INTERNATIONAL FIELD WORKSHOP ON NEOTECTONICS

Vikartovce fault (VIF) & Muráň fault (MUF) – Vernár, Slovakia, 15. – 18. 10. 2009

Medzinárodný terénny workshop so zameraním na neotektonickú aktivitu vikartovského a muránskeho zlomu – Vernár, 15. – 18. 10. 2009

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Abstract. *The research team of the Slovakian project APVV-0158-06 NEOTACT (Neotectonic activity of the Western Carpathians) has organized the International field workshop on Neotectonics, held in the Vernár mountain village, district Poprad, Tatry area. The goal of the workshop was a presentation of the progress in the research of neotectonically suspected faults in the Western Carpathian area, focused to field excursions on morphologically distinct neotectonics structures on Vikartovce fault (Hornádska kotlina Basin – Kozie chrbty Mts.), Muráň fault (central part between Tisovec town – Muráň village) and the study of active tectonic processes in the Quaternary Travertines in Gánovce travertine heap, Sivá Brada travertine heap and Spišský hrad Castle. Meeting was informal, consisting of the lectures and discussions in couloars, out of time restriction.*

Key words: *neotectonic activity, Western Carpathians, report upon seminar*

Výskumný tím projektu APVV-0158-06 NEOTACT (Neotektonická aktivita Západných Karpát, zodp. riešiteľ F. Marko, Prírodovedecká fakulta UK Bratislava), financovaného Agentúrou na podporu vedy a výskumu, usporiadal v dňoch 15. – 18. októbra 2009 vo Vernári pod Tatrami, medzinárodný terénny workshop so zameraním na neotektonickú aktivitu vikartovského a muránskeho zlomu. Hlavnými organizátormi podujatia, ktoré bolo zavŕšením výskumných aktivít na projekte a prezentáciou hlavných výstupov NEOTACTu, konfrontované na fóre prizvaných špecialistov, boli František Marko, Jozef Hók, Rastislav Vojtko a Ján Madarás. Napriek extrémnej nepriazni počasia tesne pred začiatkom workshopu, ktorá znemožnila účasť niektorým zahraničným hosťom, považujeme túto akciu za veľmi úspešnú. Počas troch dní odzneli referáty jednotlivých riešiteľov grantu a prednášky zahraničných účastníkov z Česka, Poľska a Rakúska s príbuznou problematikou neotektonického vývoja regiónov. Veľkým prínosom boli aj prednášky geodetov z Katedry geodetických základov Stavebnej fakulty Technickej univerzity v Bratislave, s ktorými výskumný tím špecialistov na neotektonickú a seizmickú aktivitu úzko spolupracuje už desať rokov.

Dva dni boli venované terénnym exkurziám. Prvá umožnila spoznať detailný geologický, tektonický, geomorfologický, geofyzikálny a geodetický obraz oblasti vikartovského zlomu. Účastníkom boli prezentované výsledky výskumu tohto výnimočného fenoménu v Západných Karpatoch, ktorý bol naším tímom vytipovaný ako jedna z najvhodnejších štruktúr na detailný neotektonický výskum. Výsledky potvrdzujú, že voľba bola úspešná. Zlom sa prejavuje výrazným morfologickým kontrastom reliéfu najmä na v.-z. rozhraní hornej časti Hornádskej kotliny s južnými svahmi Kozích chrbtov. Juvenilné rotácie horninových blokov (tilting) pozdĺž hlavného

Obr. 1. Pohľad na strednú časť priebehu muránskeho zlomu pri obci Muráň. Na ľavej strane vystupujú karbonátové komplexy mezozoického veku silicika Muránskeho príkrovu, na pravej strane je varíske kryštalinikum veporika (kohútska zóna). Foto J. Madarás.

Fig. 1. View on the central part of the Muráň fault (MUF) and the Muráň village valley. The Mesozoic carbonate complexes of the Silicic Unit (the Muráň Nappe) are on the left side, the Variscan crystalline basement of the Veporic Unit (Kohút Zone) is on the right side. Photo J. Madarás.

a sprievodných zlomov sú evidentné pri pohľade na severnú stranu Kozích chrbtov, ako aj v podobe menších elevácií s rovnakým mechanizmom vzniku v samotnej Hornádskej kotline južne od Kozích chrbtov. Mladý (pleistocénny) výzdvih hrastu mal za následok aj zmenu riečnej siete v rozvodí Hornádu a Popradu. Sprievodná neotektonická a recentná aktivita zlomu je dokumentovaná výskytmi kvartérnych travertínov v línii od Gánoviec až po najväčšie travertínové telesá na Slovensku – Sivú Bradu, Spišský hrad a Dreveník.

Druhá exkurzia viedla pozdĺž muránskeho zlomu – od tzv. vernárskeho uzla v sedle Besník, cez Muránsku Hutu, sedlo Predná hora, Muráň, sedlo Dielik až po Tisovec. Na jednotlivých zastávkach bola prezentovaná geologická história nielen jednej z najvýraznejších tektonických línií v Západných Karpatoch, ale aj geologický vývoj širšej oblasti veporika, gemerika, hronika a silicika. Neotektonické aspekty boli prezentované a diskutované v teréne najmä na lokalitách v oblasti Muráňa, včítane nových geofyzikálnych profilov vedených naprieč zlomovou zónou, ktoré boli realizované v rámci projektu.

Večerné prednášky v príjemnej atmosfére horského penziónu boli neformálne, zamerané na vecnú vedeckú diskusiu, bez časového obmedzenia – brainstorming, ktorý sa v dnešnej uponáhľanej dobe stáva napriek neoceniteľnému prínosu čoraz zriedkavejší. Kuloárové diskusie boli zárodkom ďalšej spolupráce (pokračovania projektu) a prospešného porozumenia geológov so seizmológmi a geodetmi na poli neotektonického výskumu.

