LANDFORM EVOLUTION STUDIES IN HUNGARY

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LANDFORM EVOLUTION STUDIES IN HUNGARY

STUDIES IN GEOGRAPHY IN HUNGARY, 30

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LANDFORM EVOLUTION STUDIES IN HUNGARY

Dedicated
to the 150th anniversary
of the Hungarian Geological Society
and
to the 125th anniversary
of the Hungarian Geographical Society

Edited by

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PREFACE

Several circumstances have stimulated the publication of the present summary of the main achievements in the sphere of geomorphological and geogenetic research in Hungary. The Hungarian Geological Society was founded 150 years ago, and the Hungarian Geographical Society celebrated its 125th anniversary in 1997. Both associations held jubilee sessions presenting the results of studies aimed at completing our knowledge on the endowments and values of the Hungarian land. The International Association of Geomorphologists (IAG) has recently issued a monograph (The Evolution of Geomorphology, 1995) offering an outline of relief evolution and of the history of geomorphological research by countries. The present volume is a product of the efforts by the authors of the Hungarian chapter of the above monograph[1] produced in collaboration with geologists involved in geomorphological studies and supported by the Section of Earth Sciences of the Hungarian Academy of Sciences.

Starting with this venture the collective of authors was aware of a relative decline in the sphere of earth sciences (similar to other scholarly disciplines) for the past decade, including the studies in geomorphology of Hungary. There is a not very promising perspective that the dramatically shrinking group of experts would not be able to cope with the evaluation and use of the huge amount of information and research achievements accumulated starting with the second half of the 19th century and proceeding particularly intensely over the couple of decades from the 1960s through the 1980s when interdisciplinary teams showed eager activity. This analysis would be indispensable for a general development of earth sciences and professional education and also for the promotion of the national economy and maintaining the balance of geographical environment.

There are specialists who advise us not to deal with the past and claiming that the most urgent task is to build plans for the future. Taking into consideration the basic principles of our subject now we are looking forward for the future keeping in mind the past geomorphic events and endowments as they were analysed, as-

[1] Pécsi–Lóczy–Marosi–Somogyi–Gábris–Mezősi–Szabó 1993. Geomorphology in Hungary. – In: Walker, H. J.–Grabau, W. E. (eds): *The Evolution of Geomorphology*. Chichester, New York, Wiley pp. 189–199

sessed and evaluated for utilisation purposes by the predecessors and the present generation of researchers. Studies on the Hungarian land and on the history of its evolution contribute to the enrichment of our knowledge through the achievements of successive generations.

In none of the branches of geography or geology could the actual situation (e.g. the state of the environment) evaluated or proposals for the future be made without performing a retrospective analysis. To maintain a balance in our closer geological environment and prevention of its deterioration a knowledge of its history and of the past changes in any of the components of the geographical environment is indispensable.

Comprehensive studies of the geographical environment have come to the fore for several practical purposes and projects and their implementation stands on solid bases only when they are supported by the knowledge of research methods, scientific theories and achievements of the forerunners, let them be accepted or debated.

Concerning the debated results and concepts of the surface and environment formation it can be decided with time if they are valid or of high probability as it will be demonstrated in our book. The conflicting ideas might be instrumental in shaping new approaches.

Time after time it turns out that our knowledge of certain landforms, processes forming relief, frequency and duration of the global conditions and of other effects are far from being complete or fully substantiated. Although the wealth of our knowledge is increasing permanently and is growing more sophisticated, there still is a lack of information on the past and actual changes of the geographical and geological environment. For instance, in the early 20th century it was thought that prior to the Holocene there was an ice age of longer duration and the processes involved were instrumental in shaping the present-day topography. In the middle of the century four stages of glaciation and a similar number of warming up were assumed to have occurred. This concept became dominant both in education and research. Today it seems much more colder and milder phases should be taken into account but an unambiguous concept with a clear statement of the number of glacials and interglacials, leaving behind surface forms and sediments, is still missing. At present no clear answer can be given to the question, how many glacial stages occurred during the Pleistocene.

Such and similar debated issues arise quite often, though more and more effective methods and procedures are being involved in research. One of the most hypothetic elements in the earth sciences is the dating of landforms, of rocks and unconsolidated deposits. As far as the absolute chronological dating is concerned there are considerable discrepancies between the results (ages) depending on the research concepts and methods applied. These methods, when checked by other procedures, however, in most of the cases provide necessary information.

One of the basic objectives of the present publication is the presentation of major approaches to the problems, of the working hypotheses and results of research and drawing attraction to the achievements facilitating further solution of professional issues. We did not attempt to judge about the validity of any concept described below. It should be emphasised that the achievements of both the geomorphological and morphotectonic research and their variability largely depended on the contemporaneous approaches and practical necessities not speaking about financial support.

There is a lot to be said about the importance of the awareness of research achievements but owing to the abundance of information it is often difficult to keep up with the actual results. In our case completeness could not be reached even concerning the references of the volume. At any rate an effort was made to outline working hypotheses and results achieved by our predecessors and contemporaries – especially within the topic of landform and environmental evolution – through selected examples and research trends, sometimes from the aspect of future investigations.

It should be emphasised that the results achieved both in geomorphology and morphotectonics and their variability have always been influenced by the contemporary research concepts and requirements and, not to a lesser extent, by the financial support provided.

– Landform evolution in Hungary resulted in a closed mountain frame and a basin divided by two mountain ranges. The basin fill is unconsolidated Neogene molasse with a depth of 1000–5000 m. That is why the knowledge of the basement and its structure accumulated during one hundred years' research, primarily based on the analysis and evaluation of tens of thousand artesian wells and deep boreholes drilled in the course of water and hydrocarbon exploration and on the application of new geogenetical concepts. Through the interpretation of both the relief of the Hungarian basin and of the dividing mountains of northeast–southwest striking Hungarian experts of geosciences achieved international reputation, these geogenetical explanations can be regarded exemplary for the study of similar geological geomorphological structures.

– Investigations into the landforms, the basement of the basin and mountain structures have been accompanied and completed by novel mapping methods (engineering geological and geomorphological maps and environmental typological maps).

– As far as the identification of landforms and mountain structure and the judgement about the age of relief and the role and time of the successive processes are concerned, an important part was played by stratigraphical, paleontological (paleobotanical and paleozoological), paleopedological, geophysical (seismic, paleomagnetic, K/A, radiocarbon and other radiometric analyses) and last but not least geochemical investigations. In the future a special volume should be devoted to the above disciplines through the contribution of experts active in various fields of geosciences.

– An attempt was made to compile a list of references including the most essential and relevant publications, still it is far from being complete. In this *bibliography* there were referred the enduring results, comprehensive regional studies and monographs based on detailed sources.

– One of the basic aims of the present publication was the presentation of the activities of the most prominent and productive forerunners promoting the emergence, and the subsequent one hundred years of progress leading to a 'golden age' of the subjects of geology and geography. This should be not a mere outline of their academic career but is intended to include their contribution to the knowledge of the country from the viewpoint of geosciences. There is a hope that experts missing from our volume are to be commemorated in other publications of earth sciences in English.

– Thanks are due to the authors, editors, translators and the technical staff, i.e. the team, without the joint efforts of which this volume could not be published. The printing was made possible basically through the financial support from the publication budget of the Section of Earth Sciences of the Hungarian Academy of Sciences. Further supporters were the Research Centre for Earth Sciences of the Hungarian Academy of Sciences and the Hungarian State Geological Institute and departments of geography of Hungarian universities which is highly appreciated.

We do hope that our efforts will be proved fruitful in a sense that the ideas, concepts, activities and scientific achievements of the predecessors and contemporaries be presented, evaluated and interpreted in a correct way to help the work of the forthcoming generations of geoscientists.

In the present publication an essence of the achievements in the morphogenetic research going back to the past one and a half century can be presented for the present and future generations of experts. A more complete collection of results is contained in books, series of publications, journals, map series and atlases. Since these publications represent a richness of results, we attempted to draw the attention to the series with the attachment of their photos.

Geomorphology belongs to subjects labelled as *regional and national sciences.* Indeed investigations into a manifold endowments of the Hungarian land which should be exploited for the welfare of the nation is the responsibility of the domestic science. The productivity of its representatives has always depended on the support and adaptivity of the Hungarian society. On the other hand patriotism gave enormous power and energy to scientists having taken the task of comprehensive elaboration of the Hungarian land from physical geographical (HUNFALVY, LÓCZY, PRINZ, CHOLNOKY, BULLA) or geological (TELEGDI ROTH, VADÁSZ, FÜLÖP) aspects. Along with the predecessors who were active in Hungary, a special reference must be made to two geologists, who lived most of their lives outside Hungary and devoted their creative energy to monographic publications dealing with the geology of the country: LÁSZLÓ TRUNKÓ (1969; in German and 1997; in English) and of the Carpathian region: GÁBOR FÖLDVÁRY (1988; in English). Those who have ever read physical geography or geology of Hungary, written even in a popular manner, have an idea of the amount of experience needed for the preparation of scientific synthesis on the homeland.

Márton Pécsi

INTRODUCTION

BACKGROUND OF THE HUNGARIAN GEOMORPHOLOGY

The forerunners of Hungarian geomorphology were two grammar school teachers, KATONA, M. (1764–1822) and VARGA, M. (1766–1818). Their schoolbook (1809) borrowed the concept of erosion and introduced physical geographical and geomorphological terms into the Hungarian language *(Photos 1a, b).* It was KATONA who first suggested that the geomorphological position of land masses and oceans could have been influenced by internal magmatic currents (KATONA 1824).

From the beginning Hungarian geomorphology has been associated with physical geography and maintained close links with Central European geomorphology (PETERS 1862; SUESS 1875; UHLIG 1903; KOBER 1923). Books on this subject reached Hungary very rapidly and were incorporated into teaching materials *(Photo 1c).* Conforming to the country's political and cultural orientation, at the time when geomorphology as an academic discipline was born at the end of the last century the German, French and North American schools of thinking were of particularly great influence on its development.

Hungarian geomorphology has traditionally and basically focused on the study of geomorphic evolution and it is also valid to the discipline of today but new applied trends are being developed.

Before World War II geomorphological research concentrated in universities and mainly served the purposes of geology and geography teaching. In Hungary the university professors of physical geography have ever been and still are primarily geomorphologists. In addition, in the Geological Institute – beginning with LÓCZY – there have always been geologists who investigated and explained geomorphic evolution of the landscape *(Photos 2a, b).* Particularly in the explanation of relief evolution in the Carpathian Basin, Hungarian geomorphology has relied on the results of geological research (SZABÓ 1858; KOCH 1872; BÖCKH 1873; SCHAFARZIK 1903a; PRINZ 1926, *Photo 3*; CHOLNOKY 1926, *Photo 4*; VADÁSZ 1935, 1960, *Photo 5*). Therefore, among the trends of Hungarian geomorphology, *geologically-founded geomorphology* has ever been represented, even during the predominance of *climatic geomorphology* in the 1950s and 1960s: KÉZ–BULLA (1936); KEREKES (1948); KÁDÁR (1956a); PÉCSI (1961) see further chapters A7 and B5.

Field experiments and *quantitative geomorphology* as well as *environmental geomorphology* of practical approach only emerged during the 1970s and 1980s, in many cases on the basis of contract works. With the variable dominance of trends, *long-term relief evolution* has constantly been a major direction. This is the part of the geologically-founded geomorphology which is concerned with the reconstruction of various paleogeographical situations, conditions and cyclical changes of relief forming processes (see chapter B).

The subject geomorphology at a given time was determined by the main direction of landsurface research and of the interest of university professors. Occasionally, researches were subsidised by some foundations or by the Hungarian Geological Society and Geographical Society and the Hungarian Geological Institute during the second half of the last century and the first half of this century.

Beginning with the 1950s, the Hungarian Academy of Sciences established research institutes, also for broadening geological, geographical studies in Hungary. At the same time, the Geological Institute and several ministries were also instrumental in financing investigations increasing knowledge through the geographical and geomorphological research activities. By the 1960s the number of geomorphologists had doubled both at universities and teachers' training colleges and in the newly-organised Geographical Research Institute of the Hungarian Academy of Sciences (1951). Research at that time meant not only the sum of individual research plans, but also the formulation of a nationwide plan under the financial umbrella of the Academy of Sciences and under the coordination of the State Geological Office (see chapter C).

A) WORKING THEORIES AND ELABORATIONS CONCERNING THE GEOMORPHIC EVOLUTION OF HUNGARIAN LAND

1. THE BASEMENT OF THE CARPATHIAN BASIN[1]

Introduction

Characteristic features of the Mediterranean orogenic belt, namely the sharp termination of the Alps in the East, the bifurcation of the orogenic belt (Carpathians, Dinarides), the change of the main strike of the orogeny, the curvature of the Carpathians as well as the faulted block structure of the mid-mountains and median mountains within the Carpathian Basin differing considerably from the orogenic environment played an important role in the genetic theories interpreting the development of the Carpathian Basin. So, even at the beginning of the 20th century surprising, often contradictory theories were elaborated on the basement of the Carpathian Basin, on the formation of the basin filled by several thousand metre thick Neogene sediments. These "working hypotheses" have been significantly modified in time due to the increasing geological knowledge gained mostly from boreholes as well as due to the changes in tectonic theories. Although the differences between the contradictory theories were solved partly by dialectic thinkings and new theories were born and developed, a lot of problems has remained to be solved in the geological history of the basement of the Carpathian Basin.

In the followings the centennial development, the formation and evolution of the knowledge on the Carpathian Basin are outlined mostly on the basis of the comprehensive works of the past decade by FÜLÖP, J. (1989, *Photo 6*); HAAS, J. [ed.] (1996, *Photo 7*); as well as KOVÁCS, S. et al. (1998). Geology of Hungary and geology of the Carpathian Region in English language have been written by TRUNKÓ, L. (1996, *Photo 8*) and FÖLDVÁRY, G. Z. (1988, *Photo 9*).

[1] Basic information concerning the development and evolution of geological and geomorphological knowledge on the basement.

Birth and development of the theory of "median mass" or "Tisia"

Even in the first quarter of our century a resistant, rigid crustal mass was assumed to exist in the basement of the basins surrounded by the Alps, Carpathians and Dinarides. This crustal mass, like a last, had a decisive role in the formation of the surrounding young folded mountain chain arcs. Considered in a simplifying manner as subsided old core-mountains, it was called *"continent"*, *"crystalline massif"* or *"median mass"*.

The development of the "median mass" theory can be traced back to the second half of the past century. Of the geologists working on the whole territory of the Austro-Hungarian Monarchy PETERS, F. (1853, 1862) recognised the *germanotype* Central European Triassic facies (Keuper) and Jurassic (Liassic) Gresten facies paralic coal-bearing formations in the Mecsek Mountains. In contrast, he considered the Alpine-type Transdanubian Range as a link between the Alps and the Carpathians. Based on these recognitions MOJSISOVICS, E. (1880) elaborated the so-called *Eastern Continent* concept as to which the eastern part of the Balkan Peninsula was a continent during the Mesozoic.

Mainly geomorphological and paleogeographical observations led LÓCZY, L., sen. (1918, 1924, *Photo 2*) to extend the genetic interpretation of the *Eastern Continent* (= Eastern Balkan massif) to the *Hungarian Basin* (= Carpathian Basin). During the Paleozoic and Mesozoic arms of the sea (branching continuations of the Alpine geosynclines) intruded into this massif. According to his interpretation the main part of the massif was a land also in the Paleogene, and the formation (and filling) of the basin started only in the Miocene.

As to KOBER, L. (1923, 1933) the *Pannonian (median) mass* is composed of the remnants of the older, denuded, folded mountain chains located in the neoorogenic zones. In time folds propagated outwards from the central part (massif) of the median mass. In connection with these movements the median masses themselves were faulted and subsided. The explanation of KOBER interpreted the Pannonian median mass in a narrow sense, relating this term essentially only to the autochthonous craton-like part (KOBER 1923; see FÜLÖP 1989).

Following the explanations of LÓCZY–KOBER it was PRINZ, GY. (1926) *who applied first the term "Tisia" to the Pannonian median mass (Fig. 1, Photo 3).* He believed the Tisia together with the Thracian massif of SUESS (= Eastern Land) as a twin-massif coupled with the narrow Serbian "neck", being of joint origin but of very different subsequent evolution. The geogenetic evolution of Hungary and of her environment bifurcated in the Cretaceous: one part is represented by the evolution of the *Tisia "primordial block"*, the other by the evolution of the folded mountain frame. Similarly to LÓCZY and in contrast to the interpretation in narrow sense of KOBER (autochthonous craton) PRINZ (1926, 1958) marked the boundaries of *Tisia* in a rather broad sense. He involved in the *Tisia unit* also the Vepor, the Spis-Gemer Ore Mountains, the Transylvanian Basin and its western boundary units *(Fig. 1)*.

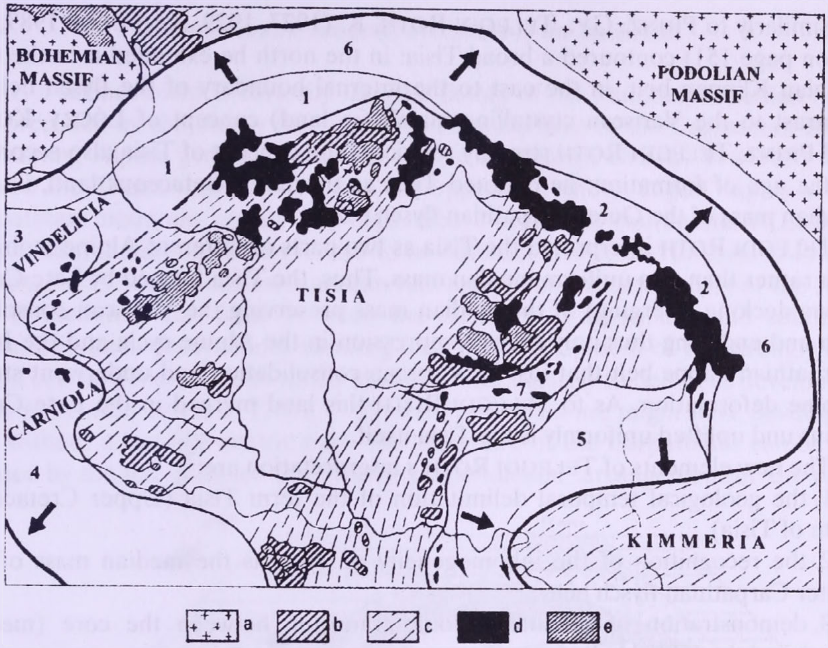


Fig. 1. PRINZ's sketch of the Tisia massif. – a = pre-Carboniferous massif; b = Carboniferous blocks; c= Carboniferous folds; d = volcanic rocks, e = remnants of Mesozoic carbonate platforms. – 1 = core mountains in the Western Carpathians; 2 = core mountains in Eastern Transylvania; 3 = Alpine nappe system thrust to the north; 4 = Dinarid folds; 5 = folds of the Southern Carpathians; 6 = the youngest flysch folds embracing the Alps and the Carpathian Mountains; 7 = minor folds in the Transylvanian Ore Mountains. (After PRINZ 1926, p. 19 the following citation and translation into English was compiled by SZEDERKÉNYI, T.).

What is the Tisia according to PRINZ's (1914, 1926) original definiton? "The Tisia is a mountain-block which accreted from the collapsed ruins of Carboniferous mountains systems. The surface of the block was considerably eroded already in the Permian period. This relief is covered by sheets of marine layers existing from the Triassic up to the Cretaceous." (PRINZ 1926, p. 19). "The Tisia block was uplifted and fragmented during the Cretaceous period between deep and long troughs along its border. The new block – the Tisia – leaning on its older brother, the Thracian massif of the Balkan peninsula by a narrow neck directly proceeded their uplifting, emerged only at the first manifestation of large and new mountain systems. Hereupon they form a median mass together, surrounded by mountain ranges and due to its extreme stability the Tisia was able to stand up against major Tertiary orogenesis." (PRINZ 1936, p. 79).

"Notwithstanding that Tisia appears as a powerful and highly tensile mass outward, there is a clear evidence that ultimately it was also destroyed. Contemporaneously, it piled up the ring of ranges of mountains outward and together with them also uplifted as a whole. Finally, it broke into blocks and most part of these pieces subsided into the depth. The sunken blocks as well as covered fillings yielded under the local pressure of blocks standing high above them, they crushed and obtained an undulated shape." (PRINZ 1946, p. 112). *What is the Tisia according to an up-to-date interpretation?* Tisia is a lithospheric plate fragment which had broken off of the southeastern margin of Variscan Europe during the Jurassic period and after complicated drifting as well as rotation it occupied its present tectonic position in the Miocene. Forming basement of the southern section of the Pannonian Basin it became very thin and subsided. Such a way it turned into the basin of a very thick and young sediment mass (SZEDERKÉNYI 1984b, 1996; KOVÁCS 1982; FÜLÖP 1994; KOVÁCS et al. 1998).

Similarly to PRINZ, GY., TELEGDI ROTH, K. (1927, 1929, see FÜLÖP 1989, *Fig. 63* on page 151) contoured a broad Tisia: in the north he extended it to the Carpathian Klippen belt, in the east to the internal boundary of the flysch belt. In contrast to the Variscan crystalline massif (= land) concept of LÓCZY–KOBER and PRINZ, TELEGDI ROTH strongly restricted the concept of Tisia also according to the age of formation: he denoted Tisia as the Late Cretaceous land, i.e. the median mass of the Outer Carpathian flysch belt.

TELEGDI ROTH interpreted the Tisia as two parts of different Alpine mobilisation rather than as a uniform median mass. Thus, the Tisia formed by Late Cretaceous docking (merging) of the median mass preserving the Variscan consolidation and enduring thus only slight compression in the Alpine cycle and the Inner Carpathian nappe belt that lost its Variscan consolidation and underwent strong Alpine deformation. As to TELEGDI ROTH this land merged in the Late Cretaceous und uplifted uniformly is the Tisia itself.

The new elements of TELEGDI ROTH's interpretation are:[2]

1. the geological temporal delimitation of the term Tisia (Upper Cretaceous state of Tisia),

2. the recognition of the inhomogeneity of Tisia as the median mass of the Outer Carpathian flysch belt,

3. demonstration of gradual tectonic transition between the core (median mass) and the folded belts formed around it.

SCHMIDT, E. R. (1937, 1947, 1961), when interpreting the Tisia in a narrower sense than it was done before, *omitted the Internal Carpathian nappe units from the Tisia.* Starting from the basalt occurrences of the Graz Basin he *delineated the Tisia boundary* along the "internal volcanic arc". So the Bihor Unit of nappe structure (of "Carpathian character") got into the area of Tisia.

He explained this contradiction by geomechanical simplification, namely by the squeezing out of the Bihor mass from the curvature of the Eastern and Southern Carpathians towards NW, and by the overthrust of the Bihor Unit onto the autochthonous mass of the Tisia. As to his opinion, in the Tisia region four Mesozoic crato-geosynclines were developed the sedimentary mass of which suffered later only simple "germanotype" deformation (SCHMIDT, E. R. 1961, see also HAAS, J. [ed.] 1996, *Figs. 2, 3* on pages 19, 20). In his model the mixture of the elements of the median mass theory and STILLE's geosyncline doctrine are found, mostly without acceptable evidence.

[2] Editor's italics because of the different interpretations of the various, recently re-defined Tisia terms.

It is a science-historic curiosity that the theory of the Pannonian median mass was preceded by the theory of orogeny of the basement of the Carpathian Basin (presuming Alpine geosyncline and/or nappe evolution): UHLIG, V. (1903) considered the Transdanubian Range as the uppermost and youngest nappe of the Carpathian mountain system and separated it from the southeastern (Eastern Carpathian) facies region considered to be different also by PETERS. As to PÁVAI VAJNA, F. (1930), the narrow Variscan fold located in the central part of the Alps was divided into flat folds between the northern (Carpathian) and southern (Dinaric) Alpine geosynclines allowing thus the development of the strongly dissected central geosyncline in which Mesozoic and Tertiary folded belts developed.

As to HORUSITZKY, F. (1961, 1969) the Carpathian arc might have developed also without a last-like central part. The curvature of the Carpathians can be explained by the not parallel but nearly perpendicular arrangement of the rigid

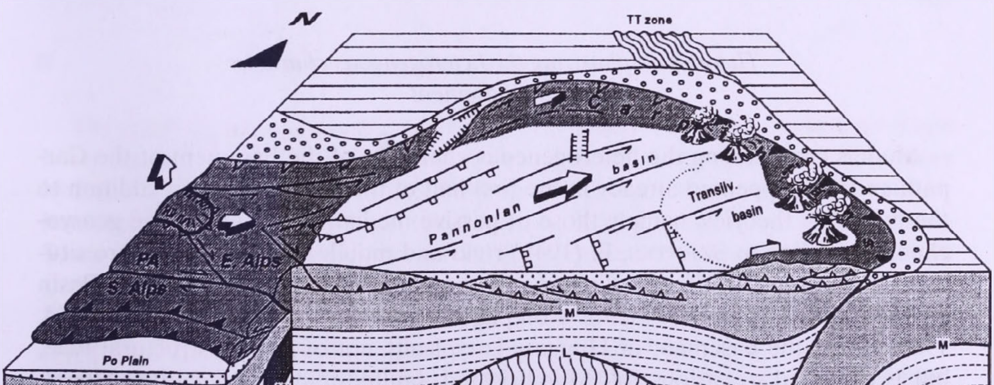


Fig. 2. Generalised block diagram to illustrate the geodynamic scenario of the Pannonian Basin and surrounding orogenic belts a few million years ago (after HORVÁTH and CLOETINGH, Tectonophysics 266 (1996) 287–300). Subduction and rotation of the foreland lithosphere plate stopped, the Pannonian Basin lithosphere plate became locked in a stable continental frame and, thus, the possibility for further extension ceased. – 1 = autochthon of the European foreland and the molasse foredeep; 2 = allochthonous units of the Alps and the Carpathians; 3 = Neogene-Quaternary sediment sequence of the Pannonian Basin; 4 = basement and crystalline crust; 5 = lower lithosphere and astenosphere; 6 = active and inactive thrust fronts with mantle updoming, diapir; 7 = normal faults of steep or gentle dip

margins (Sudetes, Russian platform). It is related also to this embayment of the rigid northern rim that within the Carpathian Basin no Alpine-sized folds and nappes could have developed. HORUSITZKY believed to recognise semicircular Tethyan branches in the Carpathian Basin (see FÜLÖP 1989, *Fig. 68*).

A similar orogeny model was developed by DANK, V. and BODZAY, I. (1971) with significant differences: they believed that during the Late Paleozoic and Mesozoic times the whole area of the Carpathian Basin proved to be a part of the Tethyan geosyncline, in which they distinguished five concentric belts characterized by different subsidence of the basement and thus by different facies *(Fig. 2,* see also FÜLÖP 1989, *Fig. 69*). As a result of the Cretaceous–Paleogene drift tectonic effect the neighbouring zones became of under- and overthrusted position. In the former one flysch, in the latter sediments of epicontinental character were deposited. Zones consisting of crystalline rocks between the facies belts represent the basement of the geosyncline sequences uplifted and eroded by Alpine orogenic phases, they were of no paleogeographic role.

Theories emphasizing the heterogeneous character of the basement

Models emphasising the heterogeneous character of the basement of the Carpathian Basin appeared already in the first half of the 20th century, in addition to the two main theories, namely those of passive median mass and Alpine geosyncline. According to SZENTES, F. (1949) rigid and mobile structural units are situated along strips of NE-SW direction in the basement of the Carpathian Basin (see also HAAS, J. [ed.] 1996, *Fig. 4* on page 22). According to VADÁSZ, E. (1954, 1960, 1961,) the basement of Hungary is typically not of Alpine structural type, but is dissected to various folded-imbricated, faulted-folded and faulted blocks, i. e. it was composed of parts of different mobility in the Alpine cycle. In the various strips of NE–SW direction the post-Variscan evolution of the semiautochthonous neoid structure overlying the autochthonous Variscan basement was different (HAAS [ed.] 1996, *Fig. 5* on page 23).

Based first of all on the experiences of hydrocarbon exploration wells KERTAI, Gy. (1957, Bullet. of Hung. Geol. Society 87. 4, map facing page 388) *refused the strip-model. As to his opinion the basement consists of "chess-board"-like Paleozoic and Mesozoic blocks of various strikes.*

Rejuvenation of the Tisia (median mass) theory in various forms

Tisia was re-interpreted even in the second half of the 20th century though treating it in a more complex, more differentiated form than in the earlier period. SZALAI, T. (1960, 1961, 1964, 1970) considered the so-called pre-Variscan and Variscan *geoanticlines* as the oldes components of the Carpathians and of the

Carpathian Basin. According to his model the land extending from the Alpine Gailtal crystalline complex through southern Transdanubia and through the Great Plain to the Bihor Mountains, i.e. *the "LÓCZY-threshold" played an important paleogeographic role during the Mesozoic.* According to him the Hungarian median mass developed through the merging of *geoanticline* nuclei of the Tisia and certain parts of the adjoining younger sediments, i.e., from formations of different origin (SZALAI 1960, *Fig. 3* on page 444). SCHÄFFER, V. (1959) identified the Hungarian "median mass" as the "Transdanubia-Bácska threshold" connecting the Pelagonian and Bohemian Massifs (see FÜLÖP 1989, *Fig. 73* on page 160).

Two recognitions, *namely the discovery of the flysch belt beneath the Great Plain* (PAPP 1940; though on the basis of geophysical data this was debated by SZÉNÁS 1969) *and the demonstration of the direct paleogeographic relation* of the Late Paleozoic formation *of the Bükk Mountains with the Southern Alps and Dinarides* (SCHRÉTER 1959; BALOGH 1964) *supported the concepts on the inhomogeneous built-up of the Carpathian Basin's basement.*

New comprehensive syntheses on the basement

The main phase of scientific cognition of the basement of the Carpathian Basin is represented by the sixties, seventies and eighties when as a result of intense hydrocarbon exploration and systematic geological mapping a series of comprehensive maps were published on the basement and on the tectonics of the region. Some of these maps were completed in international cooperation (first of all those concerning the Carpatho–Balkan–Dinaride area). These new syntheses and the related explanatory texts interpreted more thoroughly the development of the basement of the Carpathian Basin in Hungary than before.

As to the "Tectonic map of Hungary" compiled by BALOGH, K. and KÖRÖSSY, L. (1968, *Acta Geol. Hung. 12. 1–4.* Tektonische Karte Ungarns 1:1,000,000 facing page 256) the pre-Neogene basement of Western Hungary (to the Rába-line) constitutes the part of the Eastern Alps; in the southern foreground the Triassic of the Bükk Mountains can be traced to Tóalmás; in the central part of Transdanubia marine Upper Permian and Lower Triassic formations of Bükk-type are found; the Carpathian flysch belt branches into the Great Plain flysch belt. In the southern side of this flysch belt a crystalline strip belonging to the Réz Mountains is found. Crystalline rocks similar to those of the Mecsek environs are found also in several strips in the basement of the Danube–Tisza Interfluve. Further, crystalline blocks and Mesozoic of Transylvanian Mid-Mountain-type are also found in the Szeged and Békés basins.

