SÁMUEL MIKOVINY DOCTORAL SCHOOL OF EARTH SCIENCES

Head of Doctoral School:
DR. ISTVÁN LAKATOS, MEMBER OF HAS

THE EFFECTS OF ROCK QUALITY ON THE DRAINAGE NETWORK OF BÜKKALJA

Thesis of PhD dissertation

JÁNOS VÁGÓ

Scientific tutor:
DR. ATTILA HEVESI,
professor

University of Miskolc
Faculty of Earth Science and Engineering
Institute of Geography
Miskolc, 2012

I. Introduction and the aim of the dissertation

The main goal of my dissertation was the comprehensive hydrogeographic characterization of the Bükkalja. Beside the analysis of catchment areas and the drainage network, the role of Miocene tuffs (especially the welded tuffs) was also examined, which affected the evolution of the surface (development of geomorphologic levels). These volcanic materials have very different rock quality. According to the results of examined morphometric indices, the Miocene tuffs – mainly the welded-melted variations, ignimbrites – had taken a decisive part in the evolution and characteristics of the drainage network.

The role of rock quality and the effect of welded ignimbrites on the surface evolution are well known (e.g. Láng S. 1954, Hevesi A. 1997, Székely A. 1997). However, the examination of the effect of these rocks on the drainage network on the entire area, and the hydrogeographic analysis of Bükkalja are not done yet. I have examined the effect of rock quality on the morphometric parameters of the drainage network (e.g. shape, area, length of water basins, stream gradient, stream order, direction of watercourses, drainage density etc.). In this analysis, modern, GIS based methods were also used. These methods, compared with the traditional, subjective geographic methods could yield a more exact result.

In this dissertation, applying GIS based geomorphological methods, efforts were made to deliminate the pediment levels of Bükkalja (dual pediment). The location and the area of the remnants of these geomorphological levels were also determined. The relationship between the situation of pediment levels and the surface occurrence of welded ignimbrites was analyzed as well. GIS based morphometric investigations were made to confirm the field observation: the major properties of the terrain on the welded ignimbrites significantly differ from the properties in their surroundings.

According to the "official", academic literature (Marosi S. – Somogyi S. 1990) the Bükkalja is located between the valleys of Tarna- and Szinva-creeks. However, according to most of the geologists and some geographers, the western boundary of the pediment is the valley of Eger-creek. Therefore this western area, compared with the eastern part of the Bükkalja, is less known. My aim was to complement the geographic knowledge of this area.

In the dissertation numerous new, or modified analytic, mapping methods were applied: these can be used in the detailed physical geographic analysis of any landscapes.

II. Research methods

The geomorphologic results presented in the dissertation are based on field observations. The field surveys of the research area were documented by photographs. This work was complemented by the collection and processing of the area's available physical geographical, geomorphological, geological, engineering geological, topographic maps, drilling data, and other databases (digital elevation models). Beside the conventional analytical approach, I made efforts to apply and develop modern computerized GIS tools and methods.

The aim of my research was the analysis of the role of rock quality – especially the quality of Miocene welded ignimbrites – on the landscape evaluation and the development of drainage network and drainage basins. The digital format of these data layers was made by the application of ESRI ArcView 3.2 GIS software. The watersheds, valleys, permanent watercourses were identified on the basis of topographic map sheets scaled 1:10 000, which were also complemented with the results of field observations. The geologic formations have major role in the dissertation. Their identification was done on the basis of scaled 1:50 000 digital, and scaled 1:100 000 paper format geologic maps.

For the geomorphologic researches and for the examination of the terrain's main parameters (slope, aspect, relative relief etc.) digital elevation models (DEM) were used. The regional scale examinations were done on the basis of SRTM DEM, which is developed by the NASA. The spatial resolution of this DEM is ~90 m. For the more detailed, local examinations a different DEM was used, with the resolution of 10 m. It was created by the digitalized contour lines of topographic maps.

The DEM based geomorphologic analyses (slope, aspect, mean slope direction, surface dissection etc.) and the examination of pediment levels, the morphometric analysis of drainage basins, the determination of parameters of drainage network (stream gradient, stream direction, drainage density etc.) were done by the ESRI ArcGIS 9.2 GIS software.

III. New scientific results

The main goal of my dissertation was the analysis of the watersheds and the drainage network. The effect of Miocene welded tuffs, ignimbrites was also examined, which had taken decisive part in the evolution of the surface.