Obr. 2. Odborný výklad neotektonickej charakteristiky vikartovského zlomu na lokalite Spišské Bystré. Zľava: R. Vojtko, A. Mojzeš, L. Hippmanová, L. Vlček a F. Marko. Foto J. Madarás.

Fig. 2. Interpretation of neotectonic characteristics of the Vikartovce fault (VIF) in locality Spišské Bystré. From the left: R. Vojtko, A. Mojzeš, L. Hippmanová, L. Vlček and F. Marko. Photo J. Madarás.

Obr. 3. Ľ. Petro a R. Vojtko pri výklade neotektonických fenoménov v kvartérnych travertínoch pod Spišským hradom. Foto J. Madarás.

Fig. 3. Neotectonic phenomena in the Quaternary travertine below the Spišský hrad Castle were explained by Ľ. Petro and R. Vojtko. Photo J. Madarás.

Obr. 4. J. Papčo prezentuje výsledky presných geodetických meraní v Tatrách. Foto J. Madarás.

Fig. 4. J. Papčo presents the results of the precise geodetic measurements in the Tatras. Photo J. Madarás.

Obr. 5. Účastníci workshopu počas odborného výkladu na lokalite Predná hora. Foto J. Madarás.

Fig. 5. Participants of the workshop during the presentation in the locality Predná hora. Photo J. Madarás.

A. BEIDINGER[1], K. DECKER[1] and K. H. ROCH[2]: **The Lassee flower structure of the active sinistral Vienna Basin Fault System: Integrating data from seismics, tectonic geomorphology and GPR**

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The active sinistral Vienna Basin Fault System (VBFS) extends from the Eastern Alps along the Mur-Mürz Valley through the Vienna Basin into the Western Carpathians. Its development is related to the Miocene lateral escape of the Eastern Alps towards the Pannonian region, which led to the opening of the Vienna Basin as a pull apart basin between two left stepping large scale segments of the VBFS. The active fault system consists of reactivated Miocene faults and comprises several strike slip segments, which differ both in their kinematic and seismologic properties. In the region of the Vienna Basin, the active seismicity is concentrated along the SE boundary fault of the Vienna Basin. Among the several seismotectonic fault segments along the SE boundary fault, the Lassee segment 30 km E of Vienna is of particular interest for seismic hazard assessment. Considering the earthquake catalogues comprising historical earthquake recordings back to the 13th century, they show a marked seismic slip deficit with virtually no seismic slip for the considered time span. However, the segment is located about 8 km from the Roman city of *Carnuntum*, for which the archeological data indicate a destructive earthquake in the 4th century AD (local intensity I ~ 9 EMS-1998).

The seismic mapping of a grid of industrial 2D seismic lines crossing the Quaternary Lassee basin and the adjacent Pleistocene terraces depicts a negative flower structure. The flower structure developed during the Middle and Upper Miocene. It consists of several splay faults, which are regarded as Riedel shears connected by relay ramps. These Riedel shears mostly merge at the interface between the pre-Neogene basement and the Miocene basin fill. The major branch line which marks the top of the principle displacement zone is mapped at the convergence of the outermost splay faults delimiting the flower structure both to the SE and NW. Below the centre of the Lassee basin the branch line is situated at about 3 400 m depth coinciding with the interface between the Miocene basin fill and the pre-Neogene basement. It dips towards NNE to a depth of c. 5 500 m within the pre--Neogene basement in the northernmost seismic section. Contrary to the branch lines of lower order in the upper part of the flower structure, the branch line on the top of the PDZ is not controlled by the interface between the basin fill and the basement.

The growth strata within the flower structure show that the faults accumulated only moderate displacement in the Middle Miocene (Badenian to Early Sarmatian; c. 200 – 400 m vertical displacement within 4.1 Ma). Vertical throw for this time interval along the SE boundary splay faults is slightly higher than along the NW boundary splay faults. The major fault activity occurred between the Upper Sarmatian and Upper Pannonian, which comprises a time interval of about 3.2 to 4.2 Ma. In that time the maximum vertical displacement of c. 1 150 m is distributed along an 800 m wide fault zone, which comprises several minor splay faults spaced at distances of 100 to 200 m. These splay faults again merge at the interface between the pre-Neogene basement and the Miocene basin fill. The total vertical slip between Upper Sarmatian and Upper Pannonian times at the SE boundary splay faults exceeds the displacement along the NW boundary splay faults by a factor of 10. This heterogeneous distribution of vertical offset results in an asymmetric shape of the flower structure with horizons dipping towards SE.

The Pleistocene basin analyses and the tectonic geomorphology prove continued faulting during the Quaternary by reactivation of the Miocene faults. This is depicted by the asymmetric shape of the Pleistocene Lassee basin overlying the flower structure, tilting of surface topography towards the fault zone at the SE boundary of the flower and the fault controlled scarps. The Lassee basin with up to 120 m thick Quaternary sediments is confined by elevated Middle Pleistocene terraces to both sides. Towards the basin the terraces show en-echelon, right stepping morphological scarps, which coincide with the underlying en-echelon right stepping faults mapped in seismic. To the N and S the terrace boundaries are erosion controlled and terminate against the Holocene flood plains of the Danube and the March River.

Mapping the PDZ of the southern boundary fault of the Vienna Basin by using additional 2D seismic data in the NE and SW continuation of the Lassee segment reveals several segments along the active strike--slip fault, which differ by the orientation of the PDZ. NE- and NNE--striking segments with releasing bend geometries are associated with the Quaternary basins. These segments are connected by the ENE--striking segments oriented parallel to the displacement vector and not associated with a Quaternary basin. Among the releasing bends, the Lassee segment is subjected to increased extension due to the high angle (35°) between the general slip vector and the orientation of the fault. Resulting extension seems to be accommodated by both, the negative flower structure and normal faults (Markgrafneusiedl fault and its antithetic faults), which are situated W of the strike-slip fault and branch off from the PDZ south of the Lassee releasing bend.

