University of West Hungary
Faculty of Forest Engineering

Theses of Ph.D. dissertation

Neotectonics of Somogy- and Zala Hills

- morphostructural studies -

Ferenc Síkhegyi

Ph.D. School: Kitaibel Pál Ph.D. School of Environmental Sciences
Head of Ph.D. School: Prof. Dr. Csaba Mátyás

Program: Geo-environmental Sciences
Head of Program: Prof. Dr. László Szarka

Theme leaders: Prof. Dr. Gyula Mentes
Prof. Dr. Márton Veress

Sopron

2008

Preliminaries

The fundamental task of the Geological Institute of Hungary where the author works is to satisfy the needs of the state concerning geological knowledge. During the recent thirty years traditional research methods have been supplemented by the thematic interpretation of aerial images and by remote sensing broadening the palette of applied research methods.

The author acquiring also the qualification of cartographer has always been working in the boundary of geology and cartography adopting both methods in geological research.

As a head of the lowland mapping programme of Kisalföld and Zala he integrated the application of geological images in the methodology of mapping for preliminary evaluations, laying out boreholes and thematic interpretation. With his team members he introduced photogeological methods in practice for defining genetic types, relative age and lithological composition of Quaternary deposits. Additionally, they performed thematic interpretations for detecting soil erosion, accumulation, earth mass movements and landslides as well as pollution sources of the geological environment.

The introduction of spatial images enabled the author to use them for tectonic interpretation of the country's regions and the whole area of the Carpathian basin in co-operation with the specialists of neighbouring countries. Simultaneously, as the head of the Geological Institute's remote sensing group he took part in thematic evaluations, aerial geophysical surveys as well as in the introduction of GIS and digital cartography in the Institute's research methods.

Starting from the 1990s there has been an increasing demand for the investigation of geological risks. The planning of domestic major investments required the survey of earthquake risk. The author became then a member of interinstitutional teams in which he was responsible for Quaternary geological, geomorphological and morphotectonic tasks. He focused his attention to Southwest Hungary where he was facilitated by his field knowledge in understanding the neotectonic processes of the Pannonian basin. In Sümeg the author lead the geomorphological field practice of the students in the department of Environmental Sciences of the University of West Hungary acquiring thus even more thorough knowledge of geological sequences, as well as neotectonic and associated morphological processes in the region.

Objective

One of the fundamental tasks of geological survey is to reveal tectonic processes acting in the Pannonian basin during the Quaternary period. Their understanding enables to throw light upon the causes of recent geodynamic processes together with the nature, direction and magnitude of geological risk factors to be anticipated. In this respect the selected region is in outstanding intermediate position affected not only by the direct action of Eastern Alpine and Dinaridian orogenic processes but it also transmits these actions towards the Pannonian basin.

Neotectonic processes are defined first of all by the relative movement of lithospheric plates. Depending on whether they approach or move away it gives rise to compressive or extensional deformations resulting in the simultaneous uplift or subsidence of superficial formations. This process defines the possible genetic types of evolving deposits and the morphological evolution of the existing ones. The major objective of the author was to detect the types of deformations forming the young sediments as well as to describe how these deformations can be identified on the surface relief and drainage pattern.

Another objective was to put emphasis on morphostructural methods in the study and interpretation of the results; the rest of geodynamic methods should have been restricted to comparative analysis.

Methodology, the work performed

The author collected neotectonic, geodynamic and major morphotectonic works conducted in the research area and its broader surroundings. They were outlined in the first part of the dissertation.

He clarified then the key principles of the action of horizontal forces of compression and extension in determining surface evolution as well as in the formation of certain genetic types of Quaternary sediments and in morphological processes. He examined how compressive or extensional deformations can be identified on slightly consolidated sediments, their relief and drainage pattern and which of them will be specific of uplifting or subsiding areas. Their summary is outlined in the second part of the dissertation.

The subject of the dissertation is principally focused on specifying the appearance of morphological signatures of theoretically suggested neotectonic processes in the morphology and related surface evolution of the Somogy and Zala regions. For some part they are derived of different cartographic materials: relief and hydrological maps, digital terrain models, spatial images and auxiliary remote sensing data. On the other hand they are detected on thematic maps of the Geological Institute: drift geological maps, maps of recent surface forming processes, thickness maps of Quaternary deposits and data of the borehole database. Their summary is specified in the third part of the dissertation and in the annexes.