The existence of the Bükkalja's geomorphologic levels is well-known in the literature (Martonné Erdős, K. 1974, 2002; Dobos, A. 2001a, 2006) and in some parts of the pedimentation it is researched in details. However, in the entire area of Bükkalja the location and the range of these levels were not determined.

The geomorphologic levels of Bükkalja were examined by the mathematical analysis of the SRTM histogram's best-fit polynomial function. **Classifying the digital elevation model by the inflection points of the histogram's polynomial function, the eastern part of Bükkalja, which is determined by the welded ignimbrites, can be divided into two height (geomorphologic) levels. Hereby the existence of these levels was confirmed and their location was visualized by applying geoinformatic method (Thesis 1).** The lower level is situated between 151 - 243 m, the higher between 243 - 426 m, these are the remnants of the younger and the older pedimentation. Great majority of the welded ignimbrite hilltops is situated on the upper pediment level. It confirms the observation that the remnants of this older level formed primarily on the welded ignimbrites, which are more resistant to the erosion.

The geomorphologic levels were also separated by the method based on the calculation of "Topographic Position Index" (TPI), (Weiss, A. 2001). Today the pedimentation is strongly eroded and dissected, its original height is preserved only by the ridges. Therefore in this analysis not the entire surface, but only the ridges were taken into account, which were selected on the base of TPI values. These ridges were classified into height levels by applying the automatic, statistical method of unsupervised classification (IsoCluster).

The ridges were classified into two morphologic levels on the basis of this method as well: the lower level is situated between 136 - 266 m, the higher between 266 - 524 m. The area, location of the levels and the catalog of the ridges were also determined. There are significant differences in the location of morphological levels to the west and to east from Eger-creek. **On the eastern part of Bükkalja, following the ENE-WSW direction of welded ignimbrites, the remnants of upper pediment level are arranged into 2-3 parallel stripes. On the highest zone of the pediment, the stripes of the upper pediment level are merged. On the west, due to the lack of welded ignimbrite cuestas the ridges are lowering constantly to the south, so the ridges of the upper level are restricted to the northern edge of the Bükkalja (Thesis 2).** Portions of the younger, lower pediment level are located mainly to the south of the upper level and between the stripes of the upper level or in the downcast basins (Fig.1).