For the reconstruction of the youngest faulting history along the Lassee segment the additional geomorphologic studies and GPR studies at the segmented NW scarp of the Schlosshof terrace were obtained. Topographic analyses of the dry valleys, crossing the fault controlled scarp, depict hanging valleys with marked knickpoints in the valley floor. These knickpoints result from an imbalance of the tectonic subsidence and erosion by ephemeric floods, where the tectonic subsidence outweighs erosion. The about 20 m high NNE trending morphological scarp is situated above the fault zone at the SE boundary of the flower structure. There 40 MHz GPR measurements depict an offset of the base of Pleistocene sediments going along with a rapid increase in the sediment thickness. In the overlap region of two right stepping scarp segments two Pleistocene growth faults coinciding with the morphological scarps are indicated. The data obtained from the 40 MHz GPR measurements is in line with the information on Pleistocene sediments obtained from the boreholes crossing the scarps.

The higher resolution GPR measurements (500 MHz) were carried out in order to get an information on the uppermost sediment layers. Results show at least four distinct surface-breaking faults along a scarp segment including three faults, which are covered by about 2 m of post-tectonic strata. The youngest fault offsets these strata and coincides with a sharp, c. 0.5 m high linear morphologic scarp at the surface.

In summary data indicate that the Lassee Segment is capable to produce earthquakes comparable with the earthquake in the 4th century A.D., and may well be regarded as the source for the *Carnuntum* earthquake. The interpretation is in line with the local attenuation relations indicating a source close to the damaged site, observed fault dimensions and the fault offsets recorded by GPR and morphology.

L. FOJTÍKOVÁ[1], V. VAVRYČUK[2], J. MADARÁS[1,3] a A. CIPCIAR[1]: **Analýza zemetrasení použitých na určenie tektonického napätia v oblasti Malých Karpát**

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Z oblasti Malých Karpát bolo analyzovaných 44 zemetrasení s momentovým magnitúdom Mw > 1 z obdobia rokov 2001 – 2009. Na analýzu boli použité dáta zaznamenané krátkoperiodickými seizmometrami lokálnej siete EBO (Elektráreň Jaslovské Bohunice). Pre najsilnejšie zemetrasenia zo skúmaného súboru boli použité aj záznamy z krátkoperiodických a širokopásmových staníc NSSS (Národnej siete seizmických staníc). Zemetrasenia boli lokalizované a boli vypočítané ich ohniskové mechanizmy a momentové tenzory.

Epicentrá skúmaných zemetrasení sú rozptýlené v oblasti približne 50 km vo východo-západnom smere a 30 km v severo-južnom smere, prevažne v severnej časti Malých Karpát. Epicentrá tvoria približne líniu pretiahnutú v smere VSV – ZJZ. Tento smer súhlasí so smermi hlavných zlomových systémov v oblasti – s dobrovodským a brezovským zlomom. Veľký rozptyl epicentier v zóne môže indikovať, že ohniská nepatria iba k jednému zlomu.

Hĺbka zemetrasení je najmenej presne určeným parametrom pri lokalizácii. Hypocentrá sa nachádzajú približne v hĺbke od 1 km do 14 km a nevykazujú zjavnú závislosť od veľkosti zemetrasenia. Možno ale nájsť závislosť hĺbky zemetrasení od polohy epicentra. Najplytšie ohniská sa nachádzajú na ZJZ konci, kým najhlbšie ohniská sa nachádzajú na VSV od aktívnej línie.

Na určenie ohniskových mechanizmov a momentových tenzorov boli použité tri rozdielne metódy: 1) metóda využívajúca polarity Pg a Pn vĺn (program FOCMEC; Snoke, 2003), 2) inverzia momentových tenzorov z amplitúd P vĺn (program AMT; Vavryčuk, 2008), 3) inverzia momentových tenzorov z kompletných vlnových obrazov (program ISOLA; Sokos a Zahradník, 2009). Všetky tri metódy dali štatisticky konzistentné ohniskové mechanizmy a momentové tenzory. Zväčša ide o zemetrasenia s ľavostranným horizontálnym posunom so slabou normálovou (poklesovou) zložkou, alebo o zemetrasenia s mechanizmom poklesu.

Určené ohniskové mechanizmy boli použité na výpočet súčasného tektonického napätia skúmanej oblasti. Na výpočet tektonického napätia bola použitá metóda Angeliera (2002), ktorá je založená na kritériu maximálneho strižného napätia v smere sklzu (slip shear stress component criterion). Orientácie hlavných osí napätí sú (azimuth/odklon od horizontály): σ_1 = 210 – 220°/5 – 25°; σ_2 = 70 – 105°/55 – 75°; σ_3 = 305 – 315°/15 – 25°. Tvarový pomer nadobúda hodnoty R = 0,45 až 0,60. Z porovnania tektonického napätia v oblasti a v širšom regióne vyplynulo, že tektonické napätie v oblasti Malých Karpát má opačný smer maximálnej kompresie σ_1 (SV – JZ) a extenzie σ_3 (SZ – JV) voči západoeurópskemu a stredoeurópskemu napätiu. Tektonické napätie indikuje zložité tektonické podmienky v oblasti. Smer maximálnej kompresie je rovnobežný s hrebeňom Malých Karpát.

Táto práca bola podporovaná Agentúrou na podporu výskumu a vývoja na základe zmluvy č. APVV-0158-06 (úloha NEOTACT – Neotektonická aktivita územia Západných Karpát).