The distinction between the Balaton–Darnó Line and the Zagreb–Kulcs Line interpreted as the continuations of the Periadriatic Lineament as well as the recognition and characterisation of the *"Igal-Bükk Eugeosyncline"* between the two lineaments is bound to the name of WEIN, GY. (1969, *Tectonic Map of the pre-Permian basement of Hungary* facing pages 408, 1872, 1978a, see Plates No. IV.

and No. V). According to WEIN the Zagreb–Kulcs Line bisects the Pannonian Basin into two parts: the western segment developed on the shelf of Africa then was overthrusted onto the oceanic crust of the Tethys (Penninicum), while the eastern segment represents the northern margin of the Tethys (WEIN 1978b; PÉCSI 1980, p. 163, *Fig. 25,* Megatectonic Units in the Carpathian Basin).

Results gained through comprehensive national geophysical measurement systems and geothermal gradient mapping highly contributed to the recognition of the *thinned crust of the Carpathian Basin* and of the related *uplifted upper mantle and asthenosphere* (= mantle diapir) (SCHÄFFER 1959; BALKAY 1960; ÁDÁM 1965; SZÉNÁS 1969, 1972; STEGENA 1972; BOLDIZSÁR 1968; MITUCH and POSGAY, 1969; SZÁDECZKY-KARDOSS 1966, 1967, 1970; SZÁDECZKY-KARDOSS et al. 1969; HORVÁTH and CLOETINGH 1996, *Fig. 2*). *The geogenetic model presuming selective deep flows in the upper mantle and the isostatic movements played important role in the interpretation of the Neogene basin evolution.* The paleomagnetic measurements and interpretations carried out by MÁRTON, P. and MÁRTON-SZALAY, E. *contributed considerably to the reconstruction of block displacements in the Carpathian Basin* (for a recent review see MÁRTON–SZALAY 1996).

Plate tectonic models of the basement

The introduction and its firts, in some elements exaggerated application of *plate tectonics* ("new global tectonics") to the area of the Carpathian–Pannonian–Dinaride region is associated with the name of SZÁDECZKY-KARDOSS, E. (1970, 1972, 1973, 1978). STEGENA, L. (1973) revealed the relationships between the upper mantle magma flows and plate tectonic processes. Having performed a comparative analysis of Jurassic (Liassic) ammonites, GÉCZY, B. (1973, 1974) demonstrated that the Transdanubian Range belonged to the carbonate platform of the southern (African) margin of the Tethys, while the Mecsek and Villány Mountains to its northern (European) margin (see FÜLÖP 1989, p. 170). Thus, *the recent basement of the Carpathian Basin developed through the horizontal displacements of smaller plate fragments between the European and African plates.* These main elements of GÉCZY's recognition based on paleontological data served as fundamental components also for the subsequent models of the past decades. HORVÁTH, E., STEGENA, L. and GÉCZY, B. (1975) considered *the Carpathian Basin as an interarc basin of continental crust.* In the *plate tectonic interpretations the term "Tisia"* – of course as *a re-evaluated concept differing from the formes ones* – occurs first in the work of CHANNEL, J. E. T. and HORVÁTH, F. (1976) who presumed several so-called micro-plates between the Adriatic and European plates, when emphasising the role of the Adriatic plate. The *Tatride plate* broke of the so-called Adriatic block ("thorn") subsequently to the Triassic volcanism related to the Igal–Bükk zone while the *Tisia plate could broke off the European plate*

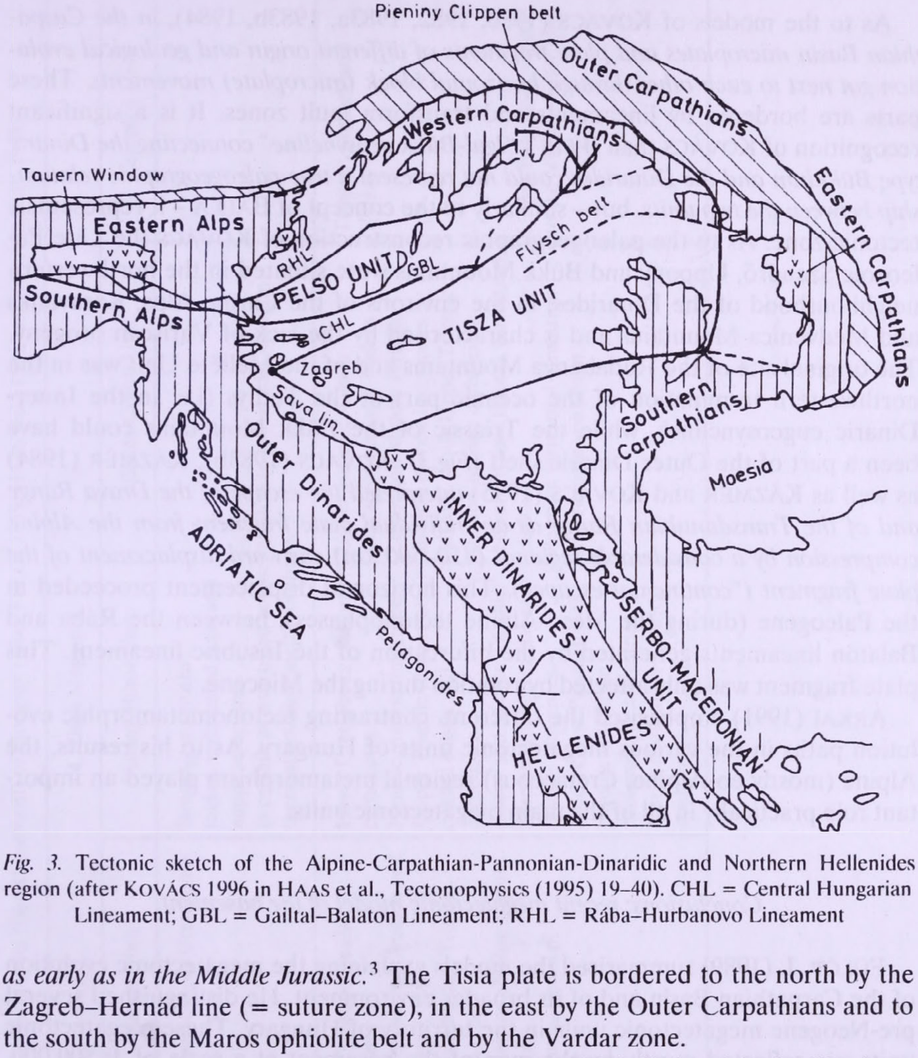


Fig. 3. Tectonic sketch of the Alpine-Carpathian-Pannonian-Dinaridic and Northern Hellenides region (after KOVÁCS 1996 in HAAS et al., Tectonophysics (1995) 19–40). CHL = Central Hungarian Lineament; GBL = Gailtal–Balaton Lineament; RHL = Rába–Hurbanovo Lineament

as early as in the Middle Jurassic.[3] The Tisia plate is bordered to the north by the Zagreb–Hernád line (= suture zone), in the east by the Outer Carpathians and to the south by the Maros ophiolite belt and by the Vardar zone.

In his megatectonic model BALLA (1982, 1987, 1988) distinguished a Northern and a Southern Pannonian unit (the southern boundary of the former is the Balaton–Hernád line while the latter is bordered to the north by the Szolnok–Maramures flysch belt and its presumed continuation in the northern foreground of the Mecsek Mountains. In the Central Hungarian belt lying between them and characterised predominantly by horizontal displacements, the strongly deformed material of the neighbouring and foreign units are found (see FÜLÖP 1989, *Fig. 90* on page 177).

[3] As to VÖRÖS (1977) a part of the European shelf broke off the European plate already in the Lower Jurassic, i.e. in the Middle Liassic.

As to the models of KOVÁCS (1980, 1982, 1983a, 1983b, 1984), *in the Carpathian Basin microplates and plate fragments of different origin and geological evolution got next to each other through horizontal block (microplate) movements.* These parts are bordered by lineaments and transform fault zones. It is a significant recognition of KOVÁCS than *WEIN's "Igal-Bükk geosyncline" connecting the Dinaric type Bükkium and the Dinarides could not represent a true paleogeographic relationship between the two units,* but – similarly to the concept of BALLA – it represents a tectonic zone. As to the paleogeographic reconstruction of KOVÁCS the Late Paleozoic Szendrő, Uppony and Bükk Mountains were situated in the northwestern neighbourhood of the Dinarides, in the environs of the Carnic Alps, Karavanks and Medvenica Mountains and is characterised by the lack of Variscan orogeny. The original site of the Rudabánya Mountains and of the Melléte Unit was in the northwestern termination of the oceanic part of the Tethys (i.e. in the Inner-Dinaric eugeosyncline), while the Triassic of the Bükk Mountains could have been a part of the Outer Dinaric shelf *(Fig.3).* KOVÁCS (1983b), KÁZMÉR (1984) as well as KÁZMÉR and KOVÁCS (1995) *interpreted the escape of the Drava Range and of the Transdanubian Range as an individual plate fragment from the Alpine compression by a considerable regional (450–500 km) eastward displacement of the plate fragment ("continental escape").* This horizontal displacement proceeded in the Paleogene (during the Meso-Alpine tectonophases), between the Rába and Balaton lineaments generated by the bifurcation of the Insubric lineament. This plate fragment was only affected by rotation during the Miocene.

ÁRKAI (1991) emphasised the different, contrasting tectonometamorphic evolution paths in the various megatectonic units of Hungary. As to his results, the Alpine (mostly eo-Alpine, Cretaceous) regional metamorphism played an important role practically in all of the main megatectonic units.

Conclusions: recent megatectonic model of the basement

FÜLÖP, J. (1989) summarised the models explaining the megatectonic evolution of the Carpathian Basin and of its broader environment. He distinguished several pre-Neogene megatectonic units in the territory of Hungary. These megatectonic units are reflected mostly by the map of the basement at a scale of 1: 500,000, edited by FÜLÖP and DANK as chief editors, by the tectonic map of the same scale (DANK, FÜLÖP et al. [eds] 1990), by the "Geological Map of 1: 2,000,000 scale of the pre-Neogene basement (BREZSNYÁNSZKY and HAAS 1989) in the National Atlas of Hungary, map No. 36, further by some chapter of the legend edited by HAAS to the basement and tectonic maps of 1: 500,000 scale (BALOGH 1996; KOVÁCS 1996; ÁRKAI et al. 1996; HAAS and HÁMOR 1996)[4]. A brief geological description of the main units is given in *Table 1.*

[4] Mainly on the basis of the above cited publications Trunkó, L. gave us a similar concept about the basic asement of Hungary *(Photo 7).*

Table 1. Pre-Tertiary structural units (basin basement) of Hungary (after FÜLÖP 1989; HAAS [ed.] 1996 and KOVÁCS et al. 1998)

A. Tisza Megaunit

Structural stage	Mecsek Unit	Villány-Bihor Unit	Békés-Codru Unit	Zemplén Unit
Paleo-Alpine (Cretaceous)	Paleogene –Upper Cretaceous flysch	Banatitic magnitism folded, imbricated scaly and nappe structures in certain overthrusted zones: very-low to low-grade, medium thermal gradient metamorphism		
Early Alpine (Tethyan "geosyncline" stage)	Lower Cretaeous mafic magmatites Lower Jurassic of Gresten and Allgau type Lower and Middle Triassic German type terrestrial and shallow marine formations ± terrestrial Permian	Lower Cretaceous platform carbonates Jurassic marine limestones Upper Triassic terrestrial – coastal clastic and carbonates Lower and Middle Triassic: Mecsek type terrestrial and marine sequences Mecsek type Permian with rhyolite volcanism Molasse type terrestrial Upper Carboniferous with coal seams	Upper Jurassic, Lower Cretaceous pelagic clastics Lower and Middle Jurassic shallow marine limestones Middle, partly Upper Triassic shallow marine carbonates Lower Triassic littoral, terrestrial clatics, Permian terrestrial formation and rhyolite volcanism	Triassic; Mecsek and Villány types Upper Paleozoic: similar to the Villány-Bihor Unit

Table 1 (continued)

A. Tisza Megaunit				
Structural stage	Mecsek Unit	Villány-Bihor Unit	Békés-Codru Unit	Zemplén Unit
	Central Hungarian "Autochthonous" Ranges		South Hungarian nappe zone	
Pre-Alpine (mostly Variscan, eventually pre-Variscan)	Mórágy Complex Variscan granitoids, migmatites with predominantly medium-grade, changing: medium to high thermal gradient polymetamorphic rocks (gneisses, mica schists and amphibolites, locally with subordinate carbonates) Drava Basin: medium-grade Metamorphic rocks Ófalu-Nagykőrös Zone: Mylonitized sheat zone	Körös Complex		medium-grade, medium thermal gradient metamorphic rocks

B. Pelso Megaunit				
	Transdanubian Range Unit	Mid-Transdanubian Unit	Bükk Unit	Aggtelek–Rudabánya Unit
Paleo-Alpine (Cretaceous, also Upper Jurassic in the Bükk and Aggtelek units)	formation of an imbricated, scaly synclinorium; without any regional metamorphism	regional alterations from late diagenesis through very low-grade up to low-grade, high to medium thermal gradient regional metamorphism	folded, overthrusted nappe structures regional alterations from late diagenesis through very low-grade up to low-grade, high to medium thermal gradient regional metamorphism	regional transformation ranging from late diagenesis through very low-grade up to low-grade, medium to low thermal gradient regional metamorphism

Early Alpine (Tethyan "geosyncline" stage)	Lower-Middle Cretaceous: mostly various limestone, subordinately flyschoid sequences Jurassic: condensed red limestones and radiolaritic facies Upper Triassic platform carbonates Middle Triassic tuffaceous pelagic and shallow marine carbonates Lower Triassic shallow marine facies Upper Permian continental red beds and coastallagoonal facies	a strongly tectonized, sheared zone consisting of various types of Late Paleozoic and Mesozoic (mostly Triassic) formations, partly resembling to the formations of the Transdanubian Range and partly to the Dinarides	Middle Jurassic marine fine-clastic sequences with ophiolites Triassic of self and marginal facies of the Dinarides with continuous marine Permian/Triassic transition. Intermediate and bimodal volcanism in the Middle Triassic and carbonate platform and intra-platform Upper Triassic facies Permian: shallow marine, Dinaric type facies	variegated Middle and Upper Triassic, mostly carbonatic facies with remnants of Triassic dismembered ophiolites Lower Triassic marine Werfen facies Upper Permian evaporites
Variscan	very low- to low-grade, high thermal gradient Paleozoic rocks with granite intrusions	–	Ordovician(?), Silurian, Devonian and Carboniferous sedimentary and volcanogenic formations (similar to the Carnic Alps, South Karawanks and Graz), without any signs of Variscan metamorphism	–

Table 1 (continued)

C. East Alpine structural units

Structural stage	Upper East Alpine nappe system	Lower East Alpine nappe system	Penninic Unit
Paleo-Alpine (Cretaceous)	nappe formation subgreenschist facies metamorphic overprint	nappe formation predominantly low-grade (high-T greenschist facies), locally medium-grade metamorphic oveprint in medium thermal gradient conditions	folding, overthrusting, nappe formation: low-grade, low thermal gradient metamorphism overprinted by mezo-Alpine (Tertiary) low-grade, medium thermal gradient metamorphism
Early Alpine	–	–	Lower Cretaceous(?) ophiolite conglomerate with Triassic pebbles pelitic-carbonatic marine formation terrigenous clastic Mesozoic (Jurassic?) formations
Pre-Alpine (mostly Variscan, eventually Pre-Variscan)	Variscan, mostly low-grade, subordinately very low-grade, high thermal gradient metamorphism Devonian(?) carbonatic and pelitic rocks with basic volcanoclastic intercalations Silurian(?) clastic rocks with subordinate rhyolite tuff intercalations	pre-Variscan(?)+Variscan or composite polyphase Variscan medium grade metamorphism of most probably Early Paleozoic, predominantly clastic, subordinately basic igneous rocks. Variscan(?) or pre-Variscan(?) granitoid intrusion. Thermical conditions: changing from Medium to high thermal gradients	

D. Central Western Carpathian (Vepor) Unit

Paleo-Alpine Early Alpine Pre-Alpine	? retrograde (greenschist facies) metamorphic overprint ? medium grade Variscan(?) metamorphism of unknown thermal regime

Essentially the same units are distinguished in the map of Hungary and in its legend prepared in international cooperation (IGCP) by KOVÁCS et al. (1998). As it is explained in the introduction of the legend by KOVÁCS *the theory of classical pre-Neogene median mass or "internide" has become groundless on the basis of the geological recognitions of the past 25 years.*

The pre-Neogene basement of the Pannonian basin and of its direct Alpine-Carpathian-Dinaric environs is composed of the collage of allochthonous terranes (= micro-plates = lithosphere or crust fragments = blocks) deriving from different regions of the Tethys.

The final accretion of these parts of different origin proceeded in the Upper Oligocene–Lower Miocene (BALLA 1988; CSONTOS et al. 1992). All the terranes of KOVÁCS et al. (1998) constituting the pre-Neogene basement of the Pannonian basin are shown in *Table 1.*

As to KOVÁCS the development of the terraneview in the Carpathian–Pannonian region was promoted partly by the recognition of the "main discontinuity zones" (GRECULA and VARGA 1979), and partly by the tectonic recognition that the "North-Pannonian Unit" consists of 6 to 8 smaller terranes that, especially in the early phase of the Paleogene, were displaced also as compared to one another (BALLA 1988).

KOVÁCS et al. (1998) distinguished the following Meso-Alpine allochthonous terranes in the Hungarian part of the Carpathian-Pannonian region:

I. *Inner Western-Carpathian s. s. or Tatra-Vepor Composite Terrane* (bordered by the Pieniny klippen belt to the north and by the Hurbanovo–Lubenik–Margecany fault zone in the south);

II. *Pelso or Pelsonia Composite Terrane,* bordered to the northwest and north by the Rába–Hurbanovo–Lubenik–Margecacny fault zone, to the south by the Central Hungarian lineament (=Zagreb–Kulcs = Zagreb–Zemplén lineament);

III. *Tisia Composite Terrane* (lying south and southeast of the Central Hungarian lineament and bordered to the southwest by the Sava-fault, to the south, i.e. to the central part of Vajdaság by an unnamed fault, and to the southeast by the Maros Ophiolite belt). The Inner Western-Carpathian and the Pelsonia Terranes moved together in the Upper Oligocene and Lower Miocene, thus this great unit was called by BALLA (1982) as *North-Pannonian Unit,* while the Tisia Terrane as *South-Pannonian Unit.*

*

It is obvious from the short review above that the term Tisia, Although introduced originally by PRINZ (1926) for a supposed rigid median mass that determined the shape of the surrounding young (Alpine) mountain chains has been applied also recently in up-to-date plate tectonic interpretations. However, not only the actual boundaries but – and what is more important – also the geological meaning, content of this re-interpreted term has been almost entirely changed. Considering the fact that the Tisia (in the present sense) originated from the northern (stable European) border of the Tethys, it has remained true that this unit represents a foreign block within the Alp–Carpathian–Dinaric young mountain chains. In contrast with the earlier interpretations, this Tisia was not intact and did not behave like a rigid median mass during the Alpine orogeny. Instead, as proved by the Alpine nappe structures discovered in the basement (SZEDERKÉNYI 1984b, 1996) – it was severely affected by Alpine compressional tectonics. In addition, Alpine (mostly Cretaceous) regional metamorphism was also proved in certain zones of the post-Variscan part of the basement (ÁRKAI et al. 1998). All these new data make clear that the re-interpreted Tisia formed an organic part of the Alpine-Carpathian-Dinaric realm of the Mediterranean orogenic belt.

2. POLYGENETIC SURFACES OF PLANATION IN THE TRANSDANUBIAN MOUNTAINS

From a geomorphological point of view the most part of *the Hungarian mediumheight mountains* are a series of Mesozoic horsts of South Alpine character, folded-faulted structure, uplifted into variable elevations. Some planation surfaces of different origin and various position are observed on them.

Until the 1950s, the surfaces of planation had been interpreted as remnants of *Davisian peneplains* (CHOLNOKY 1926, 1930, 1936) or of PENCK's *Piedmonttreppen* (PRINZ 1914, 1926, 1936, 1942; LÁNG 1955b, *Photo 10*) and after the fifties, *remnants of tropical surfaces of planation* by BULLA and his followers. The last theory (as opposed to the previous ones) did not associate planation with denudation to some base level. According to BULLA (1954, 1958b, 1962, *Photos 11a, b*) under tropical climate and prolonged tectonic tranquility, due to intensive weathering and sheet-wash, tropical surfaces of planation are formed. He believed that these conditions and processes survived through the Tertiary during the Pliocene and this process effected the young volcanic ranges of Hungary, too.

BULLA's model of *tropical planation* was similar to the one elaborated by BÜDEL, J. (1957), where the "Doppelte Einebnungsfläche" is a surface of etchplanation (according to WAYLAND, 1934).

Tropical planation in young volcanic mountains of Hungary was doubted by LÁNG, S. (1967) and PINCZÉS, Z. (1970).

At the end of sixties and beginning of seventies PÉCSI elaborated a new comprehensive model for the geomorphological evolution of *polygenetic planation surfaces* in case of the Hungarian Transdanubian Mountains. This model claims that surfaces of planation once produced by some erosional processes (peneplanation, pedimentation, pediplanation or etchplanation) were reshaped in later geological periods by alternating erosion and accumulation on the units of morphostructure also repeatedly affected by plate-tectonic uplift, subsidence and horizontal displacement (PÉCSI 1970a, c, 1996a, *Photos 12, 13*).

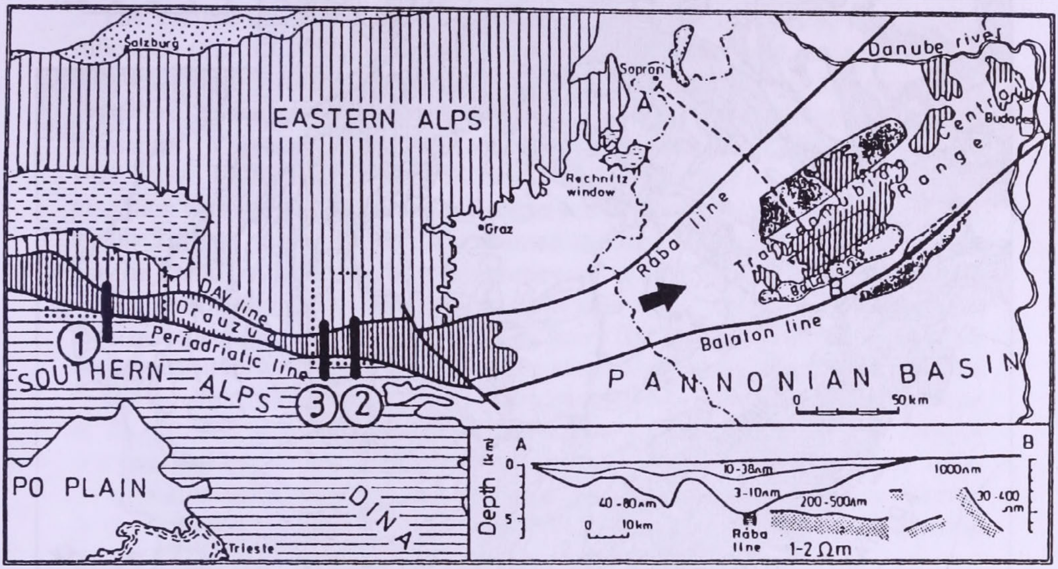


Fig. 4. Tectonic setting of the Bakony–Drauzug Unit (BDU) and high conductivity zones in the Transdanubian Central Range (after HORVÁTH et al. 1987; ÁDÁM et al. 1992). Dottes squares indicate the magneto-telluric sites in the Alps with AMT profiles (thick lines). – 1 = Gail profile; 2 = Ebriach profile; 3 = Zell Pfarre profile. The inset shows the electric structure along the profile A–B. Stippled line indicates the position of the conductor

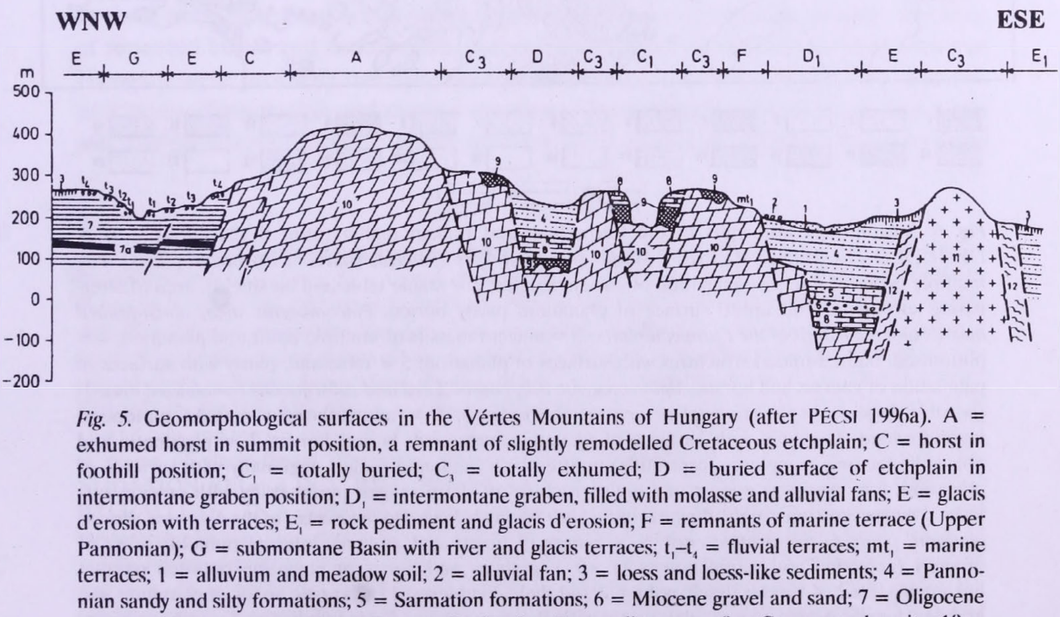


Fig. 5. Geomorphological surfaces in the Vértes Mountains of Hungary (after PÉCSI 1996a). A = exhumed horst in summit position, a remnant of slightly remodelled Cretaceous etchplain; C = horst in foothill position; C_1 = totally buried; C_3 = totally exhumed; D = buried surface of etchplain in intermontane graben position; D_1 = intermontane graben, filled with molasse and alluvial fans; E = glacis d'erosion with terraces; E_1 = rock pediment and glacis d'erosion; F = remnants of marine terrace (Upper Pannonian); G = submontane Basin with river and glacis terraces; t_1–t_4 = fluvial terraces; mt_1 = marine terraces; 1 = alluvium and meadow soil; 2 = alluvial fan; 3 = loess and loess-like sediments; 4 = Pannonian sandy and silty formations; 5 = Sarmation formations; 6 = Miocene gravel and sand; 7 = Oligocene sand and clay formations; 7a = Oligocene lignite; 8 = Eocene limestone; 9 = Cretaceous bauxite; 10 = Triassic dolomite and limestone; 11 = granite; 12 = Carboniferous metamorphic rocks

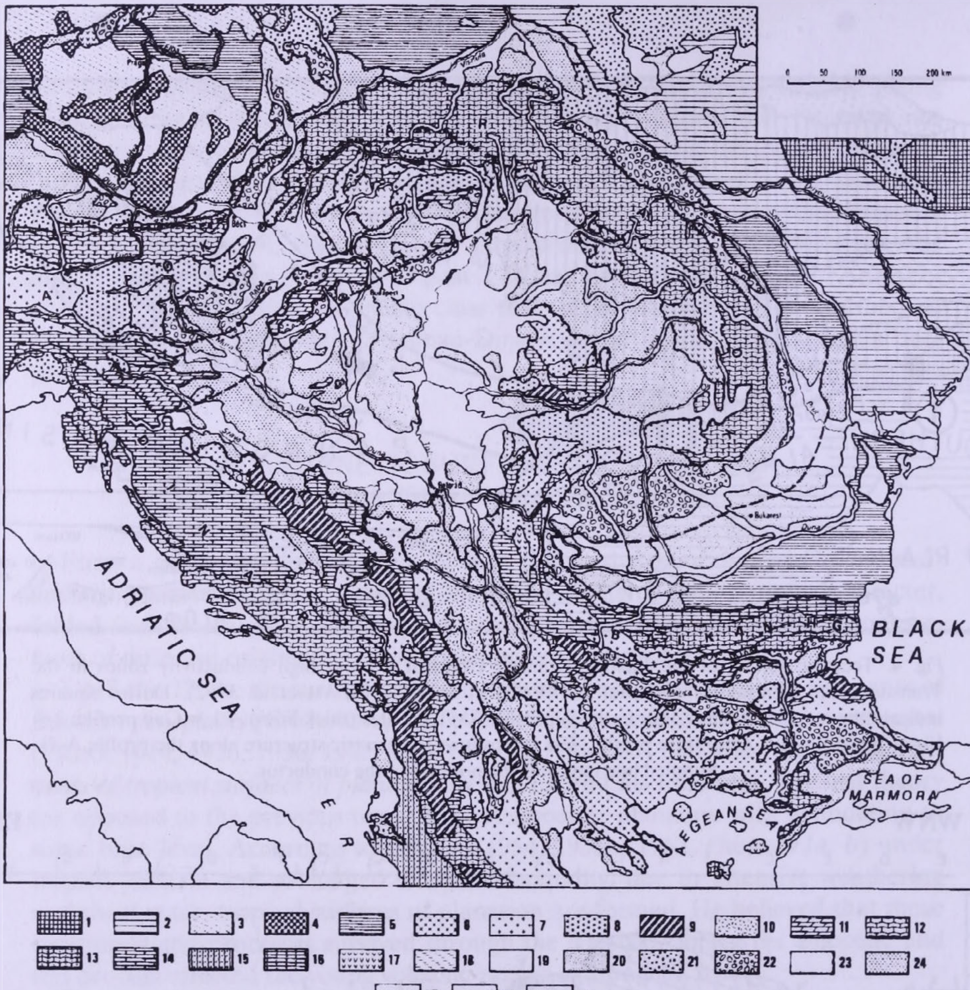


Fig. 6. Morphostructural units of the Carpathian and Balkan region (after PÉCSI 1980). – A = DENUDED TECTONIC RELIEF. *Morphostructural types of shields* (parts of European plates). 1 = multiple cycles of intensive planation of ancient shields; 2 = stable tableland on shields, area of alternating subsidence and uplift; surface of planation, partly buried. *Paleoorogenic area, block-faulted massifs and tablelands of the European plates*; 3 = ancient massifs of multiple uplift and planation; 4 = plutonised, faulted-folded structures with surfaces of planation; 5 = tableland, partly with surfaces of palanation or cuestas and horsts. *Alpine orogenic belt, consolidated and subsequently remobilised massifs (possibly fragments of continental or oceanic microplates);* 6 = autochthonous massifs, plutonised faulted-folded structures with surfaces of planation, exhumed, buried horsts; 7 = plygenetic and polycyclic tectonic complexes (centralide) uplifted high mountain ranges, regionally with surfaces of planation; 8 = overhrust nappes and fault structures of sharp ranges, peripherally with erosion surfaces. *Younger structures of the Alpine orogenic belt having belonged to the margin of the Northern African platform, partly to the oceanic crust*; 9 = ranges of horsts and grabens, internal ophiolite zone of orogeny (accretion and subduction belt); 10 = grabens and horsts of planation between parallel lineaments, zone of Vardar flysch, ophiolite and shale complexes; 11 = karstic horsts of planation and grabens, locally Alpine topography, partly with Paleozoic shale. *Folded-faulted and overthrust nappe structures in the external zone of orogeny*; 12 = mountain ranges with sharp ridges or karst plateaus;

The Triassic and Jurassic low carbonate platform was affected by tropical karstification (SZABÓ 1960; PÉCSI 1970c) along the northern rim of the African plate (GÉCZY 1973a; MÁRTONNÉ SZALAY, E. 1996). Cockpit and tower karst may have been formed under savannah climate, simultaneously with laterite and bauxite formation (VADÁSZ 1951; ERDÉLYI 1965; BARNABÁS et al. 1957; BÁRDOSSY 1977, *Photo 13*; MINDSZENTY et al. 1984). Witnesses of this marked tropical karst planation were buried 3–4 times and preserved by Lower, Upper Cretaceous and, locally Tertiary strata. Buried and exhumed surfaces of planation with paleokarst may be found on the horsts, between grabens or in the forelands (*Figs 4, 5*).