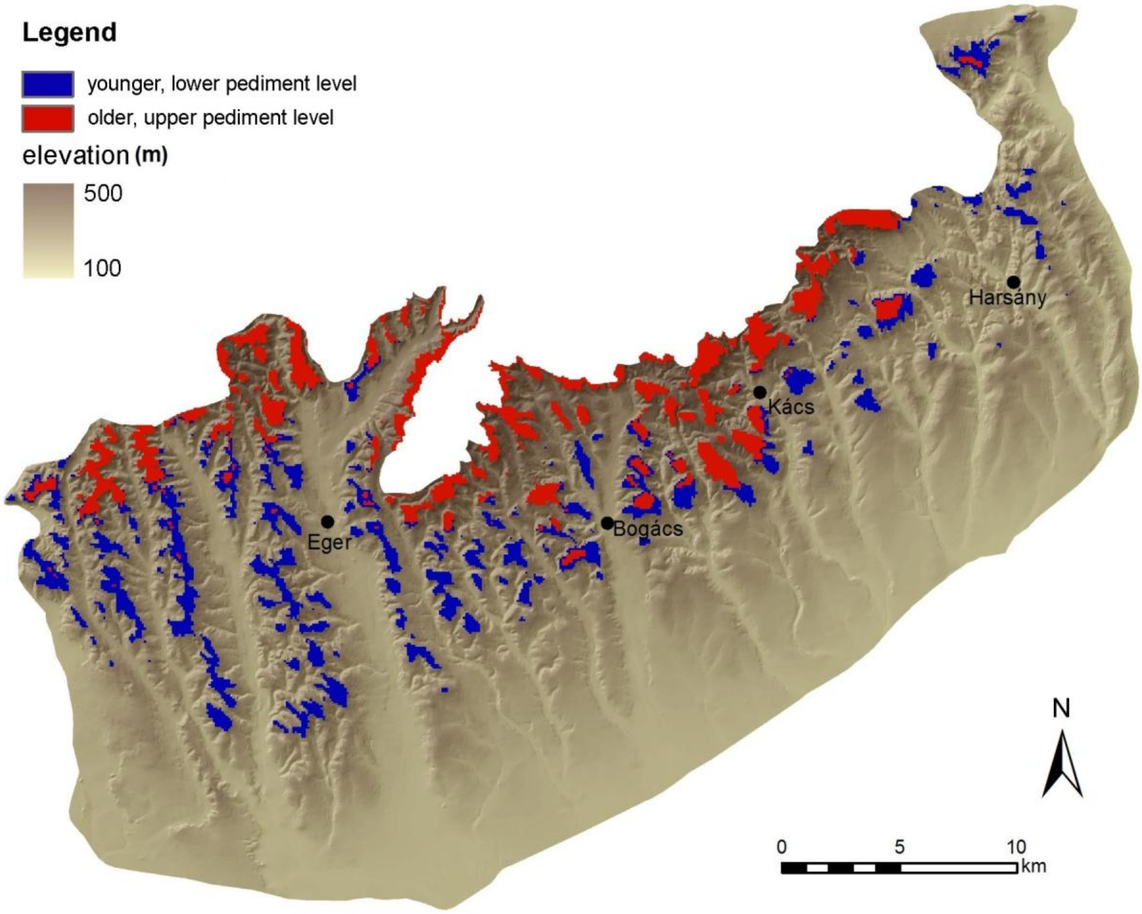

Fig.1. Geomorphic levels of Bükkalja according
to the classification of pixels (ridges) height

By the morphometric examination of areas determined by tuffs, the role of welded ignimbrites in the landscape evolution was also examined. The differences of the terrain's main features (average altitude above sea level, average slope conditions and average relative relief) were examined on the territory of welded ignimbrites and on the entire area of Bükkalja. As a result, I found that the hills covered by the welded ignimbrites of Tar Dacite Tuff Formation are the highest (259 m), and the slope is the steepest on the rocks of Tar Dacite Tuff Formation and Gyulakeszi Rhyolite Tuff Formation Kisgyőr Ignimbrite Member. **The topography of areas built up by tuffs differs significantly from the surface of the whole Bükkalja. Particularly the stripes of welded ignimbrites are different from the rest of the pedimentation, which confirms the decisive role of this rock type in the landscape evolution (Thesis 3).**

The hardness of ignimbrites basically determines the attributes of drainage basins and drainage network. **Due to the more resistant welded ignimbrites, the catchment areas of rivers passing them are narrowing in the stripes of these rocks. Between two narrowed drainage basins a third catchment area formed, which northern boundary is running on the edge of welded ignimbrite cuesta (Thesis 4).** Probably the watersheds of Geszti-, Száraz-tó- and Gyilkos-creek were formed in this way Fig.2).

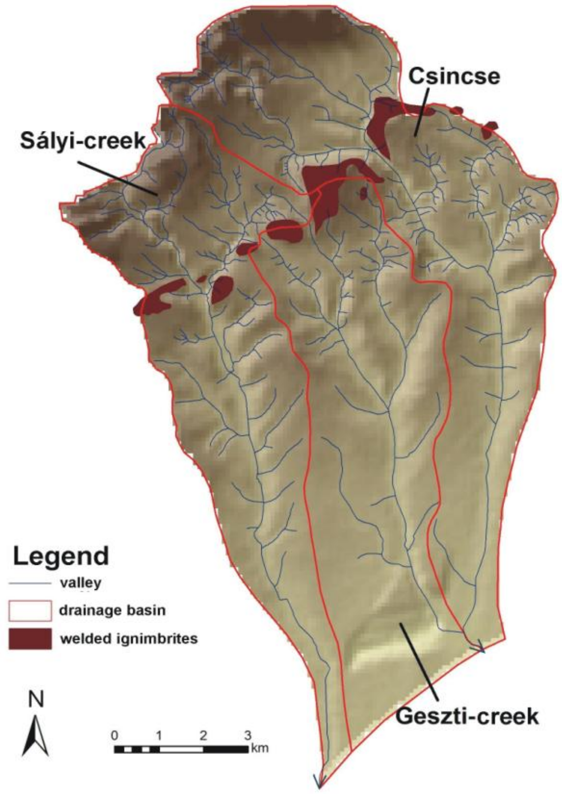

Fig.2. The drainage basin of Geszti-creek between the narrowed drainage basins of Csincse- and Sályi-creek