V. GAJDOŠ, K. ROZIMANT a A. MOJZEŠ: **Geofyzikálne práce na riešení projektu neotektonického vývoja v Západných Karpatoch**

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Projekt je koncipovaný širšie, a preto aj geofyzikálne práce boli realizované vo viacerých smeroch. Predovšetkým sa jednalo o terénne práce na štruktúrach v oblasti Dobrej Vody, Martina, na viacerých lokalitách pozdĺž línie muránskeho zlomu a v oblasti vikartovského zlomu a o kamerálne práce pri zostavení schémy geofyzikálnych prejavov zlomov pre elektronickú databázu zlomových štruktúr.

Pri terénnych prácach boli na profiloch lokalizovaných a orientovaných v súčinnosti s geologickým partnerom realizované metódy ERT (elektrická rezistivitná tomografia), VES (vertikálne elektrické sondovanie), VDV (metóda veľmi dlhých vĺn), SP (spontánna polarizácia), PEE (impulzná elektromagnetická emisia), emanometria a magnetometria.

V oblasti Dobrej Vody bol geofyzikálny profil umiestnený v miestach staršej kopanej sondy prechádzajúcej cez trhliny, ktoré vznikli pri zemetrasení v roku 1906 a v priebehu času zanikli. Z výsledkov merania bol zostavený vertikálny rez, v ktorom sa deformačné štruktúry v horninovom prostredí výrazne vyčleňujú a je možné zostaviť jeho model pozdĺž línie profilu.

V oblasti Martina boli zmerané dve lokality: Bystrička a Domašín. Na lokalite Bystrička sa vo vertikálnom geofyzikálnom reze naprieč okrajovým zlomom výrazne vyčlenila štruktúra horninového prostredia v okolí zlomu, z ktorej vyplýva, že sa nejedná o jednoduchý kontakt, ale o sériu vertikálne aj horizontálne diferencovaných, postupne smerom do kotliny poklesávajúcich blokov.

Na lokalite Domašín sa na profile vedenom v osi domašínskeho meandra vo vertikálnom geofyzikálnom reze výrazne vyčlenili jednotlivé terasové stupne, pričom z ich obrazu vyplýva, že postup poklesávania a tvorby sedimentov jednotlivých terás bol diferencovaný.

Muránsky zlom je aj vo svojich fyzikálnych prejavoch taká štruktúra, ktorá sa výrazne prejavuje v regionálnom magnetickom poli, jeho časti v tiažovom poli a v seizmickej aktivite, ako aj v anomálnej koncentrácii rôznych prvkov vrátane rádioaktívnych. Na tomto zlome, v úseku od Tisovca po sedlo Besník (východne od Telgártu), bolo vybraných 6 lokalít, na ktorých boli realizované geofyzikálne práce. Z výsledkov meraní na profiloch vedených naprieč líniou muránskeho zlomu boli zostavené vertikálne rezy. Zlom sa v rezoch prezentuje diferencovane: buď ako výrazný kontakt dvoch prostredí, alebo ako diferencovaná bloková štruktúra. Na strane poklesnutých blokov (vo väčšine prípadov sú to štruktúry paleozoika) sú vyvinuté pestré kvartérne sedimenty s materiálom z oboch strán zlomu. V rezoch je možné sledovať podrobnú štruktúru zlomového pásma a hodnotiť plynopriepustnosť jeho jednotlivých častí.

S muránskym zlomom súvisí aj projekt hodnotenia lokálnych pohybových aktivít pomocou série geodetických bodov v oblasti Málinca a Detvianskej Huty. Pre posúdenie možného vplyvu horninového prostredia na výsledky geodetických meraní bolo na deviatich bodoch siete vykonané geofyzikálne meranie metódou ERT. Z výsledkov vertikálnych rezov vedených cez geodetické body bolo možné konštatovať, že body boli lokalizované často na okraj skalného bloku, ktorý leží na vrstve mierne zvetraného skalného podložia.

V oblasti vikartovského zlomu boli geofyzikálne merania realizované na dvoch lokalitách: Vikartovské sedlo a Spišské Bystré. Meranie na Vikartovskom sedle bolo realizované na profile vedenom naprieč údolím, s cieľom vybrať miesto pre vrt na odber vzoriek pre datovanie sedimentov a následné posúdenie veku zlomu. Meranie bolo vykonané metódou VES a získaný rez dokumentoval jemnú štruktúru horninového prostredia a pomerne zložitý vývoj v tejto časti Vikartovského chrbátu.

Profil v blízkosti Spišského Bystrého bol vedený naprieč vikartovským zlomom. Výsledky geofyzikálneho merania vo forme vertikálneho rezu ukazujú výraznú zmenu v štruktúre rezu na päte svahu, prekrytú kvartérnym materiálom jednak zo svahu a tiež fluviálnymi sedimentmi toku Hornádu. Poloha zlomovej štruktúry je z rezu dobre identifikovateľná, vrátane jej sklonových pomerov.

Geofyzikálne práce vykonané v minulosti na Slovensku umožnili identifikovať prejavy zlomových štruktúr a zostaviť databázu takýchto prejavov. Podobné databázy sa postupne kreujú aj z ich poznatkových zdrojov a takto sa vytvára možnosť vzájomnej korelácie databáz a generovanie nových prierezových poznatkov. Riešenie projektu prinieslo veľa faktografického geofyzikálneho materiálu, ktorý sa postupne spracováva a publikuje.

Táto práca bola podporovaná Agentúrou na podporu výskumu a vývoja na základe zmluvy č. APVV-0158-06 (úloha NEOTACT – Neotektonická aktivita územia Západných Karpát).

