GEOGRAFICKÝ ČASOPIS

ROČNÍK XXIV 1972 ČÍSLO 2

JOZEF KVITKOVIČ, JÁN VANKO

RECENT CRUSTAL MOVEMENTS IN THE REGION OF EASTERN SLOVAKIA

Jozef Kvitkovič, Ján Vanko: Les mouvements actuels de la croûte terrestre dans la région da la Slovaquie de l'Est. Geografický časopis, Bratislava 1972, XXIV, 2; 1 figure, 1 carte, 26 bibliogr.

Dans l'étude, on résume les résultats des nivellements répétés exécutés dans la région de la Slovaquie orientale pendant les périodes de 1950—1955 et 1961—1966. Du point de vue morpho-structural, le réseau de nivellement s'étend à travers la région des Carpathes Centrales, des Carpathes extérieures de flysch et des dépressions subcarpathiques. Dans la région montagneuse, les chaînes du caractère de montagnes médiocres ou hautes alternent avec des cuvettes et sillons intramontagneux. Les montagnes individuelles représentent des structures horstiques compliquées. Les résultats obtenus par le nivellement répété étaient mis en connexion et comparés avec les résultats morphologiques. Il s'ensuit du travail que dans les montagnes les élévations de +1,6 mm/an prévalent, tandis que dans les plaines, en génénral, des baisses se montrent atteignant les valeurs de —2,7 mm par an. Ces résultats prouvent l'activité de plusieures altérations importantes de faille durant même à l'époque présente. Il est démontré que les mouvements contemporaines des différentes morphostructures sont des mouvements balancés hérités de l'époque du Pliocène et Pleistocéne.

The study of recent vertical crustal movements becomes now one of the most actual tasks of the geonomical disciplines. Knowledge of the contemporary dynamics of terrestrial crust and the tendencies of its evolution has a fundamental importance for geomorphology, geology, geophysics, geodesy and for the practical application of these scientific disciplines. Detailed knowledge is also inevitable when building large technical works in regions submitted to reciprocal movements of blocks or masses of the terrestrial crust.

A generally acknowledged method of ascertaining vertical terrestrial crust movements today is that of repeated lewelling. The precision of results is attained by perfected measuring devices, aids and methods. Nevertheless, it must be carefully pondered, how to utilize the results of repeated levelling in view of verifying the reality of movements, after having eliminated the influence of measuring errors and of natural factors other than the endogenous ones. This means that repeated levelling alone, without the aid of other geonomical disciplines, cannot satisfactorily master the given task. Only in common with geomorphological, geological, geophysical, geographical, oceanographical and other methods, it makes possible a complex approach to the study of the recent crustal tectonic regime.

From morphostructural standpoint, the network of repeated levelling passes across a quite complicated region. In its western part, it touches the Central Carpathians including core mountains of medium to high mountain characters, alternating with intramountain basins. But in the line of repeated levelling, there predominate flysch mountains originated at the northern borders of Central Carpathians, at their contact with the klippen zone. Roughly, eastwards from the line of Ľubotín—Prešov, the broad region of external flysch Carpathians extends, which is characterized by a prevailingly middle-mountain relief with smaller basins and furrows. Southwards, the unit of external Carpathians passes in the sub-Carpathian depression having a developed lowland relief. Along its borders, morphostructural unities of lower order appear, namely the volcanic horst-like mountains Slanské Vrchy Mts. and Vihorlat with the Popričný.

Based on the conserved surficial forms, especially on the levelled surfaces of the Carpathian region and the correlate sediments of sub-Carpathian depressions, we can determine by morphological-geologial methods the relief's fundamental evelutional stages and, thereby, the territory's overall movement tendencies which practically last up to the recent epoch.

From reconstructing the Carpathian region geomorphological evolution, M. Lukniš (15, 17) comes to the conclusion that, in the lower Neogene, the Western Carpathians had the feature of indifferentiated mountains outlasting up to the Tortonian, eventually the Sarmatian periods. Remainders of this relief, in the territory examined, have been but partly conserved.

For traces of this old surface, E. Mazúr (21, 22) considers the today level of summits in the High Tatra region, which now ranges in altitudes above 2000 m. More distinct remainders of this surface occur in mountains beyond our region. The mentioned author denotes this highest and oldest surface as the summit level and ranges its origin in the upper Tortonian or lower Sarmatian era. This former, relatively plain relief was, in the period of Attic phase, at the boundary between the Sarmatian and Pliocene, uplifted and dismembered. Thereby, some of its blocks were inclined, other ones sank and generated sedimentation spaces. In this period, the germs of intramountainous basins were formed, the areas of sub-Carpathian depressions were extended. During the intra-Sarmatian movements already, in the region of sub-Carpathian depression, especially on the region of the Slanské Vrchy Mts. and the Vihorlat, volcanic activity began to strongly manifest itself.

