Geogr. Fis. Dinam. Quat.
21 (1998), 79-85, 7 figg.

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GEOMORPHOLOGY OF NEOGENE VOLCANIC MOUNTAINS IN HUNGARY

ABSTRACT: SZÉKELY A., *Geomorphology of Neogene volcanic mountains in Hungary.* (IT ISSN 0391-9838, 1998).

This paper summarizes the achievements of detailed field work carried out over more than 40 years, compares the results with earlier held views and presents the methods elaborated for this research. These latter are: the study comparison of landforms in relation to geological structure, lithology and bedding and a detailed analysis and interpretation of drainage patterns.

The analysis of drainage patterns provide valuable information for the reconstruction of volcanic forms, since the main lines of the original (incipient) drainage network are preserved. Drainage patterns characteristic of the various types of volcanoes are presented; the direct and indirect impacts of primary volcanic features and their governing function in denudation are demonstrated. The original forms and sequence of erosion in the Tertiary volcanic areas are outlined with regard to the extent of postvolcanic tectonic movements and their major impact on geomorphic evolution. It is on this basis that the volcanic mountains and individual paleovolcanoes in Hungary are classified.

KEY WORDS: Volcanic mountains, Neogene, Hungary.

RIASSUNTO: SZÉKELY A., *Geomorfologia dei rilievi vulcanici neogenici in Ungheria.* (IT ISSN 0391-9838, 1998).

L'articolo sintetizza i dati acquisiti dai lavori dettagliati di campagna compiuti per oltre 40 anni, mette in relazione i risultati con le più antiche vedute e presenta i metodi elaborati per questa ricerca. Questi ultimi sono: lo studio e le relazioni delle forme con la struttura geologica, la litologia e stratificazione e una dettagliata analisi e interpretazione del reticolo idrografico.

L'analisi del drenaggio offre valide informazioni per la ricostruzione delle forme vulcaniche, poiché le principali linee dell'originale (incipiente) rete idrografica si sono conservate. Sono esposte le forme dei drenaggi dei vari tipi di vulcano; gli impatti diretti e indiretti dei lineamenti vulcanici primari e la loro funzione nella denudazione. Le forme originali e la sequenza erosionale nelle aree vulcaniche terziarie vengono tracciate con riguardo ai movimenti tettonici postvulcanici e al loro impatto sull'evoluzione geomorfica. Su questa base vengono classificati i rilievi vulcanici e paleovulcanici del'Ungheria.

TERMINI CHIAVE: Rilievi vulcanici, Neogene, Ungheria.

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INTRODUCTION

Although mountains of low medium height only comprise about 20 per cent of the area of Hungary, some two-thirds of them are of Tertiary volcanic origin. Consequently, volcanological and volcano-morphological research have been prominent topics of geological and geomorphological investigations. Geologists have collected considerable information over the last hundred years and produced many maps on the structure of volcanic mountains in Hungary. The first to present a comprehensive geomorphological evaluation of all the volcanic mountains in the Carpathian region was Cholnoky (1936), whose volcano-geomorphological approach was based on the presumption that primary volcanic forms dominated all the mountins of volcanic origin. He believed that he had recognized volcanic cones, calderas and even craters, and compared them, generally very appropriately, to active volcanoes. Bulla (1962) denied the existence of such primary volcanic features: in his opinion the present volcanic mountains have been denuded to «peneplained mountains of rolling surface», and this interpretation was supported by Láng (1967) on the basis of more than 20 years of field experience that covers most mountains in Hungary.

EVIDENCE FROM DRAINAGE PATTERN

Four decades of research led the present author to the conclusion that although primary volcanic forms had been transformed into denudational forms as early as the Tertiary, they did not disappear altogether. The heavily truncated remnants of main eruption centres may still be recognize as peaks, cones or high summits and the ruins of former caldera margins rise as arcuate crests above other mountain ridges. Most of the mountains are, however, erosional forms (Härtling) or tectonic features (horst) or combinations of two (erosional horsts). Moreover, remnants of former lava flows may still be observed in several places, while subvolcanic forms have been exposed as the result of intense denudation. Consequently, landforms must be analyzed in combination with geological structure, lithology and bedding, as cones of similar shape may prove to be a truncated eruption centre, an erosion cone or an exhumed laccolith (Székely, 1964, 1983, 1993).