Different source materials, interpretations and the results of analyses are integrated and stored in digital databases in the GIS applied in the Geological Institute ensuring the representation of spatial data.

New scientific results

Thesis 1

On the basis of my own and partly in Hungary acquired experiences I elaborated the mapping methodology of lowland areas based on the geological and thematic interpretation of aerial images which was used in the Geological Institute during the complex geological mapping of Kisalföld and Zala Hills in practice. Preliminary photogeological interpretations improved the efficiency of field examinations and layout of boreholes. Apart from assessing the genetic types, relative ages and lithology, the determination of Quaternary deposits on stereo pairs of aerial images facilitated also the elucidation of the geomorphological setting. Thematic interpretations enabled the exact recognition of the processes of surface and linear erosion and recent sedimentation as well as one-time slope movements and the examination of the conditions of their spatial distribution.

Thesis 2

By means of the interpretation of space images I prepared the map of the country’s linear and ring-like structural elements. Through orientation statistic study I revealed that the lineaments of Cainozoic sequences covering large parts of the country are associated with young tectonic processes affecting the formation of relief and drainage pattern. Analogous then digitally rectified remote sensing data enabled the morphostructural analyses of less consolidated sediments and to draw neotectonic conclusions. The related first results were published in the cosmotectonic map of the Central-European region and the related explanatory material.

Thesis 3

I compiled complex maps of the broader environment of Somogy and Zala counties delimiting the subsiding and uplifting areas during ate Pleistocene and Holocene on the basis of the genetic types of young Quaternary sediments and the erosion affecting them due to emergence. Collating these results with data of geodetic measurements I showed that apart from the correspondence of general tendencies the picture resting upon geological aspects is more detailed in its tendencies than the one based on geodetic networks. The methodology of map compilation is suitable for distinguishing the directions of vertical crust movements induced by tectonic effect. Hence I drew conclusions on crust movements and neotectonic processes governing them.

Thesis 4

My previous morphostructural studies covering the whole country showed that meridional valleys are adjusted in a structure of radial pattern progressively changing its direction from Vas Ridge through Transdanubia to the central part of Alföld. In the dissertation I bring up arguments for the tectonic origin of this pattern. Its formation is presumably due to the eastward movement of the upper levels of lithospheric plates pressed out. The plate emerging on the thick astenosphere below the Alps (or some upper zone of the crust) thinned out beneath the Pannonian basin or at least it is translocated nearly laterally on the emerging astenosphere. The downward bending of upper levels and the slightly northwardly curved trajectory induce the formation of weak zones, eventually of some small strike-slips and subsidence along near-surface listric faults. These weakened zones and lines give free way to deflation and to a less extent to fluvial erosion.

The formation of meridional valleys started after the dissection of the Zala- Lower and Middle Pleistocene gravel surface acquiring their present form after young loess deposition.

Thesis 5

On the basis of the orientation and vergence of folds manifested in morphology compressive structural evolution took place during Quaternary in the Mura- and Kerka Land and in Zala Hills. The youngest antiforms of the E–W striking fold development show up in the N part of the hills, whereas their enclosed synform produced Lake Balaton and the depression of its W continuation. Folding started in Vas Ridge and Kemenes Ridge joining from the N to the area.

The first signatures of the transpressive change of style appear on the irregularly widened S end of Zala ridges showing up in morphology as well. The westward evasion of Cserta- and Principális Valleys is due to uplifting along longitudinal valleys.

The longitudinal valleys of the Külső-Somogy are the manifestations of right-sided strike-slip faults rejuvenated during Late Pleistocene. The most prominent one can be traced in the strike of Kapos- and Tamási Lines that induced the uplift of the E Somogy Pári Hill and Tolna Ridge on the surface. Its NE continuation is marked by uplift in Mór Trench and the westward evasion of Sárvíz Valley. Due to the deformation in young loess sequences it might be referred to as the youngest, Late-Pleistocene–Holocene structural line identifiable in the morphology.