Further regional levelling, in the region of Eeastern Slovakia occurs in the Pannonian period. This levelled surface, a medium-montain level, has been conserved on larger or smaller areas almost in all mountains of Eastern Slovakia (8, 21). Its correlate sediments (gravel formations) were deposited in lake basins of the sub-Carpathian depression, reaching the thickness of 400—700 m (4). In the Rhodanian phase of movements, in middle Pliocene, far-reaching changes occurred in our region. Powerful vertical movements considerably deformed the Pannonian surface. By accumulating igneous matters and their uplift, along the faults, volcanic mountains began to morphologically manifest themselves. The connexion between the lake basins of the East-Slovakian Lowland and the Košice Basin has been interrupted. Even in the region of Central Carpathians and the external flysch Carpathians, along fault dislocations, the individual mountains and intramountain basins became more expressive. So there occurred a marked individualization of different orographical wholes, whose forms and area were then successively shaped during the Levantian and Quaternary eras. When comparing the contemporary surface level of Pannonian gravel formations, in the East-Slovakian Lowland, and the neighbouring hollow of Košice Basin, which here attains about 150—200 m of absolute altitude, with the Pannonian levelled surface, in the High Tatra, then we see that the vertical altitudinal differentiation is sharply increasing. In the Šarišská Vrchovina Mts., this level mounts up 700—1000 m altitudes, in the Branisko and Levočské Vrchy Mts., it attains about 1200 m. The same level is maintained in the Spišská Magura, while remainders of the lower Pliocene levelling, in the High Tatra, were fond by Lukniš (18) in altitudes of 1400—1700 m. Hence we see that, within Eastern Slovakia, in a relatively short distance, the altitudinal denivellation of relief provoked by the Rhodanian and younger phases of movements, attains values about 1500 m.

In the upper Pliocene, Levantian, the third levelled surface, the so-called river level was formed (17, 20, 21). It is widespread in the intramountain basins and piedmonts. Its surface above the existing river streams ranges from 60 to 150 m, while in the sinking lowland regions, it disappears under Quaternary sediments up to the depths of more than 100 m. Its denivellation caused by the Wallachian phase of movements, in the intermediary period of Neogene-Quaternary and the young intraquaternary movements, attains values of about 300 m.

By the onset Quaternary period, the formation of river level is interrupted and successive deepening of the river streams begins, leading to the origin of 4—6 terrace degrees. The oldest terrace degrees are by 40—120 m higher than the actual river streams. In general, one may observe a down-stream convergence of the river terraces. In the East- Slovakian Lowland central parts, the river terraces do not morphologically display themselves. Their correlate sediments, from the adjacent mountainous regions, are deposited here in colmations the thickness of which, according to the data ascertained hitherto, attain more than 100 m. In the lowland's plain relief, only the alluvial plain is morphologically manifesting itself, with slightly expressive Recent or old Holocene aggradation ramparts. The beds of lowland rivers are cut in the Holocene alluvia to 2,5—8 m. This fact indicates disproportionate movements in this region, even at the present time.

Hence it follows that, since the last million years, in the East-Slovakian region, the overall vertical effect of movements attained approximately 250 m, that is about 0,25 mm/year.

Starting from the fundamental conclusions on the evolution of East-Slovakia's surficial shape, in which neotectonic movements have played an important role, we shall try to explain also the actual movement tendencies of this territory, completed by the results of repeated levellings.

The used geodetical results and their workig up

In the present work, we used two levellings executed in the region of Eastern Slovakia. The first one has been carried out in 1950—1955 within establishing the uniform Czechoslovak levelling network. The second one was accomplished in 1961—1966 for the research of the terrestrial crust vertical movements. For the first levelling, the centre of epoch, with regard to the lenght of aiming lines of individual years, was related to the date of 1950,9; for the second levelling to 1964,5. Thus, the mean time interval is 13, 6 years.