L. HIPMANOVÁ, J. HEFTY, Ľ. GERHÁTOVÁ, and M. IGONDOVÁ: **Geo-kinematics of Slovakia resulting from the combination of four GPS networks**

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Slovakia is covered by the numerous GPS networks investigating its geo-kinematical behaviour. These activities started in 1993 within the measurements performed in the network SGRN (Slovak Geodynamic Reference Network). In 1994 the first observation campaign was performed within the CERGOP and CERGOP-2/Environment projects. In 1996 LAC SUT (Local Analytic Centre of the Slovak University of Technology) started with the analysis of the network CEPER (Central European Permanent Network). Local network TATRY was established in 1997 but the first successful campaign was realized in 1998. The epoch-wise campaigns were repeated regularly each year or in two year´s intervals. The number of points gradually increased since 1993. The highest quality data are provided by the CEPER network comprising also the stations of the network EPN (EUREF permanent network). In Slovakia and its nearby areas we count 11 points of permanent observation and 53 points of epoch-wise observation which participated on this experiment. The networks mentioned above were analysed independently with unequal processing parameters, different number and quality of reference points and they were related to the different realizations of the reference frames during its evolution.

The CEGRN (Central European GPS Geodynamic Reference Network) consortium which ensures the CERGOP and CERGOP-2/Environment activities gave publicity to reprocessing initiative about three years ago. They published the official rules for reprocessing of the GPS networks in the order to ensure the homogeneity and comparability of the results. All mentioned GPS networks were completely reprocessed up to the present using the same processing parameters taken over from the IGS (International GNSS Service). The reprocessed network solutions were related to ITRF2005 (International Terrestrial Reference Frame). Homogenized data served as an input for the combination and velocity estimation. For this purpose we used the CATREF (Combination and Analysis of Terrestrial Reference Frame) software which uses minimum constraint solution (Altamimi et al., 2009). This software was developed in the IGN (Institute Geographique National) in France for the ITRF activities. The combination strategy adopted in this software is applied in the global and continental GPS networks.

The combination strategy is based on the minimum constraint approach (Altamimi et al., 2009). In the first step of combination we formed the network solutions independently for each network. Progressively we estimated the velocities of CEPER 2000 – 2009 permanent network (9.63 years of permanent observation), CEGRN 1994 – 2007 network (13.14 years and 9 campaigns), SGRN 1993 to 2007 (13.82 years and 9 campaigns) and the local network TATRY 1998 – 2008 (10.02 years and 11 campaigns). In the second step we combined mentioned solutions together and obtained the aligned coordinates and velocities related to ITRF2005. The combined homogeneous velocity field comprises the velocities of 64 points in Slovakia and its nearby areas. The estimated global velocities were reduced for APKIM2000 (Actual Plate Kinematics Model) velocity model in order to obtain residual intraplate velocities of Slovakia and its nearby areas.

Slovakia is considered as a stable region from the geo--kinematical point of view. The velocity vectors in the western part of Slovakia are predominantly oriented to the north and northeast with the magnitude up to 2.5 mm/year. Central Slovakia is characteristic with the orientation to north and northwest with the magnitude up to 2 mm/year. In the Eastern Slovakia we estimated the vectors with the north-eastern orientation and the magnitude up to 2.2 mm/year. The magnitude and the orientation of velocity vectors depend on many factors as the geometry of the network, number of reference points and its long term quality, used velocity model and so on. The reliability of the velocity vectors depends on the number of observations. The most reliable vectors are provided by the permanent stations which are unfortunately not as numerous as needed. The existing epoch-wise networks were established in the order to increase the densification of permanent networks.

J. HÓK, R. VOJTKO, I. PEŠKOVÁ, S. KRÁLIKOVÁ, M. HOFFMAN and M. SENTPETERY: **Quaternary stress orientation in the western part of Slovakia obtained from the travitonics**

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The term travitonics was introduced into the structural geology by Hancock et al. (1999) using travertine in the study of active tectonic processes. Travertine or tufa deposits are preferentially located along fracture traces, either immediately above extensional fissures or in the hanging walls of normal faults. Tensional fissures filled by vertically banded travertines together with systematic joints can be used to infer the local tension directions.

More than 186 occurrences of travertine were investigated in the western part of Slovakia. The age of travertines ranges from the latest Miocene to Holocene. Travertine occurrences are arranged linearly. Linearity of travertine depositions determines the direction of extension during their formation.

The latest Miocene to Pleistocene travertine deposits are generally arranged in the direction NE – SW, while the Pleistocene to Holocene travertine and tufa mounds are oriented in the direction NW – SE to N – S.

The orientation of the latest Miocene to Pleistocene travertine occurrences and the structural features reflect the extension oriented perpendicular to the Carpathian arc course i.e. the direction NW – SE. The Pleistocene and Holocene travertine deposits, which originated during extension, are oriented generally parallel to the Carpathian arc course i.e. in the direction NE – SW.

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S. KRÁLIKOVÁ: **Morphotectonic analysis of the Hronská pahorkatina upland (northern part of the Danube Basin, Western Carpathians)**

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The Hronská pahorkatina upland is situated on the eastern flank of the Komjatice Depression and belongs among typical morphostructures of the Danube Basin. It is possible to follow its tectono-sedimentary evolution since the Middle Badenian clastic deposition, which transgressively overlies rocks of the pre-Cenozoic basement.

The research aimed to analyse and compare the relevant morphostructure features with tectonic disruptions. The results of the research have been used to explain the tectonic evolution of the Hronská pahorkatina upland during the Pliocene and Quaternary.

