RN-7
5
6
7
8
9

Tab. 2
Scale of classificatory evaluation of the monitoring measurement results

Geodetic	Surface residual stresses	Inclinometric	PEE method
Point displacement [mm per year]	$(\sigma_{i+1}/\sigma_i-1).100$** [%]	Deformation [mm per year]	Activity level [qualitative]
to 20 ..... (1)*	decrease ..... (1)	to 2 ..... (1)	low ..... (1)
20 to 60 ..... (3)	increase 20 to 100 ..... (2)	2 to 5 ..... (2)	middle ..... (2)
over 60 ..... (5)	increase over 100 ..... (4)+	over 5 ..... (5)	high ..... (4)

* in brackets is given the point evaluation of a parameter considering a weight of measuring
** here the values of measured stress σ_1 with those of the preceding measuring stage are compared
\+ this category contains also the changes in character of stress (compression – tension)

Monitoring observations include the whole set of monitoring measurements – geodetic measurements (which have been carried out since 1971), measurements of surface residual stress (once a year since 1995) and subsurface inclinometric and PEE measurements (usually once a year since 1993). Regular observation (once a week) of the ground water level and changes in discharge from subhorizontal boreholes on selected objects have been carried out since 1995. Monitoring includes measurements by two automatic water stage indicators, installed in the front and central part of the landslide (in boreholes J-1 and JH-29). Presentation of the various methods of monitoring results are shown in Figs. 5, 6 and 7.

The time course of ground water level changes, recorded by regular weekly measurements in selected boreholes, is given in Fig. 5. The ground water level is compared with the critical water level, derived from stability calculations for each borehole. The results of observations during the last year show, that some limit levels were exceeded in borehole JP-44, situated in the front part of the landslide. Critical periods are closely connected with annual precipitation. The water level in borehole M-3, is well under the critical level. Analogous information can be obtained from each borehole in observed profiles.

Results of the monitoring observations are given individually in Fig. 6. The surface and subsurface movements, recorded by geodetic and inclinometric measurements, are expressed by vectors. Development of the stress-strain state of the landslide mass (recorded by measurements of residual stress) is indicated by special marks. In some cases the results of subsurface measurements can be expressed in representative profiles as well. The results of observations during the period 1998–2000, show the active parts of the landslide body in the upper margin (movement of point P-12 and changes of stress character in points RN-01 and RN-03) and the front area (vectors of inclinometric deformations in boreholes M-2 and M-3, high stress in point RN-11 and changes in stress character in points RN-13 and RN-09). Though this way of presenting monitored results is complete, its graphical expression is complicated and, for the users, difficult to read.

We therefore attempted to simplify the expression of monitoring results by summarising them in the form of special zoning. We based this on a semi-quantitative reclassification of the measurement results by interpolating and made them into a map (Jadroň et al., 1998). The setting up of a classifying evaluating scale for the results of various monitoring measurements is an basic operation. The scale of evaluation of single monitoring measurements (according to relevance) is demonstrated in Tab. 2. According to this scale, the geodetic and inclinometric measurements are considered to be the most important.

The results of evaluation of landslide activity during the years 1998 and 1999 are given in Fig. 7. Though the centres of activity moved over time, the most active parts of the landslide are concentrated in the scarp of the landslide and near the front part, where tensile stress appeared. Activity in the front part of the landslide is dangerous for the long-term safe operation of the main railway line.

Conclusions

The regional monitoring of selected localities in Slovakia yields not only much valuable scientific information about the development of various types of slope deformation, but also helps to solve practical problems in slope stabilization, and control of the precise functioning of corrective measures. Continued attention to these problems will make it possible to collect more information, to increase the probability of derived conclusions and to extrapolate local information for areas with similar stability conditions.

Acknowledgements. The authors are thankful to the Ministry of the Environment of the Slovak Republic for the support and kind permission to publish this paper

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Metodika a niektoré výsledky monitoringu svahových pohybov na Slovensku

Svahové pohyby sa na Slovensku systematicky monitorujú od roku 1993 v rámci monitoringu geologických hrozieb, ktorý je súčasťou monitorovacieho systému životného prostredia SR. Projekt podľa uznesenia vlády hradí MŽP SR a jeho spracovateľom je ŠGÚDŠ.

Medzi hlavné ciele projektu patrí zisťovanie zákonitostí vývoja svahových pohybov v rozličnom geologickom prostredí a aplikácia poznatkov na územia s analogickými stabilitnými pomermi. V úvode sa pozornosť sústredila na výber reprezentatívnych lokalít podľa typu svahového pohybu, jeho umiestnenia v rôznom geologickom prostredí a ekonomickej dôležitosti (obr. 1). Metódy monitoringu rozličných typov svahových pohybov sú odlišné (tab. 1) a rozdielna je aj forma prezentácie výsledkov pozorovaní pri prognóze rútenia (obr. 2) alebo plazenia (obr. 3). Najrozšírenejšie je zosúvanie, ktoré sa monitoruje najväčším súborom metód vrátane nových geofyzikálnych meraní (metóda PEE – obr. 4), a preto je komplikovaná aj prezentácia jeho výsledkov. Najpoužívanejšie spôsoby sa ilustrujú v príspevku na príklade spracovania súboru meraní na lokalite zosuvu v Okoličnom. Ide o jednoduché časové vyjadrenie priebehu zmien pozorovanej veličiny (obr. 5) alebo o súborné grafické znázornenie výsledkov všetkých meraní (obr. 6). Na lepšiu názornosť sa urobili merania semikvantitatívne prehodnotené podľa presne stanovených kritérií (tab. 2) a výsledné hodnotenie aktivity jednotlivých častí zosuvu sa komplexne vyjadrilo v účelovej rajonizačnej mape (obr. 7). Kontinuálne dopĺňanie informácií z monitoringu vybraných svahových pohybov umožní spresňovať predstavy o ich vývoji a extrapolovať poznatky na územia s analogickými stabilitnými pomermi.

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Geomechanical evaluation and description of various types of slope movement and resulting slope deformations

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Abstract

The elementary types of slope movements (creep, slide, flow and fall); gravitational slope processes and the types of slope deformations (failures): resulting forms of these processes, are evaluated and described with regard to geomechanical – kinematic and static view features.

Key words: types of slope movements (creep, slide, flow, fall), kinematic and static (stability) soltions

Introduction

Mechanism and velocity, e.g. static and kinematic, are the starting points for an objective geomechanical evaluation and description of slope movements and their resulted slope deformations. The elementary types of slope movements: creep, slide, flow and fall, according to Czechoslovak classification (Nemčok, Pašek and Rybář, 1972), should be interpreted from the kinematic view point and the types of resulting slope deformation from the static (stability) view point. However, in soil and rock masses it is essential to know relevant stress-strain relations, characteristic behaviour during shear failure (brittle-dilatant or ductile-contractant), and above all, the value of their shear strength in terms of normal stress and time. It is most important to recognize the rock or the soil effective peak shear strength (τ_p) and residual shear strength (τ_r), also softened (post-peak) shear strength (τ_s), creep shear strength (τ_c), long-term shear strength (τ_t), and eventually shear strength on the dilatancy limit (τ_d), and for slope creep and flow, movements also, the value of a coefficient of dynamic viscosity (η).

Slope movements of creep type and resulting deformations

Natural, very slow slope movements indicate existence of a steady creep (creep in secondary phase – Fig. 1/1–1/2). During permanent-constant normal stress σ a steady creep is conditioned by a shear stress value τ ranging between the low and upper steady creep limits, e.g. it is over the creep shear strength τ_c (the limit stress value) and does not reach the long-term shear strength τ_t, therefore $\tau_c < \tau < \tau_t$. A stable velocity of plastic deformation is characteristic of a steady creep, and accordingly of its time dependence on a strain field, it corresponds to a viscous-plastic flow. The mentioned rheologic nature of a creep enables analysis of its *kinetic* behaviour with a planar creep velocity, according to the Bingham equation:

$dv = (\tau - \tau_c)\, dn/\eta = (\tau - \tau_c).\cos\alpha.dz/\eta,$

where η is a coefficient of dynamic viscosity of soil or rock [$10^9 - 10^{14}$ poise = $10^5 - 10^{10}$ kPa.s], n is a thickness of deformable (displacing) layer, when inclination is α and its vertical height from the base is z, than $n = z \,.\, \cos\alpha$.

Planar surface creep of a cover (colluvial) clayey layer or so-called talus creep (Fig. 1/3), planar (lateral, translational) deep-seated creep of limited softer layer under rigid rock-blocks or so-called translational rock-spread (Fig. 1/4 and 1/7), and rotational deep-seated creep of unlimited softer layers under rigid rock-blocks or so-called cambering and bulging (Fig. 1/5-1/6), are all common types of creep slope movements.

A solution of planar creep kinetics within surface (Fig. 1/3) or superficial limited layer (Fig. 1/4), according to the Bingham equation, enables to find, unambiguously, a vertical strain-stress relation corresponding to shear stress $\tau > \tau_c$, a creep zone height z_c and a creep velocity (velocity of viscous-plastic flow) v_z as well as its distribution in a creep zone and within all the layer. Maximum velocity $v_z = v_{max}$ develops when all the creep zone is activated ($z = z_c$) and $dv/dz = 0$, while on the zone base ($z = 0$) and $dv/dz = max$, the velocity equals zero $v_z = v_{min} = 0$. An understanding of planar creep kinetics and stress-strain relations as well as creep velocity enable reverse solution, as for example verifying the η value and parameters of τ_c (φ_c when $c_c \cong 0$).

In the case of thick, unlimited softer layers overlaid by heavy rigid blocks (Fig. 1/5 and 1/8), as well as in the case of high mountain slopes (Fig. 1/9–1/10), rotational creep zone develops. Creep movement velocity along

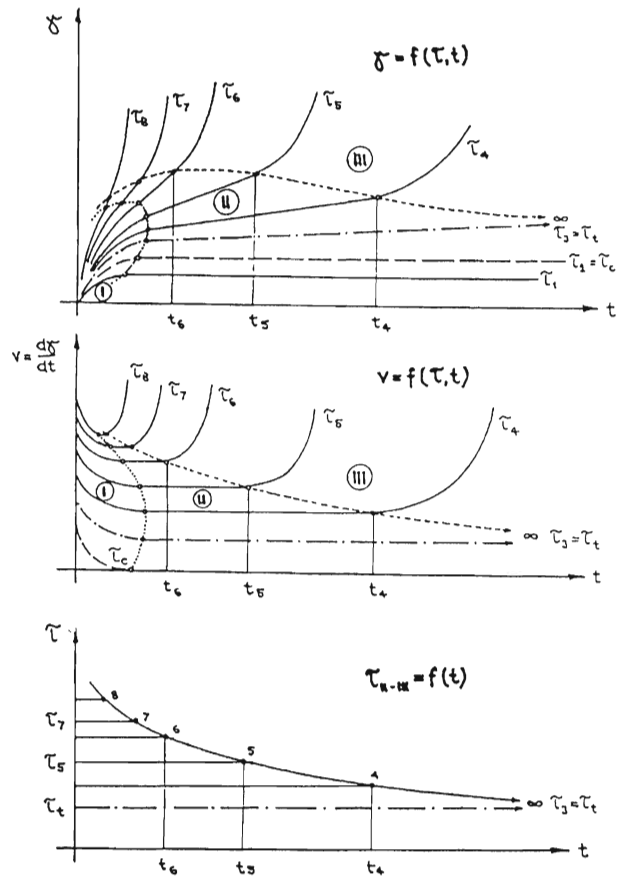
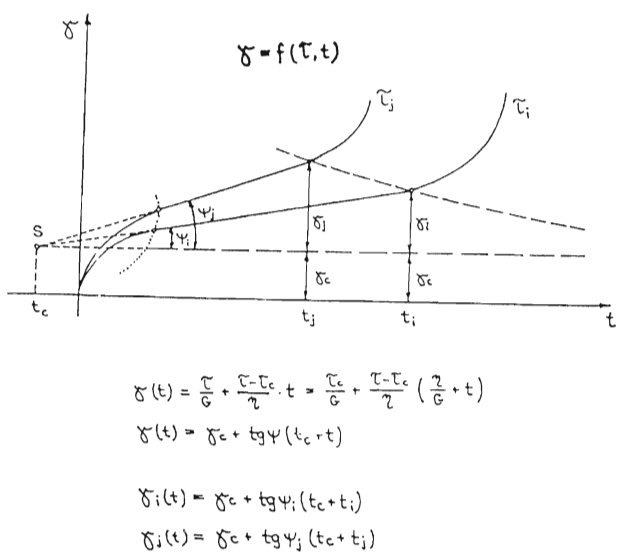


Fig. 1/1. Characteristic relationships in different creep phases (I-damped, II-steady, III- accelerating creep).



$$\gamma(t) = \frac{\tau}{G} + \frac{\tau-\tau_c}{\eta}\cdot t = \frac{\tau_c}{G} + \frac{\tau-\tau_c}{\eta}\left(\frac{\eta}{G}+t\right)$$

$$\gamma(t) = \gamma_c + \operatorname{tg}\Psi\,(t_c+t)$$

$$\gamma_i(t) = \gamma_c + \operatorname{tg}\Psi_i\,(t_c+t_i)$$

$$\gamma_j(t) = \gamma_c + \operatorname{tg}\Psi_j\,(t_c+t_j)$$

Fig. 1/2. Simplified matematical reference of steady creep (creep in secondary phase).

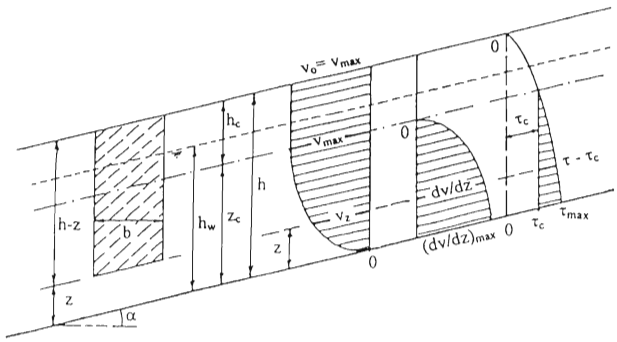


Fig. 1/3. Planar surficial earth creep (talus creep).

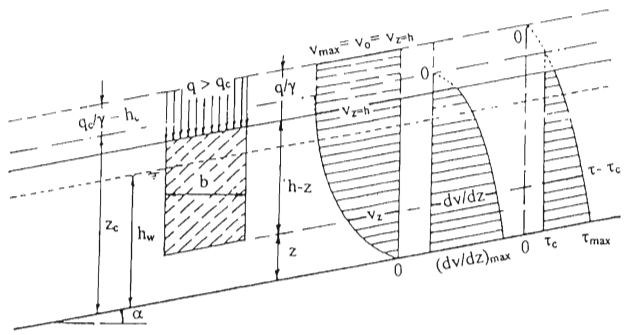


Fig. 1/4. Planar deep-seated creep of limited softer layer under rigid rock-block (translational rock-block spread).

rotational zone also corresponds to the Bingham equation transformed to the radial form:

$dv = (\tau - \tau_c)\,dr/\eta$, and $v = 1\ \eta\ r_1\ r_2\ (\tau - \tau_c)\,dr$, where r_1, r_2 are changeable radii determining a thickness of creep zone from r_2 to r_1, when $r_2 = f\,[(\tau - t_c)_{max}, \psi]$ to $r_1 = f\,[(\tau = \tau_c), \psi]$ in accordance with Fig. 1/5–1/6. Analysis by the use of the above equation is time consuming and complex due to varying slope topography and mainly unizometric-irregular margins of the creep zone in rela-

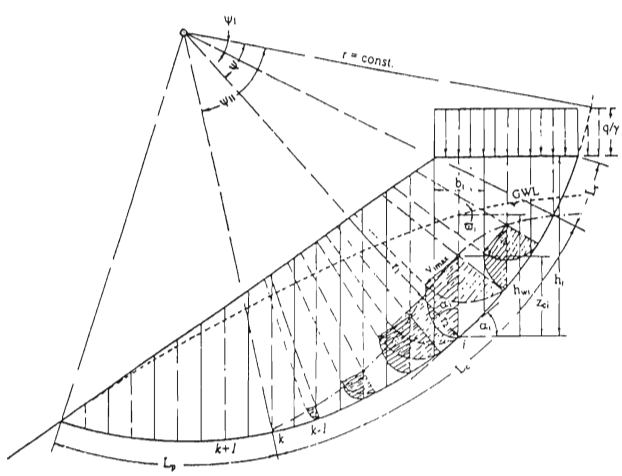


Fig. 1/5. Rotational deep-seated creep of unlimited softer substructure under rigid rock-block (cambering) and its solution by slice method.

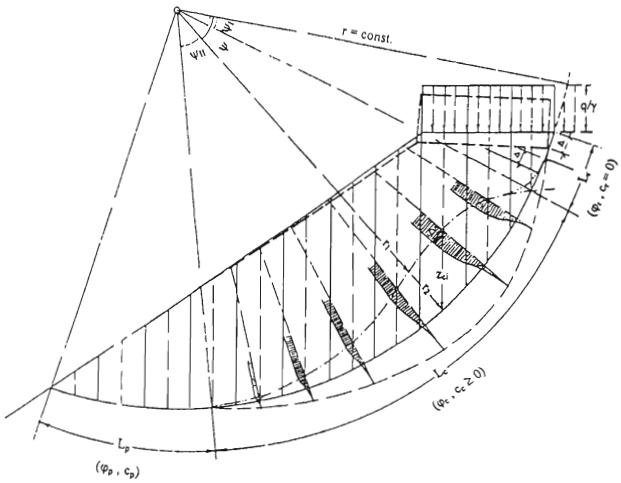


Fig. 1/6. Development of rotational deep creep zone and deformations with applied different shear strength parameters of soil along slip surface.

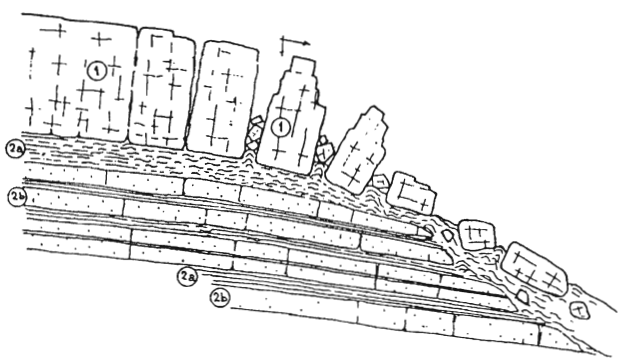


Fig. 1/7. Planar deep-seated creep of limited clayey layer unde rigid travertine-blocks on the Dreveník Mt. 1 – travertines (Pliocene), 2 – flysch layers (Cental-carpathian Paleogene): 2a – plastic marly claystones, 2b – sandstones.

tion to the rotation centre. This is why the slice method, based on the calculation of the equilibrium condition of individual slices of the creep limit, is the most advantageous. Applying this approach, we can calculate the height of the creep zone z_{ci} of particular slice i, as well as the total length of creep zone L_c, conditioned by the presence of an equilibrium state within the slice k, where $\tau_k = \tau_{ck}$.

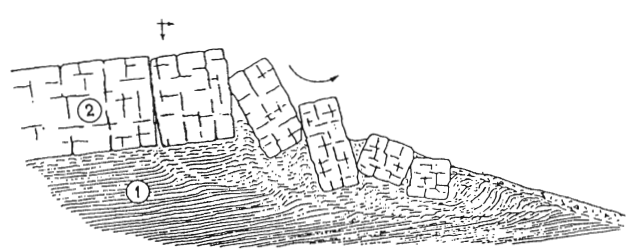


Fig. 1/8. Rotational deep-seated creep of softer clayey (1) substructure (Neogene) under marginal andesitic blocks (2) in the Biely Kameň Mt. (Vtáčnik Mts.).

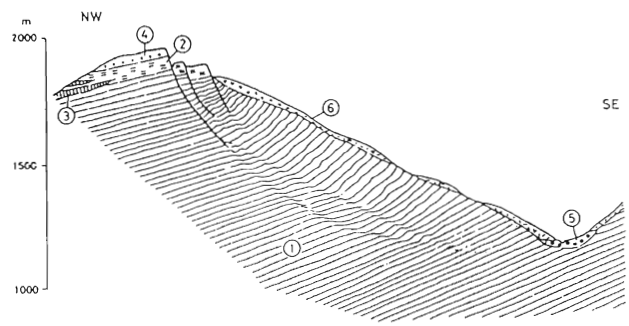


Fig. 1/9. Section through Ráztoky Mt. (West Tatra Mts.) showing potential deep creep zone of rotational shape developed within high mountain slope; 1 – paragneisses, 2 – migmatites, 3 – amphibolites, 4 – granites, 5 – moraine deposits, 6 – rock.

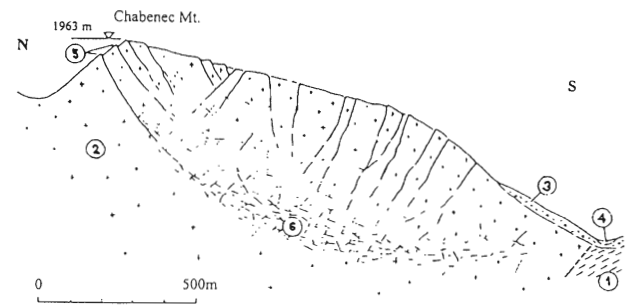


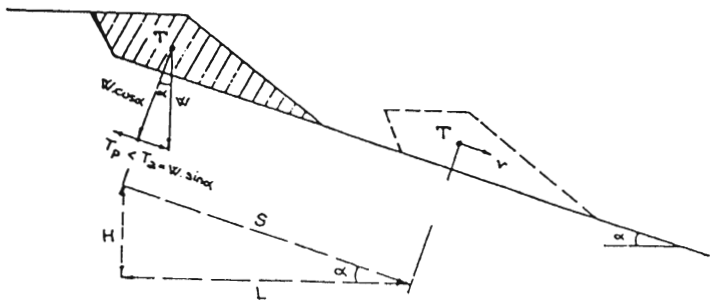
Fig. 1/10. Section through Chabenec Mt. (Base Tatra Mts.) showing predicted deep creep zone within high mountain slope; 1 – orthogneisses, 2 – granitoids, 3 – rock debris, 4 – fluvial deposits, 5 – surface of rupture, 6 – contracting creep zone.

A static solution of a creep deformation leads to methods of limit equilibrium analysis with application of rock or soil creep shear strength τ_c on the limit state of an initial local creep slope failure and with long-term shear strength τ_t on the limit state of an overall long standing creep slope failure. It is necessary to take into consideration that the values of the factor of safety for these limit states are not identical with $F_r \leq F_c < F_t < F_p$, because $\tau_r \leq \tau_c < \tau_t < \tau_p$.

Slope movements of slide type and resulting deformations

A slide resulting from fragile or ductile failure, proportional to the shear stress, is accompanied by time independent elastic and plastic deformations, according to the nature of rocks, soils and stress conditions. The peak shear strength τ_p is decisive for a total sliding failure; as well as residual shear strength τ_r or eventually also so named softened shear strength τ_s for progressive failure. A shear strength on the dilatancy limit τ_d is decisive for a local fragile failure (contractancy and plastic deformations are excluded), and during active sliding, only residual strength τ_r is decisive.

Landslide analysis in respect of *kinetics* is based on Newton's force law, valid for the acceleration of solid bodies in the gravitational field. As landslides move on a predis-



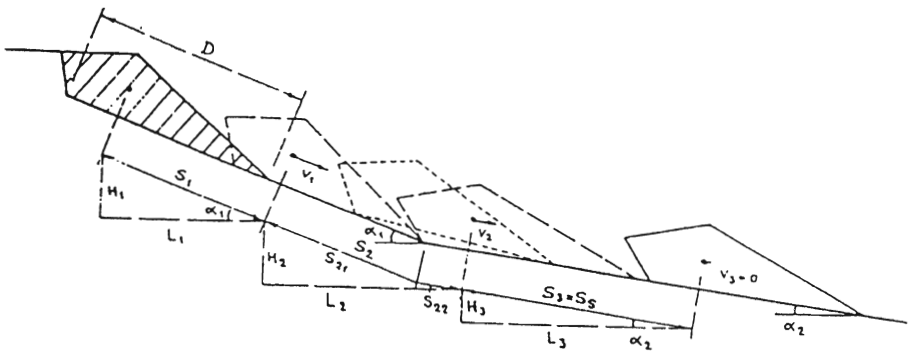


Fig. 2/1. Examples of kinematics of a planar rock (earth) block slide along an inclined slip surface.

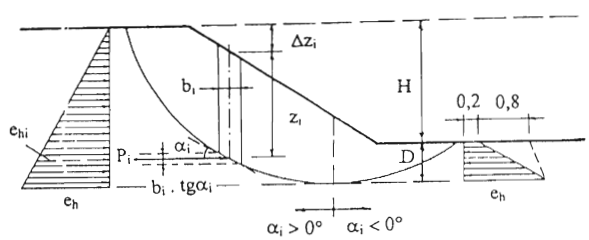
posed slip surface of variable shape, common expression for the slide kinetics is rather complicated, which is why the application is just for simple, mostly planar landslides (Fig. 2/1), when the resulting force, causing acceleration of a sliding mass, is determined from the difference of active and passive forces actuated on the slip surface.

A *static* solution of landslides focuses on their stability analysis. Slice methods of limit equilibrium analysis for slope stability are commonly used. The most suitable slice methods are those, which satisfy all conditions of static (force and moment) equilibrium for one slice or for a whole sliding body, and therefore, these methods are termed precise i.e. statically correct slice methods. Realistic results of stability analysis by the use of precise methods in the case of cut-slopes in overconsolidated soils and in the case of slopes in soils with a tendency to progressive slope failure are depend out on taking into consideration the above mentioned specific circumstances.

In the case of overconsolidated soils (Fussgänger, 1988) the insertion of sup-plementary horizontal stress e_h, corresponding to the increase of overconsolidation ΔK_o as well as excavation stress release $\Delta\sigma_v$, is needed (Fig. 2/2) in the form:

$e_h = (K_o - K_{on}) \,.\, [(\sigma_v + \Delta\sigma_v) - u] = \Delta K_o\, [(\sigma_v + \Delta\sigma_v) - u\,] = \Delta K_o\, [\gamma \,.\, (z_i + \Delta z_i) - u_i]$,

where K_o is a coefficient of earth pressure of overconsolidated soil, when for soils with plasticity index $I_p \leq 40\%$ is: $K_o = 0{,}4 \,.\, OCR + 0.0067.\, I_p$, and OCR is



$P_i = e_{hi} \,.\, b_i \,.\, tg\alpha_i \qquad \Delta K_o = K_o - K_{on} \cong 0{,}40.[\sqrt{OCR} - 1]$ for the soils with $I_p \leq 40\%$

For $\alpha_i > 0°$:

$e_{hi} = \Delta K_o\, [\gamma.\, (z_i + \Delta z_i) - u_i\,]$

For $\alpha_i < 0°$:

$e_{hi} = \Delta K_o \,\{\, [\gamma.\, (z_i + \Delta z_i) - u_i\,] - 0{,}8.\, \gamma.\, H/D\, [\, H+D - (z_i + \Delta z_i)\,]\,\}$

Fig. 2/2. Principle of cut-slope stability analysis in overconsolidated soils.

the overconsolidation ratio; K_{on} is coefficient of earth pressure of normal consolidated soil (when OCR = 1); σ_v (z_i) is vertical stress (height) above slip surface; $\Delta\sigma_v$ (Δz_i) is release difference of a vertical stress (height) before and after excavation; u_i is pore pressure; γ is bulk density of soil.

A relaxation of natural horizontal stress, up to 20% of original, takes place at a bottom of the excavation (Záru-

ba and Mencl, 1982), what reflects in linear reduction of a horizontal stress according to Fig. 2/2 it is:

$e_h = \Delta K_o \{[\gamma . (z_i + \Delta z_i) - u_i] - 0.8.\gamma.H/D [H + D - (z_i + \Delta z_i)]\}$

The process of a local progressive gradual slope failure, especially in dilatant soils with brittle behavior, leading to the total slope stability failure and a landslide, indicates shear stress redistribution and soil shear strength release from the peak to residual. A decrease of the τ_p value straight to the residual τ_r value (with parameters φ_r, c_r = = 0), or if gradual decrease due to so-called softened post-peak strength τ_s (with parameters φ_s, c_s) are applied in the slices with a shear stress τ higher as a peak strength τ_p or as a post-peak strength τ_s respectively, when using stability analysis by slice methods (Law and Lumb, 1978). A strength decrease results in unbalanced side forces between the slices and affects neighbouring slices. An initial failure gradually spreads and terminates at the slice m in which even increased side interslice forces correspond to $\tau_m \leq \tau_{pm}$.

Slope movements of flow type and resulting deformations

Generally in geomechanics, the flow, as defined, corresponds to movement of viscous fluids, e.g. viscous laminar or turbulent flow in the presence of bound water as well as free (gravity) water. The total amount of free water cannot exceed amount of rock-soil (solid) particles in this mixture, otherwise it is water transport – soil outwash. Resulting slope deformations of flow process are the earth or mud-flows and debris flows, so named in Alpine regions as murren or debris avalanches. The most frequent is a flow of fully saturated cover soils (earth or debris) having water content near the liquid limit ($w \cong \cong w_L$), where the consistency changes to very wet and thus they acquire a nature of viscous fluids.

It is possible to solve the *kinetics* of laminar flow from the geomechanics and rheology point of view or from the hydrodynamics point of view. From the rheology point of view, laminar viscous flow is a peculiar case of viscous-plastic flow, where creep strength is already practically zero $\tau_c = 0$ and coefficient of dynamical viscosity $\eta < 10^6$–10^8 ps, what means transformation of the Bingham equation to Newtonian:

$dv = \tau/\eta . dn = \tau/\eta . \cos\alpha . dz.$

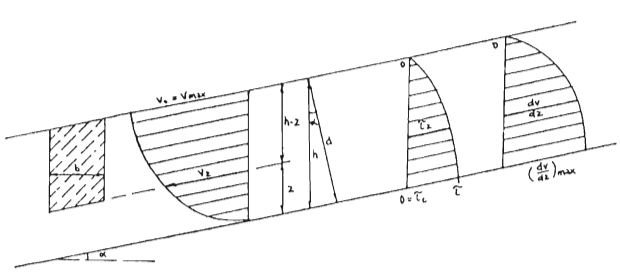


Fig. 3/1. Laminar flow of viscous earth layer and characteristics of the velocity distribution.

From the equation follows that maximum flow velocity v_{max} develops on the surface of the flow layer in a thickness $d = n = z . \cos\alpha$ (Fig. 3/1):

$v_{max} = 0{,}50.\gamma/\eta . d^2 . \sin\alpha$, where γ is bulk density of flowing soils, and α is an angle between a fixed base and horizontal.

Based on the hydrodynamics, the energy equation of Bernoulli for laminar flow, may be adapted as follows:

$v_{max} = 0.45.\gamma/\eta . d^2 . \tau g\alpha . \sec\alpha$, which is virtually the same as the previous equation.

From observations in situ of mud and earth flows an empirical relation of resembling form was derived: $v_{max} = = 3/8 . \gamma/\eta . d^2 . \tau g\alpha$.

Kinetics of a turbulent debris flow type caused by constitutional and mainly by free water due to torrents is very complicated and this is why an empirical relationship, deduced from an in situ as well as laboratory observations, is used. Deduced empirical relationships are derived either from the equation of Chézy or from the size of the solid particles which have lost their positional stability due to turbulent flow.

Statics, or the slope stability solution vis-a-vis earth and debris flows, are more or less pointless, since viscous soils of an almost liquid consistency are not able to retain any shear stress without immediate deformation.

Slope movements of fall type and resulting deformations

The most important and dangerous type of fall is usually a rock-block fall due to toppling or sliding and where some free fall takes place. Kinetics of a rock fall is closely, related to the geological condition and geometry of the rock slope topography.

The most frequent and basic *kinetic* task in rock fall related to free fall is a determining the line of fall with the maximum distance from the toe of the slope, e.g. the solution of combined free falling and rebounding (Fig. 4/1). Solution is not possible without knowing the loss in kinetic energy or free fall velocity after ground-impact followed by rebounding – oblique throw eventually. Based on modelling and observation (Broilli, 1974; Halbauer, 1986), it was found that, due to the impact after a free fall, followed by rebounding approximately a loss of kinetic energy up to 50% and 75–85% takes place after a free fall from a height of 50 m and 200 m respectively. From these data it is deduced that a 50% loss of kinetic energy on impact means a 71% reduction ($K = 0.707 = = v_p/v_o$) in free fall velocity v_o to rebound (post-impact) velocity v_p (in direction uphill as an oblique bound) and similarly a 75–85% loss of energy means a 39–50% reduction in velocity (with coefficient of restitution $K = = 0.387$–0.500). A more detailed solution was presented by Giani (1992).

From the point of view of *statics,* decisive for the fall, is the initial phase, which is related to the process of the stability loss and instant detachment of the predisposed block from the rockwall. To assess the predisposed rock block stability it is necessary to rely on the initial me-

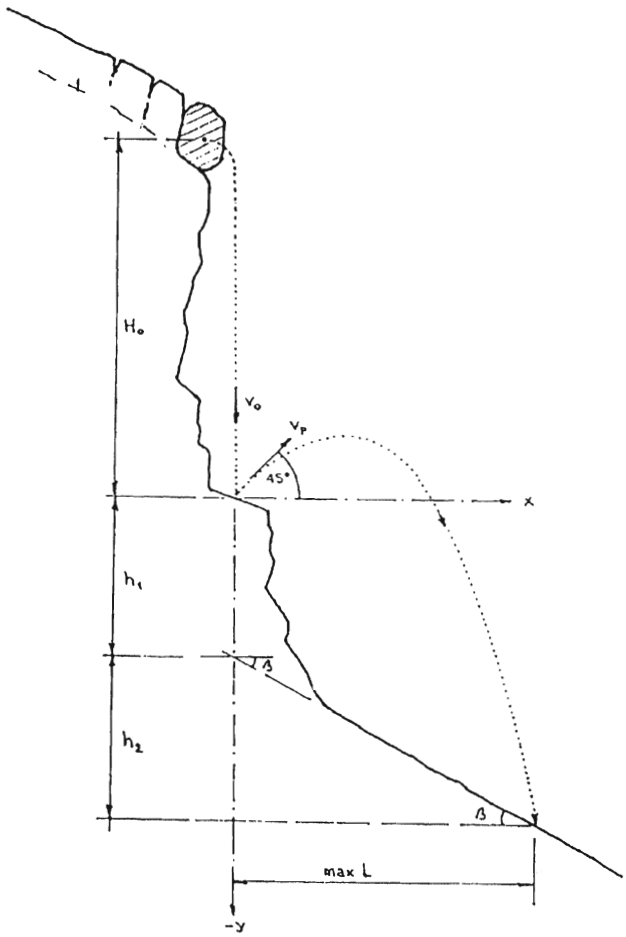


Fig. 4/1. Example of rock-block fall kinematics with free fall and rebound.

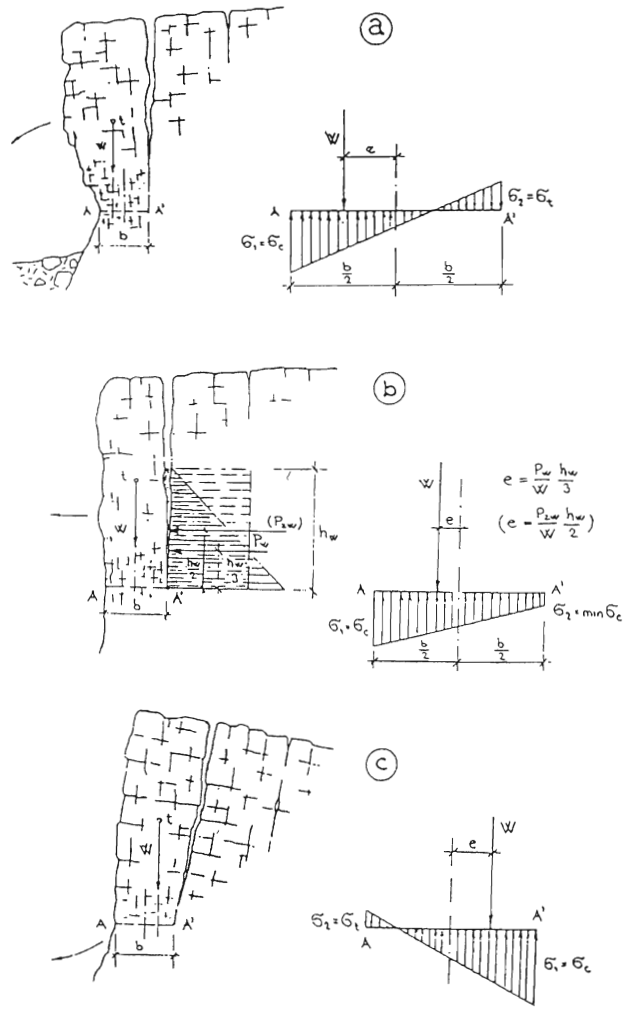


Fig. 4/2. Stability solution for a toppling rock-block failure detached by sub-vertical opened cracks.

chanism of failure due to its mass, by toppling, wedge or block sliding. The tendency of rock blocks to *sliding* results from the existence of sub-horizontal and oblique sets of discontinuities inclined to the slope surface. The solution of their stability is rather simple by conventional methods while the mechanism is identical to planar sliding or a wedge failure. The tendency of rock blocks to *topple* is related to a set of sub-vertical discontinuities inclined within the rock mass, which gives rise to an eccentric force resulting from the rock block mass.

The most frequent stability evaluation of predisposed rock blocks (columns, towers or walls) to toppling is where rock blocks become totally detached by sub-vertical open cracks or up-wards erected benches and columns with sub-vertical bedding planes. Firstly, order it is necessary to evaluate compression and tension of the eccentric forces in the most un-favourable profile of the block base (Fig. 4/2a-4/2c). Apart from the rock mass itself it is necessary to consider possibility of lateral hydrostatic water pressure in fissures as well the forces generated by freezing of ice. (Fig. 4/2b).

In the solution of the second case, e.g. the stability analysis for toppling failures, it is possible to use the simple kinematic-graphic analysis by Goodman and Bray (1976), or the stability solution by Hoek and Bray

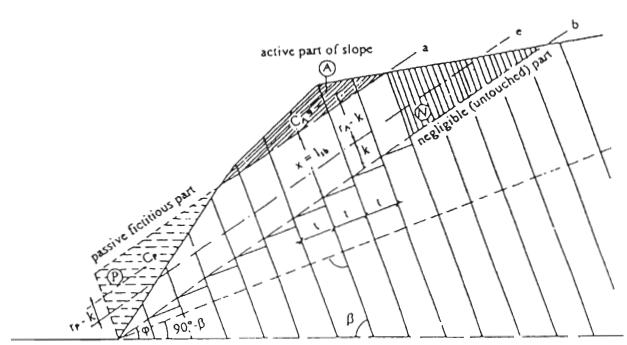


Fig. 4/3. Stability analysis for toppling failure of rock slope by method "self-bearing length" of rock-columns (benches).

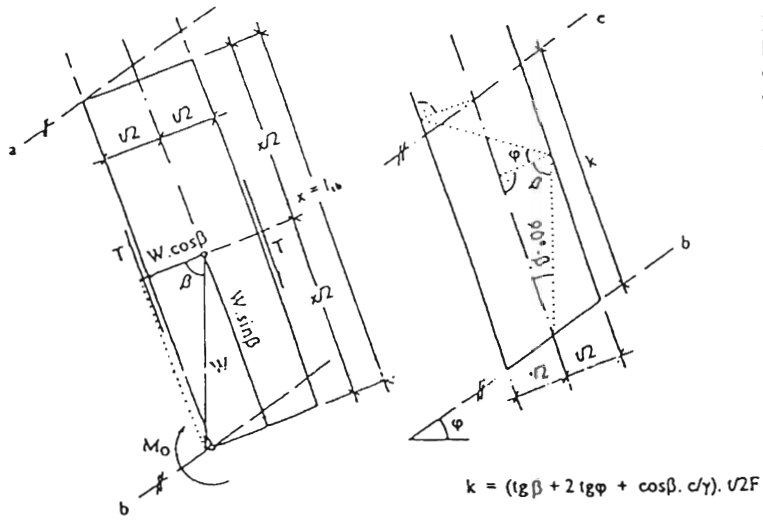


Fig. 4/4. Determination of the "self-bearing length" of rock-column ($x = l_{sb}$ from a moment equilibrium equation $\Sigma M = 0$) and the distance (k) of neutral axe (e) for a momentum relation of the passive and active slope parts [$F = M_P/M_A$, when $M_P = P.\gamma.(r_p - k)$ and $M_A = A.\gamma.(r_A - k)$]

Moment equilibrium equation of particular rock-column

$\Sigma M = M_{GT} - (M_{GN} + M_T + M_O) = 0$

where.: $M_{GT} = (x/2)\ W.\cos\beta = (x^2/2).t.\gamma.\cos\beta$

$M_{GN} = (t/2)\ W.\sin\beta = x.(t^2/2).\gamma.\sin\beta$

$M_T = T.\ t = (W.\cos\beta.\mathrm{tg}\varphi + c.x).t = x.t^2.\gamma.\cos\beta.\mathrm{tg}\varphi + x.t.c$

$M_O = W_{CS}.\ \sigma_{TB} = 1/6\ .t^2.\ \sigma_{TB}$

W_{CS} – cross-sectional modulus of the rock-column base, F–factor of safety,

σ_{TB} – strength of the rock in tension with bend, γ– bulk density of the rock

$l_{sb} = x \rightarrow :\ x^2.3\gamma.\cos\beta + x/F\ (3\gamma.\sin\beta + 6\gamma.\cos\beta.\mathrm{tg}\varphi + 6c/t) - \sigma_{TB}/F = 0$

(1981). In addition to these well-know solutions, it would be advantageous to apply the solution of Zajíc (in Pavlík, 1981), that is based on determination of so-called self-bearing length (l_{sb}) of rock benches (columns). According to this solution (Fig. 4/3–4/4), the slope stability, in regard to toppling of rock benches or columns, can be evaluated by iterative mode on the basis of moment equilibrium resulted forces of particular bench (column) around the bottom edge (Fig. 4/4) and effortlessly (Fig. 4/3) according to momentum relation of the passive fictitious (P) and active (A) slope parts to a neutral line (e) in the distance (k) from a stabile slope stepped base (line b in inclination φ). In addition for this solution it is needed to know also a bend tensile strength (σ_{TB}), friction angle (φ) and cohesion (c) along the discontinuities.

Conclusions

Recent research in geomechanics makes possible a realistic evaluation of the most essential slope movement types and resulting deformations in terms of their specific kinetics and statics. For completeness, it should be added, that in the Czechoslovak classification compared with American classification (Varnes, 1978), identifying the types of slope movements: fall, topple, slide, spread and flow, spread more or less corresponds to deep-seated creep, and the topple is identical with a specific initial phase of failure of rock columns prior to their collapse – rock fall.

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Záruba, Q. & Mencl, V., 1982: Landslides and their control. *Academia Praha, 2nd ed., 201–203.*

Geomechanické hodnotenie rozličných svahových pohybov a výsledných svahových deformácií

Pri objektívnom geomechanickom hodnotení svahových pohybov a deformácií, ktoré sa podľa československej klasifikácie (Nemčok, Pašek a Rybář, 1972) rozdeľujú na plazenie (creep), zosúvanie (slide), stekanie (flow) a rútenie (fall), treba vychádzať z ich základných klasifikačných kritérií – z charakteristického mechanizmu a rýchlosti pohybu, t. j. z ich kinematiky a statiky, ale zároveň je nevyhnutné poznať základnú charakteristiku šmykového namáhania a pretvárania hornín v závislosti od normálového napätia a času.

Mineralia Slovaca, 32 (2000), 377–379

The application of geophysical information in landslide research in Slovakia

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Abstract

The application of geophysical methods in landslide study is discussed in the paper. This theme is discussed for landslides in Slovakia, but is actual for any landslides. The new method of strain monitoring at landslides (PEE) is mentioned in the final part of the paper.

Key words: landslide, geophysical methods, monitoring

Introduction

Geophysics encompasses the study of physical fields and physical properties of the earth, and geophysicists require an accurate reading of this information for creation of geological models and geological processes. The field of application of these models and processes are landslides.

History

The use of geophysical methods in landslide study began in Slovakia in the 60's and is connected with the development of new geophysical applications in engineering geology and for this type of research electrical methods and seismic methods are usually chosen. Other methods have come into use: gravimetry, magnetometry, thermometry, radiometry and well logging. For a better understanding of time and space changes in tensile distribution geoacoustics is used, and at the present time a recently developed method – pulse electromagnetic emission (PEE) is in use.

The aims and methods

The general aim of geophysical characterization of landslides is shear zone detection. For this resistivity method (vertical electric sounding and electrical profiling – Fig. 1) and shallow seismic were applied. Results of both methods were verified by well logging. Another part of geophysical landslide characterization was study of internal landslide structure, i.e. distribution of dilatation and pressure zones. For this, the SP (spontaneous polarization) method was applied (Fig. 1). An electrical field which is created by filtration of underground water in a porous space is measured by this method. The negative SP anomaly sites indicate a dilatation (and infiltration) zone and a positive SP anomaly a pressure zone. Other methods which can help to detect landslide structure are two electrical methods: georadar and resistivity imaging. Resistivity imaging combines vertical electric sounding and resistivity profiling and by a multicable and a series of electrodes can show a high resolution picture of underground resistivity. Georadar utilisation is at an early stage, but we hope its success in special cases. For monitoring landslide movement magnetometry was used with a permanent magnet placed at various places in the landslide body. By monitoring magnetic field changes and changing the magnet's position the mobility of the soils around the magnet can be found. In the case of a block landslide, an additional method have been used, i.e. gravimetry for block location. For well logging except electrical logging and radiometric logging, precise inclinometry has been used as well.

Seismoacoustics and pulse electromagnetic emission (PEE) – a new recently developped method – have been used in wells for monitoring of landslide development and landslide movement prediction in Slovakia. PEE method measures pulse electromagnetic waves, which are emitted by mineral deformation from pressure stress in the landslide process. Time and space changes of PEE activity indicate changes in landslide mobility and can be used to predict landslide movement (Fig. 2).

Conclusion

Geophysical information provide a new way of studying slope stability and the landslide process in Slovakia. For better monitoring of landslide development and prediction of landslide movement, this information is cost effective and useful.

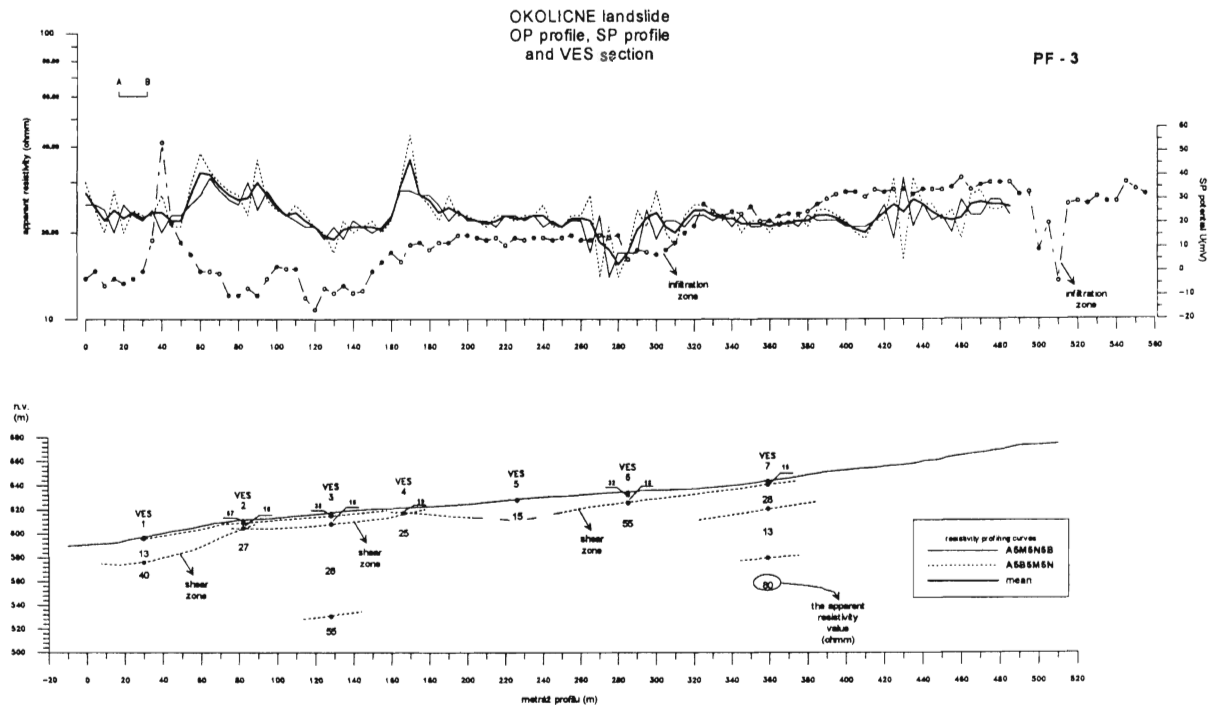

Fig. 1. Okoličné landslide. A combine results of resistivity profiling, spontaneous polarization profiling and layer parameters interpreted from vertical electric sounding results.

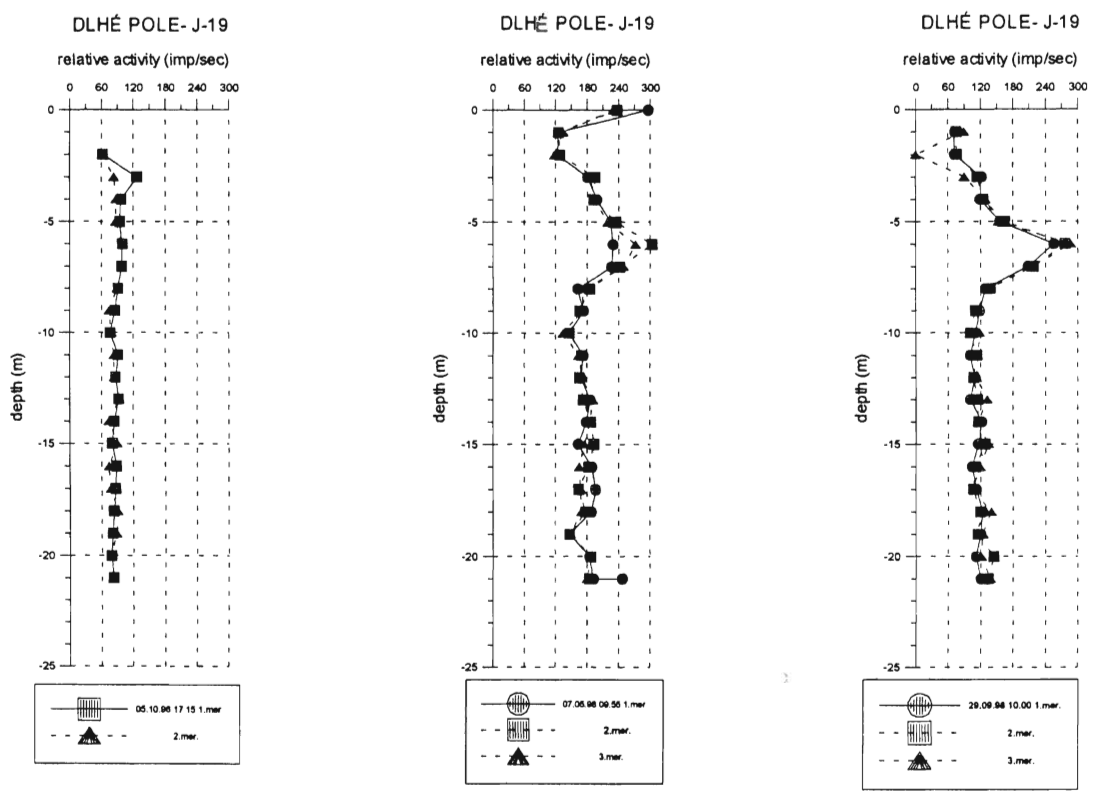

Fig. 2. Time development of pulse electromagnetic emission (PEE) activity at sheare zone by well logging measurement.