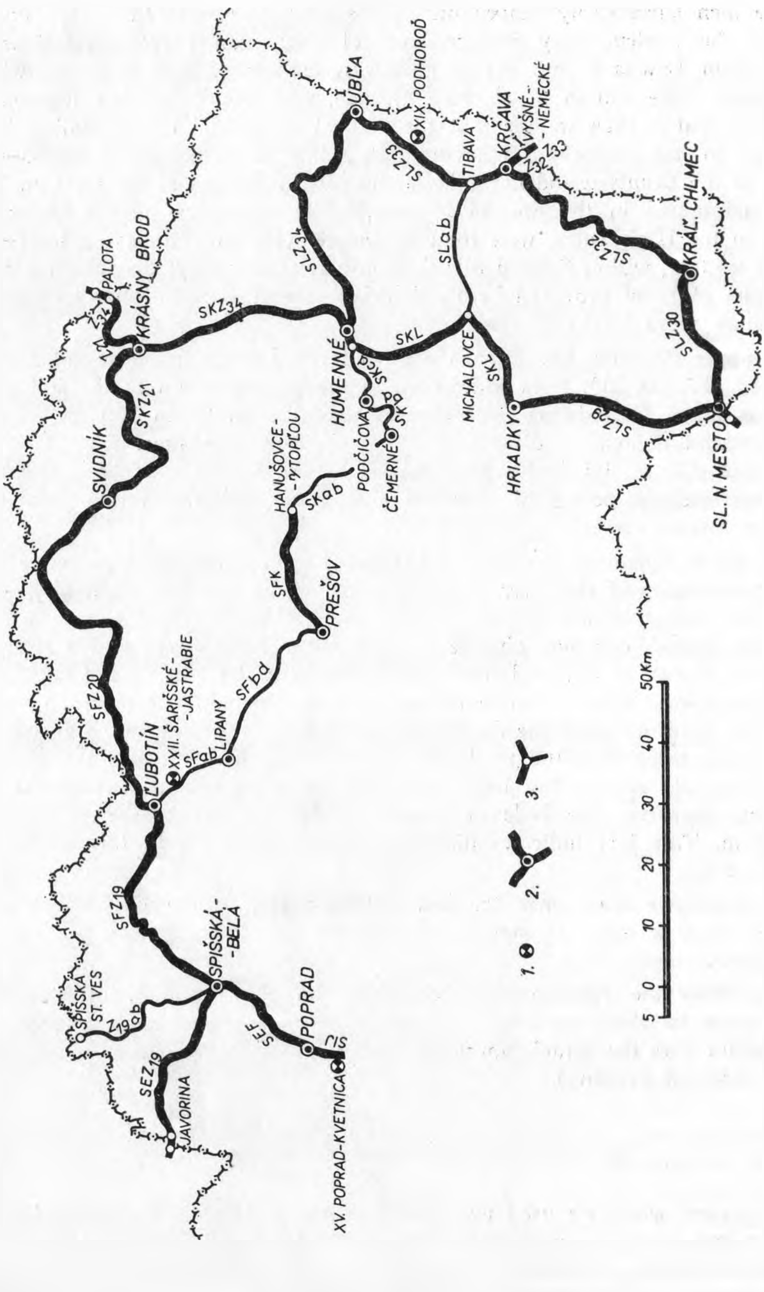


Fig. 1. The network of repeated levellings in Eastern Slovakia. 1 — fundamental levelling point (ZNB), 2 — nodal point, 3 — connecting point.

The levelling network used for this elaboration is shown in Fig. 1. It contains many levelling points which, as for the sort of stabilization, are of dissimilar qualities. For our working up, we chose as identical points those ones which were stabilized on rocks or churches. In some cases, by want of other stabilization, we exceptionally chose points stabilized on large public buildings. At the choice, we took into account that the tendency and magnitude of the chosen points' movement should correspond to the overall tendency and magnitude of the environing points' movements. We chose points in the distance of 1—13 km (on the average 5,6 km) in conformity with the points density and stabilization quality.

The differences of elevation, ascertained by both levellings, between the neighbouring points i and j represent the change of this uplift during the concrete time interval and they have been reduced to the annual change of elevation ΔV_{ij}.

Supposed that $\Sigma \Delta V_{ij} = 0$, these sums were equalized (according to condition observations) in the network, after Fig. 1, wherewith random measuring errors have been eliminated from the results.

From the equalized values $\overline{\Delta V_{ij}}$, by successive summation from the fundamental levelling point (ZNB) XXII Šarišské Jastrabie, we determined the relative annual speeds V_i of the individual chosen points.

In the present work, there are three fundamental levelling points (see Fig. 1). All of them are placed on rocks of good quality. Šarišské Jastrabie has been chosen as starting point because it was the most advantageous from the regional-morphological standpoint.

The present data have to be considered as relative ones, related to the point Šarišské Jastrabie. The relativity of these data consists in that we don't know the starting point's own movement, and we are obliged to assume that during 1950,9 — 1964,4 its position has not changed.

The accuracy of both levellings was judged by calculating the mean kilometer errors according to Lallemand's formulae (see Tab. 1). and from them the mean kilometer error in the movement's annual speed $m_r = \pm 0{,}056$ mm/km determined. The uncertainty m_v in the determination of relative annual movement speeds of the chosen identical points, lying at the distance L from the starting point (Šarišské Jastrabie) is given by the general formula

$$m_v = \pm m_r \sqrt{L}$$

where $m_r = \pm 0{,}056$ and L = distance from the ZNB XXII, measured by the shortest way through the levelling network. The mean errors m_v serve as intervals of reliability for distinguishing real movements from presumable ones and, for the distances of $L = 5-250$ km, they are listed in Tab. 2, ensuring relative interpretation for shorter distances.

Table 1

Mean kilometer error	1. levelling	2. levelling
	± mm/km	
random η	0,39	0,42
systematic σ	0,05	0,05
total m	0,53	0,55

The values of annual movement speeds V_i and corresponding mean errors (uncertainties) m_v, for some chosen points, are shown in Tab. 3.

In the entire elaboration, we also include the results of repeated measurements in the clear lines of Ľubotín—Poprad—Kvetnica, Spišská Belá—Javorina, Spišská Belá—Spišská Stará Ves, Krásny Brod—Palota and Krčava—Vyšné Nemecké. On utilizing the data on annual velocities of all chosen points, a map of relative annual speeds of the

Table 2

L	m_V	L	m_V
km	mm	km	mm
5	0,13	80	0,50
10	0,18	90	0,53
15	0,22	100	0,56
20	0,25	120	0,61
25	0,28	140	0,66
30	0,31	160	0,71
40	0,35	180	0,75
50	0,40	200	0,79
60	0,43	225	0,84
70	0,47	250	0,89

terrestrial crust vertical movements, in the region of Eastern Slovakia, has been constructed (Fig. 2). The annual speed of movements, related to the starting point, are demonstrated by isolines at intervals of 0,5 mm/year and by auxiliary ones at the intervals of 0,25 mm/year (dash lines). The presumed isolines are denoted by dotted lines.

Morphological interpretation of the map of annual speeds of vertical movements

It follows from the map of annual speeds of the terrestrial crust vertical movements that, in Eastern Slovakia, during the period examined (13,6 years), one may record movemenst of +1,6 mm/year, in the mountainous regions, and —2,7 mm/year in the region of East-Slovakian Lowland, i. e. the entire range of ascertained values attains 4 mm per year.