The shape analysis of catchment areas confirmed that the shape highly depends on the location of watersheds and the surface occurrence of welded ignimbrites. **The narrowest catchment areas pass the more resistant ignimbrite stripes, while the less narrow, round shaped ones are situated entirely south of these rocks (Thesis 5a).** The shape of 6 creeks of the Bükkalja passing the welded ignimbrites (Novaji-, Kánya-, Tardi-, Kácsi-, Sályi- and Csincse-creek) were analyzed more thoroughly. **The subwatersheds, which are passing the welded ignimbrite cuestas repeatedly, are narrower than the others, which demonstrates the effect on the drainage network (Thesis 5b).**

In the morphometric analysis of the drainage basins the relative gradient values (given in m/km), relative relief (vertical fragmentation), drainage density and the valley length were determined. The main results are the following:

- The catchment areas with the highest relative relief values are situated north of the welded ignimbrites.
- Drainage density of each watershed situated south of the welded ignimbrites is below the average.
- Watersheds with the highest average valley length are situated south of the ignimbrite stripes.

The morphometric analysis suggests that drainage basins south of the welded ignimbrites are different than the rest. Consequently, these rocks had taken decisive role in the characteristics of watersheds.

The examination of stream order (Strahler, A. M. 1957) confirmed the impact of rock quality on the drainage network. The waters coming from the north are forced to change their direction due to the ignimbrite ridges and they flow into bigger streams. Because of this confluence the stream order is increasing directly in front of these welded rock cuestas. These ridges are often dissected by short valleys and torrents, which may also contribute to the increasing stream order.

The effect of rock quality is apparent in the drainage pattern as well. On the northern part of the Bükkalja the drainage pattern is typically trellis, while on the south the parallel type is the dominant. **Streams of the Bükkalja whose catchment areas cover both the northern and the southern area are affected by the characteristics of these two different geological and geomorphologic areas. It is confirmed by the complexity of their drainage pattern. I classified the streams with trellis pattern on the north and parallel pattern on the south into a new pattern type, which is called "complex by rock quality" (Thesis 6).** The schematic figure of this new pattern was also drawn (Fig. 3).

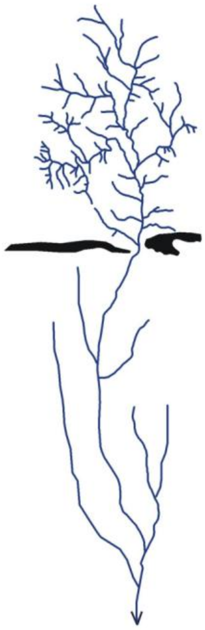

Fig.3. Schematic figure of the " complex by rock quality" pattern

According to geological maps the definite breaks in the stream profiles can be explained mainly with the position of boundaries of different rock stripes (junctions). Those creeks have the least graded, multiple broken profiles which flow across the "hardest", welded ignimbrite cuestas of Bükkalja.

The traditional stream gradient values (total and relative stream gradient) represent the whole watercourse. These values are awkward to describe the detailed conditions and changes in the steepness; therefore I tried to determine the gradient conditions by developing and applying a new method.

For the calculation of stream gradient with the modification of the stream gradient index (Hack, J.T. 1973) **a new parameter was used, which determines the ratio of the relative relief and the horizontal distance of the examined points with the following formula:**

$$\mathbf{SL_M = \frac{dH}{dL}}$$

, where dH is the change of elevation, dL is the horizontal length of the segment in kilometers ((Thesis 7).

Comparing the slope gradient data of the adjacent streams, we can determine the character of the areas between the valleys. Analyzing the spatial variation of the stream gradient data allows the recognitions of geomorphologic processes and regional characteristics in the whole area. On the basis of stream gradient values (SL_M) calculated in measuring points, a surface was interpolated by geoinformatic methods, which can be analyzed as a stream gradient map (Fig.4).

On the basis of this map **the territory of the Bükkalja can be divided into two differing parts along the Eger-creek. Most of the high gradient values can be found east of the creek, while on the western part the values are much lower. The highest values**

coincide with the occurrence of the welded ignimbrites (Thesis 8). Analyzing this map I managed to confirm, that the gradient of Kánya-creek is higher than the surroundings not only at its headwaters, but on its whole section as well, running across the Bükkalja, so its incision is higher along the whole valley compared to the surroundings. 7 km away from the headwater of the Száraz-tó-creek, an area with relatively high gradient can be observed. This shows the strong, local incision of the creek, which can be caused by the lowering of the southern foreground, or the uplift of the northern terrain (Fig. 4).