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Využitie geofyzikálnych informácií pri výskume zosuvov na Slovensku

Súčasťou štúdia zosuvov sú aj geofyzikálne informácie. V príspevku sa analyzujú možnosti aplikácie geofyzikálnych metód na Slovensku.a uvádzajú sa prvé výsledky, ktoré sa dosiahli novou, vyvíjanou metódou pulznej elektromagnetickej emisie (PEE) pri štúdiu napätostnodeformačných stavov v telesách zosuvov s ohľadom na vývoj zosuvnej aktivity.

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Landslide hazard map of Central Kyushu in Japan

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Abstract

Many of the landslides encountered in the central Kyushu Island of Japan are located along the fault zone of so-called Kurosegawa structural belt. Factor analysis of landslide with quantification theory (class II) has been adopted to study many of these landslides with the objective of estimation of landslide risk and to compile a landslide hazard map based on the statistical analysis. The results of this study showed that the quantification theory can be applied effectively for preparation of landslide hazard map.

Key words: landslide, hazard map, quantification theory

Introduction

Landslides are one of the most destructive geological processes affecting people and their work, causing thousands of causalities and property damage all over the world. It is believed that at least 75% of landslide losses are avoidable if the problem is recognized before the event taking place. Therefore, construction of the landslide hazard map is a prime important task. Various methods are adopted in construction of such landslide hazard maps and the current study is aimed at using statistical techniques to study the geological, geomorphological, structural and landuse data to prepare such hazard maps.

Central Kyushu Island of Japan has been selected as the study area for the current research, as quite a large number of landslides are concentrated within this area. This research work commenced in the Kyushu Tokai University of Japan with the aim to estimate the possibility for application of quantification theory for preparation of landslide hazard maps. The procedure adopted for risk assessment is indicated in Fig. 1.

Geology and Topography of the Study Area

Large number of landslides encountered within the central Kyushu Island (Fig. 2) of Japan are elongated along the crushed zone of so-called Kurosegawa structural belt. Most of them exist on the gentle slopes of approximately 200–800m above the mean sea level. This region consists mainly of Paleozoic and Mesozoic sedimentary rocks of mudstone, sandstone, chert, limestone and, some basic rocks of serpentinite etc. Material of certain landslides are partly consist of granite and welded tuff, shale or conglomerate as shown in Fig. 3 (Watanabe, 1984).

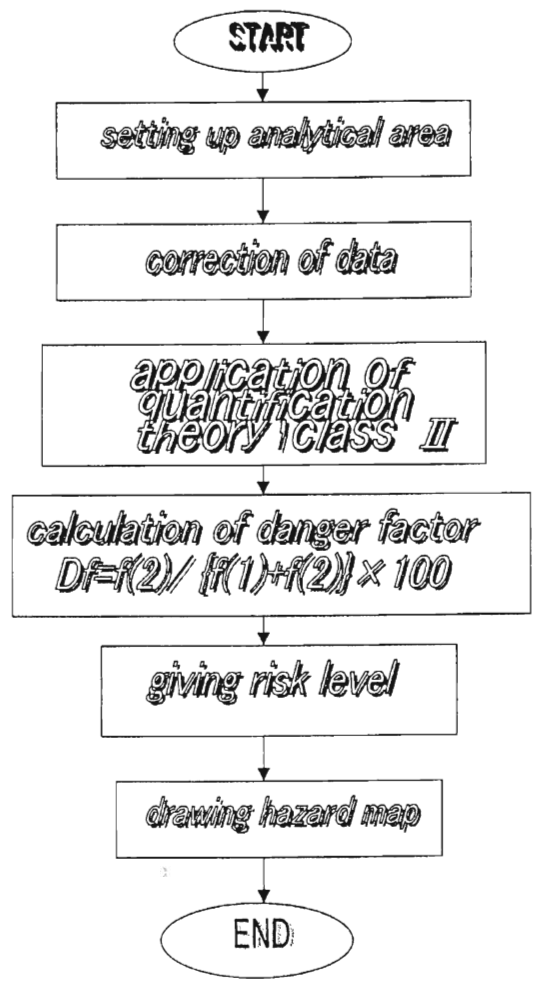

Fig. 1. Flow-chart for risk assessment.

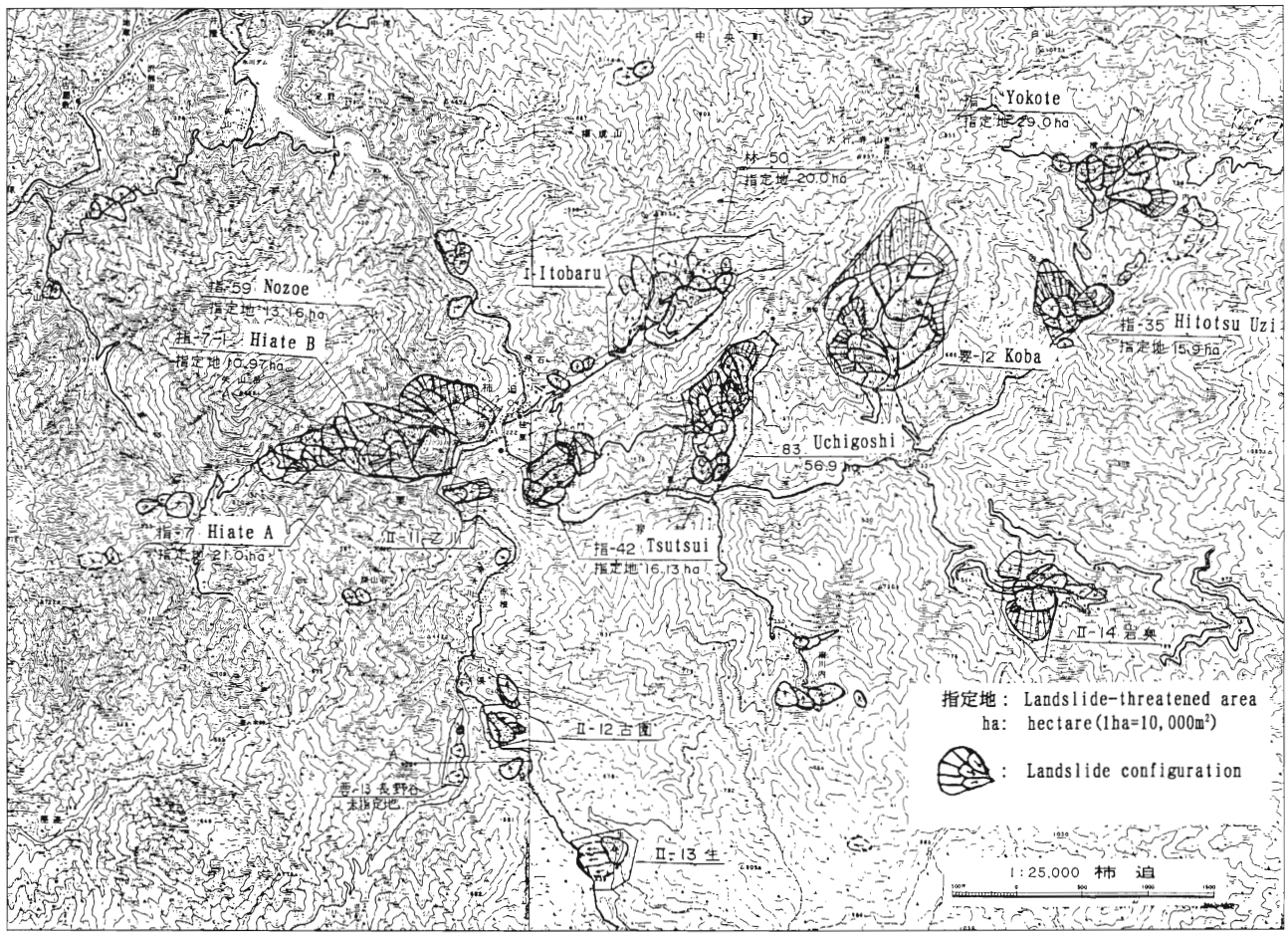

Fig. 2. Landslide-threatened area in central Kyushu, Japan.

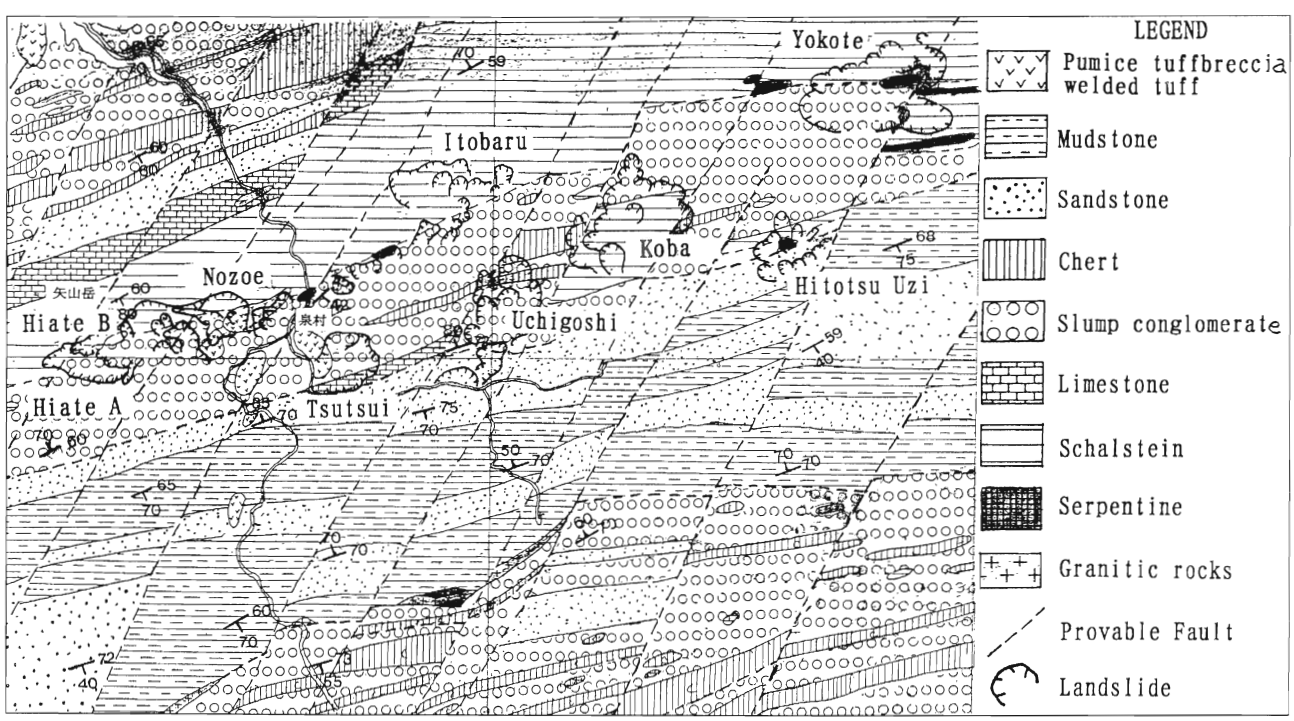

Fig. 3. Geological map of central Kyushu.

item	categories	quantity of mesh	quantity of category	range
geology	basic rock	7903	0.43399	1.0646
	welded tuff	201	0.59172	
	sedimentary rock	10071	-0.30949	
	limestone	415	-0.47288	
	granite	610	-0.38634	
degree of inclination (°)	0~5	43	-1.19225	1.95412
	5~10	117	0.10579	
	10~15	311	0.38088	
	15~20	736	0.76187	
	20~25	1422	0.50496	
	25~30	2235	0.33409	
	30~35	3362	0.04166	
	35~40	4223	-0.17357	
	40~45	3932	-0.22650	
	45~50	1942	-0.21780	
	50<	877	-0.25187	
direction of inclination	E~SE	1652	0.22234	1.19902
	SE~S	2373	0.56967	
	S~SW	2699	0.17040	
	SW~W	2422	0.03011	
	W~NW	2925	-0.26630	
	NW~N	2921	-0.28958	
	N~EW	2411	-0.17366	
	EW~E	1781	-0.12525	
	flat	16	0.90945	
vegetation	grass·farm	1717	0.82624	4.03988
	rice paddy	774	2.38608	
	bamboo grove	22	-1.44117	
	bush	1977	-0.07024	
	cryptomeria	13072	-0.26077	
	sapanese cypress	1239	-0.26476	
	orchard	30	1.50479	
	others	263	2.59871	
	water	106	-0.81780	
geological structure	stratum of opposite dip	10641	-0.05229	0.11729
	planes dipping to the slope	8559	0.06501	

Fig. 4. Analytical results of quantification method.

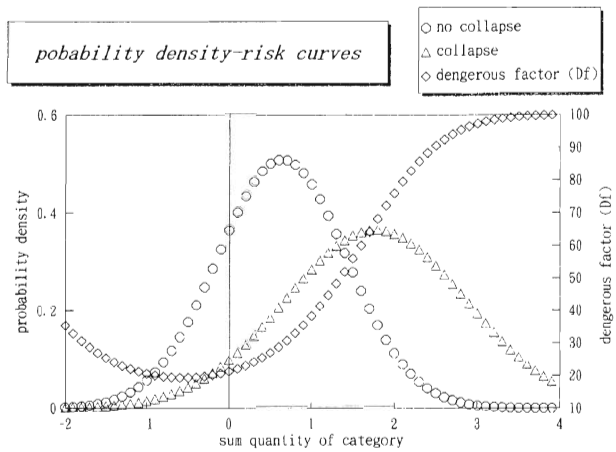

Fig. 5. Relationship between probability density curves.

Tab. 1
Reliability of hazard map

		Prediction quantity of mesh	
		Collapse	No collapse
Truth	Collapse	a 854	b 373
	No collapse	c 4464	d 13508

Analysis Method

Data used for analysis were managed to be included in 50 m mesh using the base map of Japan. The maximum slope inclination and directions as well as the height above mean sea level were indicated on the mesh.

Geology and vegetation were incorporated with the use of aerial photographs and the geological map. Geological structure was determined by studying the direction of maximum slope inclination and the dip and strike data of the strata. The data were analyzed using quantification theory (class II) and, the primary causes of landslides were estimated quantitatively.

Prediction of Landslide Hazard Area

The total quantity of each category is calculated from the analytical results of the quantification theory – class II (Fig. 4). It could be estimated that the distribution of total quantity of categories obey the normal distribution pattern. Dangerous factor (Df) is calculated from this expression as;

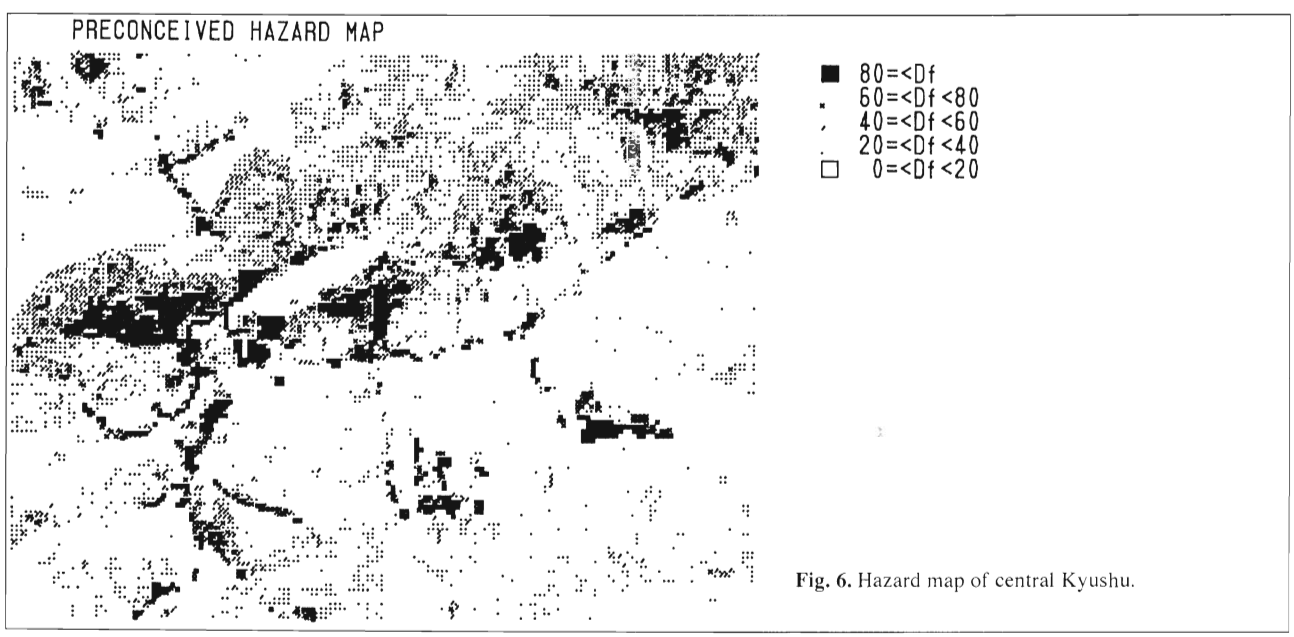

Fig. 6. Hazard map of central Kyushu.

$Df = [f(2)/(f(1) + f(2))]*100\ (\%)$

Where;

$f(1)$ = probability density of collapse group

$f(2)$ = probability density of no collapse group

Five risk levels were identified based on the results of the above dangerous factor.

Risk level 1 $Df > 80$

Risk level 2 $60 < Df < 80$

Risk level 3 $40 < Df < 60$

Risk level 4 $20 < Df < 40$

Risk level 5 $0 < Df < 20$

Total reliability $P = [(a + d)/(a + b + c + d)] \times 100 = 74.8\%$

Fig. 5 indicate the relationship between the probability density curves and Fig. 6 shows one of the important product of the landslide hazard map for Kyushu Region. Tab. 1 shows the analytical results of the reliability of landslide hazard map in which many landslide-threatened areas are classified as level 1. According to these results, the reliability of the hazard map is found to be considerably high.

Conclusion

This study was aimed to estimate the landslide risk and construction of landslide hazard map using statistical technique. The study area of the central Kyushu is abundant with landslides and the method of analysis used was quantification theory class II.

The factors of geology, structure and the maximum slope inclination as well as the direction, landuse and vegetation etc., were taken into consideration. The objective of estimating the landslide risk and the investigation of the applicability of the quantification theory on compiling landslide hazard maps were achieved. The results revealed that the quantification theory can be applied effectively for determination of landslide risk and also in preparation of landslide hazard map.

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Mapa zosuvných území na strednom Kjúšu, Japonsko

Na strednom Kjúšu v Japonsku je pozdĺž tzv. kurosegavskej zlomovej zóny veľa zosuvov na miernych svahoch v nadmorskej výške 200–800 m. Podložie tvoria sedimentárne horniny paleozoika a mezozoika, a to ílovec, pieskovec, rohovec, vápenec, ako aj bázické horniny typu serpentinitu, zlepenca a premenených bazaltových a spilitových hornín. V menšej miere je zastúpená žula a spečený tuf. Výskyt zosuvov, pri ktorom sa využili základné mapy, sa hodnotil pomocou kvantifikačnej teórie (trieda II) po štvorčekoch so stranou 50 m a nasledujúcim štatistickým spracovaním. Na hodnotenie geológie sa popri geologických mapách využili aj letecké snímky a terénna dokumentácia.

Mineralia Slovaca, 32 (2000), 385–390

Shear deformation of the tuff layer on Mt. Washio, Kyushu

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Abstract

The paper deals with so-called Hokusyo-type landslides which is well known for its huge sliding mass of molasse-type Neogene sediments and tuff layers. The model of shear zone structure similar to those in fault zone as brittle failure or mylonite as ductile deformation is presented.

Key words: landslide, shear zone, fault zone, ductile deformation

Outline of Mt. Washio Landslide

Sizeable landslides occur in the Hokusho region, formally called the Hokusyo Coal Field, and cover an area of more than 200 square kilometers, northwestern Kyushu of Japan. The landslides are characterized by a geological combination of molasse-type Neogene sediments and overlaid basalt lava in the Tertiary Period. So that they are known as the "Hokusyo" type of landslide. The landslides on the northern slope of the Mt. Washio, which are of the Hokusyo type, are well known for the huge extent of sliding mass and repeated disasters over the last several decades.

In the spring of 1950, cracks were observed in the head of the landslide for the first time, on the north side of Mt. Washio peak (285 m.a.s.l.). Nobody was killed or inju-

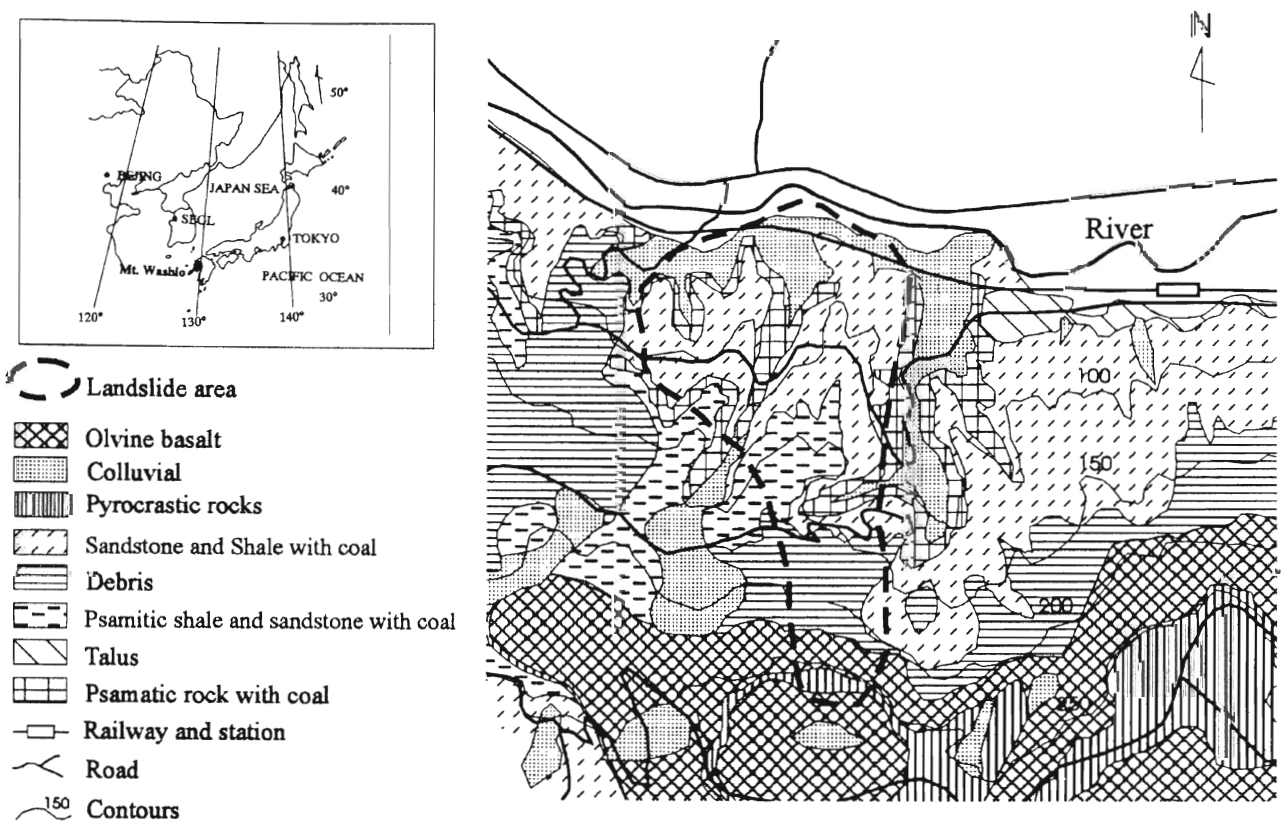


Fig. 1. Location map and the geological map of the surrounding area of Mt. Washio landslide.

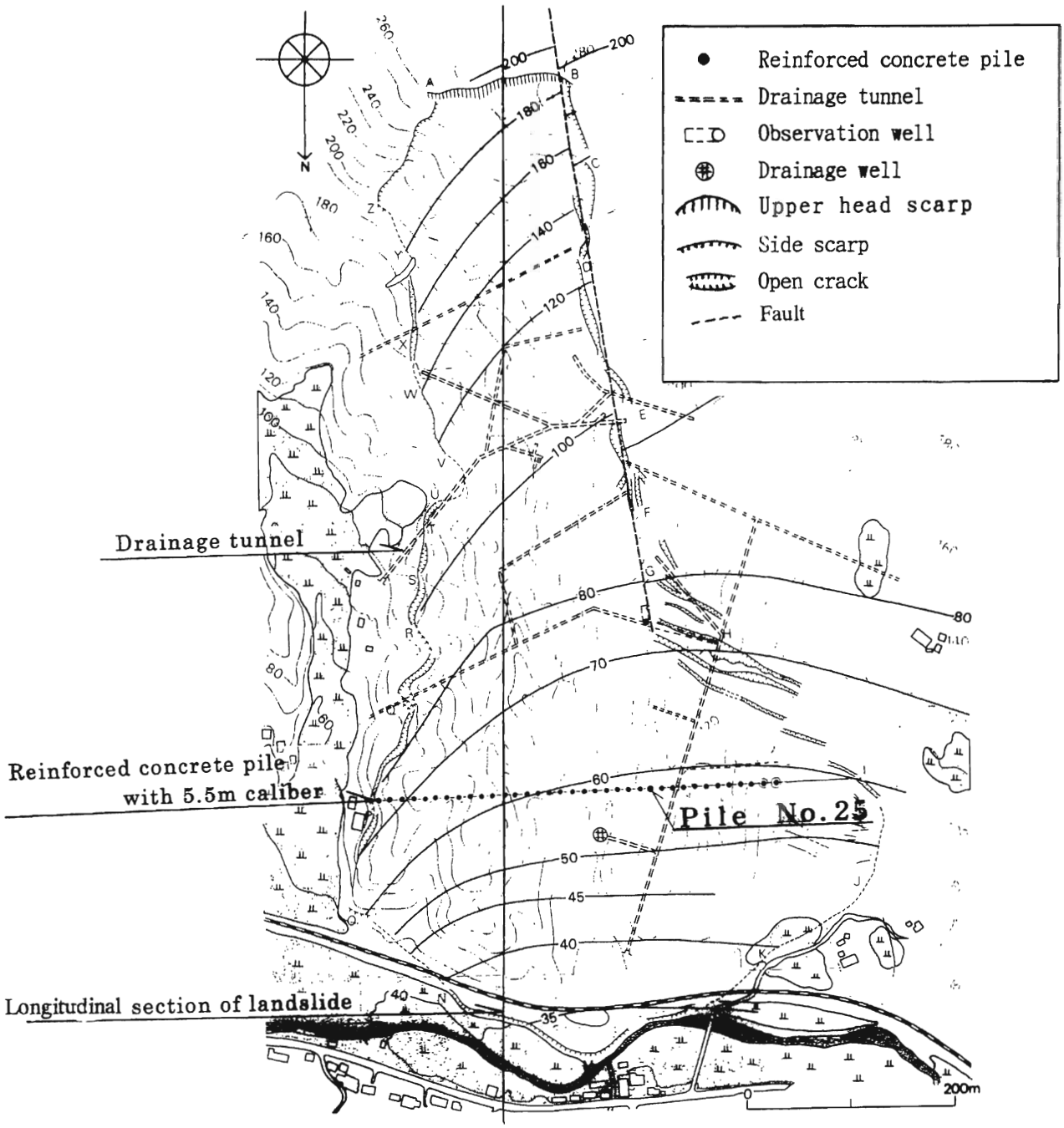


Fig. 2. Topographic and survey map of the landslide area (original map collected from the Landslide record No. 8, 1975).

red, for the landslide moved slowly, but public insecurity increased appreciably because the national railway Matsura line along Emukai River was thrust up ahead of the sliding mass. Urgent protection work began in 1957, and continued until the construction of the reinforced concrete piling finished in 1992.

The landslide mass dimension were 1.0 km long, 0.2–0.5 km wide and about 20–50 m thick with a volume of about 125×10^6 m^3. Fig. 1 shows the location and the geological setting of the landslide.

Observations of the Sliding Zone including Several Slide Planes

It is the purpose of the present paper to point out that shear structures in slide zones are similar to those occurring in a fault zone, as brittle failure, or Mylonite as ductile deformation. In the present paper, we show for the first time, a clear photograph and a sketch of the slide zone. There figures were then compared with the data in the columnar sections of the old report.

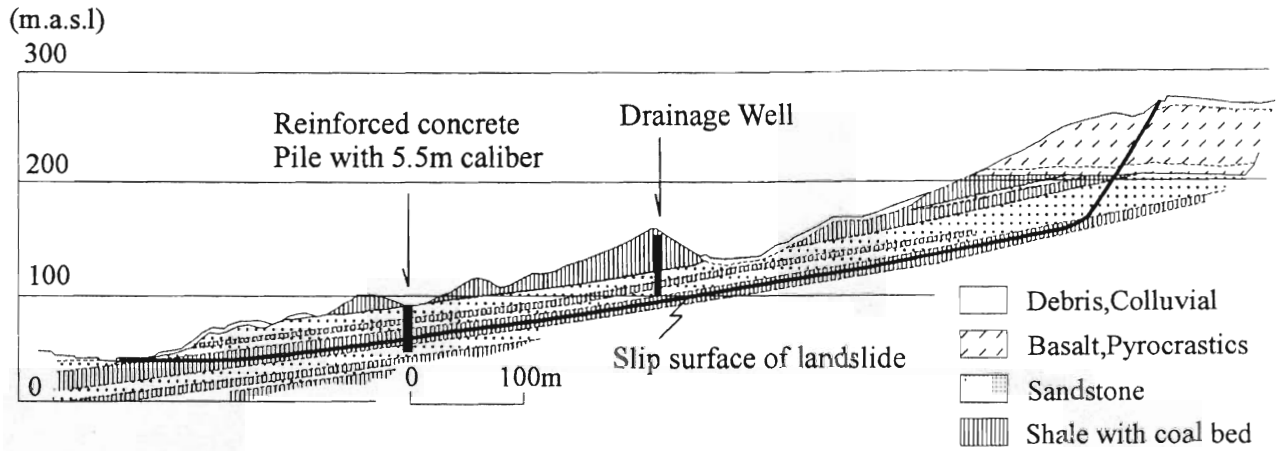


Fig. 3. Longitudinal section of Mt Washio landslide

Fig. 4. Photograph showing shear structures of the main slip zone observed in the pile No 25 excavation

Thirty six piles of re-inforced concrete for the disaster prevention works were constructed in 1992, as mentioned above. The in situ piles were 30–60 m long and 5.5 m caliber. The geological sketches of all the wall-planes in the pile excavation were done in detail down to the depth of the working levels.

The slip surface of the landslide is approximately 30–50 m in depth and composed of a thin tuff bed within fine coal. Total moving distance of the slide is estimated to be about 10–20 m.

Progressive Shear Deformation of Mt. Washio Landslide

The initial sliding zone was composed of 3 sheets of tuff layer and 4 sheets of thin coal bed, and is shown in Fig. 7. The sliding plane in these zones is recognizable

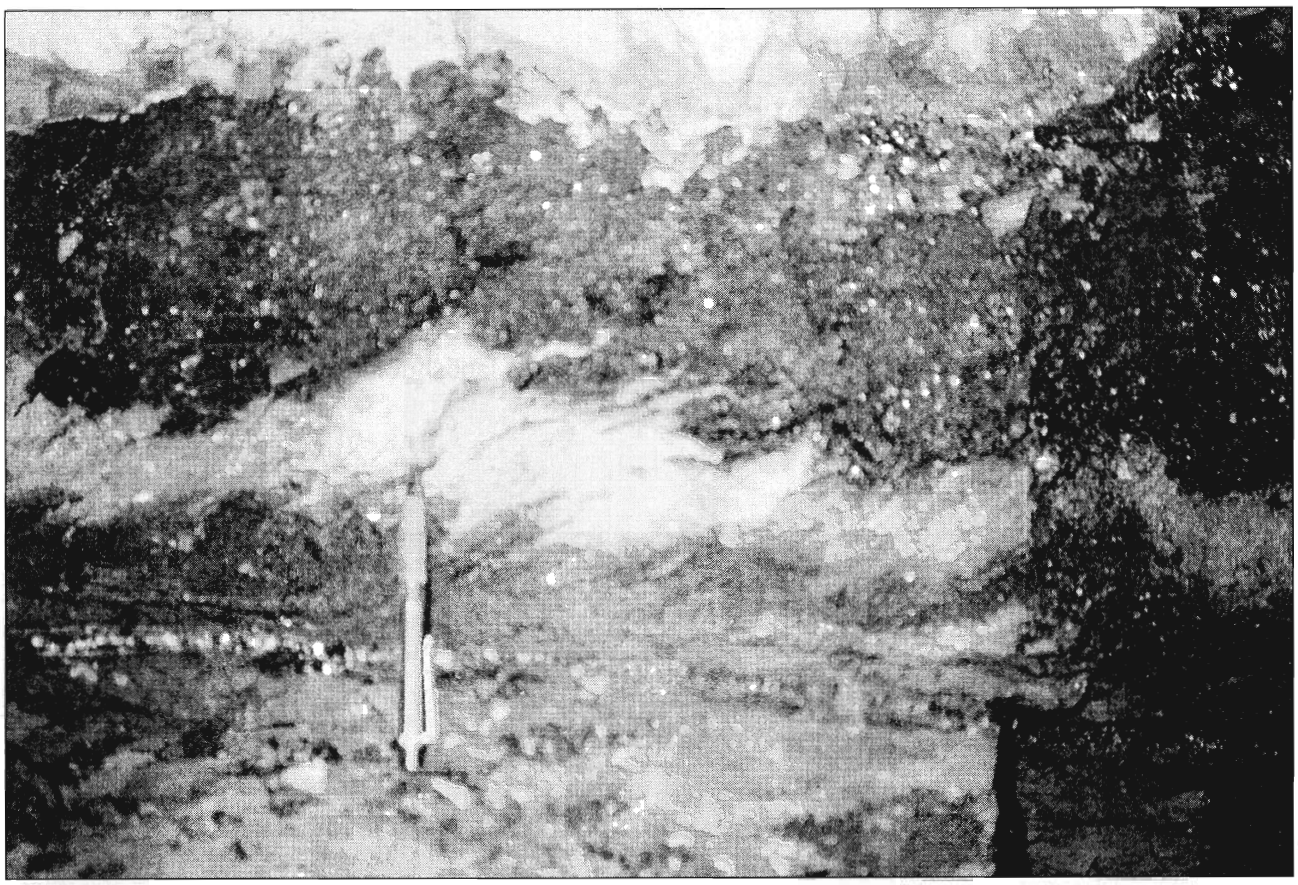


Fig. 5. Close-up view of the tuff layer (from Fig. 4)

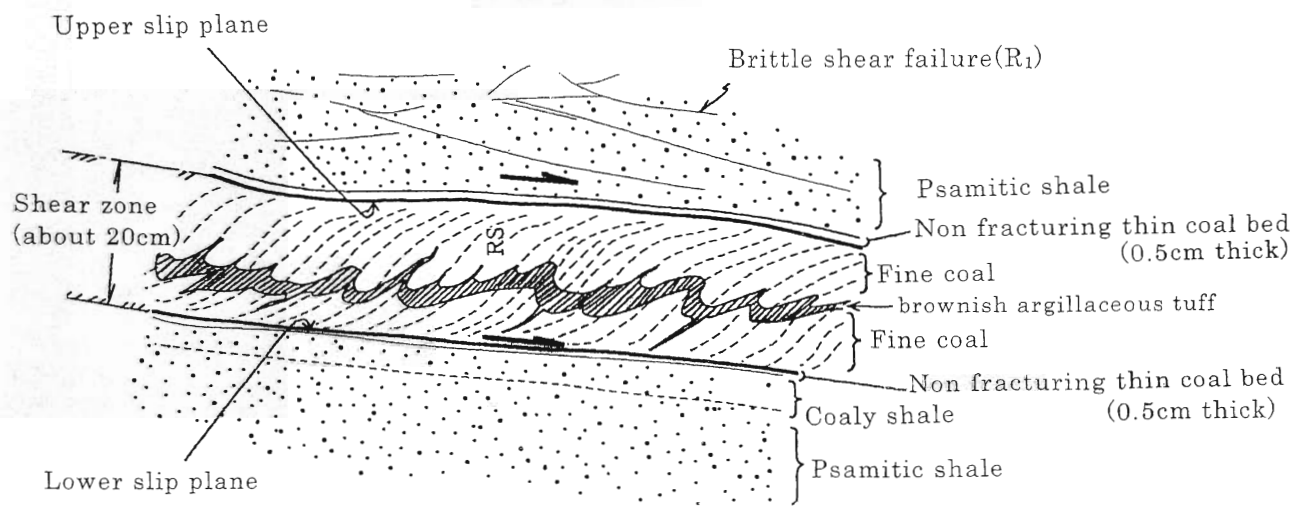


Fig. 6. Sketch of Fig. 4 (after T. Fujii et al., 1994).

as 2 stratigraphic horizons in the initial stage of the landslide.

These 2 tuff layers, the upper and the lower sides except for central, disappear during the progressive shear; so that the total thickness of the slip zone thinned out and the 2 coal beds in the slip zone were shattered (Fig. 8).

On the other hand, the central tuff layer is elongated diagonally along the so-called P-foliation or S-surface as shown in Fig. 9. It appears that, in the long run of the

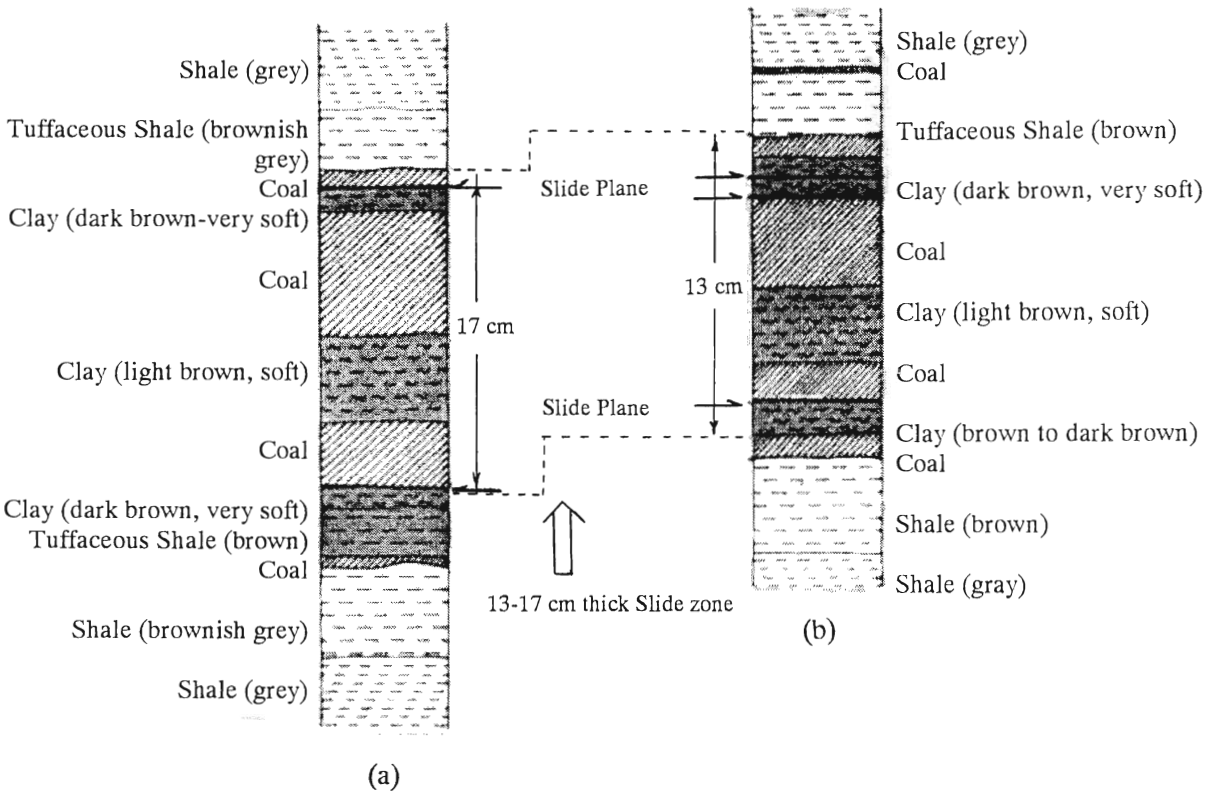


Fig. 7. Columnar section of C37c coal bed as slip zone observed about 20 years ago. a – at 24 m depth in the observation well, b – at lower part of the left side wall in the drainage tunnel F.

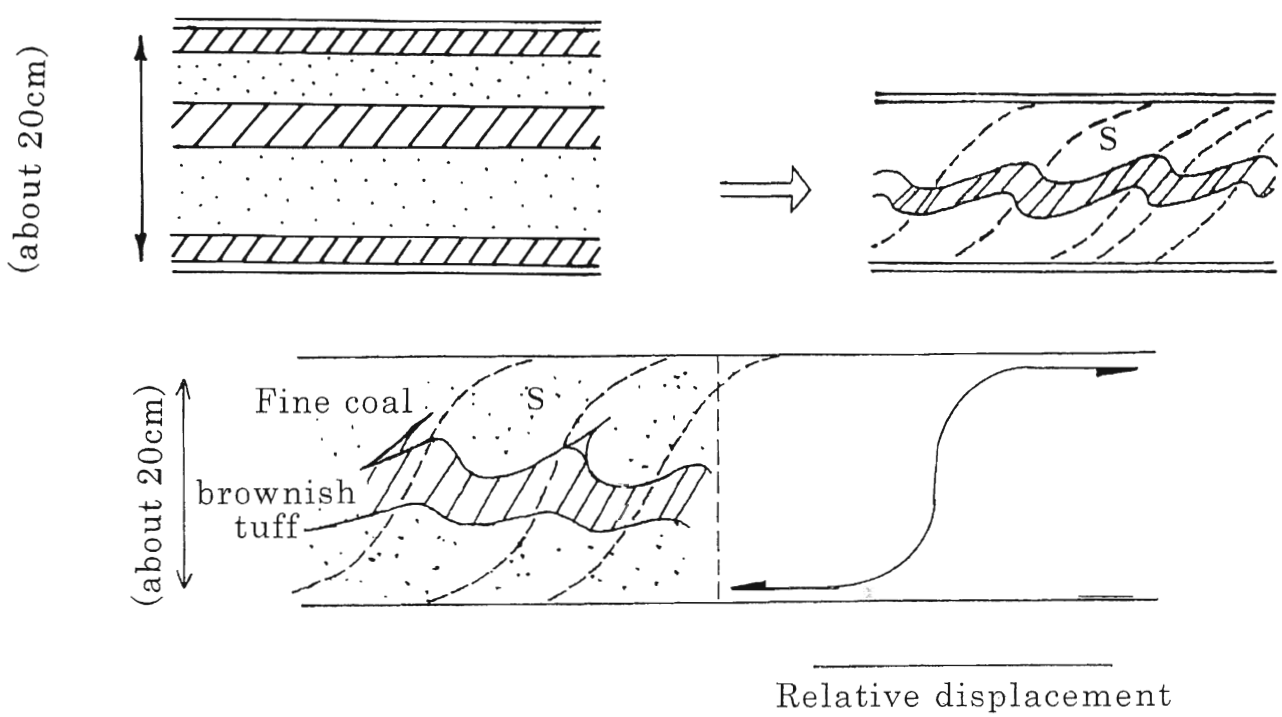
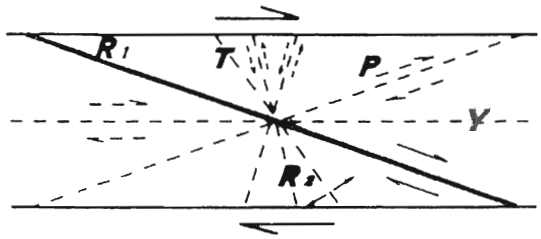
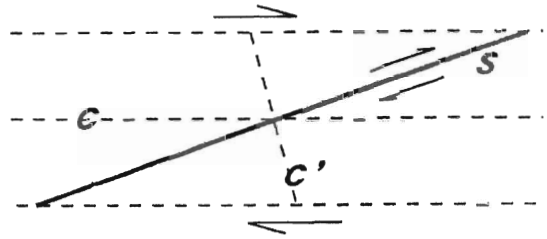


Fig. 8. Illustration of possible deformed process in the brownish tuff layer.



Riedel Shear in brittle shear zone.

R_1; Riedel Shear
R_2 ; Conjugate Shear with R_1
P ; P foliation
T ; tension crack



S-C Planer fabrics of Mylonite in ductile shear zone.

S; S surface (parallel to maximum elongated plane)
C ; C surface (parallel to the shear surface
C'; Shear band (or normal slip crenulation)

Fig. 9. Comparative fFigures of brittle shear zone with ductile nature.

slide, P or S surface become parallel to the both Slip planes of the upper and lower sides.

Unstable Structure(s) in the Slip Zone

The unstable structure(s) shown in the sketch of the Fig. 4, appear to have been formed along the maximum elongated axis of strain ellipsoid. Riedel Shear (R_1) is commonly missing in the slip zone, but been formed in the hanging wall. The S-surface in the sketch is similar to those of S-C mylonite in ductile shear zones and P-foliation in brittle shear zone.

Concluding Remarks

Shear deformation structure in fault gouges is similar to unstable structures in mylonite has been reviewed by many research workers (Shimamoto, 1989 and Takagi et al., 1996).

Shear deformations in the slide zone of the landslide resemble those in faults and mylonite. This similarity is ascribed to the plastic flow of fine fractions due to excess pore-pressure of groundwater. Further consideration is necessary. Here we presented only a few problems of landslide and expect that this will be useful in solving various problems later. Finally we would point out, that there is a possibility of standardizing the following model in the slide surface from the data described above.

(1) A slide surface in a landslide is a compound surface composed of a slide zone of a certain thickness and two or more sharp slide planes.

(2) The factor determining the thickness of the slide zone is not yet clear. If we take into account the similarity to a fault zone, it is probable that the thickness of the slide zone is more than a few meters.

Acknowledgement. The authors thank Dr. Y. Iwao and his cooperation during the preparation of this paper.

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Šmykové deformácie v tufových vrstvách pohoria Wašjo, Kjúšu

Príspevok sa zaoberá zosuvmi typu Hokusjo, ktoré sú známe zosúvaním obrovskej masy molasových neogénnych sedimentov a tufových vrstiev, predstavuje aj model štruktúry šmykovej zóny a porovnáva ho so štruktúrou zlomových zón s krehkým porušením a plastickými deformáciami mylonitových zón.

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Disaster induced by debris flow and flash water of Harihara river in Kagoshima, Japan

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Abstract

A case history of disaster induced by debris flow and sudden flash flood is described in this paper Debris mudflow was induced by a flash flood following heavy rainfall and wiped out an entire village in southern Japan, killing 21 people on the tragic night of 9 July, 1997 Detailed field investigation, in--situ survey, electrical prospecting, and hydro-geological analyses were carried out to find the cause of the disaster. The site of the hazard area is located on the southern slopes of Mt. Yahazu, at an elevation of 687 m. The fan-shaped area is close to a local stream, Harihara, that has its source on the mountain and flows downstream towards the Ariake sea. The fundamental cause of the disaster was traced to a hidden fault, which had been weakened by confined ground water. Debris flow combined with flash floods acted like an hydraulic gradient and washed out the area. Conclusions on the sequential processes were drawn as, partial failure at the fault, failed material damming or lake formation, increase in back pressure, bursting of the dammed lake, induced flow of debris and total progressive slope failure of the area.

Key words: Debris flow, Landslide disaster, Flash flood, Failure plane

Introduction

On the ill-fated midnight of 9th, July 1997, debris mudflow combined with flash flood wiped out the entire village in Harihara river district, in the southern Kyushu of Japan. Rapid flows of mixtures of mowing earth, rock debris and water that originated on the steep slope after heavy rainfall devastated the downslide area. A sudden trigger of debris flow without any pre-warning or awareness signal made it very damaging and dangerous. Debris flow on that tragic midnight pouring out in a sudden flash flood took 21 human lives. The hazard area is located on a hill on the southern side of Mt. Yahazu, at an elevation of 687.5m. The mountain terrain spreads around the bottom circumference and is fan shaped. A small local stream, Harihara, originates from Mt. Yahazu spring and flows downstream to the Ariake Sea. The downhill side of the mountain nearby, geologically spreads in a fan deposit along Harihara stream. To determine the key mechanism of this disaster, a detailed study of hydro-geological processes and analytical models was conducted. A brief review of the main findings is described in this paper.

Tragic Moment

Except for a later collected audio report of a loud noise, none of the visual photographic evidence was conclusive as the event happened at midnight all within a few moments of time. The survivors testified to the disaster as follows:

Around 4 p.m. of the previous day, the water level in the river reached its maximum level. River water overflowed the banks on to the orange groves, and house gardens. The flood level fell to the normal level only after 11 p.m. The local people had returned to their own housing and went to bed as usual. The sudden echoes of loud sounds awakened them at midnight. But most of them could not figure out the reason for the noise, until it was too late to get away. Only a few lucky survivors guessed the tragic disaster and recognized the awful noise and were able to escape in time.