The region of Central Carpathians exhibits relatively unequivocal elevations, while some smaller regions of this territory behave as stable ones. Insignificant negative movements appear in the Zamagurie. It is remarkable that this region of subsidence is connected with earthquake focusses, the intensity of which has not been precisely established (1). However, it must be noted that despite the relatively sufficient density of levelling points, the map of annual speeds of the vertical movements does not express, in satisfactory breadth, the investigated territory actual movements because the levelling lines, with small exceptions, do not pass across the crests of mountains where, based on morphological analyses, we may assume that the intensity of positive vertical movements should be greater than in the intra-mountain basins and furrows, or in the river valleys, traversed by the evaluated levelling network.

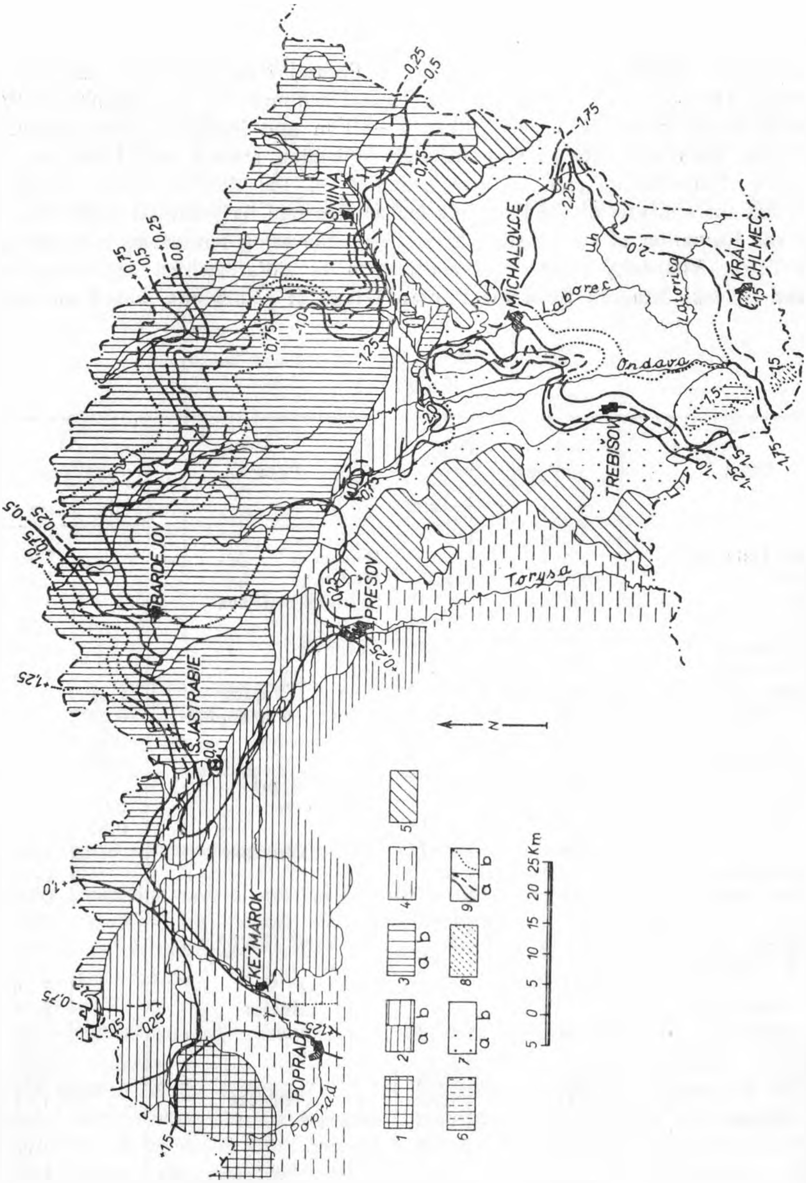
From the established annual isolines of movements, occurring in the period considered, it follows that, in the Poprad Basin NE part, vertical movements proceed within +1,0 to +1,6 mm/year. After accounting the mean errors, uncertainties (see Tab. 3), these values indicate in the valley of Poprad uplifts, the origin of which can surely be supposed to be a tectonic one. The valley of Poprad river essentially follows a fault disturbance. The bed itself is covered with fluvial sediments of predominantly Würmian age, the thickness of which varies within 2—10 m and increases down-stream. In its central parts, the river cuts its way through Würmian gravels and flows on a flysch basis. Recent movements can be also assumed in the neighbouring Hornád Basin, mainly from the analysis of the Hornád's bed course and its youngest sediments, as well as from the formation of the existing travertines. Elevation tendencies also emerge after the sub-Tatran-Ružbachy fault, in the direction of Ždiar, which separates the High Tatra and Spišská Magura from the Poprad Basin. It is obvious, based on the results

Table 3

Point	V_i mm/year		m_v
	+	—	± mm
Šarišské Jastrabie (ZNB)	0,00	0,00	0,00
Ľubotín	0,97		0,13*
Plavnica	0,58		0,22*
Stará Ľubovňa	0,95		0,28*
Nižné Ružbachy	1,16		0,35*
Podolínec	1,06		0,37*
Spišská Belá	1,01		0,41*
Kežmarok	0,92		0,44*
Veľká Lomnica	1,25		0,47*
Poprad	1,45		0,49*
Poprad-Kvetnica (ZNB)	1,51		0,51*
Ždiar	1,09		0,47*
Ždiar-Javorina	1,42		0,52*
Slovenská Ves	1,14		0,43*
Reľov		0,38	0,48
Matiašovce		0,51	0,50
Spišská Stará Ves		0,78	0,52
Orlov	1,05		0,17*
Ruská Voľa nad Popradom	1,24		0,22*
Gerlachov	0,65		0,32*
Bardejov	0,21		0,38
Zborov	0,35		0,43
Nižný Mirošov		0,01	0,48
Svidník	0,14		0,52
Tisinec		0,19	0,55
Makovce	0,29		0,60
Krásny Brod	0,48		0,64
Medzilaborce	0,66		0,65
Medzilaborce-Vydraň	0,75		0,66
Palota	0,34		0,67
Čabiny		0,04	0,66
Zbudské Dlhé		0,82	0,66
Hankovce		0,57	0,65