Thesis 6

I set up a model to explain the saw-tooth pattern of longitudinal valleys. Accordingly, some faults of the Middle-Hungarian zone are rejuvenated as right-sided strike-slip faults due to NW–SE compressive stress. In the space between, clockwise rotation of the blocks dismembered by the weakened zones of the radial structure occurs. As a result of the resistance of the lateral space the rotated blocks evade the generated compressive effects by uplifting quite distinct in the morphology.

Thesis 7

The area of inner Somogy is a significant boundary for it separates the W, predominantly compressive structural evolution of the trnspressive one prevailing in E Somogy. Furthermore it delimits the Zala folds and virtually separates the denudation area of the material with Alpine provenance from the one deriving of the Transdanubian Central Range. Due to its sharp boundaries coinciding with the radial pattern and thickened Quaternary fill it can be thought of having tectonic origin.

Thesis 8

I demonstrated that the Middle-Hungarian zone, the main structural zone of the Pannonian basin plays subordinate role in Quaternary structural evolution. Irrespectively of some minor rejuvenations that were activated as transpressive right-sided strike-slip faults and beside the saw-tooth, zig-zagged pattern of the so-called longitudinal valleys it has a minor effect on surface evolution. The fragment pertaining to the Tisza–Dácia microplate wedged in between the Dinarides and ALCAPA unit is pressed out jointly with the ALCAPA unit.

The general uplifting and joint surface evolution refer to this scenario which is framed by the intensely subsiding regions of Kisalföld, Mura- and Dráva Basins and Nagyalföld.

Thesis 9

Neotectonic processes in Somogy and Zala counties fit in the generally accepted model according to which the roughly northward movement of the Adria microplate and its counter clock-wise rotation are the main driving forces of neotectonic and geodynamic processes occurring in the Pannonian basin. The microplates enclosed by the Carpathians and Dinarides react by being pressed out to E-NE.

As a result of the awakening lateral stresses compressive deformations can be recognised in the W margin of the Pannonian basin bringing about transpressive deformations in Quaternary deposits under the effect of the progressively south-eastward tending forces towards Külső-Somogy.

Prospects of the utilisation of the results

The undisputedly useful achievement of the dissertation is that it proves the utility of morphostructural – in other words morphotectonic – studies for broadening the toolset and methods of neotectonic investigations and for explaining the spatial distribution and relationships of Quaternary formations.

Its practical utility consists in detecting the causality in recent surface forming forces and processes. Neotectonic processes have key impact on the evolution of geological risk factors and the determination of the anticipated spatial location of their appearance. One of the related key issues is the recognition of recent surface forming processes, the conditions of their occurrence as well as the detection and interpretation of the signatures of the deriving deformations on the surface. The materials applied for the morphostructural examinations encompassing the analyses of aerial images, remote sensing data, terrain models together with the derived data are put in and stored in a uniform GIS the processing of which facilitates performing complex evaluations and their collation with the results acquired by other geodynamic research methods.

Publications related to the subject

BREZSNYÁNSZKY, K. & SÍKHEGYI, F. 1987: Neotectonic Interpretation of Hungarian Lineaments in the Light of Satellite Imagery. – Journal of Geodinamics **8,** pp. 193-203

FODOR, L., BADA, G., CSILLAG, G., HORVÁTH, E,, RUSZKICZAY-RÜDIGER, ZS. & **SÍKHEGYI, F** 2005a: New data on neotectonic structures and morphotectonics of the western and central Pannonian Basin. – Occasional Papers of the Geological Institute of Hungary **204**, pp. 35-44

FODOR, L., BADA, G., CSILLAG G., HORVÁTH, E., PALOTÁS, K., RUSZKICZAY-RÜDIGER, ZS., **SÍKHEGYI, F.,** TIMÁR, G., CLOETHING, S. & HORVÁTH, F. 2005b: An outline of neotectonic structures and morphotectonics of the western and central Pannonian Basin. – Tectonophysics **410,** 1-4, pp. 15-41

HORVÁTH F., BADA G., WINDHOFFER G., CSONTOS L., DÖVÉNYI P., FODOR L., GRENERCZY GY., **SÍKHEGYI F.,** SZAFIÁN P., SZÉKELY B., TIMÁR G., TÓTH L. & TÓTH T. 2005: A Pannon-medence jelenkori geodinamikájának atlasza: Euro-konform térképsorozat és magyarázó. OTKA T034928 sz. projekt zárójelentés. – ELTE Geofizikai Tsz., Budapest, p. 38
http://geophysics.elte.hu/atlas/geodin_atlas.htm