Pre-warnings

Many people reported remembering the loud noise occurring between 11 and 12 p.m. The disaster took place in the space of a few minutes after the noise. The kind of noise resembled the smashing of huge rocks, the collapse of rocks, and was comparable to a landslide in action. The noise echoed not only once, but also repeatedly, several times before the flood. The survivors reported hearing a loud, repeated noise like "Ghoh ... Ghoh...", as if the giant rocks were grinding, smashing and rolling, just before the disaster. Some people ran out of their beds and houses. It was later recognized as a noise typical of some kind of landslide or debris flow. Many people lost

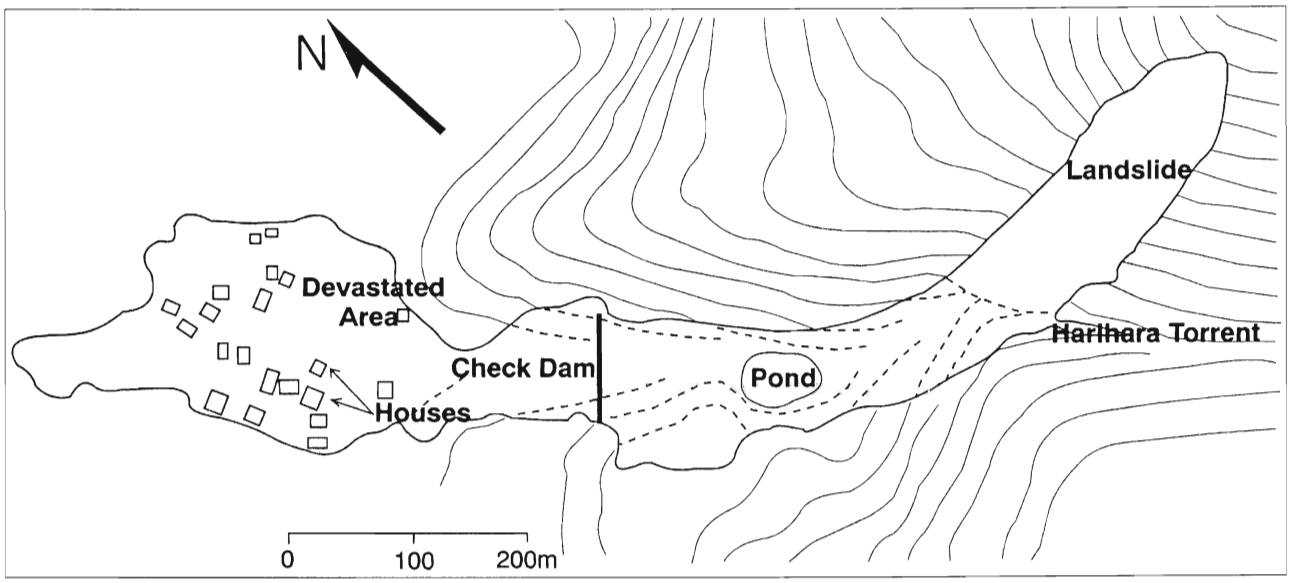


Fig. 1. Sketch of the general layout of the site.

consciousness during at that time. Only the lucky ones were able to return the real world a few moments later. The bodies of the dead were scattered under the debris deposits, between damaged cars, refrigerators and even the remains of houses. Dammed up barrier traces of mud water were found on the trees near the midpoint of the slope failure and on the left bank of the Harihara River.

Geology of the area

The hilly terrain at the foot of the hazard area that extends between the elevation of about 100 to 190 m, had failed in a deep spoon scooped shape area of around 70 to 80 m width. The geology of this area is characterized by pyroxene andesite. The slope is composed of andesitic autobreccia with several slip discontinuities. The layout diagram of Harihara torrent, collapsed slope, pond, Check dam and the devastated area are illustrated in Fig. 1. Fig. 2 shows the longitudinal profile of the slope before and after the failure. Fig. 3 gives a general idea of the surrounding area of the landslide and the extent of the disaster.

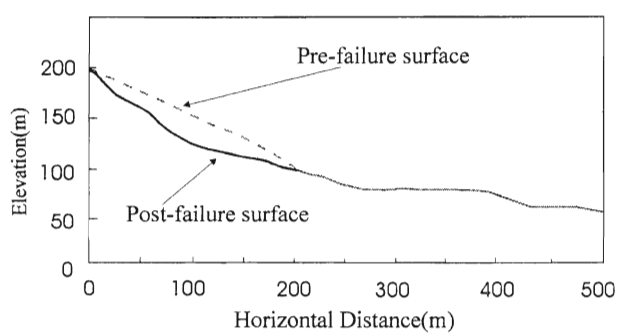


Fig. 2. Longitudinal profile of the landslide (from crest area to check dam).

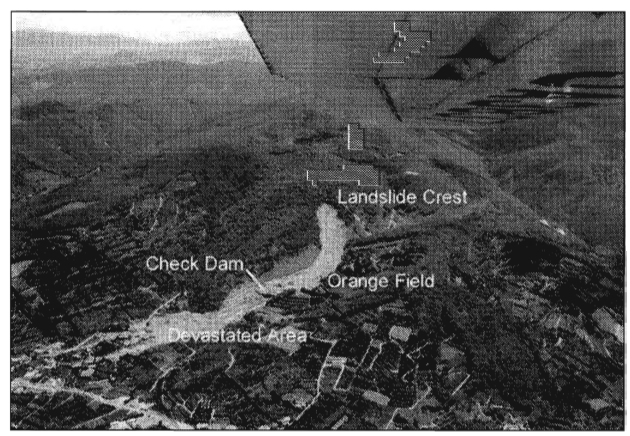


Fig. 3. Photograph showing the aerial View of the landslide area.

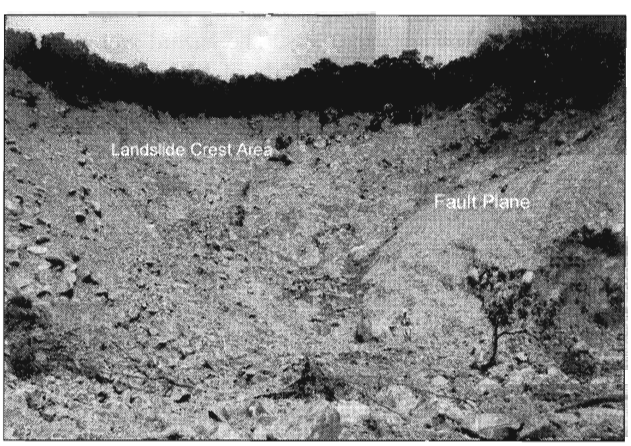


Fig. 4. Close-up view of the landslide crest area and failure plane along the fault.

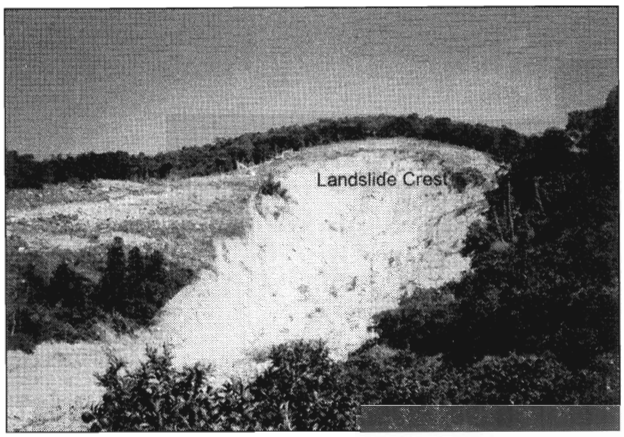


Fig. 5. General view of the landslide area.

Tab. 1
Consistency index limits of soil (from the failure surface)

Sample No.	W_L (%)	W_P (%)	I_P (%)
1	66.6	39.6	27.0
2	77.5	39.5	38.0
3	96.0	41.9	54.1

Slip fault surfaces (Fig. 4), indicated a horizontal slip around the failed slope. The measured strike and dip were N50–70° E and 55–70° W respectively. The upper surfaces of the soil mass bore vegetation of at least 1 m thickness. On the left side of the failed convex valley, numerous slip fault surfaces exist. Ground water was identified as coming from the fault zones.

The structure of the failed concave valley side consists of a number of slip discontinuities forming fault zone. Existence of the fault was re-confirmed by electrical prospecting as well. The other geological details on the weathering state of rock, rock mass condition, groundwater and the presence of joints and slip surfaces at the site showed that the fault was the main reason for the failure. Structural measurement of the general direction of strike ranged between N50–70° E and the dip ranged 55–70° W.

Residual soil from weathered rock was found concentrated around the fault area. The failed slope was composed of autobreccia of andesite with many cracks and the upper part was strongly weathered. Some reddish clayey soils around the fault were tested for consistency limits. The test results of liquid limits and plasticity indexes are summarized in Tab. 1. The reduction in the shear strength of the ground along the fault plane, is a basic indicator of slope instability. The soil in the fault location showed a greater plasticity index and higher liquid limits than that of the soil in the debris, due to higher clay mineral content.

Flow hydrology of runoff

Takahashi (1981) attributes initiation of debris flow to landslide and water streaming during heavy rainfall. A sudden input of groundwater in weak geology initiates debris movement. In a landslide, rock avalanches, mudflows, and rapid debris flow are very dangerous. Such landslides are associated with flow-like phenomena. The terminal flow velocity, V_t, of the debris flow mass may be approximately estimated as $V_t = 2aL$; where a – is the acceleration down-slope and L – is the distance travelled by the debris slide mass. Flow states may be turbulent or laminar as determined by the Reynold number of the flow. Fig. 6 shows the longitudinal bed level of Harihara Torrent. The Manning formulation was used to estimate the flow speed. Using the record of hydrological precipitation on that day, the outflow of Harihara Torrent was analysed and is presented in Fig. 7. The hydrographic plot depicts the normal flow and the peak flood level. The effect of such a peak flow can have tremendous impact on a downslope area. A more detailed analysis of the other debris-flow dynamics is beyond the scope of the present paper.

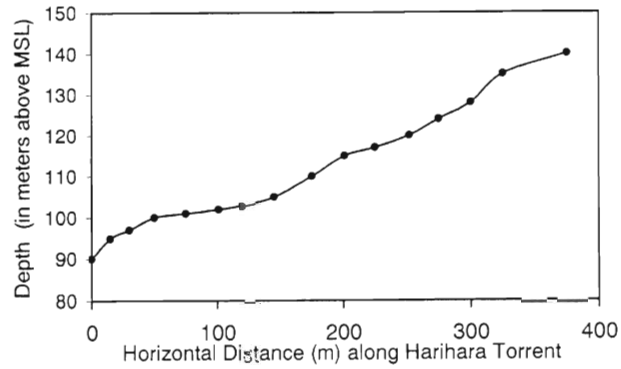


Fig. 6. Longitudinal section along Harihara river

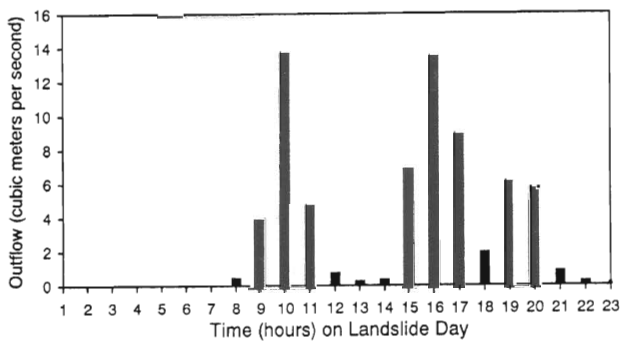


Fig. 7. Hydrographic simulation of out-flows on the down-slope.

Detailed measurements of the landslide are as follows:

Area of catchment basin:	0.69 km^2
Slope of fan (of the debris flow):	about 3 degrees

Distance from agricultural pond to failed slope: 160 m
Volume of boulder/sand on original riverbed: 30.000 m^3

Capacity of pond:	16.000 m^3 (depth 3m), 20.000 m^3 (depth 4m)
Volume of collapsed material:	about 150.000 m^3
Thickness of collapsed slope:	maximum 40 m
Capacity of dammed water:	1.200 to 4.000 m^3
Capacity of debris barrier:	20.000 m^3

Debris water, with great force jumped, flowed, eroded and flattened the left side of Harihara River and then slowly spreaded out on the orange groves. The head of the debris flow was in the shape of a tongue with large boulders. The riverbed of Harihara looked like a flood plain. Large boulders were buried beneath a mix of red clayey soil. Some trees were sitting on the flood plain as through planted there. No trace of the pond after the disaster could be detected. Debris dammed barrier was partially destroyed, and then filled by further liquefied debris flows.

The dynamic and static pressure from the combined debris flash water burst the dammed lake. Grass and vegetation were moved down stream on both sides of the debris barrier without leaving any visual debris traces. The highest level reached more than 5 to 8 m above the top. Downstream of the debris barrier, 19 dwellings and 11 other non-residential buildings were destroyed and orange trees in the adjacent orange groves were wiped out. Other dwellings were less damaged but bore a distinct stain of red soil water. Some cars and trucks were wrecked and were without trace of debris.

Discussion

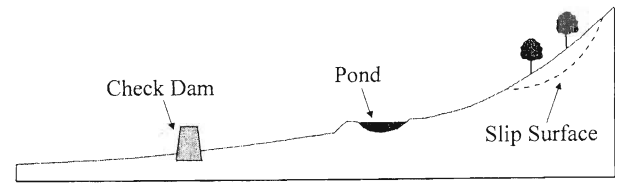
An extensive and intensive site survey, detailed field investigation, laboratory tests, field measurements and hydro-geological studies were conducted to find the main cause of the disaster. An aerial photographic study, field survey, geological mapping, attitude measurement, soil and rock material testing, electrical prospecting, local rainfall and flood level studies and model hydro-geological analyses were carried out to investigate the process of flash water and debris flows.

Some possible alternative events and processes were postulated, compared, discussed, weighed, and reasoned out for analysis based on the available hydro-geological facts of the area (Iwao et al., 1999). Fig. 8 illustrates the sequential process of the disaster induced by debris flow and flash-water.

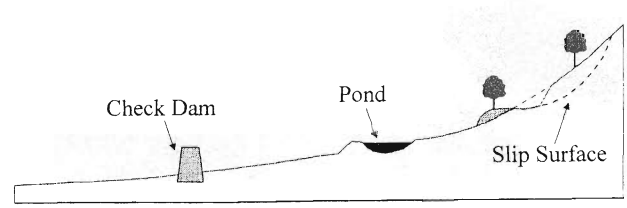
From the above, some of the hypothetical combinations of factors leading up to the process that is thought to have caused the disaster on that ill fated night are listed as follows:

a) a fault weakened the zone at the foot of the mountain following heavy rainfall;

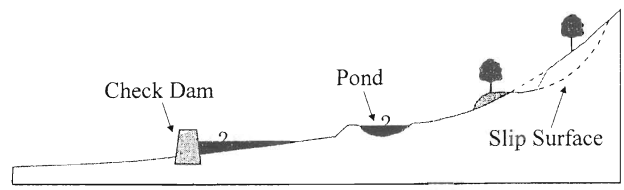
b) triggering of the failure and formation of the pond above the check dam;



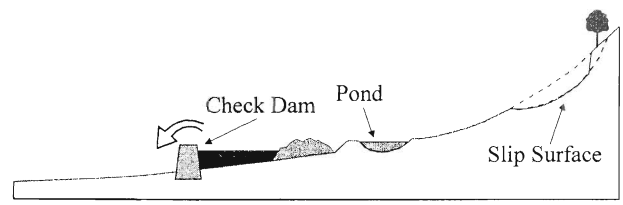
a) Slope along the fault become weak following the heavy rainfall



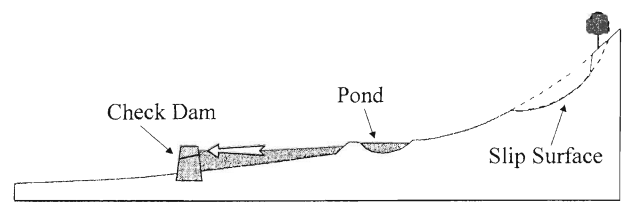
b) Initialization of the failure and formation of the pond



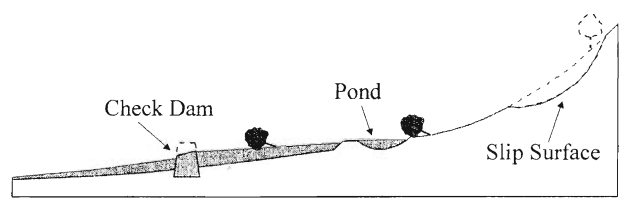
c) The pond is filled with landslide material and the water level at check dam,increased



d) Pond collapsed with progressive failure of slope, and the debris flow dashed into the reservoir



e) Debris flow mixed with flash flood overtopped and destroyed the check dam



f) Complete distortion of the slope carried the debris flow further downstream of the check dam

Fig. 8. Sequence of the process of the disaster induced by debris flow and flash flood.

c) debris mass dammed up the pond along the Harihara Torrent, and after two hours, catastrophic overflow and destruction occurred;

d) progressive failure of the slope moved a large chunk of soil mass into the reservoir increasing the water level;

e) mowing debris chunks were thrown into the reservoir, creating rapid flash water hydraulic gradients and damaged the check dam;

f) liquefied earth block mass due to mixing with pond water had attained critical hydraulic gradient and destructive velocity. Then, flash water generated debris flow and fluid hydraulic gradient devastated the downstream areas of orange groves, debris barriers, farms and dwellings.

Summary of conclusion

The fundamental cause of this tragedy was found to be hidden fault weakening by confined ground water. The reduction in the shear strength of the ground along the fault plane, is a basic factor in slope instability. The soil mass moved down-slope into the agricultural pond caused the flash water, and the combined flash flood with soil mass flow acted like a kind of debris hydraulic gradient. Conclusions on the sequential processes were drawn as partial failure at the fault, failed material dam or small lake formation, increase in pressure from behind, bursting of the dammed lake, induced flow of debris and progressive slope failure. Flash water mixed with debris hydraulic anomalities in the area led to the loss of many lives, orange groves and farm buildings. The ill-fated event killed twenty--one people in one night. The big slope failure on the hill and the flat plain below was observed on the morning of the next day. None of the action of that tragic event could be photographed or video recorded to explain the real disaster event.

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Katastrofa vyvolaná kamenitohlinitým prúdom a povodňovou vlnou na rieke Harihara v Kagošime, Japonsko

Príspevok opisuje živelnú katastrofu spôsobenú kamenitohlinitým prúdom a povodňovou vlnou po silných daždoch v noci 9. júla 1997 v južnom Japonsku na južných svahoch hory Jahazu v nadmorskej výške 687 m v údolí rieky Harihara, ktorá vyviera na svahu kopca a ústi do zátoky mora Ariake.

Na zistenie príčin katastrofy sa vykonal podrobný terénny výskum, geoelektrický prieskum, hydrologická aj geologická analýza. Hlavnou príčinou bol skrytý údolný zlom, pozdĺž ktorého nastalo oslabenie hornín, ktoré nasiakli vodou, vznikol zosuv, prehradil údolie, a tak sa vytvorilo dočasné jazero. Jeho dočasná hrádza po preliatí erodovala, jej materiál stekutel, vzniknutý kamenitohlinitý prúd v kombinácii s povodňovou vlnou poškodil nižšie položenú ochrannú hrádzu, vymietol údolie a zmietol aj dedinu v ňom, v ktorej pritom zahynulo 21 obyvateľov.

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Pipe roof method for a tunnel mouth which has some topographical features of landslides

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Abstract

In Kyushu district, many tunnels for roads and railways are planned or under construction. This tunnel is located in the southern area of Kyushu.

Around the tunnel mouth, there were some topographical features of landslides, and the surface stratum consisted of loose soil. So, it became necessary to protect the mouth of the tunnel without affecting the potential landslide areas, and we made a plan of complementary operations for tunneling called "Pipe Roof".

In this report, I wish to give an idea of the geology involved and a description of the pipe roof method.

Key words: pipe roof method, tunnel mouth, topographical features of landslides, talus, secondari shirasu, propulsive machine

Introduction

The mouth of the tunnel is situated at the foot of the mountain, and along this mountain there is a small river that has eroded out the upstream valley and has deposited soil terraces.

The planning tunnel direction intersected the slope obliquely. In such an oblique tunnel mouth against the mountain slope, it sometimes occurs some influences of unsymmetrical earth pressure, ground loosening, collapse, landslides and so on. Because of that reason, we had to examine some countermeasures and worked the plan of "Pipe Roof Method". Consequently the tunnel had been excavated without any geological accident.

Regional Topography and Geology

Basements in this area are composed of Mesozoic sedimentary rocks, sandstone, shale and variation. Slopes of the mountain are covered with talus. And at the foot of the mountain a sand and gravel terraces have been accumulated.

Photo 1 is a panoramic view around the tunnel mouth. The location of the tunnel mouth is indicated by a white arrow in the photograph. Fig. 1 shows a topographical map of this area. There are some roads and houses near the tunnel mouth 15m above the top of the tunnel. Using the topographical map, the aerial photographs and geological surveying, we recognized some typical landslide features. The results are shown in Fig. 1, by broken red lines.

Fig. 2 shows the geological longitudinal section of the ground near the tunnel mouth. A talus deposit is composed of gravel and soil. It has 20~50 N-value of SPT. A gravel terrace has 30~50 N-value of SPT. Both two strata over 50 N-value represent dense gravel. A sand terrace composed of sandy soil (secondary pyroclastic flow called "Secondary Shirasu"). It has 5~10 N-value of SPT.

Examination of Pre-support Method of Tunneling

Because of those unstable strata around the tunnel mouth, we were concerned about the following occurrences:

(a) asymmetrical earth pressure on tunnel arch
(b) possible failure at tunnel face or tunnel crown
(c) ground surface displacement
(d) landslide or slope failure
(e) effects on nearby structures

There are some pre-support methods for dealing with those occurrences, for example, Pipe Roof Method, Poly-Urethans Injection Forepoling, Trebitube, AGF etc. We proposed the pipe roof method for the following reasons:

(a) Tunneling at the face and pipe roof at the tunnel mouth would be carried out at the same time.

Tab. 1
Specification of propulsive machine

Model		TH-200	
Propulsive mechanism	Propulsion system	Twin cyrinder oil-hydraulic propulsion	
	Thrust force	kN	1,960
	Thrust speed	mm/min	365
	Sylinder stroke	mm	2,250
	Applicable Steel Pipe	mm max.	812.8
	Power(oil pump unit)	4p-15kw	
Drilling mechanism	Feed system	Twin cyrinder oil-hydraulic feed	
	Feed stroke	mm	280
	Thrust force	kN	353
	Torque	kN-m max	35
	Power	4p-15kw	
Steering control mechanism		Triple cyrinder oil-hydraulic power wrench	
Mass	All mass	kg	8,050
	Maximum resolution mass	kg	3,940
Dimensions	H(min,max)×W×L	mm	4,735(8,735)×2,040×1,700

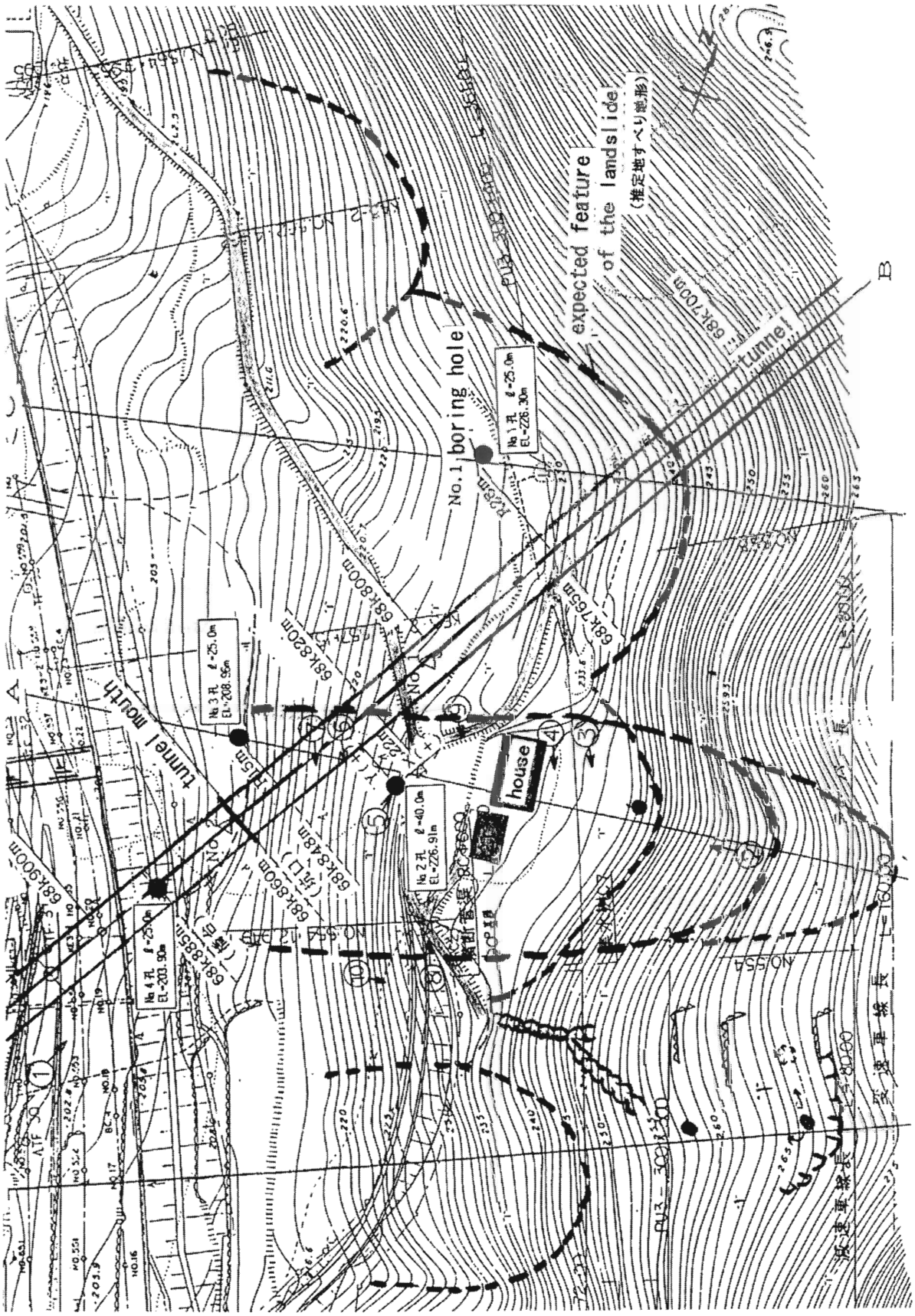


Fig. 1. Topographical map.

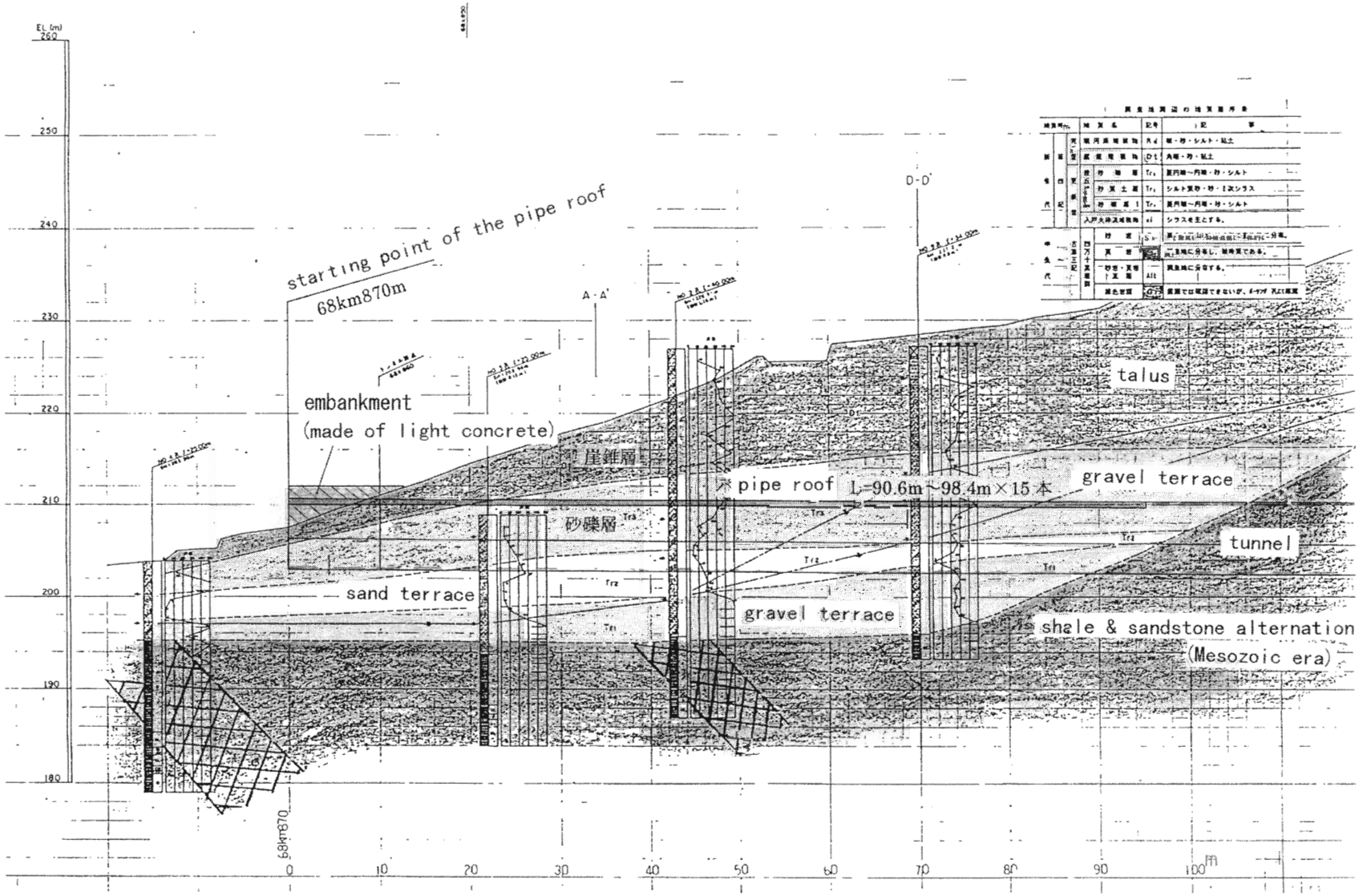


Fig. 2. Geological section of the ground (longitudinal)

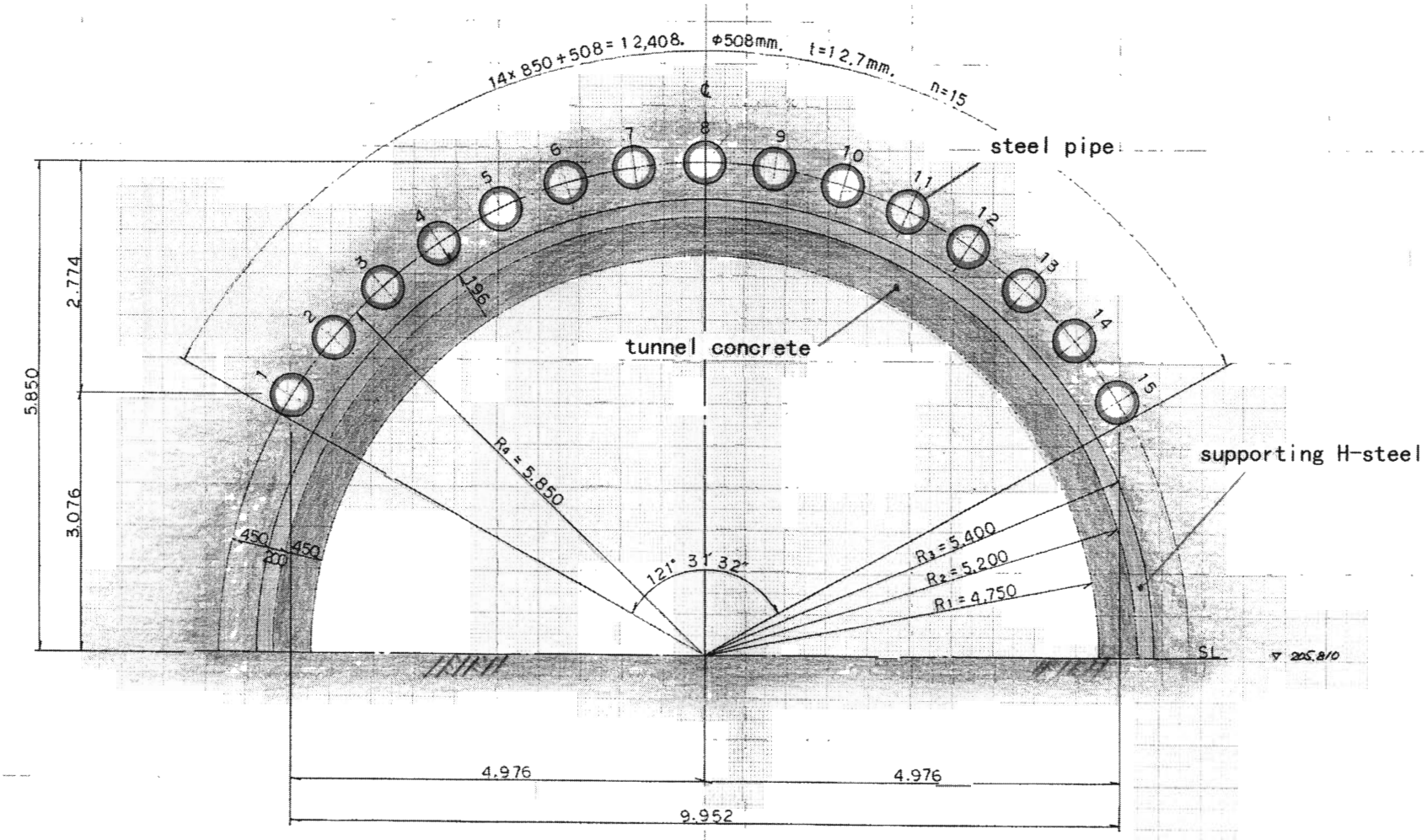
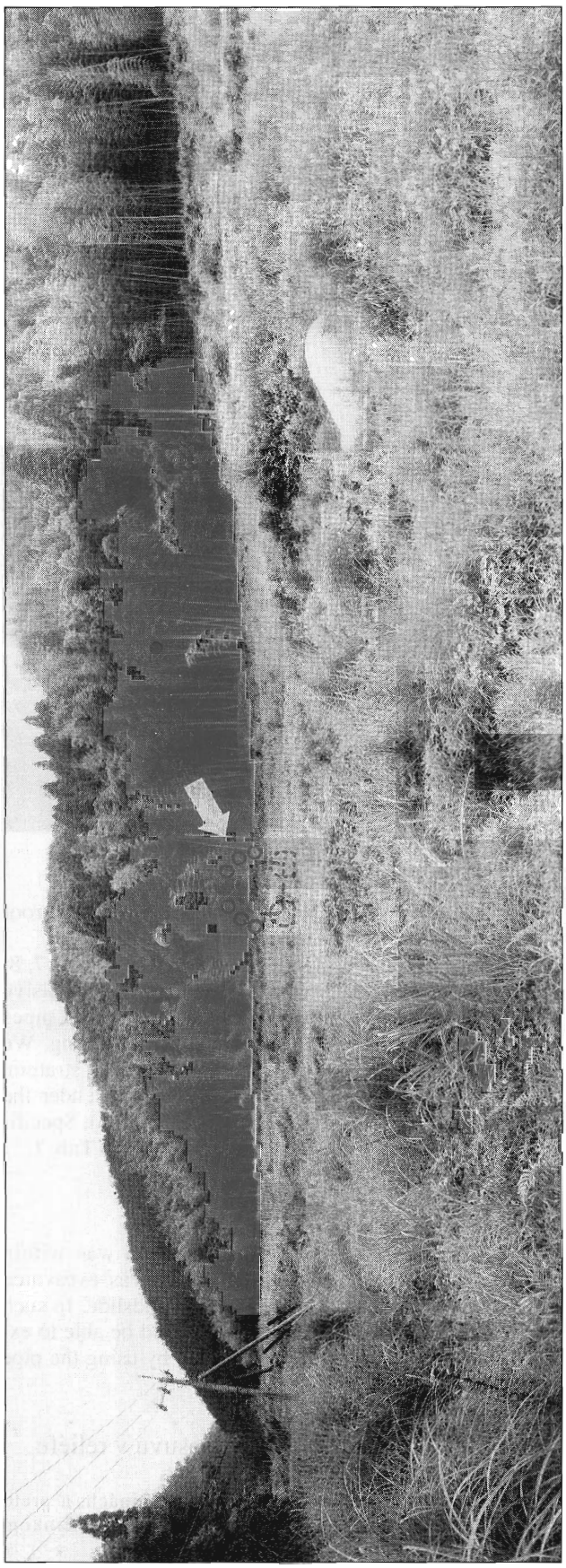


Fig. 3. Cross section of the pipe roof



◀ **Photo 1.** Panoramatic view of the tunnel mouth.

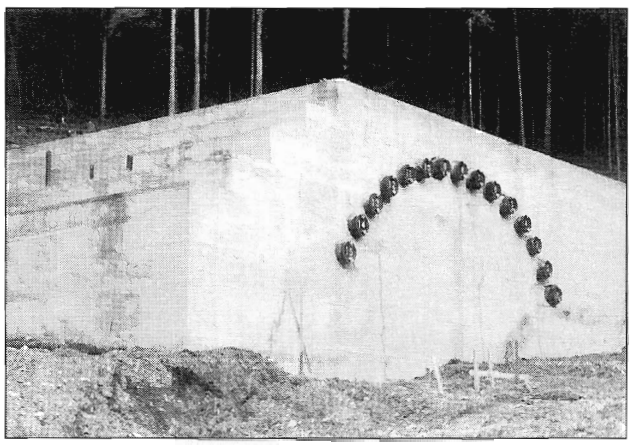


Photo 2. Completion of the pipe roof method.

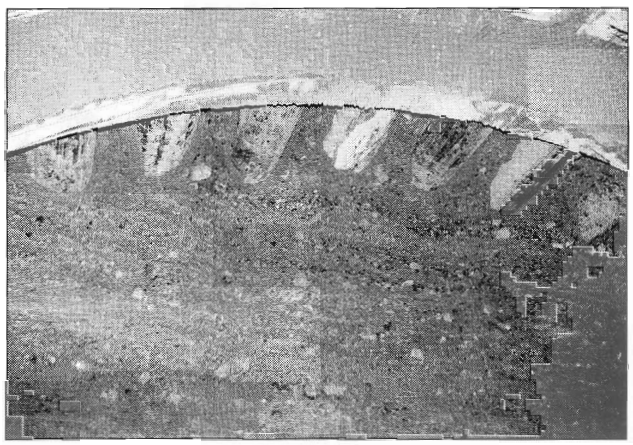


Photo 3. Face-view of the tunnel.

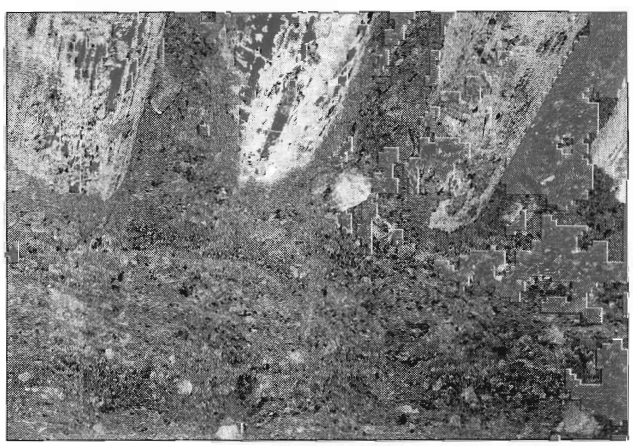


Photo 4. Close shot (pipes and the ground stick together).

(b) In comparison with pre-support method at the tunnel face, it would not take longer, so it would be more efficient.

(c) Pipe roof method is well proven in tunneling.

(d) We would be able to apply the pipe roof method in those geological conditions.

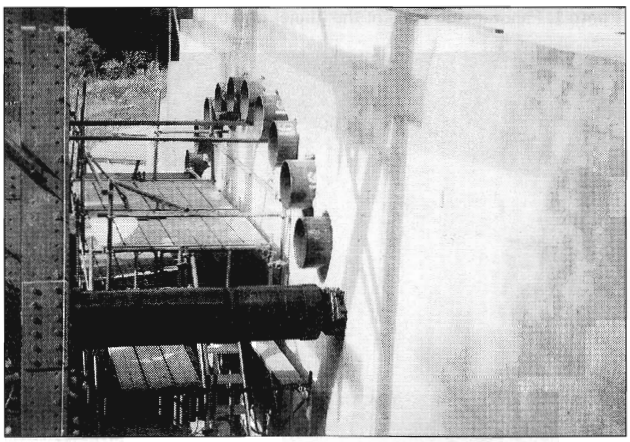


Photo 5. Roof-pipe setting for digging.

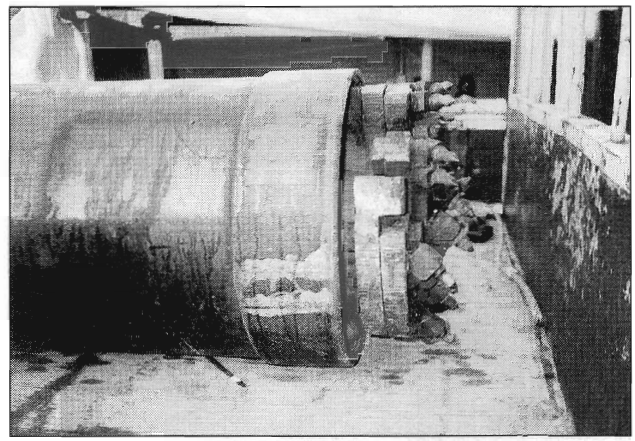


Photo 6. Digging cutter.

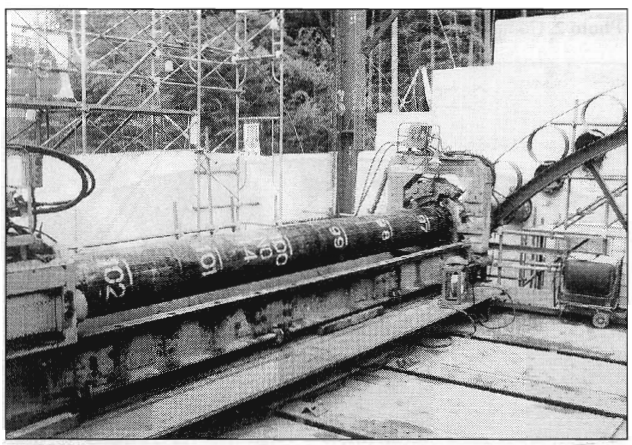


Photo 7. Roof-pipe seeting on the machine.

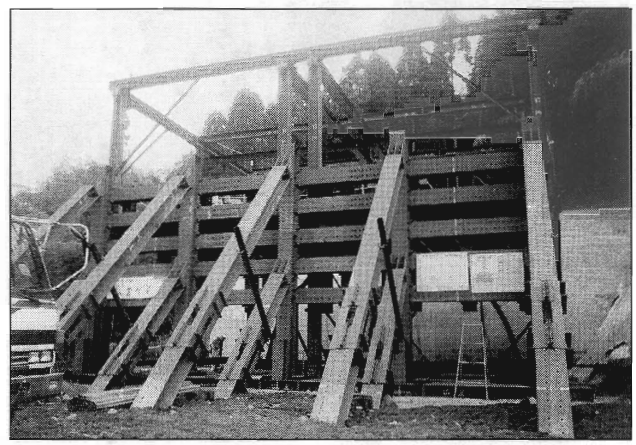


Photo 8. Machine base (backside).

Pipe Roof Method

The pipe roof method is a pre-support technique involving pushing steel pipes into unstable ground around the tunnel arch. Insides and surroundings of these steel pipes are filled with air-mixed mortar.

In this case, we planned to protect the tunnel by the pipe roof method for about 100m length from the tunnel mouth. We used 500mm-diameter, 12.7mm-thick and 6.0m-long steel pipes, and pushed 15 roof pipes (90~98m in length) into the mountain from outside the tunnel. Before inserting the pipes, we made an embankment at the tunnel mouth as a portal, in order to prevent slope failure.

Fig. 2 shows the longitudinal section of the tunnel mouth and its geology. Fig. 3 shows the cross section of the pipe roof arrangement.

Photo 2 shows completion of the pipe roof method at the site of the tunnel mouth. The concrete structure looking like a portal is the embankment made of air-mixed concrete. We can see the accuracy of the pipe roof direction and the adherence to ground in Photo 3, 4.

Pictures of pipe roofing are shown in Photo 5, 6, 7, 8. 6.0m length steel pipes were thrust by two propulsive machines with a driving force of 2.0 MN. Steel pipes were connected with each other by electric welding. We were able to make roof holes in almost every stratum, such as sand, clay, gravel, cobble and rock (=under the unconfined compressive strength of 40~50 MPa). Specifications of the propulsive machine are shown in Tab. 1.

Conclusion

The accuracy of the pipe roof direction was within 30mm per 100m length, and the tunnel was excavated smoothly, without any slope failure or landslide. In such of similar geological conditions, we would be able to excavate the tunnel safely and effectively by using the pipe roof method.

Zabezpečovanie kaloty tunelového portála oceľovými rúrami v prípade prejavov zosuvu v reliéfe

Príspevok opisuje a ilustruje použitú metódu zabezpečovania kaloty tunela rúrovou klenbou v zosuvnom území na juhu ostrova Kjúšu v Japonsku, kde sa v reliéfe okolia tunela prejavovali zosuvy v nekonsolidovaných zeminách, a preto bolo nevyhnutné zabezpečiť portál tunela proti účinkom zosúvania tzv. strechou z oceľových rúr.

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Some types of landslide in Niigata Prefecture, Central Japan

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Abstract

General image of landslide in Niigata prefecture is "Creep" or "Earthflow" which slowly moves and doesn't give rise to so serious damage. Any other types of landslide such as "Slide" or rapid "Flow", however, also occur in the same region. Many agents control those types of landslide, but basic control one is mechanical properties of the sliding material. In this paper, the author shows some examples of various types of landslide occurred in this region, and discusses the relationship between types of movement and mechanical properties of the bedrocks or sliding materials. The author gives support the Uemura's suggestion on which mode of slope movement is controlled by the ductility of sliding materials.

Key words: types of landslide, geo-mechanical property, ductility

1. Introduction

As shown in Fig. 1 and Fig. 4, landslides are much more densely distributed in southern half of Niigata prefecture than the other area of Japan. The primary cause is due to the specific geological conditions such as soft rocks and their mode of weathering. The other reason is thick snow which reaches 2–5 m in mid-winter. Snow melting is the most effective agent and long-lasted rainfall in June to July is also the triggering cause of landslide in this region as shown in Fig. 2 and Fig. 3 (Ito, 1998).

General image of landslide in Niigata prefecture is that slow movement lasts a long time on a gentle slope, and there aren't so many disastrous hazards nor casualties caused by the rapid movement. Many more rapid ones, however, have occurred and killed a lot of people in the past. In fact, various other types of landslide have occurred in this region, but analogous types of landslide tend to occur in the same geological and geomorphologic conditions.

In this paper, it will be described various types of landslide occurred in Niigata prefecture in the past, which were more or less investigated by the author. Then the relationship between the types of landslide and geomechanical properties will be discussed with the concept of ductility.

2. Regional geology and types of landslide

As shown in Fig. 4 and Fig. 5, landslide-prone area in Niigata prefecture nearly coincides with the distribution of young sediments ranging from Miocene to Pleistocene series. There is no doubt that the primary cause of

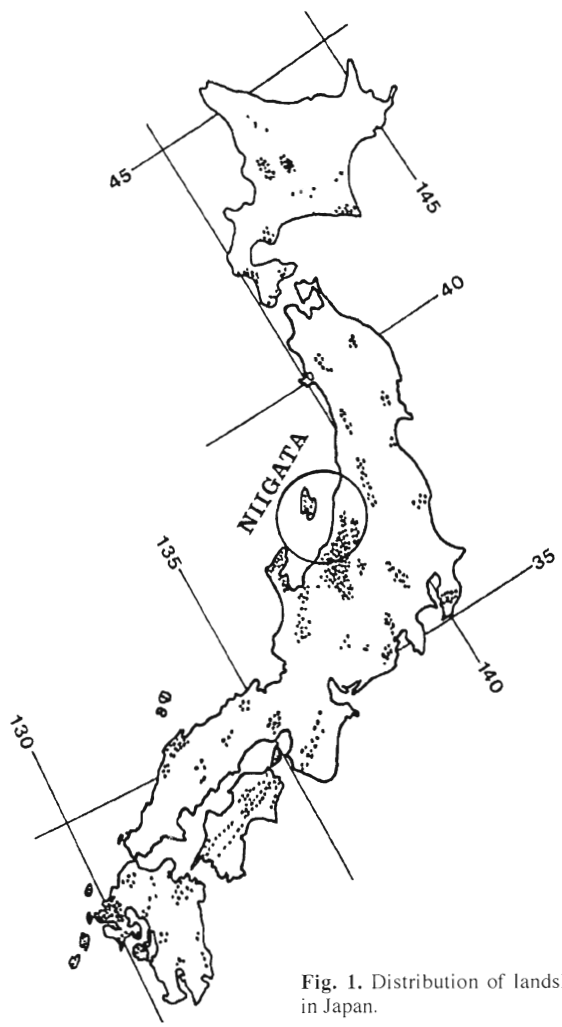


Fig. 1. Distribution of landslide in Japan.

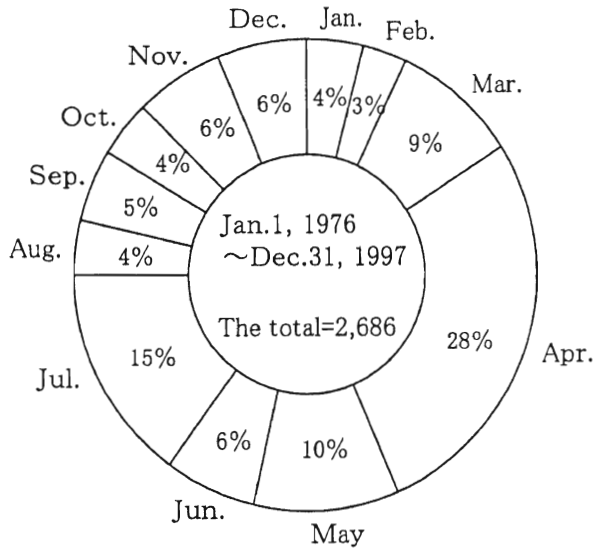


Fig. 2. Monthly landslide incidence in Niigata prefecture (1976–1997).

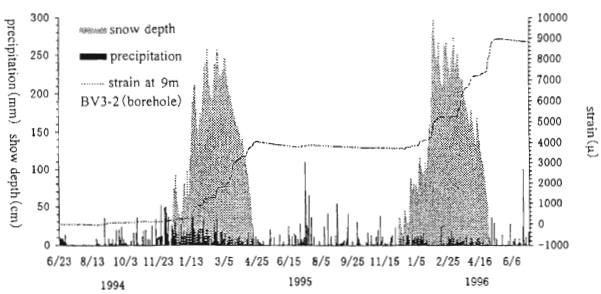


Fig. 3. Relationship between snow and strain at Matsunoyama landslide area (Ito, 1998).

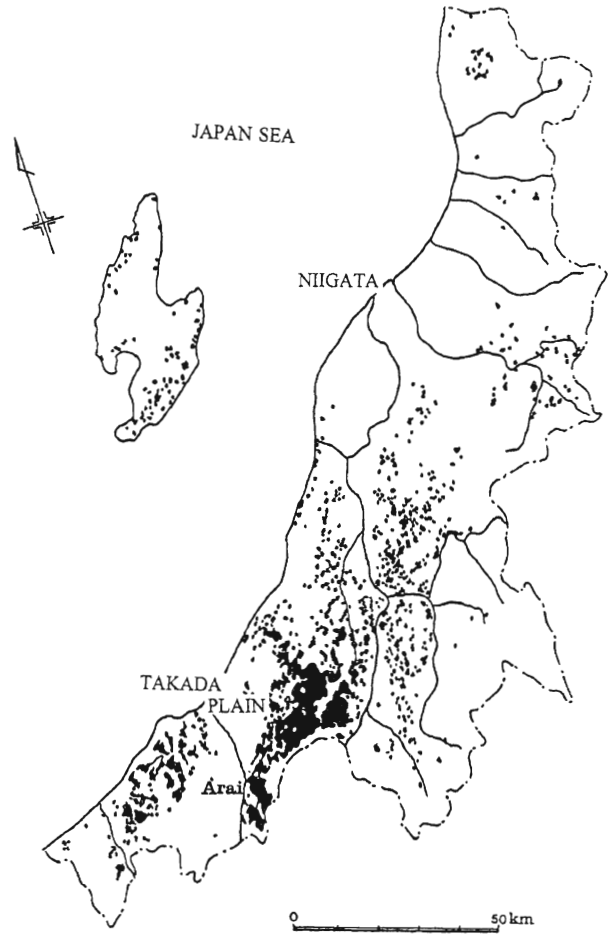


Fig. 4. Distribution of landslide in Niigata Prefecture.