The direct impact of primary volcanic landforms on present features is much more significant than the existence of volcanic remnants, since they may control denudation. Thus major eruption centres, although in a heavily eroded form, may rise conspicuously above surfaces of denudation. In the first place, drainage lines followed primary volcanic slopes (consequent streams), but, subsequently, on the lower-lying surfaces between the main eruption centres (in the intercolline basins and cols) drainage patterns corresponding to the shape and slope conditions of these surfaces evolved. It has to be emphasized that in our research the detailed and comprehensive evidence yielded by the drainage pattern is of utmost importance. While areas of high relief underwent denudation and lost their original shape as the valleys cut deeper and broadened out, new systems of tributary valleys also developed. The original drainage pattern, however, has survived in its major lines, although the evidence for this is indirect.

The drainage pattern in itself is a source of valuable information for the reconstruction of the original volcanic landforms, since it preserves the main lines of the initial drainage network (Székely 1983, 1992). Major eruption centres are generally marked by a radial pattern; the inner slopes of calderas have dendritic or centripetal patterns, while their outer slopes exhibit radial patterns (fig. 1). Lava and pyroclastic terrain of ridges and foothills is dissected by parallel valleys, the foot-slopes of cones, parasitic cones and near-surface subvolcanic features such as laccoliths are typified by annular drainage, while arcuate valleys are observed on the sides of cones or domes. Reflecting the diversity of original volcanic forms, such patterns may also appear in combination as in the case of a slope with small parasitic cones, where parallel and arcuate drainage patterns may be combined. Thus, original volcanic forms are reflected in the relief, especially in drainage patterns, or million of years after their original forms have been destroyed.

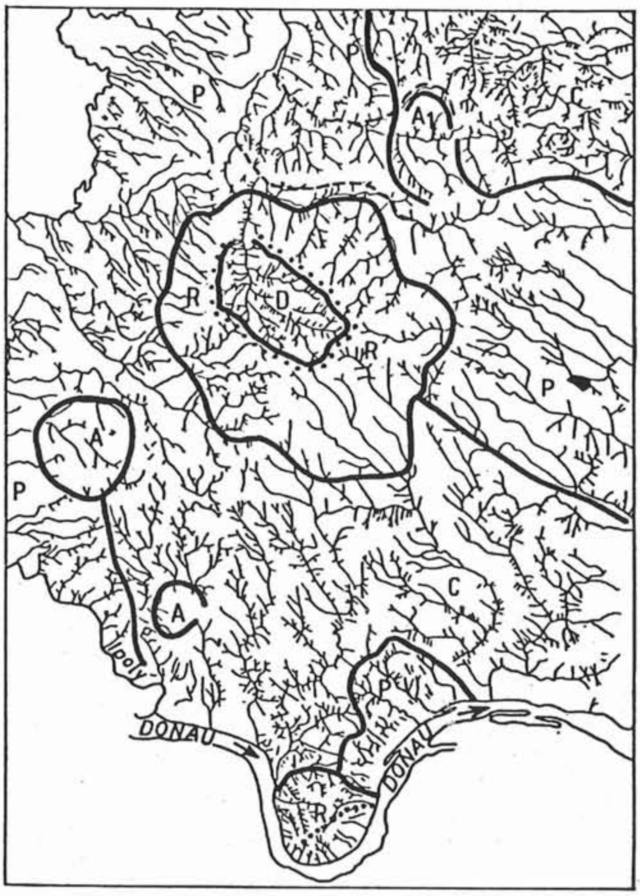

FIG. 1 - Drainage patterns in the Börzsöny Mountains from aerial survey (by Czakó, interpreted by Székely). 1) boundaries of drainage pattern types with genetic interpretation; 2) remnants of the inner caldera margin; 3) remnants of the assumed outer caldera; D) dendritic drainage with relict caldera; R) radial drainage; R1) on oute slopes of caldera; P) parallel consequent drainage; A) annular drainage; A1) distorted annular drainage on margin of former parasitic cone (eruption centre); C) parallel and distorted arcuate drainage combined.