HORVÁTH F., BADA G., WINDHOFFER G.†, CSONTOS L., DOMBRÁDI E., DÖVÉNYI P., FODOR L., GRENERCZY GY., **SÍKHEGYI F.**, SZAFIÁN P., SZÉKELY B., TIMÁR G., TÓTH L. & TÓTH T. 2006: A Pannon-medence jelenkori geodinamikájának atlasza. Euro-konform térképsorozat és magyarázó. – Magyar Geofizika **47, 4,** pp. 133-137

MARSI I. & **SÍKHEGYI F.** 1997: Magyarország negyedidőszakban süllyedő és emelkedő területei távérzékelési és földtani adatokból – In: VII. Földfelszíni és meteorológiai megfigyelések a világűrből, Budapest, pp. 177-184

MENTES, G., THEILEN-WILLIGE, B., PAPP, G., **SÍKHEGYI, F.** & ÚJVÁRI, G. 2008: Investigation of the relationship between subsurface structures and mass movements of the high loess bank along the River Danube in Hungary. – Journal of Geodynamics, doi:10.1016/j.jog.2008.07. 0005

MEZHELOVSKIY, N. V. (editor in chief), PANAYOTOV, A., **SÍKHEGYI, F.**, ZELT, F., KRULL, P., BAZYNSKI, J., GRANICZNY, M., VIJEDA, V., SANDULESCU, M., KOZLOV, V. V., STAVTSEV, A. J., BAGINYAN, M. K., FARADZHEV, V. A., DORNIC, J., REICHWALDER, P., MARKOVIC, M., PAPP, J. & PETROVA, C. (eds.) 1987: Space tectonic map of European countries – the CMEA members and SFRY. Scale 1:1 000 000 (Magyarország területe). – CMEA Moscow, USSR

SÍKHEGYI F. 1984: A Kisalföld regionális komplex földtani vizsgálata. – A Magyar Állami Földtani Intézet Évi Jelentése az 1982. Évről, pp. 43-48

SÍKHEGYI F. 1985: Kozmikus felvételek szerkezeti értelmezése. – In: Gyakorlati szerkezetföldtani továbbképző, MFT Special Papers, Budapest, pp. 129-144

SÍKHEGYI, F. 1987: Kainoziskie kosmolineamentü Vengerskogo basseina. – In: Kosmoaerogeologiceskie issledovanija, KGST, Moszkva 1987, pp. 8-14

SÍKHEGYI F. 1996: Vonalas szerkezeti elemek. – In: Haas J. (szerk.): Magyarázó Magyarország szerkezetföldtani térképe c. térképlaphoz. A MÁFI térképmagyarázói, Budapest. pp. 129-134.

SÍKHEGYI F. 1999: A felszínmozgások megjelenése légifényképeken. – Földtani Kutatás **XXXVI,** 3, pp. 8-13

SÍKHEGYI F. 2001: A Dél-Dunántúl neotektonikája. – MFT Általános földtani szakosztályának előadóülése

SÍKHEGYI, F. 2002: Active structural evolution of the western and central parts of the Pannonian basin: a geomorphologial approach. – EGU Stephan Mueller Special Publication Series, **3,** pp. 203-216

http://www.cosis.net/members/journals/df/abstract.php?a_id=2698

SÍKHEGYI F. & TULLNER T. 1982: A Kisalföld komplex térképezésének távérzékelésen, légifénykép-kiértékelésen alapuló előkészítése és mérnökgeológiai munkái. – Mérnökgeológiai Szemle **29,** pp. 59-69

SÍKHEGYI F. & TURCZI G. 1990: A távérzékelés és digitális feldolgozási módszerek alkalmazása a földtani térképezésben. – Földtani Kutatás **XXXIII.** 3, pp. 33-40

SÍKHEGYI F., SZÉKELY B. & UNGER Z. 2005: A Pannon-medence és környezete morfostrukturális elemei. – In: Horváth et al. 2005: A Pannon-medence geodinamikai atlasza, 7. térképlap