Point	V_i mm/year		m_v
	+	—	± mm
Humenné		1,30	0,61*
Hudcovce		2,15	0,58*
Sedliská-Podčičva		1,75	0,57*
Vranov		2,67	0,54*
Čemerné		1,73	0,54*
Soľ		1,52	0,51*
Čierna n/Topľou	1,21		0,48*
Hanušovce n/Topľou	0,04		0,46
Prešov	0,25		0,36
Sabinov	0,02		0,27
Červenica pri Sabinove	0,65		0,22*
Lipany	0,51		0,11*
Dlhé n/Cirochou		1,06	0,65
Snina		0,35	0,67
Stakčín		0,28	0,69
Ubľa		0,66	0,74
Podhoroď (ZNB)		0,61	0,76
Tibava		1,56	0,74*
Sobrance		1,74	0,73*
Malé Zalužice		2,01	0,70*
Michalovce		1,59	0,68*
Strážske		0,85	0,64
Krčava		2,43	0,75*
Vyšné Nemecké		1,73	0,76*
Jenkovce		2,00	0,77*
Bajany		1,65	0,80*
Veľké Kapušany		1,92	0,82*
Kráľovský Chlmec		1,59	0,85
Bodrog		1,64	0,83
Viničky		1,64	0,81*
Slovenské Nové Mesto		1,78	0,80*
Čerhov		1,27	0,78
Trebišov		1,28	0,74
Vojčice		1,44	0,73*
Trhovište		0,97	0,70

* Values surpassing the critical interval of reliability, for which we consider the double of the mean error m_v. We already hold these values for real movements provoked by endogenous forces.



Map 1. Map of the annual speeds of vertical terrestrial crust movements, in the region of Eastern Slovakia, for the epoch of 1950,9 — 1964,5. Isolines in mm/year. 1 — high mountains of the Central Carpathians with glacial relief on mesozoic and older structures, 2 — middle mountains and hills, (a) of the Central Carpathians with furrows or low mountains, (b) prevailingly on flysch folding fault structures, 3 — middle mountains and hills of the external Carpathians, (a) with small basins and furrows, (b) on nappe-folding structures, 4 — intra-mountain erosional-tectonic basins, 5 — middle mountains of the volcanic Carpathians on horst structures, 6 — lower mountains of horst character on exotes of the Central Carpathians, 7 — sub-Carpathian depressions — East-Slovakian Lowland, (a) low-mountain degree — dismembered pediment, (b) young accumulation plain, 8 — volcanic exotes, 9 — isolines, (a) real, (b) presumed.

of repeated levellings, that its function asserts itself even at the present time. Hence we can suppose that the actual uplift of the High Tatra and Belanské Tatry is considerably higher as compared with the values measured in the adjacent basins. Similarly, the positive isolines include a larger region of uplifts between the valleys of Poprad and Torysa. Here belong the Levočské Vrchy and the western part of the Šariš low mountains, where elevations of +0,5 to +1,0 mm/year are prevailing. The mentioned results do not contradict to the morphological conclusions drawn for this region.

In the central course of Torysa near Prešov, lying on the N-S fault system of the Hornád, there occur in short distances territories with contrary movement tendencies. Westwards from the Hornád fault, positive values prevail, while eastwards negative values appear. This fact might indicate the activity of the Hornád fault system even for the present period.

The mountains of external flysch Carpathians are also characterized by elevations especially the Ľubovnianska Vrchovina and Čerchov. Čerchov is morphologically very expressive. While on its western side the Šarišský Úval seems, on the whole, to be a stable region, its NNW borders exhibit elevations up to +1,25 mm/year. The positive gradient of Čerchov, as a complicated horst structure, is well demonstrated by the course of zero-isoline which, in the Basin of Bartošovce, nearly touches its eastern foot.

In our geomorphological literature, the boundary between the Western and Eastern Carpathians is placed along the eastern foot of the Slanské Vrchy Mts., continuing towards the eastern foothill of the Čerchov, in the region of the Kurov saddle. It seems that this dividing line, with few exceptions, is likewise reflected by the map of annual vertical movements. The Eastern Carpathians begin, in our territory, by a marked syncline formed by the extensive Low Beskyds. Its central and southern parts, except the broader frontier region towards the Polish Poeple's Republic, are characterized by a tendency of negative movements which more expressively manifest themselves in the broader region of the Humenné Basin and at the transition to the East-Slovakian Lowland (14). Positive elevations in this frontier region are also proved by the fact that here a fight for sources is conducted between the basins of Bodrog and Visla. The valleys here are deeply cut in and without alluvial sediments. From the synoptic maps of P. Vyskočil (26) it may be seen too that, in the broader region of Dukla pass, positive movements occur.