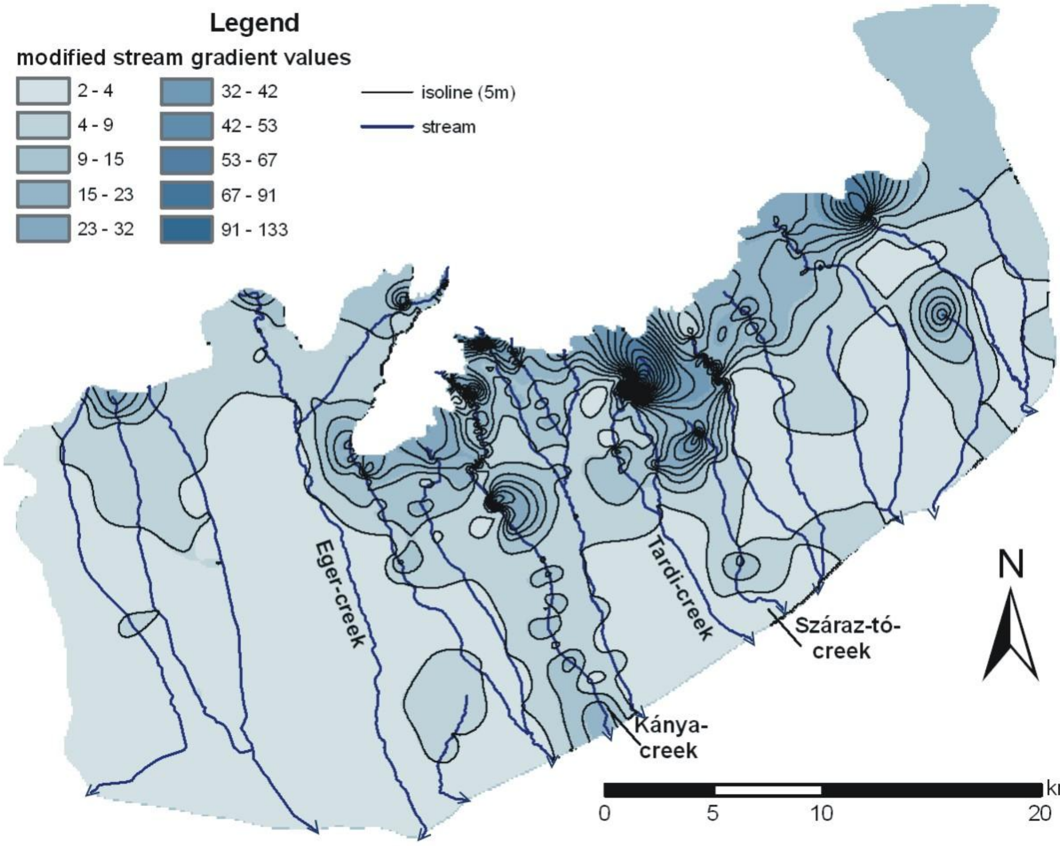

Fig.4. Stream gradient map interpolated from modified SL index (SL_M) values

The side valleys – running parallel with the main valleys – in front of the ignimbrite cuestas are forced to change their direction. These valleys turn to the east or to the west, and almost rectangularly join to the main valleys (Láng, S. 1954, Székely, A. 1997, Hevesi, A 1997a, 2002). Because of this confluence the drainage- density is very different in the Bükkalja. **According to the measured values, the drainage- and valley network of the Bükkalja – depending on the hardness and occurrence of welded ignimbrites – can be divided into two parts, which are characterized by different density values (Thesis 9).**

The direction of the pediment's streams was examined on the basis of geologic and topographic map. The flow direction of streams is determined by faults and/or rock quality. Two peaks can be identified on the streams' flow direction diagram, which are specific to different parts of the watersheds. **In the southern subwatersheds the flow direction generally coincides with the general aspect of the Bükkalja. In the northern subwatersheds the flow direction is mainly perpendicular to the general aspect, which is caused by the faults and the strike of welded ignimbrite cuestas (Thesis 10).**

In some cases, the direction of the streams is changed by the strong backward erosion of the Bükkalja's creeks, which causes stream captures (Pinczés Z. 1955, Székely A. 1958). According to my field observations – confirmed by the analysis of digital elevation model and the streams' longitudinal profiles– **the flow direction change of Csincse-creek between Kisgyőr and Mocsolyástelep; and the development of the wide, relatively low gradient valley section of Geszti-creek to the west of Meredek-hill are formed by stream captures (Thesis 11)**, (Fig. 5).