Reports and manuscripts related to the subject

JÁMBOR Á. (szerk.), BIHARI D., CHIKÁN G., FRANYÓ F., KAISER M., RADÓCZ GY. & **SÍKHEGYI F.** 1993: A pleisztocén során működött magyarországi törésvonalak bizonyító anyaga. – Kézirat. MÁFI Adattár

MARSI I. & **SÍKHEGYI F.** 1995: Magyarország jelenkorban süllyedő és emelkedő területeinek meghatározása földtani, geomorfológiai és távérzékelési adatok alapján. – Integrated Basin Studies (ELTE Geofizikai tanszék, témafelelős: dr. Horváth F.) 1995 december. 14 old. + 2 térkép, angol összefoglalás 3 old. + 4 ábra. Kézirat. MBFH Adattár, T 17094

SÍKHEGYI F. 1992: Magyarázó Magyarország 500.000-es lineamentum térképéhez. Szerk.: Angyal J.,Kalafut M., Rakonczai K., **Síkhegyi F.** (főszerk.), Szurkos G. – OTKA jelentés kézirat, 1992 december. MBFH adattára, T 21461

SÍKHEGYI F. 1994: Magyarország jelenkori süllyedő és emelkedő területeinek elkülönítése. A Dunántúl és a Duna-Tisza közének déli része. – Munkaközi jelentés az Integrated Basin Studies Projekthez. (ELTE Geofizikai tanszék, témafelelős: dr. Horváth F.) 1994. december. Kézirat. 16 p. + 1 térkép. ELTE TTK Geofizikai Tanszéke MGSz Adattár, T 17027

SÍKHEGYI F. 1999: A negyedidőszaki képződmények fotogeológiai kiértékelése az üveghutai terület téli repülésén. – Kis- és közepes radioaktivitású erőművi hulladékok végleges elhelyezése; Nemzeti Projekt II. szakasz (1998. március). 1 térkép, 12 ábra, 13p

SÍKHEGYI F., TISZA A. & UNGER Z. 2005: A goricai terület légifelvételeinek kiértékelése vízföldtani szempontból. – A BAF minősítését célzó Középtávú Program I. kutatási fázisa, MBFH Adattár

SÍKHEGYI F. 1987: Magyarázó Magyarország 1 000 000-es méretarányú kozmotektonikai térképéhez. 25 old. és mellékletek, MÁFI Adattár

SZURKOS G. & **SÍKHEGYI F.** & 1992: A Kárpát-medence lineamentum kiértékelései. – Irodalmi összefoglalás. Kézirat. MÁFI Adattár. 36p

Abstracts and posters

SÍKHEGYI, F. 2001: Effects of neotectonic processes ont he forming of the Kapos walley. – Poszter, 3rd Stephan Müller Conference, EGS, Balatonfüred. Abstract book of the 3rd Stephan Müller Conference, EGS, Balatonfüred, p. 58

FODOR, L., HORVÁTH, E., MAGYARI, Á., NOVOTHNY, Á., RUSZKICZAY, ZS., **SÍKHEGYI, F.,** SZÉKELY, B., TIMÁR, G., UNGER, Z. & WEBER, J. 2001: Tectonic and non-tectonic control on landform evolution, drainage pattern in a loess-covered area (Gödöllő Hills, central Hungary). Abstract book of the 3rd Stephan Müller Conference, EGS, Balatonfüred, p. 18.

FODOR, L. BADA, G., CSILLAG, G., DUNAI, T., HORVÁTH, E., RUSZKICZAY-RÜDIGER, ZS., **SÍKHEGYI, F.,** LEÉL-ÖSSY, SZ., CLOETINGH, S., HORVÁTH, F. 2003a: Neotectonics of the Pannonian basin II: interplay between deformation and landscape evolution. EGS- AGU- EUG Joint Assembly, Nice, Geophysical Research Abstract, Vol. 5, 9671.

FODOR, L., HORVÁTH, E., RUSZKICZAY-RÜDIGER, ZS., **SÍKHEGYI, F.,** MAGYARI, Á., NOVOTNY, Á., TIMÁR, G. & UNGER, Z. 2003b: Pliocene-Quaternary landform evolution of the Gödöllő Hills, Central Hungary: completing aeolian to fluvial denudation, sedimentation and tectonic forces. Abstracts of the XVI. INQUA Congress, July 24-30, 2003, Reno, Nevada, USA. p. 80