The distinctive transversal asymmetry of the fluvial valleys as well as the orthogonally oriented drainage basins refers to tectonic predisposition. The flanks with the gentle gradient are characterized by maintained older fluvial accumulation of sediments in the terrace development. The terraces are absent at the steeper flanks. The uppermost Miocene and Pliocene sediments (Beladice and Volkovce Fms.) are cropping out at the side of the steeper flanks. Active normal faults have smaller, shorter, steeper drainages adjacent to the fault and the longer, gentler drainages on the back-tilted flank, which are commonly hanging wall basins (Burbank and Anderson, 2001). The flanks with gentle drainage basins are characterized by the loess accumulations which absent at the flanks facing to the more active fault. If the formation of the valleys was affected by the tectonic movements before the loess deposition, then the loess would probably overlies the flank with steeper drainage basins. Then the functionality of the actual faults was during the loess deposition, respectively after its deposition.

The morphostructural and neotectonic research of the faults structures manifested that the faults system operated as the normal faults with dominating NE – SW to ENE – WSW and NW – SE to WNW – ESE trending faults. Generally, the NNE – SSW and ENE to WSW trending faults are considered to be older and disturbing the Volkovce Formation (Dacian), but not continuing to the younger strata. These faults were generated under the NW – SE oriented extension during the Upper Pliocene to the Lower Pleistocene.

The younger normal fault system is characterised by the NW – SE and WNW – ESE orientations of the fault planes. These faults were active during the generally NE – SW oriented tension. The conformity between the faults orientation and trending of the youngest dells filled by the Würmian to Holocene sediments refers to the faults origin within the Upper Pleistocene to the Holocene.

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F. MARKO[1], R. VOJTKO[1], V. GAJDOŠ[2], J. MADARÁS[3, 4], A. MOJZEŠ[2] and K. ROZIMANT[2]: **Neotectonic records in the Muráň fault zone (Western Carpathians)**

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The Muráň fault (MUF) can be divided to three segments: the southern Divín segment, middle Muráň segment and the northern Maľcov segment. This important NE – SW trending regional fault is best expressed in the Muráň segment, where represents tectonic contact between the Mesozoic Silica unit (Muráň nappe) and the pre--Mesozoic crystalline basement of the Veporic unit. Its trace is very evident thanks to the juxtaposition of two above mentioned contrasting units, as well as thanks to its distinct expression in geomorphology. Continuation of MUF towards the SW (Divín segment) is not so clear due to monotonous lithology of the Veporic crystalline unit on the both sides of the fault. In the Divín segment the trace of fault is interpreted mainly according to morphological phenomena, and in the southernmost tip the trace of fault is interpreted as a tectonic contact separating the Mesozoic Divín synform (Plašienka, 1983) from the Veporic crystalline basement. Continuation of MUF south of the Divín segment is covered by the Sarmatian volcano-sedimentary complex, representing the upper age limit of the large-scale fault activity. Another age limit of MUF activity is recorded at the northern tip of the Muráň segment, where the fault trace is covered by the basal Central Carpathian Paleogene Basin (CCPB) sediments. At the Hrabušice outcrop, the N – S trending meso-scale post-Gosau strike-slip fault related to MUF zone is colmated by the Middle Eocene sediments, so the age brackets of MUF large-scale activity can be established as the Upper Cretaceous–Early/Middle Eocene (Marko, 1991). Nevertheless, the MUF zone is very distinct in the terrain morphology along its whole length, even in the CCPB (Levočské vrchy). MUF represents one of the most spectacular photolineaments in the visible spectrum as well as in the radar scenes (ERS-2) thanks to well developed linear phenomena in the morphology following the MUF zone. It points to neotectonic reactivation of the MUF zone, which has not caused large offsets, but only the moderate faulting and jointing, allowing the increased rate of selective erosion within the MUF zone that had appeared. At the Muráň quarry the tectonic contact of the Muráň nappe with Veporic crystalline rocks is exposed. This contact – the Muráň fault sensu stricto is colmated by the Middle-Upper Pleistocene (Ložek, 1960) dolomite breccia not affected by the fault, what declares the uppermost age limit of MUF s. s. activity as the Upper Pleistocene. However, it does not exclude its possible neotectonic activity in the Pliocene–Middle Pleistocene time span. Using geophysical ERT profiling across the course of the Muráň fault at this locality, another normal faults parallel with MUF, having the subsided eastern walls, were detected within the MUF zone. These normal faults cut also the Pleistocene breccia, so represent the subrecent reactivation in the MUF zone. Such structure can be expected along the whole length of MUF zone as show ERT profiles realized in the frame of the project. Except the distinct morphology, to recent activity of MUF at the middle segment points also the distribution of the historical and recent earthquakes events, which epicentres are evidently clustered along the middle segment of MUF. Radon emanations measured along ERT profiles detect open dislocations existing in the middle segment of MUF, related to recent activity. To evaluate the recent movement tendencies along MUF a precise, during several years repeated GPS measurements were realized in the frame of the project. The GPS network is situated in the Divín segment of MUF on both walls of the fault. The final reprocessing of GPS data from all campaigns using the latest software does not show any important, recognizable movement of blocks separated by the Divín fault during the last 8 years (see Mojzeš in this issue). Measurements by the mechanical-optical (moiré) extensometer of TM-71 type have been used as additional monitoring method for the detection of recent movements. One TM-71 extensometer was installed in the Izabela adit located in the area of GPS network 7 years ago. The recent activity recorded by this device along the meso-scale dislocation, subparallel with MUF was really negligible. Only 1.5 mm vertical movement has been detected (see Petro in this issue). From the above commented observations next scenario results. MUF operated as an important strike-slip and dip-slip fault between the Upper Cretaceous and the Middle Eocene. After that time the fault was covered by CCPB basin sediments, products of the Neogene volcanism and the Pleistocene cover. During the Holocene period the normal faulting appeared in the MUF zone, but subvertical MUF s. s. itself has not been reactivated because of its not appropriate vertical attitude for extensional forces. In spite of using two independent monitoring methods, there were not observed any detectable recent movements along the MUF zone during the last decade. However, several microearthquakes related to the middle segment of the MUF were recorded. It can indicate a period of stress accumulation along the fault, which can be followed by the stress releasing with the high strain rate, not excluding earthquake events.