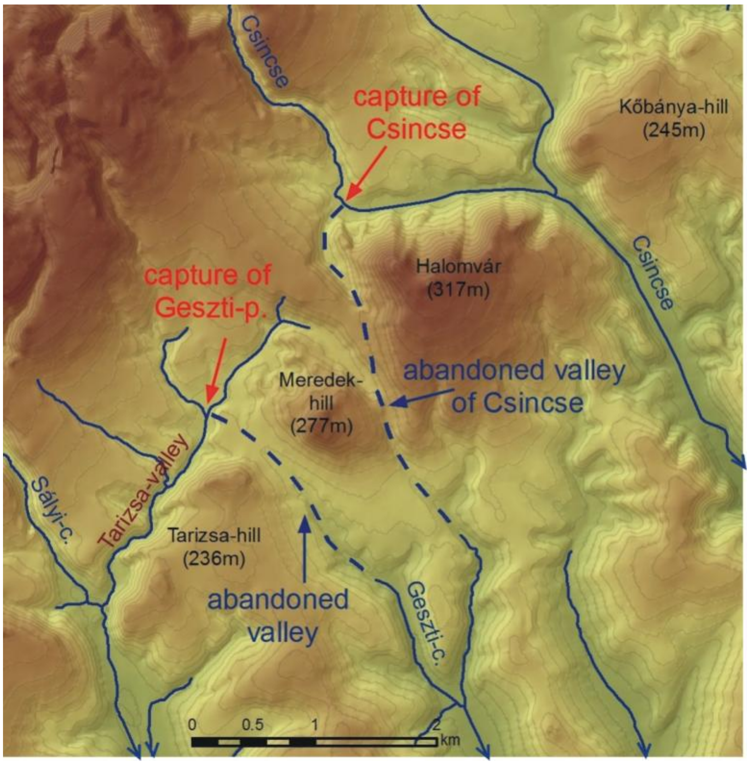

Fig.5. Stream captures of Csincse- and Geszti-creek

In the watershed of Kácsi-creek, on the northern foreground of Várhegy (325 m), numerous meanders can be found, which are probably formed by stream captures. The abandoned valley section between the Várhegy and Szentkereszt-bérc (323 m) is likely to be a stream capture as well.

The derasion valleys are also part of the Bükkalja's surface dissection system. According to my examinations, these valleys are mostly simple, not complex landforms, which are situated next to each other. Most of them are formed on Miocene tuffs.

References

DOBOS A. (2001): Az átmeneti (puffer)-zóna geológiai értékvédelemben játszott szerepének bemutatása egy bükkaljai mintaterület alapján. „A földrajz eredményei az új évezred küszöbén", A Magyar Földrajzi Konferencia tudományos eredményei, SZTE TTK Természeti Földrajzi Tanszék, Szeged.
Letöltve: *geography.hu/mfk2001/cikkek/DobosA2.pdf*

DOBOS A. (2006): Az átmeneti (puffer)-zóna geológiai értékvédelmében játszott szerepének bemutatása az Egri-Bükkalja mintaterülete alapján – OTKA beszámoló. Eszterházy Károly Főiskola, Környezettudományi Tanszék, Eger.
Letöltve: *real.mtak.hu/420/1/37967_ZJ1.pdf*

HACK, J.T. (1973): Stream-profile analysis and stream gradient index. Journ. Res. U.S. Geol. Survey, Vol.1. No 4. July-Aug. pp. 421-429.

HEVESI A. (1997a): A Bükk. In: Pannon Enciklopédia. Magyarország földje. Szerk.: Karátson D. Kertek 2000 könyvkiadó, Budapest. pp. 337-344.

HEVESI A. (2002): Felszínalaktani jellemzés, karsztformakincs. In: A Bükk hegység földrajzi helyzete, kialakulása, éghajlata. In: A Bükki Nemzeti Park. Szerk.: Baráz Cs. Bükki Nemzeti Park Igazgatóság, Eger. pp. 109-148.