The Austro-Hungarian cooperation continued after 1986 by audiomagnetotelluric measurements made in every second year. The first problem to be solved by these measurements was to determine the structure of the graphitic blocks in the Paleozoic Altkristallin and which are accompanied by a magnetic anomaly at one of the profiles measured at Zell Pfarre. *Figure 4* shows the N-S AMT profiles crossing the Periadriatic line and the Transdanubian anomaly within the independent geological unit Bakony–Drauzug. MT measurements made in Austria proved, that the cause of the Transdanubian anomaly are graphitic conducting formations.

The tower karst features of the Transdanubian horsts have been formed in tropical belt and after having escaped by long-distance horizontal displacement, without a significant tilting the towers of karst remained perpendicular until now (*Photo 14*).

In the meantime, the horsts of the Mesozoic mountain range were exhumed twice or three times and some horsts underwent pedimentation along their margins. Because of repeated burial and exhumation, during the Neogene the Mesozoic horst series of Hungary were probably not affected by either tropical or other kinds of planation, only peripedimentation and marine abrasion. The uplifted horsts of calcareous rocks and the paleokarsts now in grabe position were once part of the same erosional

◄———————

13 = flat-topped or rounded flysch ranges around the deep lineaments of flysch structures. *Autochthon-like faulted-folded structures*; 14 = ranges of sharp ridges of karst plateaus, partly with marginal karst plains; 15 = simple fault structure of foreland orogeny (Albania); 16 = monoclinal structures, slightly dissected plateaus, pediments. *Young volcanic mountains in the Alpine belt and in the paleo-orogenic area;* 17 = deeply eroded stratovolcanoes, probably related to subduction belt; basalt sheets of late volcanism; 18 = marine-limnic plains, fluvio-palustric plains, coastal plains. B = ACCUMULATION RELIEF IN BASIN AREAS; 19 = alluvial plains, flood plains, delta plains, valley bottom; 20 = alluvial fans and terrace above the flood plain level, covered by wind-blown sands and sandy loess; 21 = plains of glacio-fluvial deposition, young morainic landscape. C = ACCUMULATION-DENUDATION RELIEF IN YOUNG BASINS AND TERTIARY FOREDEEPS DISMEMBERED BY VALLEYS; 22 = dissected ancient alluvial fans and foothill surfaces; 23 = slightly and moderately elevated loess plains, loess plateaus with pattern of gullies and derasional alleys (dells); 24 = hilly region of molasse, sculptured by erosion-derasion, regionally covered by loess mantle or loess derivates. D = MISCELLANOUS; 25 = zone of klippen, isolated tectonic klippen along the subduction belt of Alpine–Carpathian range; 26 = boundary of macro-morphostructures; 27 = buried boundary of morphostructures in the Hungarian mountains belt

surface i.e. etchplain. By their present-day positions and morphogenetics they fall into the following categories (PÉCSI 1970a, c, 1996a, *Table 2*).

Table 2. Genetic classification of the polygenetic geomorphic surfaces of planation of the Transdanubian horst-series (after PÉCSI 1996)

1. (semi) exhumed horst of etchplanation in summit;
2. buried horst of etchplanation in uplifted position;
3. horst of etchplanation in threshold position, buried or exhumed and reshaped, mostly pedimented;
4. crypto-etchplain in graben position;
5. rock peripediments, locally buried under strata of detritus (*Fig. 5*)

This model of polygenetic geomorphic surfaces evolution applies not only to the Hungarian mountains, but also to numerous other geomorphological regions, e.g. the Alpine–Carpathian–Dinaric Ranges, several old mountains and massifs of Europe and other continents (*Fig. 6*).

This working hypothesis was further confirmed by the investigations of SZÉKELY (1972) and BULLA's other followers and the classification was made more detailed, e.g. by JUHÁSZ (1988, 1995) and KAISER (1997) for the Transdanubian Mountains (*Fig. 7*).

The horsts etchplained in the Cretaceous then buried, semi-exhumed and being uncovered may occur at different elevations (*Fig. 5*). Some types can be found e.g. at the same heights besides each other within one mountain range. It is also common that planated horsts covered by Oligocene sandstone range steplike one above the other. The surfaces of different heights of these horst types do not necessarily represent geomorphological surfaces of different ages.

Along the mountain margins the *Neogene marine terraces* usually represent younger geomorphological surfaces than the uplifted and exhumed horst surfaces. Nevertheless, it is frequent that the Pannonian marine formations overlie horsts uplifted to 400–500 m height which were buried in the Paleogene, elsewhere the Upper Pannonian travertine overlies the Mesozoic geomorphic surface (Balaton Highland, at about 300 m a.s.l.).

In the margins of horsts of the Transdanubian Mountains the Late Cenozoic geomorphological surfaces (marine terraces, pediments, river terraces) were preserved by the hard strata of travertines from the subsequent erosion. Travertines were formed by karst springs in the base level. In the Transdanubian Mountains at least 12 Neogene and Quaternary geomorphological surfaces were preserved by travertines. This phenomenon is characteristic of the mountain margins and of some larger valleys (SCHEUER and SCHWEITZER 1983). In the valley-side terraces a lower sequence of travertines was deposited (between 120 and 250 m a.s.l.). The higher situated sequence of travertine covers pediments and marine terraces. For their dating, fauna remnants, paleomagnetic and absolute chronological data were available (PÉCSI, SCHEUER and SCHWEITZER 1988; see PÉCSI 1996b, *Fig. 55*, p. 79).

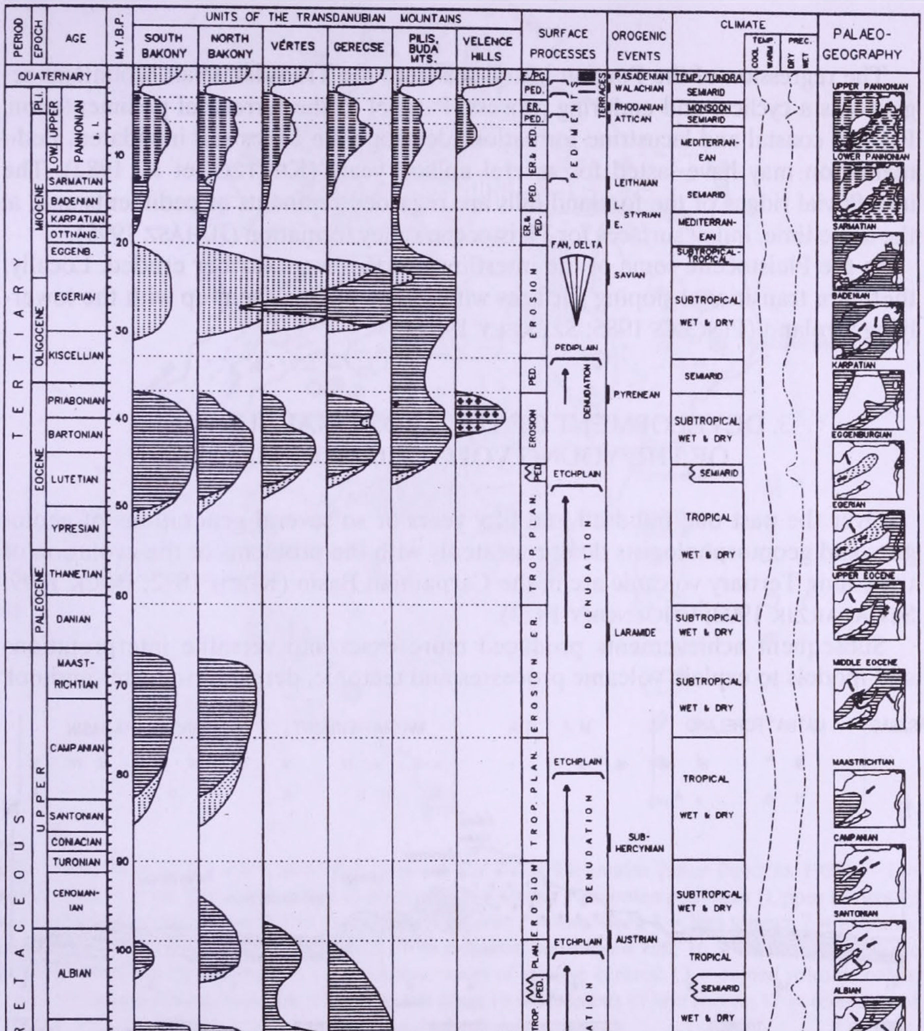


Fig. 7. Geomorphic evolution of the Transdanubian Mountains (after KAISER 1997). – 1 = marine sedimentation; 2 = lacustrine (inland sea) sedimentation; 3 = terrestrial sedimentation; 4 = volcanism; 5 = direction of sediment transport, ER – fluvial erosion; valley evolution; TROP.PLAN. – tropical planation, etchplanation; PED. – pedimentation PG. – periglacial processes

The regression of the Pontian inland sea from the Transdanubian Mountains region was a cyclical and enduring process. Parallel to the terrestrial pedimentation, Pontian coastal and lacustrine formations developed in zones still inundated. Pedimentation may have lasted for several million years (KRETZOI et al. 1982). The interfluvial ridges of the foreland hills are regarded remnants of pediments and, at the same time, initial surfaces for Pleistocene valley formation (JUHÁSZ 1995).

In the Pleistocene some of the interfluvial ridges were further eroded. Locally, there are transitional sloping surfaces with scarps linking them up with the lower-lying foreland (PINCZÉS 1985; SZÉKELY 1987).

3. DEVELOPMENT OF THE EROSIONAL SURFACES OF THE YOUNG VOLCANIC MOUNTAINS

Over the past one hundred and fifty years or so several generations of geologists and geomorphologists dealt repeatedly with the problems of the evolution of the young Tertiary volcanic arc in the Carpathian Basin (KOCH 1872; BÖCK 1899; SCHAFARZIK 1902; CHOLNOKY 1923).

Subsequent achievements produced more exact and versatile interpretations and models to explain volcanic processes and tectonic, denudation forms and not

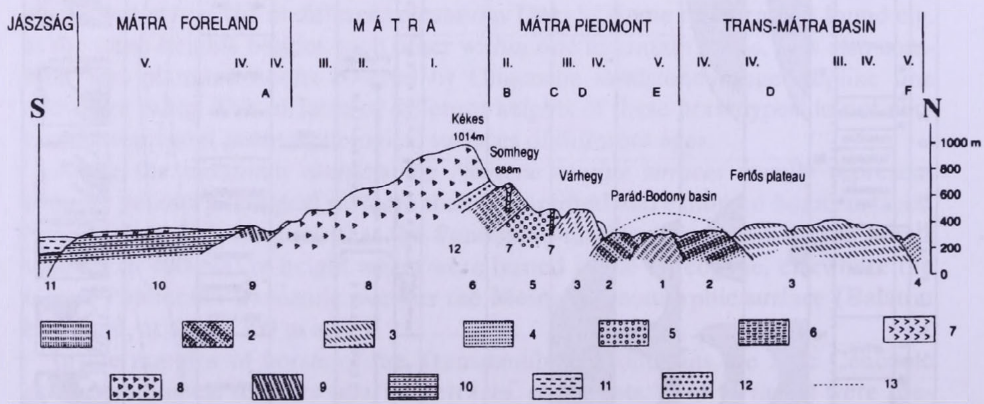


Fig. 8. Cross-section of the Mátra Mountains (after SZÉKELY 1989b, 1997). – 1 = Middle Oligocene; 2 = Upper Oligocene (Lower Chattian) schlier; 3 = Upper Oligocene hard sandstone; 4 = Upper Oligocene (Upper Chattian), less consolidated schlier; 5 = Lower Miocene sediments (variegated clays, friable sandstone, Lower rhyolithic tuff, lignite seams); 6 = Miocene schlier; 7 = subvolcanic bodies (laccoliths, dykes) etched out by selective erosion; 8 = Badenian volcanics (andesite agglomerate, tuff, rhyolite tuff); 9 = Sarmatian sediments (clay marl and others); 10 = Upper Pannonian brackish clay and sand; 11 = Quaternary alluvial fans, slope deposits, loess; 12 = Middle Rhyolite tuff; 13 = relief inversion; I = Sarmatian surface of planation, summit level; II = Lower Pannonian piedmont; III = Upper Pannonian (middle) piedmont; IV = Upper Pliocene piedmont (glacis); V = Quaternary surfaces of erosion and accumulation; A = Mátraalja structural basins; B = upper laccolith set; C = lower laccolith set; D = Upper Chattian sandstone scarp; E = erosional basins of he Mátralába; F = erosional basins of the Trans-Mátra region

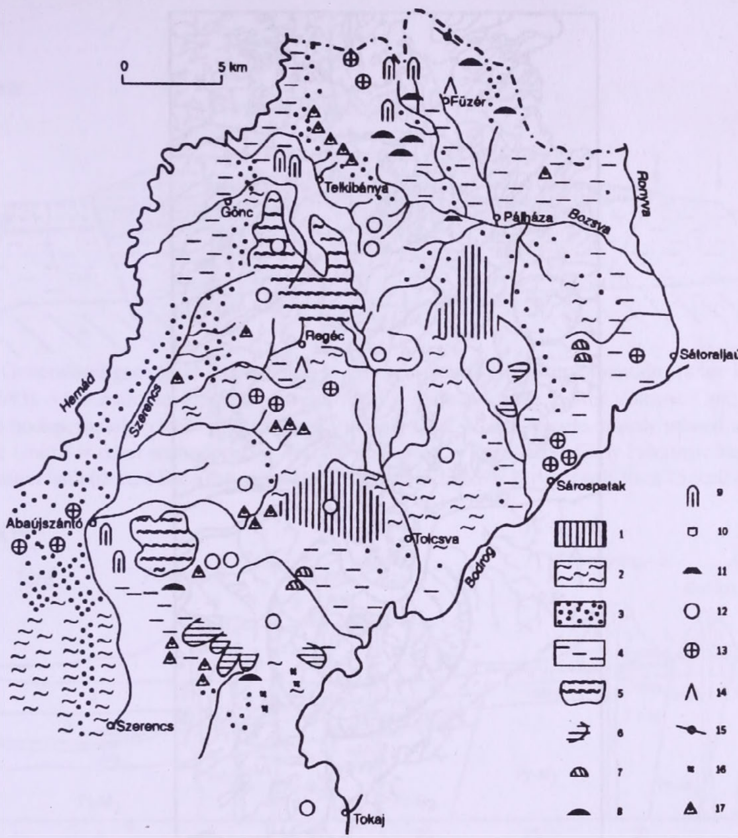


Fig. 9. Surfaces of planation and local forms in the Tokaj Mountains (after PINCZÉS 1989). – 1 = Sarmatian (Upper Miocene) surface of planation; 2 = Upper Pannonian pediment (Upper Miocene); 3 = Upper Pliocene pediment; 4 = Pleistocene cryoglacis; 5 = lava sheet; 6 = lava tongue; 7 = exhumed laccolith; 8 = exhumed subvolcanic body; 9 = exhumed subvolcanic hill; 10 = exhumed dome-like eroded hill; 11 = denuded veins; 12 = volcanic cones of effusive centres; 13 = ruined volcanic cones; 14 = remnants of volcanic neck; 15 = volcanic plug; 16 = remnants of lava sheets; 17 = remnants of hydrothermal volcanic activity

least to interpret volcanic rocks and the minerals enclosed by them (NOSZKY 1940; PANTÓ and FÖLDVÁRINÉ, VOGL, M. 1950).

Since the beginning of the 1970s, following the emergence of the models of orogenesis related to the theory of plate tectonics, the young Inner Carpathian Neogene volcaninc arc has become associated with tectonic movements along a zone of downthrust due to subduction by HORVÁTH, F. (1974); STEGNA, L. (1972) and SZÁDECZKY-KARDOSS, E. (1970, 1972, 1973).

Relief traces of older Paleogene volcanism in the Hungarian Mountains have only *some subordinate role as minor subvolcanic bodies,* which were exposed during the intense Tertiary denudation e.g. subvolcanic andesite necks in the Velence and Mátra Mountains. Remnants of Paleogene andesite volcanics are also present in the environs of the Bakony and Buda Mountains, mostly buried under sediments

Fig. 10. Valley system of the volcanic remnants of the Visegrád and Börzsöny Mountains in the Danube Bend (after GÁBRIS 1986b; SZÉKELY 1997). – 1 = boundary of drainage type; 2 = internal wall of caldera; 3 = assumed external wall of caldera on the outer slope; D = dendritic drainage within the caldera remnant; R = radial drainage; S_1 = on outer slope; S_2 = on inner slope of drainage; G = annular drainage on the slopes of the former lateral cone; G_1 = annular distorted drainage; P = parallel consequent drainage on former lava floor; C = a combination of parallel and distorted drainage; 4 = assumed centre of eruption in the inner caldera; 5 = margin of inner caldera; 6 = margin of outer caldera; 7 = tectonic line: boundary between Mesozoic sediments and Middle Miocene volcanics

(HOFFMAN 1871; KOCH 1872; JANTSKY 1957; SZÉKYNÉ FUX, V. 1957; WEIN 1977; KORPÁS [ed.] 1998).

The most recent investigations found that the oldest Neogene Stratovolcanoes of the Visegrád and Börzsöny mountains were active for a relatively short interval – 15–14 Ma B. P. – in the Middle Miocene according to HÁMOR et al. (1978); BALLA (1978); BALLA and KORPÁS (1980).

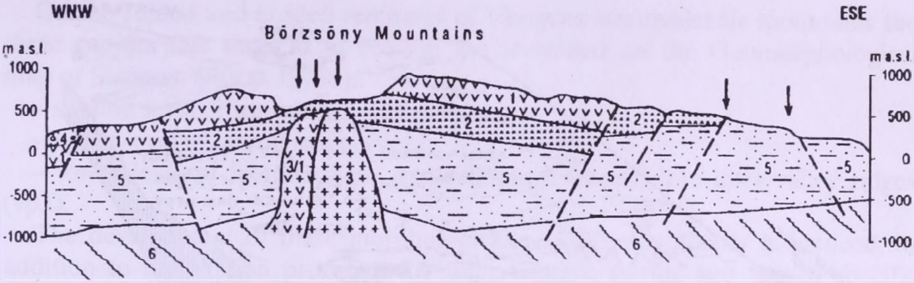


Fig. 11. Generalised geological cross-section of the neovolcanic Börzsöny Mountains (after KORPÁS and LÁNG 1993). – 1 = andesite, Upper Volcanic Unit; 2 = andesite-dacite, Lower Volcanic Unit; 3 = shallow intrusive bodies, mainly related to the Upper Volcanic Unit; 3/1 = andesite, mainly related to the Lower Volcanic Unit; 4 = cover sediments; 5 = Tertiary molasse; 6 = Proterozoic-Early Paleozoic basement; 7 = main fault (dotted line), the age of the volcanism is dated by K/A analysis to ca 15.0±0.4 Ma

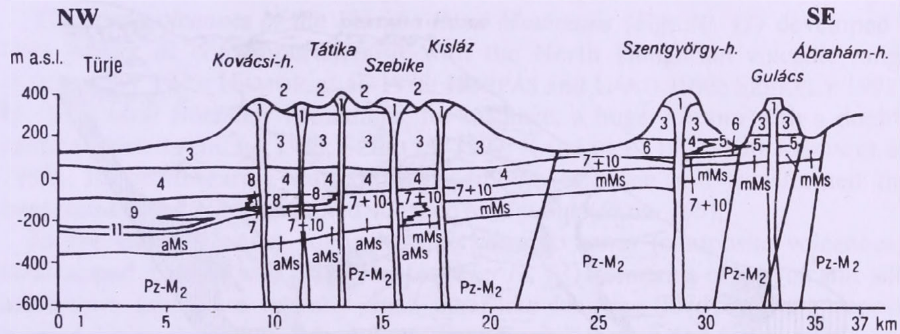


Fig. 12. Basalt buttes in the Tapolca Basin, NW of Lake Balaton (after JÁMBOR 1980). – 1 = Tapolca Basalt (Pontian-Dacian); 2–11 = Pannonian-Pontian (Upper Miocene) marl, clay, sand, gravel deposits; mMs = Sarmatian (Middle Miocene) limestone; aMs = Lower Sarmatian clay, clayey marl; $Pz–M_2$ = Paleozoic, Mesozoic basement

In the central part of both mountains, *huge volcanoes with double calderas* were produced with some parasite-volcanic cones, but because the mountains were transformed by erosion into *ruined volcanoes,* many traces of exhumed *subvolcanic structural forms* (CHOLNOKY 1936; LÁNG 1955b; LENGYEL 1953; VARGA et al. 1975; GYARMATI 1977; SZÉKELY 1997, *Photo 15*; KARÁTSON 1996, 1997, 1999) exist.

The results of geological, geomorphological investigations have been focused on the structural forms (KORPÁS [ed.] 1998, see Figs 4.32, 5.8) and have scarcely dealt with the forms of erosional surfaces.

Major surfaces of planation took shape, at 550–600 m, 600–700 and >800 m above sea level (PÉCSI 1963a, 1976a; PINCZÉS 1960, 1989; SZÉKELY 1993a, 1997. *Figs 8, 9*). It is remarkable that in spite of considerable Pliocene and Quaternary uplift (200–300 m) the drainage pattern also has been shaped by the former calderas (BALLA and KORPÁS 1980; GÁBRIS 1987; NEMERKÉNYI 1986).

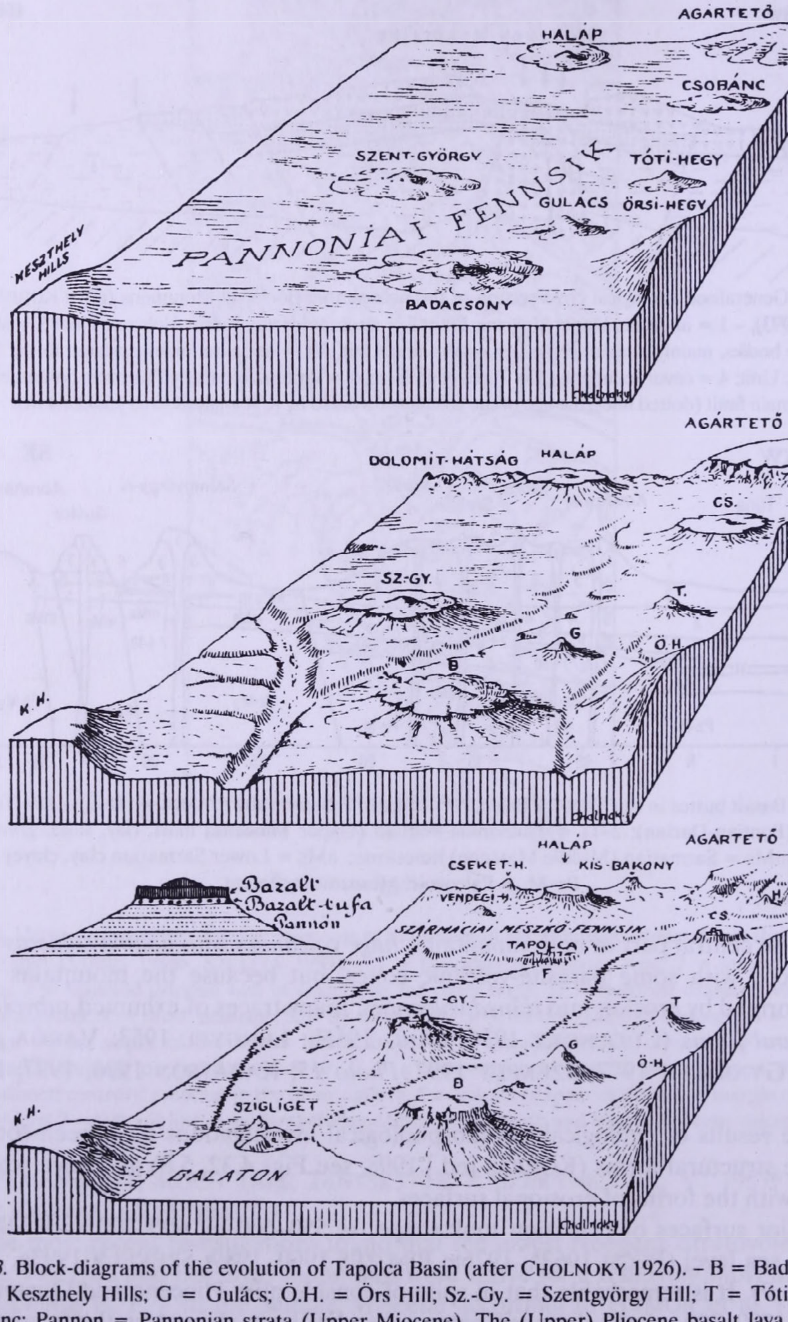


Fig. 13. Block-diagrams of the evolution of Tapolca Basin (after CHOLNOKY 1926). – B = Badacsony; K.–H. Keszthely Hills; G = Gulács; Ö.H. = Örs Hill; Sz.-Gy. = Szentgyörgy Hill; T = Tóti; CS = Csobánc; Pannon = Pannonian strata (Upper Miocene). The (Upper) Pliocene basalt lava on the Tapolca Basin and its vicinity overlie Upper Pannonian unconsolidated deposits and preserved hill surfaces of planation from downwearing (see the buttes of Szentgyörgy Hill in *Fig. 12*)

On the ruined and eroded remnants of Neogene stratovolcanic mountains the three geomorphic surfaces of erosion are identified on the Geomorphological map of Hungary (PÉCSI 1976b):

- summit level or top surface (index vp1),
- upper level of lateral ridges (vp2),
- lower level of lateral ridges or pediment dissected into intra-valley ridges (vp3).

The development of these morphological surfaces was greatly influenced, in addition to denudation processes, by their tectonic setting and by the specific features of their volcanic rock structure (KUBOVICS and PANTÓ 1970, *Photo 16*; PINCZÉS 1989; SZÉKELY 1997; KARÁTSON 1997).

The basaltic lava sheet structures, however, have been mostly preserved Pliocene – i.e. post-Pannonian – foothill surfaces as mesa-buttes that have hardly been affected by denudation (Badacsony, Somló, Medves, stc.).

The *stratovolcanoes of the Danube Bend Mountains (Figs 10, 11)* developed a little earlier or contemporaneously with the North Hungarian volcanic range (CHOLNOKY 1926; HÁMOR et al. 1978; KORPÁS and LÁNG 1993; SZÉKELY 1997). In the central Börzsöny Mountains, for instance, a huge volcano with a double caldera existed (BALLA 1980; SZÉKELY 1997; KARÁTSON 1997; KARÁTSON et al. 1999). Its downwearing started in the Middle Miocene and transformed the mountains into a stepped ruined volcanic mountains (*Photo 16b*).

In the Bakony region young basaltic volcanic cones (composite volcanoes), lava-capped residual hills, basalt buttes (*Figs 12, 13*), remnants of subvolcanic sills are known and more recently small maar-like features filled by shale deposit formed during the Pliocene have been discovered (JÁMBOR and SOLTI 1976). The composite volcanoes on Pontian (Upper Miocene) formations probably extended over Pliocene foothill surfaces affected by pedimentation (LÓCZY 1916; CHOLNOKY 1926; JUGOVICS 1969; JÁMBOR et al. 1980; KORPÁS 1981; BOKOR 1988, 1992).

4. MOUNTAIN FORELAND – FOOTHILLS AND HILLY REGIONS

Meridional valleys

About a quarter of the area of Hungary is *hill regions* built of Oligo-Miocene sands and clays between mountains or in their foreland. In addition to tectonic control, erosional-derasional processes have been important in landform evolution (see also section landforms of derasion).

Various explanations have been suggested for the unique development of the *meridional valleys* and *ridges* of almost exact north to south alignment, particularly striking features in the Zala Hills (see Geomorphological Map of Hungary, in PÉCSI [ed.] 1989, pp. 30–31).