TECTONIC INFLUENCES AND DENUDATION HISTORY

Volcanism, however, is always accompanied by synvolcanic or postvolcanic tectonic movements, which modify the entire topography. Also in Hungary postvolcanic tectonic movements have played a decisive and governing role in the evolution of volcanic mountains. Vertical displacement in excess of 2000 m have occurred since the decline of volcanic activity in the Upper Miocene. Firstly, the volcanoes of the Intra-Carpathian basin had subsided even before the cessation of volcanism either abruptly due to the collapse of the emptied magma chamber (Szádeczky-Kardoss, & *alii*, 1959) or gradually through the compaction of the underlying sediments (Kubovics, Pantó, 1970). (The first hypothesis is contradicted by some borehole evidence [Baksa & *alii*, 1977] and by geophysical data). Moreover, the lower parts of the volcanoes were protected from erosion by the inundation of the Upper Badenian sea, and surfaces of lesser elevation are still protected by a Badenian sediment cover (locally still 300 to 450 m thick).

Under these circumstances, denudation of the volcanoes only started subsequent to the gradual uplift and parallel marine regressions during the Upper Sarmatian and Pannonian periods. In other words, the volcanic mountains of Hungary are much younger than the Mesozoic block mountains, and have been eroded for much shorter period of time and through much less intense processes. As a result, conditions did not favour the formation of such extensive planation surfaces in the volcanic mountains as in the block mountains, and only marginal and piedmont surfaces of varying width could evolve. The systems of sediments is best developed in the volcanic mountains (Pinczés, 1978; Székely, 1969, 1978; Pécsi, 1965, 1970, 1996), since the original surface and lithology (thin-bedded composite volcanoes) were most favourable for rapid sculpturing. During the millions of years of denudation even the highest volcanic centres have been heavily eroded and, mostly since the Upper Pliocene, dissected without planation. As a result, the volcanic forms have not been entirely obliterated.

STAGES OF VOLCANIC ACTIVITY

There were three major stages of volcanic activity in what is now Hungary during the Tertiary:

1. The first period was one of small-scale initial volcanism during the Early Eocene (41-37 Ma BP) (all the following dates are based on K/Ar dating). As a volcanic arc on a plate margin, the resulting andesite mountains have been heavily eroded and volcanism survives only as subsidiary traces.
2. The main period of volcanic activity is placed in the Middle Miocene (19-12 Ma BP) (ca 95 per cent of eruptions determining the present forms are between 16-14 Ma BP), when the Intra-Carpathian volcanic range was produced. The North Hungarian Mountains date from this period stretching more than 200 km from the Visegrád Mountains to the Tokaj (Zemplén) Mountains. In the Bükkalja and particularly in the Tokaj Mountains intense volcanic activity continued into the Upper Miocene and, as a consequence, more original volcanic forms have been preserved in this areas. Most of the material produced during this main stage (ca 80 per cent in the Middle Miocene) was andesite and associated pyroclastics, with some acidic rhyolites, rhyolitic tuffs and dacite.
3. The final stage of basaltic volcanism is dated to the Late Pliocene (mainly 4-2 Ma BP) and the Early Pleistocene (1.8-1 Ma BP). It was again of lesser intensity and produced basaltic mantles and cones only in Transdanubia (since 7.5 Ma BP) to the west of the Bakony Mountains and south of the Little Plain (generally 4-1 Ma BP) and around Salgótarján (2-1 Ma BP). Compared to andesite mountains these are only subsidiary elements.

TYPES OF ANDESITE VOLCANIC MOUNTAINS IN HUNGARY

In the Intra-Carpathian volcanic range relief types are controlled by original volcanic forms, postvolcanic tectonic movements and the denudation processes governed by them. The original forms could only survive the millions of years of erosion in heavily remodelled and truncated forms. Nevertheless, in the central zone, the indirect influences of primary volcanic forms are demonstrated in the following types (fig. 2):

I - *Remnants of volcanic mountains* are in various stages of remodelling, depending on their age, altitude, position, lithology and original forms (Székely, 1983, 1993).