Tab. 1
Stratigraphy in the study area

Geological age	Eastern region	Western region
Pleistocene	Uonuma G.	
	Haizume F.	
Pliocene		Tanihama F.
	Nishiyama F.	Nadachi F.
		Kawazume F.
Miocene	Shiiya F.	Nohdani F.
	Teradomari F.	

landslide is due to the rock-mechanical properties of the bedrock or its specific mode of weathering and tectonic structures, Quaternary tectonic movement or its residual force might have influenced to the "primitive" or the "potential" landslide though. All these bedrocks of landslide-prone area are mainly composed of soft mudstone or alternating beds of mudstone and sandstone, but their rock facies and mechanical properties are a little different in each geological formation. Variable mode of slope movement arises from such differences.

Tab. 1 shows the standard stratigraphy of the landslide-prone area. The stratigraphy and rock facies are a little different between the eastern region and the western region bordering Takada Plain (see Fig. 5).

Rocks of the eastern region are usually composed of thick mudstone and alternating beds of mudstone and sandstone. In general, mudstone prevails in the Teradomari Formation, the Nishiyama Formation and the Haizume Formation, and alternating beds prevail in some parts of the Shiiya Formation. Clay fraction of these mudstones is usually higher than that of the western region except for the Uonuma Group. The Uonuma Group is mainly composed of alternating beds of mudstone and sandstone intercalating gravel beds in some places. Volcanic rocks are intercalated in some parts of the Nishiyama Formation.

All present formations in the western region (see Tab. 1) are also composed of mudstone and/or alternating beds, but mudstone is sandy and alternating beds a little more prevail than that of the eastern region. The Nohdani Formation is most widely distributed and composed of mudstone or alternating beds.

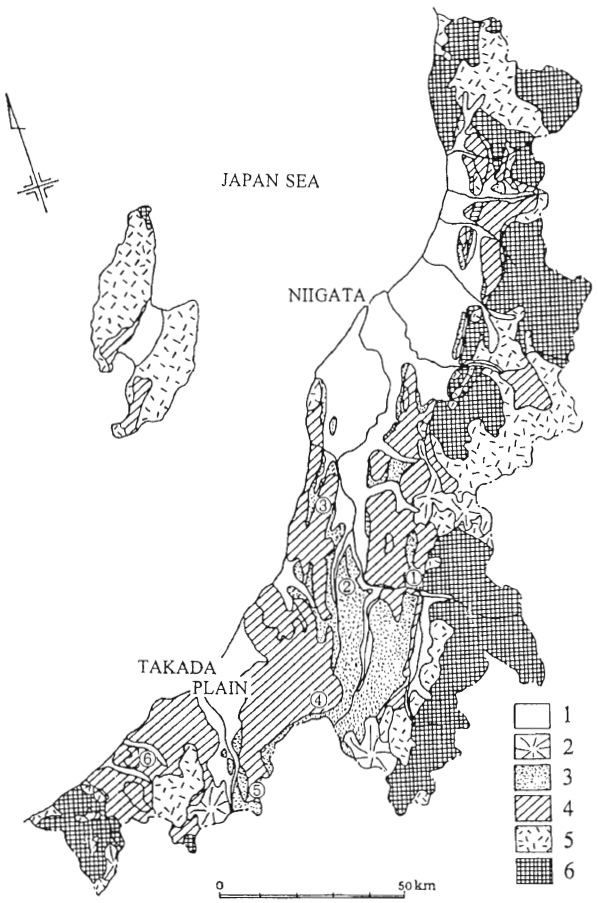


Fig. 5. Geological zoning of Niigata Prefecture and location map of study area. 1 – Alluvium, 2 – Quaternary volcanics, 3 – Late Pliocene-Middle Pleistocene series, 4 – Late Miocene-Pliocene series, 5 – Early-Middle Miocene series, 6 – Pre-Tertiary series, 1. Landslide area studied in the text.

The relationship between the rock facies of these formations and the modes of slope movement are as follows.

In general, landslides recorded in the history have a tendency of large scale in the mudstone dominant formations, and tend to chronically repeat in the same area. Hence almost all landslides in those formations can not keep their original shape of amphitheater. Sliding speed, however, is usually slow, so that the direct damage to the residents is scarce. On the other hand, many old big amphitheaters remain in the area of alternating beds, and they are especially remarkable in the area of the Uonuma Group. This topographical feature shows that big initial primary landslides quite often occurred in the ancient times, which have been stable or dormant as a whole since the first event. There are a few traces of secondary landslide in the area of these big original ones, but they can hardly repeat in the same place except for a few rare cases. Many human lives, however, have been victimized in the area of the Uonuma Group, because they were accidental and rapid. In the area of the Nohdani Formation and other western formations, there is an analogous tendency, but it is not so catastrophic as the case of the Uonuma Group, and the secondary (or tertiary) movement tends to become gentler in due order of repetition.

3. Classification of landslide

Uemura (1975) classified the types of slope movement into four categories: Flow, Creep, Slide and Fall, and indicated that the mode of slope movement are controlled and/or the way of evolution is restricted by the geo-mechanical properties of the slide material as shown in Fig. 6. He used ductility to represent the geo-mechanical properties. Here, mean ductility (Dm) represents the average value of the whole material, and ductility contrast (Dc) represents the difference between the ductility of plural materials. Hence, homogeneous sandy mudstone may have the same Dm with alternating beds equivalent in volume of mudstone and sandstone, but it can not have any Dc. The author follows this classification except the concept of Fall in discussing the landslide movement.

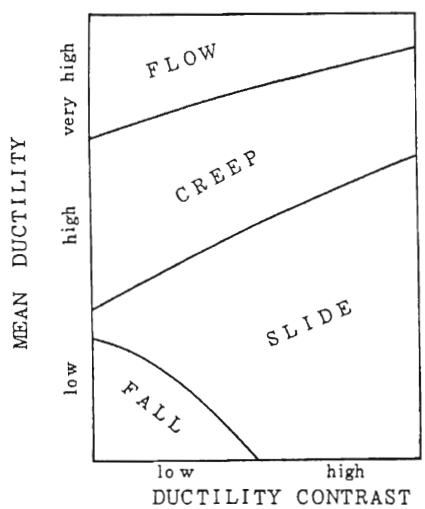


Fig. 6. Relationship between ductility and types of slope movement (Uemura, 1975).

4. Examples of types of landslide

4.1 Slide type

1 Mizusawa-shinden landslide

In the early morning of April 26, 1969, a rapid rockslide occurred at the upper reaches of the right tributary of the Aburuma River. Foot of the sliding mass fell into the gorge and changed to debris flow. It blocked the main river and rushed into a small village located at the bottom of the valley killing 7 lives, and one person is still missing.

This slide occurred in the Uonuma Group that is mainly composed of sandstone intercalating mudstone and gravel beds. These strata are nearly flat or gently dip toward the southerly direction (less than 10).

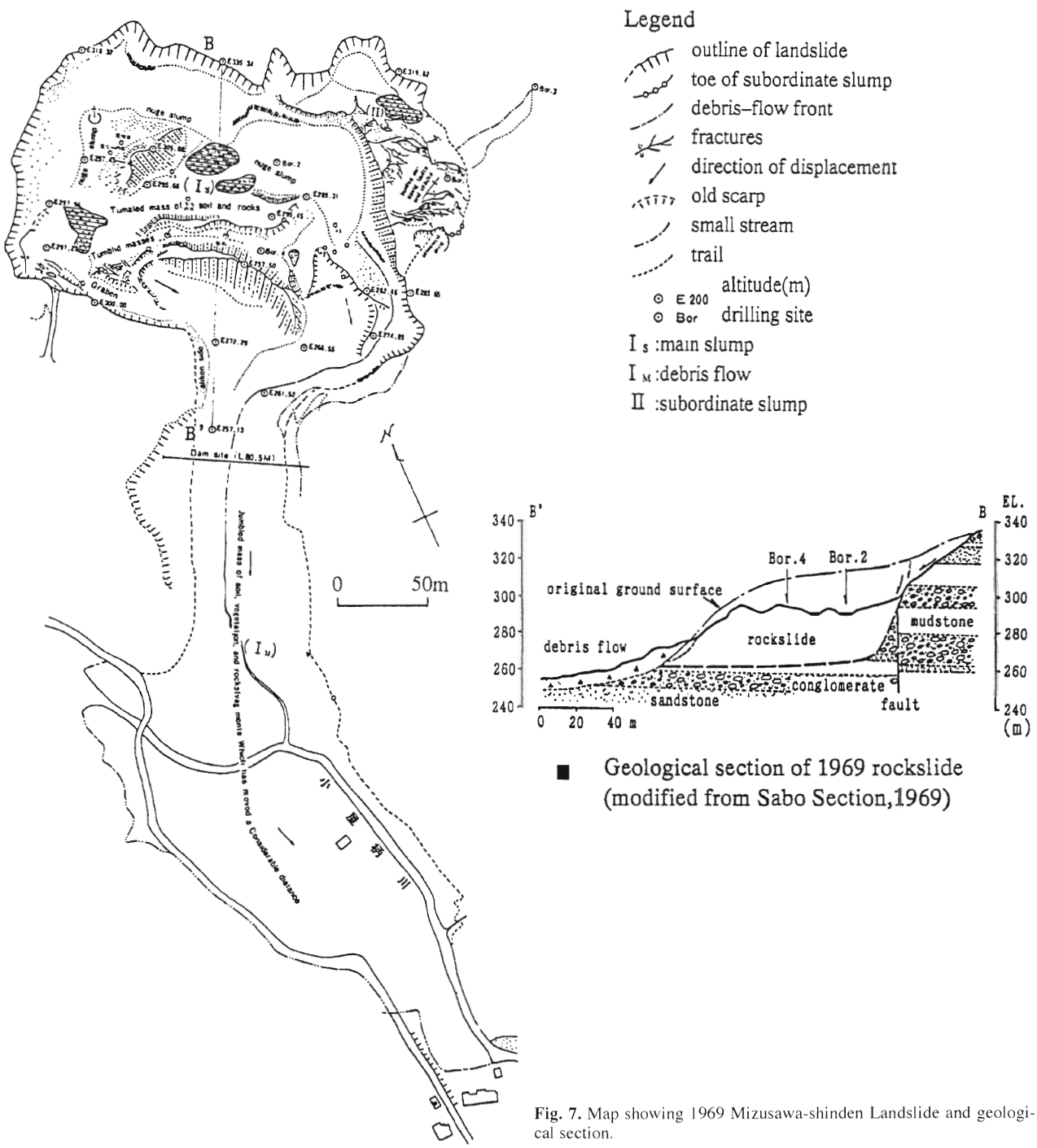


Fig. 7. Map showing 1969 Mizusawa-shinden Landslide and geological section.

As shown in Fig. 7 (Sabo Section, 1969), the affected area of this slide is divided into three units according to the type of failure; main body of the slump (I_S), deposit area of the debris flow (I_M) and subordinate mass of the slump at the east side (II). The size of the main slump is 250 m wide and 150 m long. The length of debris flow reached 450 m and its average width was about 80 m. The height of the main scarp was about 40 m. The depth to the sliding surface is estimated about 50 m from the original ground surface, and the sliding surface looked almost flat except for the head area, which is usually called "chair type" as shown in the section. The triggering cause of this failure must have been melting snow. From one survivor's observation, the debris flow traveled approximately 450 m in 30 seconds (15m/sec).

2 Tokimizu landslide

On August 13 1991, a rapid rockslide occurred on a convex slope as shown in Fig. 8. A part of the foot fell

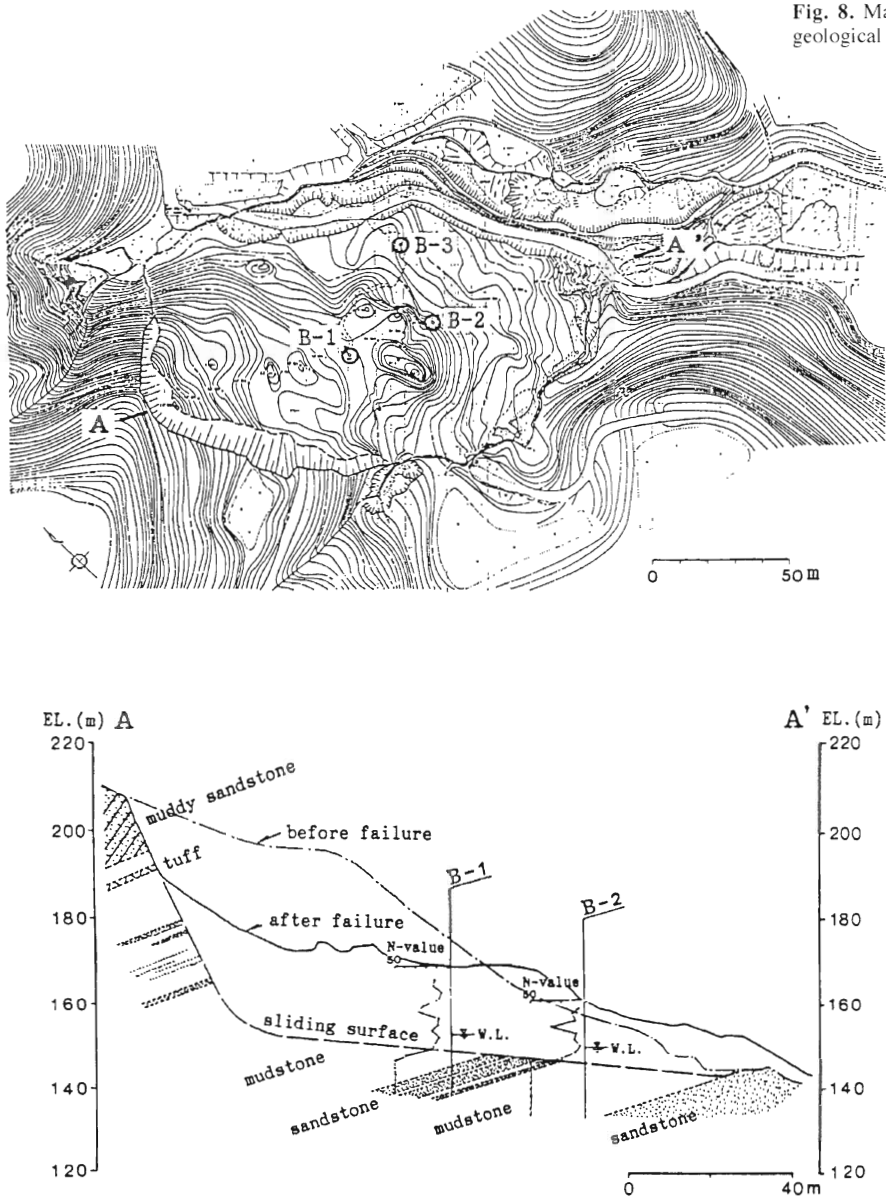


Fig. 8. Map showing 1992 Tokimizu landslide and geological section.

into the small valley, but it didn't travel so long distance, and the main body of the debris stopped as a mass on the slope. Some paddy fields and a small pond were devastated, but there was no other serious damage. As a matter of fact, this slope failure had been anticipated. It happened that the author was just investigating this landslide area including the failure slope, and found the premonitory sign. When the author examined this convex slope for the first time, there was a pretty big outcrop of intact mudstone at the side slope, and nothing was bad. After the rainfall, however, a small failure occurred on the southern side of the slope in early July with cracks reaching to the top of the ridge, then the toe of the slope was pushed up a little. After that, on August 13, whole failure finally occurred.

This rockslide occurred in the Lower Pleistocene sediments (Uonuma Group) gently dipping against the slope. The author believes that the triggering cause was a heavy rainfall, but this slide was a potential one in which the sliding surface had been prepared, because pre-existed small fault was found on the head scarp, which was a part of the sliding surface. The configuration of the sliding surface was also a "chair type", and the sliding surface was extremely deep in contrast to the whole scale.

4.2 Creep type

5 Yakushi tunnel landslide

When the tunnel excavation was approaching to its south entrance, the roof of the tunnel subsided with the re-activation of the old landslide. The excavation of the landslide debris started as a counter measure, but it induced a bigger rockslide on the upper slope.

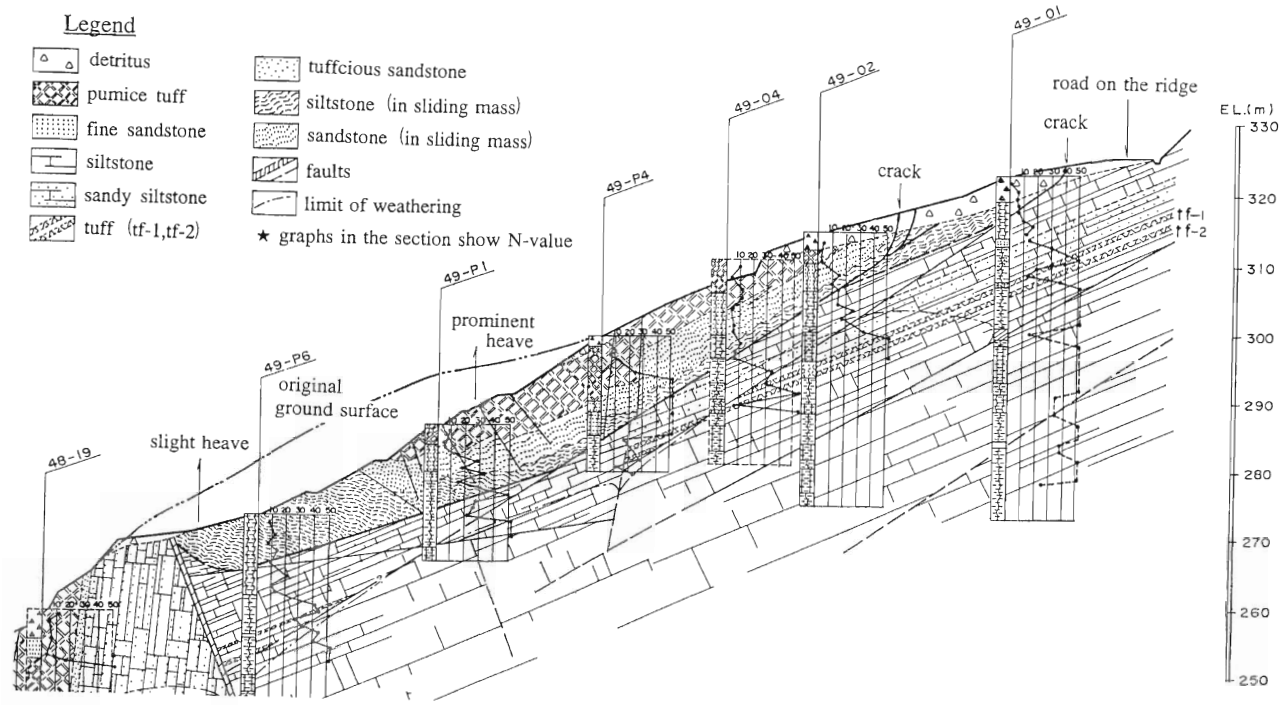


Fig. 9. Geological section of Yakushi tunnel landslide.

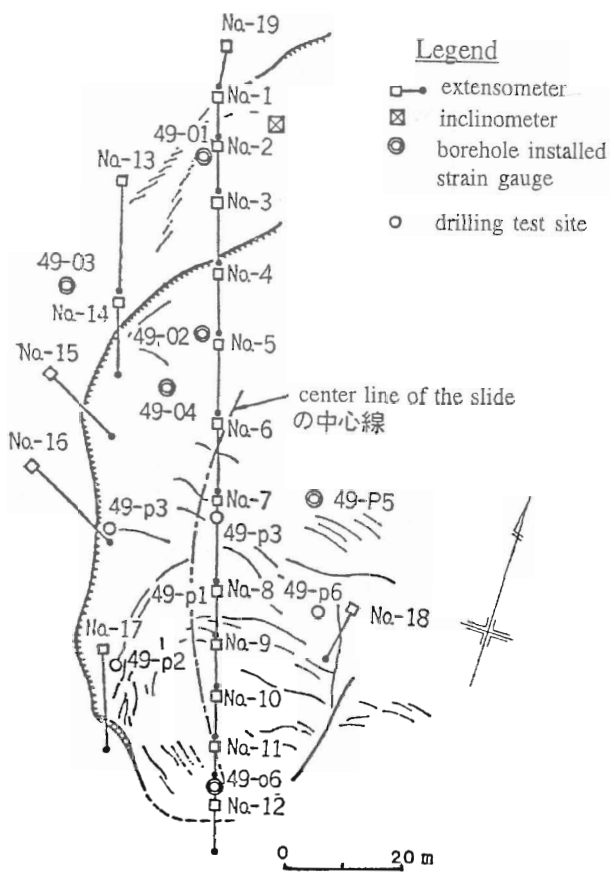


Fig. 10. Cracks due to the slope movement.

In April 1973, the rock slope started to move beyond the upper limit of the excavation site, and the head crack finally reached to the top of the hill. The scale of the rockslide was about 15 0m long, 60 m wide and 10–15 m deep. The rock mainly consists of weathered mudstone intercalated with a thick pumice tuff and sandstone (Shiiya Formation) as shown in Fig. 9, and the sliding surface was nearly parallel to the bedding plane dipping about 30 degrees toward the valley. At the beginning, the movement was very slow, but it suddenly increased with the occurrence of many cracks on the cut slope (see Fig. 10) during long lasted rain fall; however, it decreased again with stopping rain fall as shown in Fig. 11. After that, it was protected by the drainage drillings and pile driving. The sliding mode of this rock slide looked like a Slide type, but it didn't move so long distance nor collapsed on such a steep sliding surface.

4 Matsunoyama-koshi landslide

In the vicinity of this landslide area, snow depth reaches 3–5m in winter (see Fig. 3). In this case, the main unit of the landslide area is the shaded one with lateral lines in Fig. 12, which is surrounded by many other smaller units. The author made a field reconnaissance and drilling tests for this landslide in May to June 1975. It had been repeating prominent movement every snow melting season, but it wasn't so rapid nor serious; therefore mulberry plantation instead of paddy field had been doing on this slope. The basement rock mainly consists of mudstone intercalating tuff layers (Teradomari Formation). This main landslide unit is elongated EW direction that is near-

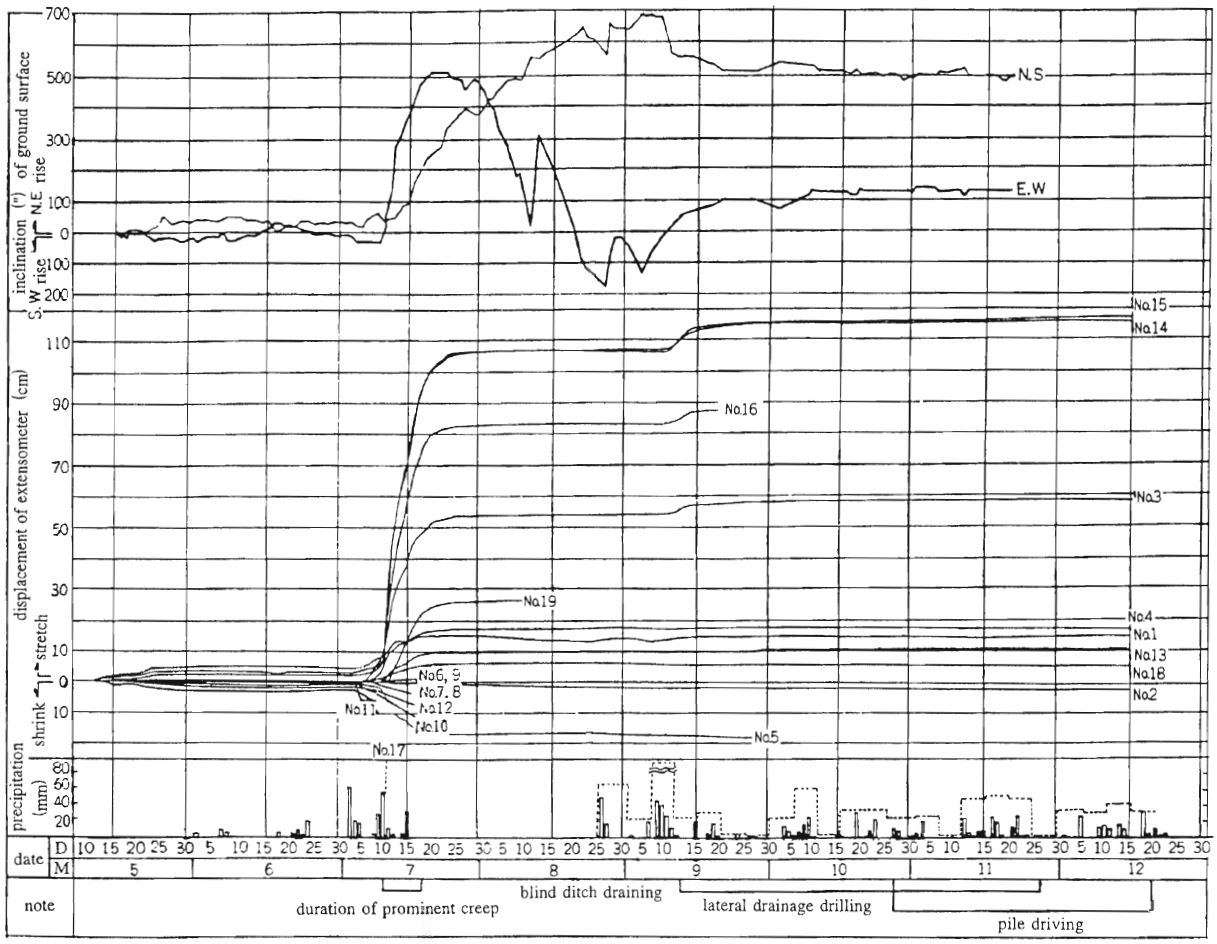


Fig. 11. Monitoring of the slope movement.

ly parallel to the strike of the basement strata. It was confirmed that some parts of the sliding surface inclined along the bedding plane, which meant the traversing section was unsymmetrical and the depth to the sliding surface was deeper toward the south.

The average slope angle was about 10 degrees and the plane figure was very elongated; that is, the length was about 500 m long and 60–80 m wide, and the depth to the sliding surface was 10–15 m at the central part. This configuration of the landslide looked like a Flow type, but there were many topographical features peculiar to landslide such as grabens, mounds, depressions, ponds, minor scarps and so on. In addition, it could be divided into several sub-units or secondary units considering these features and minor relief; therefore, this unit must be designated as one of the Creep type.

4.3 Flow type

5 Yoshiozawa landslide

This landslide is a small part of a big landslide area and consists of two units of landslide as shown in Fig. 13. The total length was about 200 m and the width was about 40–70 m. The premonitory sign occurred after the typhoon on Sep. 12–13, 1982 (total rainfall was about 200 mm); that is, small cracks were found along the farming road at the foot of the slide. After that, in March 1983, a rockslide occurred with snow melting on the eastern side of the upper slope, and it moved onto the upper slope of the unstable pre-existed one. The height of its main scarp reached 15m, and it moved relatively a long distance (more than 30m) making the ground surface ragged. The pre-existed landslide was reactivated by this rockslide without so conspicuous deformation on the surface, and moved like a glacier on the gentle slope (5–10 °K). The first slide is clearly classified to Slide, but second one can be classified as Flow.

6 Maseguchi landslide

The premonitory sign of this landslide was observed from a few days before, and the main movement lasted almost all day on May 19, 1947. As this disaster occurred shortly after the World War II, there is no way to do the geological survey except the field reconnaissance. Detail record, however, was reported by Dr. Koide about the progress of this slide or disaster with his idea of the

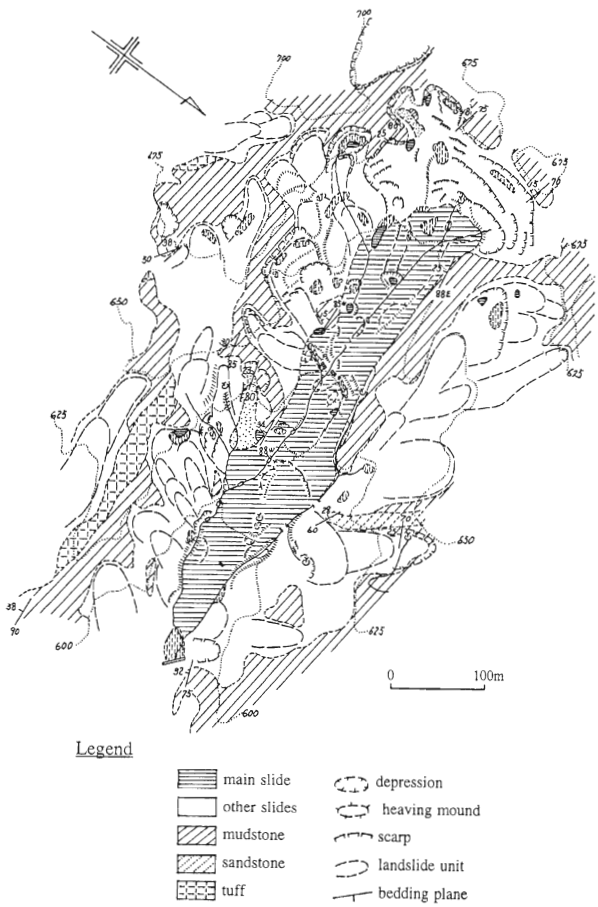


Fig. 12. Map of Matsunoyama-koshi landslide.

landslide mechanism (Koide, 1948). There was no casualty during this disaster; however, a catastrophic event happened after 40 years from this disaster at the sama place: at the severely cold night in Jan. 26, 1986, the snow avalanche started from the steep slope above the head scarp of this landslide area, then it run down on the landslide slope and killed 13 residents. The author had a chance to work for the construction project for the leading wall of snow avalanche, which was constructed on the head area of the landslide slope. Fig. 14 is the revised map of the 1947 slide with the reference of the Koide's report mentioned above, and Fig. 15 is the geological section based on the drilling tests for this project. Basement rocks are mainly composed of mudstone (Nohdani Formation) intercalating some shear zones, and it is intruded by the porphyrite at the head scarp.

As shown in Fig. 14, the head area deeply sank (20–50 m) and depression zones occurred, and it didn't laterally move so long distance; however, the lower eastern slope traveled 300–600 m and it finally blocked the river at the foot. The upper slope of the slide is clearly classified as Slide. The lower eastern part, however, is able to classify as Flow, because it moved long distance like an escalator; houses were transported without demolishing on it except the foot area.

5. Variation of geo-mechanical properties

Nozaki (1995) studied on the rock mechanical properties of the soft rocks in the landslide-prone area in Niigata prefecture, which was based on the *in-situ* rock shear and deformation tests for the dam foundation, and some other laboratory tests. He indicated the relationship between ductility and initial normal stress of the *in-situ* rock shear tests as shown in Fig. 16. Although the ductility is changeable due to the condition of temperature, time and stress, these tests were done in the almost same condition except the stress.

This figure shows that the mean ductility (Dm) of the Uonuma Group is very low, but the ductility contrast

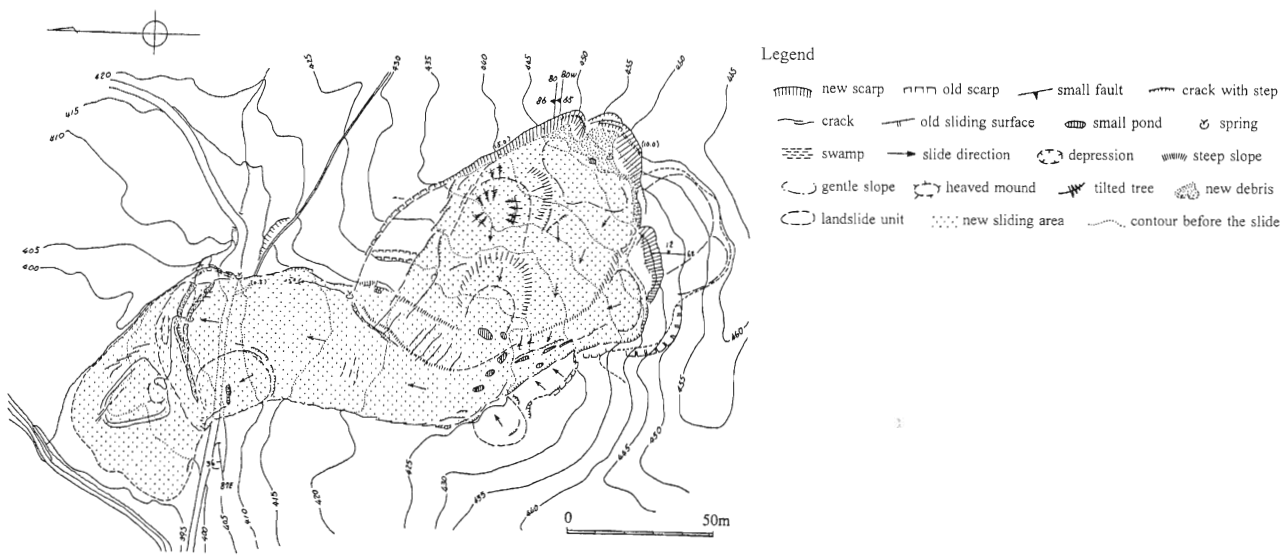
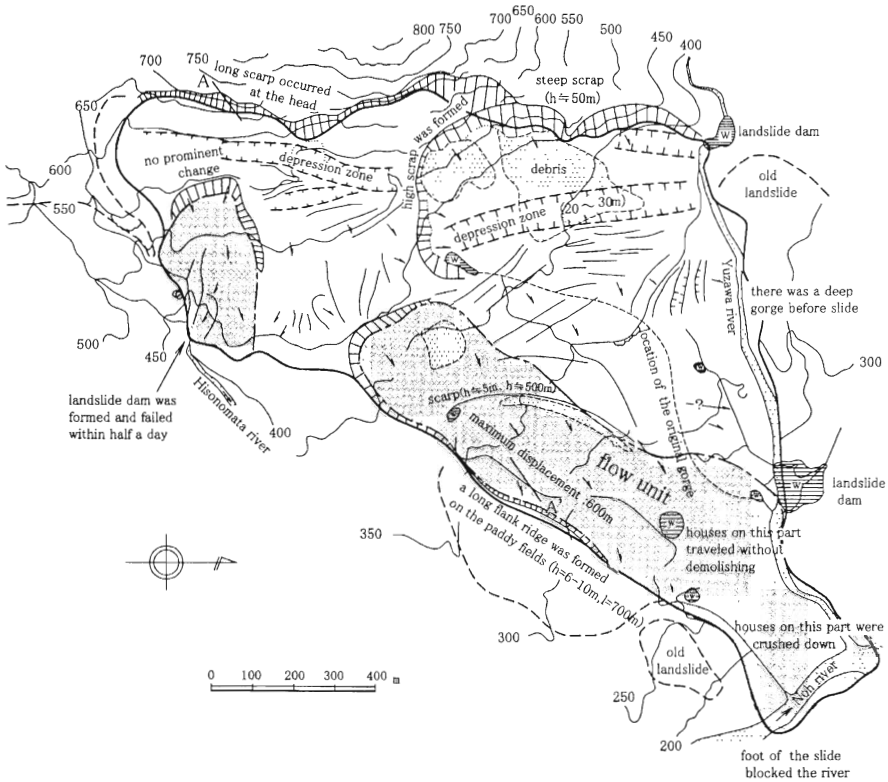


Fig. 13. Map of Yoshiozawa landslide.

Fig. 14. Map showing 1947 Maseguchi landslide.



(Dc) is high, and Dm of the Teradomari Formation is high, but there is no Dc. The upper Nohdani Formation shows almost same as the value of the Teradomari Formation, but this test site was in the "slump layer" mixed up with sand and mud before consolidation; therefore, representative property of the Nohdani Formation might be the one by the test of the lower Nohdani Formation. It shows very high Dm and high Dc.

Based on this study, he also indicated that the geomechanical properties are not necessarily increase or decrease in due order of the geologic sequence as shown in Fig. 17.

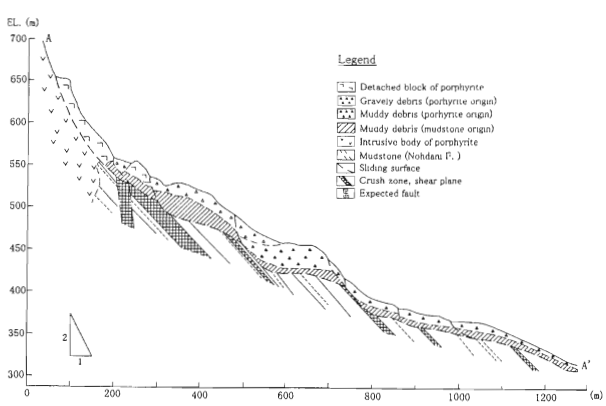


Fig. 15. Geological section of Maseguchi landslide.

6. Relationship between ductility and mode of slope movement

Ductility is an ability to successively deform, and it is designated as the strain at the peak strength here.

As mentioned above, rocks of the Uonuma Group show low Dm and high Dc, and rapid Slide tend to occur in this Group, even if the angle of sliding surface is very low. Influence of Quaternary tectonic movement to the (primitive or potential) primary occurrence of big rockslide should be considered in this region (Nozaki, 1996), but this issue is excluded here.

The Haizume and the Nishiyama Formations also show low Dm, and the Slide tend to occur in the case of primary rock slide, but the secondary or tertiary ones tend to become slower (Creep). These phenomena indicate that Dm of the sliding material changes higher little by little repeating slope movement. It means a sort of evolution of landslide.

On the other hand, rocks of the Teradomari and the Shiiya Formations usually show high Dm and low Dc, and Creep or Flow tends to occur in these formations. Rockslides usually don't move so fast or a long distance nor collapse even on the pretty steep slope. Flow slide usually consists of clayey debris because of crushing or softening with slide repetition, and there is no conspicuous morphological change on the sliding slope and is analogous to the "Earthflow" of Varnes' classification. The

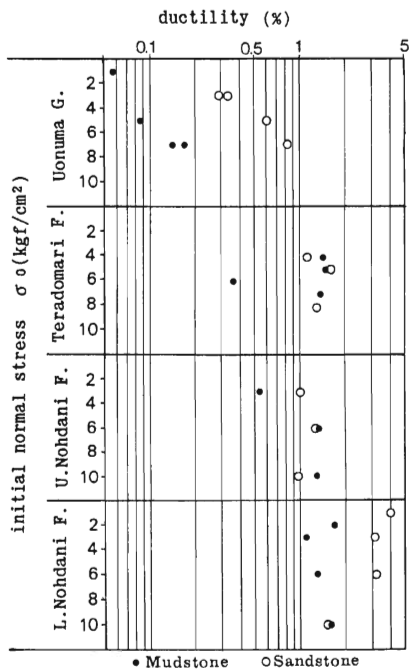


Fig. 16. Relationship between ductility and normal stress of rock shear test.

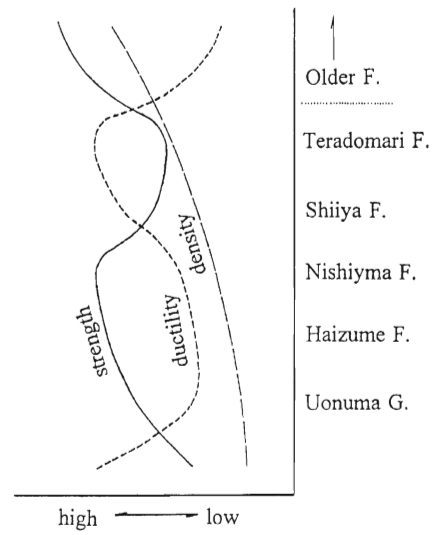


Fig. 17. Schematic diagram showing variation of geo-mechanical properties in the sequence of geological formations.

most typical one is Sarukuyohji Landslide in the Teradomari-Siiya Formation.

Rocks of the Nohdani Formation show very high Dm and high Dc except for the special layers, and Slide or Creep is common in the western region, but a part of the Slide mass sometimes change to Flow as the case of the Maseguchi Landslide. That must be due to the extremely high Dm. The way of Flow in the western region, however, tends to be fast and dangerous from time to time; for example, 1963 Kodomari Landslide, which occurred in the Nadachi Formation, killed 23 people, squeezed out the train toward the sea and houses were buried under the debris.

7. Conclusions

Stereotype of landslide in Niigata prefecture is Creep or Earthflow, which slowly moves and doesn't give rise to severe damage nor casualty, but more disastrous ones also often occur in this region, especially in the snow-melting season.

The mode of landslide movement is mainly controlled by the variable geo-mechanical properties in the sequence of the young Cenozoic sediments or in the stage of the evolution of landslide. It is able to explain with the concept of ductility.

As a result, the author gives a support to the Uemura's suggestion on the relationship between the concept of ductility and type of slope movement.

Acknowledgement. Professor Yushiro Iwao of Saga University gave me the chance to join the field excursion in Czech Republic, Slovakia, Austria and Italy in May 2000, and encouraged to give my presentation for the symposium on May 13 2000, at the Comenius University Bratislava. Professor Rudolf Ondrášik of Comenius University gave me the chance to publish my paper to the proceedings of symposium and he leaded us the excursion in Europe with Dr. Tatiana Durmeková. They are all gratefully acknowledged for their kind help.

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Niektoré typy zosuvov v prefektúre Niigata, stredné Japonsko

V prefektúre Niigata je prevládajúcim typom zosuvov plazenie a tečenie, ktorých pohyb je pomalý a nespôsobujú vážne škody, ale vyskytuje sa tam aj zosúvanie a rýchle prúdy. Na týchto typoch zosunu sa zúčastňuje viac faktorov, ale základným sú mechanické vlastnosti zosuvného materiálu. Autor v príspevku uvádza niekoľko prípadov rozličných zosunov v tejto oblasti, analyzuje vzťah medzi typom pohybu a mechanickými vlastnosťami podložia a zosuvného materiálu. Stotožňuje sa s Uemurovým náhľadom, podľa ktorého je režim svahového pohybu ovládaný duktilitou (tvárnosťou) zosuvného materiálu.

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Landslides in the Košice district

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Abstract

Slope deformations of landslide type are a significant natural geological barrier in the Košice district. Their negative impact on engineering structures of various types increases relatively as more and more building activities move to slope areas which are prone to landslides or to landslide areas. Slope instability problems on the eastern periphery of Košice (Furča housing estate, locality Heringeš – Krásna nad Hornádom) are well known. Costs of investigation and remedial works as well as material damage to the structures and economic activities amount to millions of crowns every year Evaluation of the registered landslides in the district, the main sliding geological structures, the conditions and causes of landslide origination and physical-mechanical properties of soils and sediments of sliding slopes, is the main subject of this contribution.

Key words: Košice district, landslides, evaluation

Introduction

Landslides are the most significant geological hazard in the Slovakia. Nearly 15 000 landslides are registered, which represent about 3.7 % of the entire area of Slovakia (Liščák and Caudt, 1997). The frequent occurrence of landslides reflects the geological and tectonic nature of the territory as well as its geomorphological evolution, mainly during the Quaternary. Landslides are concentrated mostly in Flysch regions, neo-volcanic mountains and Neogene tectonic depressions. Košice as the second largest city in Slovakia is situated in the middle of the Košická kotlina depression (Fig. 1) which is a part of East-Slovakian Basin.

Landslides and erosion gullies represent a significant geological barrier to urban development of the city. Various types of engineering structures (dwelling and recreation buildings, roads, power lines and pipelines) are threatened and/or damaged by landslides. Landslide hazard increase during the recent years is connected with move of building activities to slope areas which are prone to landslide. A well known example of a development threatened by landslide is the Furča housing estate situated on the eastern margin of Košice (Nemčok, 1982).

Landslides in Košice and its surroundings have been studied by several specialists in the past. During the preparation of engineering geological maps on the scale of 1:10 000, landslides were mapped and partly verified by boreholes (Jedľa et al., 1977; Modlitba et al., 1981; Kováčik and Modlitba, 1982 and Spišák et al., 1988). Detail inventory of landslides in the Košice district on the scale of 1:10 000 was made by Petro (in Modlitba et al., 1987 and 1988; in Modlitba and Petro, 1990). A small scale landslide investigation for the planned building of roads, complex and/or individual housing on the eastern margin of the town was done, for example, by Jedľa et al. (1978) and Grmanová et al. (1989, 1992 and 1996). A description of slope deformations in the same area was done by Spišák (in Karoli et al., 1989a). A special map of relative susceptibility to landslides on the scale of 1:50 000 of the area to the E of the Hornád river was prepared by Petro et al. (1993) and to the W of the Hornád river by Dluhý et al. (1993). The same methodology was used by Petro et al. (1999) to prepare the similar but more detailed (1:25 000) map as part of the International Slovak – – Luxembourg project "Košice – abiotic component of the environment".

Geomorphological setting

According to Mazúr et al. (1986), the district of Košice covers the middle part of the Košická kotlina depression and the margins of the Čierna hora and Volovské vrchy Mts. (Fig. 1). The relief of the area is gently sloping and hilly with relative height differences up to 200 m and an average slope angle from 2° to 6°, or less frequently from 6° to 14°. The upland relief with relative height differences up to 350 m and an average slope angle from 14° to 24°, dominates in the north and north-western parts of district. Average annual rainfall ranges from 558 to 752 mm. The area is drained by the Hornád and Torysa rivers, together with the Ida, Myslava and Čermeľ streams.

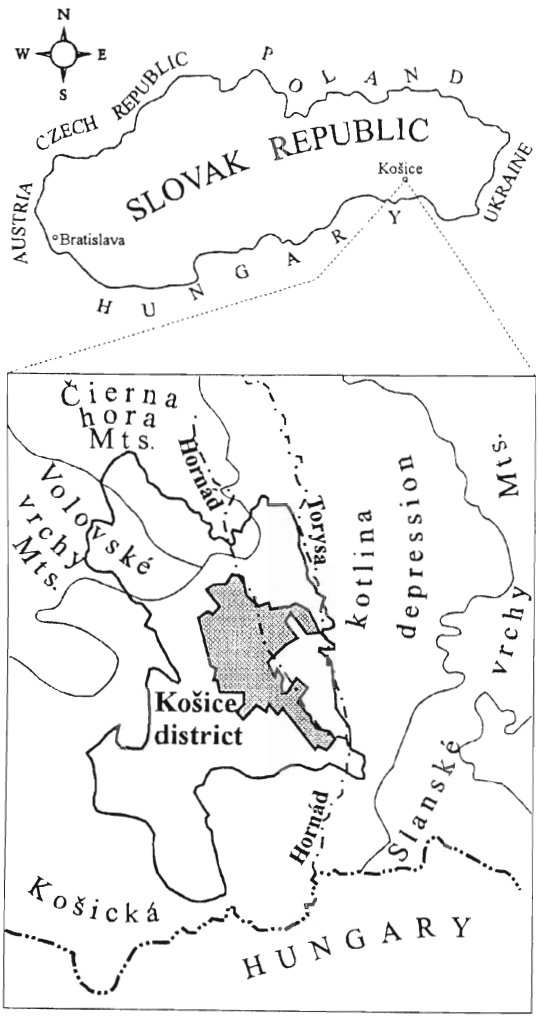


Fig. 1. Location map of the Košice district with indications of geomorphological units (after Mazúr et al., 1986).

Geological and tectonic setting

From the geological and tectonic maps of the Košice district (Karoli et al., 1998), it is clear that the area consists of Quaternary and Tertiary sediments, as well as pre-Tertiary rocks. Quaternary is represented mainly by fluvial (terraces and flood plains), proluvial (alluvial fans), eolian-deluvial, deluvial and anthropogenic (man-made) sediments. Their thick-ness ranges from 1 to 25 m. These sediments occur mostly in the middle and southern part of district and cover Neogene sediments.

The Tertiary is represented by the molasse sediments (marine, deltaic a lacustrine-fluvial) of the East-Slovakian Neogene Basin. According to Karoli et al. (1998), they belong to the following formations – *Kladzany, Klčovo, Stretava, Kochanovce* and *Sečovce*. The prevailing lithologies include clay and claystone with sand and gravel intercalations, silt and siltstone, gravel, sand, as well as rhyolite and pumice tuff and tuffite.

Pre-Tertiary rocks outcrop in the northern and northwestern parts of the district. They are re-presented by a varied lithological set of Paleozoic and Mesozoic rocks from the *Veporicum, Gemericum* and *Hronicum* – – gneiss, migmatite, granodiorite, breccia, conglomerate, sandstone, shale, quartzite, limestone, dolomite, phyllite, diabase, keratophyre, rhyolite, dacite, tuff and tuffite, magnesite and amphibolite.

The area of district is deformed by a number of disjunctive tectonic failures. One of the most significant is the Margecany thrust fault which is responsible for the Gemericum displacement over the Čierna hora Mts. The rocks along the fault have been tectonically deformed. Dominant faults of the area are oriented NW–SE, NE–SW and N–S. In terms of heavy engineering structures for building purposes the most important are faults active during Quaternary. They are dominant in the middle and southern part of the district.

Landslide characteristics

About 87 landslides have been registered by detailed field mapping on the scale of 1:10 000 and by aerial photography (1:16 660 scale). They are of various shapes, activity degree, age and thickness. Landslides cover 10.8 km^2 and represent 4.2 % of the entire district area (257.7 km^2, Fig. 2). According to statistical analysis of morphometric and some other parameters it is clear (Tab. 1) that most landslides are dormant and stabilized, with well defined deformation, dry surface, medium depth of slip surface and moderate inclination. Most landslides have a

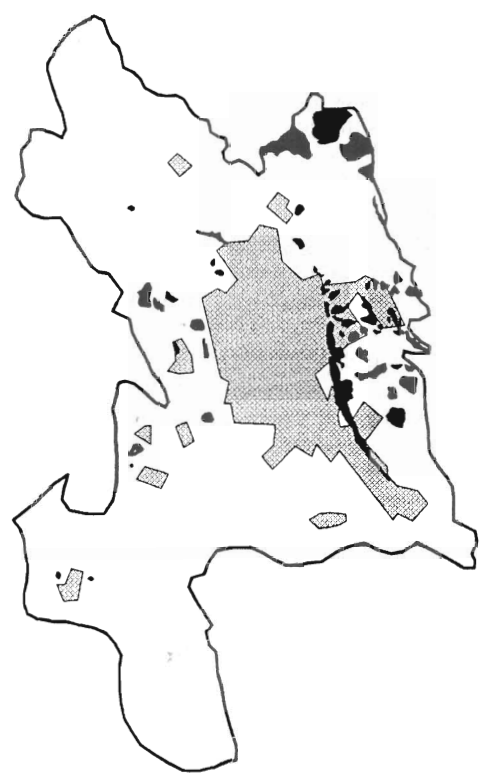
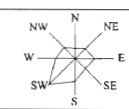


Fig. 2. Landslide distribution map of the Košice district (after Petro et al., 1999).