Early this century tectonic control was emphasised. Relying on their research in Inner Asia, LÓCZY Sen. (1913) and CHOLNOKY (1923) attributed a decisive role

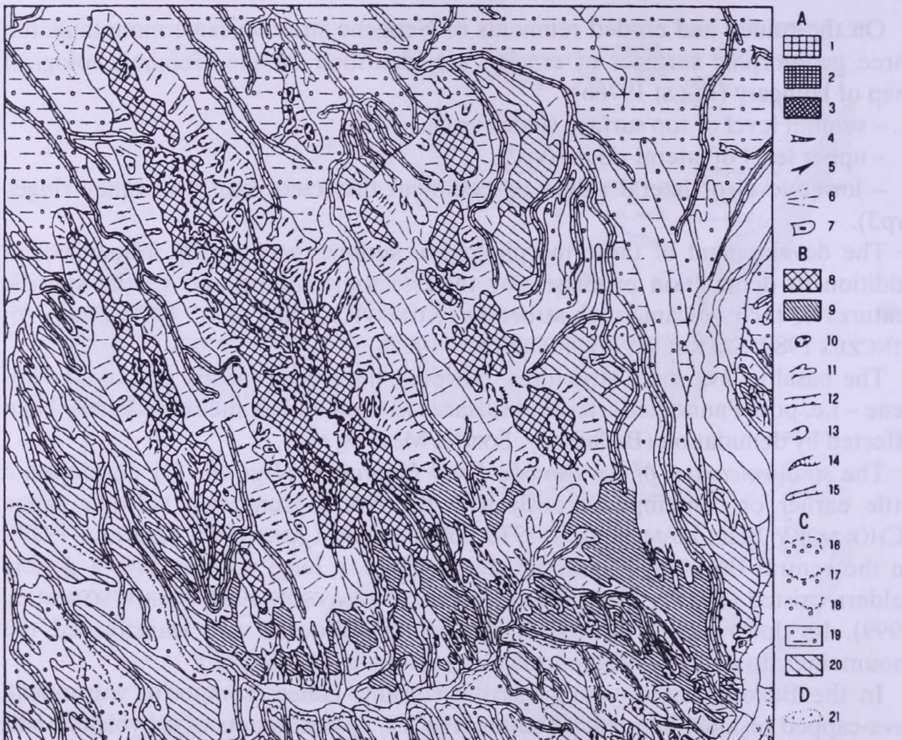


Fig. 14. Geomorphological map of the foreland of the North Bakony and the Pannonhalma Hills (after JUHÁSZ 1988). – A = mountain types: 1 = semi-exhumed horst; 2 = exhumed horst; 3 = piedmont scarps; 4 = dry valleys; 5 = ravines; 6 = taluses; 7 = gentle slope segments; B = hill relief types: 8 = remnants of foothill surfaces in uplifted position; 9 = derasional ridges; 10 = residual hills; 11 = derasional valleys; 12 = erosional-derasional valleys; 13 = derasional cirques, dells; 14 = erosional gullies, gorges; 15 = erosional valleys; C = plain relief types: 16 = glacis and alluvial fans in elevated position; 17 = glacis and alluvial fans in intermediate position; 18 = glacis and alluvial fans in low position; 19 = young alluvial fans; 20 = gently sloping and dissected alluvial-fan ridges; D = floodplains terraces: 21 = waterlogged floodplains; 22 = meander remains; 23 = cut-off stream channels; 24 = water-courses; 25 = terraces of small streams; 26 = landforms of blown sand; E = slope types: 27 = stable slopes; 28 = slopes with sheet erosion hazard; 29 = slopes with landslide hazard; 30 = line of abrupt change in slope inclination; 31 = cliff; 32 = strong siltation; 33 = col

to deflation by wind among other exogeneous processes in the deepening of valleys and removal of material. According to CHOLNOKY the *meridional valleys* of Zala are vast wind furrows and the interfluves are streamlined *residual ridges of yardang type, which developed under Pliocene semiarid climate* (according to new geological time-scale it belongs to the Uppermost Miocene). Even by this theory there are two undoubtedly terracces of Quaternary origin of the Zala river. After CHOLNOKY's concept the Pannonhalma Hills in the foreland of the North Bakony are also residual ridges of yardang type (*Fig. 14,* form B8).

In contrast, BULLA (1954, 1962); SÜMEGHY (1955) and MIKE (1980) underlined the importance of fluvial erosion in the formation of this landscape during the Pleistocene. No reliable sedimentological or geomorphological evidence have been found to support this opinion.

According to PÉCSI (1986b) Upper Pannonian Miocene *cross bedded – Unio wetzleri* – sand also occurs in the *meridional valleys* and on their walls, and therefore, the valleys had been cut before them. In addition, cross-bedded sand does not always indicate fluvial origin but may point to dune structure and consequently, is partly of eolian accumulational origin. This latter phenomenon has rather been neglected. It seems probable that the cross-bedded sands have a specific eolian variety which is difficult to distinguish in space from the fluvial facies. The *meridional valley* is a unique issue at an international and European level. The more than half-a-century long cannot be settled as easily as it has been thought earlier. Moreover, in this debate PÉCSI cannot even exclude the possibility that (part of) the meridional valleys had been shaped before the Quaternary, they were buried subsequently and exhumed again or reshaped during the Pleistocene.

A complex origin has been proposed by SZILÁRD (1967) and LOVÁSZ (1975, 1981). According to PÉCSI (1986b) the valleys and ridges had developed before the Mio-Pliocene boundary, probably during the early *Messinian salinity crisis.*

Most recently SCHWEITZER (1993) found geological evidence (iron crust weathering remnants, desert varnish and ventifacts) of the semidesert climatic conditions which prevailed in the Carpathian Basin during the Late Miocene (SCHWEITZER and SZŐŐR 1992).

Erosional and derasional types of hilly regions

Almost half of the area of geomorphological regions in Transdanubia and North Hungary falls into the category of hills. In Hungarian literature hill regions are defined as surfaces of unconsolidated Tertiary and Quarternary sediments between 200–400 m altitude and predominantly used by agriculture.

In Transdanubia *independent hill* regions have also been *delimited* (*Fig. 15*) while within the macroregions of the Transdanubian and the North Hungarian Mountains *types of hills in mountain foreland* and *in inter-mountain position* have been distinguished (CHOLNOKY 1936; BULLA 1962; PÉCSI and SOMOGYI 1969).

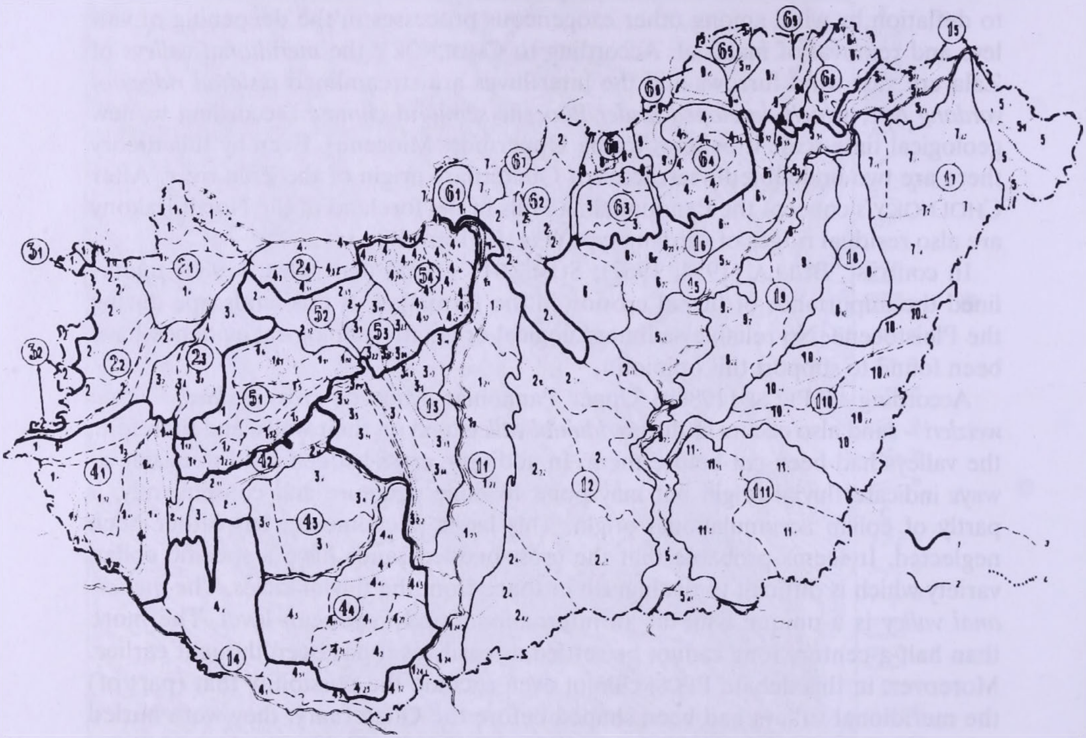


Fig. 15. Geomorphological regions of Hungary (after PÉCSI and SOMOGYI 1969). – 1 = Great Hungarian Plain; 1.1 = Danubian Plain; 1.2 = Danube–Tisza Interfluve; 1.3 = Mezőföld Plain; 1.4 = Dráva Plain and plain of Inner Somogy; 1.5 = Tisza Plain; 1.6 = Northern Great Plain alluvial-fan plain; 1.7 = Nyírség sand region; 1.8 = Hajdúság loess plain; 1.9 = Nagykunság-Hortobágy alluvial plain; 1.10 = Berettyó-Hármas-Körös floodplain; 1.11 = Maros alluvial-fan plain; 2 = Little Plain; 2.1 = Győr Basin floodplain; 2.2 = alluvial-fan plain of Sopron and Vas counties; 2.3 = Marcal Basin; 3 = Foothills of the Alps; 3.1 = Sopron Hills; 3.2 = Kőszeg Hills, Vas county piedmont surface; 4 = Transdanubian Hills; 4.1 = hills of Upper Vas and Zala counties; 4.2 = Lake Balaton Basin; 4.3. = Somogy Hills; 4.4 = Mecsek Mountains and Tolna-Baranya Hills; 5 = Transdanubian Mountains; 5.1 = Bakony Mountains; 5.2 = hills in the Bakony and Vértes mountain foreland; 5.3 = Vértes Mountains and Velence Hills; 5.4 = Danube Bend Mountains; 6 = North Hungarian Mountains and intramontane Basins; 6.1 = Börzsöny Mountains; 6.2 = Cserhát Hills; 6.3 = Mátra Mountains; 6.4 = Bükk Mountains; 6.5 = North Borsod Karst; 6.6 = Tokaj-Zemplén Mountains; 6.7 = Middle Ipoly Basin; 6.8 = hills between the Zagyva and Tarna rivers; 6.9 = Sajó-Hernád Basin; a = boundary of macroregions; b = boundary of mesoregions; c = boundary of subregions; d = boundary of microregions

Over the last 125 years generations of experts have repeatedly studied the hill regions of Hungary for their typical landforms and varied utilisation. The independent and mountain-foreland hills are dissected into interfluvial ridges. The investigation and interpretation of terraced erosional valleys began in the late 19th century (LÓCZY, sen. 1881, 1890; STRÖMPL 1913; CHOLNOKY 1926). At the beginning only two terraces above the floodplain have been described. Then in the wake of research by KÉZ (1937, 1942); BULLA (1934, 1941); LÁNG (1949, 1955b); ISPAITS (1943); KÁDÁR (1955) and KRIVÁN (1958) valleys with four or more terraces have been recognised (PÉCSI 1957, 1959; PINCZÉS 1955; SOMOGYI 1961; ÁDÁM et al. 1962; MAROSI 1965, 1966; SZÉKELY 1977; SZILÁRD 1965b, 1967).

Periglacial cryogenic phenomena were identified in many places on hill slopes and valley sides (cryoplanational or altiplanational terraces, half-planes – KEREKES 1941; PEJA 1941; PÉCSI 1961; PINCZÉS 1974, 1983; SZÉKELY 1969; LOVÁSZ 1975).

A new group of terrace steps and minor head-slopes not indirectly associated with the base level of erosion, *derasional terrace* or *derasional surface* (*Fig. 43, Photo 17*), has also been described on interfluvial ridges, slopes and foothills of hill surfaces mostly built of unconsolidated rock (PÉCSI 1963b, 1964a, b; ÁDÁM 1966; MAROSI 1965; SZILÁRD 1965a, b; MAROSI and SZILÁRD 1969, 1971; LOVÁSZ 1975).

Fluvial valley formation was followed under the ana- and cataglacial types by the formation of flat derasional valleys (dells). The occupied the majority of the slopes of the hill regions (60 to 80 per cent). *The alternation of derasional phases of valley formation with those of infilling resulted in a derasional rolling landscape of low relief coupled with frequent geomorphological inversions on the slopes.* On the other hand, *the foreland of the mountains was subjected to pedimentation through cryoplanation.*

The periglacial processes occurred repeatedly in several phases during the Pleistocene, however, they did not change completely the character of the valley landscape shaped by normal fluvial erosion, they rather remodelled and smoothed it to a considerable extent.

Loess mantle is also a product of the Pleistocene periglacial environment. Typical loess, slope loess, and loess derivates covered and *smoothed the landscape* expecially on plains, plateaus, pediments, river valleys and basins.

During the detailed geomorphological investigations in the 1960s, the development of the summit levels and slopes of hills in the forelands of mountains in Hungary was explained by pedimentation and derasion (PÉCSI 1961, 1963a, b). Previously, in Hungarian literature not only the explanation of *derasional terraces* and *derasional valleys* and their geomorphic significance was missing but even *foothill surfaces* (like *pediments* or *glacis*) failed to be identified as common independent, genetic landforms. From the 1960s on such landforms were identified and mapped along the margins and mountain-foreland hills of most mountains in Hungary (see the geomorphological maps of Hungary and BULLA 1962; PÉCSI 1969b, 1976b, 1987; SZÉKELY 1970, 1972, 1997; JUHÁSZ 1988a, b; KAISER 1997; PINCZÉS 1970).

Enclosed by volcanic ranges, Mesozoic horsts and Paleozoic crystalline mountains, hill regions in basins formed on unconsolidated Tertiary molasses. They are called *basin hills* (PÉCSI 1984b; LEÉL-ŐSSY 1984; MEZŐSI 1985c, *Fig. 16*) because the surfaces of Carpathian inter-mountain basins can be divided – both by their

Fig. 16. Geomorphological map of the Sajó–Bódva interfluve (after MEZŐSI 1985c). – 1 = low planated summit levels of block mountains; 2 = planated plateaus of Mesozoic horsts, 3 = horst surfaces, crests; 4 = horst facets; 5 = summit levels of hills; 6 = (remnants of) pediment; 7 = erosional-derasional interfluvial ridge; 8 = lower floodplain level; 9 = higher floodplain level; 10 = river terrace II/a; 11 = river terrace II/b; 12 = river terrace III; 13 = river terrace IV; 14 = river terrace V; 15 = derasional valley; 16 = erosional valley, gorge; 17 = erosional stream; 18 = erosional-derasional valley; 19 = karst features undistinguished; 20 = lapiés field; 21 = doline or uvala; 22 = line of bacthycapture; 23 = entrance to cave of considerable length; 24 = slope undistinguished; 25 = barren rocky slope; 26 = eroded slope; 27 = unstable slope; 28 = major landslide; 29 = slope with landslide hazad; 30 = river; 31 = type of river mechanism; 32 = lake or swamp; 33 = major opencast mine; 34 = major settlement

geology and geomorphology – into groups or ranges of hills or foothill surfaces of various length and basin floor sections.

The summit-level interfluvial ridges of inter-mountain hill regions *as well as of mountain forelands* can be interpreted *as foothill glacis remnants.* According to many researchers (PÉCSI 1963a, 1964c; PINCZÉS 1970; SZÉKELY 1970; JUHÁSZ 1983, 1988; MEZŐSI 1985c; SCHEUER and SCHWEITZER 1988, *Photo 18*; SCHWEITZER 1993; SZABÓ 1996, Figs 34, 40; KAISER 1997), they took shape under the warm, semiarid, mediterranean-type of climate following Upper Pannonian lacustrine-marine sedimentation.

In addition to erosion, the investigations of the geomorphologists mentioned in this chapter suggest that in the *Quaternary cryoplanation and derasion were decisive in the resculpturing of lower interfluvial ridges and foothill surfaces and in the development of hill landforms.*

5. EVOLUTION MODELS FOR THE HUNGARIAN GREAT PLAIN

The greater part of Hungary lies in an extensive lowland basin encircled by the Alps, Carpathians and Dinaride ranges. This is called the *Carpathian Basin, subdivided disproportionately into three partial basins* by the Transdanubian and Bihor Mountains of SW–NE strike (*Fig. 17*). Several hypotheses have been proposed to explain the mechanisms of Neogene to Quaternary tectonic subsidence.

Because the basins locally with up to several kilometres deep sedimentary molasses store vast amounts of artesian water, tens of thousands of wells have been bored during the last two centuries (URBANCSEK 1963–1980, *Photo 19*). In the past decades many thousands of oil and gas exploration wells were added in the basins (BOHN 1975–1990, *Photo 20*, KŐRÖSSY 1989–1990, 1994; POGÁCSÁS et al. 1990; SCHMIDT 1937).

Fig. 17. Position of the Carpathin Basin within the Alpine-Carpathian system (compiled by RAISZ, E.) The Pannonian Basin is divided into two separate sub-Basins, the Little Hungarian Plain (1) in the west and the Great Hungarian Plain in the east (2), the Transylvanian Basin (3) is bordered by the Eastern and Southern Carpathians and the Transylvanian Central Mountains

The information available at the turn of the 20th century made it possible to identify four stages in the filling of the basins. The predominant processes in this filling initially were the sea–floor deposition in an inland sea (Pannonian[5]), deposition in a brackish to freshwater lake, river (alluvial) and delta sedimentation, finally wind action with eolian deposition (HALAVÁTS 1888, 1891a, b, 1895, 1896; LŐRENTHEY 1911; LÓCZY, sen. 1918; PRINZ 1914 and their followers).

By the middle of the 20th century geologists had described many facies in the Pannonian inland sea sequence: littoral gravels, fluviatile gravels, deltaic sands and, attesting to deeper water, clays SÜMEGHY (1944, *Photo 21*) and STRAUSZ (1941, 1949). Some geologists suggest that the stage of marine accumulation, fluvial-deltaic deposition occasionally stretched into the centre of basins, i.e. there were major spatial and temporal variations in the area of inundation (JÁMBOR et al. 1987; JUHÁSZ 1994; KŐRÖSSY 1982; URBANCSEK 1963–1980).

Most recent views are in accordance with a *new working hypothesis* that the *structural evolution* of the basement of the basin may have *terminated in the Miocene* with a major horizontal wedging from the direction of the Adriatic sea (SZÁDECZKY-KARDOSS 1970; BALLA 1982; CSÁSZÁR et al. 1982; FÜLÖP 1989; HORVÁTH 1995; HAAS and HÁMOR 1996; *Photo 22*).

The Pannonian Sea had shrunk in extension gradually and ceased to exist. In the Plio-Pleistocene *lacustrine, fluvial and mainly terrestrial deposition* took place. Previously, larger post-Pannonian lakes were assumed to fill the partial basins and opinions vary substantially about their location, extension and duration (*Lake Csalló* – PRINZ 1926, *Levantan Lake* in the present-day territory of Croatia and of the southern Great Plain – HALAVÁTS 1891a, b; SZÁDECZKY-KARDOSS 1938a; SÜMEGHY 1955).

In the sequence of Pannonian marine deposition four interruptions under the late Neogene semidesert conditions on the basin margins were assumed (POGÁCSÁS et al. 1994).

The Great Hungarian Plain comprises several partial basins. In the Pannonian (ca 12 to 5.3 Ma) repeated gaps of marine deposition have been found and infilling shifted from the margins towards the centre: first marginal basins were filled by the prograding deltas of inflowing rivers. Most recently, it is interpreted that the most extensive and longest subsiding basin section, the southeastern part, was filled through the merging of extensive delta plains of gentle slope and ca 6000 m deep molasses accumulation was found in the Békés Basin (after POGÁCSÁS et al. 1990).

Comparing paleomagnetic and seismic data for the marginal sediment sequence of the Pannonian Basin, it can be concluded that the accumulation of Pannonian marine sediment was interrupted by four major gaps at 4.6–5.4, 5.7–6.8, 7.6–7.9 and 10.5–11.5 Ma B.P. Thus almost half of the Pannonian stage is characterised by erosion gaps indicating terrestrial evolution (POGÁCSÁS et al.

[5] At that time Pannonian marine deposits were referred to the Lower and Middle Pliocene. Today they are dated Upper Miocene (between 12 and 5,4 million years).

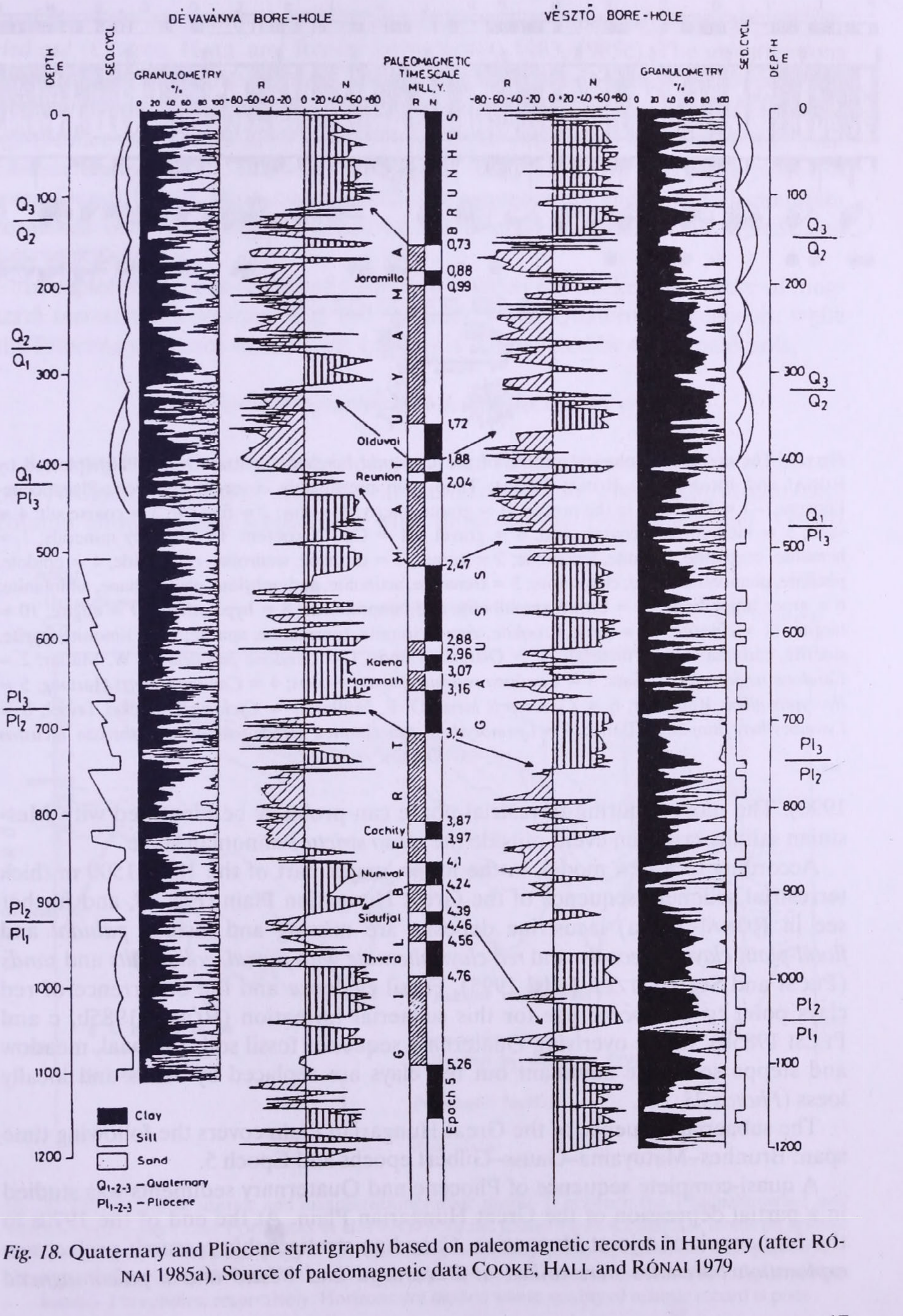


Fig. 18. Quaternary and Pliocene stratigraphy based on paleomagnetic records in Hungary (after RÓNAI 1985a). Source of paleomagnetic data COOKE, HALL and RÓNAI 1979

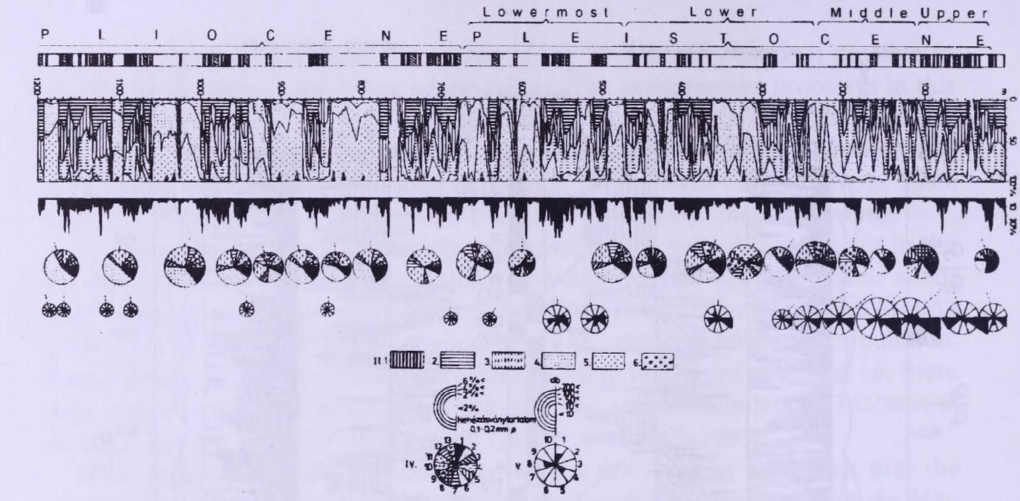


Fig. 19. The complex geological profile of the *Csongrád borehole,* central Great Plain (plotted by RÓNAI and FRANYÓ in: RÓNAI 1985a). Time span presumably covered: Holocene-Pleistocene-Pliocene. – I = Paleosols in the profile. II = granulomerty: 1 = clay; 2 = fine silt; 3 = coarse silt; 4 = sand; 5 = medium and coarse sand; 6 = gravel. III = $CaCO_3$ content. IV = heavy minerals: 1 = hematite, magnetite, ilmenite, leucoxene; 2 = garnet; 3 = disthene, staurolite, chloritoide; 4 = epidote, pistacite, piemontie, zoisite, clinasoisite; 5 = tremolite, actinolite, anthophyllite, glaucophane, sillimanite; 6 = green amphibolite; 7 = brown amphibolite and lamprobolite; 8 = hypersthene; 9 = augite; 10 = biotite; 11 = chlorite; 12 = rutile, brookite, zircon, titanite, tourmaline, apatite; 13 = limonite, pyrite, siderite, carbonates, clay minerals. V = Ostracoda finds: 1 = *Candona parallela* G. W. Müller, 2 = *Candona neglecta* G. O. Sars; 3 = *Candona rostrata* BRADY-NORM; 4 = *Candona protzi* Hartwig; 5 = *Ilyocypris gibba* Ramdohr; 6 = *Cyclocypris laevis* O. F. Müller; 7 = *Cyclocypris huckei* Tribel; 8 = *Lymnocythere inopinata* Baird; 9 = *Lymnocythere sanctipatricii* Brady-rob; 10 = *Cytherissa lacustris* G. O. Sars

1990). The most enduring terrestrial phase can probably be identified with Messinian salinity crisis, an event outside the *senso strictu* Pannonian stage.

According to a new model, in the lower, major part of the 1000–1500 m thick terrestrial sediment sequence of the Great Hungarian Plain (*Fig. 18*, and further see in RÓNAI 1985a) lacustrine deposits are missing and instead *paludal* and *flood-plain clays, paleosols* and *red clays alternate* with *fluvial, eolian silts* and *sands* (PÉCSI and SCHWEITZER [eds] 1995). Fossil evidence and the occurrence of red clays point to a *Pliocene age* for this subaerial formation (RÓNAI 1985b, c and PÉCSI 1985b). In the overlying Quaternary sequence fossil soils (alluvial, meadow and steppe soils) are abundant but red clays are replaced by sands and locally loess (*Photos 23, 24*).

The subaerial sequence of the Great Hungarian Plain covers the following time span: Brunhes–Matuyama–Gauss–Gilbert epochs and Epoch 5.

A quasi-complete sequence of Pliocene and Quaternary sediments was studied in a partial depression of the Great Hungarian Plain. At the end of the 1970s in the framework of a joint Hungarian–Canadian stratigraphic research project *two exploration boreholes were drilled at Dévaványa and Vésztő and a paleomagnetic* *analysis of the core samples of 1100 and 1200 m thick subaerial sequences was carried out* (COOKE, HALL and RÓNAI 1979; RÓNAI 1983, 1985c). The investigations revealed 5 paleomagnetic epochs. These boreholes did not reach the Upper Pannonian (Upper Miocene) lacustrine sediments. *These records of great scientific significance has not yet been used sufficiently for chronological correlation of past climatic change events.* In these boreholes as many as three times more paleosols were found than in the loess and subaerial sequences of the hills and mountain forelands over the marginal zones of the Great Hungarian Plain (PÉCSI and SCHWEITZER 1991).

In exploration wells described by RÓNAI (1985a) the thickest sequence of long-term terrestrial deposition (*Fig. 19*), includes 50–60 Quaternary paleosols, while the Pliocene sequence of sand, silt and clay is intercalated by 45–55 paleosols.