In the Low Beskyds, on the rivers middle courses, we observe increasing thicknesses of alluvial sediments in the river beds, e. g. between Svidník and Stropkov, in the bed of Ondava, the accumulation mean thickness is 5 m, while at its contact with the East-Slovakian Lowland it attains 5—10 m or on places still more. The morphological conditions of this region confirm the results obtained from the repeated levellings. Similarly as northwards, eastwards too, one can suppose negative values successively passing into positive ones. This strikingly appears in the region at the contact between the nappe of Magura and the unit of Dukla. The Bukovské Vrchy, built by the unit mentioned, should already exhibit positive values. This is confirmed by the fact that in the valleys of this region, the river streams are cut in Würmian bed fillings and flow on flysch base. Our suppositions for the adjacent region of the Soviet Carpathians are indirectly confirmed also by the results of I. D. Gofštejn (7), who reports elevations of +9 to +10 mm/year. For our territory movements of such intensity appear to be too high. The reciprocal regularities cannot be reliably determined because of the discordance of bases used.

As already mentioned, from the map of actual velocities of the vertical movement, we see that the external flysch Carpathians, at their contact with the sub-Carpathian depression, exhibit marked negative movements. In this region, a system of fault dislocations of higher order proceeds in the NW-SE direction, which during the whole Neogene, separated the accumulation region of the Košice Basin and East-Slovakian Lowland from the mountainous region of the Carpathians. At the same time, it is an important seismo-tectonic line of Eastern Slovakia. Sinking of the Basin of Humenné attains —1,25 mm/year. Beside morphological data, the actual movements of this region are also supported by the more frequent occurrence of earthquake focusses, concentrated in the region Humenné—Strážske—Vranov. Their intensity attains 7—8°M.C.S. (1).

The movement tendency of the volcanic arc Vihorlat—Popričný can be estimated but indirectly. There are probably uplifts within negative values, in relation to the Basin of Humenné and the East-Slovakian Lowland, which exhibit more intensive sinking. From morphological studies it follows that the Vihorlat—Popričný represents young horst structures of stratovolcanic feature, which were disproportionally lifted, while the broad region of East-Slovakian Lowland, representing a young developing accumulation plain, is up to now differently sinking (11, 12, 13). This reality is obvious from the present map too. The lowland's central parts, with prevailing actual river accumulation, sink with the intensity of —2 mm/year. Towadrs the hills at the foot of Vihorlat and the Slanské Vrchy Mts., the tendency of sinking acquires smaller intensity, what complies with the morphological results derived from this region. It is interesting that by repeated levelling we succeeded to find out localities of still more intensive sinking, so near Krčava and Sejkov, in the foreground of the Quaternary fault slope, which is also a seismo-tectonic line actively asserting itself in the Transcarpathian Ukraine, in the direction Užhorod-Mukačevo (6). Further, relatively intensive sinking which, however, can be compensated by the accumulation of the Topľa and Ondava rivers, exists between Vranov and Továrne, attaining the value of —2,7 mm/year.

Within the East-Slovakian Lowland, there emerge isolated horst structures as f. i. the Kráľovské Kopce near Kráľovský Chlmec, the Tarbucka near Somotor and especially the Zemplínske Vrchy Mts., southwards from Trebišov. It was supposed hitherto that they represented a stable unit of terrestrial crust, in contrast to the generally sinking lowland (10, 12). But the repeated levelling showed that these horst structures exhibited a slight sinking intensity, what confirmed foregoing suppositions.

At the NE end of East-Slovakian Lowland, in the valley of Topľa, a positive structure occurs with the value of +1,0 mm/year, between the villages of Bystré and Čierne nad Topľou. The expressive movements of Topľa and the formation of two striking Holocene terraces, in the region mentioned, do not exclude this structure.

From this survey it follows that the region of East-Slovakian Lowland has a fault-block structure, within which the individual blocks are sinking with unequal intensities.

The Slanské Vrchy Mts., forming the western boundary of the East-Slovakian Lowland, have a similar evolution as the Vihorlat and Popričný. As for the movement tendencies, we see that the isolines of the adjacent part of East-Slovakian Lowland, towards the mountains, have an increasing tendency. It may be assumed that the mountain itself can also have an increasing tendency, still in negative values, similarly as in the Vihorlat and Popričný. From the relief analysis we conclude that the Slanské Vrchy Mts. should have uplift tendencies with positive values, what is confirmed by the map of P. Vyskočil (26) for the period 1929—1949. The isoline of +0,5 mm/year is passing across this region.

From the Slovak translated by J. Belaj

LITERATURE

1. The Atlas of the Czechoslovak Socialist Republic. Vydala Československá akademie věd a Ústřední správa geodézie a kartografie. Praha 1966. — 2. BAŇACKÝ, V., HARČÁR, J., SABOL, A.: Neue Kentnisse über den Einfluss der tektonischen Bewegungen auf die quartäre Entwicklung der slowakischen Niederungen. Geologické práce, Zprávy 36, Bratislava 1965. — 3. BÖHM, J.: Vyrovnávací počet, Praha 1964. — 4. BUDAY, T. und Koll.: Naphta und Gas in den tschechoslowakischen Karpathen. ČSAV, Praha 1961. — 5. BUDAY, T., KODYM, O. senior, MAHEĽ, M., MÁŠKA, M., MATĚJKA, A., SVOBODA, J., ZOUBEK, V.: Tectonic development of Czechoslowakia. Nakladateľstvo ČSAV, Praha 1961. — 6. GOFŠTEJN, I. D., SOMOV, V. I.: Sovremennyje tektoničeskije dviženija na teritorii Sovetskich Karpat. Geofizičeskij sbornik, Vypusk 18, Akademija Nauk Ukrainskoj SSR, Kiev 1966. — 7. HOFSTEIN, I. D.: A map of the velocity of recent crustal movements of the Soviet Carpathian region. Dopovidi Akademii Nauk Ukrainskoj RSR, Kiev 1971. — 8. KARNIŠ, J., KVITKOVIČ, J.: An Outline of the Geomorphological Conditions of Eastern Slovakia. Geografické práce, roč. I, č. 1, Bratislava 1970. — 9. KRUIS, B.: Technologie opakovaných nivelací konaných k sledování svislých pohybů zemského povrchu. Edice Výzkumného ústavu geodetického, topografického a kartografického (VÚGTK) v Praze, Praha 1970. — 10. KVITKOVIČ, J.: Die geomorphologischen Verhältnisse des südöstlichen Teiles der Tisa — (Theiss) — Ebene. Geografický časopis, roč. VII, č. 1—2, Bratislava 1955.