Tab. 1
Morphometric and some other parameters of landslides in the Košice district

Landslide parameter		X_{min}	X_{max}	M(x) [N=87]	Evaluation of landslides
Length [m]		50	1300	263	Total area of landslides: 0.12 km^2
Width [m]		30	6180	485 (418*)	
Thickness (estimated) [m]		3	35	7.2 (6.7*)	medium depth landslides
Inclination [°]		4	29	10.5 (9.5*)	moderately inclinated landslides
Height difference [m]		6	140	39	landslides with small and medium height differences
Height of the main scarp [m]		0	25	4.5	-
Height of the toe [m]		0	15	2.3	-
Activity	number of landslides	active	dormat	stabilized	dominating of dormant and stabilized areal landslides with great and clear intensity of slope deformation and dry surface
		7	51	29	
Shape		areal	frontal	elongated	
		73	6	8	
Slope deformation intensity		great	clear	insignificant	
		34	38	15	
Surface of the landslide		dry	partly wet	small lakes	
		63	19	6	

Exposure of the slope [number of landslides]	N	NE	E	SE	S	SW	W	NW
	6	8	11	8	13	21	11	9



(* without extreme values)

combined (e. g. rotational-planar) slip surface. Sliding slopes often represent outfield, forest, garden, vineyard and/or ploughland. Age of landslides is usually Holocene or recent. Palustrine clayey sediments with a high content of organic material of Holocene age (Janočko in Karoli et al., 1987) occur in undrained depressions in some "block" landslides (around the Viničná hill – northern part of district) and their morphological position could indicate the Upper Pleistocene age. In view of the similar morphology, huge dimensions and polycyclic development, it is possible to predict the same age for the large landslide (length ranges from 100 m to 650 m, total width 6180 m) on the eastern margin of Košice (Heringeš – Vyšné Opátske – Krásna nad Hornádom).

Conditions and main causes of landslides

Evaluation of conditions of landslide origination and development is mainly based on the results of mapping and research work presented above, as well as the accessible results of drilling and laboratory works done by other investigation companies. Landslides are concentrated in the eastern part of the district (Fig. 2) consisting of a morphologically expressive and relatively narrow hilly ridge between Hornád and Torysa rivers bounded by N–S oriented faults (Viničná ridge).

According to slip surface direction and position of sedimentary layers it is possible to distinguish two main sliding geological structures in the Košice district – 1. landslides on slopes built up by clayey and gravelly-clayey deluvial soils covering mostly clayey Neogene sediments, locally pre-Tertiary rocks (Fig. 3a); 2. "block" landslides on slopes built up by clayey and gravelly-clayey deluvial soils covering Neogene alternating cohesive and cohesionless sediments (Fig. 3b). The first is represented by shallow and medium depth landslides with slip surface running along contact Quaternary-basement as well as medium depth landslides with slip surface crossing the upper weathered part of pre-Quaternary basement. Pre-Quaternary sediments have the nature of soil and, due to landsliding, are mixed with deluvial soils. The second is represented by medium depth and deep-seated (up to 35 m) landslides with slip surface crossing the Neogene sedi-

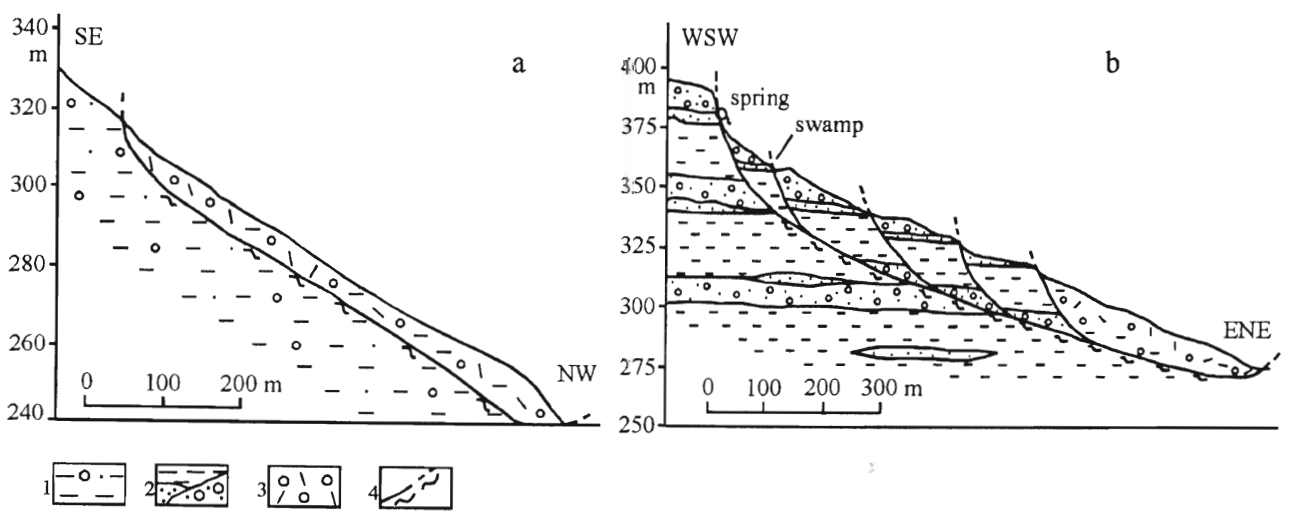


Fig. 3a, b: Cross sections through slopes representing two main sliding geological structures in the Košice district. a – landslides on slopes built up by clayey and gravelly-clayey deluvial soils covering mostly clayey Neogene sediments, locally pre-Tertiary rocks; b – "block" landslides on slopes built up by clayey and gravelly-clayey deluvial soils covering Neogene alternating cohesive and cohesionless sediments. 1 – mostly clayey Neogene sediments, 2 – alternating cohesive and cohesionless Neogene sediments, 3 – clayey and gravell-clay soils in the landslide body, 4 – slip surface.

Tab. 2
Selected physical-mechanical parameters of fine-grained soils of landslides (Dz) and fine-grained Neogene sediments – Nk (Klčovo, Stretava and Kochanovce Fms.), Ni (Kladzany and Sečovce Fms.)

Parameter	Fine grained soils					
	Dz		Nk		Ni	
	Soil class (STN 73 1001)					
	CH, CV, CI, F, CG		CH, CV, CI, F, CS		CH, CV, CI, CS, CG	
	M(x)	n	M(x)	n	M(x)	n
Liquid limit w_L [%]	53,6	93	52,7	776	54,1	119
Plastic limit w_P [%]	20,7	93	23,0	776	24,2	119
Plasticity index I_P	32,9	93	29,7	776	29,9	119
Consistency index I_C	0,97	88	0,99	722	0,96	107
Carbonate content O_u [%]	0,7	23	5,4	133	12,3	53
Effective internal friction angle φ_{ef} [°]	16,4	13	19,5	42	21,6	2
Effective cohesion c_{ef} [MPa]	0,027	13	0,023	42	0,012	2
Total internal friction angle φ_u [°]	7,3	9	6,5	66	8,9	11
Total cohesion c_u [MPa]	0,092	9	0,098	66	0,082	11
Oedometer modulus of deformation E_{oed} [MPa]						
- for load 0,1 MPa	8	2	7,3	52	7,6	10
- for load 0,2 MPa	8	2	9,5	63	8,4	10
- for load 0,4 MPa	10,5	2	12,1	63	10,2	10

ments. Disturbed sediments create "blocks" of various size (from 10 to 200 m) with surface inclined to the massif. The blocks are separated by partial slip surfaces and preserve the original sequence of Neogene layers. Undrained depressions between adjacent blocks are often filled with water (marsh or small lakes). Landslides have typical steplike surfaces and their general morphology indicates a polyphase development.

The principal causes of landslides in the area of the district are *natural* and/or *anthropogenic*. Apart from the favourable *geological setting* other relevant natural causes are – *geomorphological* and *hydrogeological conditions, excessive precipitation, rock weathering, physical-mechanical properties of rocks* and *soils, lateral erosion* by streams, *neotectonic movements* and *seismicity*.

The Hornád and Torysa valleys are the result of morphogenetic processes during the Upper Pliocene. Intensive deep erosion and mostly mechanical weathering, created good conditions, not only for solifluction, but also for sheet erosion and landsliding during the Quaternary.

Excessive rainfall and springs increase slope instability. In spite of the low average annual precipitation ranging from 558 to 752 mm, the monthly total occasionally exceeds 100 mm. Due to snow melt, there is a lot of water on slopes during the spring season. Several springs occur on slopes along the Viničná ridge. Together with rainwater they reduce slope stability by loading the slope (marsh and/or small lakes on the surface), deterioration of soil parameters, and infiltration into the layers causing the buoyancy.

Some sediments (e. g. claystones, siltstones, tuffs and/or tuffits) are greatly weathered. Some rocks are locally completely desintegrated. Physical-mechanical parameters of landslide deluvial soils and Neogene sediments in the Košice district were statistically evaluated by Petro et al. (1999). Deluvial (Dz) and Neogene (Nk and Ni) sediments have mainly the nature of fine-grained soils (Tab. 2). The ratio of cohesive (clay and silt) and cohesionless (gravel and sand) soils ranges from 6:1 to 7:1. Clayey soils have usually high or very high plasticity. Some Neogene clays are sensitive to volume changes due to Ca-montmorillonite content (Grmanová et al., 1989).

A frequent cause of slope instability in the district is lateral erosion of streams, and is found along stream valleys especially on the Viničná hilly ridge. The absence of this triggering factor in the Hornád river valley is due to the Ružín earth dam and flood protected embankments constructed along the both banks during the 60s.

Some faults have been reactivated and some new ones have originated since the Lower Pleistocene (Janočko in Karoli et al., 1998). Four terrace stages (günz, mindel, ris and würm) of the Hornád river were created by unequal tectonic uplift of depression and climatic oscillations. If we accept the existence of recent vertical movements in the Košická kotlina depression (Kvitkovič and Plančár, 1979), their activity during the Holocene is probable. Most landslides originated during the Holocene.

Seismic impact on landslides indicates several facts about the district area. According to Slovak Technical Standard (STN 730036, 1997) the area is of 6° MSK seismic intensity. Košice (Heringeš hill) recorded an earthquake with macroseismic intensity of 7° MSK, in 1676 (Procházková et al., 1978). In addition, a seismoactive N–S oriented fault has been identified in the Hornád river valley (Karoli et al., 1998). Its possible Quaternary tectonic activity was suggested by Janočko (in Kaličiak et al., 1996).

The main anthropogenic causes of landslides are earth works (cuttings, excavations, landfills), deforestation and slope watering. Impact of groundwater infiltration from active tailings on the eastern margin of district has not been confirmed yet (Grmanová et al., 1996), but is possible.

Conclusion

Landslides are not only a significant geomorphological phenomenon but are also a geological hazard in the Košice district. They represent a barrier to urban development of the area. Evaluation of landslides revealed the following facts:

1. Landslides are concentrated mainly in the east and northeastern parts of the district.

2. Two main sliding geological structures have been found: a) slopes built up mainly by the clayey sediments of Neogene and Quaternary age; b) slopes built up by alternating cohesive and cohesionless Neogene sediments with Quaternary cover.

3. The causes of landslides are: a) natural – position of layers, slope morphology, lateral erosion of streams, excessive rainfall, parameters of rocks and soils, weathering, impact of neotectonics and seismicity is possible;

b) anthropogenic – earth works, deforestation and watering of slope.

Moving building activities to slopes and/or landslide areas obliges us to study landslides in a more detailed and systematic way and to prepare maps of areas susceptible to land-slide as well as maps of actual landslide hazard areas and/or landslide risk maps. These maps will allow us to reduce the total costs of building new structures and damage to property and economic activities as well as to mitigate the negative effects of landslides on existing structures.

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Zosuvy v okrese Košice

Najvýznamnejším geologickým nebezpečenstvom pre mesto Košice sú zosuvy, ktoré každoročne spôsobujú miliónové škody na objektoch (obytných a rekreačných budovách, cestách, elektrickom vedení a potrubí) a poľnohospodárskej pôde. Rast zosuvného rizika v posledných rokoch je spätý s presunom výstavby do svahovitých území náchylných na zosúvanie. Všeobecne známe sú problémy z výstavby sídliska Furča na východnom okraji mesta (Nemčok, 1982).

Územie zaberá strednú časť Košickej kotliny, resp. okraje Čiernej hory a Volovských vrchov (obr. 1) a má typický pahorkatinný reliéf. Na jeho geologickej stavbe sa zúčastňujú kvartérne a terciérne sedimenty, ako aj litologicky pestré predterciérne horniny.

Terénnym mapovaním v mierke 1:10 000 a hodnotením leteckých snímok (v mierke 1:16 660) sa na území Košíc zaregistrovalo 87 zosuvov rozličného tvaru, stupňa aktivity, veku a hrúbky. Ich celková plocha je 10,8 km^2, teda 4,2 % z celkovej plochy (257,7 km^2). Prevažujú potenciálne a stabilizované stredne hlboké zosuvy so silnou a zreteľnou intenzitou porušenia svahu, suchým povrchom, strednou hĺbkou šmykovej plochy a miernym sklonom. Zosuvy sú holo-

cénneho až recentného veku. Výskyt lakustrinných holocénnych sedimentov a morfologická pozícia niektorých zosuvov na východnom okraji Košíc naznačuje ich pleistocénny vek. Zosuvy sa koncentrujú najmä vo východnej časti (obr. 2). Ich morfometria je zrejmá z tab. 1.

Na sledovanom území možno vyčleniť dva hlavné typy geologických štruktúr náchylných na zosúvanie: 1. zosuvy na svahoch budovaných deluviálnymi ílovitými a štrkovito-ílovitými sedimentmi v nadloží ílovitých neogénnych sedimentov, resp. predterciérnych hornín (obr. 3a); 2. „kryhové" zosuvy na svahoch budovaných deluviálnymi ílovitými a štrkovito-ílovitými sedimentmi v nadloží striedajúcich sa súdržných a nesúdržných neogénnych sedimentov (obr. 3b). Prvý typ reprezentujú plytké a stredne hlboké zosuvy porušujúce kvartérne zeminy, resp. zvetrané neogénne sedimenty v ich podloží. Druhý typ tvoria stredne hlboké a hlboké zosuvy so šmykovou plochou zasahujúcou do neogénneho podložia (až 35 m).

Príčiny vzniku zosuvov na území okresu sú prirodzené a antropogénne. Okrem geologickej stavby sú to geomorfologické a hydrogeologické pomery, extrémne zrážky (> 100 mm/mesiac), zvetrávanie hornín a s tým spojené zhoršovanie ich vlastností (tab. 2), laterálna erózia tokov, neotektonické pohyby a seizmicita. Z antropogénnych príčin dominujú zemné práce (odrezy, zárezy a navážky), odlesňovanie a prevlhčovanie svahov.

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Engineering geological assessment of the rock cliff Vyhne

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Abstract

The rock slopes of narrow valleys in Slovakia's mountainous areas are potentially instable very often. The stability problems increase in connection with various people technical activities (construction of roads, residential and industrial areas etc.). The instability of natural rhyolite cliff in the village Vyhne (Central Slovakia) endangers human life, traffic on the state road and the objects of the Steiger Ltd brewery and complicates preparation of a new road design. The engineering geological investigation was concentrated to assessment of rock mass structure (its discontinuities, blockiness and loosening). According to the results of field measurements the rock cliff was divided into homogeneous units. The stability conditions for each of them was solved and on the basis of the stability analysis the system of remedial measures was proposed.

Key words: cliff stability, discontinuity, structure of the rock mass, homogeneous units, remedial measures

Introduction

Rock mass stability problems are very frequent in mountainous areas of Slovakia. The paper deals with the stability conditions of a rhyolite cliff which instability endangers human life, traffic on the state road and the objects of the Steiger Ltd brewery in the village Vyhne. The critical stability state of the cliff was known several years ago, during which large blocks of rock were loosened and felt down. After the rock fall of the huge block in 1998, traffic on the road was limited and engineering geological investigation followed.

Geological setting

The rhyolite cliff is located in the village Vyhne, on the boundary of Štiavnické Vrchy Mts., in Central Slovakia (Fig. 1). It is about 75 metres long and 23 to 29 metres high (Fig. 2). The rhyolite belongs to huge volcanic rock body with a stratovolcanic structure. The volcanic activity was limited to Badenian and Sarmatian periods, related to dissection and disintegration of the volcanic bodies into individual structural blocks.

During the end of the Sarmatian to Lower Pannonian periods, the rhyolite volcanic activity was renewed. Channels of the rhyolite lava were formed along the well developed faults. The volcanic body represents an extrusion of a laccolith type penetrating the older Sarmatian rocks, characterised by a high viscosity and explosive behaviour. During the Pliocene and Pleistocene, continued uplift caused denudation and separation of the extrusive flows into individual regional bodies. Intense frost weathering in periglacial conditions of Early Pleistocene locally caused total disintegration of the rhyolite bodies resulting into extensive areas of slope debris and scree sediments deposited mostly at the toes of steep slopes (Konečný, 1998).

The rhyolite body is bordered by a tectonic fault system, oriented generally in a NE–SW direction, dipping to SE. The general orientation changes to NNE–SSW, or N–S, locally. The rock mass discontinuities are interpreted to be joints caused by the rock cooling, weathering, or by the tectonic activity. An irregular spatial arrangement of the discontinuities causes a blocky rock mass, variable in forms and sizes.

Structure of the rock mass

Stability of the cliff parts is evidently estimated by the orientation of discontinuity planes dividing the rock mass. They influence also the conditions for progressive loosening of the cliff face, and the rock fall from the cliff.

For the estimation of discontinuity parameters and their properties, the following methods have been used:

– Direct measurements of the discontinuity parameters at the toe of the cliff and in 5 specified profiles (Fig. 3) by the "climbing method".

– Indirect measurements using terrestrial photogrammetry methods (23 profiles) in stereoscopic mode. These methods enable the topographic configuration of the cliff face to be produced, to draw characteristic profiles in any part of the cliff, to evaluate the spacing and the orienta-

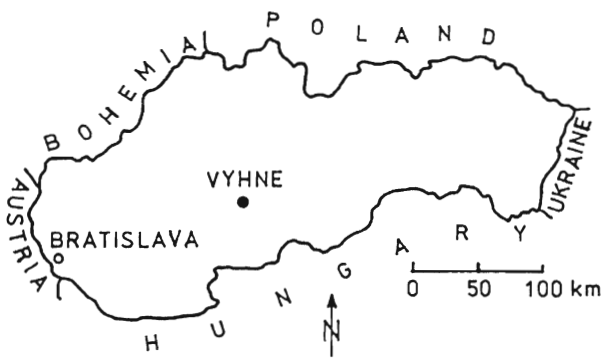

Fig. 1. Location map.

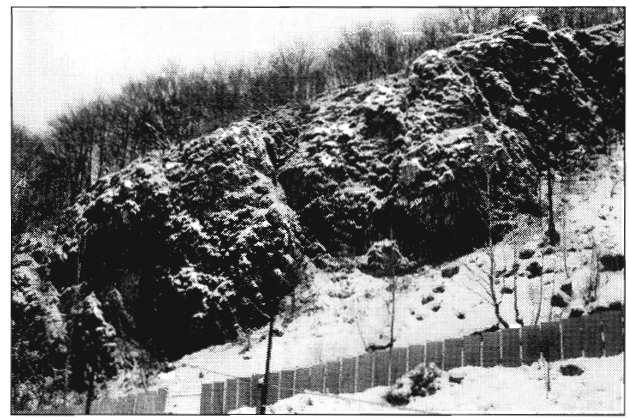

Fig. 2. A general view of the Vyhne cliff. In the lower part of photo is the fence of the Steiger brewery (Bartoš and Gregor, 2000).

tion of the discontinuity planes (Bartoš, Gregor in Fussgänger et al., 1999).

The results of measurements indicate a very steep dip of discontinuity planes. It is possible to distinguish the following main sets of discontinuity (Fig. 4):

Set 1 (striking NE–SW) represents tectonic joints conformable with the orientation of the main fault dislocation. Set 2 (NNE–SSW) and set 3 (NW–SE, NNW–SSE up to N–S) include systematically arranged tectonic joints non-conformable with any fault dislocation. Significant set 4 (NW–SE), in the complicated non-regular joint pattern can represent primary cooling joints. It is completed by the weathering joints due to the entire rock mass disintegration and loosening. Dominant among them is the tension crack subparallel to the rock face (see profile Pf 12, Fig. 5 and 6), reaching a width of 1.5 m and depth of

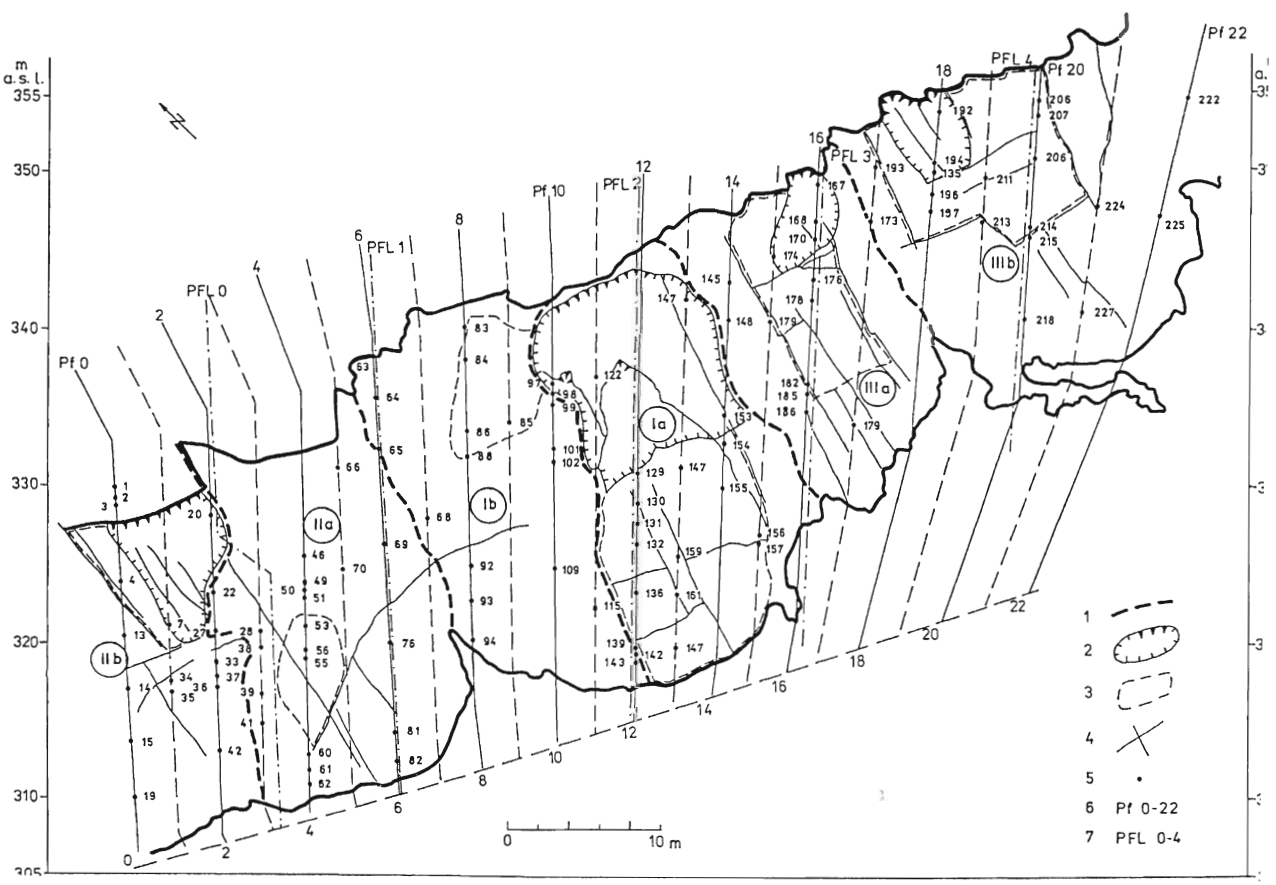

Fig. 3. A face of the rhyolite cliff. 1 – the borders of homogeneous units and sub-units, 2 – most unstable parts of the cliff with discontinuities of separation, 3 – less unstable parts, 4 – expressive discontinuities, 5 – number of measured discontinuities, 6 – photogrammetric profiles, 7 – profiles of direct measurements of discontinuities (used photogrammetric plan according to Bartoš and Gregor, 2000).

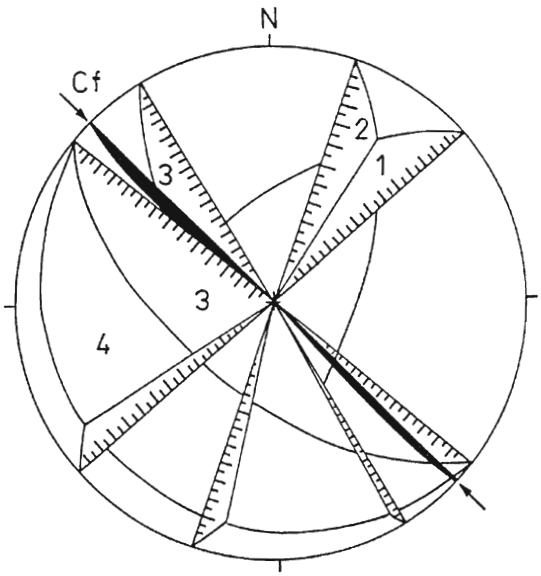

Fig. 4. Stereographic projection of principal discontinuities sets (1 up to 4) and the cliff face (Cf).

5 and more metres, filled with rock rubble. Other weathering strain release cracks causes the detachment of huge rock blocks (in volume up to 5 m^3).

Loosening of the rock mass is connected with the above mentioned dense discontinuity pattern of the rock mass, which is emphasised by the influence of weathering. Due to the steep joints dip, the penetration of weathering agents (chiefly water) is very intensive. In the near-surface zone the rock mass is almost completely loose and has the shape of free deposited blocks in some parts. The partial movement of such structure could be evoked by a minimum disturbance.

The basic shape and size of rock blocks are determined by the spatial parameters of the main discontinuity sets. Due to the process of loosening acting predominantly along the joints, the size and the shape of blocks change considerably from place to place. Irregular blocks with some transitions into tabular or rhomboidal type prevail. The size of blocks is very irregular, too - from some m^3 down to small lumps or particles (cm in diameter).

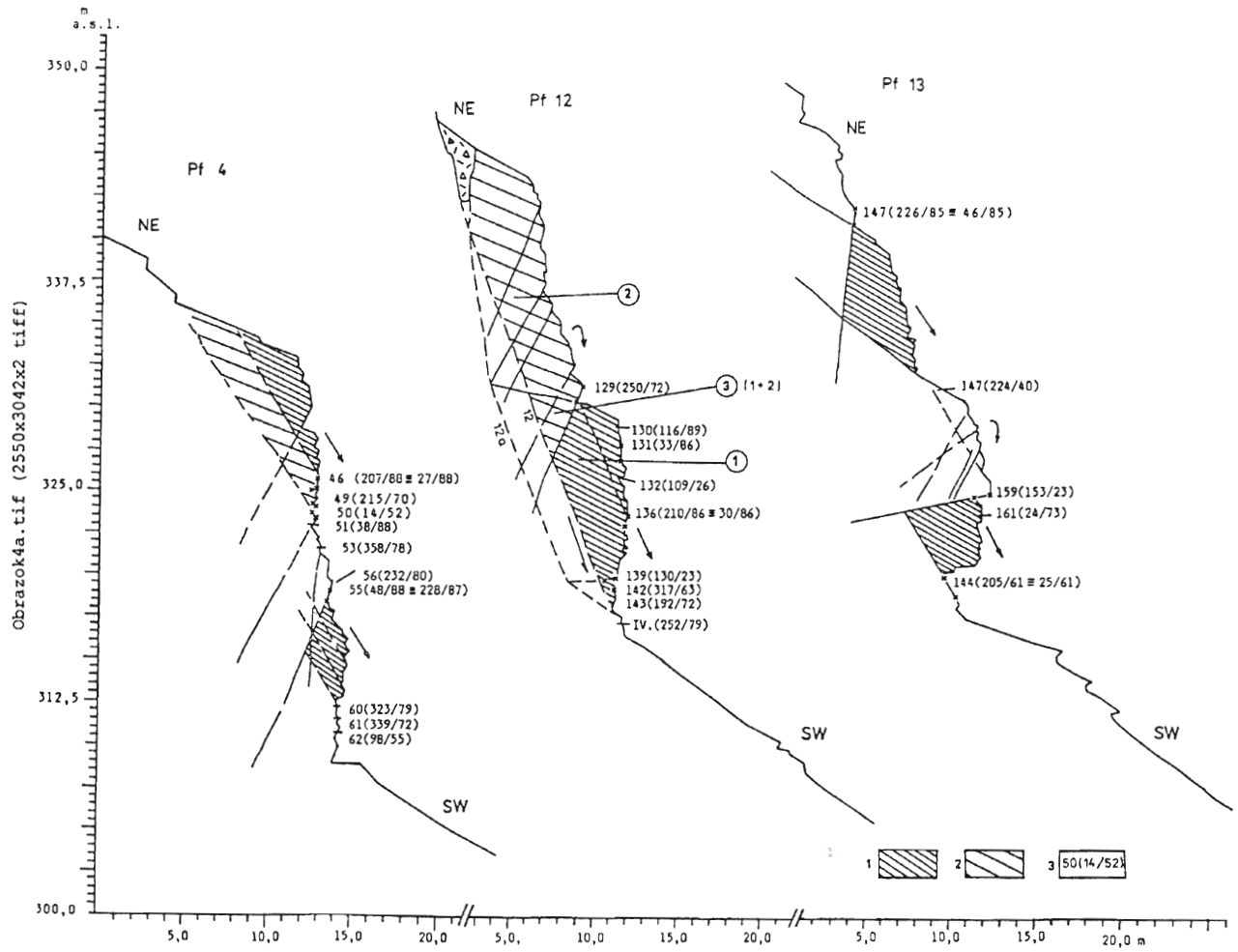

Fig. 5. The representative profiles of the unstable parts of the cliff. 1 – the most unstable parts of profiles, 2 – less unstable parts, 3 – number (dip direction/dip) of measured discontinuity.

Engineering geological zoning

The critical state of the cliff depends on its geological development. Favourable conditions for slope failure are conditioned by its intensive tectonic disintegration, lubrication and pressure effects of the joint water and processes of weathering. The process of rock weathering acting along weakness planes and entirely in rock blocks increases permeability and decay.

Considering all important data about the rock mass structure it is possible to zone it according to the degree of disintegration and the degree of endangering underlying objects. Primary information about the rock mass, its discontinuity and processes of loosening enables the rock mass to be divided into quasi-homogeneous units. Each of them is characterised by the various intensity of disintegration and stability conditions.

According to the the shape and size of basic blocks in the structure influencing the decreased stability of the cliff, the rock mass was divided into three main homogeneous units I., II., and III. The degree of deterioration, loosening and decay of the structure, individual types of cliff instability are decisive for the further subdivision into more or less decomposed sub-units (Fig. 3).

Due to obtained data sub-unit Ia becomes the most unstable part. The joint sets 3 and 4 which prevail in this unit undercut the cliff face. Unit IIb represents the part of wall with slightly better stability.

The unit III does not endanger the objects at the cliff toe significantly due to the greater distance away from the cliff.

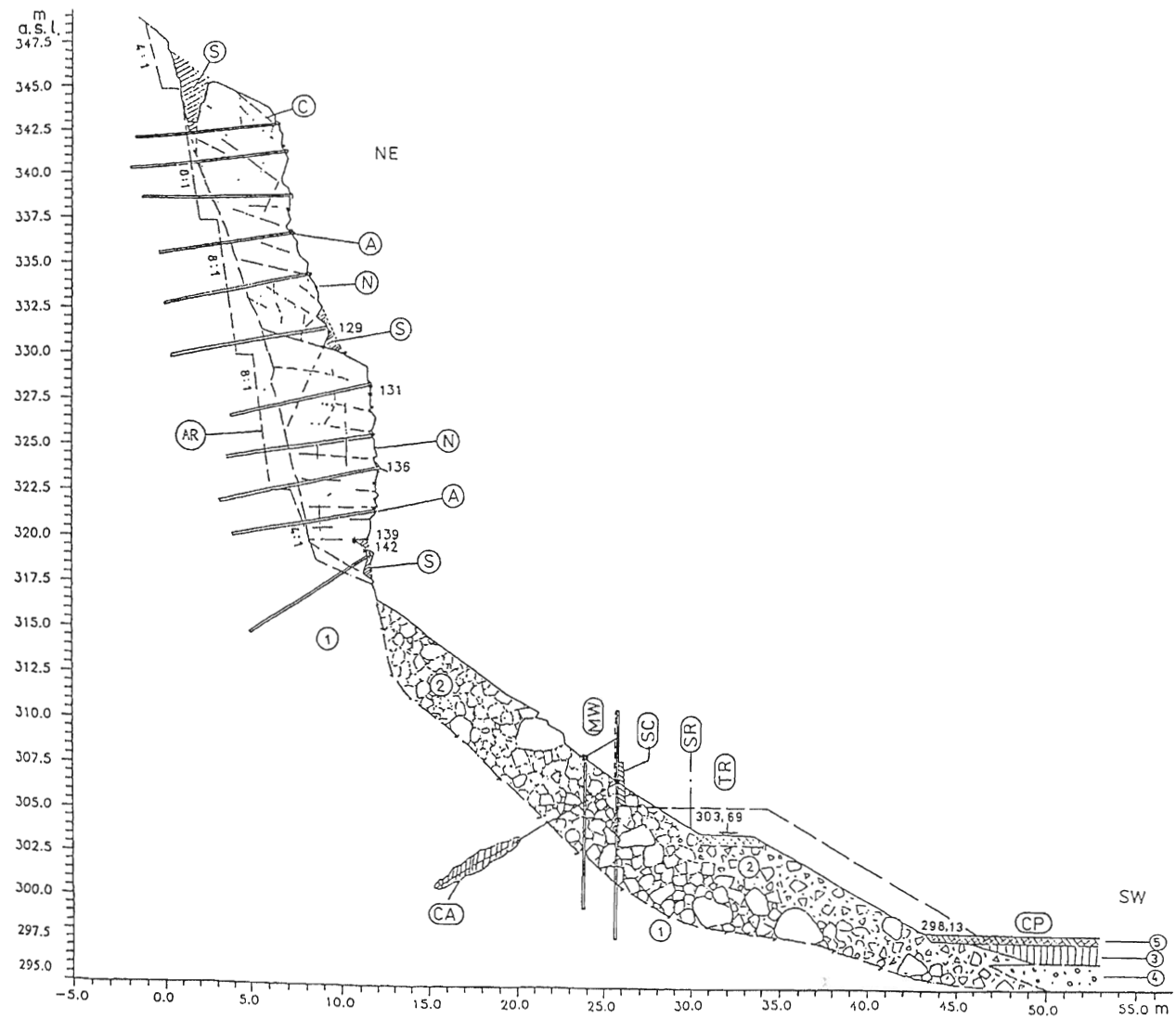

Fig. 6. Typical profile with proposed remedial measures (according to Sikora in Fussgänger et al., 1999). 1 – rhyolite (Neogene), 2 – coarse scree and huge rockfall blocks, 3 – fluvial clayey sand and clay, 4 – fluvial gravel, 5 – artificial deposits (2–5: Quaternary), C – cleaning the wall, S – concrete sealing and support, A – bar anchors non-prestressed, N – anchored cables and protective net, AR – alternative solution with a modification step-extraction of the strongly disturbed parts of the cliff, CA – cable anchors, MW – supporting and catching anchored micropile wall, SC – final setting with the stone casing, SR – the axis of the proposed state road, TR – the axis of temporal access road, CP – cancelled parking place.

Stability analysis

The estimation of the cliff stability was realized by the utilisation of graphical and computing methods. Stability was graphically assessed in all photogrammetric profiles (Fig. 3), as well. Examples of representative profiles of unstable units of rock wall are presented in Fig. 5 (Pf-4 in unit IIa, Pf-12 and Pf-13 in Ia).

Weakness planes which substantially decrease the stability of the cliff were expressed using the graphical Markland (1972) method. It allows the division of the cliff into unstable and potentially unstable units in profiles.The relationship between the discontinuity measurements and the rock wall orientation indicates that the fall of blocks develops mainly along planes which are parallel to the cliff face (dip direction 200° to 240°) with the dip lower than that of the cliff face. Thus, the originating failure is of planar type. Rarely other combined types of failure – toppling and wedge failures – occur.

Laboratory testing has been provided to obtain data for special stability analysis which asks for the estimation of the uniaxial compressive strength values. According to results of laboratory tests on regular and non-regular samples, siliceous rhyolite is very solid and brittle. Bulk density of rock varies from 2.36 g.cm^{-3} to 2.46 g.cm^{-3}. Unexpected high porosity (about 7%) results from a dense net of microfissures. The point load tests show extremely high strength of rock lumps (values $Is_{(50)}$ vary from 6 to 11 MPa), but the uniaxial compressive strength on regular cubic samples (5x5x5 cm) varied from 70 up to 120 MPa. The strength in indirect tension of saturated cubes was estimated from 8 to 20 MPa. On the basis of the laboratory value of uniaxial compressive strength using the criterion of deterioration of solid rocks (according to Hoek and Brown in Turner, Schuster, 1996), the shear parametres of the rhyolite mass were indirectly determined (φ = = 47°, c = 170 kPa).

Calculation according to Kovári and Fritz (1976) shows the lowest degree of stability in profile Pf 10 (degree of stability F = 1.062) and in upper parts of profiles Pf 12 (F = 1.228) and Pf 13 (F = 1.243). Potentially unstable are also blocks in upper cliff part in profiles Pf 1, Pf 2 and blocks in profiles Pf 16, 17 and 18. Generally, the calculation confirmed the field observation which estimated the lowest degree of stability in sub-units Ia, IIb and IIIa. The stability coefficient was used in proposal of remedial measures (Drusa in Fussgänger et al., 1999).

Remedial measures

After summarising the real possibilities and cost of the various proposals, the technical remediation of the rock cliff was designed (Sikora in Fussgänger et al., 1999). A complex of remedial methods has been illustrated in one of the most unstable profiles, Pf 12 (Fig. 6).

The following remedial measures were designed:

– construction of the supporting and catching anchored micropile wall, which will serve as a retain wall after the road construction,

– anchored cables and protective net on the whole cliff face,

– anchoring (non-prestressed) of the most unstable parts of the cliff,

– filling up of open cracks with cement mortar,

– coat the strongly weathered parts with shot concrete.

The proposed remediation helps to solve the geotechnical problem of the new construction of the state road which was designed as part of improvement of the environmental conditions below the cliff.

Acknowledgments. The authors are thankful to the Ministry of the Environment of Slovak Republic for its kind permission to publish this paper. The authors would also like to express thanks to the Grant Agency VEGA (scientific grants No 1/7364/20 and No 1/5216/98) for its support in presented work.

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Inžinierskogeologické zhodnotenie skalného brala Vyhne

Nestabilita skalného brala v horninovom telese ryolitu, prejavujúca sa uvoľňovaním a pádom blokov horniny (často v objeme niekoľkých m^3), ohrozuje ľudí, štátnu cestu a prevádzku v pivovare Steiger vo Vyhniach. Inžinierskogeologický prieskum lokality sa sústredil najmä na hodnotenie štruktúrnych prvkov, ktoré v rozhodujúcej miere spôsobujú nestabilitu jednotlivých častí brala. V prieskume sa použilo viac metód, najmä pozemná fotogrametria, ako aj priame meranie diskontinuity a stanovovanie jej parametrov. Podrobná dokumentácia diskontinuít, doplnená laboratórnym určením vlastností horninového materiálu, umožnila rozdeliť skalné bralo na kvázihomogénne celky, zhodnotiť stabilitný stav v každom z nich a navrhnúť efektívne a ekonomicky prijateľné sanačné opatrenia. Na základe inžinierskogeologického prieskumu vypracoval GEOstatik, s. r. o., Žilina projekt sanácie, ktorý sa realizoval krátko po skončení prieskumu na jeseň roku 1999 a spočíval v prikotvení uvoľnených blokov, v aplikácii ochrannej siete, vyplnení otvorených puklín cementovou zmesou a povrchovou ochranou vytypovaných častí začistenej steny.

Mineralia Slovaca, 32 (2000), 425–428

Photogrammetric evaluation of the Vyhne rock cliff stability

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Abstract

Analytical terrestrial photogrammetry was used for monitoring of the Vyhne rock cliff. The method enables to check the stability of rock cliff cuts and is based on spatially measured model as well as remote (noncontact) evaluation of geodynamic events.

The 3D measurement is a good base for evaluation of the rock cliff structure and its breaks at the most important components of the stability especially in parts, where standard survey is impossible. It also enables the identification of quasihomogeneous parts concerning stability and indirectly yields data necessary for stability measures.

Key words: terrestrial stereophotogrammetry, analytical photogrammetry, photogrammetry with time base, digital terrain model (DTM), camera, camera orientation, photo-coordinates, horizontal parallaxes

1. Introduction

In engineering geology for last decades have been used methods of terrestrial photogrammetry for monitoring of the stability of rock masses. In the application presented are taken into consideration:

- terrestrial stereophotogrammetry suitable especially for profile measurement, measurement of the orientation of discontinuity planes as well as expanding the rock cliff wall into the plane or transformation of perspective contour lines respectively,
- analytical method used in the case of measuring not too many points with high accuracy required,
- methods of time base, yielding the highest accuracy of displacements determination in the plane parallel) with the image plane.

Contribution to uses of methods mentioned above in different engineering-geological applications can be (Holzer, 1995):

- detailed expression of the morphology of rock massif,
- determination of structural, lithologic and tectonic lines of the massif,
- yielding of quantitative data concerning position, orientation, density of discontinuities, blocks etc. in massif,
- metric photographs are primary materials for engineering-geological interpretation of basic characteristics of the massif as well as for the quantitative spatial evaluation of the massif as by detail points or profiles,
- possibility of identification of quasihomogeneous parts with respect to the stability together with indirect data necessary for stability measures,
- outstanding data for remote evaluation of geodynamic events.

2. Rhyolite rock cliff Vyhne

Rhyolite rock cliff in Vyhne is in neighborhood of the brewery Steiger on the slope NE over main road in elevation of 306–360 m above sea level, while the base of the rock cliff is at the level of 306–335 m above sea level and the top of rock cliff at the level of 331–360 m above sea level. The exposed part of the rock cliff taken in account is in average 75 m long and 26 m high with inclination of 80–90°. Rhyolite rock cliff was divided into three areas (I, II, III) with two subareas (a, b) with the most potentially dangerous subarea Ia, the most predisposed to fall down (Holzer et al., 2000).

3. Results of geodetic and photogrammetric measurements

Among essential input data for preliminary engineering geologic investigation as well as for safety measures and monitoring are results of three geodetic-photogrammetric measurements:

- XII/1998 – stereophotogrammetry used for profile measurements, orientation of discontinuities and expanding the rock cliff wall into the plane XZ in combination with tachometric measurement,
- IX/1999 – stereophotogrammetry for repeated profile measurement after cleaning the rock wall from loosen fragments, smaller blocks and vegetation and simultaneously stereomodel for digital terrain model (DTM) of the rock cliff,

– X/1999 – pictures for monitoring of rock cliff stability using the method of analytical terrestrial photogrammetry from metric as well as semimetric and nonmetric cameras.

3.1 Geodetic measurement

The main goal of geodetic measurement is co-ordinate determination of pass-points necessary to reconstruct geometric relation of photogrammetric processing usually in local co-ordinate system (Sokol, 1999). Mostly used is the polar method in combination with spatial intersection respectively. Coordinate system is oriented with respect to magnetic north by means of special compass with accuracy of 0.1 gon.

As a measuring instrument total station TOPCON GTS GA is used – the theodolite with distance-meter yielding distance measurement accuracy of 3 mm ± 2 pp m.

Tachymetric measurement of the main road with parking place as well as accessing road to the brewery required the micro-network in the form of triangle in local coordinate system. Elevations are in the state elevation system Balt after adjustment derived from the benchmark No. 11. The plan of the area of interest is in Holzer et al. (2000).

3.2 Photogrammetric field work

Before taking photographs pass points are marked by means of diagonal targets with size (formal) of 10/10 or 15/15 cm with respect to their distance. Photographs were taken with universal metric camera UMK 10A Zeiss with wide-angle lens. Optimal location for photogrammetric base was the roof of the storehouse.

Methods of time base is suitable for monitoring of displacements of rock cliff blocks using pictures taken at given time interval with the same camera and the same camera orientation and camera station (the same interior and exterior camera orientation).

3.3 Data processing

Methods of data processing used for this application are analog as well as analytical methods. Basic input data for analytical processing are photo-coordinates and horizontal parallaxes measured on stereocomparator. Stereocomparator Zeiss STEKO 1818 is at disposal equipped with encoders of photo-co-ordinates and parallaxes measured and registered by means of computer on the disc.

Results of analytical processing for preliminary investigation of the rock are:

– photogrammetric profiles of the rock cliff with regular interval – 23 profiles,
– orientation of discontinuities.

3.3.1 Profile measurement

With regard to broken foot-line the rock cliff is its part among profiles 0 to 16 approximately parallel to the photogrammetric base with average interval of 2.5 m and

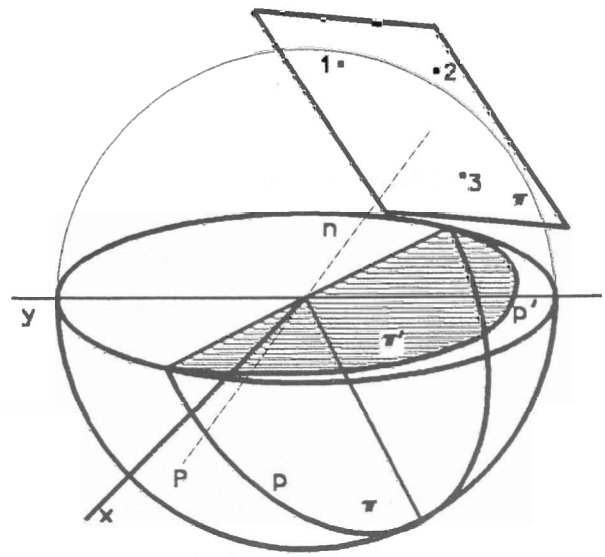

Fig. 1. Graphical presentation of the discontinuity.

with increasing distance of the rock cliff from the base increases also interval among profiles up to 3.5 m (pf. 17–22).

The irregularity of interval among profiles in situ is caused by regular interval of perspective profiles in the image plane only as constant difference in the photo-coordinate x' (in the case given $\Delta x' = 3.00$ mm). The effect of the perspective is resulting in convergence of profiles in the left perspective center of photogrammetric base.

Processing of profile data starts with determination of coordinates of detail points in the local photogrammetric coordinate system taken transformed using spatial transformation into reference coordinate system. Photogrammetric profiles with corresponding engineering-geological interpretation are in paper Holzer et al. (2000).

3.3.2 Photogrammetric measurement of discontinuities orientation

Discontinuity inclination and the azimuth of the inclination give discontinuity orientation. Graphical presentation of the discontinuity (Fig. 1) is based on the assumption, that the plane π approximating the discontinuity is projected in direction of the normal **n** into the lower hemisphere passing through its center as the origin of the left-handed Cartesian coordinate system (x, y, z). Simultaneously the globe center is projected into the pole P as foot-point of the normal vector on the lower hemisphere surface. Intersection line p of the plane π with surface of the lower hemisphere as well as the pole P are projected into the horizontal plane π' passing through the center of the globe.

Formulas for calculation of orientation elements of discontinuities are derived from vector formula of the plane defined by three non-colinear points $1(\mathbf{r}_1)$, $2(\mathbf{r}_2)$, $3(\mathbf{r}_3)$ or $1(x_1, y_1, z_1)$, $2(x_2, y_2, z_2)$, $3(x_3, y_3, z_3)$ respectively (Bartoš et al., 1982), (Fig. 1):

$$(\mathbf{r} - \mathbf{r}_1)[(\mathbf{r}_2 - \mathbf{r}_1) \times (\mathbf{r}_3 - \mathbf{r}_1)] = 0 \qquad (3\text{–}1)$$

The vector product in the formula (3–1) is the vector of the normal **n** of the plane π:

$$\mathbf{n} = (\mathbf{r}_2 - \mathbf{r}_1) \times (\mathbf{r}_3 - \mathbf{r}_1) \qquad (3\text{–}2)$$

Formulas expressing coordinates of the normal vector derived from formula (3–2) in left-handed Cartesian coordinate system are:

$$\begin{aligned} x &= \Delta y_{21}\Delta z_{31} - \Delta z_{21}\Delta y_{31} \\ y &= \Delta z_{21}\Delta x_{31} - \Delta x_{21}\Delta z_{31} \\ z &= \Delta x21\Delta y_{31} - \Delta y_{21}\Delta x_{31} \end{aligned} \qquad (3\text{–}3)$$

and the normal length:

$$n = x_2 + y_2 + z_2 \qquad (3\text{–}4)$$

Calculation of the direction of discontinuity inclination α

The bearing of the discontinuity σ is given by formula (Fig. 2, σ_I and σ_{II})

$$\sigma = \text{atan } y\,x \qquad (3\text{–}5)$$

with regard to quadrants (Michalčák and Sokol, 1999).

The direction of discontinuity inclination α in geographic coordinate system (from magnetic north) is given by formula (Fig. 2, α_I and α_{II}):

$$\alpha = \sigma - \sigma_s \qquad (3\text{–}6)$$

where σ_s is bearing of the magnetic north in left-handed Cartesian co-ordinate system.

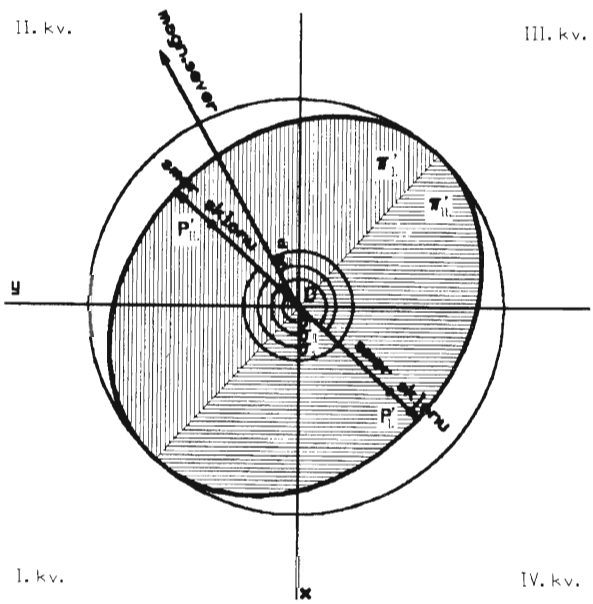

Fig. 2. Direction of discontinuity inclination α.

Calculation of the discontinuity inclination β

Bearing of the discontinuity inclination ψ in left-handed Cartesian co-ordinate system is (Fig. 3, ψ_I and ψ_{II}):

$$\psi = \text{atan } z \;\; n_2 + z_2 \qquad (3\text{–}7)$$

Discontinuity inclination β with regard to following conditions is:

if $\psi \leq 90° \Rightarrow \beta = 90° - \psi$ corresponding to red scale reading of the geological compass,

if $\psi > 90° \Rightarrow \beta = \psi - 90°$ corresponding to black scale reading of the geological compass.