Seismostratigraphic and deep reflection survey

A survey *borehole at Csongrád* near the Tisza River exposes the basin sediments of a Neogene depression in the Great Hungarian Plain. The lithostratigraphical column shows strong similarities with those of the Dévaványa and Vésztő

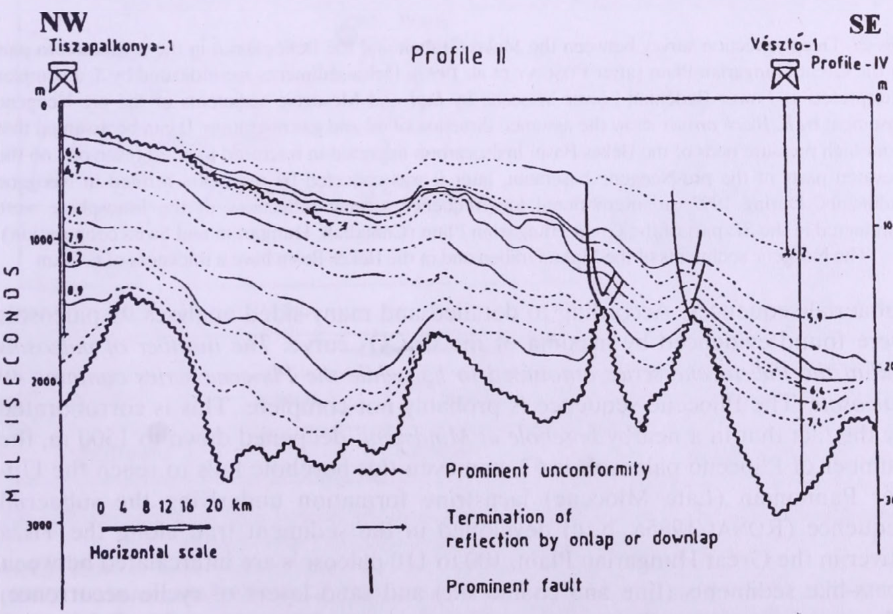


Fig. 20. Correlation of seismic and magnetostratigraphic profile II between the Tiszapalkonya–1 and Vésztő–1 boreholes (after POGÁCSÁS et al. 1994). With the exception of 4.2 and 5.9, labels on seismic horizons indicate inferred age (My) of corresponding magnetic polarity epoch at the Tiszapalkonya–1 borehole. The horizons labellad 4.2 and 5.9 refer to polarity epochs identified in the Vésztő–1 and Kaskantyú–2 boreholes, respectively. Horizons are dashed where quality of seismic record is poor

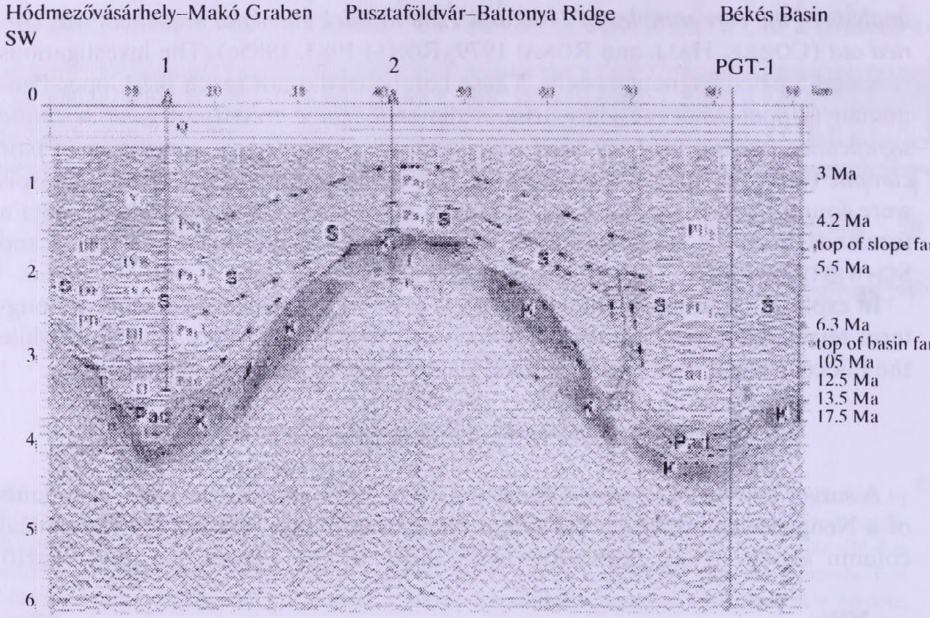


Fig. 21. Deep reflection survey between the Makó Graben and the Békés Basin in the southeastern part of the Great Hungarian Plain (after POSGAY et al. 1996). Delta sediments are indicated by *S*, a complex interpreted as Lower Badenian-Lower Miocene by *Bad* and Mesozoic sediments of the pre-Neogene basement by *K*. *Black arrows* show the assumed direction of oil and gas migration. It can be assumed that from high pressure beds of the Békés Basin hydrocarbon migrated in fractured fissured reservoirs on the elevated parts of the pre-Neogene basement, later it was collected by reservoirs formed in Neogene sediments. During 1992 an international low-frequency seismic reflections of the lithosphere were conducted in the SE part of the Great Hungarian Plain (Canadian, Hungarian and Swiss cooperation).

The Neogene sediments of the Makó Graben and in the Békés Basin have a thickness of 6–7 km

subaerial sequences. According to detailed and many-sided analyses 95 paleosols were found evidenced by maxima of the $CaCO_3$ curve. *The number of paleosols within the Pleistocene series amounted to 55, while the Pliocene series contains 40 paleosols.* The Pliocene sequence is probably not complete. This is corroborated by the fact that in a nearby *borehole at Mindszent,* deepened down to 1500 m, the number of Pliocene paleosols is 67, and even this borehole fails to reach the Upper Pannonian (Late Miocene) lacustrine formation underlying the subaerial sequence (RÓNAI 1985a, b, c) developed in the sediment trap along the Tisza River in the Great Hungarian Plain. 100 to 110 paleosols are intercalated between loess-like sediments (fine and coarse silt) and sand layers of cyclic occurrence. The number of the Pleistocene paleosols amounts to about 50. RÓNAI, A. (1985a), who carried out investigations of several boreholes in the region and evaluated the results, found more than 25 cyclic changes in the past climate based on the Quaternary subaerial sequences.

On the basis of the detailed geophysical investigations of the Great Hungarian Plain POGÁCSÁS (1990; 1994) *correlated the* above-mentioned *long-term* *magnetostratigraphic* and the *seismostratigraphic sequences* in Southern Hungary (*Fig. 20*).

In international (Hungarian–Canadian–Swiss) cooperation the *EÖTVÖS Loránd Geophysical Institute performed deep reflection seismic measurements in the Great Hungarian Plain* in order to survey and evaluate the Neogene sequence *along the "Hungarian geotraverse"* (POSGAY et al. 1996, *Fig. 21*).

A younger than ca 6 Ma B.P. series with considerable thickness of deltaic deposits in its basal part can be followed along the whole length of the profile (*Figs 20, 11*). According to seismo-, sequence and magnetostratigraphical investigations and radiometric dating by VAKARCS et al. (1994), the shallow sea was isolated from world ocean and became a lake on the Sarmatian/Pannonian boundary (11.5 Ma). At the end of the Sarmatian and beginning of Pannonian, the deepening of the Békés Basin and of the Hódmezővásárhely–Makó Graben (south-eastern part of the Great Hungarian Plain) was more rapid than sediment accumulation so they were relatively starving basins (POGÁCSÁS et al. 1989).

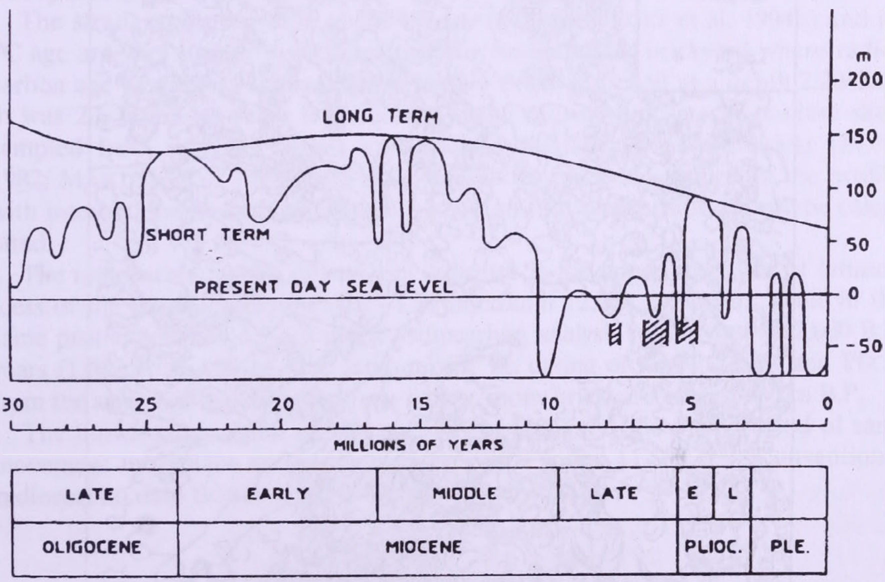


Fig. 22. Conceptual correlation between sea level eustatic fluctuations and the non-marine depositional periods of the Pannonian Basin (after POGÁCSÁS et al. 1994).

Meters above or below present-day sea level are approximate. Figure modified from HAQ and others (1987). Hachured areas (7.9–7.6, 6.8–5.7 and 5.4–4.6 Ma B.P.) show non-depositional periods on the flanks of the Pannonian Basin. These periods of non-depositional appear to correlate with the eustatic sea level minima of 7.8 and 5.2 Ma B.P. PLE = Pleistocene. At least 3 sediment gaps were identified on seismic profiles from the northern margin of the Pannonian Basin. These appear to correlate with global eustatic sea level minima (7.9–7.6, 6.8–5.7 and 5.4–4.6 Ma B.P.). The Pannonian inland sea, probably slowly became isolated from the world oceans, and fluctuated in phase with the global sea level changes. The so-called *Messinian salinity crisis* can probably be correlated with the Messinian global stage (6.8 and 5.7 Ma?)

There are three explanations for the origin of the surficial sand cover and loess mantle and the prevailing geomorphic processes:

1. The sand layers on the surface and intercalated into loess acre both alluvial fan materials reworked by wind into dunes (BULLA 1939, 1962; SÜMEGHY 1955; MAROSI 1958; FRANYÓ 1964 and others).

2. They are mostly eolian sands blown out from river beds (MIHÁLTZ 1967; MOLNÁR 1961; MOLNÁR et al. 1995).

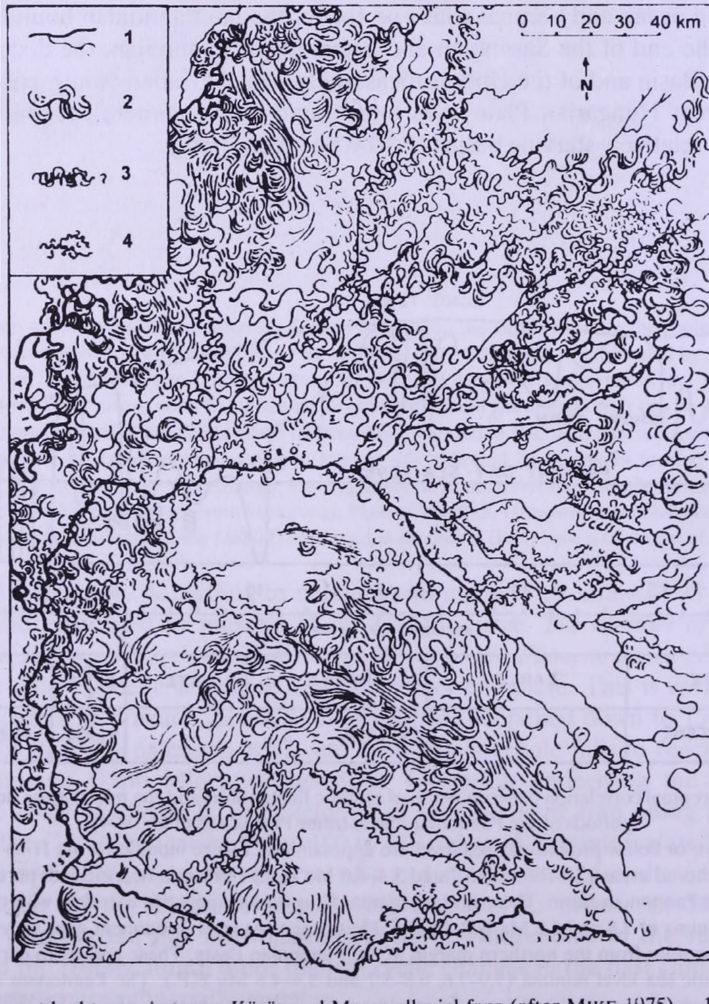


Fig. 23. Recent bed traces between Körös and Maros alluvial fans (after MIKE 1975). – 1 = present-day hydrography 2 = Tisza-size bends (amplitude = 600 m, length of arch 7 2000 m; length of chord = = 1000 m); 3 = Maros-size bends, 4 = Körös-size bends

3. Some envisage a complex (fluvial and eolian) genesis (BORSY 1990; MÁRTON et al. 1979; PÉCSI 1993a and SOMOGYI 1978). This interpretation is also backed by recent laboratory results (BORSY et al. 1982; LÓKI et al. 1994a, b).

The proponents of prevailing fluvial action in the Quaternary geomorphic evolution of the plains assume thousands of metres of subsidence in some parts of the basins (accompanied by the uplift of the mountain frame) and, consequently, *alluvial fan formation was important throughout the Quaternary* (*Fig. 23*). Wind action only played a retouching role in alluvial fan formation and locally accumulated sand dune regions (BORSY 1991; MAROSI 1967; PÉCSI [ed.] 1989, National Atlas of Hungary maps No. 30–31).

The extensive, 1–3 m thick *infusion loess* derives from floodplain loessy silt and considered a loess derivate variety (HORUSITZKY 1898; SÜMEGHY 1944, 1955; PÉCSI 1993a).

In contrast, those on the ground of the eolian theory (MIHÁLTZ 1967; MOLNÁR 1961 and RÓNAI 1985a, c) regard infusion loess a product of dustfall on the floodplain.

The stratigraphical profile of the Abony brickyard (LÓKI et al. 1994b) and its ^{14}C age are very similar to those of the Törökszentmiklós brickyard where radiocarbon age of mollusc shell collected from a flood-plain soil at a depth 2.20–2.60 m was 20, 100±300 years B.P. Based on the radiocarbon age of mollusc shell sampled from infusion loesses at Hódmezővásárhely and Tiszaföldvár (PÉCSI 1982; MÁRTON et al. 1979) and from the Abony brickyard section of the profile with interbedded flood-plain soils a 2–2.5 ka/m rate of deposition could be calculated.

The radiocarbon dating of molluscs indicates in the uppermost layer of infusion loess of the Abony brickyard (1.25–1.50 m) round 12,000 B.P. years, while in the same profile between 4.5–5.0 m the radiocarbon analysis results round 22,000 B.P. years (LÓKI et al. 1994b). The most recent TL dating of A. FRECHEN and PÉCSI from the same layers of infusion loess of the Abony brickyard gave 45–55 ka B.P.

The blown sand region of Nyírség (NE of Hungary) the main period of sand movement took place during the *Younger Dryas* round 11,500 B.P. (conventional radiocarbon date BORSY et al. 1982; LÓKI et al. 1994a).

6. QUATERNARY AND LOESS RESEARCH

This has been a discipline with a long-lasting and significant tradition within the geosciences in Hungary, achievements of which have gained reputation and its representatives have been highly respected internationally (LÓCZY 1890–99, 1913; CHOLNOKY 1910, 1911; KORMOS 1909, 1912; SCHERF 1935, 1936; SZÁDECZKY-KARDOSS 1936, 1938a; BACSÁK 1940, 1942; KRETZOI 1953, 1956; SÜMEGHY 1944, 1955).

As a result, the International Union for Quaternary Research (INQUA) requested Hungary to organise its congress in 1948. The preparatory work of the congress and field excursions lasted for long years during which a close professional cooperation was established among the Hungarian experts in Quaternary research being proud to host the meeting. This made a profound impact on the development of the subsequent research work. Regretfully, the Ministry of Interior cancelled the congress referring to the tension in international politics. Scientific links at an international level were reestablished only in the years of detente during the 1960s; since then several symposia with field trips were organised in Hungary and series of volume of studies and proceedings were published (BACSÁK 1955; KRIVÁN 1953, 1955; KORDOS 1981, 1987; PÉCSI 1964a, 1985b, 1993, 1997a; PÉCSI and VELICHKO [eds] 1987; PÉCSI and STARKEL [eds] 1988; PÉCSI and FRENCH [eds] 1987; PÉCSI and KRETZOI [eds] 1985; PÉCSI and RICHTER 1996; PÉCSI and SCHEITZER [eds] 1991, 1995; RÓNAI 1972, 1985a; *Photos 25–27*).

Until the 1950–1960s, the time frame of *Pleistocene climatic evolution,* based on the studies by MILANKOVITSCH (1941) and in accordance with the climatic calendar by BACSÁK (1942, 1955) was considered by Hungarian geologists and geographers-geomorphologists for the past 600,000 years (the so-called short Pleistocene period, *Table 3*).

Table 3. Major changes of climate types during the (classical short-term) Pleistocene along the 55° N latitude, based on data of MILANKOVITSCH (1930, 1941) and BACSÁK (1940, 1942) after BARISS (1953–1954, 1991), partly modified

Periods of culmination (B.P.) and solar climate types	Thousand years (ka)	Amplitudes (in canonic units)	
		Qs	Qw
1 800 st	5 700	– 136	154
11 100 a	10 600	438	– 367
22 100 W III	9 500	– 456	375
32 700 sa	12 000	– 46	– 22
47 100 st	13 700	107	– 31
55 000 a	3 100	76	– 62
60 600 sa	9 500	– 139	– 157
71 800 W II	11 200	– 546	473
85 000 a	7 500	468	– 423
94 000 st	11 500	187	268
105 100 sa	10 400	187	– 267
116 100 W I	11 400	– 644	569
127 700 a	11 200	529	– 471
145 500 g	5 500	–234	194
152 200 sa	12 300	138	– 190
164 300 st	10 200	–248	282
175 000 a	9 800	528	– 482
187 500 R II	10 800	– 643	588
198 500 Sa	8 900	– 399	– 431
209 600 st	12 000	– 344	326
220 000 a	5 400	– 518	– 494
230 000 R I	11 000	– 676	570

Table 3 (continued)

Periods of culmination (B.P.) and solar climate types	Thousand years (ka)	Amplitudes (in canonic units)	
		Qs	Qw
249 200 g	6 000	250	– 170
280 000 a	8 500	– 395	350
292 700 g	10 400	554	– 493
305 000 sa	4 000	– 387	368
313 400 g	10 300	– 139	– 201
323 300 a	7 500	– 393	364
332 800 a	8 800	413	– 357
374 000 g	10 000	405	– 349
299 200 a	9 400	– 331	271
410 000 a	5 600	214	– 160
424 000 M II	6 800	235	– 209
435 500	10 300	– 529	440
444 000 sa	9 000	207	215
454 800 st	11 700	– 216	286
465 000 s	6 000	481	475
475 600 M I	10 400	– 601	556
486 100 sa	8 000	339	– 360
497 100 st	11 100	– 145	170
537 800 a	11 500	429	– 387
550 000 G II	7 900	– 479	459
559 500 sa	10 500	365	414
569 400 st	7 400	– 498	515
579 700 a	10 300	715	– 647
59 300 G I	8 900	– 555	515

Amplitudes with negative sign: deficit of radiation. Qs = summer half years; Qw = winter half years; W, R, M, G = Würm, Riss, Mindel, Günz; a = antiglacial (strongly continental, after BARISS); sa = subarctic (moderately oceanic, after BARISS); st = subtropic (moderately continental, after BARISS); g = glacial (strongly oceanic, after BARISS). Climate types (based on BACSÁK 1940, modified by BARISS): strongly oceanic (DUs>–1.8°), moderately oceanic (–1.8°>DUs>–0,6°), strongly continental (DUs> +3.5°), moderately continental (+3.5°>DUs> +0.6°)

Principally the loess formation and the deposition of terrace gravel (though the latter not in all cases) *are assumed to have been associated with Pleistocene glacials (or with stadials), while soils (and sand layers) buried in loess and terrace formation were correlated with interglacals* (*Fig. 24*).

When studying landforms and sediment sequences in Hungary and subdividing loess series and terraces chronologically, *these principles of loess-paleosol stratigraphy* and *terrace geomorphology* served as a starting point together with the *biostratigraphical principle* of the vertebrate and mollusch fauna and pollen sequence cyclicity (KRETZOI 1953, 1969; MOTTL 1941, 1942; JÁNOSSY 1979, *Photo 28*; KORDOS 1987; KROLOPP 1977, 1979; JÁRAINÉ KOMLÓDI 1987; ZÓLYOMI 1987) until the 1980s.

There had been discrepancies in the establishment of the beginning of Pleistocene and of the Tertiary–Quaternary boundary. Adoption of the so-called

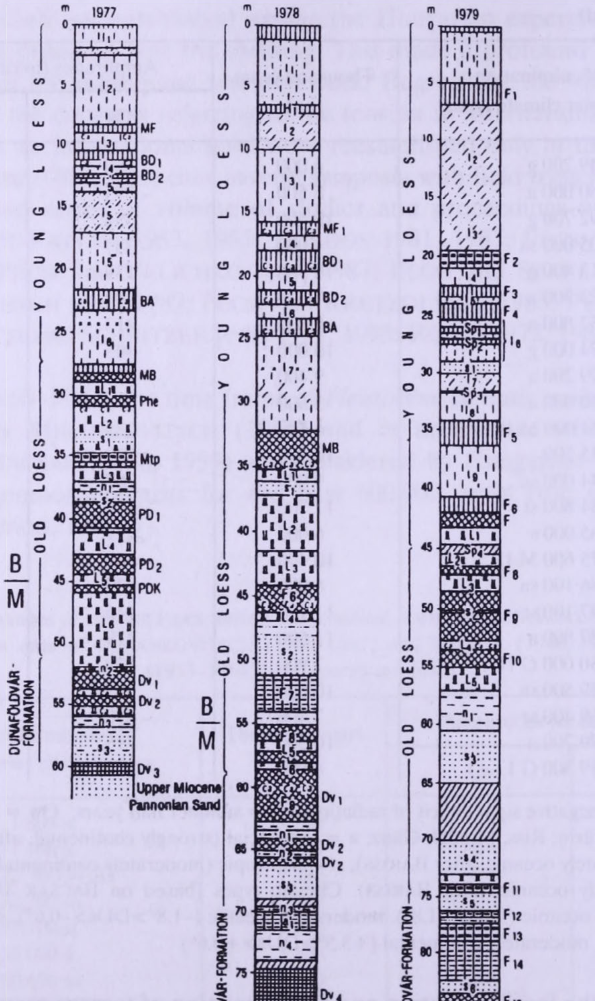


Fig. 24. Lithostratigraphy of the exposures in the Paks brickyard (Paks 1977) and of boreholes in the vicinity of Paks (boreholes Paks 1978 and Paks 1979) (after Pécsi and Pevzner 1974; Pécsi 1997a; see also *Tables 4* and *5*)

"long Pleistocene period" (1.8–3.0 Ma, *Table 4*) became general among Hungarian geologists and geomorphologists following the 1980s (KRETZOI 1983, 1987; KRETZOI et al. 1982; KRETZOI and PÉCSI 1982; PÉCSI 1985b, 1993a, 1996b; RÓNAI 1985a; JÁMBOR 1997; FRANYÓ 1982; KROLOPP 1982). For the subdivision of this Quaternary of longer duration and of a new concept, for the establishment of chronology of terraces, loess sequences and geomorphic surfaces mainly covered by freshwater limestones (travertines), radiometric and paleomagnetic methods of dating had been involved as well (PÉCSI and PEVZNER 1974; MÁRTON 1979a, b; PÉCSI and SCHWEITZER 1991; FRECHEN et al. 1997; ZÖLLER et al. 1994). Several Hungarian institutions and foreign laboratories have taken part in the solution of these tasks (PÉCSI et al. 1985, *Table 2* on page 57; PÉCSI and SCHWEITZER [eds] 1995. Fig. 2 on page 65).

For a chronostratigraphical subdivision a lithostratigraphical profile was selected where probably the least number of gaps are found. No uninterrupted profile could be identified. For the same reasons the paleosols in the loess profiles are not numbered continuously (like S_1, S_2, etc), since their sequence – because of erosional gaps – does not always reflect the same stratigraphical or chronological position. Paleosols are marked with indices according to the locality of their best development and to their pedotypes.

A frequently occurring question is: what kind of a time-scale should be used to correlate the long-term loess-paleosol sequences?

1. The *loess-paleosol stratigraphical procedure* is only capable of providing an approximative loess chronology with general information.

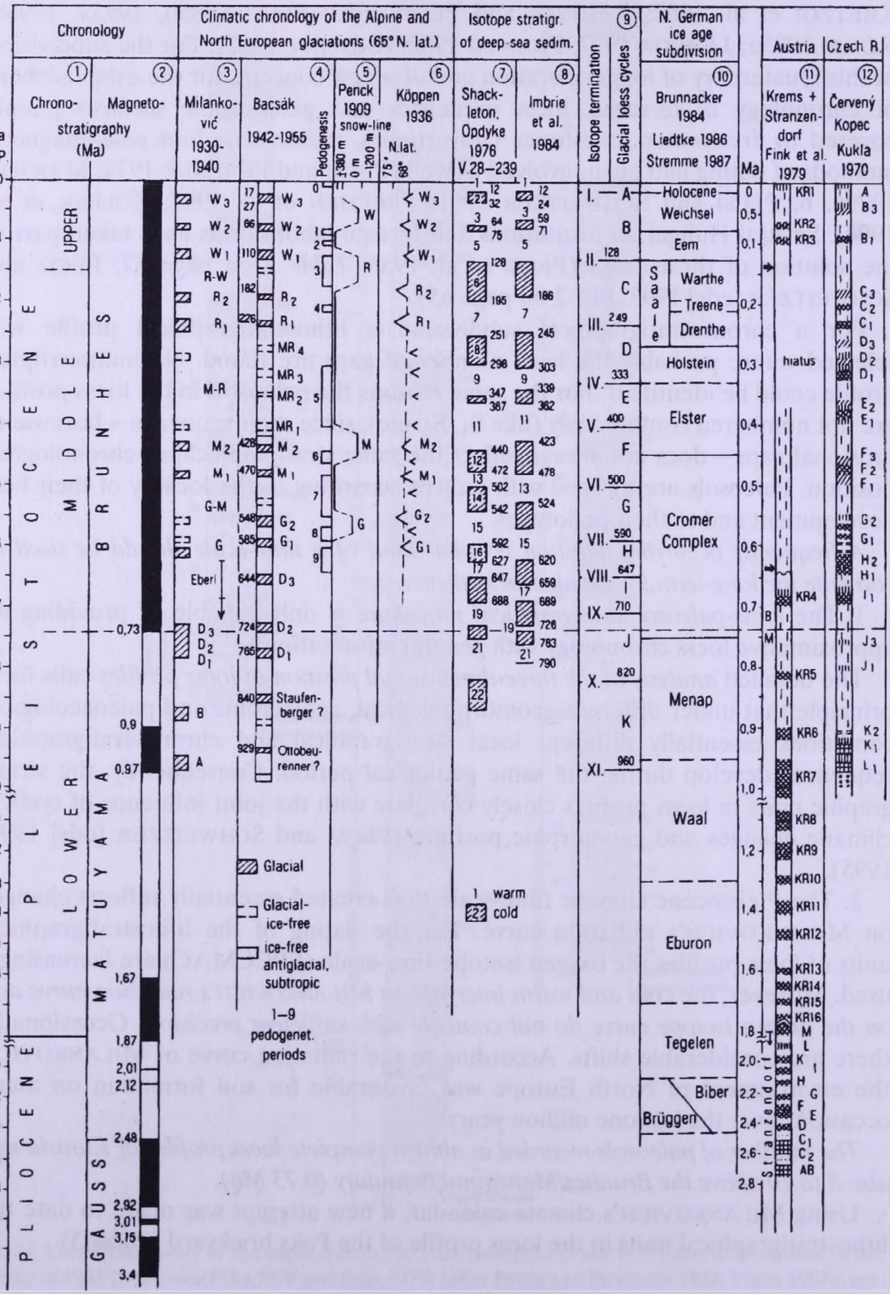
The detailed *analysis of the three-dimensional position of loess profiles* calls for a principle that under different geomorphological, geotectonic and paleoecological conditions essentially different loess stratigraphical and chronostratigraphical sequences develop during the same geological period. Consequently, the stratigraphic units in loess profiles closely correlate with the joint influence of cyclical climatic changes and geomorphic position (PÉCSI and SCHWEITZER [eds] 1991, 1995).

2. The Pleistocene climatic time-scale thus created essentially reflects changes on MILANKOVICH's radiation curve. For the dating of the lithostratigraphical units of loess profiles the oxygen isotope time-scale (SPECMAC) are increasingly used. Morever, the *cold and warm intervals on MILANKOVICH's radiation curve and on the oxygen isotope curve do not coincide with sufficient precision.* Occasionally, there are considerable shifts. According to the radiation curve of MILANKOVICH the environment of North Europe was favourable for soil formation on many occasions over the last one million years.

The number of paleosols recorded in almost complete loess profiles of Eurasia was also 8 to 10 above the Brunhes/Matuyama boundary (0.73 Ma).

Using MILANKOVICH's climate calendar, a new attempt was made to date the lithostratigraphical units in the loess profile of the Paks brickyard (*Table 5*).