11. KVITKOVIČ, J.: Ein Beitrag zur Kenntnis der neotektonischen Bewegungen in den Ostslowakischen Tiefebene und in den anliegenden Gebieten. Geografický časopis, roč. XIII, č. 3, Bratislava 1961. — 12. KVITKOVIČ, J.: Concerning the Basic Geomorphological Problems of the East Slowakian Lowland. Geografický časopis, roč. XVI, č. 2, Bratislava 1964. — 13. KVITKOVIČ, J.: La jeune tektonique et son reflet dans le relief sur l'exemple de l'arc volcanique de Vihorlat-Popričný et la plaine de la Slovaquie de l'Est. Geographia Polonica 9. Warszawa 1965. — 14. KVITKOVIČ, J., VANKO, J.: Studium der rezenten Erdkrustenbewegungen auf dem Gebiet der Slowakei. Geografický časopis, roč. XXIII, č. 2. Bratislava 1971. — 15. LUKNIŠ, M.: Die Reliefentwicklung der Westkarpathen. Wissenschaftliche Zeitschrift d. M. L. Univ. Halle-Wittenberg, Math-Nat. XI/10, 1962. — 16. LUKNIŠ, M.: Die Entwicklungsperioden der Hohen Tatra in Bezug auf Quartärablagerungen. Report of the With International Congress on Quaternary, Lódž 1963. — 17. LUKNIŠ, M.: Die Überreste älterer Verebnungsflächen des Reliefs in den tschechoslowakischen Karpaten. Geografický časopis, roč. XVI, č. 3, Bratislava 1964. — 18. LUKNIŠ, M.: Geomorphologische Karte der Hohen Tatra und ihres Vorlandes. Geologický ústav Dionýza Štúra, Bratislava 1968. — 19. Map of recent vertical crustal movements of Eastern Europe. Glavnoje upravlenije geodezii i kartografii pri Sovete ministrov SSSR, Moskva 1971. — 20. MAZÚR, E.: The Žilina Basin and the Adjacent Mountains (Geomorphology and Quarternary era). Vydavateľstvo SAV, Bratislava 1963.

21. MAZÚR, E.: Intermountain Basins a Charakteristic Element in the Relief of Slovakia. Geografický časopis, roč. XVI, č. 2, Bratislava 1964. — 22. MAZÚR, E.: Major features of the West Carpathians in Slovakia as a result of young tectonic movements. Geomorphological problems of Carpathians. Vydavateľstvo SAV, Bratislava 1965. — 23. PORUBSKÝ, A.: La disposition des alluvions de flysch du Poprad, Torysa et Ondava pour acquérir des sources d'eau. Geografický časopis, roč. XXIII, č. 3, Bratislava 1971. — 24. VYSKOČIL, P.: Využití výsledků nivelace pro sledovaní vertikálních pohybů zemské kůry. Geodetický a kartografický obzor, 9—10, Praha 1968. — 25. VYSKOČIL, P.: Vertikální pohyby zemské kůry v oblastech Slovenska z nejnovějších nivelací. (Výzkumná zpráva VÚGTK č. 316), Praha 1969. — 26. VYSKOČIL, P.: Comparison of two Maps of annual Speeds of Vertical Crustal Movements on the Territory of the ČSSR. Presented at the Fifteenth IUGG General Assembly Moscow 1971, Prague 1971.

Jozef Kvitkovič, Ján Vanko

SÚČASNÉ POHYBY ZEMSKEJ KÔRY V OBLASTI VÝCHODNÉHO SLOVENSKA

V úvode predloženej štúdie sa analyzuje reliéf v oblasti východného Slovenska z hľadiska jeho pohybových tendencií v neotektonickej etape, ktoré sú potencionálnym predpokladom výskytu súčasných pohybov. Neotektonické pohyby majú prevažne germanotypný charakter a prebiehajú pozdĺž porúch ZV—JV SV—JV, a neskoršie S—J smeru, ktoré sa prejavujú v horskej, ako aj v nížinnej oblasti. Najsilnejšie vertikálne pohyby majúce zásadný význam pre morfoštruktúrnu a orografickú individualizáciu reliéfu východného Slovenska sa udiali v strednom pliocéne v súvislosti s rhodanskou fázou pohybov. Forma a plošný areál jednotlivých morfoštruktúr sa postupne dotváral v priebehu levantu a kvartéru. Z konvergencie riečnych terás po toku a v niektorých oblastiach z ich ponárania pod súčasné niveau nížiny usudzujeme o nerovnomerných pohyboch v kvartérnom období. Za posledných milión rokov v oblasti východného Slovenska dosiahol celkový vertikálny efekt pohybov približne 250 m, čo je asi 0,25 mm/rok. Z morfologickej analýzy územia vyplýva, že v oblasti východného Slovenska sú reálne predpoklady výskytu súčasných pohybov zemskej kôry. Tieto predpoklady boli potvrdené aj na základe výsledkov opakovanej nivelácie.