Photogrametric determination of discontinuities parameters is based on measurement of photo-co-ordinates of trinity points defining corresponding discontinuities transformed into left-handed Cartesian co-ordinate system. Trinity points are selected to define the discontinuity as well as possible. The number of trinity points depends upon the range of discontinuity plane and resulting discontinuity inclination and its direction is determined as the mean value of individual discontinuity parameters.

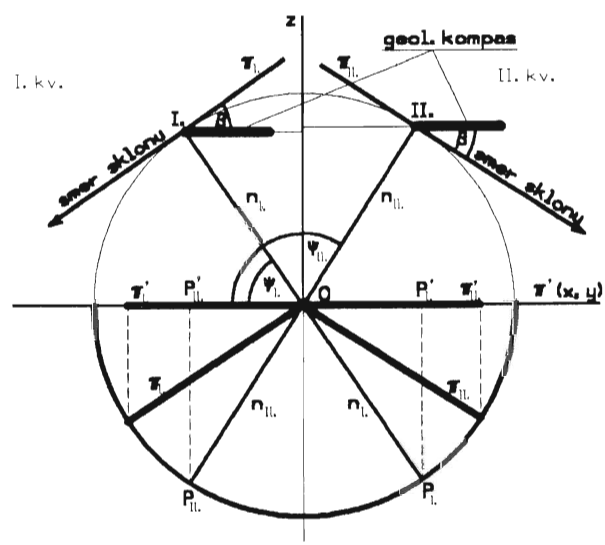

Fig. 3. Discontinuity inclination β.

3.3.3 Expanding the rock wall into XZ (vertical) plane

Required graphical output for safety measures calculation as well as for design was expanding the rock cliff wall into vertical (XZ) plane. Relative height of the rock cliff, the short distance for camera station located on the roof were reasons to take photographs with horizontal camera axis and longer formal size up. Plotting instrument for terrestrial photogrammetry – stereoautograph 1318

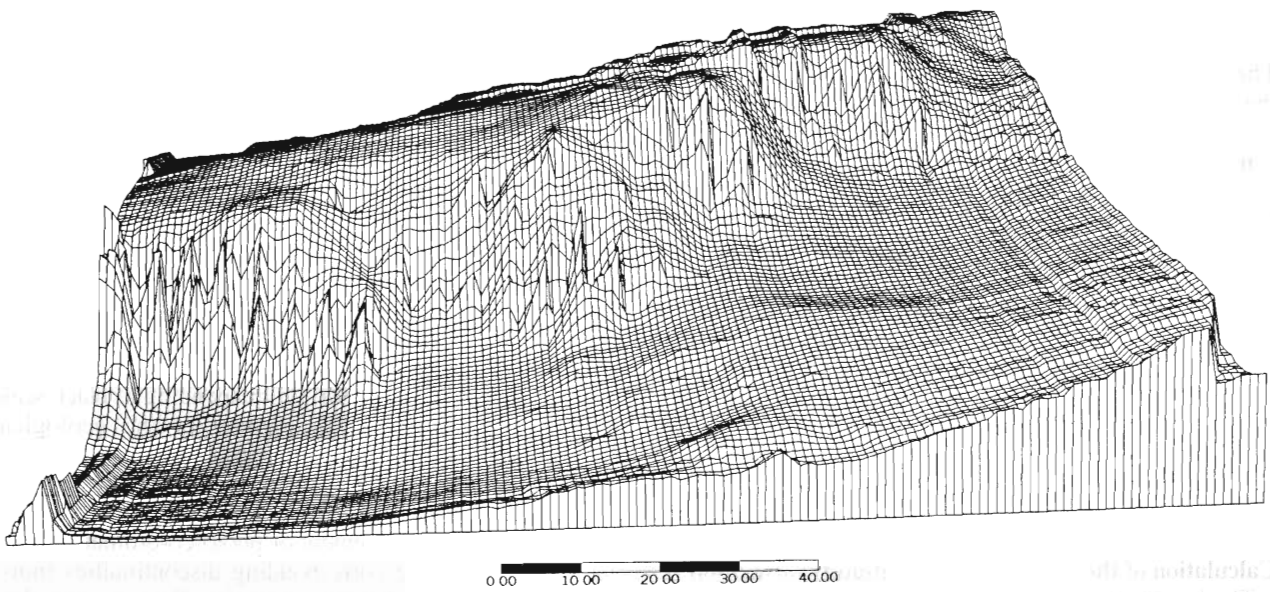

Fig. 4. Digital terrain model of the rock cliff Vyhne.

Zeiss – does not enable plotting this way oriented pictures and therefore universal plotting instrument stereometrograph D Zeiss was used. With regard to the instrument parameters and maximal object distance of 130 m as optimal plotting scale of the expanded wall was 1:200; witch is with corresponding engineering-geological interpretation in paper Holzer et al. (2000). The subject of the plotting are upper and lower edges of the rock, three areas (I, II, III) with two subareas (a, b) as well as lines and numbered areas of expressive discontinuities.

3.3.4 Digital terrain model of the rock

In spite of irregular density of detail points by profile measurement is it possible to use profiles for relatively acceptable approximation of spatial illustration of the rock cliff by means of digital terrain model. Fig. 4 presents digital terrain model of the rock cliff viewed from the camera station, using program SURPHER

4. Conclusion

Facts mentioned above concerning use of possibilities of terrestrial photogrammetry methods and their application for the stability evaluation of the rock in Vyhne show as convenience of terrestrial photogrammetry as well as its contribution in the area of engineering geology in general.

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Fotogrametrické hodnotenie stability skalného brala vo Vyhniach

Na monitoring skalného brala vo Vyhniach sa použila analytická pozemná fotogrametria, ktorá na základe priestorového merateľného modelu umožňuje monitoring stability zárezov v skalnom brale, ako aj diaľkové (bezkontaktné) hodnotenie geodynamických javov. Priestorový model je dobrým východiskom na hodnotenie štruktúry skalného brala a jej porušenosti ako najdôležitejších zložiek stability najmä na miestach, kde štandardný prieskum nie je možný, umožňuje identifikovať kvázihomogénne celky podľa stability a nepriamo poskytuje údaje potrebné na návrh sanačných opatrení.

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Gravitational tectonics and slope deformations along the tunnel line Višňové in the Lúčanská Fatra Mts., Slovakia

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Abstract

Unexpectedly high water inflow, totally about 250 litres per second, occurred during the driving of a pilot tunnel for the Višňové tunnel through granitic rock of Lúčanská Fatra mountain. Numerous slope deformations were detected by the surface survey as well as by the geophysics linked to fault zones. Existence of the two phenomena could be explained by the principles of extension and gravitational tectonics.

Key words: gravitational tectonics, fault zones, stress release

Introduction

Lúčanská Fatra mountain lies in northwest Slovakia. Geology of the mountain has been studied by several authors, e.g. Andrusov, Kuthan (1944), Ivanov, Kamenický (1957), Mazúr (1963), Rakús (1993). Tectonic inhomogeneity in respect to engineering projects has been studied by Ondrášik, Matejček and Trabalíková (1990). Preliminary engineering geological investigation for the Višňové highway tunnel was carried out in 1997–1998 (GEOHYCO, 1998). Engineering geological model of the rock mass in the line of the tunnel was set up, and a detai-

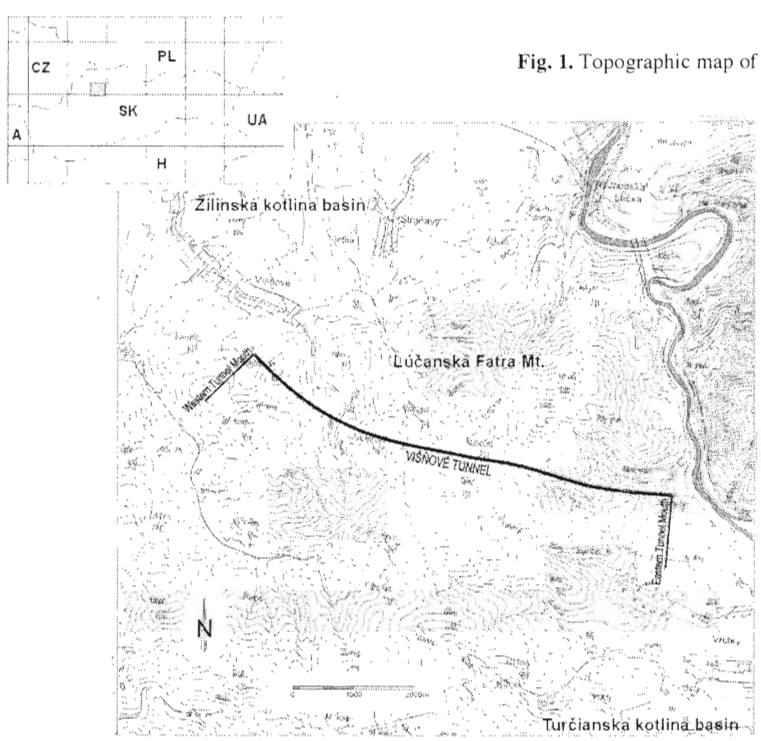


Fig. 1. Topographic map of the Tunnel Višňové area.

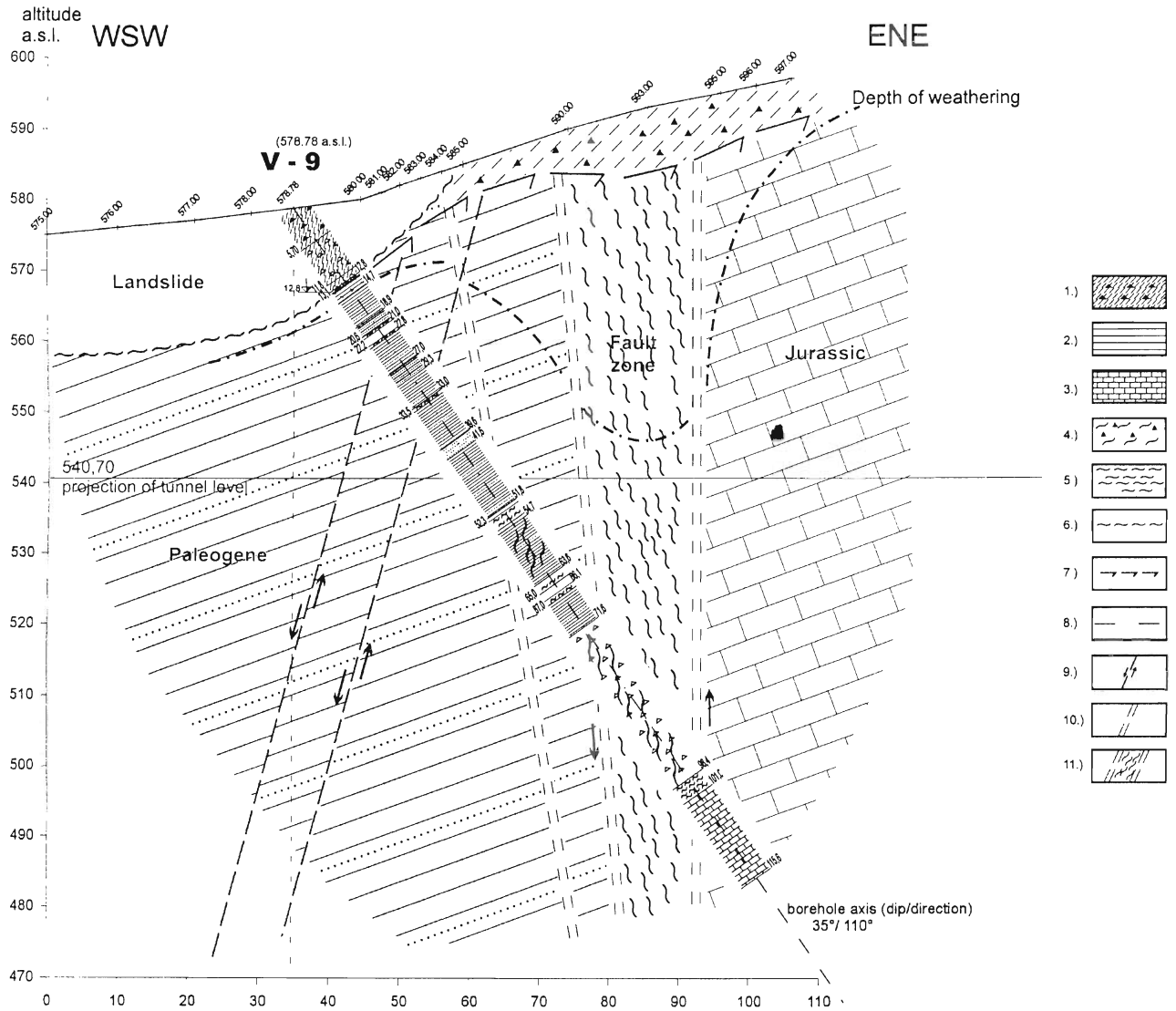


Fig. 2. Scheme of a tectonic contact between Mesozoic suits of the Malá Fatra with the Paleogene flysch in the bore hole V-9. (Matejček, 1999). 1 – Quaternary – landslide in colluvium, 2 – Paleogene flysch – layers of claystone and sandstone, 3 – Mesozoic suit – limestone of Lower Jurassic, 4 – Tectonic breccia composed of limestone and claystone, 5 – Tectonic clay (gouge), 6 – Shear zone, 7 – Indicated surface of pre-Quaternary bedrock, 8 – Indicated depth of weathering, 9 – Tectonically deteriorated zone with thickness up to 0.1 m and indicated movement direction, 10 – – Fault zone with thickness up to 1 m, 11 – Fault zone with thickness up to 10 m.

led engineering geological investigation by the pilot tunnel started at both ends of the tunnel in 1999. About 3 km from the east and 1.5 km from the west mouth have been driven to date. The results of the investigation and their interpretation are discussed here.

Geomorphology and Geology

Lúčanská Fatra mt. is a horst between Žilinská kotlina basin on the northwest and Turčianska kotlina basin on the southeast. It has the shape of an extented mountain range with a wide central ridge running northeast to southwest. The total length is about 45 km and width 7 to 15 km. The central ridge is rimmed by parallel ridges which are dissected by deep valleys, with rock cliffs on the slopes. The maximum height of the central ridge is 1467 m a.s.l. (Veľká Lúka). The maximum altitude along the tunnel line reaches 1300 m a.s.l (Fig. 1). The altitude of parallel ridges reaches 1000 to 1100 m a.s.l. Average annual precipitation is 1200 to 1400 mm per year.

The erosion basis is 490 m a.s.l. in the norhwest part of the Žilinská kotlina basin, 390 m a.s.l. in the north--west part of the Turčianska kotlina basin respectively. Kainozoic fill in the Žilinská kotlina basin consists of Central Paleogene flysch sediments. Maximum thickness is shown by geophysics to be up to 1200 m (Šalagová et al., 1996). Neogene sediments occur to a very small extent. The thickness of Quaternary deposits is over 20 m. Turčianska kotlina basin is filled with Neogene deposits with a thickness of 1027 m verified by borehole ZGT3

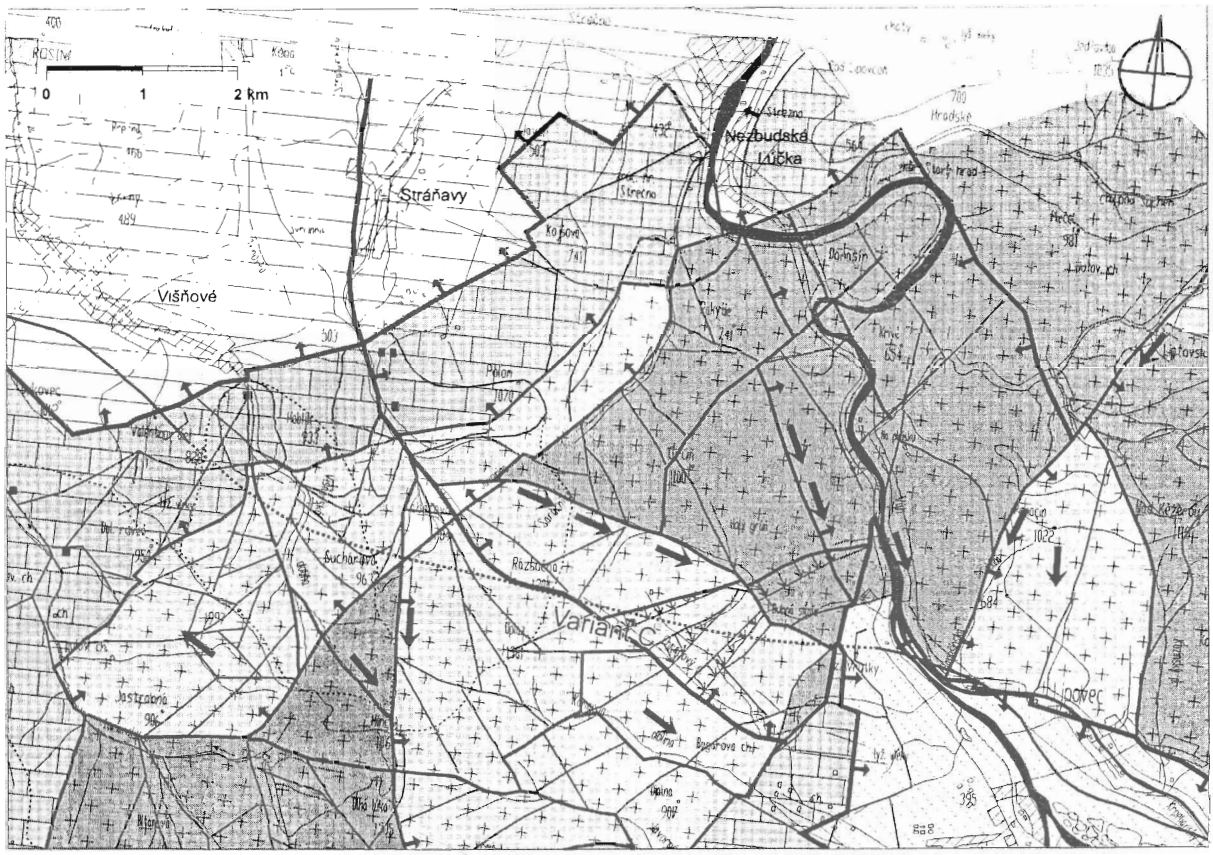


Fig. 3. Scheme of tectonic inhomogeneity (Ondrášik, 1998 in GEOHYCO 1998). 1 – Crystalline rocks granitoids undistinguished, gneiss, 2 – Mesozoic rocks undistinguished, 3 – Paleogene fill of Žilinská kotlina basin, 4 – Neogene fill of Turčianska kotlina basin, 5 – Tectonic faults of the I. rank, 6 – Tectonic faults of the II. rank, 7 – Tectonic faults of the III. rank, 8 – Stress-release direction in selected blocks, 9 – Area of strongly loosened (disrupted) and water-saturated crystaline rocks, 10 – Area of Mesozoic rocks with joint and karst permeability, 11 – Protected zone of ground water resources, 12 – Opening of joints due to the stress release in adjacent rock mass units.

(Hók et al., 1998). The thickness of Quaternary deposits is up to 35 m (Fussgänger and Jadroň, 1977).

The geology of Lúčanská Fatra mountain is very complex, with variscian pre-Upper Carboniferous crystalline core, Alpine Mesozoic mantle and overthrusted units. Pre-Quaternary bedrock is covered by the Quaternary mantle, except for rock cliffs.

The central ridge is composed of crystalline rocks. Parallel ridges as well as the southern part of the central ridge consist of Mesozoic sedimentary suits. Foliation in crystalline rock and bedding planes in sedimentary rocks incline generally to the northwest, with local anomalies. Mesozoic suits are built up by three tectonic units – the sedimentary mantle in transgressive position on underlying crystalline rock, and two overthrusted units – the lower Križňan and upper Choč nappes. Clastic and carbonate sediments alternate in all three units. They are intensively tectonically deformed. Mesozoic sediments are in tectonic contact with Kainozoic fill of the basins. The tectonic contact between the Mesozoic suits of Lúčanská Fatra mt. and Paleogene flysch of Žilinská kotlina basin was detected by borehole V-9 (GEOHYCO 1998, Fig. 2).

On the basis of the data obtained and geomorphological analysis, using aerial photographs, a map of the tectonic inhomogeneity of the studied area was compiled on the scale 1:50 000 (A scheme is shown in Fig. 3). Assumed direction of vertical as well as horizontal components of movement is indicated by the delineated fault lines. Predicted faults were delineated in the map on the scale 1:5000 (Fig. 4). A cross-section forecast along the tunnel line was also set up (Fig. 5).

Hydrogeology

Regional hydrogeological study was carried out (Šalagová, et al., 1983). It was noted that, there is a deficit of groundwater in the balance of precipitation, surface outflow and discharge from springs. Hydrogeology of

Fig. 4. A section of the geology map in the scale 1:5000 (Vrábľová, 1988 in GEOHYCO 1998).

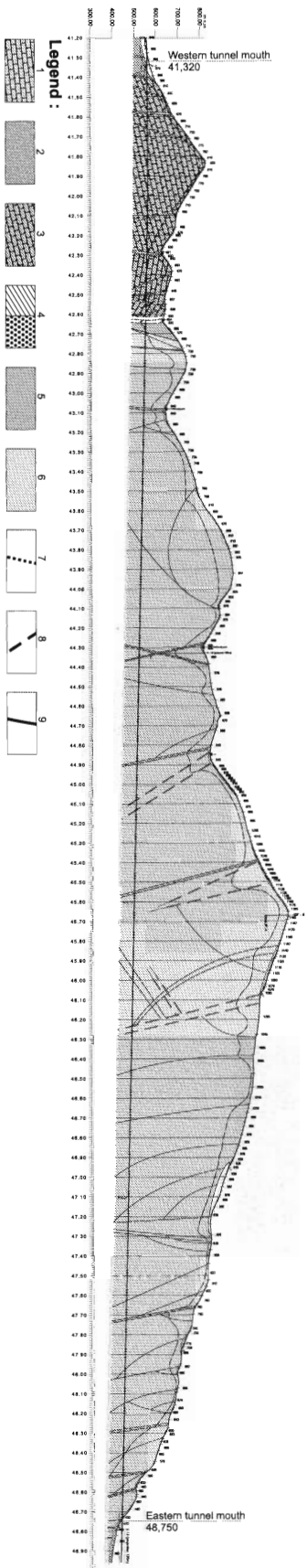
crystalline rock mass was seen as having shallow circulation and ground water percolation along joints into sediments of both basins. Joint permeability was thought to be restricted to a depth of some 300 to 500 m. The first indication of open joint groundwater circulation was detected during the preliminary engineering geological investigation in the bore hole V-12 (GEOHYCO 1998). Three water bearing horizons, with discharge of about 2 litres per second from each, with a positive pressure, were detected.

Karst caverns, some tens of metres long and some metres wide, were thought to occur particularly along fault zones in the Mesozoic suits. Barrier karst springs, from contact of Mesozoic carbonate rocks with the Central Carpathian flysch of the Žilinská kotlina basin, were tapped for the water supply. Their yield ranges from some ten litres up to some hundred litres per second depending on precipitation.

Geology of the pilot tunnel

The 1.47 km long highway tunnel will cross the northern part of the Lúčanská Fatra mt. The western tunnel mouth is situated on the eastern margin of the Žilinská kotlina basin, in flysch rocks. The eastern tunnel mouth is near to norhwestern edge of the Turčianska kotlina basin in granitic rock. Most of the tunnel will be driven through crystalline rock, with about 2 km of the western section to be driven through Mesozoic sediments and the mouth itself, in flysch rocks and Quaternary colluvial deposits.

Data gained from the pilot tunnel showed a complex geologic structure as predicted in the preliminary engineering geological report (GEOHYCO 1998). Granits, tonalite, migmatite, gneiss xenolite, with quartzite veins, and lamprofyre dykes up to 1 m thick, occur in the east part of the pilot tunnel. Landslides, indicated by field research and geoelectric resistivity methods at the western tunnel



◀**Fig. 5.** A cross-section along the tunnel line. 1 – Neogene, 2 – Paleogene flysch, 3 – Mesozoic carbonatic rocks, 4 – Lower Triassic basal detritic sediments, 5 – Paleozoic granitic rocks, 6 – Paleozoic gneiss, 7 – Tectonic faults of the I rank, 8 – Tectonic faults of the II. rank, 9 – Tectonic faults of the III. rank.

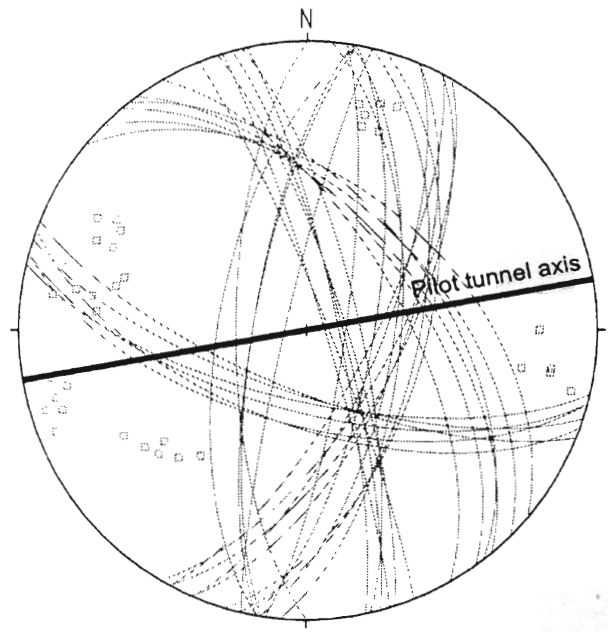


Fig. 6. A tectonogram of faults found in the eastern part of the pilot tunnel.

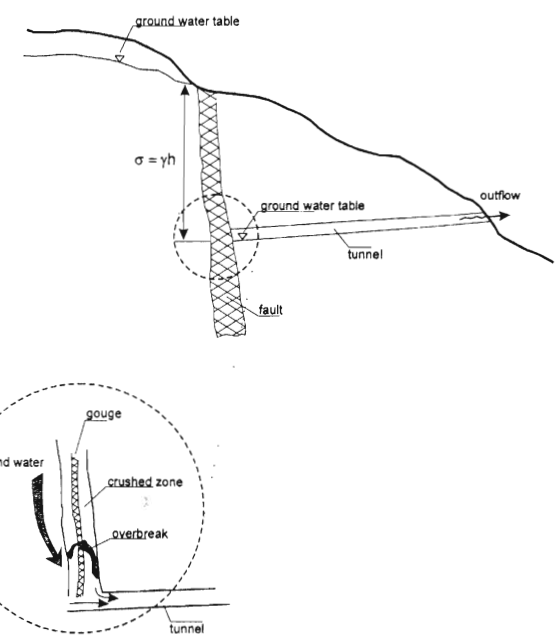
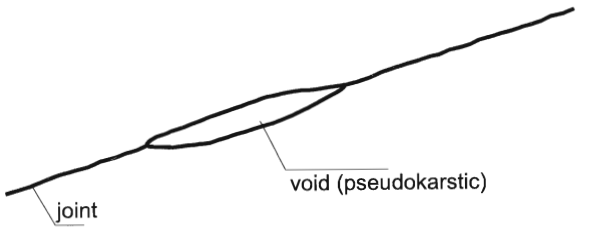
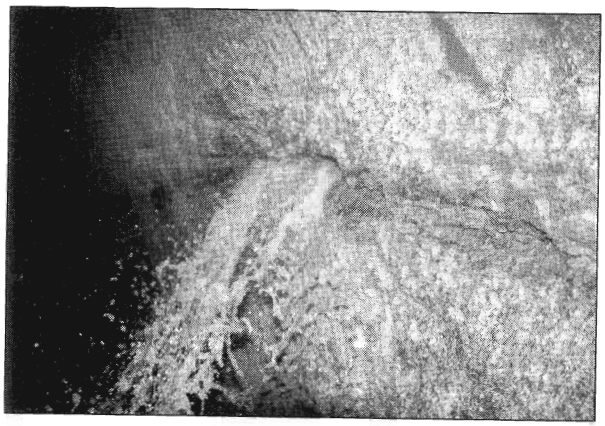
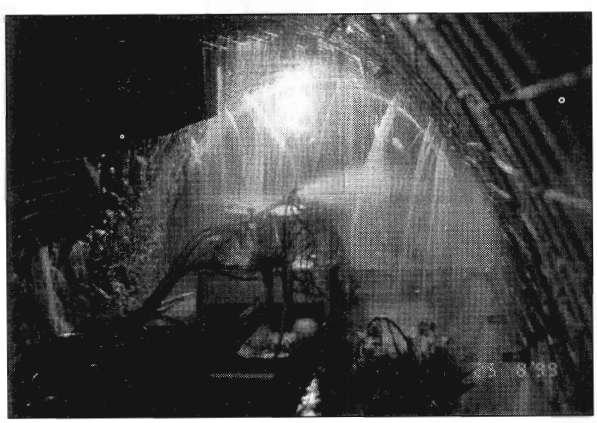


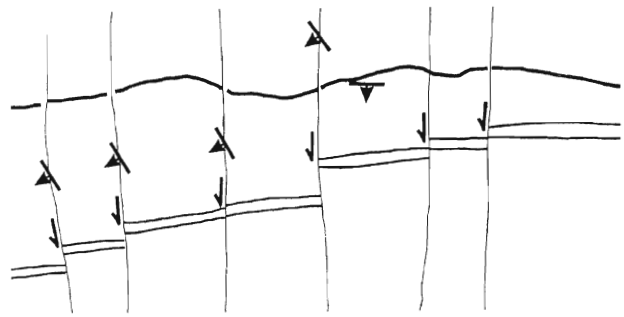
Fig. 7. A scheme of an overbreak along a fault zone.







◀**Fig. 8a.** A shape of waterbearing joints and photo of water outflow from the pilot tunnel rock wall.



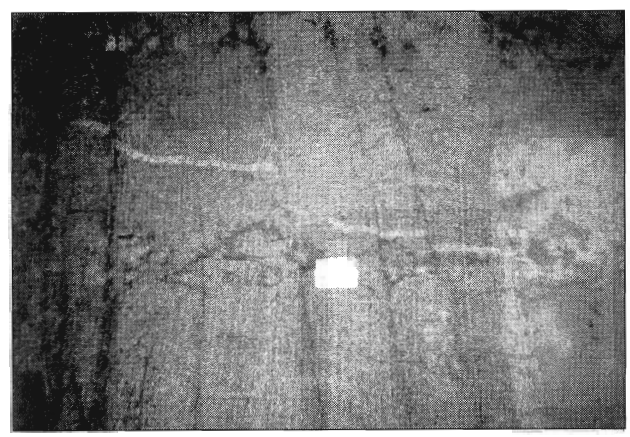


Fig. 8c. A scheme and photo of serie of dislocation on the pilot tunnel wall.

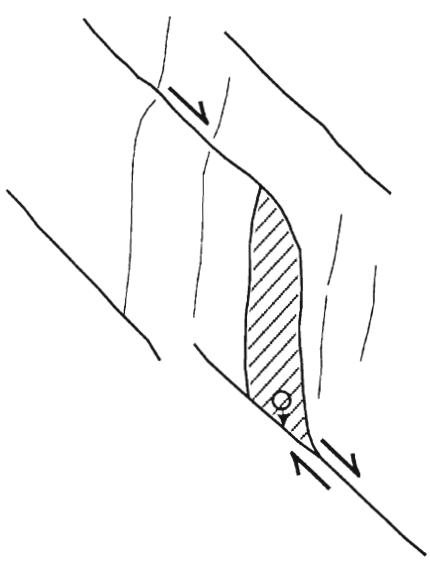


Fig. 8b. A shape of a waterbearing open crack and photo of water outflow from the pilot tunnel rock wall.

GeOvestník

Informačný spravodajca pre geológiu, baníctvo, úpravníctvo a životné prostredie

Príloha časopisu Mineralia Slovaca, roč. 32, č. 4

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Študentská a doktorandská konferencia

13. a 14. apríla 2000 sa v Herľanoch konala odborná konferencia študentov a doktorandov, na ktorej sa zišli mladí adepti geológie z Bratislavy, Banskej Bystrice a z Košíc. Hlavným cieľom akcie bolo poskytnúť nastupujúcej generácii slovenských geológov vhodnú príležitosť prezentovať výsledky vlastného vedeckého bádania, vzájomne ich konfrontovať a napokon aj nadviazať prepotrebné a pre odborný či vedecký rast nevyhnutné osobné kontakty, ba priateľstvá.

Účastníkov konferencie privítal a úvodné slovo za Fakultu BERG Technickej univerzity v Košiciach predniesol jeden z odborných garantov podujatia doc. S. W. Faryad, CSc.

Prvý deň konferencie odzneli všetky odborné referáty, ktorých abstrakty ďalej uverejňujeme, a druhý deň prebiehala odborná exkurzia do vybratých lokalít Slanských vrchov a ich okolia.

Osobitná pracovná a zároveň srdečná atmosféra, nové kontakty, ale aj takmer profesionálna úroveň prednesených odborných referátov bez akýchkoľvek pochybností dokázali opodstatnenosť a užitočnosť konferencií takéhoto druhu. Preto sa účastníci aj organizátori zhodli na potrebe organizovať konferenciu pravidelne. Už na budúci rok sa plánuje podobná akcia, ale už s medzinárodnou účasťou. Organizátori veria, že bude aspoň taká vydarená ako tá prvá.

J. Kondela

M. SABOL: **Medveďovité mäsožravce *(Ursidae, Carnivora)* z vrchného pleistocénu Slovenska**

Nálezy zástupcov čeľade *Ursidae* sú na území Slovenska pomerne časté. Doteraz sa z terciérnych a kvartérnych sedimentov na našom území dovedna zistilo 11 taxónov z tejto čeľade. Sú to: *Hemicyon sansaniensis, Ursavus brevirhinus, Pseudarctos* aff. *bavaricus, Ursus* sp., *Ursus* cf. *minimus, Ursus thibetanus mediterraneus, Ursus deningeri, Ursus spelaeus, Ursus* cf. *taubachensis, Ursus arctos priscus* a *Ursus arctos arctos.*

Vo vrchnom pleistocéne (10 000–130 000 BP) žili na území Slovenska zástupcovia speleoidnej *(U. spelaeus)* aj arktoidnej vetvy *(U. taubachensis, U. arctos priscus)* a na samom konci tohto obdobia možno aj recentný medveď hnedý *(U. arctos arctos)* fylogenézy medveďovitých, pričom nálezy jaskynných medveďov *(Ursus spelaeus)* sú najčastejšie (našli sa vo viac ako 50 slovenských jaskyniach).

Väčšina nálezov medveďa jaskynného je z jaskynných sedimentov posledného glaciálu (würmský glaciál, zaľadnenie Štrbského plesa v Tatrách), avšak na naše územie tento druh prenikol už v poslednom interglaciáli (ris–würmský alebo émsky interglaciál), resp. sa ojedinele objavoval už aj v závere stredného pleistocénu, t. j. v období riského glaciálu (rakytovské zaľadnenie v Tatrách), ale na konci posledného glaciálu na slovenskom území Západných Karpát vymrel.

Z arktoidnej vetvy medveďovitých sa na našom území vo vrchnom pleistocéne stretáme s dvoma taxónmi. V poslednom interglaciáli (émsky interglaciál) tu žil druh *Ursus taubachensis,* ktorý koncom tohto interglaciálu náhle vymrel, a preto jeho nálezy majú určitú stratigrafickú hodnotu. Druhým taxónom arktoidných medveďov, ktorý na území Slovenska žil v poslednom glaciáli, je fosílny poddruh medveďa hnedého *Ursus arctos priscus.* Žil na rovnakom území a v rovnakých životných podmienkach spolu s medveďom jaskynným a zároveň s ním koncom pleistocénu vymrel. Na prelome pleistocénu a holocénu na naše územie z južnej Európy cez Balkán v rámci migračnej vlny prišiel aj recentný medveď hnedý *(Ursus arctos arctos).*

J. PRŠEK: **Rudné mineralizácie v okolí obce Bacúch (Nízke Tatry, veporikum)**

Obec Bacúch sa nachádza na južných svahoch kráľovohoľskej časti Nízkych Tatier asi 15 km na V od Brezna. Na geologickej stavbe študovaného územia sa zúčastňujú rozličné horninové komplexy veporika–kráľovohoľský komplex, ktorý tvoria telesá biotitického granodioritu a pararuly, hronský komplex z dvojsľudných svorov s polohami pegmatitov a amfibolitov, a vulkanicko-sedimentárny komplex Jánovho grúňa, zložený z fylitov, metamorfovaných vulkanitov (ryodacity, dacity; Miko a Korikovskij, 1993). Vek komplexu Jánovho grúňa sa U/Pb metódou stanovil na 216 ± 5 Ma , 255 ± 2 Ma a 278 ± 11 Ma (Kotov et al., 1996). V oblasti Sokolej doliny vystupuje jednotka Veľkého boka, ktorú tvoria telesá kvarcitu, vápenca a dolomitu triasovo-jurského veku. V študovanom území sa vyskytuje karbonátovo-sulfidická mineralizácia – Sokolia dolina a Jánov grúň, a magmetitovo-hematitová mineralizácia – – Biely kameň, Babiná a Javorinka. Hydrotermálne karbonátové žily majú smer V–Z, sklon na J, maximálnu hrúbku 1 m a ležia v horninách komplexu Jánovho grúňa. Magnetitová mineralizácia vystupuje vo svoroch hronského komplexu a tiahne sa smerom SV–JZ z Bieleho kameňa až po Javorinku. Magnetitovú mineralizáciu tvorí najmä magnetit, hematit, ktorý vzniká martitizáciou z magnetitu, a pyrit. Magnetit tvorí tri typy rudy: vtrúseninovú, pásikavú a masívnu. Z nerudných minerálov je zastúpený chlorit, biotit, kremeň, ortoklas, turmalín zirkón, monazit a xenotím. Mladšia sulfidická mineralizácia, ktorú opísal Petro (1973) – pyrit, pyrotín, chalkopyrit, sfalerit a žilky kremeňa – sa nepotvrdila. Karbonátová mineralizácia vznikla v dvoch etapách – karbonátovej a kremenno-sulfidickej. Karbonátovej etape predchádzala hydrotermálna alterácia hornín, čo sa prejavilo najmä „sericitizáciou" a prekremenením. V alterovaných zónach sa vyskytujú aj chlority, karbonát, pyrit a TiO_2 oxidy. Karbonáty tvorí najmä ankerit a siderit, výnimočne dolomit a kalcit. Ankerit sa tvorí v dvoch fázach – s vyšším a s nižším obsahom Fe. Siderit obsahuje málo Mg (1 až 2 hm %) a do 5,5 hm % Mn. Z ostatných nerudných minerálov je ako podstatná časť žilnej výplne zastúpený biely kremeň a v Sokolej doline aj biely jemnozrnný baryt. Z rudných minerálov je najhojnejší pyrit a chalkopyrit, menej je galenitu a sfaleritu. Vedľajšie až akcesoricky je zastúpený arzenopyrit – Jánov grúň, markazit a Bi minerály – Sokolia dolina. Bizmutové minerály mikroskopickej veľkosti sa identifikovali v asociácii s galenitom. Tvoria inklúzie v galenite, myrmekitické prerastanie alebo ojedinelé zrnká v galenite a v kremeni. Identifikovali sa: rýdzi bizmut, sulfosoli aikinitovo- bizmutínového radu, a to bizmutín s obsahom Ag od 0 do 3,47 hm %, Cu od 0,14 do 0,33 hm % a Pb od 1,26 do 5,78 hm %; aikinit (EMA hm %) – Cu 9,19–10,21, Pb 34,9–36,19, Bi 37,41–39,24, S 15,49–17,43; friedrichit (EMA hm %) – Cu 8,46–9,34, Pb 30,72–32,93, Bi 39,94–44,47, S 16,74–18,7; lindströmit (EMA hm %) – Cu 5,57–5,67, Pb 21,74–23,54, Bi 52,88–52,97, S 17,23–17,45; hammarit (EMA hm %) – Cu 4,47–7,89, Pb 26,29–32,33, Bi 44,38–49,25, S 16,81–17,08; cosalit (EMA hm %) – Pb 36,85–41,99, Bi 39,85–42,79, S 15,73–17,33 s obsahom Cu 1,03–2,06 a Ag 1,26–2,11; schirmerit (EMA hm %) – Ag 7,13–7,48, Pb 32,56–38, Bi 39,14–43,22, S 15,85–16,45 s obsahom Cu do 0,55 s gustavitom (EMA hm %) – Ag 7,18–8,45, Pb 22,91–25,27, Bi 48,96–52,16, S 15,85–17,67 s obsahom Cu do 0,46.

N. HUDÁČKOVÁ a M. SLAMKOVÁ: **Paleoecological Reconstruction of the Pannonian sediments of the NW part of the Vienna Basin based on palynology**

The Pannonian sediments are very typical for the Paratethys. The typical Pannonian interconnected lake system existed in the Pannonian, Transylvanian, Dacian, Euxinian and Caspian Basins. In the Pannonian Basin and adjoined satellite basins (including the Vienna Basin), the endemic brackish water facies with *Congeria, Melanopsis* and characteristic *Ostracodes* are developed in the Pannonian.

For the study was elaborated 15 samples from an outcrops and a shallow boreholes near the Gbely town. Rich association of the palynomorphs was obtained from processed samples using the traditional palynological methods. In the Dinoflagellata association were mainly *Spiniferites bentori* (ROSSIGNOL, 1964), SARJEANT 1970, *Gonyaulax (Gonyaulacysta) digitale* (POUCHET), KOFOID 1911, *Pontiadinium obesum* SZUTO - SZENTAI 1978, *Chytroeisphaeridia* sp. present. Some of the samples were rich in *Pleurozonaria* (?*Mecsekia ultima*). Spores are less frequent and represented by *Leiotriletes, Laevigatosporites, Sellaginela, Verrucatosporites.* Among Gymnospermae the most frequent were pollen of the genus *Pinuspollenites, Piceapollis, Inaperturopollenites, Abiespollenites, Cedripites, Tsugaepollenites.* Angiospermae were the most frequent, especially the pollen of botanical genera *Salix, Carya, Myrica, Betula, Momipites, Quercus, Ilex, Juglans, Oleoidearumpollenites, Ulmus, Carpinus, Fagus, Tilia. Salixipollenites div. sp.* and various herb species, especially grasses from *Graminidites* sp., dominated over the others species. Other herb species comprised: *Chenopodiaceae, Asteraceae, Ericipites* and others ranged to NAP. In all samples prevaile AP group. Some of the samples in the

upper part of this stratigraphical stage was rich in halophytic taxa, mainly *Chenopodiaceae*. Probably this accumulation of the *Chenopodiaceae* indicates the local salty swampy process following the regresion of the sea.

Stratigraphical position of the studied samples (E2-3 zone, Jiřiček, 1975) or Spiniferites bentori zone (Sűto Szentai, 1982) were given on the Ostracoda and Dinoflagellata basis. Mentioned dinoflagellate zone of Spiniferites bentori is well correlable with the same zone (Fuchs and Sűto Szentai, 1991) in Algyö Fm $P_{1,2\ s.l.}$ (Gaidos I., pap. S., Nemeth, G., and Juhasz, Gy. in Csaszar ed. 1997) in the Hungarian region and in the Upper Pannonian s.s. in the Vienna basin.

R. KOVÁČ: **Mineralogickogeochemické štúdium turmalínu z hydrotermálnych žíl Spišsko-gemerského rudohoria**

Pri štúdiu turmalínu z hydrotermálnych žíl Spišsko-gemerského rudohoria sa skúmali vzorky z Dobšinej, Vlachova, Rožňavského Bystrého, Malej Idy, Úhornej, Krásnohorského Podhradia, Hnilčíka, Rožňavy–Nadabuly, Rakovnice, Rožňavy–Grexy a Prakoviec. Všetky vzorky sú z rudných žíl staropaleozoických sekvencií gelnickej skupiny s paragenézou kremeň–karbonát–jemnošupinatý muskovit–lokálne sulfidy.

Na základe optického štúdia, mikrosondových analýz a rtg. difrakčných analýz možno hovoriť o skoryle, dravite, foitite a magnéziofoitite. Turmalín vykazuje výraznú zonálnosť, pričom jadrá kryštálov sú silne vakantné v pozícií X, kým v smere k okrajom vakantnosť klesá. Hodnota X-vakancií sa pohybuje od 0,130 do 0,632. Je to opačný trend ako pri turmalíne z granitových telies Spišsko-gemerského rudohoria (Broska et al., 1998).

Smerom k okraju naopak silne stúpa zastúpenie Ti pričom sa nameral najvyšší obsah TiO_2 v turmalíne na svete. V šiestich analýzach hodnota TiO_2 vystúpila nad 2 % a vo vzorke Rožňavského Bystrého až na 2,38 % TiO_2.

Pomer Fe/(Fe+Mg) sa v smere jadro–okraj takmer nemení, resp. vo vzorkách z Dobšinej a Hnilčíka mierne pribúda Mg na úkor Fe.

Neočakávane častá je prítomnosť foititu a magnéziofoititu. Magnéziofoitit z Hnilčíka je druhým opísaným svetovým výskytom. Prvý z alterovaných zón v dacite až andezite z lokality Kjonosava v Japonsku opísal Hawthorne et al. (1999).

Pri spektrálnej analýze sa zistil vysoký obsah V vo vzorke z Malej Idy (550 ppm), Y z Rožňavského Bystého (457 ppm) a vzorka z Krásnohorského Podhradia mala vyšší obsah Sr (513 ppm) a Zr (141 ppm).

M. MAŤAŠOVSKÝ: **Zlepence krynickej jednotky magurského flyšu**

Študované územie sa nachádza 5 km na S od Humenného v okolí Nižných Ladičkoviec v oblasti pravostranných prítokov potoka Ľubiška. Geologicky patrí do východoslovenského sektora magurského flyšu, a to do krynickej jednotky a budujú ho pieskovcové a zlepencové telesá strihovských vrstiev. Mišík et al. (1991) zlepence tohto územia zaraďujú medzi pročské. Na porovnanie sa odobrali vzorky aj z okolia Strihoviec.

Au zo zlepencov sa skúmalo na elektrónovom mikroanalyzátore JEOL 840 JXA metódou WDS pri urýchľovacom napätí 20 kV. Obsah Ag v zlatine s kremeňom (rastie od okrajov do stredu) sa pohyboval od 0,63 do 15,27 hm % a obsah ostatných sledovaných prvkov bol maximálne 0,63 hm %. Veľkosť zlatín je 80 x 30 x 16 μm až 1040 x 272 x 128 μm, priemerne 272 x 168 x 42 μm (Križáni, 1976) a priemerná hmotnosť 0,0406 mg.

Typológia zirkónov zo zlepencov indikuje dva typy zdrojových hornín, a to granodiority až monzogranity vápenato-alkalickej série, resp. vápenato-alkalické orogénne ryolity a hypersolvné granity alkalickej série. Granity patria medzi granity ostrovných oblúkov plášťového alebo prevažne plášťového pôvodu, granodiority až monzonity sú kôrového a plášťového pôvodu. Priemetný bod typogramu padá do poľa granitoidov s granátom a turmalínom. Výsledky veľmi dobre korelujú s výsledkami geochemického štúdia granitoidov z obliakov zlepenca moravskej časti magurského flyšu, ktoré vykonal Hanžl et al. (1999).

Na zistenie dĺžky transportu obliakov sa vykonala ich analýza a na jej základe sa vypočítala dĺžka transportu kremenných obliakov zlepencov strihovských vrstiev okolo 150 km. Au sa v strihovských vrstvách viaže na zlepenec. Jeho výskyt v pieskovcových fáciách je sporadický. Au sa viaže na matrix aj kremenné obliaky. Podľa obsahu kremeňa a granitoidov v zlepenci a asociácie ťažkých minerálov predpokladáme, že zlepence z okolia Nižných Ladičkoviec nepatria medzi pročské, ale strihovské vrstvy.

M. KYSELICA: **Geochémia Sm-Nd izotopov**

Datovanie Sm-Nd rádioaktívnym izotopickým párom sa vyvinulo len v posledných rokoch, a to najmä pre nedokonalosť analytických a separačných metód, ale dnes je to dynamicky sa vyvíjajúca metóda, ktorá sa využíva v modernej petrológii, mineralógii a vo všeobecnej geológii.

Sm (Z=60) a Nd (Z=62) sú vzácne zeminy v skupine III B periodickej tabuľky. Obidva majú sedem prirodzených izotopov, z ktorých izotop ^{148}Sm, ^{147}Sm a ^{144}Nd sú rádioaktívne, ostatné stabilné. Geologické využívanie týchto prvkov vychádza z faktu, že sa izotop ^{147}Sm rozpadá ? procesom na izotop ^{143}Nd. Polčas rozpadu je 106 miliárd rokov. Ako referenčný izotop sa používa ^{144}Nd. Sm a Nd sú litofilné prvky a ich množstvo odráža kondenzáciu v počiatočných štádiách chladnutia Slnečnej sústavy. Len malý vplyv na ich výskyt mala tvorba zemského jadra (DePaolo, 1988).

Izotopy Sm-Nd systému sú citlivé na zaznamenávanie istých geologických procesov. Ide najmä o magmatické a vysokoteplotné metamorfné procesy (Faure, 1986). Naopak nie sú mobilné v povrchových, blízkopovrchových a nízkoteplotne metamorfných podmienkach, čo je v porovnaní s inými izotopickými pármi (U–Pb, Rb–Sr) jedna z ich výhod. Najviac Sm a Nd je v horninotvorných mineráloch (živce, pyroxény, amfiboly a granáty). Tie zväčša tvoria veľké zrná, ktoré sú odolnejšie voči vylúhovaniu alebo difúzii ako akcesorické minerály alebo sľuda používaná na datovanie U–Pb, Rb–Sr a Ar–Ar metódami (DePaolo, 1988).

Na datovanie Sm-Nd metódou sa používajú celohorninové vzorky (cca 200 g) alebo minerálne separáty (100–200 g). Dôležité je dosiahnuť čo najväčší rozdiel v pomere $^{147}Sm/^{144}Nd$ vo vzorkách. Z minerálov má amfibol, pyroxén, granát, zirkón a titanit vysoký pomer $^{147}Sm/^{144}Nd$, živce, apatit a monazit nízky. Priemerný rozsah v hornine je okolo 0,1. Vzorky sa rozpúšťajú v čistých kyselinách a separujú sa z nich vzácne zeminy pomocou katiónového meniča. Sm-Nd izotopový pomer možno merať viacerými technikami, ktorých základom je hmotnostná spektrometria (Faure, 1986). Medzi najpoužívanejšie patrí hmotnostná spektrometria (MS), hmotnostná spektrometria s indukčne viazanou plazmou (ICP-MS), hmotnostná spektrometria s laserom vybudenou indukčne viazanou plazmou (ELA-ICP-MS) a iónová mikrosonda (IM). Posledné dve metódy pracujú bodovou analýzou, takže nie je potrebná predpríprava vzoriek (Geyk a Schleicher, 1990).