LÁNG S. (1954): Hidrológiai és morfológiai megfigyelések a Bükkben. Hidrológiai Közlemények 34. pp. 70-81.

MAROSI, S. – SOMOGYI, S. (szerk.) (1990): Magyarország kistájainak katasztere. MTA Földrajztudományi Kutatóintézet, Budapest. pp. 851-860.

MARTONNÉ ERDŐS K. (1974). Areális és lineáris folyamatok egyidejűsége egy vulkáni hegylábtérségben, a Déli-Bükkben, Acta Geographica Debrecina 1973. XII. pp. 75-114.
PINCZÉS Z. (1955): Morfológiai megfigyelések a Hór völgyében. Földrajzi Értesítő IV. pp. 145-156.
STRAHLER, A. M. (1957): Quantitative analysis of watershed geomorphology. Transaction of the American Geophysical Union 38. pp. 913-920.
SZÉKELY A. (1958): A Tarna-völgy geomorfológiája. Földrajzi Értesítő. VII. 4. pp. 389-414.
SZÉKELY A. (1997): Vulkánmorfológia (tűzhányó-felszínalaktan). ELTE Eötvös Kiadó, Budapest. pp. 114-115.
WEISS, A. (2001): Topographic Position and Landforms Analysis. Poster presentation, ESRI User Conference, San Diego, CA.

Publications in the topic of dissertation

VÁGÓ JÁNOS (2003): A Bükkalja völgyhálózatának kialakulása és jellemzése, Földrajz, A Miskolci Egyetem Közleménye, A sorozat, Bányászat, 64. kötet. pp. 187-202.
VÁGÓ JÁNOS (2005): Vulkanitok szerepe a völgy- és vízhálózat kialakulásában a Bükkalján, Doktoranduszok Fóruma, Miskolci Egyetem. (szerk.: Dr. Tihanyi L.). pp. 115-120.
VÁGÓ JÁNOS (2006): The effects of miocene volcanic rocks on the surface dissection system of the Bükkalja, microCAD 2006 International Science Conference, Miskolc, pp. 147-152.
VÁGÓ JÁNOS (2006): A vulkanitok szerepe a völgyhálózat kialakulásában a Bükkalján, III. Magyar Földrajzi Konferencia, Budapest, CD-ROM kiadvány.
HEGEDŰS ANDRÁS, VÁGÓ JÁNOS (2007): The Examination of the Bükkalja using digital elevation model, microCAD 2007 International Science Conference, Miskolc, pp. 47-52.
VÁGÓ JÁNOS (2008): Szállítóközeg nélküli lejtős tömegmozgások a Bükkalja keleti részén, IV. Magyar Földrajzi Konferencia, Debrecen. pp. 99-104.
VÁGÓ JÁNOS, HEGEDŰS ANDRÁS (2008): A bükkaljai ignimbritvonulatok morfometriai vizsgálata domborzatmodell alapján, IV. Magyar Földrajzi Konferencia, Debrecen, 154.p.
HEGEDŰS ANDRÁS, VÁGÓ JÁNOS (2009): Deráziós formák vizsgálata a Bükkalján. 100 éves a jégkorszak. A jégkorszaki klímaváltozások kutatása Penck-Brücknertől napjainkig (1909-2009) Konferencia (szerk.: Fábián Szabolcs Ákos – Görcs Noémi Lívia). Pécs, 29.p.
VÁGÓ JÁNOS: Csuszamlásveszélyes domboldalak kijelölése domborzatmodell felhasználásával. HunDEM2009 Konferencia és kerekasztal Kiadványa, 2010, CD-ROM kiadvány.
VÁGÓ JÁNOS (2010): Térinformatikai módszerek alkalmazási lehetőségei vízfolyások esésviszonyainak vizsgálatában. Térinformatikai Konferencia és Szakkiállítás "Az elmélet és gyakorlat találkozása", Debrecen, 2010.június 10-11. 445.p.
VÁGÓ JÁNOS (2010): Stream Gradient investigation in the Bükkalja using interpolated surfaces. AGD Landscape and Environment 4. (editor: Szilárd Szabó), Debrecen. pp. 23-36.
VÁGÓ JÁNOS, HEGEDŰS ANDRÁS (2011): DEM based examination of pediment levels: a case study in Bükkalja. Hungarian Geographical Bulletin. Bp. Vol. 60 No. 1. pp. 24-44.