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M. MOJZEŠ: **The Muráň fault recent movement tendencies determined by the GPS technology**

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The neotectonic activity of the Muráň-Divín fault was studied in the central part of the fault. The recent movement tendencies were measured on seven sites by the Global Positioning System (GPS). The sites were mounted by the special brass module to the concrete pillars or into the rocks on the ground. The antenna adapter was screwed onto the brass module with accuracy 0.1 mm. The four GPS observation campaigns were performed (2001, 2003, 2007 and 2009). Every observation campaign was observed 48 hours with Trimble dual frequency receivers. All GPS measured campaigns were processed by the Bernese software, version 5.0 as a free network for each campaign using standard procedure. In this strategy we used five permanent stations of the European Permanent Network (GRAZ, JOZE, PENC, BOR1 and GOPE). The coordinates and the velocities of permanent stations were derived from the reference frame ITRF2005 for each epoch of observation. The global Cartesian coordinate differences were transformed to local Cartesian coordinate differences and the horizontal relative velocities as well as the vertical velocities were determined by the special software using the full covariance matrices for the each observation campaign. We found that the horizontal relative velocities and the vertical velocities were not statistically significant (see Table 1) and therefore we can argue that Muráň-Divín fault is without tectonic movement in the tested time interval.

Tab. 1
Relative horizontal and vertical velocity of the point

Point	n mm/y	Sigma n mm/y	e mm/y	Sigma e mm/y	v mm/y	Sigma v mm/y	Time Interval Year	Number of Campaign
BRAT	0.13	0.55	–0.01	0.41	–2.19	3.19	8.10	3
LULO	0.34	0.53	0.02	0.39	–2.71	3.07	8.10	4
MALI	0.47	0.53	0.25	0.39	–3.87	3.23	8.10	4
PERE	0.53	0.54	0.21	0.40	–3.20	3.18	8.10	4
SKVR	0.15	0.53	0.13	0.39	–3.04	3.12	8.10	4
ZABI	0.67	0.52	0.17	0.38	–2.89	3.04	8.10	4
KLAT	–0.01	0.53	–0.06	0.39	–2.98	3.15	8.10	4

Ľ. PETRO: **Current results from 3D monitoring of micro--displacements at Muráň and Šindliar faults**

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The monitoring of the micro-displacements along the active tectonic faults by the TM-71 extensometers (Košťák, 1969) in the Western Carpathians started in 1990 (Petro et al., 2004). These devices are capable of detecting movements and micro-displacements in three dimensions with the accuracy 0.01 mm/0.01 gr. They operate using the principle of optical interference (moire`s pattern) which records displacement as a fringe pattern on superposed optical grids that are mechanically connected to the opposite crack faces. Data are obtained in three Cartesian coordinates (*x* – across joint/crack enabling to measure compression or extension of a joint/crack width, *y* – horizontal shear displacement along a crack and *z* – the vertical shear displacement) calculated from recorded interference patterns.

Since 1993 the monitoring is performed in the frame of national project entitled "Partial monitoring system of geological factors of the environment in Slovakia – Tectonic and seismic activity" and funded by the state budget. In the period 2000 – 2006 the detection of micro-displacements at four selected sites (Košický Klečenov, Branisko, Demänová, Ipeľ) was incorporated into an international project COST Action 625 (3D monitoring of active tectonic structures). Current results from the sites Branisko and Ipeľ are presented below:

Branisko: One TM-71 extensometer was installed inside the emergency tunnel in December 2000. The device is located directly at NE – SW oriented Šindliar fault (eastern border of the Branisko Mts. horst). This neotectonic structure (Hók et al., 2002) represents a contact between the Hercynian crystalline basement, the Mesozoic sedimentary rocks and the Tertiary flysch complexes of the Inner Carpathians. The Branisko Mts. belong among the areas manifesting medium seismic activity ($I_0 = 5 – 6$).

Nine years of monitoring by TM-71 have proved continuous shear displacement along fault planes being interpreted as a dextral shearing. Some trends in rotations of tectonic blocks are also evident from the monitoring results. Several fresh cracks appeared at both sides of the Šindliar fault inside parallel highway tunnel tube during last years.

Ipeľ: The Muráň fault belongs among the longest and morphologically most distinctive disjunctive structures in the Western Carpathians. The fault is most distinct NE from the site where it separates the Mesozoic sedimentary rock complexes from the Paleozoic crystalline rocks. Two different types of movement were recognized along the fault. First movement is normal with the subsidence of the NW flank (Miocene) and the second one is sinistral along the fault. Neotectonic activity of the area is deduced from the position and thickness of the Quaternary sediments, relics of the flat denudation surfaces as well as the displacements of geological markers inside the pilot tunnel. Seismicity of the region is of medium rate ($I_0 \leq 6$). One TM-71 extensometer was installed in the Izabela pilot tunnel realized in connection with the projected pump-storage power station in July 2002. Results from the more than 7 years monitoring period confirmed about 1.5 mm vertical displacements along the faults planes. It means that SE tectonic blocks subsides. Rotations can be interpreted as non-significant.