1. Relict volcanoes (paleovolcanoes) with double caldera are exemplified by the Dunazug relict volcano (the Visegrád Mountains). The older volcanic cone is ca 15 km in diameter, with a collapsed centre probably due to a heavy explosion. In the resulting caldera (9.3 km) another explosive cone, the Keserühegy paleovolcano, ca 6 km in diameter was built up (Balla, 1978) on which another caldera was formed by a smaller explosion (fig. 3). Arcuate ridges, with steep inward and gentler outward slopes, attest to the margins of both calderas. The inner sides of the relict calderas are marked by arcuate annular drainage patterns of asymmetric valleys, while the outer slopes are marked, by centripetal drainage and the western foot by an arcuate valley (Gábris, 1983-84) (fig. 3). These relict composite volcanoes are mostly built up of andesite agglomerate with embedded volcanic bombs which increase in di-

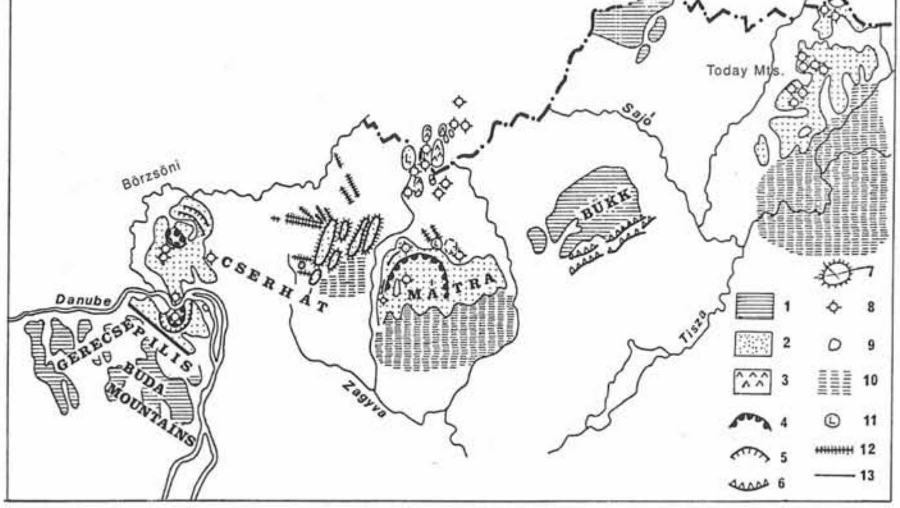

FIG. 2 - Tectonic morphological types of volcanic members of the North Hungarian Range (by Székely). 1) Mesozoic mountains of horst series; 2) Miocene volcanics (mostly andesite agglomerate and tuff; subordinately rhyolite and rhyolitic tuff) exposed; 3) Upper Pliocene basalt; 4) remnants of inner caldera margin; 5) assumed relict outer caldera margin; 6) rhyolitic and dacite tuff remnants; 7) horst series of volcanic material; 8) volcanic cone remnants; 9) vent remnants; 10) buried volcanic features; 11) laccolith; 12) dyke; 13) main lineament between Mesozoic rocks and Miocene volcanics.

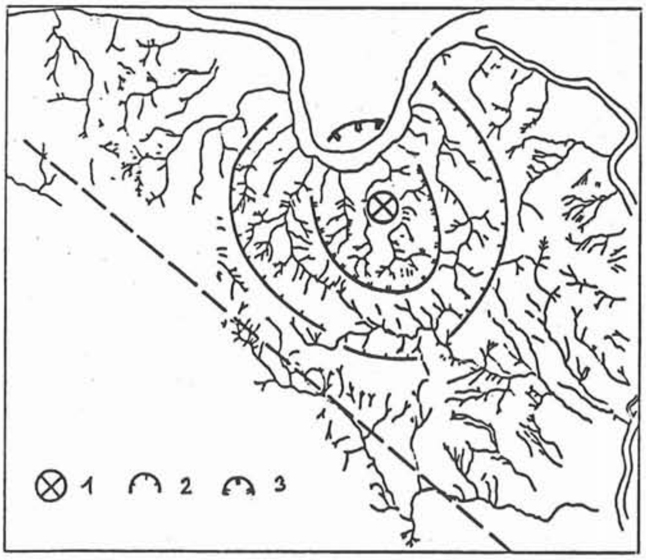

FIG. 3 - Drainage pattern of the Dunazug Mountains from aerial survey (by Gábris). 1) assumed eruption centre in inner caldera; 2) inner caldera margin; 3) outer caldera margin (arcuate drainage on the inner slope, radial on the outer and arcuate to W); 4) main lineament; boundaries of Mesozoic sediments and Middle Miocene volcanics.