Table 4. A possible correlation between Pleistocene climate chronology, oxygen isotope stages and loess-paleosol stratigraphy (after PÉCSI 1995)



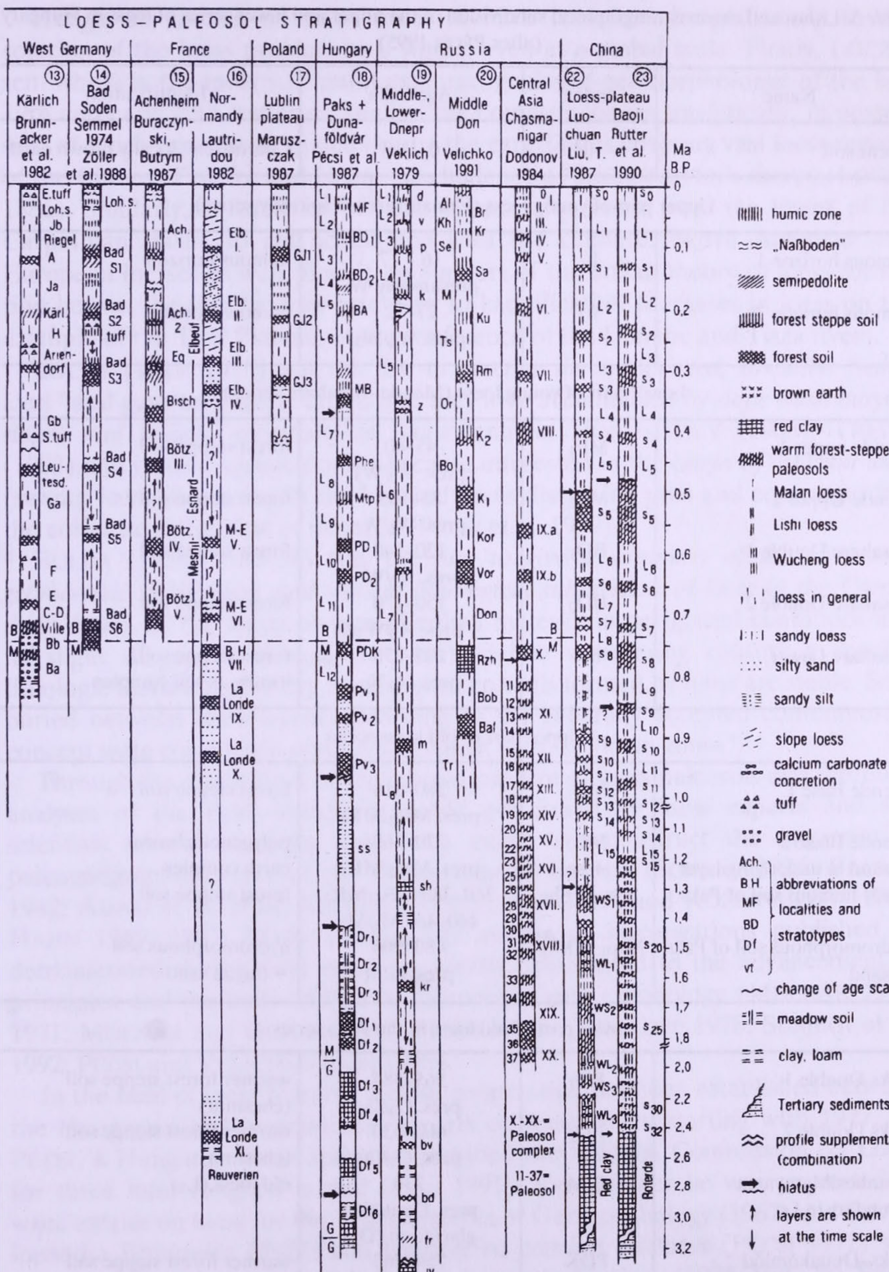

LOESS–PALEOSOL STRATIGRAPHY
West Germany
France
Poland
Hungary
Russia
China
⑬ Kärlich Brunnacker et al. 1982
⑭ Bad Soden Semmel 1974 Zöller et al. 1988
⑮ Achenheim Buraczynski, Butrym 1987
⑯ Normandy Lautridou 1982
⑰ Lublin plateau Maruszczak 1987
⑱ Paks + Dunaföldvár Pécsi et al. 1987
⑲ Middle-, Lower-Dnepr Veklich 1979
⑳ Middle Don Velichko 1991
Central Asia Chasmanigar Dodonov 1984
㉒ Loess-plateau Luochuan Liu, T. 1987
㉓ Baoji Rutter et al. 1990
Ma B.P.
X.-XX.= Paleosol complex
11-37= Paleosol
Red clay
Roterde
humic zone
„Naßboden"
semipedolite
forest steppe soil
forest soil
brown earth
red clay
warm forest-steppe paleosols
Malan loess
Lishi loess
Wucheng loess
loess in general
sandy loess
silty sand
sandy silt
slope loess
calcium carbonate concretion
tuff
gravel
Ach.
B H
MF
BD
Df
vt
abbreviations of localities and stratotypes
change of age scale
meadow soil
clay, loam
Tertiary sediments
profile supplementatio (combination)
hiatus
layers are shown at the time scale

Table 5. Litho- and chronostratigraphical subdivision of the upper and lower series of loess in Hungary (after PÉCSI 1995)

Name	Index	Age in ka	Identification
recent soil	0	0–11.3	Chernozem, locally brown earth
Upper part of young loess (Dunaújváros–Tápiósüly series)			
humous horizon 1	h_1	16 – 17 presumably W_3	humous horizon
humous horizon 2	h_2	27–32 pres. W_2/W_3	humous horizon
Lower part of young loess (Mende–Basaharc series)			
Mende upper 1	MF_1	45–60 pres. W_2/W_3	forest steppe soil
Mende Upper 2	MF_2	85–105 pres. W_1/W_2	forest steppe soil
Basaharc Double 1	BD_1	120–140 pres. R_2/W_1	forest steppe soil
Basaharc Double 2	BD_2	150–170 pres. R_2/W_1	forest steppe soil
Basaharc Lower	BA	195–230 pres. R_1/R_2	forest steppe soil, locally as soil complex
Upper part of old loess series			
Mende Base 1	MB_1	280–310 pres. MR_3/MR_4	forest steppe soil
Mende Blase 2 + sand in underlying layer	MB_2 + sa	320–360 pres. MR_2/MR_3	polygenetic brown earth complex
sandy humous soil of Paks	Phe_1+Ph_2	360–380 MR_1/MR_2 440–460 M_1/M_2	forest steppe soil
hydromorphous soil of Paks + sand	$Mtp_1 + Mtp_2$	480–500 pres. G/M	hydromorphous soil + fluvial sand
Lower part of old loess in the Paks series			
Paks Double 1	PD_1	565–585 pres. G_1/G_2	warmer forest steppe soil (chestnut)
Paks Double 2	PD_2	600–630 pres. G_1/D_3	warmer forest steppe soil (chestnut)
Brunhes/Matuyama boundary in L_5	B/M	730 pres. Danubian glaciation (D_3)	old loess (L_5)
Paks–Dunakömlőd soil complex	PDK	750–765 pres. D_1/D_2	warmer forest steppe soil (chestnut)
old loess L_6	L_6–L_6	750–900? pres. D_1 glaciation	old loess series in Paks

Hungarian studies on loess seem to have contributed significantly to the solution of the loess problem as a whole, even at a global scale. Firstly, LÓCZY, sen. who was the most successful explorer, geologist-geomorphologist of the late 19th and early 20th centuries, studied the domestic loesses analytically, in possession of a rich experience gained during the expeditions covering vast loess regions of the Chinese Empire and facing the challenge of RICHTHOFEN's theory.(LÓCZY 1886). Similarly, CHOLNOKY had the opportunity, apart from the losses of the Carpathian Basin, to get acquainted with the Chinese, North American and European loesses as well. Beside his support of the eolian theory of loess formation he was the first to draw attention to karstification processes in loess on the example of the Titel Plateau, at the confluence of the Danube and Tisza rivers.

LÓCZY (1913, 1916) was the *first to describe the redoposited, so-called "valley loess"* and gave an interpretation that they *were accumulated by slope wash burying slopes and valleys,* especially in Transdanubia. HORUSITZKY (1903); TREITZ (1903) and several agrogeologists became interested in the *origin of infusion loess* (swamp loess) occurring in the lowland areas discussing pros and cons regarding the eolian accumulation of material (PÉCSI et al. 1979).

BULLA (1934, 1937–38) was the *first to give a summary of the horizontal geomorphic distribution and vertical lithological subdivision of loess in the Carpathian Basin,* of the accumulation of eolian material in periglacial conditions and its slight diagenesis through carbonate-siallite weathering causing a specific lithologic feature that in dry condition steep walls formed by loess are stable. Soils buried between loess layers, according to the generally accepted contemporary concept were considered remnants of forest soils, as "loam zones".

Through the application of the current concept of loess-paleosols and thorough analyses of the Paks brickyard profile performed by loess experts and soil scientists several attempts have been made to reconstruct the sequence of paleogeographic events of the Quaternary in Europe (SCHERF 1935; BACSÁK 1942; ÁDÁM et al. 1954; KRIVÁN 1955; STEFANOVITS and RÓZSAVÖLGYI 1962; HAHN 1969, 1987; PÉCSI 1993b). The results of investigations published or demonstrated during field symposia greatly contributed to the advancement of principles and methods applied in European loess chronology (MOLNÁR 1966, 1971; MOLNÁR and GEIGER 1981; MOLNÁR and KROLOPP 1978; SÜMEGI et al. 1992; PÉCSI and VELICHKO [eds] 1995).

In the field of loess research a close cooperation has been established between the Hungarian and international experts on loess when, starting with 1977, M. PÉCSI, a Hungarian loess specialist presided the INQUA Commission on Loess for three inter-congress period (until 1991). Even earlier he was requested to write entries on loess for the Encyclopaedia of Geomorphology (1967) and Encyclopaedia Britannica (1972) and his applied concept on loess (PÉCSI 1972) was republished as a volume of Benchmark Papers in Geology (1975, Vol. 26). PÉCSI organised field symposia with the participation of scientists from the most relevant loess region of the world (Russian Plain, Siberia, China, North and South America, etc.) in the course of which exchange of ideas on loess highly promoted interregional correlation in the field of loess chronology and research methodology (*Table 4*).

In Hungary an active working community emerged (composed by experts from several institutions of geosciences and university departments) which have collaborated with research laboratories from abroad. As a result, a wide range of volumes of studies and methodological publications were issued in the 1980s and 1990s PÉCSI [ed.] 1987, *Loess and Environment,* Catena Supplement band No. 10; PÉCSI and VELICHKO [eds] 1987, *Paleogeography of Loess;* PÉCSI [ed.] *Problems of Loess Chronology,* GeoJournal 1991; PÉCSI and SCHWEITZER [eds] 1991, *Quaternary Environment in Hungary, Studies in Georg.* No 26; PÉCSI and LÓCZY [eds] 1991, *Loess and Paleoenvironment, Quaternary International* Vols 7–8; FRENZEL, PÉCSI and VELICHKO [eds] 1992, *Atlas of Paleoclimates and Paleoenvironments…*; PÉCSI and VELICHKO [eds] 1995, *Principles, method… in loess-paleosol investigations,* GeoJournal 36. 2/3; PÉCSI and SCHWEITZER [eds] 1995, *Concept of loess,* Loess in Form No. 3 [6] (*Photos 26, 27*).

There has been an increasing interest toward Quaternary and loess research by the end of the millennium. In spite of serious problems with financial support, research activities have recently been conducted in seven scientific workshops of the country (institutes of the Academy of Sciences, Geological Institute, university departments, museums) active in the solution of problems.

7. GEOMORPHOLOGICAL EVOLUTION OF THE BALATON BASIN

More than one hundred years ago LÓCZY, L. sen. organised a Commission on Lake Balaton in the framework of the Hungarian Geographical Society. This commission undertook investigations aimed at the acquisition of novel scientific knowledge on the evolution of the lake basin and its environs and its geographical endowments and the publication of results in the form of monographs.

At the end of the 19th century rudimentary ideas existed about the origin of the lake; even SZABÓ (1888) considered it remnant of the Miocene inland sea. JUDD, J. W. (1876), an English geologist and traveller assigned its emergence to the subsidence following the Tertiary volcanic activity and the appearance of basaltic lava on the surface.

During the 20th century, as a result of detailed and comprehensive geological and geomorphological studies by LÓCZY and his disciple CHOLNOKY and due to the expanding research activities in the fields of geography and hydrography carried out by the Commission on Lake Balaton, even in international comparison a unique *monograph on Balaton was published in 32 volumes* (*Photo 2* entitled "A

[6] "Concept of loess, a comprehensive information" recently published in the second edition of Encyclopaedia of Geomorphology (FAIRBRIDGE, R. W. and GERRARD, J. [eds] 1998) after 30 years was contributed again by PÉCSI, M.

Balaton tudományos tanulmányozásának eredményei" (Results of the Scientific Investigations of Lake Balaton).

In these volumes LÓCZY and CHOLNOKY have formulated basic principles of earth sciences e.g. on the evolution of the closer and wider environment of the lake, the occurring landforms, the geomorphic (endogeneous and exogeneous) factors. Among them *deflation under semiarid climatic conditions* played a decisive role in shaping the so-called meridional valleys in the vicinity of the present-day Balaton during the Upper Pliocene (Levantan stage). This working hypothesis provoked a heavy (and still lasting) debate (see also chapter A4) both in the domestic and international scientific circles. According to LÓCZY (1913) *the lake basin emerged as a series of partial basins, i.e. foredeeps stretching along the strike of the Transdanubian Mountains* (italics by MAROSI 1970). In this respect there was a kind of antagonism between the concepts by LÓCZY and CHOLNOKY. Nevertheless, they held a joint hypothesis on the narrow ridges having existed between these depressions deepened chiefly by deflation, and they put the emergence of the lake to Late Pleistocene. Also they recognised that layers of basaltic lava and tuff preserved some 100–200 m thick sequence of the Pannonian formation (see CHOLNOKY's *figure 13* depicting the Tapolca Basin). Apart from the formation of depressions an other basic element of this concept is the selective denudation of the Upper Pannonian layers.

Starting with the 1940s *concepts of the polyglacial and climatic morphological geomorphic evolution* came to the fore. Based on the effect of climate fluctuations during Pleistocene, subdivided then into four periods, on the formation of terraces of Zala River, KÉZ (1943) and BULLA (1943) put the *emergence of the lake basin into the Riss-Würm Interglacial* (italics by MAROSI).

Based on the pollen analysis of samples collected from the bottom deposits (peat and mud) of the present-day lake ZÓLYOMI (1987, 1995) came to a conclusion about a Late Würm origin, and the latest chronological and palinological investigations by CSERNY et al. (1996) similarly testified of the emergence of the water at the very end of the Pleistocene.

The concept of Lake Balaton being of Holocene age was first voiced by SÜMEGHY (1955). His argument was that within loess deposits formed during Late Pleistocene along the present-day southern shore, dolomite, gravel and other clastic material is to be found redeposited by streams having flown from the actual northern side. MAROSI (1970) and SZILÁRD (1967) proved that this loess with dolomite and red sandstone interbeddings were subsequently redeposited in derasional valleys toward the subsided basin of the lake at the end of the Würm, presumably during phases Dyras I and II (MAROSI and SZILÁRD 1977, 1981, *Fig. 12,* Sóstó profile). They held that the Balaton Basin is a polygenetic formation being a result of a subsidence of spatial and temporal variation since the Middle Pleistocene. This concept, in order to provide a clear interpretation of the genesis of the lake distinguishes between i) the lake bottom, bordered by the present-day shoreline, ii) the Balaton Basin deepening into the lake's environs characterised by the surface covered during the highest water level and affected by a presumed abrasional activity. Farther away from the Balaton Basin of the latter interpretation on both (southern and northern) sides of the lake i.e. within the Balaton catchment or its broader basin, three *geomorphic levels* can be detected at higher altitudes indicating phases of geomorphic evolution induced by stages of subsidence. To reconcile the conflicting ideas with regard to the way of the emergence of the Balaton Basin MAROSI and SZILÁRD (1981, 1983) made an attempt to *elaborate a compromising concept.*

The first stage of subsidence was correlated with the Middle Pleistocene a geomorphic level at 160–190 m a.s.l. The second stage affected a reduced area below a geomorphic level of 120–150 m. The third stage comprised a single abrasional terrace of the lake formed at an altitude of 110–112 m during the Late Würm. This event is assumed to have led to a single basin covered by water.

According to this hypothesis the Balaton emerged as a single standing water in its basin later than it was supposed by LÓCZY (1913), CHOLNOKY (1918) and KÉZ (1943) but earlier than it was assumed by ZÓLYOMI (1987, 1995) CSERNY (1987) and CSERNY et al. (1987, 1991).

The emergence of the Balaton Basin was assigned by MIKE (1980) to the erosional activity of the ancient Danube; in shaping his concept he was influenced by statements of SZÁDECZKY-KARDOSS (1938a) and SÜMEGHY (1955) about this river to have flown into an inland lake having existed near Dráva River at the end of the Neogene. MIKE (1991) recognised buried and extensive meanders in the valley bottom of the Zala River filled by peat.

According to CHOLNOKY the lake shore was shaped by a series of sandbars elevating above the present-day water level by 1.5, 1.5 to 3 and 4 m, respectively. *LÓCZY and CHOLNOKY identified Pannonian abrasional levels between 112–130 m* a.s.l. in several places on the Balaton Upland. In the course of the geomorphological mapping of the Balaton and its environs, PÉCSI (1969b, 1989) found Pannonian abrasional gravel underlying Upper Pannonian clay horizon and overlying Triassic limestone in the Balatonfüred brickyard, at an altitude of 113–114 m. (This *abrasional gravel* is still seen in the railway cut.) Well-rounded fine and coarse grain of abrasional quartz pebbles occur similarly at geomorphic levels at 150–160 and 190–207 m altitudes on terraces between Balatonfüred and Arács. In several spots of the Mesozoic planation surfaces of the Balaton Upland (e.g. before the bend of the road leading to Szentkirályszabadja) Upper Pannonian travertine with fossils is bedding with considerable thickness and extension. These geological and geomorphological formations (according to the concept of planation by PÉCSI 1969b, 1996a) are to be interpreted by stages of burial during the Upper Pannonian and exhumation at the end of the Pannonian and during post-Pannonian (Pliocene–Pleistocene). It means that the abrasional level (at 112 m. a.s.l.) at Balatonfüred overlain by clay with *Congeria* and the higher gravel and exhumed abrasional levels presumable are not Pleistocene landforms of cryogenic origin but they are surfaces of at least Upper Miocene age subsequently covered by Pannonian sediments up to 280–330 m altitude a.s.l., i.e. up to a summit level of the Somogy Hill region. Then the ancient landforms and geomorphic terraces became exhumed as e.g. Sarmation limestones locally covered by gravels among the basalt residual hills of the Tapolca Basin and in the vicinity of Zánka, near the lake, at 130 m a.s.l. (see figures by CHOLNOKY and JÁMBOR). According to PÉCSI's explanation not only the evolution of the Balaton Basin but the emergence of the so-called meridional valleys of the Zala Hills as well had been affected by the exhumation of valleys (see also chapter A/4).

A latest genetic interpretation of planation surfaces in the mountains and on the Balaton Upland has been provided by PÉCSI (1970d, 1995a) who studied in detail the pediment formation and periglacial processes and guided the geomorphological mapping of Lake Balaton at a scale of 1 : 300,000 (1989).

It should be emphasised that the basis of the above-mentioned geological, geomorphological (*Fig. 51*) and ecological mapping activities, both in detailed and in general scales, has been the heritage (bequeathed by our predecessors with their manifold and comprehensive activities started more than one hundred years ago) in the form of remarkably rich data bases and interpretations, explanations and syntheses achieved through mapping.

The emergence of the [illegible] was assigned by [illegible] (1930) to the [illegible] of the [illegible], in shaping his concept he was influenced by [illegible] of [illegible] (1938a) and [illegible] (1955) about the [illegible] to have been [illegible] lake having existed near [illegible] at the end of the [illegible] (1991) recognised [illegible] in the valley bottom of the Zala River filled by peat.

According to [illegible] the lake shore was shaped by [illegible] of sandbars [illegible] rising above the present-day water level by 1.5, 1.5 to 2 and 4 m, respectively. [illegible] and [illegible] identified Pannonian abrasional levels between 112–150 m [illegible] at several places on the Balaton Upland. In the course of the geomorphological mapping of the Balaton and its environs, [illegible] (1980, 1989) found Pannonian [illegible] gravel underlying Upper Pannonian clay horizon and overlying [illegible] formations in the [illegible] Upland, at an altitude of 112–115 m. (The abrasional [illegible] is still seen in the [illegible].) Well-rounded fine and coarse gravels of [illegible] quartz pebbles occur similarly at geomorphic levels of 150–160 and 190–200 m altitude [illegible] between [illegible] and [illegible]. In several spots of the Mesozoic planation surface of the Balaton Upland (e.g. before the bend of the road leading to [illegible]) Upper Pannonian [illegible] with fossils is [illegible] with considerable thickness and extension. These geological and geomorphological [illegible] (according to the concept of planation by [illegible] 1980, 1989a) are to be interpreted as stages of burial during the Upper Pannonian and exhumation at the end of the Pannonian and during post-Pannonian (Pliocene–Pleistocene). It means that the abrasional level (at 112 m [illegible]) [illegible] covering by clay [illegible] and the higher gravel and [illegible] levels [illegible] are not Pleistocene landforms of erosional origin but they are surfaces of at least Upper Miocene age subsequently covered by Pannonian sediments up to 260–270 m altitude a.s.l., i.e. up to a summit level of the [illegible] Hill region. Here the [illegible] landforms and [illegible] terraces

B) MAIN GEOMORPHIC PROCESSES

1. FLUVIAL LANDFORMS

The investigation of *river channels, floodplains* and *terraces* have the longest tradition in Hungarian geomorphology. River regulation and drainage measures in the 19th century affected almost one million hectares of inundated lowlands in the Carpathian Basin. Cut-offs considerably reduced the length of meandering rivers and almost 5000 km of flood-control dykes and ca. 40,000 km of drainage canals were built. Consequently, virtually all the geomorphologists have been engaged in studies on history of river courses and the impacts of regulation on floodplain landforms (ORTVAY 1882; SOMOGYI 1978; SALAMIN 1980). For these investigations field survey and laboratory experiments were supplemented by the

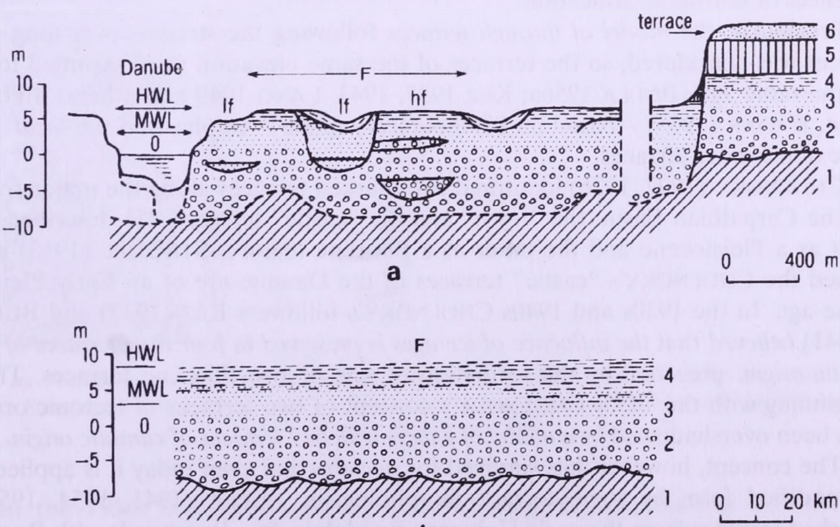


Fig. 25. The structure of the river bed and the flood plain deposits of the Danube (after PÉCSI 1959, 1964a). – a = cross-section of the valley floor; b = longitudinal section of the valley floor of middle section of the river; 1 = bedrock; 2 = gravelly sediments upwards turning finer; 3 = fluvial sands; 4 = fluvial sandy silt, silt, occasionally clay; 5 = loess; 6 = blown sand; F = flood plain; lf = low-level flood plain; hf = high-level flood plain; HWL = highest water level; MWL = mean water level; 0 = 0 level

use of old maps, archeological finds and satellite imagery (CHOLNOKY 1907; PÉCSI 1933; SOMOGYI 1974; GÁBRIS 1995).

Among others, it was found that over the floodplain levels of alluvial fans each square kilometre was reworked by stream meanders in a thickness adjusted to actual channel depth (MIHÁLTZ 1967; MIKE 1980, 1991; ORTVAY 1882; PÉCSI 1959, 1964a).

By investigating a number of cross-sections from floodplains and terraces PÉCSI (1959, 1964a) came to the general conclusion that the depositing activity of the Danube had taken place during the Holocene and even earlier, within the range between the deepest point of the river bed and the highest level of the culminating flood. *According to this concept, in the Holocene the Danube was able to deposit about 15–20 m thick sediments.* As a result of the horizontal changes of the river bed, a layer of sediment of such a thickness may be reckoned with, without assuming the sinking of the area (*Fig. 25*).

The *duration of a meander cycle* was estimated at ca 150–200 years for the lowland section of the Danube and 80–120 years for the Tisza river (SOMOGYI 1974, 1978, *Fig. 26*). Cultivation has obliterated many of the old meander traces by now (PAPP 1960; MIKE 1991; KIS–LÓCZY 1985; BALOGH–LÓCZY 1992).

The rivers of Hungary built *terraced alluvial fans* when leaving the mountain frame (SZÁDECZKY-KARDOSS 1938; KÁDÁR 1955, 1957; PÉCSI 1959; BORSY 1990). The terraces converge towards the basin and continue in sediment sequences of normal stratification.

Previously, the *model of through terraces* following the streams over long distances was considered, so the terraces of the same elevation were assumed to be of the same age (BULLA 1956a; KÉZ 1937, 1943; LÁNG 1949 and others). In contrast, KÁDÁR (1955) – based on his laboratory mode – emphasised the *local* nature of meander terraces.

CHOLNOKY (1907, 1926) identified two marked terraces along the major rivers of the Carpathian Basin: the "town" and the "castle" terraces. He described the first as a Pleistocene and the latter as a Pliocene feature. STRÖMPL (1913) supposed the CHOLNOKY's "castle" terraces of the Danube are of an Early Pleistocene age. In the 1930s and 1940s CHOLNOKY's followers KÉZ (1937) and BULLA (1941) *believed* that *the influence of ice ages is preserved in four river terraces of climatic origin,* preceded by the formation of one or two Pliocene terraces. Thus, beginning with the 1950s CHOLNOKY's concept of two terraces of tectonic origin has been overshadowed *by a model of valleys with 6–7 terraces of climatic origin.*

The concept, however, has survived for decades and even today it is applied in a modified form by some terrace morphologists. BULLA (1941, 1954, 1956a) marked terraces from the early Holocene floodplain (no. I) upwards with Roman numbers (levels II to VII) in the Carpathian Basin. He dated terraces in accordance to the Quaternary chronology applied at that time (*Table 6*).

The terrace systems were held to be similar along the Danube and tributaries in the Carpathian and Alpine region. Regarding terrace systems identical, the development of terraces was also explained by a single factor, Quaternary climatic changes.

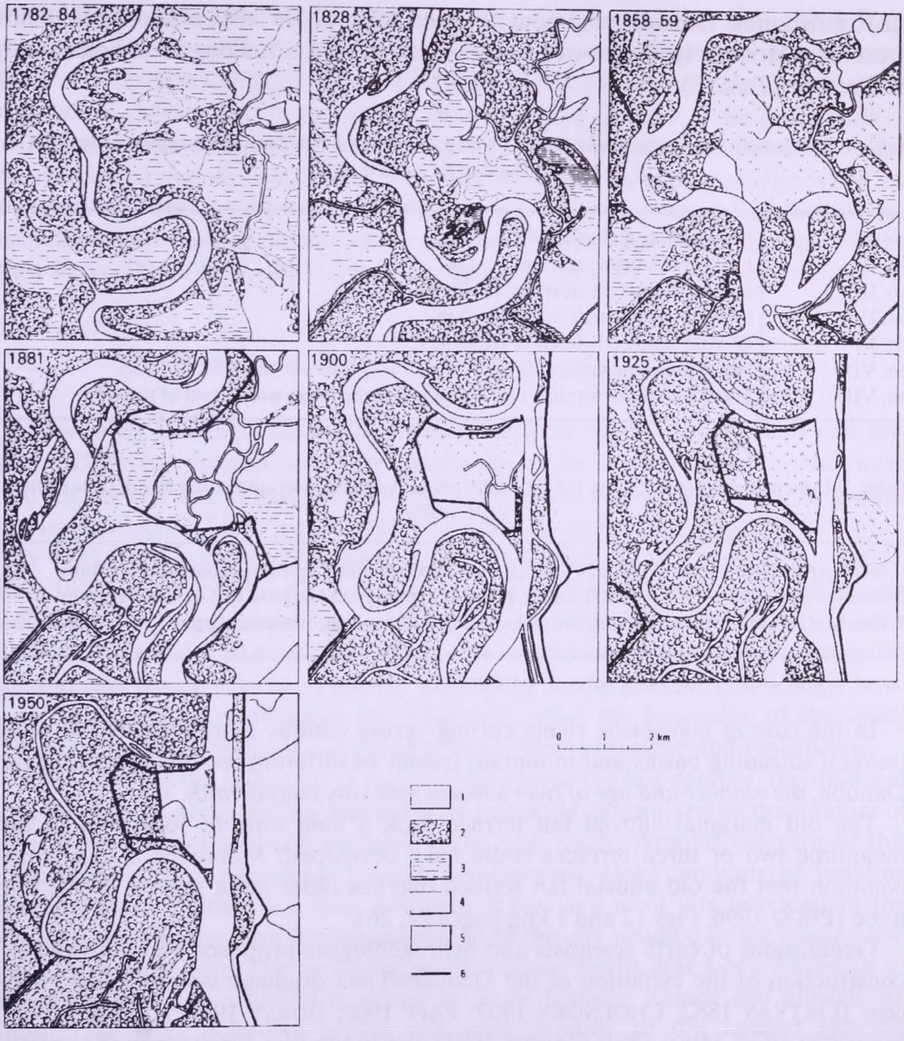


Fig. 26. Profiles of the maps of the Sárköz reach of the Danube reconstructed to the same scale (after SOMOGYI 1974). – 1 = arable; 2 = forest; 3 = marshy-boggy area; 4 = waterlogged meadow; 5 = zone shallow; 6 = dam

In the *1950s and 1960s detailed geomorphological investigations and terrace mapping modified and differentiated the above schematic model,* particularly in respect to the Danube. At first, following detailed studies, MAROSI (1955) and GÓCZÁN (1955) found that on the Csepel and Szentendre Islands, terrace no. II (the "town" terrace of CHOLNOKY) is a double feature: a gravel terrace (IIa) and a rock terrace (IIb) can be distinguished. PÉCSI (1959) identified two levels on the Danube floodplain: the *low floodplain level* (Ia) and the *higher floodplain level*

(Ib)[7] attributing their development to river regime. He also observed that not even the relative heights of lower terraces remain constant along the whole length of the river (*Table 7*).

Table 6. Terrace-chronological model for the terraced valleys of the Carpathian region (after BULLA 1941, 1956a and KÉZ 1934, 1937)

no. I:	Early Holocene floodplain, 3–5 m
no. II:	Upper Pleistocene terrace, 6–12 m
no. III:	Middle Pleistocene terrace, 15–20 m
no. IV:	Lower Pleistocene terrace, 36–65 m
no. V:	Oldest Pleistocene terrace, 70–95 m
no. VI:	Upper Pliocene terrace, 110–160 m
no. VII:	Middle Pliocene terrace, 170–200 m above the mean water level of the river

Table 7. Concept of terrace system for the different polygenetic sections of big rivers (after PÉCSI 1959, 1996b)

1. multiterraced river section (with 5–7 terraces) in predominantly uplifting mountains and hills
2. river sections with some (3–5) alluvial fan terraces in mountain foreland and on basin margin
3. river sections in submerging basins, with no or only 1–2 terraces of accumulation

In the *case of polygenetic* rivers cutting across various morphostructural units (several subsiding basins and mountain frames of different tectonics) such as the Danube, *the number and age of river terraces may vary considerably.*

The old marginal alluvial fan terrace took a long time to form and in the meantime two or three terraces could have developed. Moreover, it is not uncommon that the old alluvial fan terrace overlies older delta gravels of the Danube (PÉCSI 1996, Figs 12 and 13 on pages 24, 26).

Generations of earth scientists and hydrogeologists proposed views for the reconstruction of the evolution of the Danube–Tisza drainage system in the *Holocene* (ORTVAY 1882; CHOLNOKY 1907; PAPP 1960; BORSY 1967; KÁROLYI 1957; SOMOGYI 1974; MIKE 1991; GÁBRIS 1995) and in the Plio-Pleistocene (SALAMON 1978; SZÁDECZKY-KARDOSS 1938a; SCHAFARZIK 1918; SÜMEGHY 1955; PÉCSI 1959; ERDÉLYI 1960; MIHÁLTZ 1967; MOLNÁR 1961; MAROSI and SZILÁRD 1977, 1981; MIKE 1980, 1991; BORSY 1990; GÁBRIS 1997). Detailed paleogeographical analyses suggest that the Tisza and its tributaries on the Great Hungarian Plain only acquired their present-day channels in the Holocene (*Fig. 23*).

Opinions differ in the matter *when the Danube occurred in the Carpathian Basin* for the first time. In the 1950s this event and the *origin of the Visegrád Gorge* was dated to the Late Pliocene (KÉZ 1937; BULLA 1941; SÜMEGHY 1955; LÁNG 1955;

[7] *In sensu strictu* the floodplain levels (Ia, Ib) along the Danube are not yet terraces proper, only higher – seasonal – levels of the river bed.