Princíp datovania Sm-Nd systémom je rovnaký ako pri Rb-Sr datovaní. Základom výpočtu absolútneho veku kogenetických vzoriek je izochrónový diagram. Ide o dvojosový diagram meraných

rodičovsko-dcérskych izotopových pomerov, kde sklon línie odráža rozpad ^{147}Sm na ^{143}Nd a je proporčný veku vzoriek. Priesečník línie s osou x je počiatočný pomer $^{143}Nd/^{144}Nd$, ktorý sa využíva v petrogenetických štúdiách (Rollinson, 1993). Sm-Nd systémom sa dá zistiť aj tzv. modelový vek, čo je dĺžka času, odkedy bola vzorka odseparovaná zo zdrojového rezervoára. Tento vek sa počíta pre samostatnú vzorku z meraného pomeru $^{143}Nd/^{144}Nd$. Na výpočet modelového veku sa používajú dva rezervoáre CHUR (chondritický uniformný rezervoár) a DM (ochudobnený plášť). Rozdiel v interpretovanom veku medzi týmito rezervoármi môže byť až 200 miliónov rokov (DePaolo, 1981).

Iniciálny pomer $^{143}Nd/^{144}Nd$ zistený z izochrónového diagramu poukazuje na príslušnosť vzorky do istého typu zdrojového rezervoára. Rozdiel v tomto pomere je však veľmi malý, preto sa zaviedla „epsilon hodnota-$?_{Nd}$", ktorej nulová hodnota sa rovná hodnote zistenej z chondritických meteoritov (DePaolo a Wasserburg, 1976). Negatívne hodnoty $?_{Nd}$ poukazujú na kôrový a pozitívne na plášťový zdroj. Ešte presnejšie možno typ zdrojového rezervoára určiť kombináciou $?_{Nd}$ hodnôt s hodnotami pomeru $^{87}Sr/^{86}Sr$ a $^{206}Pb/^{204}Pb$ (Zindler a Hart, 1986).

Datovanie Sm-Nd systémom sa využíva najmä na datovanie starších (?20 miliónov rokov) bázických a ultrabázických vyvretých hornín (Hamilton et al., 1977). Úspešne sa datujú aj granitoidy (Belyatsky et al., 1998) a metamorfované horniny, ktorých vek sa takmer nedal zistiť inými metódami (Hensen a Zhou, 1995). Touto metódou možno aj priamo datovať hydrotermálne mineralizácie so scheelitom, volframitom, turmalínom, monazitom, flouritom, sfaleritom alebo granátom, ktoré majú obsah Sm a Nd ?2 ppm (Anglin et al., 1990; Chesley et al., 1991, Kent et al., 1995 a i.).

L. BAKOVÁ a J. SOTÁK: **Olistostrómy a melanžové útvary bradlového pásma na Orave (štruktúrny profil Záskalie a Krivá)**

Termínom olistostróma a melanž sa označujú chaotické jednotky sedimentárnych formácií (napr. Silver a Beutner, 1980). Takéto jednotky vznikajú sedimentárnou (olistostróma) alebo tektonickou deformáciou (melanž) alebo aj ich kombináciou (tektonosóma). Kritériá na odlíšenie sedimentárnych melanží (t. j. olistostróm) a tektonických melanží vychádzajú z identifikácie štruktúr postlitifikačnej deformácie. Chaotická vnútorná stavba je v Západných Karpatoch typická hlavne pre bradlové pásmo, ktoré termínom melanž označil už Andrusov (1938). Chaotické jednotky bradlového pásma sú dobre odkryté v profile Záskalie a Krivá na Orave a detailne sa skúmali z hľadiska ich príslušnosti k tektonickým melanžiam alebo k sedimentárnym olistostrómam.

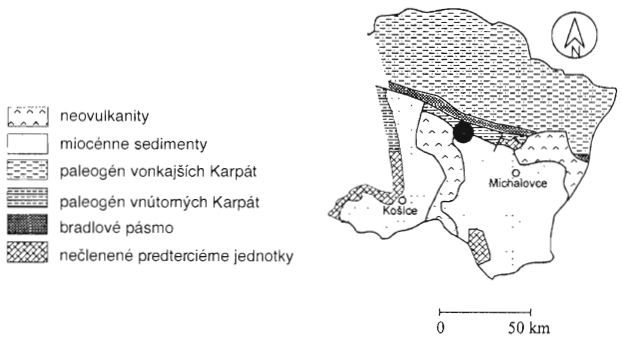
Profil Záskalie je na pravom brehu Oravy asi 3 km na SSV od Dolného Kubína. Odkryté sú v ňom vrchnokriedové sedimenty kysuckej série bradlového pásma, tzv. záskalské brekcie, ktoré vystupujú v rámci gbelských vrstiev. Profil je orientovaný v smere SSV–JJZ. Brekcie sú z ostrohranných blokov slienitého vápenca uložených v usmernenom ílovitom matrixe. Bloky sú vzájomne separované do budín, ktoré sa splošťujú a predlžujú v smere toku matrixu. Typické sú rozbudinované úseky so zúžením (necking) a vzápätí zdurením (swelling) vrstiev, ktoré pravdepodobne vznikli pôsobením tlaku a nasledujúceho strižného pohybu v nehomogénnych vrstvách. Koncentráciu strižného napätia v duktilnom ílovci kompenzuje frakturácia a rozkĺzavanie rigidných blokov po Riedlových plochách. Systémy Riedlových strihov vyhojuje kalcit. Z orientácie pretiahnutých blokov a Riedlových strihov sa identifikoval strižný pohyb smeru SSV–JJZ so zmyslom „vrch na JJZ" (top to the SSW). Na zúžených koncoch blokov sa v tlakovom tieni pravdepodobne zachovala pôvodná vrstvovitosť S_0. Ílovitý matrix je charakterizovaný vývinom bridličnej foliácie S_1 a S_2, ktorých kombináciou vzniká výrazná S/C stavba. Na S plochách možno pozorovať tektonické zrkadlá, drobné odtrhy a strečingové lineácie. Paralelne s týmito plochami sa vyvíjajú aj systémy žiliek s výplňou fibrózneho kalcitu, ktoré dokumentujú odliepanie a vzperové otváranie vrstvových puklín pri pôsobení strihu a pretlaku fluíd (Capuano, 1994; Stoneley, 1983). Sekundárnu bridličnatosť predstavujú plochy S_2 so sigmoidálnym ohnutím v smere strižného pohybu. Opísané S/C štruktúry indikujú vznik v strižnom systéme so zmyslom „vrch na JJZ". V strednej časti profilu sú zovreté až izoklinálne subhorizontálne vrásy s vergenciou na JJZ. V okolitých vrstvách ílovca možno pozorovať intenzívny vývoj S/C stavby a fragmentáciu slienitých vápencov. V tektonickom nadloží záskalských brekcií smerom na SSV vystupujú gbelské vrstvy, v ktorých je intenzita tektonického postihu nižšia. Ich vrstvový sled má zväčša prevrátenú pozíciu, čo dokumentuje prítomnosť hieroglyfov na vrchných vrstvových plochách. Šupiny s prevráteným vrstvovým sledom sa tu striedajú so šupinami s normálnym vrstvovým sledom (Jablonský, 1994). Ílovec je nesystematicky zbridličnatený. V telesách pieskovca sa ojedinele vyskytujú synsedimentárne vrásy, ktoré „obtekajú" ílovec sivej farby. Okolie vrás nie je tektonicky postihnuté. Nadložné vrstvy vypĺňajú objemový deficit po vzniku vrás bez tektonického porušenia. Podložné vrstvy nie sú porušené. Opísané štruktúry záskalských brekcií sú diagnostické na tektonickú melanž.

Profil Krivá je v záreze pri železničnej trati medzi obcou Krivá a Dlhá na Orave. Vystupujú v ňom vrchnokriedové sedimenty nižnianskej sukcesie bradlového pásma v normálnej pozícii (hieroglyfy na spodných plochách pieskovcových vrstiev). Profil je orientovaný v smere JZ–SV. V súvrství vystupujú rozličné fácie podmorského vejára vo vývoji turbiditových, konglomerátových a blokovitých sedimentov. Turbiditové sekvencie deformuje sklz do veľkorozmerových vlečných vrás s osou 234/9°. Vlečné vrásy vystupujú v rámci gravitačných sklzov, kde vrstvy pieskovca laterálne menia hrúbku a prechádzajú do lámaných formácií. Na kontakte s podložnými nedeformovanými vrstvami vidieť prejavy bazálneho šmyku s vývinom vyhladených plôh a tektonických zrkadiel. Lámanie formácií sprevádzajú systémy malých poklesov. Smerom na SV sa mení smer a veľkosť sklonu pieskovcových vrstiev. V tejto časti profilu vystupuje teleso hrubozrnného až balvanovitého zlepenca, ktorý vypĺňa korytá. V profile sa nezistili štruktúry typické pre tektonickú melanž. Opísané štruktúry poukazujú skôr na deformáciu nekonsolidovaných sedimentov, ktoré sa pri gravitačnej nestabilite vrásnili, lámali a skĺzavali. V tomto zmysle ide o tektonickosedimentárnu formáciu, t. j. olistostrómu (endoolistostrómu v zmysle Okamura, 1990).

S. JACKO: **Štruktúrna analýza severozápadného okraja východoslovenského neogénneho bazéna**

Študovaný areál je súčasťou východoslovenskej neogénnej panvy charakteru „pullapartového" bazéna (Vass et al., 1988), ktorý sa začal otvárať v spodnom miocénne (egenburgu). Jeho tektonickou históriou sa zaoberalo viac autorov (Rudinec, 1978, 1989; Rudinec et al., 1981; P. Kováč, et al., 1994; M. Kováč et al., 1995), ktorí sa opierali najmä o informácie z vrtov, geofyzikálneho prieskumu a v ostatnom čase aj zo štruktúrneho výskumu.

Sledovaná oblasť leží v blízkosti obce Lada, obsahuje sedimenty egenburského veku čeľovského súvrstvia (Leško, 1957), ktoré sú najstarším sedimentom východoslovenského neogénneho bazéna, a je dôležitá pri vysvetľovaní vývoja neogénneho bazéna, hlavne jeho počiatočnej fázy – otvorenia, ale aj záverečnej etapy sedimentárneho vývoja vnútrokarpatského paleogénneho bazéna.



Obr. 1. Prehľadná mapa študovaného územia s lokalizáciou.

Pri výskume sme sledovali niekoľko typov štruktúr, najmä úložné pomery sedimentov, kliváž, krehké strižné zóny a extenzné štruktúry, reprezentované predovšetkým kalcitovými žilami.

Študovanú oblasť (obr. 1) tvoria sedimenty egenburgu zo semioválnych až oválnych polôh zlepenca, z pieskovcových a prachovcových lavíc striedajúcich sa so zriedkavejšími polohami ílovca. Významné sú aj ojedinelé slojky uhlia hrubé niekoľko cm. Sedimenty sa vyznačujú priebehom vrstvovitosti, ktorá generálne sleduje smer SZ–JV a má mierny monoklinálny sklon na SV, no miestami rotuje a má smer SV–JZ a mierny sklon na JV. Okrem monoklinálnej mierne sklonenej stavby možno vo vrchnej časti sledovať aj takmer vztýčené polohy pieskovca, ktoré sú výsledkom hákovania vrstiev (Janočko a Jacko, 2000).

Študovaná oblasť sa vyznačuje aj pestrou paletou tektonických štruktúr, v rámci ktorých sme vyčlenili štyri epizódy vývoja. Ich veková selekcia sa opierala aj o poznatky už známych výsledkov, ktoré úzko súvisia s vývojom severnej časti východoslovenského neogénneho bazéna.

Štruktúrna interpretácia

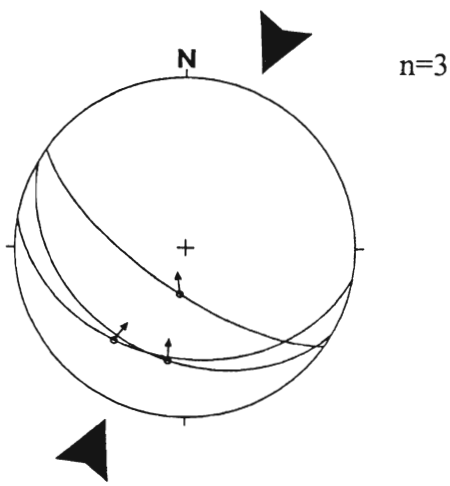
Epizóda 1 – otnang

Geológovia, ktorí interpretovali vývoj bazéna, sa stretli s problémom otnanskej epizódy. Neprítomnosť sedimentov vo vrtoch a na povrchu sa vysvetľovala hiátom, ale priamy dôkaz o tom sa nikdy nenašiel. Predpokladáme však, že práve táto lokalita odkryla ďalšiu mozaiku, ktorá pomôže pri tvorbe celkového obrazu vývoja panvy.

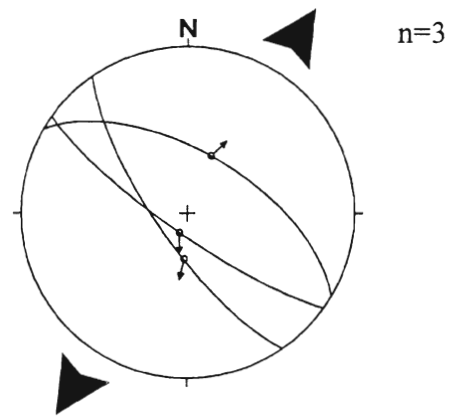
V študovaných sedimentoch sa analyzovali prešmykové štruktúry, ktoré evidentne posúvajú ešte nespevnené vrstvy zlepenca a pieskovca egenburského veku. Tieto štruktúry majú smer ZSZ–VJV so stredným sklonom 35–60° na SSZ. Tento systém zlomov možno charakterizovať ako penetratívne uzavreté disjunktívne štruktúry vyhojené pôvodnou, ešte nespevnenou horninou. Tieto štruktúry sa dajú sledovať len veľmi obmedzene. Zaznamenali sa iba na litologicky kontrastných vrstvách, ktoré treba sledovať kolmo na ich priebeh. Na základe tohto možno oprávnene predpokladať, že sa koncom egenburgu, resp. začiatkom otnangu sedimentácia prerušila. Zmena podmienok sedimentácie súvisela so zmenou pôsobenia maximálneho kompresného napätia σ1 smeru SSV –JJZ (obr. 2). V tom období sa bazén začal postupne vynárať, čo potvrdzuje aj takmer vertikálne exténzné napätie σ3. Táto deformačná etapa vysvetľuje aj neprítomnosť sedimentov otnangu vo východoslovenskom neogénnom bazéne, a tak sa exaktne potvrdzuje doterajší predpoklad o hiáte v tomto časovom období.

Epizóda 2 – spodný až stredný karpat

Po hiáte sa východoslovenský neogénny bazén začal v spodnom až strednom karpate opätovne otvárať. Svedčia o tom aj sedimenty soľnobanského súvrstvia nachádzajúce sa na V od študovaného odkryvu. Túto deformačnú epizódu v odkryve reprezentujú strmé poklesy smeru SZ–JV so strmým (60–80°) sklonom zlomových plôch na SV, resp. JZ. Tento systém zlomov sa vyznačuje pomerne veľkou amplitúdou poklesu (10–20 m), je uzavretý a vyplnený tektonickou brekciou, ktorú tvoria úlomky pieskovca a častý je aj povlak hematitu na zlomových plochách. Ide o penetratívne zlomy v hrúbke 0,5–1 m. Najvýraznejší je zlom v spodnej časti odkryvu, kde možno sledovať amputáciu západnej časti koryta delty. Priebeh zlomov je zreteľný v celom odkryve, ale štruktúrne markery sa nachádzajú len málokedy, keďže tmel pieskovca je silne zvetraný. Poklesy sú odpoveďou extenznej tektoniky v tomto období, ktorú charakterizuje maximálne extenzné napätie σ3 smeru SV–JZ (obr. 3). Naše výsledky, ktoré súvisia s touto epizódou, korelujeme s výsledkami Kováča et al. (1994) získanými zo širšieho okolia.



Obr. 2. Diagram zlomových plôch (otnang). Čierne šípky označujú smer kompresie alebo extenzie.



Obr. 3. Diagram zlomových plôch (spodný – stredný karpat). Čierne šípky označujú kompresie alebo extenzie.

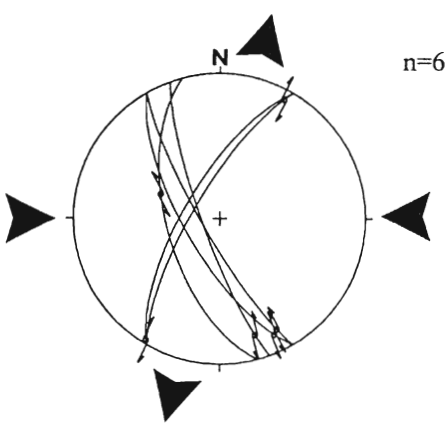
Epizóda 3 – vrchný báden

Epizódy dokumentujúce vývoj od vrchého karpatu po stredný báden sme v odkryve nezachytili. Ich chýbanie sa dá vysvetliť externou pozíciou odkryvu v rámci východoslovenského neogénneho bazéna, čiže tak, že študovaný odkryv bol v uvedenom časovom rozmedzí v tektonickom tieni. Ttreba dodať, že v tom období bola sledovaná oblasť pochovaná pod mladšími karpatsko-bádenskými sedimentmi.

Až vo vrchnom bádene sa lokalita opätovne dostala pod vplyv napäťových štruktúr, ktorých výsledkom sú dislokačné štruktúry dvoch smerov. Prvá má priebeh smeru SSV–JJZ a strmý 70° sklon na VJV. Jej kinematická aktivita mala dextrálny posuvný charakter. Na odkryve sa prejavuje ako uzavretá, penetratívna štruktúra vyplnená tektonickou brekciou s fragmentmi stôp ryhovania.

Druhý systém reprezentujú zlomy smeru SSZ–JJV so sklonom 70–80° na ZSZ. Aj táto štruktúra má posunový charakter, avšak sinistrálneho smeru a na odkryve sa často prejavuje ako penetratívna uzavretá štruktúra bez výplne a s tektonickými zrkadlami, na ktorých sú často zachované stopy lineácií, resp. ryhovania. Tieto dislokácie reprezentujú konjugovaný zlomový systém s takmer vertikálnymi posunovými zlomami, ktoré vznikli v kompresnom poli reprezentovanom napätím σ1 smeru V–Z a napätím σ3 smeru SSV–JJZ. Pôsobením týchto zložiek napätia sa vytvoril konjugovaný systém zlomov s dextrálnymi štruktúrami smeru SSV–JJZ a sinistrálnymi smeru SSZ–JJV (obr. 4). Aktivovaním priečnych zlomových štruktúr bazén naďalej subsidoval a tým v sebe vytváral nový priestor na sedimentáciu.

Podobné štruktúry nameral Kováč et al. (1994), z čoho sa dá usudzovať, že súvisia s vrchnobádensko-spodnosarmatským otváraním bazéna a núkajú myšlienku, či sa „pull-apartové" otváranie bazéna nezačalo až v tomto období.



Obr. 4. Diagram zlomových plôch (vrchný báden). Čierne šípky označujú smer kompresie alebo extenzie.

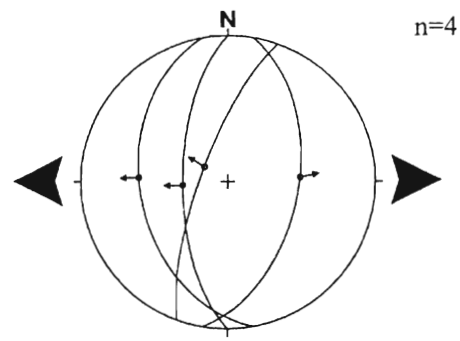
Epizóda 4 – pliocén – kvartér

Najmladšia epizóda zistená na študovanom odkryve odzrkadľuje súčasnú geologicko-tektonickú stavbu, ktorú možno sledovať v širšom okolí a súvisí s extenziou, pri ktorej vznikali neogénno-kvartérne kotliny po obidvoch stranách odkryvu.

Na odkryve sa tento vývoj odzrkadlil vznikom evidentne najmladších poklesových listrických zlomov prevažne smeru S–J s miernym až strmým sklonom na Z, resp. V, ktorý miestami pretína predchádzajúci, už opísaný systém poklesov smeru SZ–JV. Ide o systém listrických poklesov, ktoré možno sledovať v celom priebehu odkryvu. Amplitúda poklesu nie je až taká výrazná (najčastejšie niekoľko cm až 2,5 m) ako pri predchádzajúcom zlomovom systéme. Sú to predovšetkým často otvorené štruktúry s tektonickými brekciami, ktoré tvoria úlomky pieskovca a ílovca. Tieto poklesové štruktúry sú sprevádzané aj paralelnými extenznými zlomami vyplnenými kalcitovou mineralizáciou s hrúbkou kalcitu od 3 mm do 3 cm.

Na štruktúrach vo vrchnej časti odkryvu nastalo hákovanie vrstiev a jeho výsledkom sú otvorené vrásové štruktúry.

Zlomy vznikali v extenznom tektonickom režime pôsobením napätia σ3 smeru V–Z (obr. 5). Táto deformačná etapa je zjavne najmladšia a narúša všetky ostatné namerané štruktúry, a preto predpokladáme, že súvisí s pliocénnym formovaním Košickej kotliny na Z od študovanej oblasti.



Obr. 5. Diagram zlomových plôch (pliocén – kvartér). Čierne šípky označujú smer kompresie alebo extenzie.

Záver

Zo študovaného odkryvu sme opísali viacetapovú deformačnú stavbu územia, vyčlenili štyri deformačné epizódy dokumentujúce vývoj sz. okraja východoslovenského neogénneho bazéna a v ich rámci sme sa pokúsili aj o časovú kalibráciu štruktúr opierajúcu sa hlavne o naše terénne výsledky.

V prvej epizóde sme exaktne doložili výzdvih bazéna v otnangu, čo potvrdzuje prítomnosť predpokladaného hiátu. Toto zistenie pokladáme za hlavný prínos tejto práce, lebo doteraz sa hiát predpokladal iba na základe chýbania sedimentov otnangu vo vrtoch vyhĺbených vo východoslovenskej neogénnej panve.

V druhej epizóde sme zachytili postupné otváranie bazéna v spodnom až strednom karpate, keď vo východoslovenskej neogénnej panve sedimentovali morské, lagunárne a plytkomorské sedimenty.

V rámci tretej epizódy sme doložili štruktúry vrchného bádenu, ktoré takmer isto súvisia s „pull-apartovým" otváraním bazéna a naznačujú, že sa táto transtenzná štruktúra nemusela začať až v tomto období. Túto myšlienku podporuje aj „oneskorený" vulkanizmus v tomto priestore, ktorý sa tu kumuloval až od vrchného bádenu do sarmatu.

Posledná epizóda súvisela s pliocénno-kvartérnym formovaním Košickej kotliny, ktorá je založená na kvartérnych zlomových štruktúrach smeru S–J.

R. SCHMIDT: **Modelovanie zlomových pohybov v severovýchodnej časti Slovenského rudohoria**

Sv. časť Slovenského rudohoria zaberá prevažne veporikum Čiernej hory, čiastočne súvrstvia centrálnokarpatského paleogénu a okrajovo tam zasahujú aj neogénne sedimenty Košickej kotliny. Zastúpené sú aj kvartérne náplavy. Pri neoalpínskom tektonickom vývoji sa v tomto priestore uplatnilo viacnásobné napäťové pôsobenie. Vývoj paeloalpínskych a mezoalpínskych strižných zón vytvoril najvýraznejšiu štruktúrnu predispozíciu na formovanie sa ďalších disjunktívnych štruktúr v krehkom režime deformácie. Celou oblasťou prestupuje niekoľko zón mylonitov a fylonitov generálne orientovaných v smere SZ–JV (Jacko et al., 1997). Regionálne najvýznamnejšia je margecianska strižná zóna na rozhraní veporika a gemerika. Tak sa sformoval systém zlomov paralelných so staršími strižnými zónami a niekoľko systémov v priečnom smere. Z hľadiska regionálnej štruktúrnej stavby oblasti sú z nich najvýznamnejšie zlomové zóny smeru SSZ–JJV až S–J na východnom okraji pohoria, známe ako hornádsky zlomový systém. Centrálnu časť pohoria pretínajú dve významné zlomové pásma: v pásme Bradlo – – priehradný múr vodnej nádrže Malá Lodina – dolina Rakytina prechádza zóna zlomov smeru S–J a SSV–JJZ a cez obec Margecany pohorie pretína transgemerický zlomový systém smeru SSV–JJV (Grecula, 1990; Pospíšil, 1995), ktorý prechádza z gemerika cez veporikum Čiernej hory až do paleogénu. V kontaktnej oblasti veporika Čiernej hory a tatrika Braniska je vyvinutý šindliarsky zlomový systém, ktorý oddeľuje Branisko od centrálnokarpatského paleogénu.

Priamo na aktivitu predneoalpínskych strižných zón nadviazali *smerné šikmé násuny a horizontálne dextrálne posuny* v kompresnom napäťovom poli. Kompresia pôsobila v smere *SZ (S) – JV (J).* Pohyby boli prevažne po plochách foliácie mylonitov a staršej bridličnatosti, prípadne sa v ich zónach sformovali nové zlomové plochy v krehkom režime. Po vyznení kompresného pôsobenia v regióne nastalo v horninovom masíve uvoľňovanie, prevládlo *extenzné napäťové pôsobenie v smere SSV–JJZ,* v ktorom sa tvorili *poklesové zlomy smeru ZSZ–VJV a SZ–JV dextrálne šikmé posuny smeru SV–JZ,* zaklesávali horninové bloky v miestach, ktoré boli predtým najviac vystavené kompresnému pôsobeniu. Po línii margecianckej strižnej zóny od Košíc po Kluknavskú kotlinu sa sformoval systém poklesových štruktúr, v ktorých sú zaklesnuté horninové bloky všetkých zúčastnených predterciérnych geologických jednotiek. Severnú vetvu týchto poklesov neskôr vyplnili sedimenty centrálnokarpatského paleogénu. Druhé pásmo poklesov sa sformovalo na sv. okraji veporika Čiernej hory paralelne s kontaktom so súvrstviami centrálnokarpatského paleogénu. Priestorové rozloženie, funkcia zlomov tejto etapy a spomenuté vzťahy k sedimentom centrálnokarpatského paleogénu naznačujú, že sa sformovali pred formovaním sa paleogénnych sedimentačných bazénov alebo počas neho. Zlomové štruktúry, ktoré mohli vznikať v tomto napäťovom poli, sme v paleogénnych horninách neidentifikovali.

V ďalšej etape tektonického vývoja sa oblasť dostala pod vplyv regionálneho *kompresnoextenzného napäťového poľa s kompresnou zložkou v smere SV–JZ a extenznou v smere SZ–JV.* Lokálne sa uplatnila iba extenzia smeru SZ–JV. Výsledným produktom je rozsiahly súbor zlomov prestupujúci celým masívom (Jacko et al., 1996). Tvorili sa *šikmé poklesy smeru SV–JZ a sinistrálne posuny smeru ZSZ–VJV,* čiastočne nadväzujúce na staršie štruktúry a vo veľkej miere na novo sa formujúce. Z regionálnych zlomov sa uplatnili pohyby na transgemerickej zlomovej zóne a aktivovala sa zlomová zóna v pásme Bradlo – Rakytina.

Relatívne najmladšie bolo napäťové pôsobenie *s kompresnou zložkou pôsobiacou v smere SZ–JV a extenznou zložkou v smere SV–JZ,* pri ktorom nastala značná rotácia napätí proti smeru hodinových ručičiek. Nositeľmi tohto napäťového poľa boli reaktivované *zlomy smeru SV–JZ, a najmä generálne sinistrálne horizontálne posuny smeru S–J.* V priestore Čiernej hory sa uplatnili najmä vo východnom pásme a dotvorili tam hornádsky zlomový systém do súčasnej podoby. Relatívne vekové zaradenie tejto etapy zlomového vývoja minimálne na koniec neogénu umožňuje dezitegrované a zaklesnuté súvrstvie vrstiev varhaňovského štrku klčovského súvrstvia.

S. JUHANOVÁ: **Súčasnosť a budúcnosť slovenského hnedého uhlia na slovenskom a európskom trhu**

V energetike má uhlie v súčasnosti a pravdepodobne bude mať aj v budúcnosti významné miesto. Zásoba ropy a zemného plynu klesá, bude stačiť približne na 50 rokov, ale hnedého a čierneho uhlia je dosť približne na 200 rokov. Podiel uhlia v celkovej spotrebe primárnych energetických zdrojov je dnes okolo 24 %, ale prognóza o jeho spotrebe roku 2100 hovorí o 35 %.

Podiel uhlia v celkovej spotrebe primárnych energetických zdrojov na Slovensku roku 1997 bol 29,1 %. Hnedé uhlie zostáva dôležitou zložkou energetickej politiky SR, ale jeho význam v ostatných rokoch najmä v súvislosti s úsilím o celoštátnu plynofikáciu poklesol. Predaj hnedého uhlia bol roku 1995 približne o 28 % vyšší ako roku 1998, hoci v tom istom období mierne vzrástla jeho ťažba.

Slovensko je schopné pokryť vlastnou produkciou 10 % spotreby primárnych energetických zdrojov. Z nich 6 % tvorí uhlie, ktoré sa na Slovensku ťaží na týchto piatich lokalitách: Handlová, Cigeľ, Nováky (a. s. Hornonitrianske bane Prievidza), Modrý Kameň (Baňa Dolina, a. s., Veľký Krtíš), Gbely (Baňa Záhorie, a. s., Holíč). Dominantným dodávateľom domáceho hnedého uhlia je a. s. Hornonitrianske bane Prievidza, ktoré produkujú 77 % slovenského hnedého uhlia.

Na predajnosť slovenského hnedého uhlia negatívne pôsobia nasledujúce faktory: konkurencia zo strany českých importérov, štátom podporovaná globálna plynofikácia, rast nákladov súvisiaci so zložitými geologickými podmienkami ložísk, čo vedie k ustavičnému rastu ceny uhlia, nízka kvalita ťaženej suroviny a jediný majoritný odberateľ (Elektrárne Nováky, a. s., Zemianske Kostoľany).

Spomenuté činitele a takmer nijaká podpora zo strany štátu spôsobujú, že sú ťažobné podniky v kríze, ktorú treba nevyhnutne riešiť. Možností je niekoľko. Patrí medzi ne napr. rozšírenie trhu, zmena úpravníckej technológie, zmena orientácie ťažobných podnikov, intenzívnejšia podpora zo strany štátu.

Jednou z možností na zvýšenie príťažlivosti slovenského hnedého uhlia sú tzv. čisté uhoľné technológie (z angl. Clean Coal Technologies). Týmto termínom sa označuje technológia v oblasti úpravy (z úpravne vychádza čistejšia surovina, čiže pri jej spaľovaní vzniká menší odpad), v spôsobe spaľovania (zefektívnenie spaľovania, a tým zníženie odpadovosti) a napokon vo využívaní produktov spaľovania.

Ďalšou možnosťou je alternatívne, mimoenergetické zužitkovanie hnedého uhlia. Uhlie možno využívať na výrobu tepla a elektrickej energie, výrobu brikiet, ale aj v kozmetickom, farmaceutickom, chemickom a stavebnom priemysle. Hnedé uhlie a lignit sa v najväčšej miere využívajú na výrobu tepla a elektrickej energie, výrobu hnojív a syntetického zemného plynu.

Slovenské uhlie má kvalitatívne znaky, ktoré umožňujú využívať ho aj v iných oblastiach, ako je energetika. A práve v tom je záruka

zachovania ťažby hnedého uhlia v slovenských uhoľných baniach. Novými výrobkami z uhlia, ako sú napríklad umelé hnojivá, plyn, uhlie na chemickú výrobu a pod., sa slovenské ťažobné organizácie budú môcť presadiť aj na zahraničnom trhu. Tento spôsob môže byť akousi pridruženou výrobou popri majoritnej produkcii energetického uhlia a môže zvýšiť príjmy z predaja pri minimálnych investičných nákladoch.

K. PETRASOVÁ a S. W. FARYAD: **Petrografická charakteristika mastencového ložiska Gemerská Poloma–Dlhá dolina**

Mastencové ložisko Gemerská Poloma, ktoré vystupuje v centrálnej časť gemerika, je predmetom geologického prieskumu od roku 1988. V súčasnosti pod vedením s. r. o. Rozmín v Rožňave prebiehajú prípravné práce na jeho otvárku a ťažbu. Ložisko sa nachádza uprostred metamorfovaných pelitických a psamitických hornín gelnickej skupiny. V nadloží mastencovo-karbonátového telesa vystupujú tzv. laminované fylity, zdola ho tektonicky ohraničuje granit. V ložisku sa lokálne vyskytujú polohy a preplástky chloritického, chloriticko-sericitického a kvarcitického fylitu.

Okrem hrubých monominerálnych partií mastenca je súčasťou ložiska karbonátovo-mastencová hornina zložená z magnezitu, mastenca a v menšom množstve aj z dolomitu, chloritu, pyritu a grafitu. Z akcesorických minerálov vystupuje apatit, albit a kalcit. Mastenec sa vyskytuje v intergranulárach zŕn magnezitu. Grafitická prímes, ktorá často sleduje plochy bridličnatosti, sfarbuje horninu do sivočierna. Na kontaktoch medzi mastencom a magnezitom je častý pyrit, ktorý sa koncentruje viac v mastenci ako v magnezite. Dolomit a kremeň miestami – hlavne v spodnej časti telesa – tvoria žilky, ktoré prenikajú cez magnezit. Pre najčistejšie mastencové polohy je charakteristický vyše 90-percentný obsah mastenca. Z petrografickej analýzy mastencového ložiska, ale aj z okolitých hornín vyplýva, že súčasná minerálna asociácia hornín je výsledkom najmenej troch metamorfných procesov – (regionálnej variskej, kontaktnej permskej a regionálnej alpínskej metamorfózy).

Mikrosondové analýzy ukazujú takmer ideálne zloženie mastenca s maximálnym obsahom Al = 0,027 a Fet = 0,06 atómov vo vzorcovej jednotke, ktoré substituujú Si a Mg v kryštálovej mriežke. Chlorit prítomný v asociácii s mastencom je bohatý na Mg a má obsah X_{Mg} = Mg/(Mg+Fe) = 0,96. V rámci karbonátov sa rozlíšil magnezit, ktorý je hlavnou zložkou, dolomit a breunnerit. Magnezit má relatívne vysoký obsah sideritovej zložky (Fe_2CO_3 = 4,8 %). Obsah sideritovej molekuly v breunnerite dosahuje až 12,6 %. Pomer Ca/Mg v dolomite je 1,0. Akcesorický apatit je bohatý na F a zodpovedá fluórapatitu s obsahom F = 3,82 %.

P. MIŠOVIC: **Návrh štruktúry geografického informačného systému ložísk nerastných surovín Slovenskej republiky – GISMinDepSR**

Ložisková geológia je jednou z mnohých oblastí geológie využívajúcich obrovské množstvo rôznorodých dát a informácií, ale získať ich rýchlo a efektívne nebýva ľahké. Údaje o ložiskách sa často archivujú nekomplexne, a tak chýba možnosť pružného výberu, správy, aktualizácie a analýzy, ktoré sú na hodnotenie a rozhodovanie v prostredí trhovej ekonomiky nevyhnutné.

Východisko z nepriaznivej situácie je vo vytvorení centrálnej dátovej a informačnej správy, ktorá by poskytovala používateľom počítačom riadený výber a hodnotenie údajov kombinovaných s geografickým výstupom informácií, t. j. vo vytvorení geografického informačného systému (GIS).

Aplikácia GISMinDepSR vychádza práve z takejto filozofie. Systém sa skladá z dvoch navzájom závislých modulov – *databázového a geografického*. Databázová časť sa zakladá na relačnom modeli bázy dát, ktorá využíva princíp „zdola nahor" a „zhora nadol". Ako vhodné vývojové prostredie na vytvorenie takýchto modelov – vzhľadom na finančné možnosti a dostupnosť – sa navrhol databázový modul *MS ACCESS 97* (v budúcnosti s prevodom do prostredia Borland Delphi) a modul *GIS ESRI ArcView 3.1*.

Navrhovaná štruktúra ložiskových údajov je rozdelená na nasledujúce tematické skupiny: 1. základné údaje o ložisku (evidenčné číslo v Geofonde, názov prevádzky, súradnice prevádzky, druh hlavnej suroviny...), 2. administratívne údaje o ložisku (správca, geografická poloha, okres, kraj...), 3. geologické údaje o ložisku (hydrogeologické, inžinierskogeologické, tektonická a štruktúrna charakteristika, chemizmus podzemnej vody...), 4. charakteristika surovín ložiska (typ, hlavná a vedľajšia surovina, súčasné a alternatívne využívanie suroviny...), 5. zásoba a zdroje ložiska (spôsob výpočtu zásoby, kvalita zásoby podľa kategórií...), 6. zásoba a zdroje ložiska podľa klasifikácie OSN z roku 1997 (členenie v súlade s normami OSN), 7. charakteristika ložiskového telesa (hrúbka...), 8. banská a ťažobná charakteristika (stav banskej činnosti, metódy ťažby...), 9. vzťah ťažobného závodu k životnému prostrediu (geofaktory ložiskového územia, CHKO, CHKÚ...), 10. všeobecná štatistika výhradných surovín.

Časti štruktúry bázy dát a relačné vzťahy medzi nimi sú navrhnuté tak, že bázu dát možno aktualizovať a rozširovať. Rozhraním ODBC (Open Database Connectivity) je štruktúra dát prepojená na geografický modul. Rastrový mapový podklad tvorí geologická mapa SR v mierke 1 : 200 000, metalogenetická mapa SR v mierke 1 : 200 000 a tektonická mapa SR v mierke 1 : 200 000. Pri ložiskách s rozvinutou ťažbou a ložiskách vo výstavbe sa používajú lokálne mapové podklady, a to banská mapa, topografické mapy v mierke 1 : 10 000, mapa chemizmu podzemnej vody a podrobné geologické mapy v mierke 1 : 25 000. Digitálne spracované mapové podklady sa využívajú ako vektorová a informačná hladina priamo prepojená s databázovými záznamami.

Problémom zostáva spôsob spracúvania a sumarizácie jestvujúcich údajov, časové údaje, finančné krytie, spôsob archivácie (často nedodržaná kompatibilita nasledujúcich verzií vývojových prostredí) a napokon aj personálne možnosti a zabezpečenie.

Napriek spomenutým nedostatkom by navrhnutý GIS v praxi priniesol do ložiskovej geológie prehľadnosť, rýchlosť, komplexnosť a efektívnosť pri narábaní s ložiskovými údajmi, možnosti rozličných štatistických výpočtov, analytického spracovania a variabilnosť tematických tlačových výstupov.

D. STAREK a J. SOTÁK: **Príspevok k sedimentológii bielopotockého súvrstvia na Orave**

Sedimentologickým výskumom bielopotockého súvrstvia na Orave sa zistilo niekoľko faciálnych vývojov. Najtypickejší je vývoj masívnych telies pieskovca zodpovedajúci stratotypovej lokalite pri Oravskom Bielom Potoku. Polohy pieskovca dosahujú hrúbku 1 až 3 m, pričom ílovec je zastúpený len podradne a zväčša obsahuje značnú prímes prachu. Pieskovcové lavice majú zväčša na báze vyvinuté tenké gradačné intervaly z hrubozrnného pieskovca až drobnozrnného zlepenca, ktoré smerom nahor plynulo prechádzajú do masívneho homogénneho pieskovca (typ S_1 *sensu* Lowe, 1980). Bezštruktúrna a masívna povaha pieskovca poukazuje na depozíciu z kohéznych zmesí piesku v prúdoch bez vnútornej separácie. Takéto sedimenty vznikajú z prehustených turbiditných prúdov alebo pieskových úlomkotokov, ktoré charakterizuje súdržnosť matrixu, disperzný tlak a vztlakový zdvih. Depozíciu bielopo-

tockých telies pieskovca z hustých stekutených prúdov dokumentuje zväčša ploché nasadanie hrubých lavíc (koncentrácia disperzného tlaku na bázu vrstiev), pomerne častý výskyt ílovcových intraklastov vo vyšších častiach alebo aj v strope vrstiev (erózia, vztlak a zmrznutie krehkých klastov), neprítomnosť stôp po úniku vody (vysoká solidifikácia prúdov s malým podielom pórových fluíd a pod.). Na spodných vrstvových plochách zväčša chýbajú stopy prúdovej erózie, ale častejšie sú stopy trenia a hrnutia v dôsledku bazálneho šmyku prehustených prúdov. Masívne alebo gradačne zvrstvené pieskovcové telesá majú niekedy vrchnú laminációu, ktorá je produktom pretekania zmrznutých prúdov zriedenými suspenziami s laminárnym charakterom prúdenia (trakčné koberce). V medzivrstvových polohách pieskovca sa koncentruje najjemnejšia frakcia prúdov vo forme prachovcov a íloprachovcov.

Bielopotockého pieskovcové súvrstvia vo vývoji progradačných lalokov majú sčasti odlišný charakter, ktorý poukazuje na dynamickejší prúdový režim. Súvrstvie sa skladá zo strednorytmických postupností pieskovca (Podbiel, Zábiedovo, Tvrdošín), ktorých zvrstvenie svedčí o frakcionácii a gradačnom vytriedení prúdov, niekedy s bazálnou trakciou jemnejšieho materiálu a vztlakom hrubších zŕn a intraklastov do vyšších častí vrstiev (typ S_3 *sensu*, Lowe, 1982), prípadne aj s trakčnou laminációu v strope vrstiev (typ S_2 *sensu* Lowe, 1982). Objavujú sa aj vrstvy s mnohonásobným vývinom laminácie (Habovka), ktoré sedimentovali v trakčných kobercoch vysoko koncentrovaných turbiditov. Laminované zväzky niekedy vykazujú štruktúru syndepozičnej konvolutnej laminácie, ktorá vznikala hydroplastickou deformáciou pri expulzii fluíd zo sedimentov skvapalnených prúdov. Opisované polohy pieskovca nezodpovedajú typickému vývinu bielopotockého pieskovcového súvsrtvia ani z hľadiska absencie, ani zo sporadickej prítomnosti prúdových stôp (Gross et al., 1984). Na viacerých lokalitách (Podbiel, Zábiedovo, Habovka a i.) ich naopak charakterizujú intenzívnejšie prejavy prúdovej erózie s vývinom kónických a lingvoformných stôp (flute casts), hrčovitých otlačkov (bulbous moulds), jazykovitých stôp so špirálovitými koncami (corkscrew casts with spiral welts), vejárovitých stôp (frondescent marks, deltoid marks) a pod. Prejavy erózie a vtláčania v pieskovci bielopotockého súvrstvia dokumentujú vysoký prúdový režim a unášaciu schopnosť prúdov.

Distálny vývoj progradačných lalokov v bielopotockom súvrství predstavuje drobnorytmický flyš so zastúpením rovnovekých biozón nanoplaktónu (NP 24–NP 25). Vývoj distálnych fácií charakterizuje striedanie jemnozrnného pieskovca a ílovca s nízkym P/I pomerom (Tichá dolina). V rámci pieskovcových lavíc s hrúbkou od 1 do 10–15 cm možno pozorovať takmer výlučne vrchné časti Boumových intervalov. Na pieskovcovej báze, ktorá je vždy ostrá, sú slabo vyvinuté vlečné ryhy a sporadickejšie aj rozmyvy. Takéto sekvencie s laterálnou stálosťou vrstiev vznikajú z riedkych zvyškových prúdov v distálnych častiach turbiditných systémov.

Akumulácia pieskových vejárov v bielopotockom súvrství poukazuje na špecifické hydraulické podmienky prúdov. Prehustené turbidity a pieskové úlomkotoky deponovali materiál veľmi rýchlo (takmer naraz), pričom najčastejšie vznikali bezštruktúrne alebo gradačne zvrstvené masívne telesá pieskovca (fácie A2.7 *sensu* Pickering, 1986; F5 *sensu* Muttiho, 1992). Pri zmene gradientu svahu sa v takýchto prúdoch náhle menia fyzikálne podmienky a vzniká tzv. hydraulický skok (Weirich, 1988). Pri hydraulickom skoku sa prúd náhle rozšíri a spomalí, tak stráca unášaciu schopnosť a akumuluje sedimentárny náklad. Sedimenty sa najčastejšie usadia v podobe masívnych a horizontálne zvrstvených telies hrubozrnného pieskovca až drobnozrnného zlepenca (fácie F3–F5 *sensu* Mutti, 1992). Ak nenastal hydraulický skok, tvoria sa na dne trakčné koberce, z ktorých najčastejšie vzniká tenký horizontálne laminovaný hrubozrnnejší pieskovec s celkovou normálnou gradáciou (fácie S_1 *sensu* Lowe, 1982; B 2.1 *sensu* Pickering, 1986). V nadloží trakčných kobercov alebo ďalej v smere prúdu sa takmer naraz usadí masa piesku a z nej vznikajú telesá strednozrnného až drobnozrnného masívneho pieskovca (fácie F7–F8 *sensu* Mutti, 1992). Tečúci hustý turbiditný prúd máva navrchu aj zriedenú časť, z ktorej sa môžu formovať najvrchnejšie časti hrubých lavíc so slabo vyvinutými Boumovými intervalmi, ale tie často eroduje nasledujúci prúd a tak nastáva amalgamácia pieskovcových vrstiev.

P. BLIŠŤAN: **Možnosti aplikácie geografických informačných systémov pri spracúvaní dát z ložiska Slaná – – Kobeliarovo**

Ložisko metasomatického sideritu v Nižnej Slanej je v súčasnosti jediným ťaženým ložiskom Fe rudy – sideritu na Slovensku. Ruda sa ťaží banským spôsobom, ktorý je veľmi nákladný, ale napriek tomu ešte stále rentabilný. Na hodnotenie rentability ťažby má okrem mnohých iných faktorov (cena suroviny na trhu, technológia úpravy) veľký vplyv aj kvalita a preskúmanosť zásoby ťaženej suroviny, a preto sú metódy určovania kvality a zásoby pri stanovovaní ceny a využiteľnosti ložiska veľmi dôležité.

Moderné baníctvo patrí do skupiny odvetví, pre ktoré je charakteristická vysoká informačná intenzita, ktorú predstavuje vysoký obsah informácií o procesoch aj o ich produktoch. Pre finančnú náročnosť banských procesov a technológií je základnou stratégiou slovenského baníctva v súčasnosti a isto bude aj v budúcnosti využívanie informačných technológií znižujúcich náklady. Táto stratégia zahŕňa:

- nákup a zavádzanie nových technológií ťažby, úpravy a spracúvania,
- zavádzanie informačných technológií na zvýšenie flexibilnosti výroby,
- zdokonaľovanie komunikácie na všetkých úrovniach podniku,
- podporu a uľahčovanie rozhodovania efektívnym prístupom k informáciám.

Problematika spracúvania ložiskových dát orientovaná na analýzu použiteľnosti nových metód komplexného spracovania dát a modelovania ložísk je u nás pomerne málo rozpracovaná. Tieto špeciálne metódy sa v geológii a baníctve obmedzujú iba na niekoľko priekopníckych prác, ktoré zvyčajne neriešia všetky otázky spracúvania dát, t. j. od analýzy základného súboru vstupných hodnôt cez priestorové modelovanie ložiskovej situácie až po variantný výpočet zásob prihliadajúcich na ekonomické aspekty ťažby v podmienkach trhovej ekonomiky.

Široké využívanie matematických metód v geovedách, ktoré sa začalo len nedávno, vyplýva z toho, že pri formovaní sa geologických telies interakciou množstva faktorov vznikli veľmi zložité systémy, ktoré sa vyznačujú istou priestorovou štruktúrou a zastúpením náhodnej zložky. Najčastejšou vlastnosťou geologických telies je zmiešaná povaha priestorovej distribúcie modelovaného javu. Základným a často aj najťažším krokom pri riešení geologických otázok je prevod reálnych geologických objektov na abstraktné modely. Modelovanie v zásade rozlišuje priestorové modelovanie morfológie geologických telies a modelovanie ich vnútorných atribútov. V prípade ložísk nerastných surovín to znamená vytvorenie modelu ložiska a v konečnom výsledku aj výpočet zásoby jeho surovín.

Výpočet zásoby pokusne odskúšaný na ložisku Kobeliarovo je príkladom a zároveň stručným návodom na variantný výpočet. Takýto princíp sa doteraz na ostatných ložiskách (Manó a Gabriela) nerealizoval. Jeho existencia je teda prvým a základným podkladom na ekonomické zhodnotenie ložiska. Pri súčasných ekonomic-

kých problémoch ťažobného závodu je existencia variantného výpočtu pri plánovaní a riadení ťažby výraznou devízou. Analýzou grafov závislosti množstva a kvality zásoby na okrajovej vzorke možno vybrať optimálny variant, a tak znížiť napríklad náklady na úpravu.

Používanie databázových a informačných systémov pri spracúvaní dát a špeciálne využitie CAD systémov pri modelovaní banskogeologickej situácie a riešení niektorých problémov ťažby nachádza konečne uplatnenie aj na Slovensku. Zavedenie takéhoto princípu spracúvania grafickej dokumentácie je síce finančne náročné, ale výsledný efekt vyrovná vstupné náklady a v krátkom čase prinesie výsledky v podobe zefektívnenia práce v geologickomeračskom oddelení.

Priestorový model ložiskového územia banskogeologickej situácie má veľké možnosti použitia, ktoré sa dnes dajú len ťažko oceniť. V blízkej budúcnosti môže slúžiť ako podklad pri projekte prípravy a otvárky banských diel pod 6. obzorom alebo na výpočet zásoby suroviny v ložisku. Najťažšou úlohou v súčasnosti je monitoring vplyvu podrúbania a potom modelovanie jeho postupu a rozsahu na povrchu. Takúto úlohu by model bez väčších problémov zvládol a umožnil by aj priestorovo zobraziť poddolovanie postihnutých oblastí.

Aktivity SGS

Seminár Slovenskej geologickej spoločnosti, bratislavská skupina, konaný dňa 22. marca 2000

Nové poznatky o kryštaliniku západných Karpát

V. BEZÁK: **Nová geologická mapa západnej časti Slovenského rudohoria – model a inšpirácia**

Koncom roku 1999 vyšla nová geologická mapa Slovenské rudohorie-západná časť v mierke 1:50 000 (autori: V. Bezák, L. Dublan, Ľ. Hraško, V. Konečný, M. Kováčik, J. Madarás, D. Plašienka, J. Pristaš), ktorá zobrazuje územie medzi Poľanou na Z a líniou Hnúšťa – Tisovec – Brezno na V, na S siaha po údolie Hrona a na J po južné výbežky rudohoria.

Mapa vznikala pomerne dlho, tak ako sa darilo dokončovať listy jej základnej mapy v mierke 1:25 000. Do skôr zmapovaných území bolo preto treba zakomponovať novšie poznatky o stavbe reambuláciou. Tak sa podarilo vytvoriť aktuálny model tohto mimoriadne komplikovaného územia, nie síce vo všetkých častiach úplne presný, ale koncepčne jednotný. Keďže ide o najsúvislejšie odokrytú plochu kryštalinika v Západných Karpatoch, územie je z hľadiska rekonštrukcie hercýnskeho vývoja kľúčové. Mapa zachycuje všetky vývojové etapy tektonickometamorfného aj magmatického hercýnskeho vývoja. Rekonštrukciu však sťažuje intenzívne alpínske prepracovanie, a preto aplikácia petrologických, štruktúrnych aj izotopových metód už oddávna naráža na komplikácie, o čom sa presvedčilo viac generácií geológov pracujúcich v tomto regióne.