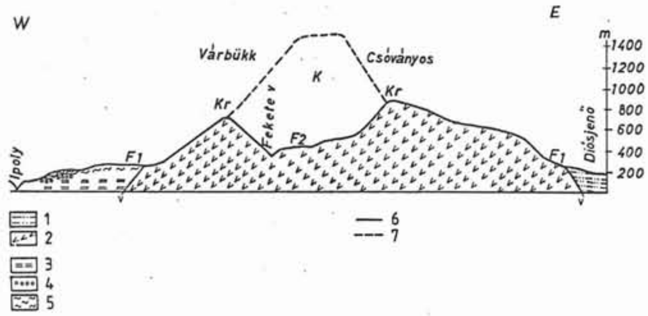

FIG. 4 - W to E profile across the Börzsöny Mountains. 1) Carpathian schlier, 2) Lower Badenian andesite (stratovolcano series); 3) Pannonian sand and clay; 4) Pleistocene terrace gravel; 5) loess-like slope deposit; 6) fault; 7) paleovolcano recostruction (based on data by Balla); K) caldera; Kr) caldera margin; F) pediment: F_1) on outer caldera margin; F_2) within caldera.

ameter from the margins (some tens of cm) to the centre (8-10 m) and also with depth in the andesite series (from 200 to 100 m). Heavy hydrothermal weathering is observed in the inner caldera.

The northern margin of the caldera was separated by the Danube bend at Dömös and, thus, topographically now belongs to the Börzsöny Mountains. The Danube gorge at Visegrád is both antecedent (Pécsi, 1959) and superimposed. The Danube initially followed a sinuous course on an Upper Badenian Leitha limestone surface, but following the post-Pannonian uplift of the mountains, cut down through this surface onto the buried composite volcano beneath, where the Leitha Limestone has been preserved up to 400 m altitude.

2. Denuded volcanoes with central caldera are represented by the Börzsöny Mountains. The central Börzsöny is dominated by the remnants of a single composite volcano of 12-14 km diameter and ca 1200 m original height (Börzsöny Paleovolcano, Balla, 1978). An erosional caldera of ca 4 km diameter has evolved in the centre through erosional widening of the one-time explosion caldera, while the volcanic cone has been heavily eroded and tilted to the west-northwest. A remarkable asymmetry (fig. 4) characterizes the whole mountain range today, with steep eastern and gentler western slopes. Unambiguous geological evidence for this asymmetry is to be seen in the position of the volcanic cover layers (Upper Badenian) at 300 m altitude on the western side, while at the same altitude base layers (Carpathian) occur in the east. The asymmetry is also obvious in the pediments, which are better developed, longer and gentler in the upper segments to the west to the east. Pediments also occur within the caldera, although here they are dissected by deep valleys owing to their higher altitude.

The caldera form is much better preserved than in the Dunazug paleovolcano, with more discernibile margins that almost form a full circle. Regular dendritic drainage is seen within the caldera, while the outer slopes are typified by a radial drainage pattern with parallel valleys on the western side (Czakó & Nagy, 1974). At the base of the composite volcano towards the north and northeast runs the sickle-shaped Kemence-patak valley. Beyond it, however, the two ranges of the North Börzsöny are relict sommas of two subsequent older paleovolcanoes (Balla, 1977).

In summary, the Börzsöny Mountains were built up during three consecutive volcanic phases in a relatively short period of the Lower Badenian, since they were subsequently overlain by Lower Badenian marine sediments. Each phase saw the production of a new caldera within the previously existing one which are therefore of ever decreasing dimensions in extension and height. Younger volcanic activity destroyed most of the older forms; and the relief is presently dominated by the heavily eroded ruins of the youngest volcano.

3. Relict composite volcano with a semicircular caldera (as in the Western and Central Mátra Mountains). In contrast to the Börzsöny, volcanism in the Mátra lasted with some interruptions for millions of years (Carpathian, 18 Ma BP and late Lower Badenian, 15 Ma BP). There were three distintc volcanic stages of andesite-rhyolite production and an additional fourth and final stage of more alkaline basaltic andesite volcanism (Baksa & *alii*, 1977). In the Lower Badenian a composite volcano of ca 30 km diameter and 3000 m altitude was built up over a relict, mostly submarine Carpathian volcano. Today in the Western Mátra this Lower Badenian volcanic ruin is predominant.