PÉCSI 1959 and others). Before that there was a view that the Danube also appeared in the Great Plain as early as the late Tertiary (Pontian – SZABÓ 1879; INKEY 1892; SCHAFARZIK 1903a, 1918). In the same period KÉZ (1937); SZÁDECZKY-KARDOSS (1938a) traced the deposits of the Danube in the Little Plain.

Recent studies of larger gravel pits and analyses of geological boreholes *allow the conclusion that the delta fravels of the Danube deposited during or even before the Pannonian* (Pontian), not only in the present Little Plain (Bana–Bábolna terrace islands), but also along the northern margins of the Gerecse Mountains and in the Pest Plain (PÉCSI 1987, 1992; JASKÓ and KORDOS 1990).[8]

The development concepts of the Visegrád Gorge of the Danube

This valley has been studied by many scientists over the last hundred and fifty years. Different explanations were proposed for the *origin of the Visegrád Gorge* and for the conditions and date of deposition of the alluvial fan and delta gravels around Budapest. Most regarded *the water gap as antecedent* (SZABÓK 1879; LÓCZY 1881; SCHAFARZIK 1918; BÖCK 1899, 1902; CHOLNOKY 1937; BULLA 1941; KÉZ 1937; PÉCSI 1959), others as *superimposed* (PÉCSI 1959; SALAMON 1878) *and still others as of regressional* river capture (SZABÓ 1858; SALAMON 1878; SÓBÁNYI 1893; KÁDÁR 1955; BULLA 1962) *origin.* The occurrence of the Danube along this section was placed into the Pliocene (according to the present chronology, however, into the Upper Miocene and Pliocene), while the formation of the valley with seven or eight terraces was dated to the (Upper) Pliocene and Pleistocene.

Disregarding the influence of popular theories of the last century, the different and sometimes contradicting concept were primarily determined by the number of gravel pits and information available from their study. Around the turn of this century, Budapest experienced rapid development, large amounts of building material were needed and thus extensive gravel and sand pits operated in the present-day suburbs. The further expansion of the city resulted in the closing and burying of these pits. The geologists active before World War I could observe in these exposures, in addition to gravel series of Danube terrace and alluvial fan origin, Neogene delta-like gravel and sand deposits of the ancient Danube (SZABÓ 1879; INKEY 1892; LÓCZY, sen. 1898; HALAVÁTS 1898; LŐRENTHEY 1904; BÖCKH 1899, 1902; SCHAFARZIK 1918). The latter could not be identified in exposures between the two world wars, only the near-surface terrace and alluvial fan gravels could be studied. As a consequence, the geomorphological explanations put forward for the origin of the Danube did not consider the Neogene delta structured gravel beds for decades. Thus they described the occurrence of the Danube in the area and the formation of its valley on the basis of the Upper Pliocene and Pleistocene alluvial fan and terrace gravels (KÉZ 1937; BULLA 1956a;

[8] Most recently a concept has been formulated that the Danube in the Visegrád Gorge have only developed in the Late Pleistocene (KORPÁS [ed.] 1998).

PÉCSI 1958, 1959 and others). STRÖMPL (1913) assumed CHOLNOKY's *two-terrace river valley* concept for the Visegrád Gorge, too.

Later, particularly in the 1960s and 1970s, considerable constructions started again in Hungary and in the area of Budapest and many new gravel quarries were opened. Moreover, a number of boreholes were deepened to promote the engineering geological mapping of the major towns and the national inventory of gravel deposits (BOHN 1975–1990).

The continuous investigations and evaluations of these new exposures and borehole samples indicated that Upper Miocene deltaic gravels are not limited to the northern margins of the Gerecse Mountains, but they also occur next to or under Pliocene-Pleistocene alluvial fan deposits on the older *Little Plain* Danube alluvial fan, in the northern, *higher part of the Pest Plain* (Fót, Mogyoród, Kistarcsa, Rákosliget, Pestlőrinc) and in its *lower areas* (under the surface near Ócsa). The Upper Miocene age of these deltaic gravels is supported by the occurrence of Pannonian (Pontian) mollusc and vertebrate finds in the travertine layers covering the gravel beds of the Danube (SCHWEITZER and SCHEUER 1986).

Regarding these circumstances, the formation of the Visegrád Gorge of the Danube could not begin in the Upper Pliocene or on the Plio-Pleistocene boundary, as it was held earlier on the basis of the data from the 1960s (PÉCSI 1959 and others), but the development of this section of the Danube can be placed back to the Upper Miocene at latest. This conclusion was drawn from the critical evaluation of more than a hundred years of scientific research and experience and from almost half a century of investigations by PÉCSI (1991, 1992), and last but not least, from the interpretation of the engineering geological and geomorphological maps prepared over the last 25 years *(Photos 30a, b, c)*.

Summarising the older and more recent explanations, during the gradual regression of the Pannonian inland sea the Danube was filling up the partial basins one after another at least since the Middle Miocene. *The Visegrád Gorge may have functioned as a strait of the Pannonian inland sea between the inland sea of the Little and Great Hungarian Plains* at least during the formation of the huge series of *Gödöllő sand* e.g. within the Carpathian Basin, the number, thickness and relative height of the *Danube deltas, alluvial fans* and *terraces are variable and differences are obvious according to mountain (a), basin margin (b) and basin sections.*

It can be stated that older terraces of the same age are found at variable heights along the mentioned sections. Terraces of the same height cannot be detected throughout the whole length of the river. There is a measurable variation even in the height of floodplain levels between sections and occasionally even within lowland sections.

All these variations result from tectonic movements of different rate and direction. These movements constituted the basic control of valley terrace formation and basin sedimentation, while climatic changes were of secondary importance (PÉCSI 1959, 1996b).

2. SOIL EROSION

Water erosion is hazard over almost two-thirds of Hungary. Consequently, along with soil scientists (DUCK 1957; STEFANOVITS 1977; VÁRALLYAY and DEZSÉNY 1979), geomorphologists have increasingly contributed to *soil erosion studies.*

Under the guidance of PINCZÉS a team of the Department of Regional Geography, Debrecen, conducted important research into the spatial variation of soil erosion in the Bükk foothills and the phenomena of suffosion – piping – loess in the Bodrogkeresztúr basin, North Hungary (*Fig. 27*). The detailed geomorphic mapping, which located the factors controlling soil erosion (PINCZÉS and KERÉNYI 1979; PINCZÉS 1991), has been of great practical value for farmers.

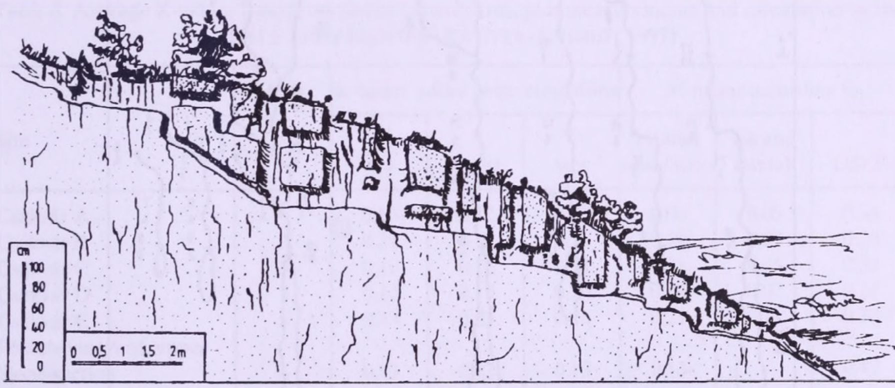


Fig. 27. Slope erosion by suffosion on the loess-covered Tokaj Hill (after PINCZÉS 1968)

Laboratory and field measurements (*Fig. 28*) are widely used to estimate the significance of splash erosion (KERÉNYI 1991a, b; BOROS 1997, *Photos 31a, b, c*), soil and nutrient loss from the catchment of Lake Balaton and its off-site effects (KERTÉSZ 1993). Field stations were installed in some mountain and hill regions of Hungary (GÓCZÁN 1969, 1971; GÓCZÁN and KAZÓ 1969; KERTÉSZ 1993). Recently a new method was introduced for soil erosion assessment of in a test area on the Lake Balaton studied by an international working group[9] (KERTÉSZ–RICHTER–SCHMIDT 1997).

The complex analysis of the test area comprised first a detailed mapping of all the relevant parameters at the scale of 1 : 5000:

[9] The project carried out in 1990–1995 within the framework of an international project supported by the German Research Fund (Deutsche Forschungsgemeinschaft), the Hungarian Academy of Sciences and the Hungarian National Scientific Research Fund (OTKA) under cooperation of the Institute of Physical Geography, University of Trier, and the Geographical Research Institute of the Hungarian Academy of Sciences. The research also formed part of the MEDALUS II (Mediterranean Desertification and Land Use) collaborative research project under the Environment Programme of the European Community.

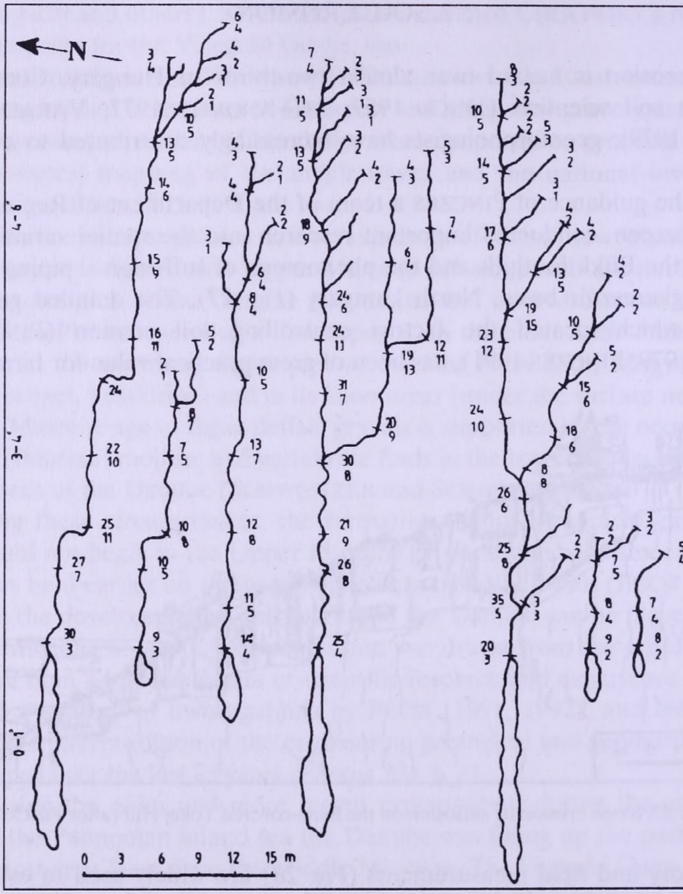


Fig. 28. Rill erosion on the dune surface between villages of Szabolcs and Timár, sandy region of Nyírség (Northeastern Hungary) (plotted by BOROS 1997). – The width of the rills generally varies between 10–30 cm and the rills are 2–15 cm deep. These phenomena mainly occur on the N and E exposed slopes during snow melting (early spring)

– slope categories, based on a digital elevation model;

– shape of relief (convex and concave forms as water divides and water collectors, respectively;

– the linear elements of the agricultural landscape (dirt roads, walls, terraces, ditches);

– soil tecture classes;

– soil depth;

– humus content of the topsoil;

– stone content of the topsoil;

– land use/vegetation, and

– the ecotopes, the separate catchment areas of unconcrated runoff.

The maps were digitised and stored in a GIS, organised by the computer programmes ARC/INFO and ARCVIEW.

For the assessment of the soil loss within the test area the Universal Soil Loss Equation (USLE) was applied. The main parameters R and K were calibrated by analysis of data from four pluviograph stations and by plot measurements under natural rainfall and rainfall simulation (*Photo 32, Table 8*). Using the calibrated parameters, the potential soil loss was determined for each erotope of the test catchment. The potential annual soil loss of the catchment of Örvényesi Séd was then compared with the actual input of sediment into the lake at the gauging station at the catchment outlet. The amount of solutes leaving the test area and entering the lake was also measured.

Table 8. Average K-values based on rainfall experiments, plot measurements and calculation by the USLE (after KERTÉSZ–RICHTER–SCHMIDT 1997)

Site	No.	K-factor under given conditions			K-factor according to		
		dry	moist	wet	rainfall simulation	natural rainfall	USLE
Csákvár A	1	0.06	0.12	0.13	0.08	0.05	0.36
Csákvár B	2	0.24	0.41	0.36	0.29	0.07	0.20
Csákvár C	3	0.10	0.13	0.11	0.11	0.05	0.33
Csákvár D	4	0.12	0.19	0.20	0.14	0.07	0.21
Csákvár E	5	0.18	0.25	0.26	0.21	0.11	0.30
Pécsely vineyard, upper Slope section	6	0.13	0.13	0.13	0.13	–	0.47
Pécsely vineyard, lower Slope section	7	0.20	0.23	0.25	0.21	–	0.45
Pécsely cropland	8	0.11	0.18	0.24	0.14	–	0.61
Pécsely vineyard, loess	9	0.19	0.40	0.37	0.26	–	0.64
Pécsely maize I. loess	10	0.17	0.24	0.28	0.20	–	
Pécsely maize II. loess	11	0.01	0.09	0.15	0.04	–	0.63

Based on these results and their extrapolation to the northern shore of the lake, proposals could be made to diminish the soil and nutrient input to the lake.

Table 8 shows the results of the rainfall simulation experiments, expressed as average K-values under dry, moist and wet conditions. These three values had now to be connected to a single K-value. This was done on the basis of the rainfall recordings of station Pécsely for 1984–1991. During this period, some 65 per cent of the erosive rainfall (>10 mm) fell on dry soil with less than 5 mm rain being registered during the previous two days. Some 25 per cent of the rainfalls occurred in moist conditions, defined by 5 mm or more of rain falling during the previous two days, and 10 per cent occurred in wet conditions, defined by 10 mm or more rain falling since the day before.

In this way the three K-values were weighted by the factors 0.65, 0.25 and 0.10 respectively. The average K-values of the rainfall simulations are shown in *Table 8* and compared with the K-values obtained by plot measurements under natural rainfall and those calculated by the USLE.

Rainfall simulation experiments were performed in two or three cycles, each cycle consisting of three experiments, i.e. under dry, moist and wet conditions.

– experiment under dry conditions	60 minutes
– break	12–24 hours
– experiment under moist conditions	30 minutes
– break	15 minutes
– experiment under wet conditions	15 minutes

The 28 rainfall simulation experiments represent altogether 168 simulations including repetitions.

3. LANDFORMS OF BLOWN SAND

Wind erosion and accumulation and the origin of blown-sand landforms in another traditional field of geomorphological research in Hungary.

At the beginning of the 20th century, Jenő CHOLNOKY (1902) already published a paper on the rules of blown sand feature development, where he explained the accumulation of freely shifting sand (barkhans, dunes perpendicular to prevailing wind direction) and the origin of semifixed blown sand surfaces (wind *furrows, residual ridges, "garmada"* dunes, *river bank dunes*).

KÁDÁR (1966a) has been elaborated the *natural system of eolian landforms* (*Table 9*). The frames of this system are the types of load transport (rolling blown sand, saltational sand and suspended sand movement) and the stages of surface development (*Fig. 30a, b, c*).

KÁDÁR (1938) recognised *parabolic dunes,* BULLA (1951) *sand veneers* on the Danube–Tisza Interfluve, BORSY (1961) the *asymmetric parabolic dunes* in the Nyírség and MAROSI (1958) described *longitudinal "garmada" dunes* in the Pest Plain and wind furrows open at both ends in the Inner Somogy sand regions (MAROSI 1962). Further investigations are necessary to reveal the origin of the *elongated sand dunes* of the Danube–Tisza Interfluve of several kilometre length, mantled by chernozems and loess sands, FRANYÓ (1964, *Fig. 29*); RÓNAI (1985a) assumed these forms as remnants of bounded longitudinal dunes, but BORSY (1977) identified them as asymmetric parabolic dunes.

The three major Quaternary blown-sand areas of the country are mostly used by agriculture and partly by forestry. In dry years their productivity is reduced and sand drift may begin. In addition to the study of sand movements and the classification of the resulting features (CHOLNOKY 1927; KÁDÁR 1938, 1966a; BORSY 1974; MAROSI 1958, 1967; FRANYÓ 1964; RÓNAI 1985a), the Early Holocene and Last Glacial main phases of sand movement have also been dated by radiometric methods (BORSY et al. 1982).

Table 9. Natural system of the eolian (exogenic) landforms (after KÁDÁR 1966a)

Evo-lution stages	K	Q (KS)	(SR)	S	X (US) (SU)	U	Y (UR) (RU)	R	(RS)	Z (RO) (OR)	O
Nd	KNd			SNd		UNd		RNd			ONd
D	KD	QD	(SR)D	SD	XD	UD	YD	RD	(RS)D		OD
V	KV	QV	(SR)V	SV	(US)V (SU)V	UV	YV (UR)V (RU)V	RV			OV
Ne	KNe			SNe		UNe		RNe			ONe
A	KA		(SU)A	SA		UA	(RV)A	RA	(RS)A		OA
Na	KNa			SNa							

Explanation of the signs: A = Pruce accumulation; D = Pure denudation; K = Transport of dissolved load; M = Marine surface evolution; N = Neutral stage of surface evolution; O = Sliding load; Q = Rhythmic alternation of dissolved and suspended kinds of load transport; R = Rolling load transport; S = Transport of suspended load; U = Transport of saltated load; V = Stage of variable surface evolution with rhythmic alternations of denudation and accumulation; X = Rhythmic alternation of suspended and saltated load transport; Y = Rhythmic alternation of saltation and rolling; Z = Rhythmic alternation of rolling and sliding; a = Predominance of accumulation in the stage of variability, respectively the existence of some accumulation in the stage of neutrality; d = Predominance of denudation in the stage of variability, respectively the existence of some denudation in the stage of neutrality; e = Equilibrium of denudation and accumulation in the stage of variability and neutrality.

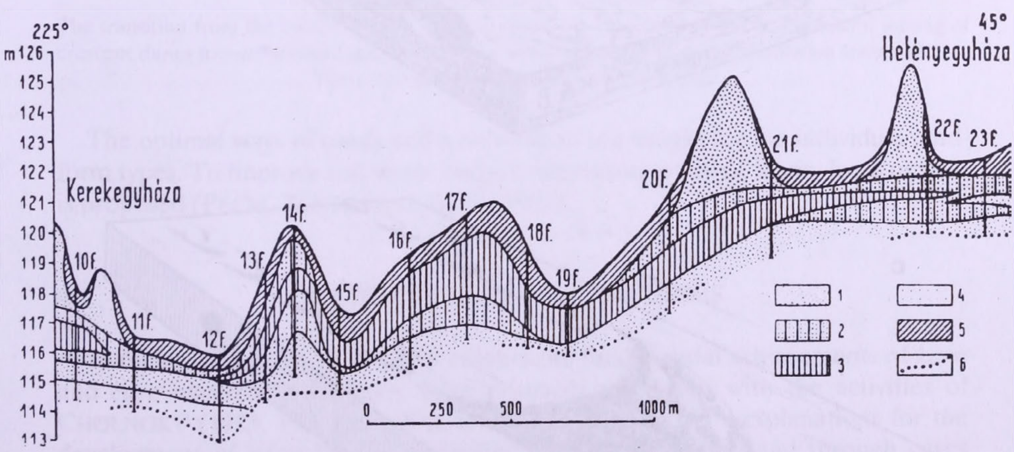
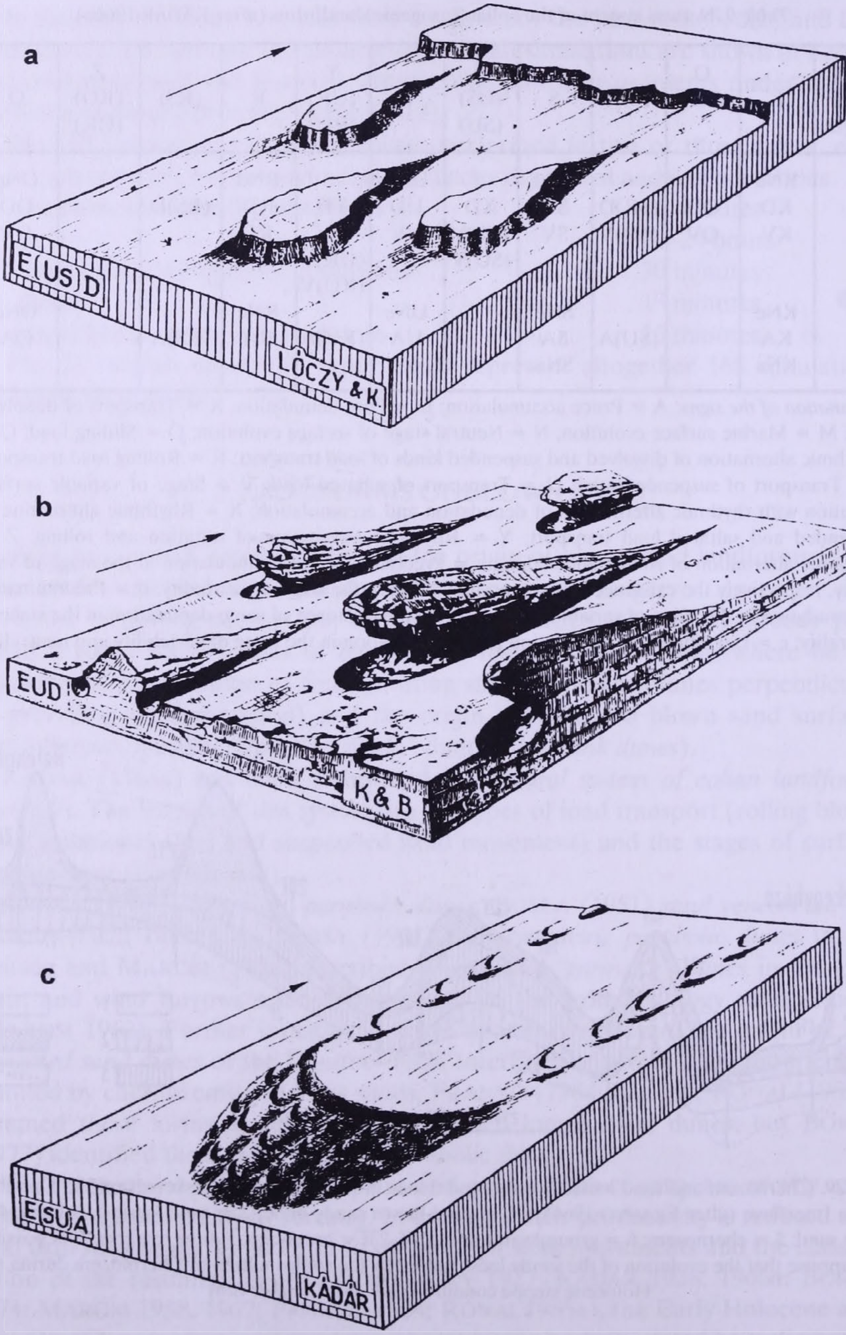


Fig. 29. Chernozem and sand loess covered sand dunes in the vicinity of Kecskemét on the Danube–Tisza Interfluve (after FRANYÓ 1964). – 1 = wind-blown sandy dune; 2 = sand loess; 3 = loess; 4 = river sand; 5 = chernozem; 6 = groundwater level; 10f–23f = boreholes. Editor remarks: It is possible to suppose that the evolution of the sandy loess caused by the soilformation of Chermozem during the Holocene steppe condition (see also Chapter B/6)


a
E(US)D
LÓCZY & K.
b
EUD
K & B
c
E(SU)A
KÁDÁR

←

Fig. 30. A few examples for the *"Natural system of eolian landforms"* (after KÁDÁR 1966a). – (*Fig. 30a*) Loess mesas in China with streamlined ground plan (after LÓCZY 1886); b = sphinx-shaped eolian crags and tails; c = two storeyed barckan after an aerial photograph of A. HEIM from Peru. Correctly: in the natural system of exogenic landforms shown in the *Table 9* of KÁDÁR (1966) all known eolian landforms are arranged genetically taking into account the system of fluvial landforms and the results of investigations on blown sands by BAGNOLD, R. A.

The frames of this system are the types of load transport and the stages of surface development. The main geomorphologic features of *rolling blown sand* (*ER*) are the *concave parabolic surfaces* of the dunes and of the deflation throughs or wind furrows channelling the surface wind. The *erosion stage* (*ERD*) shows long and narrow *yardangs* parallel to wind direction between the *wind furrows*. They alternate with *parabolic dunes* in the *stage of variability ERV*. They are often rhythmically recurring and sometimes they become jammed to *twinned parabolic dunes*, expecially *in the accumulation stage ERA* and *ERVa*.

The most significant morphologic features of *saltating sand transport (EU)* is the convex inswept shape of *seif dunes (EUV)* and (*EUA*) and of the *sphinx-shaped* eolian *crags and tails (EUD* and *EUVd) (Fig. 30b)*. The most common form of desert dunes, the *crescent dune or barchan* belongs to the *E/SU/V* type of sand motion. It means that *it accumulates partly from suspended sand grains and partly from saltated ones.* Its convex shield-like shape being similar to the forepart of the inswept *seif dunes* proves the effect of rolling sand and its large back and steep slip-slope showing relations to the stepped flat areas of the sand sheets indicate suspended sand motion. This is most conspicuous on the *two-storeyed barkhan* of the accumulation stage, where, on the back of a large crescent dune there are heaps of smaller ones *(E/SU/A) (Fig. 30c)*. The crescent shape of the slopes denotes the simultaneity of their dune forming activity.

Earlier KÁDÁR himself explained some dune forms by changing of the wind direction. Later he became convinced by relative landforms caused by fluvial and corrasive processes that *all dune forms can be explained by one unchanged wind direction* which naturally may be deviated above the surface, according to SUNDBORG, A. even by 90°.

The transition from the barchan shape to the stepped sand sheets is shown by the lateral joining of crescent dunes to *twin barchans and to transerval dunes*, especially in the accumulation stage *E/US/A*. These are the most common forms of the *ergs*

The optimal ways of sandy soil amelioration are sought for the individual landform types. To improve soil water budget intermixing of clays, loamy loess or peat is proposed (PÉCSI, ZENTAI and GEREI 1982).

4. KARSTIFICATION PROCESSES

In the early decades of the 20th century the fundamental achievements of *karst* and *cave research* in Hungary were primarily associated with the activities of CHOLNOKY (1923, 1926) and BALÁZS (1982). CHOLNOKY's explanations for the development of karst landforms (doline, ponor, polje, etc.) and through caves depicted on block diagram are still valid in many respects. CHOLNOKY's achievements were further elaborated by his student and followers (STRÖMPL 1914; KESSLER 1938; LÁNG 1955a; LEÉL-ŐSSY 1957, 1987; VENKOVITS 1959; BALÁZS 1969, 1971).

For some decades, the studies on karst features and ecological problems of karst have been mostly associated with the Department of Physical Geography, University of Szeged. L. JAKUCS, an international authority in karst geomorpho-

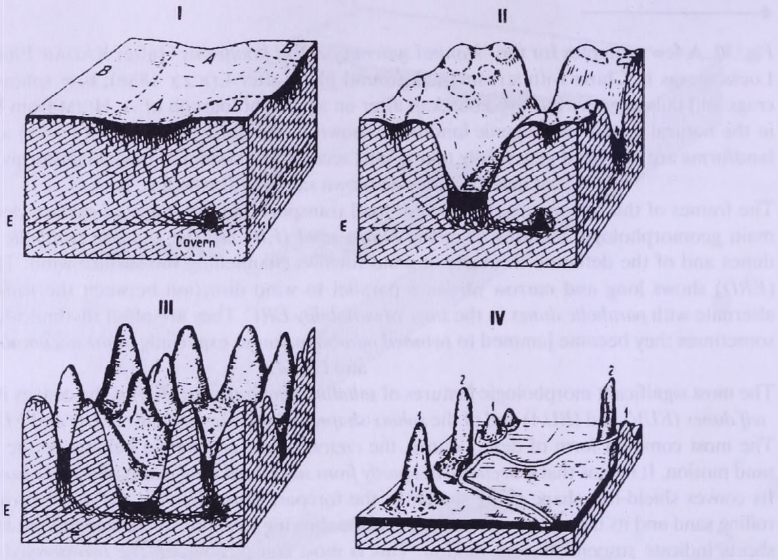


Fig. 31. Generalised model for the planation of karst surfaces in the tropical zone (after JAKUCS 1971b, 1977a). Phase I: Soils and regolith are removed from hummocks and deposited in the depressions of the prekarst surface, resulting in more intense karstification in the areas marked A than in areas marked B (E represents the base level of erosion).

Phase II: Intense karst corrosion under soils in areas A causes surface lowering at a rate higher than in areas B; areas B are becoming progressively distinct from areas A, due to cumulative effects (such as subaerial erosion).

Phase III: Tropical cockpit karst development. Areas B are reduced in dimensions and divided into peaks and ridges with a low rate of vertical erosion (any soil formed is soon washed off from steep hillsides). The cockpit thus evolves as a permanent landform of the tropical karst. At its base, where soils accumulate, erosion rates are tenfold higher than at the summit.

Phase IV: Lateral erosion and river corrasion occur at the base level in areas. A Cockpits are remodelled into karst towers through undercutting. During this process former underground streams cut channels on the surface of areas A. Later these surfaces widen into intermontane plains, while the area occupied by karst inselbergs, left over from former areas B, is gradually reducing (1 = cone karst; 2 = tower karst)

logy, is a devoted proponent of the significance of climato-biogenic impacts on the formation of karst features (*Fig. 31*). He claims (JAKUCS 1980a, b) that forest clearance and the destruction of vegetation cover do not increase but reduce the rate of karstification. JAKUCS (1971a, b, 1977a, b) also pointed out the process of selective karstification by cold water contributing to the weathering of dolomite and explained why impure dolomite surfaces do not show dolines or lapiés fields. His trend of research is carried on by his followers (JAKUCS et al. 1983; KEVEI and ZÁMBÓ 1986; JAKUCS and MEZŐSI 1987), who also investigated the surface karst features from landscape ecological viewpoints.

BALÁZS (1969, 1971) conducted laboratory experiments on the rate of karst corrosion and classified the karst formation and processes under tropical conditions in many countries on all continents.