Pre zostavenie mapy ročných rýchlostí vertikálnych pohybov zemskej kôry boli použité výsledky opakovaných nivelácií z oblasti východného Slovenska z obdobia rokov 1950—1955 a 1961—1966. Stredný časový interval je 13,6 rokov. Za východiskový bod bol zvolený základný nivelačný bod Šarišské Jastrabie, ktorý sa nám javil ako najvýhodnejší z regionálno-morfologického hľadiska

Z mapy ročných rýchlostí vertikálnych pohybov zemskej kôry vyplýva, že na východnom Slovensku za skúmané obdobie je možné registrovať pohyby o hodnotách +1,6 mm/rok v horských oblastiach a až —2,7 mm/rok v oblasti Východoslovenskej nížiny, čiže celkové rozpätie zistených hodnôt dosahuje cez 4 mm/rok.

Oblasť centrálnych Západných Karpát vykazuje pomerne jednoznačné zdvihy, resp. menšie regióny územia sa chovajú ako stabilné. Nepatrné negatívne pohyby sa prejavujú iba v Zamaguri. Je pozoruhodné, že na región týchto poklesov sa viažu zemetrasné ohniská. V Popradskej kotline prebiehajú vertikálne pohyby v rozpätí +1,0 až +1,6 mm/rok. Taktiež zdvihové tendencie sa prejavujú po prechode podtatransko-ružbašského zlomu v smere na Ždiar, ktorý oddeľuje vnútrohorskú kotlinu od vysokohorskej, resp. stredohorskej oblasti. To znamená, že na základe výsledkov opakovanej nivelácie sa prejavuje jeho aktívna funkcia aj v súčasnosti. Z toho nepriamo vyplýva, že súčasné zdvihy Vysokých a Belanských Tatier sú oproti nameraným hodnotám v Popradskej kotline značne vyššie. Podobne sa zdá aktívny aj hornádsky zlomový systém v širšej oblasti Prešova.

Z pohorí vonkajších flyšových Karpát sa vyznačujú zdvihmi najmä Ľubovnianska vrchovina a Čerchov. Pozitívne stúpanie Čerchova ako zložitej hrasťovej štruktúry dobre zvýrazňuje priebeh nulovej izoplety, ktorá v Bartošovskej kotline sa dotýka takmer jeho východného úpätia.

Centrálne a južné časti Nízkych Beskýd s výnimkou pohraničnej oblasti s Poľskou ľudovou republikou a pravdepodobne aj Bukovských vrchov sa vyznačujú sklonom k negatívnym pohybom, ktoré sa výraznejšie prejavujú v širšej oblasti Humenskej kotliny a pri prechode do Východoslovenskej nížiny. O recentnej aktivite hlbinných zlomových porúch, prebiehajúcich v zóne styku horskej oblasti Východných Karpát s prikarpatskou depresiou, ktoré sú význačnou seizmotektonickou líniou, svedčí popri geologicko-morfologických údajoch aj pomerne vysoká intenzita zemetrasných ohnísk v širšom regióne Humenné — Vranov.

Východoslovenské sopečné pohoria majú zdvihové tendencie, a to buď ešte v záporných, resp. v kladných hodnotách, kým oblasť Východoslovenskej nížiny, v ktorej sa prejavuje zlomovo-kryhová štruktúra, prevládajú poklesy o intenzite až —2,7 mm/rok. Na základe morfologickej interpretácie mapy ročných rýchlostí vertikálnych pohybov usudzujeme, že súčasné pohyby jednotlivých morfoštruktúr sú zdedenými kolísavými pohybmi z pliocénu a pleistocénu.

Obr. 1. Sieť opakovaných nivelácií na východnom Slovensku. 1 — základný nivelačný bod (ZNB), 2 — uzlový bod, 3 — pripojovací bod.

Mapa 1. Mapa ročných rýchlostí vertikálnych pohybov zemskej kôry v oblasti východného Slovenska pre epochu 1950,9 — 1964,5. Izolínie v mm/rok. 1 — vysoké pohoria centrálnych Karpát s ľadovcovým reliéfom na mezozoických a starších štruktúrach, 2 — stredné pohoria a vrchoviny (a) centrálnych Karpát s brázdami, resp. pahorkatinami (b) prevažne na flyšových vrásovo-zlomových štruktúrach, 3 — stredné pohoria a vrchoviny vonkajších Karpát (a) s malými kotlinami a brázdami (b) na príkrovo-vrásových štruktúrach, 4 — vnútrohorské erózno-tektonické kotliny, 5 — stredné pohoria sopečných Karpát na hrasťových štruktúrach, 6 — nižšie pohoria hrasťového charakteru na exotoch centrálnych Karpát, 7 — prikarpatské zníženiny — Východoslovenská nížina; (a) pahorkatinný stupeň — rozčlenený pediment, (b) mladá akumulačná rovina, 8 — sopečné exoty, 9 — izolínie skutočné (a), predpokladané (b).