In all probability also through explosion and subsequent collapses, a large caldera-like depression of ca 16 km diameter formed in this volcanic cone and this was followed by minor acidic volcanism with the production of rhyolites and rhyolitic tuffs and intense hydrothermal activity. As a result, the rocks of the caldera were largely decomposed and promoted erosional remodelling. There then followed the final stage of basaltic andesite volcanism which overwhelmed with its deep lava covering and preserving previous volcanics in many places. Subsided together with the Great Hungarian Plain, the southern part of the caldera, and is buried under 400 to 700 m of Pannonian deposits at present. At the same time, the northem part had undergone gradual uplift together with the Carpathians and intensified erosional activity exposed subvolcanic laccoliths and dykes along the northern margin. Asymmetry is strongest in the Mátra because of the uplift to the north and subsidence to the south (Székely 1964, 1969, 1978, 1989 (fig. 5). To the north strata underlyin the volcanics are located several hundred metres higher (Carpathian schlier at 400-500 m) than the strata overlyin the volcanics to the south (Upper Badenian, Sarmatian and Pannonian at 200-250 m). Consequently, steep slopes clearly expose the composite volcano structure, while the southern slopes are long gentle (as in the Börzsöny along an eastern to western section).

Planated surfaces also show a striking asymmetry, particularly the best developed, young (Upper Pliocene-Pleistocene) pediments (Székely, 1964, 1969, 1978, 1993), which generally extend over several kilometres, although along the northern foot of the steep slopes of the composite volcano gentle glacis d'erosion could form. Here, pediments extend far into the caldera too. The drainage pattern provides major evidence as to the original volcanic structure (fig. 6). Within the half-caldera the dendritic drainage is asymmetrical and extends more to the west than to the east. On the outer caldera margin radial drainage form a semicircle to the west and north, towards the Zagyva river.

4. In contrast to the above described denuded but still recognizable calderas, relict calderas do not present the characteristic caldera form. They are found at Recsk, Mátralába (northern foothills of Mátra), in the remains of

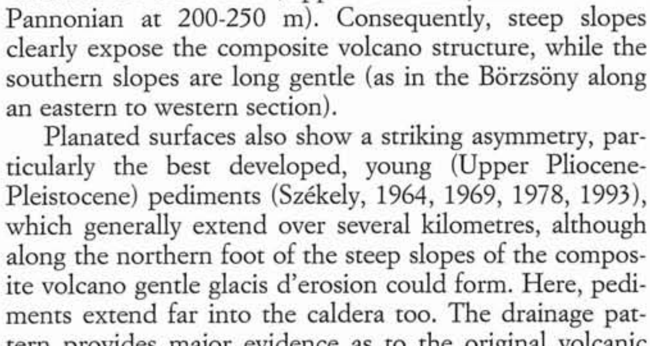

FIG. 5 - General profile across the Mátra Mountains (by Székely). 1) Middle Miocene schlier, 2) Upper Oligocene schlier, 3) Upper Oligocene resistant sandstone; 4) Upper Oligocene loose sandstone; 5) Lower Miocene variegated clay, loose sandstone, Lower Rhyolite Tuff, brown coal seams; 6) Carpathian schlier, 7) subvolcanic features exposed (dykes, laccoliths) or remains of older Miocene lava flows; 8) Lower Andesite Series (Uppermost Carpathian); 9) Middle Rhyolite Tuff; 10) Badenian volcanics (andesite, andesite agglomerate and tuff); 11) Upper Pannonian sand and clay; 12) Pleistocene alluvial fan, talus and slope deposits; 13) faultline. P) pediment; L) laccolith; M) Lower Miocene lava flow remains; O) Upper Kattien sandstone escarpment; B) erosion basins on the Mátralába.