R. VOJTKO, Z. ŠIMOVIČOVÁ and J. HÓK: **Neotectonics of the western part of the Turiec Depression**

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The Turiec Depression represents an intramontane depression, being unique in the Western Carpathians. Its evolution began in the Middle Miocene and continues till Quaternary. The tectonic evolution is connected with the transpressive, transtensive strike-slip and extensive tectonic regimes. The normal faults play a decisive role mainly in the western part of the Turiec Depression. The neotectonic research required a multidisciplinary approach. In the western part of the Turiec Depression the methods of morphotectonic analysis have been used. The neotectonic investigation was focused on the Hradište fault. The Hradište structure strongly influenced the evolution of the area during the Plio-Quaternary. Three groups of the relief forms have been distinguished along the entire mountain front. The facet slopes situated on the western side of the fault system represent the first group. The second group encompasses the flat surfaces situated on the eastern side. These groups of the forms fringe the mountain front from the both sides. Third group forms the valleys, crossing and disintegrating the previously mentioned landform groups. The facets are situated above the mountain front line. These facets are still well-preserved, gradually dissecting by incipient backward erosion of the recently seated valleys. The tectonic activity of the mountain front system is recorded in the longitudinal profiles of the selected valleys. The Quaternary activity of the Hradište fault was additively proved by the valley floor-to-height ratio method, by the valley cross-section ratio method and by the interpretation of the remote sensing data.

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R. VOJTKO[1], F. MARKO[1], J. MADARÁS[2, 3], J. BETÁK[4] and F. PREUSSER[5]: **Quaternary tectonic activity of the Vikartovce fault (Hornádska kotlina Basin, Western Carpathians)**

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The Vikartovce fault is one of the most distinctive faults in the Western Carpathians, being very evident in the geological architecture of the area. It forms an E – W trending; perfectly linear northern boundary of the narrow depression, which is filled up by the Paleogene deposits of the Central Carpathian Paleogene Basin (CCPB). From the north, the basin is rimmed by the narrow morphostructural elevation which consists of the Permo–Triassic volcano-sedimentary succession of the Ipoltica Group belonging to the Hronic Unit. The southern slopes of the horst are steep and they are related to the dynamics of the Vikartovce fault, while the opposite slopes are gentle inclined to the north. The crest line of this horst plunges gently to the east where it is submerged under the CCPB deposits. The fault is regarded as a neotectonically active dislocation. This is because of the very distinctive morphological expressions of the fault trace and its evident relationship to the distribution of the Quaternary deposits, travertine mounds and cascades. These are distributed along the eastern continuation of the Vikartovce fault trace. The fault has strong influence on the change of the rivers courses due to neotectonic fault activity. These arguments are based on the premise that ancient rivers flowing to the north were cut off by the Vikartovce fault. This led to a change in the paleo-rivers network. A possible causative mechanism for this is the block tilting, where E – W faults in the area operated as normal faults which caused subsidence and block tilting. To confirm this idea, a strenuous effort was focused on the localization and sampling of the cut off and buried alluvial sediments preserved at the recently dry Visová pass which was formed by the ancient river flow (Paleo-Hornád river). The age of these alluvial deposits dates the age of the river interruption, and this means the age of the Vikartovce fault's latest activity. Based upon the geophysical profiling and geological mapping, three shallow boreholes with core recovery were located and drilled at this pass. Third borehole penetrated the brownish/yellowish sandy loam in the upper part of the profile (deluvium), and deeper (at 13 – 17 m depth) a sequence of grey sands intercalated by clays, and pebble clays was reached. Samples for OSL dating were selected from this alluvial horizon, which represents the remnants of the faulted alluvial sediments. These alluvial sediments have been dated at 120 – 180 ka according to OSL dating.

The Vikartovce fault represents a neotectonically active structure and this is proved by many morphotectonic attributes. Along the entire mountain front we can distinguish three groups of relief forms. The first are the facet slopes situated north of the studied fault system; next are flattened surfaces situated on both sides, and the third group produces small valleys, which cross and disintegrate this system of the relief forms. The youngest generation of facets is situated above the mountain front line. These facets are still well preserved and are gradually dissected by the incipient backward erosion of recently seated valleys.

Additionally, a few remnants of flattened surfaces were identified inside the facets. Some of these are randomly situated but some of them are related to each other on the basis of their altitude. The main flattened surfaces have the same altitude as the saddle which is situated approximately 100 m above the Hornád valley. However, the above mentioned small valleys are generally N – S oriented, and they have a very anomalous morphostructural pattern, characterized by a flattened valley near the mountains crest, and they also have a very deep "V" shape with cascades near the mountain front.

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GEOCHÉMIA 2009

Bratislava 2. – 3. decembra 2009

Geochemistry 2009

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Abstract. *The 12th continuation of the seminar Geochemistry 2009, being organized regularly at the end of each calendar year, was held on 2. – 3. 12. 2009 in Bratislava with the participation of 58 geochemists from the Slovak and Czech republics. Altogether 31 lectures and 11 posters were presented in the seminar, being simultaneously published in its proceedings. Scientific presentations encomassed a wide spectra of topics, ranging from the origin of stars, through the modern endogene and exogene geochemistry to isotopic and environmental geochemistry.*

Key words: *achievements in geochemistry, report upon seminar*

Tradične koncom kalendárneho roka usporadúvajú Katedra geochémie PriF UK, oddelenie Geochémie životného prostredia ŠGÚDŠ a Slovenská asociácia geochemikov v spolupráci s ďalšími organizáciami a odborníkmi seminár GEOCHÉMIA, ktorý bol tohto roku organizovaný už dvanásty raz. Konal sa v dňoch 2. a 3. 12. 2009 v Bratislave pri príležitosti dvoch významných jubileí celej slovenskej geochemickej komunity: 40. výročia založenia Katedry geochémie PriF UK v Bratislave a nedožitých deväťdesiatin zakladateľa slovenskej geochémie – akademika Bohuslava Cambela.

Cieľom seminára bolo umožniť všetkým absolventom, bývalým a súčasným učiteľom, vedeckým pracovníkom Katedry geochémie PriF UK, ako aj širokej odbornej verejnosti a domácim i zahraničným spolupracovníkom:

• prezentovať dosiahnuté vedecké výsledky formou odborných referátov a posterov,