Treba veriť, že nová geologická mapa západnej časti Slovenského rudohoria bude inšpiráciou pre súčasných, ale najmä budúcich geológov tým, že odkrýva nedoriešené otázky geologickej stavby a vývoja (napr. problém konvergencie minerálneho zloženia metamorfitov pri diaftoréze a progresívnej nízkej metamorfóze, odčlenenia neohercýnskych a mezohercýnskych intrúzií vrátane ich rádiometrického datovania, postavenia komplexov s karbonátmi vo vzťahu k najnovším výskytom hornín ochtinskej skupiny pod muránskym príkrovom a mnohé ďalšie).

I. BROSKA: **Rozpad titanitu v granitoch Tribeča – redistribúcia prvkov a dôsledky pre úložiská rádioaktívneho odpadu**

Titanit je hojným akcesorickým minerálom granitov typu I Západných Karpát. Okrem neho charakteristickú asociáciu akcesorických minerálov v granitoch dotvára magnetit, allanit, apatit a zirkón s dominantným subtypom S_{12} a S_{17}. Paragenéza v granitoch tohto typu indikuje vyššiu fugacitu kyslíka.

V tribečských granitoch sa zistila netypická premena titanitu na ilmenit za vzniku pseudomorfóz ilmenitu po titanite. Makroskopické „obálkovité" formy titanitu tak získavajú čiernu farbu a pod mikroskopom sa stávajú opakovými. Titanit sa spravidla mení od okraja zŕn k stredu a potom ďalej po trhlinkách, čo je dobre dokumentovateľné mikrosnímkami v odrazených elektrónoch. S postupujúcou premenou sa v titanite tvoria aj mnohé mikrodutinky, a tak titanit často postupne nadobúda až „špongiovitú" štruktúru. Nový ilmenit v titanite má vyšší obsah Mn, čo zrejme signalizuje nižšie teplotné podmienky jeho vzniku, a teda subsolidové štádium jeho genézy. Okrem ilmenitu v titanite druhotne vznikal aj epidot a kremeň. Látková bilancia poukazuje najmä na prínos Fe a odnos Si, pričom obsah Ti zostáva nezmenený.

Okrem sekundárneho ilmenitu, kremeňa a epidotu sa v titanite vyskytujú aj primárne uzavreniny, ktoré reprezentuje predovšetkým biotit a titanomagnetit. Biotit v titanite má obsah MgO často o niekoľko percent vyšší ako voľný biotit z medzizrnného priestoru horniny. Práve vyššia horečnatosť biotitu v titanite indikuje skoršiu populáciu tohto minerálu v granite a z tohto hľadiska poskytuje cennú petrologickú informáciu o jeho pôvodnom zložení v skorších fázach magmatického procesu. Uzavreniny titanomagnetitu sa rozpadávajú na pár ulvöspinel – magnetit a hematit – ilmenit. Takýto rozpad sa v Tribeči doteraz v individualizovaných magnetitoch hostiteľskej horniny nikde nezistil, pretože voľné titanomagnetity sú vždy reekvilibrované. Uzavretý vysoko horečnatý biotit spolu s titanomagnetitom sú presvedčivým dôkazom o primárnom pôvode titanitu v granitoch typu I Tribeča.

Hľadanie príčiny rozpadu titanitu na ilmenit má aj praktický význam. Ilmenit svojho času v Kanade navrhli ako možný keramický komponent skla na blokáciu rádionuklidov v úložiskách rádioaktívneho odpadu na vyhorené nukleárne palivo (Hayward et al., 1983), lebo sa predpokladala jeho pomerne vysoká stabilita a sorpčná kapacita. Dešifrovanie príčin, ktoré viedli k nestabilite titanitu a potom k vzniku ilmenitu v hydrotermálnom procese v prípade granitov Tribeča, sa tak stáva informáciou o stabilite jedného z komponentov keramických foriem v úložiskách rádioaktívneho odpadu.

M. KOHÚT: **Studenecké granity Starých hôr po štyridsiatich rokoch**

Studenecké granity kryštalinika starohorského tektonického okna definoval Kubíny (1962). Na základe častých kremitých hydrotermálnych žíl prechádzajúcich z granitoidov do nadložných spodnotriasových kvarcitov prisúdil granitoidom mladý, kriedový vek, pretože kremité žily pokladal za prejav kontaktného účinku granitoidu. Alpínsky vek granitoidov vyvrátil Kantor (1964) K-Ar datovaním biotitu z týchto granitoidov a vykázal vek chladnutia 296 Ma.

Náš súčasný výskum v rámci úlohy Starohorské vrchy a Bystrické podolie, hradený MŽP SR, je zameraný na komplexné zdokumentovanie kryštalinických výskytov nielen v samom tektonickom okne – studenecké granity, ale aj výskytov ortorúl v nadloží, ktoré sa podľa superpozície spolu s hojným permom zaraďujú do krížňanského príkrovu.

Základné geologické mapovanie v mierke 1 : 25 000 potvrdilo, že studenecké granitoidy sa vždy vyskytujú v podloží lúžňanského súvrstvia – bazál-

nych zlepencov a pieskovcov spodnotiasového veku, tatrickej obalovej jednotky. To znamená, že tieto granitoidy boli pri sedimentácii obalovej jednotky kompletne exhumované bez svojho intruzívneho „metamorfovaného obalu", čo je pri tatrickom kryštaliniku bežné. Petrografické štúdium – hrubozrnný, porfyrický charakter s prítomnosťou tmavých jemnozrnných enkláv – potvrdilo afinitu týchto granitoidov k prašivským granitom Nízkych Tatier. Podľa modálneho zloženia tieto granitoidy označujeme ako biotitické granodiority, ojedinele dvojsľudné granity (QAP diagram). Geochemicky studenecké granity patria medzi plutonické, peraluminózne horniny, strednodraselnej až vysokodraselnej, granodioriticko-monzonitickej série, vápenato-alkalických magmatitov (ASI = 1,05–1,25). Obsah SiO_2 varíruje od 64,5 po 70,0 hmotnostných percent. Pomer K_2O versus Na_2O je v týchto granodioritoch – granitoch vyrovnaný (0,85–1,1) a indikuje diferencovaný charakter s prítomnosťou porfyrických K živcov, kým pomer Rb/Sr = 0,13–0,7 poukazuje na relatívne slabú frakcionovanosť granitoidov. Normalizované záznamy REE vykazujú vyrovnaný trend distribúcie s nevýraznou zápornou Eu anomáliou a slabým stupňom diferenciácie La_N/Yb_N = 10,5–12,1. Celkovým chemizmom zodpovedajú granitoidom kontinentálnych oblúkov (CAG) vzniknutých recykláciou, pretavením starej kontinentálnej kôry v pokročilom štádiu hercýnskeho, subdukčnokolízneho orogénu. Naše nové $^{40}Ar/^{39}Ar$ izotopové datovanie muskovitov a biotitov z týchto granitoidov urobené v BVFA Arsenal Viedeň s vekom 337–332 Ma je identické s vekom obdobných granitoidných hornín okolitých jadrových pohorí Veľkej Fatry a Nízkych Tatier a potvrdzuje ich karbónsky vek. Prekvapujúce je však zistenie obdobného veku z ortorulových hornín Starých hôr, aj keď sme na izotopické štúdium vybrali nealterované horniny, bez znakov mladšieho (alpínskeho) deformačného postihnutia. Penetratívny charakter hercýnskej deformácie (zrulovatenia) je však výsledok, ktorý si treba všimnúť, pretože tieto ortoruly sa dávajú do súvislosti s fatrikom – krížňanského príkrovu!

M. KOVÁČIK: **Poznámky k petrogenéze vysokoželezitých rúl pri Kokave nad Rimavicou**

V oblasti Hrabiny (pri hradskej asi 3 km od Kokavy nad Rimavicou smerom na Hriňovú) sa v prostredí rúl, migmatitov, grafitických metakremencov atď. uzavretých v hybridných granitoidoch vyskytuje magnetitová železná ruda. Magnetit sa najčastejšie viaže na rozličné typy granatickej ruly (až granátovcov) s charakteristickou metamorfnou minerálnou asociáciou granát (prevaha almandínovej zložky) – amfibol (grunerit až Fe cummingtonit) ± Fe biotit, kremeň, chlorit, grafit. Primárne minerálne asociácie dopĺňa všadeprítomný apatit (bežne 1–3 obj. %) a akcesorický allanit. Dominujúce vysokoželezité minerálne asociácie vznikli pri hercýnskej regionálnej metamorfóze a podľa viacerých údajov predpokladáme, že sa v priemere tvorili pri teplote 600–650 °C v strednotlakových podmienkach. Periplutonický účinok mladších leukokratných granitov miestami spôsobuje značnú rekryštalizáciu (napr. vývoj všesmerného Fe biotitu alebo 1–2 cm porfyroblasty granátu v okolitých metapelitoch) v obdobných metamorfných podmienkach. Alpínska deformácia a/alebo rekryštalizácia sa na lokalite neprejavuje natoľko ako v iných oblastiach južného veporika, čo je zrejme výsledkom odolnejšej reológie týchto hornín, ktoré sú navyše uzavreté v relatívne izotropnom granitoidnom telese.

Drobnozrnné uzavreniny magnetitu, apatitu, chloritu, biotitu a gruneritu v granáte v niektorých prípadoch naznačujú, že ide o relikty z predmetamorfného alebo ranometamorfného štádia vývoja hornín. Grunerit sa vyskytuje vo viacerých petroštruktúrnych formách. Staršie generácie vystupujú ako drobnozrnné agregáty, ktoré sa často prerastajú s magnetitom a/alebo vo forme idiomorfných porfyroblastov. Pozoruhodný je neskorší kostrovitý vývoj gruneritu, ktorý v kryštalizačnom systéme naznačuje prebytok Fe^{2+} pri súčasnom nedostatku Al. Objavuje sa vo forme tenkých ihlíc či trsov vo Fe biotite, niekedy aj v kremeni. Lokálne sú dlhé úzke vlákna gruneritu vrastené do chloritickej hmoty, čo už môže byť alpínsky fenomén.

Výskyt magnetitu v hornine je výsledkom pôsobenia množstva faktorov. Všeobecne sa ukazuje, že jeho prítomnosť je podmienená vyhranenejším pelitickým rázom vysokoželezitých hornín (uplatňuje sa vyšší podiel Al, prípadne K). Pri regionálnej metamorfóze sa pôvodný oxidačno-redukčný charakter polôh v zásade nemení a veľmi determinuje podobu neskoršej metamorfnej kryštalizácie. V otázke pôvodu magnetitových rúl sa stotožňujeme s Korikovským et al. (1989), ktorí v súlade so Zoubkom a Nemčokom (1951) spresňujú charakter sedimentárneho zdroja na fanerozoické chamositovo-goethitovo-sideritovo-kremenné železné rudy. Veľmi pravdepodobne išlo o príbrežné usadeniny a zdrojom P môžu byť vápnité schránky odumretých organizmov.

Správa zo stretnutia Českej tektonickej skupiny v Bublave

Juraj Janočko, Ivana Filová, Jozef Hók a Alexander Nagy

12.–15. apríla 2000 sa v západočeskej Bublave konalo už piate stretnutie Českej tektonickej skupiny, ktoré na profesionálnej úrovni zorganizoval Geofyzikálny ústav AVČR. Miesto sa nevybralo náhodne, pretože z geologického hľadiska patrí medzi najaktívnejšie v Čechách. Je známe recentnou geodynamickou aktivitou, ktorá sa prejavuje mnohými minerálnymi prameňmi, výronmi oxidu uhličitého, anomáliami kôrového hélia, pleistocénnymi vulkanitmi a výskytom recentných zemetrasení. Prvý raz v histórii týchto stretnutí sa veľká časť rokovania venovala aj sedimentárnej geológii, čo svedčí o pokračujúcom multidisciplinárnom prístupe v geologických vedách. Účasť takmer 120 geológov a geofyzikov z Čiech, Slovenska a Poľska prekonala aj počiatočné očakávania organizátorov.

Prvý a posledný deň stretnutia sa venovali exkurziám. Prvá viedla do bílinskej povrchovej bane, v ktorej možno študovať unikátne odkryvy v miocénnom jazernodeltovom systéme vyvinutom v mostianskom bazéne, ktorý je súčasťou grabenu Ohře a patrí medzi najväčšie tektonickosedimentárne fenomény strednej Európy. V bani možno vidieť rozlične orientované stovky metrov dlhé a desiatky metrov vysoké unikátne profily rozličných častí delty. Detailne sú odkryté sedimenty deltovej pláne a čela delty, ktoré tvoria mohutné „foresety" alebo ústové bary a sedimenty prodelty.

Druhý deň exkurzie patril tektonickému a metamorfnému vývoju centrálnej časti Krušných hôr. Aplikácia nových poznatkov tektonickometamorfného výskumu oblasti značne pozmenila doterajší pohľad na vývoj tohto územia. Metamorfnú zonálnosť od jadra Krušných hôr po ich paleozoický obal prerušujú mohutné telesá hornín eklogitovej fácie. Eklogity sú obkolesené ortorulami a viacerými typmi metasedimentov, ktoré formujú štyri hlavné štruktúry oblasti – antiklinálu Klínovca a Medenca, synklinálu Medenca a štruktúru Oberwiesenthalu. Chýbanie extenzných štruktúr poukazuje na prevažujúci kompresný režim rozličnej orientácie pri variskej orogenéze.

Dva dni stretnutia patrili prednáškam, posterom a diskusiám. Napriek tomu, že v niektorých prednáškach prevláda sedimentologická problematika a iné boli zamerané viac tektonicky, jasne bolo cítiť interdisciplinárny prístup k riešeniu tektonickosedimentárneho vývoja oblastí, o ktorých sa referovalo, a tak mohli byť spokojní sedimentológovia aj štruktúrni geológovia.

Na stretnutí sa zúčastnili štyria pracovníci ŠGÚDŠ a podľa diskusie po prednáškach bolo ich vystúpenie úspešné. Referovali o tektonickosedimentárnom vývoji centrálnokarpatského bazéna, sedimentárnej evolúcii plytkovodných sedimentov v oblasti podunajskej panvy, neotektonike Slovenska a o mikroštruktúrnej i geochemickej charakteristike metamorfitov v severnom veporiku.

Pri záverečnom zhodnotení seminára dostali slovenskí geológovia ponuku od českých kolegov na organizáciu budúceho stretnutia tejto skupiny na Slovensku. Po úspešnom stretnutí v Bublave je táto ponuka pre slovenských geológov poctou aj výzvou na zodpovednú prípravu budúceho seminára.

Rádioaktivita v životnom prostredí Spišská Nová Ves 17.–18. mája 2000

Prvá konferencia Rádioaktivita v životné prostredie sa konala 21.–22. októbra 1997 a odvtedy sa získali nové vedecké a zdravotné poznatky o rádioaktivite a skončili sa ďalšie výskumné a prieskumné úlohy dotýkajúce sa tejto problematiky. Preto, ako aj na základe záverov z prvej konferencie sa 17.–18. mája 2000 v Spišskej Novej Vsi uskutočnila druhá konferencia s medzinárodnou účasťou pod názvom Rádioaktivita v životnom prostredí.

Záštitu nad konferenciou prevzal minister životného prostredia SR prof. RNDr. László Miklósz, DrSc., hlavným organizátorom bol URANPRES, s. r. o., Spišská Nová Ves, spoluorganizátorom MŽP SR, ŠGÚDŠ Bratislava, Geocomplex Bratislava, ÚPKM Bratislava, Koral, s. r. o., Spišská Nová Ves a Združenie na reguláciu rizika z radónu Banská Štiavnica.

Okrem príhovoru ministra životného prostredia SR a pozdravných prejavov sa na konferencii prednieslo týchto 26 odborných referátov a prednášok:

L. ANDOR, J. DANIEL a P. HANAS: Riešené úlohy a hlavné výsledky v oblasti prírodnej a umelej rádioaktivity Slovenskej republiky v rámci MŽP SR
D. NIKODÉMOVÁ a M. FUTAS: Prírodné zdroje žiarenia a ich miesto v systéme radiačnej ochrany
J. THOMAS: Radónový program ČR
T. TRCKA: Monitoring rádioaktivity a spracúvanie údajov v SHMÚ
V. STAROSTOVÁ: Správa úložišť radioaktivních odpadů
A. ČIPÁKOVÁ: Štúdium migrácie rádionuklidov v pôde s možnosťou eliminácie ich negatívnych účinkov
Š. GRUBEL. Monitorovací systém jadrovej elektrárne Mochovce
J. BEZÁK, J. DANIEL a J. MORÁVEK: Prírodná a umelá rádioaktivita v priestore rádioaktívneho úložiska rádioaktívneho odpadu Mochovce
M. ŠELIGA: Epidemiologická štúdia je súčasťou bezpečnostnej dokumentácie jadrovej elektrárne Mochovce
Ľ. ČECHVALA a A. ONDRUŠKOVÁ: Predprevádzkový a prevádzkový monitorovací program kontroly rádioaktivity životného prostredia v okolí atómových elektrární z pozície štátneho zdravotného dozoru
M. VRŠKOVÁ a Z. KASSAI: Monitoring rádioaktivity Dunaja a jeho prítokov – Váhu, Hrona a Ipľa
Z. KASSAI a E. ELEXOVÁ: Kumulácia rádionuklidov v biomase bentických organizmov v porovnaní so sedimentmi v Dunaji
W. CIEZOWSKI, A. SOLECKI, A. A. OCHMANN a H. SZTUK: Radioaktywność naturalna Ziemi Klodzkiej
A. A. OCHMANN· Przyklady zmian antropogenicznych mocy dawki promieniowania gamma na terene górnictwa uranowego w Sudetach
A. SOLECKI a M. WISLOCKA: Wplyv antropogenicznych zmian radiacyjnych na terenie górnictwa uraniowego w Sudetach na stan wybranych gatunków flory
M. C. THORNE a P. DŽUPPA: Remediation of Uranium Liabilities in Slovakia
T. GRAND a S. DANIEL. Využitie GISu pri spracúvaní rizikových analýz projektu Remediation of Uranium Liabilities in Slovakia
M. VIČANOVÁ a M. ĎURČÍK: Stanovovanie objemových aktivít radónu a torónu
S. WOLKOWICZ a R. STRZELECKI: Ocena wplywu tektoniki na potencjal radonowy jednostek litologicznych
J. LANC: Prírodná a umelá rádioaktivita Košíc
J. HRICKO a F. SUCHÝ· Regionálne radónové mapovanie Košíc
K. ĎURECOVÁ a L. LUČIVJANSKÝ: Rádioaktivita minerálnych a termálnych vôd Slovenska
Ľ. DRAHOŠOVÁ a J. KOŠTIAL. Umelá rádioaktivita v životnom prostredí
J. DANIEL, P. ČÍŽEK a M. KANDRIK: Výsledky mapovania umelej rádioaktivity v mierke 1:200 000 cézia 137 Slovenskej republiky
I. MAŠLÁROVÁ, J. DANIEL a L. LUČIVJANSKÝ· Prírodná a umelá rádioaktivita dnových sedimentov severného Slovenska
J. ŠÁNDOR: Geopatogénna zóna ako negatívny faktor životného prostredia

Prednášky boli na vysokej odbornej úrovni a priniesli informácie zo širokej oblasti výskumných a prieskumných prác zaoberajúcich sa rádioaktivitou. Potvrdila to aj bohatá diskusia, prezentácia 16 posterov, ako aj praktická ukážka monitorovacieho automobilového laboratória z Laboratória radiačnej kontroly okolia EMO Mochovce z Levíc.

Okrem prednášok o nových výsledkoch, medzi ktoré nesporne patrí aj mapovanie Cs-137 územia Slovenska v mierke 1:200 000, zaujali referáty o monitoringu rádioaktivity, zdravotných účinkoch, ako aj o jadrovej bezpečnosti v okolí jadrových elektrární. Osobitne vysoko treba hodnotiť referáty účastníkov seminára z Poľska, ale najmä z ČR, z ktorých osobitne zaujal referát vynikajúceho odborníka v jadrovej bezpečnosti RNDr Josefa Thomasa Radónový program ČR. V ČR totiž v koncepcii radónového programu uznesením vlády ČR č. 538/1999 nastali výrazné zmeny. Predseda Štátneho úradu pre jadrovú bezpečnosť (SÚJB) presadil predstavu komplexného, cieľového, kontrolovaného a termínovaného radónového programu ČR, v ktorom sa SÚJB stal gestorom aj koordinátorom. Súčasťou tohto programu, ktorý je časovo obmedzený do roku 2009, sú štátne dotácie na protiradónové ozdravné opatrenia, na ozdravovanie domov a vodovodných sietí z hľadiska rádioaktivity, participácia ústredných a okresných orgánov štátnej správy, vývojová a výskumná činnosť a informovanie verejnosti vrátane osvety.

Bolo by vhodné a užitočné vytvoriť podobný model riešenia aktuálnej a naliehavej problematiky aj na Slovensku.

Účastníci vyjadrili želanie, aby poznatky z prednášok, posterov a diskusie pomohli zvýšiť environmentálne poznanie a podporiť princíp trvalo udržateľného rozvoja a zlepšovania životného prostredia.

Kedže na Slovensku stále chýba pracovná a poradná nadrezortná komisia pre rádioaktivitu, konferencia prijala uznesenie na jej vytvorenie a poslala ho ministerstvu životného prostredia, zdravotníctva, poľnohospodárstva, hospodárstva, vnútra, výstavby a verejných prác SR.

Zo zasadania odborníkov v rámci 2. medzinárodnej konferencie vyplynula naliehavá potreba intenzívnejšie a koordinovanejšie venovať pozornosť hodnoteniu rádioaktivity v životnom prostredí.

Pretože táto problematika na Slovensku nepatrí iba do pôsobnosti jedného rezortu, účastníci konferencie v súlade s uznesením vlády SR č. 726/94 odporúčajú obnoviť činnosť medzirezortnej koordinačnej rady pri MŽP SR na zvýšenie kvality ochrany obyvateľstva pred nepriaznivými účinkami ožiarenia prírodnými zdrojmi žiarenia. Rada by mala plniť najmä tieto úlohy:

– Formulovať národný program hodnotenia rádioaktivity v životnom prostredí, jeho priority a realizáciu,
– urýchliť legislatívnu prípravu na zabezpečenie národného programu v súlade s predpismi EÚ,
– zabezpečiť odbornú gesciu podporných projektov na plnenie národného programu hodnotenia rádioaktivity v životnom prostredí,
– koordinovať prípravu jednotnej metodiky merania a hodnotenia rádioaktivity v životnom prostredí,
– upraviť a prijať slovenskú technickú normu na ochranu stavieb pred prenikaním radónu do pobytových priestorov,
– začleniť problematiku rádioaktivity v životnom prostredí do environmentálneho vzdelávania obyvateľstva,
– zlepšiť informovanosť pracovníkov verejnej správy o uvedenej problematike a s ňou súvisiacich legislatívnych úpravách,
– zintenzívniť uvedomené vyhľadávanie pobytových priestorov s vysokou objemovou aktivitou prírodného žiarenia,
– v zmysle zákona č. 90/1998 Z. z. o stavebných výrobkoch systematicky kontrolovať obsah prírodných rádionuklidov vo všetkých stavebných materiáloch a výrobkoch,
– legislatívne zabezpečiť, aby súčasťou žiadosti o stavebné povolenie boli aj výsledky merania objemovej aktivity radónu v pôdnom vzduchu,
– rozvinúť nápravné protiradónové opatrenia, zabezpečiť kontrolu ich účinnosti, záväzne ich testovať a uvádzať do praxe,
– pripraviť informáciu do vlády SR o stave hodnotenia ožiarenia obyvateľstva prírodnými zdrojmi žiarenia v SR.

J. Daniel
predseda organizačného výboru konferencie

Spomienkové oslavy pri 175. výročí narodenia A. K. Meššu a 100. výročí narodenia V. Čechoviča vo Veľkom Krtíši

1. a 2. júna 2000 sa vo Veľkom Krtíši konali Dni A. H. Škultétyho, ktoré boli v tomto roku venované pamiatke dvoch priekopníkov uhoľného baníctva v Ipeľskej kotline – Andreja Krasislava Meššu a Vsevoloda Čechoviča. Dvojdňové podujatie zorganizovali kultúrne, školské a cirkevné inštitúcie Veľkokrtíšskeho okresu s Mestským úradom vo Veľkom Krtíši, Baňou Dolina, a. s., Veľký Krtíš a Slovenskou geologickou spoločnosťou. Podnetom na konanie slávností bolo 175. výročie narodenia A. K. Meššu a 100. výročie narodenia V. Čechoviča.

Andrej Krasislav Mešša bol podnikateľom v ťažbe uhlia, ale aj rodoľubom a básnikom, no jeho banské podnikanie bolo limitované dobovými poznatkami o geologickej stavbe územia. Ťažbou sa zameral na okraje uhoľného ložiska, kde uhoľné sloje na navzájom izolovaných vyzdvihnutých kryhách vystupovali na povrch. Stopy po jeho ťažobnej aktivite sú dodnes viditeľné v morfológii krajiny. Príkladom je depresia s východom vrstiev piesku uhľonosných pôtorských vrstiev nazvaná Meššova baňa. Vlastné uhoľné ložisko v Ipeľskej kotline však objavil niekoľko rokov po uzavretí posledných kutačiek v kraji okolo Veľkého Krtíša Ing. Dr. Vsevolod Čechovič. Krátko po druhej svetovej vojne z poverenia Handlovských hnedouhoľných baní prišiel do vtedy zabudnutého kraja, kde boli iba prašné cesty a nijaký priemyselný závod a za jednu mapovaciu sezónu zostavil geologickú mapu územia medzi Veľkým Krtíšom, Pôtrom a Stracinami. Pochopil geologickú stavbu a nasmeroval vrtný prieskum na hlavné spodnomiocénne uhľonosné pôtorské vrstvy, kde boli sloje ložiska najhrubšie. Vrtmi zdokumentoval túto časť ložiska a dal podklad na výpočet zásoby a projekčné práce na banské otvorenie ložiska.

Na tejto energetickosurovinovej báze sa potom rozvíjal priemysel a kedysi zabudnutá dedinka Veľký Krtíš sa premenila na banícke a priemyselné mesto, dnes sídlo okresu. Po päťdesiatich rokoch intenzívnej ťažby je ložisko uhlia zväčša vyčerpané a ťažba uhlia pochovaného v hĺbke pod vulkanitmi Krupinskej planiny v súčasnosti neprichádza do úvahy. Mesto Veľký Krtíš však zostáva okresným mestom, aj keď samo i celý okres úsporne hľadajú náhradný výrobný program namiesto vyznievajúceho hnedouhoľného baníctva.

Program Dni A. H. Škultétyho, čo je názov periodicky sa opakujúcich kultúrnych akcií s meniacim sa programom, sa začal slávnostnou akadémiou, vernisážou výstavy o jubilujúcich osobnostiach, slávnostným prijatím baníkov predstaviteľmi mesta, kladením kvetov k pamätníku V. Čechoviča a odhalením pamätnej dosky A. K. Meššovi na mestskom cintoríne. Druhý deň sa konal popularizačný seminár, ktorého cieľom bolo bližšie zoznámiť verejnosť, najmä študujúcu mládež so životom a dielom obidvoch oslávencov. Históriu uhoľného baníctva v oblasti Veľkého Krtíša na seminári zhodnotil Ing. Eugen Kladivík, CSc., pracovník Slovenského banského múzea v Banskej Štiavnici, osobnosť A. K. Meššu, jeho podnikateľskú aj literárnu činnosť predstavila PhDr. Marta Kamasová zo Štátneho archívu vo Veľkom Krtíši. Prednášku o vedeckej a prospektorskej práci Ing. RNDr. V. Čechoviča, DrSc., člena korešpondenta SAV, ako aj o jeho životných osudoch a zástojoch predniesol člen výboru SGS prof. Dr. Dionýz Vass, DrSc. Význam banského podnikania v druhej polovici 20. stor. a jeho vplyv na rozvoj Veľkého Krtíša i celého okresu zhodnotil Ing. Igor Cífer z Bane Dolina, a. s.

Na slávnosti sa zúčastnili potomci A. K. Meššu a dcéra V. Čechoviča Irina.

Myšlienka zorganizovať spomienkové oslavy významných ľudí, ktorí žili, resp. pracovali v regióne Ipeľskej kotliny, si zaslúži vysoké ocenenie. Na Slovensku je podobných osláv stále málo a ak sú, nemajú náležitú publicitu. Organizátorom platí za prípravu a dokonalú realizáciu programu zaslúžená vďaka. Obidvaja oslávenci svojím tvorivým a zmysluplným životom môžu byť vzorom dnešnej mladej generácii a aj preto si v roku nedožitých jubileí pietnu oslavu a spomienku plne zasluhujú.

D. Vass

Ospravedlnenie

Autori publikácie O. Samuel a P. Grecula sa ospravedlňujú RNDr. Miroslavovi Slavkayovi, PhD., za nesprávne uvedené údaje v publikácii **60 rokov Štátneho geologického ústavu Dionýza Štúra**. Prosíme čitateľov o opravu a doplnenie nasledujúcich častí textu.

– Na s. 53 má byť: Obr. 89 Dr. Miroslav Slavkay, riaditeľ ústavu 1985–1990.

– V poslednom odseku na s. 53 má byť konštatácia, že sa na ústavnej schôdzke požadovalo zrušenie aktívnej činnosti straníckej organizácie v ústave, ale nie abdikácia vedenia ústavu (akčný výbor, ktorý vznikol 29. 11. 1989 zo štrajkového výboru, abdikáciu vedenia vo svojom uverejnenom programe nemal). Pôsobenie základných organizácií všetkých politických strán v ústave bolo zrušené doplnkom č. 1 (z 22. 12. 1989) opatrenia č. 106/1989 (1. 12. 1989).

– Nesprávny je údaj z 31. 12. 1989 o abdikácii riaditeľa GÚDŠ (s. 54). RNDr. Miroslav Slavkay, CSc., v tradičnom novoročnom prejave riaditeľa (1990) informoval pracovníkov ústavu o svojom rozhodnutí a zámere požiadať Ing. V. Pikarta (vtedy povereného vedením Slovenského geologického úradu) vypísať konkurz na obsadenie funkcie riaditeľa GÚDŠ, lebo vzhľadom na formovanie sa nových ekonomicko-spoločenských podmienok sa nechcel stať prípadnou prekážkou vývoja ústavu. Na základe jeho žiadosti ho z funkcie riaditeľa 22. januára 1990 odvolal už novovymenovaný predseda SGÚ RNDr. Ing. Ján Burian, CSc. RNDr. Miroslav Slavkay, CSc., 25. januára 1990 funkciu protokolárne odovzdal RNDr. Tomášovi Korábovi, CSc., ktorý ju prevzal so všetkými náležitosťami bez akýchkoľvek pripomienok.

– RNDr. Miroslav Slavkay, CSc., v prejave na schôdzke ústavu pri odovzdávaní funkcie riaditeľa a uvádzaní RNDr. Tomáša Korába, CSc., do funkcie riaditeľa GÚDŠ uviedol pohnútky, ktoré ho viedli k odstúpeniu.

– Na s. 55 má byť: Obr. 96 Dr. M. Kaličiak, CSc., poverený vedením ústavu koncom roka 1995.

– Odkaz na modifikovanú štruktúru ústavu (t. j. na s. 95) má byť na obr. 97

– V niektorých výtlačkoch je namiesto s. 20 vytlačená s. 60 a namiesto s. 24 s. 64.

– O vzájomnej spolupráci riaditeľa a vedenia GÚDŠ s akčným výborom svedčí aj výsledok spoločnej porady z 1. 12. 1989, na ktorej sa okrem iného uzniesli zasadiť sa o dobré nažívanie a dobrú pracovnú atmosféru v ústave.

– Vedecká rada, zvolená tajným hlasovaním (s. 54), bola vymenovaná až roku 1990.

Významné udalosti, ktoré mali vplyv na ďalší vývoj slovenskej geológie, sa v publikácii neuviedli. Na seminári k 70. výročiu založenia Ústredného ústavu geologického v Prahe odznel diskusný príspevok s návrhom zriadiť federálny Československý geologický ústav a na ministerstvách úrady aplikovaného geologického výskumu (tým by sa bol zrušil rezort geológie). Riaditeľ ústavu RNDr. Miroslav Slavkay, CSc., s jeho obsahom zoznámil akčný výbor a v tejto súvislosti inicioval spolu s vedením ústavu, VPN SGÚ a VPN GÚDŠ poradu zástupcov SGÚ, Geologického ústavu SAV a Prírodovedeckej fakulty UK, ktorá sa konala 8. 12. 1989 a návrh uvedeného príspevku odmietla. Zástupcovia organizácií sa dohodli podporovať zachovanie rezortu slovenskej geológie (SGÚ) a pripraviť návrh na ďalšiu orientáciu geologického výskumu a prieskumu. Vedenie ústavu iniciatívne postupovalo aj pri organizovaní a v priebehu porady 21. 1. 1990 zvolanej k návrhu kandidáta na funkciu predsedu SGÚ.

Tieto aj ďalšie udalosti a ich priebeh po novembri 1989 sú zachytené v ústavných novinách Spravodaj 1/90 až Spravodaj 4/1990, v Ročenke GÚDŠ za rok 1989 a 1990 (sú uložené v knižnici a poskytujú obraz o dianí v ústave počas ich vydávania), v zápisoch z porád, rokovaní a schôdzok uložených v archíve ústavu.

O. Samuel a P. Grecula

Autori publikácie **60 rokov Štátneho geologického ústavu Dionýza Štúra** (Štátny geologický ústav Dionýza Štúra, Bratislava, Vydavateľstvo Dionýza Štúra 2000, ISBN 80-88974-17-8) sa touto cestou verejne ospravedlňujú RNDr. Kamilovi Vranovi, CSc., Planckova 4, 851 01 Bratislava, za zverejnenie nepravdivých informácií na s. 55 uvedenej publikácie a potvrdzujú, že RNDr. Kamil Vrana, CSc., bol do funkcie riaditeľa Geologického ústavu Dionýza Štúra v Bratislave od 1. apríla 1994 vymenovaný na základe výsledkov konkurzu, ktorý vypísalo Ministerstvo životného prostredia Slovenskej republiky, a odporúčania konkurznej komisie výberom z piatich uchádzačov a z funkcie riaditeľa ústavu bez udania dôvodu odvolaný 30. októbra 1995.

O. Samuel a P. Grecula

D. Bodiš – S. Rapant: **Geochemický atlas Slovenskej republiky – časť VI – Riečne sedimenty.** Bratislava, Štátny geologický ústav D. Štúra 1999. 145 s., 48 obr. a 38 tab.

ŠGÚDŠ v rokoch 1991–1999 vykonal rozsiahle geochemické mapovanie jemnej frakcie riečnych sedimentov z celého územia Slovenskej republiky a jeho výsledky predstavuje recenzovaná publikácia. Geochemický atlas riečnych sedimentov je šiestym a zároveň posledným dielom radu geochemických atlasov Slovenska, ktorým sa končí celoslovenské geochemické mapovanie a tvorba geochemických báz dát o podzemných vodách, lesnej biomase, prírodnej rádioaktivite, horninách, pôde a o riečnych sedimentoch. Tento atlas teda završuje etapu základného poznávania a mapovania geochemického prostredia SR.

Z environmentálneho hľadiska predstavujú riečne sedimenty v prírodných podmienkach SR – krajiny s veľmi členitým terénom a s rozvinutou riečnou sieťou – najdôležitejšie médium na charakterizovanie geochemického pozadia. Sú prostredím, v ktorom sa odráža geochemická povaha a zloženie vody, pôdy, hornín a produktov ich zvetrávania, v ktorom prebieha rozhodujúca časť prírodných samočistiacich procesov, dôležitým akumulačným, ale aj migračným prostredím chemických prvkov. Aj preto bola hustota odberu vzoriek riečnych sedimentov odobratých v súvislosti s tvorbou geochemických atlasov Slovenska najväčšia – jedna vzorka na 2 km^2. Pri záverečnom spracúvaní a tvorbe geochemických máp atlasu sa použilo dovedna 24 432 vzoriek.

Vzorky sa odobrali v pomerne úzkom časovom rozpätí v širšom letnom období v rokoch 1991–1995, sušili sa pri 40 °C a osievali na frakciu pod 0,125 mm. Analyzoval sa obsah nasledujúcich 35 prvkov: Al, As, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cu, Fe, Ga, Hg, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Rb, Sb, Se, Sn, Sr, Ti, V, W, Y, Zn a Zr

Všetky laboratórne práce sa vykonali v akreditovanom skúšobnom laboratóriu GAL ŠGÚDŠ v Spišskej Novej Vsi Ich vysokú kvalitu – porovnateľnú s kvalitou analýz najlepších svetových geologických laboratórií – garantuje vyspelá laboratórna technika, použité referenčné materiály, komplexný systém vnútornej kontroly a externého auditu.

Výsledky geochemického mapovania riečnych sedimentov sa predstavujú v štandardnej forme, plošnými a bodovými mapami distribúcie prvkov v mierke 1 : 1 000 000. Pri každom prvku sa uvádza jeho základné matematickoštatistické spracovanie, podstatné geochemické vlastnosti s dôrazom na správanie v geologických procesoch, opisuje sa jeho distribúcia v riečnych sedimentoch na Slovensku, uvádzajú sa jeho viaceré geochemicky dôležité environmentálne štandardy, ako aj priemerný obsah v riečnych sedimentoch hlavných horninových typov geologického prostredia znosových oblastí.

Recenzovaný atlas uzatvára edíciu geochemických atlasov, a preto treba veľmi vysoko oceniť aj fakt, že sa jeho autori neobmedzili iba na hodnotenie riečnych sedimentov, ale opisujú a charakterizujú aj zdanlivo s témou veľmi voľne súvisiacu problematiku. Stručne predstavujú históriu geochémie aj geochémie na Slovensku (kapitola 2), geologickú stavbu (kapitola 4), kvartérne sedimenty (kapitola 5), geochémiu hornín (kapitola 6) a metalogenézu územia SR (kapitola 7).

Keďže recenzovaný atlas – ale aj celá edícia geochemických atlasov – slúži a bude slúžiť na environmentálne hodnotenie rozličného druhu, treba ako múdre privítať rozhodnutie, že sa do tohto záverečného dielu spracovala aj kapitola 8 Geofaktory a zdravie, ktorá obsahuje medicínsku a geochemickú charakteristiku sledovaných prvkov a analyzuje – aj keď iba v akejsi rešeršnej forme – potenciálny vplyv nadbytku alebo nedostatku chemických prvkov na ľudské zdravie.

Odber vzoriek, ich úprava a chemická analýza, ale aj kompilácia a tvorba monoprvkových máp prebiehali podľa najmodernejších metodických postupov používaných aj v zahraničí (IGCP259, IGPC360).

Význam publikácie **Geochemický atlas Slovenskej republiky – časť VI – Riečne sedimenty** vidíme po prvé v tom, že komplexne a objektívne charakterizuje geochemické prostredie a úroveň antropogénnej kontaminácie riečnych sedimentov Slovenska, a po druhé v tom, že rozsahom i úrovňou analýz a výsledkov umožňuje slovenskej geológii zapojiť sa do komplexných environmentálnych programov monitoringu životného prostredia v rámci SR, Európy aj sveta.

(Recenzované dielo si možno kúpiť v Štátnom geologickom ústave Dionýza Štúra, Mlynská dolina 1, 817 04 Bratislava za 1900 Sk.)

P Grecula

P. Semrád – J. Kováč: **Dubnícke opálové bane.** Prešov, Vydavateľstvo Michala Vaška 2000. 112 s.

Monografiu Dubnícke opálové bane, ktorá vyšla v júli roku 2000 a ktorej by som rád venoval pár riadkov, možno právom pokladať za vzácny prínos do knižnice mnohých z nás. Zaoberá sa jedinečným slovenským prírodno-technickým skvostom opálových baní v Slanských vrchoch na východnom Slovensku. V pomerne rozsiahlom texte autori účelne a pre široký okruh čitateľov zrozumiteľne napísanú monografiu rozdelili do siedmich kapitol. Text dopĺňa kvalitne spracovaná farebná príloha a šesť voľne priložených máp z oblasti sledovaných opálových baní.

Recenzovaná publikácia nie je knižnou prvotinou o sledovanej problematike. Roku 1970 vyšla známa knižka Dr. Butkoviča pod názvom *História slovenského drahého opálu z Dubníka*, ale tá je už takmer zabudnutá a navyše sa orientáciou aj štruktúrou od svojej nástupkyne diametrálne odlišuje.

Nová monografia nesleduje iba históriu dubníckych baní, ale v oveľa širšom zábere, a najmä aktuálnym pohľadom približuje čitateľovi prostredie Dubníka a Šimonky, kde v minulosti prekvitala ťažba vzácneho opálu. Ale práca vonkoncom nie je zameraná iba na opál a pohnutú históriu jeho ťažby, ako je to v prípade diela Dr. Butkoviča, ale slovami nadšených účastníkov tábora Stromu života sviežo a pútavo vypovedá o neopakovateľnej kráse tejto časti Slanských vrchov, o ich geografických a geologických pomeroch, histórii ťažby, zachovaných pamiatkach bývalých opálových baní, prírodných hodnotách starých banských diel i o nových záujmoch a o ochrane lokality. V prílohovej časti autori navyše uvádzajú zaujímavý zoznam predmetov uložených v depozitároch štátnych múzeí aj súkromných zberateľov, čo celé dielo ešte obohacuje. Vhodne sa do publikácie zaradil aj účelový slovník odborných termínov.

Po starostlivom preštudovaní možno mať k recenzovanej publikácii aj niekoľko výhrad alebo skôr poznámok.

– Pri čiernobielych celostránkových fotografiách chýba vysvetľujúci text.

– Na viacerých miestach nie je presne uvedený prameň, odkiaľ sa text preberá (napr. 2. odsek zhora na s. 5 – autorom je Dr. Butkovič).

– Na s. 12 chýba zdroj, z ktorého sa prevzal výrok Plínia st. – ale aj tak ide o nesprávnu interpretáciu pôvodného textu (o nesprávny preklad).

– Pri drahom opáli odporúčame používať termín opalescencia, nie opalizácia, lebo ten trochu mýli (pozri s. 20).

– Na ciele recenzovanej práce by azda bolo vhodnejšie zostaviť nové, presnejšie analýzy (tab. 2 na s. 21).

– Opál Horiaca Trója je súčasťou francúzskych korunovačných klenotov (s. 59). Navyše aj tu chýba citácia zdroja historických údajov. V tejto časti je nepresností viac.

– Na s. 66 by medzi hnuteľné pamiatky bolo vhodné v budúcnosti zaradiť aj jednu z mála cirkevných pamiatok s dubníckym drahým opálom – cibórium Farského kostola v Prešove.

– Niektoré značky (napr * na s. 153 označujúca fotografiu) nie sú v texte vysvetlené.

Ďalšie drobné chyby sú pravopisnej a technickej povahy. Uvedené nedostatky a chyby nemajú podstatný vplyv na kvalitu publikácie.

Dubnícke opálové bane boli a aj v budúcnosti by mali zostať vzácnym klenotom v srdciach nás všetkých. Drahý opál, za ktorým sa dodnes v túžbe po bohatstve ženú do podzemia mnohí fanatici, by sa mohol a azda právom aj mal stať naším národným drahokamom. Ale ten ani tu – na Dubníku – nie je jediným. Je tam aj veľký prírodný pamätník ľudskej práce v podobe starých opálových baní, ale aj mnoho skvostov živej prírody.

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Náš drahokam nemá cenu len ako kameň, aj keď ide o vzácny dubnícky opál, ale aj ako súčasť čarokrásnej krajiny, ako ho predstavuje recenzovaná práca. Aj preto ju úprimne odporúčam všetkým záujemcom o krásy slovenskej prírody a o stále tajomný svet drahokamov

(Cena recenzovanej publikácie je okolo 250 Sk.)

Maroš Barok

Exkurzná trasa zjazdu SGS
28. – 29. 6. 2001

•--•--• 1 deň
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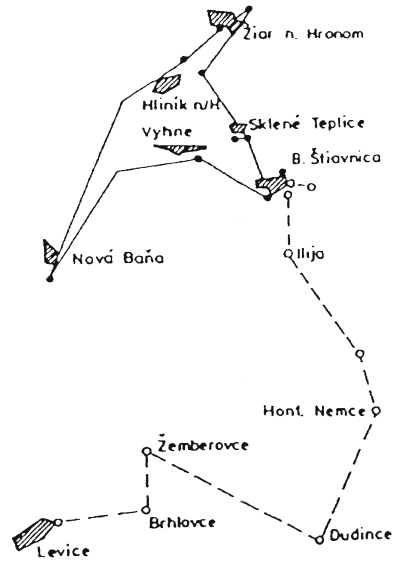

KONTAKTNÁ OSOBA:
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Zjazd SGS 2001
Štátny geologický ústav Dionýza Štúra,
Mlynská dolina 1
817 04 Bratislava
Slovenská republika

ZJAZD
Slovenskej geologickej spoločnosti
pri SAV

2001

1. cirkulár

Mesto na vulkáne

BANSKÁ ŠTIAVNICA

**GEOLOGICKÁ STAVBA,
METALOGENÉZA
A ŽIVOTNÉ PROSTREDIE
ŠTIAVNICKÉHO STRATOVULKÁNU**

Tématické zameranie:

Nové výsledky:

- geologického
- vulkanologického
- ložiskového
- hydrogeologického
- inžinierskogeologického
- enviromentalne-geologického výskumu v stredoslovenských neovulkanitoch

(K daným témam budú vyžiadané prednášky)

Organizátori:

Slovenská geologická spoločnosť pri SAV
Bratislava; vulkanologická skupina
a pobočka SGS Banská Bystrica

Program:

1. deň: 27.6.2001
Odborné prednášky

2. a 3. deň: 28.-29.6.2001
Exkurzia po štiavnickom stratovulkáne

MIESTO:

Banská Štiavnica
Štiavnický stratovulkán

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nečlenovia SGS: 1 000.-Sk
Ubytovanie*: 200.-Sk/noc
(v internáte)
Celodenná strava: 200.-Sk

Exkurzia: 470.-Sk

Poznámka:
**možnosť zaistiť hotelové ubytovanie*

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Mesto na vulkáne
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27. – 29. 6. 2001**

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5. Zreteľne treba odlíšiť východiskové údaje od interpretácií.
6. Neopakovať údaje z tabuliek a obrázkov, iba ich komentovať a odvolať sa na príslušnú tabuľku, resp. obrázok.
7. Text treba členiť nadpismi. Hlavné nadpisy písať do stredu, vedľajšie na ľavý okraj strany. Voliť najviac tri druhy hierarchických nadpisov. Ich dôležitosť autor vyznačí ceruzkou na ľavom okraji strany: 1 - hierarchicky najvyšší, 2 - nižší, 3 - najnižší nadpis.
8. V texte sa uprednostňuje citácia v zátvorke, napr. (Dubčák, 1987; Hrubý et al., 1988) pred formou ... podľa Dubčáka (1987). Ani v jednom prípade sa neuvádzajú krstné mená.
9. Umiestnenie obrázkov a tabuliek sa označí ceruzkou na ľavom okraji rukopisu, resp. stĺpcového obtiahu.
10. Grécke písmená použité v texte treba identifikovať na ľavom okraji slovom (napr. sigma).
11. Pri písaní starostlivo odlišujte pomlčku od spojovníka.
12. Symboly, matematické značky, názvy skamenelín, slová a pod., ktoré treba vysádzať kurzívou, autor v rukopise podčiarkne vlnovkou.
13. K článku treba pripojiť kľúčové slová.
14. Abstrakt, resumé, vysvetlivky k obrázkom a názvy tabuliek predloží autor redakcii aj v angličtine.

Ilustrácie

1. Musia byť vysokej kvality. Majú dokumentovať a objasňovať text. Originál (pred zmenšením) môže mať rozmer najviac 340 x 210 mm. Maximálny rozmer ilustrácie vytlačený v časopise je 170 x 230 mm. Skladacie ilustrácie treba úplne vylúčiť.
   V prípade ilustrácií vytvorených na počítači prosíme o ich zaslanie na diskete 3,5" vo formáte CorelDraw (PC), Adobe Illustrator (PC, Mac) alebo Aldus FreeHand (Mac).
2. Ilustrácie pripravovať s vedomím, že sa budú zmenšovať (zvyčajne o 50 %) na šírku stĺpca (81 mm) alebo strany (170 mm). Podľa toho pripravovať ich veľkosť a formu, resp. ich zoskupenie.
3. Voliť takú veľkosť písma a čísel, aby najmenšie písmená po zmenšení boli veľké aspoň 1,2 mm. Úmerne zmenšeniu voliť aj hrúbku čiar.
4. Obrázky popisovať šablónou, nie voľnou rukou.
5. Všetky ilustrácie včítane fotografií musia obsahovať grafickú (metrickú) mierku.
6. Zoskupené obrázky, napr. fotografie, diagramy, musia byť pripravené (nalepené) ako jeden obrázok a jeho časti treba označiť písmenami (a, b, c atď.). Takto zoskupené obrázky sa citujú ako jeden obrázok. Zoskupené fotografie treba starostlivo upraviť a nalepiť na biely kriedový papier.
7. Fotografie musia byť ostré, čiernobiele, kontrastné a vyhotovené na lesklom papieri. Je vhodné, aby sa zmenšovali minimálne o 50 %.
8. Na všetkých obrázkoch sa na okraji (na fotografiách na zadnej strane) ceruzkou uvedie číslo obrázku a meno autora. Na fotografiách sa šípkou doplní aj orientácia obrázku.
9. Na mapách a profiloch voliť jednotné vysvetlivky, ktoré sa uvedú pri prvom obrázku.
10. Názvy obrázkov a vysvetlivky sa píšu strojom na osobitný list.
11. Všetky ilustrácie sa musia citovať v texte.
12. Ilustrácie sa zasielajú redakcii už imprimované, teda pri korektúre ich už nemožno opravovať a dopĺňať.
13. Farebné ilustrácie sú vítané, ale náklady na ich tlač hradí autor.

Tabuľky

1. Tabuľky sa píšu na osobitný list. Ich rozsah a vnútornú úpravu treba voliť tak, aby sa tabuľka umiestnila do stĺpca alebo na šírku strany. Rozsiahlejšie tabuľky sa neprijímajú.
2. Údaje zoraďujte do tabuľky iba vtedy, ak sa nedajú uviesť v texte.
3. Nadpis tabuľky a prípadný sprievodný text sa píše strojom na osobitný list (úpravu nadpisov pozri v časopise).
4. Vertikálne čiary v tabuľkách nepoužívať.
5. Tabuľky sa číslujú priebežne a uverejňujú sa v číselnom poradí.

Literatúra

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   Kniha
   Gazda, L. & Čech, M., 1988: Paleozoikum medzevského príkrovu. Alfa Bratislava, 155.

   Časopis
   Vrba, P., 1989: Strižné zóny v komplexoch metapelitov. Mineralia Slov., 21, 135 - 142.

   Zborník
   Návesný, D., 1987: Vysokodraselné ryolity. In: Romanov, V. (red.): Stratiformné ložiská gemerika. Špec. publ. Slov. geol. spol., Košice, 203 - 215.

   Manuskript
   Radvanský, F., Slivka, B., Viktor, J. & Srnka, T., 1985: Žilné ložiská jedľoveckého príkrovu gemerika. Záverečná správa z úlohy SGR-geofyzika. Manuskript—archív GP Spišská Nová Ves, 28.
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