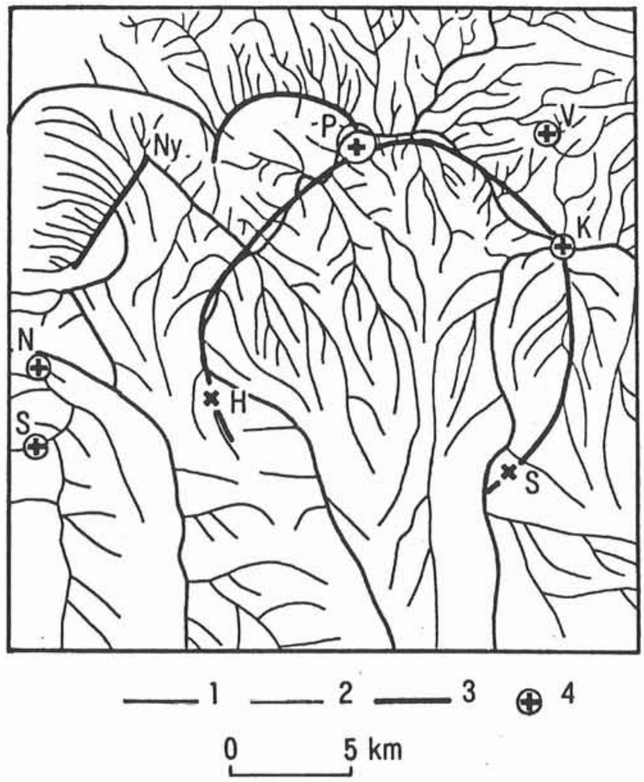

FIG. 6 - Catchmentes of the Mátra Mountains (by Gábris, from aerial and space survey). 1) main divide; 2) divide; 3) volcanic (tectonic) structures; 4) dome. K) Kékes; V) Várhegy; P) Piszkés-tetö; T) Tóthegyes; H) Havas-tetö; Ny) Nykom-tetö; N) Nagy-Hársas; S) Somlyó.

the Upper Eocene volcanics and have been reconstructed from a dense network of borehole information (Földessy, 1980).

5. The centrolabial composite volcano system of the Tokaj (Zemplén) Mountains. Here the heavily truncated remnants of volcanic cones are aligned along rift systems, and more original forms are generally preserved than in other areas, since volcanic activity lasted longer, from the Badenian into the Late Miocene, to Early Pannonian (17-12 Ma BP). The oldest segments to the northeast have been most heavily eroded. Recent research indicates submarine volcanism initially. To the south in the younger (Upper Miocene) volcanics, more original forms; primary eruption centres, remnants of composite volcano cones and lava flows, are preserved. Volcanic activity finished by a basalt flow on the eastern side (9 Ma BP).

Volcanic rocks are also found in great variety. While in other areas acidic lavas are only subsidiary elements, here mainly rhyolite and locally dacites and associated tuffs are principal rock types. In addition, postvolcanic activity and ore mineralization were most prolonged here with important geomorphological implications. Geomorphological inversions are also characteristic, where lava flows, resistant to erosion that filled former valleys now stand out a ridges, while limnoquartzites deposited in depressions form flat top rises. As a result of prolonged volcanic and postvolcanic activity, the greatest diversity and best preservation of original and remodelled volcanic forms are found in the Tokaj Mountains. In contrast to uniform giant composite volcanoes, in the Tokaj Mountains there was no dominant central volcano, but rather a row of volcanoes of various size (centrolabial type), distinct in the generally radial or centrifugal drainange pattern.

The mountains are tilted slightly to the east; this asymmetry, however is much less striking than in the Mátra and the Börzsöny. Pediments are best developed on the gentler eastern side and extend further into the mountains (Pinczés, 1978). The individual volcanoes or volcano groups are separated by broad basins with wide, extensive pediments. The western, eastern and southern margins of the mountains are marked by major fault systems and the volcanics extend further beneath several hundreds of metres of Pannonian-Quaternary deposits.

6. Volcanic horst series of the East Cserhát Mountains. Originally the western margin of the vast West Mátra composite volcano, was isolated by the subsidence of the Zagyva graben after the Upper Badenian and simultaneously the volcanic Cserhát itself was dismembered. The Upper Badenian transgression affected the whole volcanic Cserhát and most of it was also inundated by the Sarmatian sea. During the most recent uplift from the Pliocene on four mountain zones were further elevated by north-northeastern to south-southwestern faults. Today these surfaces form a series of asymmetric horsts partly or totally stripped of their postvolcanic sedimentary mantles to form buried, semiexhumed, exhumed or residual surfaces. The three separating grabens have preserved the postvolcanic sequence in their basins, in which splendid examples of Upper Pliocene–Pleistocene pediments occur and determine the character of the relief.

The western margin of the Ancient Mátra was further shaped by postvolcanic tectonic movements resulting in the present horst-graben structure which is broadly similar to that of the Mesozoic horst series in the Transdanubian Mountains (e.g. the Gerecse and Buda Mountains). Only the volcanic rocks are preserved and here the drainage pattern does not indicate primary volcanic forms, but is adjusted completely to the postvolcanic structures. The water-courses follow the graben basins and occasionally with mostly rectangular changes of direction, break through the series of horsts (rectilinear drainage).

II - *Remnants of volcanic mantles* are composed of flat, structurally preformed surfaces in vaious stages of denudation and dissection depending primarily on their age, relative height and resistance.

7. The relict lava mantle of the East Mátra. Its more extensive southern portion has subsided together with the Great Plain basin and has been buried under several hundred metres of Upper Miocene and Pannonian deposits. The whole volcanic body was tilted to the south and has produced a striking asymmetry of relief, drainage and planated surface. A regular parallel, consequent and asymmetric drainage has emerged with short and steeply sloping valleys towards the south, adjusted to the relief of the lava mantle. With the subsidence of the Great Plain foreground the mantle was dissected into parallel deep valleys and interfluvial ridges (relict volcanic mantle), but the correspondence between strata of both sides of valleys can be established easily. The ridges are of a thick andesite cover which controls relief forms and presents itself as a dissected planated (slightly truncated) structural surface.

8. Remnants of lava mantles. The young (Upper Pliocene) basalt lava mantles have not yet been dissected and the flat plateaus preserve the original structural form of the lava mantle. Only the margins have retreated, but here are not yet lowered nor have they been dissected. The most beautiful and largest is the Medves (13 km^2) along the northern border of Hungary (original extension: 16-18 km^2). Basalt thickness ranges from 10 m to 100 m, depending on the relief of the underlying material.

9. The relict tuff mantle (dissected tuff mantle) of rhyolite and dacite tuff scarps of the Bükkalja. During the major volcanic stage of the Middle Miocene the Bükkalja was buried under more than 10 m rhyolite and dacite tuffs associated with a fissure of eruption located to the south under the Great Plain. The highly variable resistance of the tuffs to erosion is decidive in the landscape. Thus, during subsequent denudation the two most resistant ignimbrite layers were eroded into a marked double scarp preserving the loose tuff lying below (fig. 7). The forms of the tuff mantle in the Bükkalja are primarily determined by these two parallel scarps. With the Late Pliocene subsidence of the Great Plain the tuff mantle was tilted to the south and was dissected into ridges and broad parallel valleys, by streams running from the Bükk Mountains giving the main valleys a parallel alignment, while the tributary valleys were preformed by the scarps. The rather regular dendritic drainage pattern conforms to structure.

MORPHOLOGICAL TYPES OF VOLCANOES

The observation of various active and inactive volcanoes of the Earth allowes the conclusion that volcanoes develop through repeated geomorphological inversions and their denudation equally follows a series of inversions. This statement was proved on the 12-19 Ma old volcanic mountains of Hungary (Székely, 1995).

On this basis volcanoes can be referred by their present-day state into six morphological types:

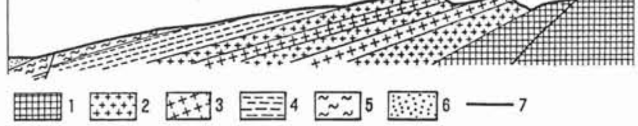

FIG. 7 - General S to N profile of Bükk foothills south-tilted tuff mantle. 1) Triassic basement; 2) Miocene rhyolite and dacite tuffs; 3) ignimbrite; 4) Pannonian clay and sand; 5) Pleistocene deposits; 6) Holocene deposits; 7) faults.

1. intact volcanoes: original shape is preserved (primary forms);
2. truncated volcanoes: attacked by erosion agents, partly resculptured, but the original volcanic forms are still characteristic (secondary forms);
3. volcanic ruins (tertiary forms): original volcanic forms substantially remolled, surface dissected by deep valleys, but still recognisable and they control the present topography (Börzsöny, Tokaj Mountains);
4. relict volcanoes (quaternary forms): original volcanic landforms discernible primarily by geophysical and geological methods; rahter obscure and uncertain indirect impact on present-day topography (Visegrád and Mátra Mountains);
5. volcanic remnants (fifth-grade forms): destroyed by denudation and postvolcanic tectonic movements; only their material is volcanic, the forms are tectonic (horsts and grabens) and erosional (East-Cserhát Mountains);
6. volcanic stumps (sixth-grade forms): most surface volcanic features removed by erosion; subvolcanic features (laccoliths, dykes etc.) exposed over long periods of denudation and control topography (North Cserhát Mountains).

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