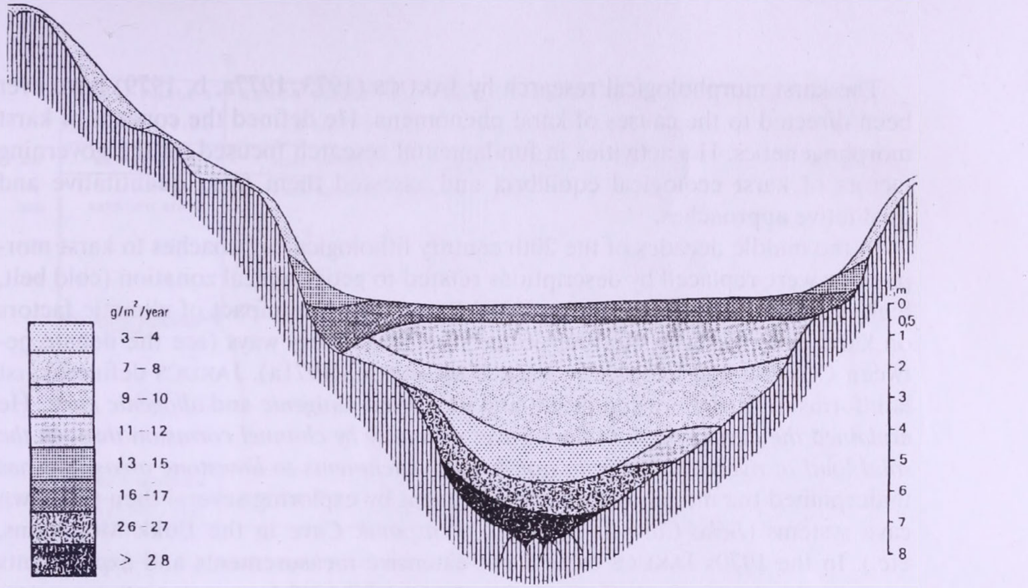


Fig. 32. Concept of limestone dissolution processes (after ZÁMBÓ 1997; ZÁMBÓ and FORD 1997). (A) Doline and sideslope groundwater infiltration expressed as a percentage of precipitation recorded at Beke Doline, the two sideslope sites and two other dolines, March 1981 – April 1983. (B) Mean annual $CACO_3$ dissolution rates for the doline and sideslopes calculated from the data presented above.
Aggtelek National Park, Hungary, is a limestone karts upland characterised by karren, dolines and caves. For a period of three years, climatic and carbonate dissolution variables were monitored at 18 measuring stations in 0.5–10m deep shafts through the soil fill in the floor of 4 typical large (100–150 m diameter) dolines. Results are compared to other monitoring stations in shallow soils on slide slopes. Runoff and groundwater flow are focused into the base of the doline soil fill, where moisture is maintained at 70–90 per cent field capacity and temperatures permit year-round production of coil CO_2. The capacity to dissolve calcite (limestone) ranges from ca 3 gm^{-2} per year beneath thin soils on the driest slopes to 17–30 gm^{-2} per year in the top 1–2 m of doline fill and at its base 5–10 m below. The regional value of sub-soil corrosion (the potential lime solution capacity) is 12.71 gm^{-2} per year in the average, calculated from the annual mean values of a large number of controlled data in the years 1980–1983. The generalised cross-sections of karst slopes and dolines represent the average quantity of surface limestone loss originating from corrosion in karst areas under continental climate.
The value of complete average limestone solutional loss is 0.0106 mm per year or ca 10 mm per thousand years. Calculations show the following values of solutional denudation for karst slopes and some other types of landforms: plato surfaces: 7 mm/ka; recession of steep slopes by solution: 7 mm/ka; recession of moderate slopes: 6.5 mm/ka; recession of gentle slopes: 6 mm/ka; edge of doline bottom: 10 mm/ka; permeable doline bottom: 13–16 mm/ka; blocked (always relatively) doline bottom: 1–2 mm/ka

For the classification of karst features produced by descending waters, HEVESI (1989) proposed a system. He also explained the development of surface karst landforms on the Bükk Mountains (HEVESI 1984).

Based on decades of field measurements in the Aggtelek Mountains, North Hungary, ZÁMBÓ (1985) set up a hydrogeochemical model for the corrosional behaviour of clay doline fills with different rates of solution in the three zones (saturated, unsaturated and swollen clay zones) identified in doline cross-section (*Fig. 32*).

The karst morphological research by JAKUCS (1973, 1977a, b, 1979) have ever been directed to the causes of karst phenomena. He defined the concept of karst morphogenetics. His activities in fundamental research focused on the governing factors of karst ecological equilibria and assessed them from quantitative and qualitative approaches.

In the middle decades of the 20th century lithological approaches to karst morphology were replaced by descriptions related to geographical zonation (cold belt, high mountain, temperate and tropical karsts) but the impact of climatic factors on karst dynamics was still interpreted in contradictory ways (see the debate between CORBEL and LEHMANN, backed by JAKUCS 1971a). JAKUCS defined karst landforms of fluvial erosion origin and identified *autigenic* and *allogenic karst.* He *explained the development of karst caves primarily by channel corrasion through the solid load of rivers carried from non-karstic catchments to limestone areas.* He has underpinned the model for cave development by exploring several then unknown cave systems (*Béke Cave* at Aggtelek, *Pénzpatak Cave* in the Bükk Mountains, etc.). In the 1970s JAKUCS carried out extensive measurements and experiments to prove the decisive role of karst microspaces, rhizo-spheres, soil microorganisms and other soil properties in karst corrosion. He defined landforms of abiogenic and biogenic origin and referred the concept of karst into the scope of landscape ecology. He *established a Hungarian school of karst research* by his comprehensive work on the "Morphogenetics of Karst Regions" (1977a, b, *Photo 34*), *still widely cited all over the world.* In the 1980s and 1990s, his attention turned to environmental changes in karst regions and began to study the sensitivity of karsts. Analysing the causes of deputation of forest on limestone plateaus, he claimed that the new type of speleothem degradation (dissolution) is an indirect impact of atmospheric contamination (particularly of acid rains and deposition).

Recently, a *nature protection approach* appeared in the methods of investigating dolines as ecological systems since pollutants easily reach the passages of karst water and exert harmful influence on karst (JAKUCS and BÁRÁNY 1984; KEVEI and ZÁMBÓ 1986; BÁRÁNY and KEVEI 1992).

The Triassic calcareous rocks were affected by etchplanation producing *tower* and *cockpit* karst beginning with the Jurassic but primarily during the Cretaceous Period (SZABÓ 1960; PÉCSI 1970c; JAKUCS 1971c; KORPÁS and JUHÁSZ 1990). The paleokarst features and the enclosed bauxite lenses were preserved by Upper Cretaceous and Paleogene strata from removal. According to JUHÁSZ, KORPÁS and BALOGH (1995) *in the Triassic limestone even older stages of karst cave formations can be traced.* They are filled with Jurassic limestone, dolomite powder, bauxitic material and sand. Karstification may have occurred repeatedly in four stages prior to the Neogene (*Fig. 33*).

On the surfaces of planation with paleokarst, first covered by Tertiary gravel and the uplifted (to 400–500 m altitude) and exhumed, swallow holes and dolines are common. The quartz gravels occurring in them support the assumption that part of them developed in buried karst (VERESS 1983, 1993; JUHÁSZ and KERTÉSZ 1985).

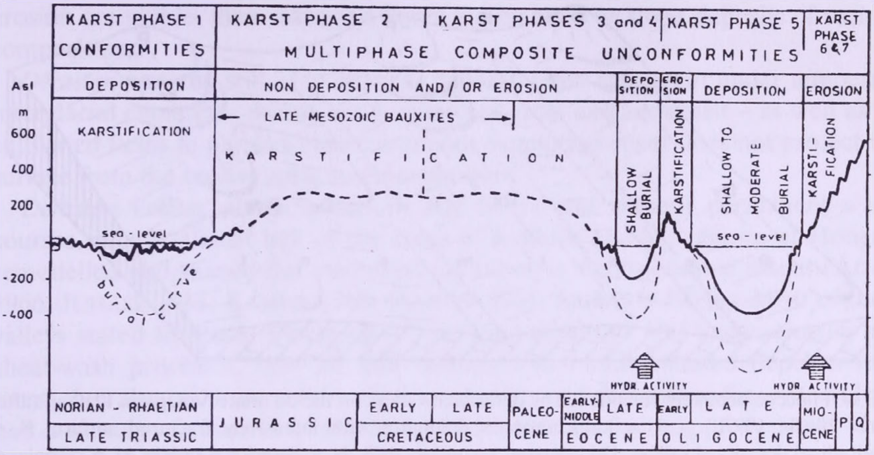


Fig. 33. Estimated curve for burial history with karstification intervals indicated (after JUHÁSZ, KORPÁS and BALOGH 1995)

In the Transdanubian Mountains, *deep karst features* are represented by large caverns. Some of them adre capable to store ten thousand cubic metres of karst-water endangering coal and bauxite mining with water bursts (HORUSITZKY 1953; SZABÓ 1960). In addition to dolines and lapié fields, there are more than 800 cold water and thermal caves. Their dimensions are particularly large, there are no spacious through caves. In some gorges spring caves are observed and along the mountain margins karst springs issue (like the thermal springs of the Buda Mountains, LEÉL-ŐSSY 1987, *Fig. 34* on page 190).

5. PERIGLACIAL PROCESSES AND LANDFORMS OF DERASION

It was first around the turn of the 20th century that terrace geologists, geomorphologists described ice-wedge casts in Pleistocene gravel surfaces in Hungary. The explanation was first given by INKEY (1892), who supposed that the lenslike carbonate powder and clay content[10] in the upper part of the gravel strata in the Pest Plain occasionally caused swelling and folding features. According to SCHAFARZIK (1918) these deformations of the uppermost 1.5–2 m gravel had been produced by ice-floes during floods. In the 1930s SZÁDECZKY-KARDOSS (1936) was the first to attribute them to periglacial frost action during the Pleistocene. Later some other polygonal ground features were also identified. According to BULLA (1939); KEREKES (1938, 1939, 1941) the Carpathian Basin only belonged to the pseudo-periglacial zone during the Pleistocene glacial stages. A

[10] The "Mastodon" gravel of the Pest Plain in some places is covered by bentonite, elsewhere it is interfingered with gravel sheet (*Photo 30c*).

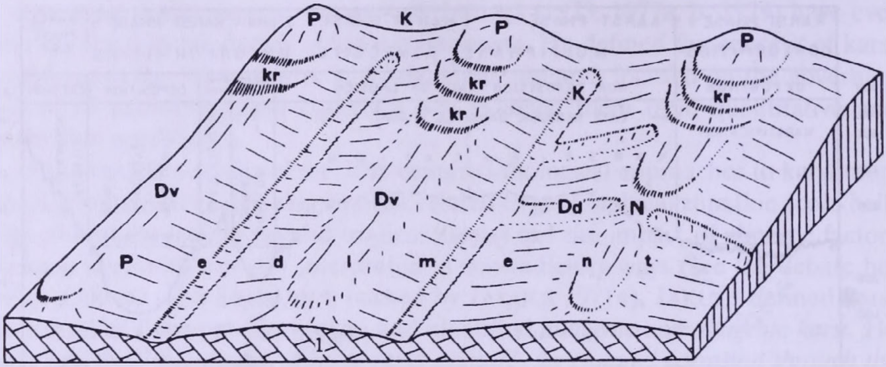


Fig. 34. Pliocene pediment remodelled by derasional valleys on the dolomite Veszprém Plateau (after PÉCSI 1963b, 1997b). – 1 = autochthonous dolomites with intensively fractured surface; K = longitudinal derasional valleys; Dd = minor, secondary dells; N = derasional saddle; kr = cryoplanational terraces; P = remnants of Pliocene pediment; Dv = inter-dell ridges which, altogether, form a periglacial pediment.

The function of the derasional valleys (dells) had an important part in modelling the relief, especially in that of the slopes formed during the Pleistocene. Their development is explained by derasional processes. Having extended the thorough analysis of derasional processes to the whole country we could ascertain that these processes were not confined to certain rock types, in other words, derasional valley is not a lithomorphological phenomenon but aclimatic–morphological one. Such valleys could be observed on granites, dolomites, Tertiary limestones, volcanic rocks, clays and different types of slope deposits as well as on gravel sheets and gravel terraces (PÉCSI 1961). They occur most frequently on slopes, but are encountered on terrace half-planes and on somewhat higher elevated plains as well

recent achievement that the basin is considered a genuine periglacial area. In the course of the systematic study of periglacial features additional polygonal tundra phenomena were described in the 1950s and 1960s (ÁDÁM et al. 1962; MAROSI and SZILÁRD 1957; PÉCSI 1961, *Photos 33a, b*) as well as a series of solifluctional, cryonival and cryoplanational features were found (LÁNG et al. 1958; KRIVÁN 1958; PÉCSI 1963b; PINCZÉS 1974, 1995a; SZÉKELY 1969).

The country wide geomorphological mapping of periglacial features (PÉCSI 1963b, 1997b) revealed that the Carpathian Basin – at least during the last two glacials – belonged to the belt of true periglacial processes and even discontinuous remnants of permafrost can be recognised (PÉCSI 1964c, *Fig. 56,* facing page 54).

It has recently been proposed (PÉCSI 1964a, b; SZÉKELY 1977, 1983a; PINCZÉS 1974, 1983) that frost action played a decisive geomorphic role in the evolution of the medium-height mountains and foothills during the Quaternary glaciation.

The intensity of the processes of solifluction, cryonivation, pluvionivation and cryoplanation varied with slope exposure, but significantly contributed to down-wearing. These processes fall into the group described by PÉCSI (1963b) under the heading of *derasion*.

Under the notion of *derasional valley* PÉCSI understands dish-shaped or narrow semicylindrical "dells" of different length. In thesse valleys no traces of linear erosion are visible, their sides and floors are mantled by slope deposits of various compositions.

Derasion was and still is an efficient process. Even at present under temperate interglacial climates – during early spring soil frost and snowmelt – as well as on cultivated fields in places where continuous vegetation cover does not protect the surface from the erosive early summer showers.

Derasion valleys, characterised by flat floors and without permanent water courses, occupy almost half of the areas of foothills and hill regions of Hungary remodelled and shaped but smoothed the relief to a considerable extent (ÁDÁM 1966; JUHÁSZ 1988; KAISER 1965; MAROSI 1965; SZILÁRD 1965a). Most of these valleys stated by PÉCSI the result of the joint action of –50 linear erosion and sheet-wash processes, they are not restricted to unconsolidated deposits (like loess), but also occur on solid rock (like granites and dolomites, *Fig. 34*). At least half a century of research of the periglacial landscape forming processes in Hungary has recently been summarised by PÉCSI (1997b).

6. WEATHERING IN LOESS-PALEOSOLS RESULTED IN SPECIFIC GRAIN-SIZE DISTRIBUTION

A constant problem of the theories of loess formation is the origin of the quartz grains of 20–50 μm size. This makes up the bulk of loess material. The fundamental question more than a century ago was how the huge amounts of the silt-size grains were produced. According to different explanations the coarse silt fraction can be derived from mechanical weathering caused by glacial grinding, particles originated from till and outwash plain and finally from fine textured fluvial and lacustrine deposits (molasses), or often from sandy desert.

According to PÉCSI (1993a) several kinds of processes can produce the initial material of loess. During loess formation first of all the pedogenic-geochemical processes were decisive to produce the coarse silty grain size. The unique loess fabric is a textured loam, not only a simple sediment.

Recently NEMECZ and HARTYÁNI (1995) has taken off samples in 10 cm steps of the soil (loess) fractionating them into 8–9 fractions according to grain size. The mineralogical composition of fractions was determined quantitatively and plotted in three dimensions. *Figure 35a* shows a typical distribution of the grain size of a Hungarian loess paleosol (PMB) and we can recognise two maxima, one at size of <5 μm and an other at 20–45 μm on the diagram. Very similar distributions were found in cases of other types of recent soils, too (*Fig. 35b*). It is interesting to mention that the distribution of decomposing minerals in soils and loess (quartz, feldspar, etc.) (*Fig. 35c*) are mainly present in the fraction of 20–45μm while autigenic minerals (kaolinite, montmorillonite, some of calcite, etc.) prevail in fraction of <5 μm.

The results of the granulometrical and mineralogical investigation show a *specific grain size distribution in loess and its paleosols rather related to the loessification or other soil formation processes, than to some exogeneous accumulation events.*

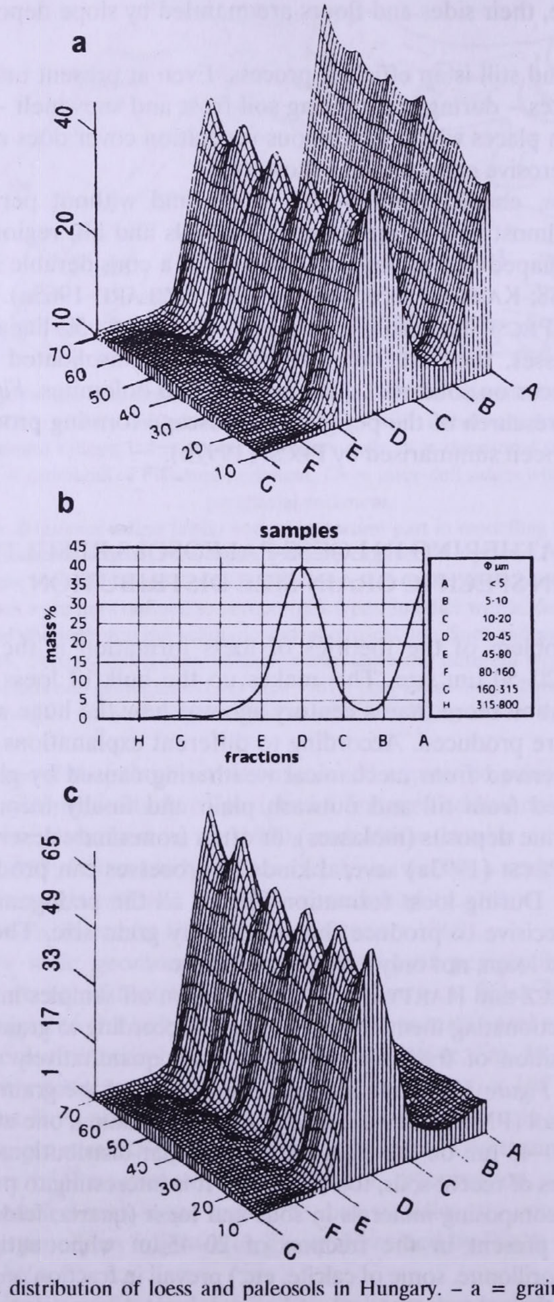


Fig. 35. Grain-size distribution of loess and paleosols in Hungary. – a = grain-size distribution of paleosol MB$_1$ at Paks loess exposure in Hungary (after NEMECZ–PÉCSI–CSIKÓS-HARTYÁNI 1998); b = grain-size composition of 16 recent soils in Hungary, mainly steppe and forest-steppe soils; c = grain-size distribution of quartz of paleosol MB$_1$ at Paks brickyard exposure in Hungary

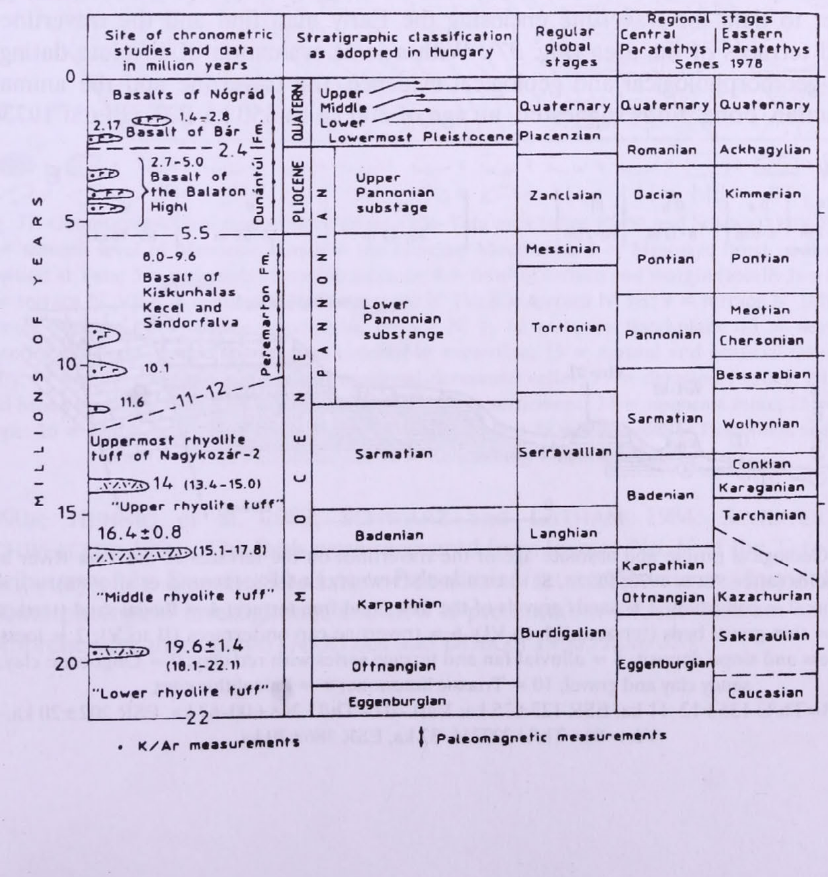
7. CHRONOLOGY OF GEOMORPHIC SURFACES AND LONG-TERM SUBAERIAL SEQUENCES

The time sequencing of deplanation and planation which cause some topography to turn gradually plain-like i.e. surface of planation (or erosion) has traditionally long been studied in Hungary (LÓCZY, sen. 1881, 1891; PRINZ 1941, 1958; BULLA 1941, 1954, 1958; SÜMEGHY 1955; LÁNG 1955b, 1958).

Recently, the correlation of planation surfaces and their correlative deposits (PÉCSI 1963a, 1970c; PINCZÉS 1960, 1970; SZÉKELY 1972; JÁMBOR and KORPÁS 1971; JUHÁSZ 1988; KAISER 1997) and reconstruction of long-term records of loess and other subaerial deposits (JÁMBOR 1989; PÉCSI and SCHWEITZER 1991, 1995; KRETZOI and PÉCSI 1982; RÓNAI 1985a) have come to the fore. As attested by radiometric, paleomagnetic and relative dating, the loess-paleosol sequence is ca 1 million years old in Hungary (PÉCSI 1997a, *Table 5*), while other Cenozoic subaerial sediments are ca 5.4 million years old (*Figs 18, 19*).

Some horsts in the Hungarian Mountains show as many as 12–15 geomorphic surfaces i.e. 6–8 Pleistocene river terraces 1–2 pediments, 2–3 Miocene marine

Table 10. Stratigraphic classification used in Hungary showing comparable global and regional stages (after HÁMORI et al. 1987)



terraces and 1–2 remnants of older planation surfaces. In some profiles – as an unique phenomenon – these surfaces are mantled by series of travertine (SCHEUER and SCHWEITZER 1986).

The position and ages of surfaces of planation, raised beaches and terraces studied in detail in some mountainous regions of Hungary are shown in PÉCSI (1996b, pp. 110–111), based on investigations carried out in recent decades. The now assumed chronological subdivisions of loess sequences and the underlying thick subaerial deposits are depicted in *Table 4.*

The consecutive series of Late Cenozoic sedimentary cycles and the intercalating or covering volcanic rock formations constituting the different stages of relief development explained by *Table 10.*

Traces of Lower Paleolithic Early man at Vértesszőlős enclosed in travertine

On the occasion of a geochronological field trip surveying the *terrace sequence of Tata river* in 1962 PÉCSI found a lower Paleolithic pebble tools industry site in the travertine layer, overlying an Early Pleistocene terrace of the river at Vértesszőlős (*Fig. 36*).

This unique find initiated further research in archeo-geology and geomorphology in order to date the travertine enclosing the Early man find and the travertine-covered terraces of the area (*Fig. 37*). With a joint evaluation of absolute dating, terrace-geomorphological and geological evidence, the travertine and the animal and human bone finds suggested an age of 500 ka to 350 ka B.P. (PÉCSI 1973,

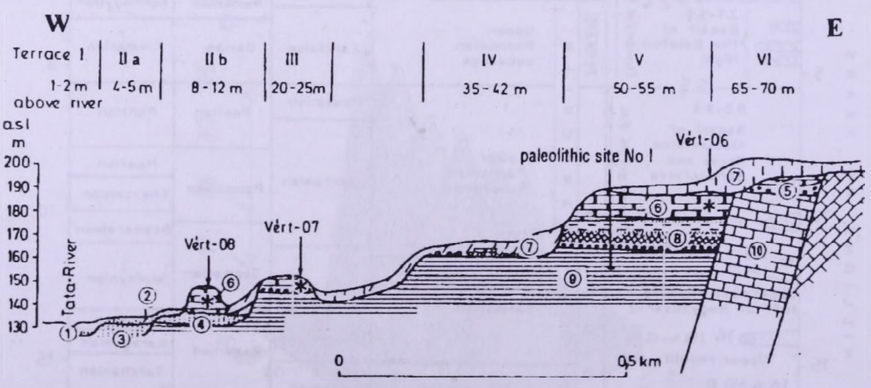


Fig. 36. Geological profile and absolute age of the travertines on the terraces of the Tata River at Vértesszőlős (after PÉCSI 1973; PÉCSI, SCHEUER and SCHWEITZER 1988; HENNIG et al. 1983). – 1 = floodplain; 2 = colluvium; 3 = sandy gravels of the first flood-free terrace; 4 = fluvial sand (terrace II/b); 5 = thin gravel beds (terraces II/b to VI); 6 = travertine cap on terraces III to VI; 7 = loess, slope loess and slope deposit; 8 = alluvial fan and terrace series with red clay; 9 = Oligocene clay, sandy clay and gravel; 10 = Triassic limestone; ∗ = Paleolithic sites.
Vért –08=Th/U 135+12–11 ka, ESR 123±25 ka; Vért –07=Th/U 248+00–67 ka, ESR 202±20 ka; Vért –06=Th/U 227356–37 ka, ESR 386±39 ka

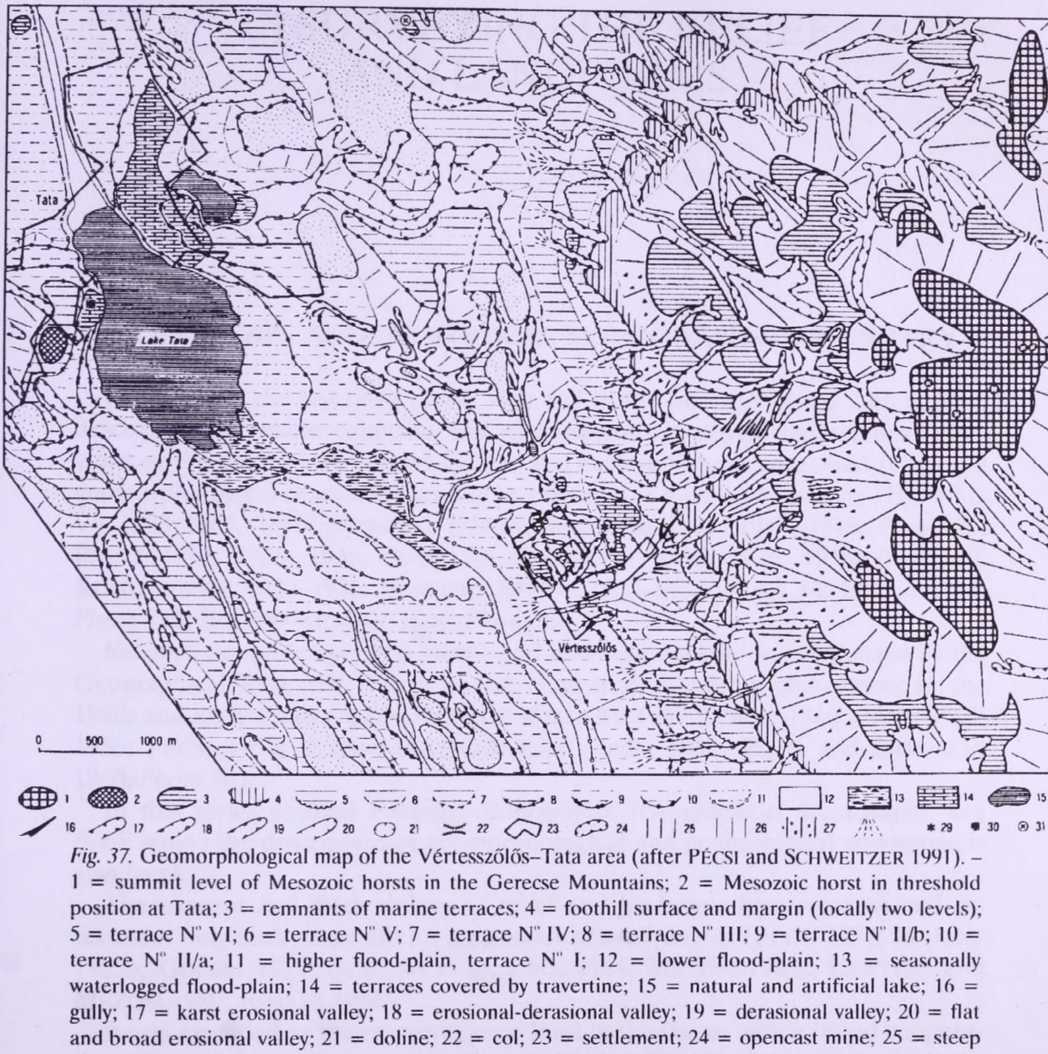


Fig. 37. Geomorphological map of the Vértesszőlős–Tata area (after PÉCSI and SCHWEITZER 1991). – 1 = summit level of Mesozoic horsts in the Gerecse Mountains; 2 = Mesozoic horst in threshold position at Tata; 3 = remnants of marine terraces; 4 = foothill surface and margin (locally two levels); 5 = terrace N° VI; 6 = terrace N° V; 7 = terrace N° IV; 8 = terrace N° III; 9 = terrace N° II/b; 10 = terrace N° II/a; 11 = higher flood-plain, terrace N° I; 12 = lower flood-plain; 13 = seasonally waterlogged flood-plain; 14 = terraces covered by travertine; 15 = natural and artificial lake; 16 = gully; 17 = karst erosional valley; 18 = erosional-derasional valley; 19 = derasional valley; 20 = flat and broad erosional valley; 21 = doline; 22 = col; 23 = settlement; 24 = opencast mine; 25 = steep slope; 26 = gentle slope; 27 = lapies slope; 28 = alluvial fan; 29 = Vértesszőlős Paleolithic site; 30 = Tata Paleolithic site 31 = Kenderhegy Paleolithic site

1990a; HENNIG et al. 1983; SCHWARZ and LATHAM 1984; SCHEUER and SCHWEITZER 1990). The finds were recovered from terrace No. V of the Tata river, a tributary of the Danube. The Lower Paleolithic Vértesszőlős site was found during geomorphological investigations and now is presented in a local museum and in a comprehensive monograph (KRETZOI and DOBOSI 1990 *Photo 35*).

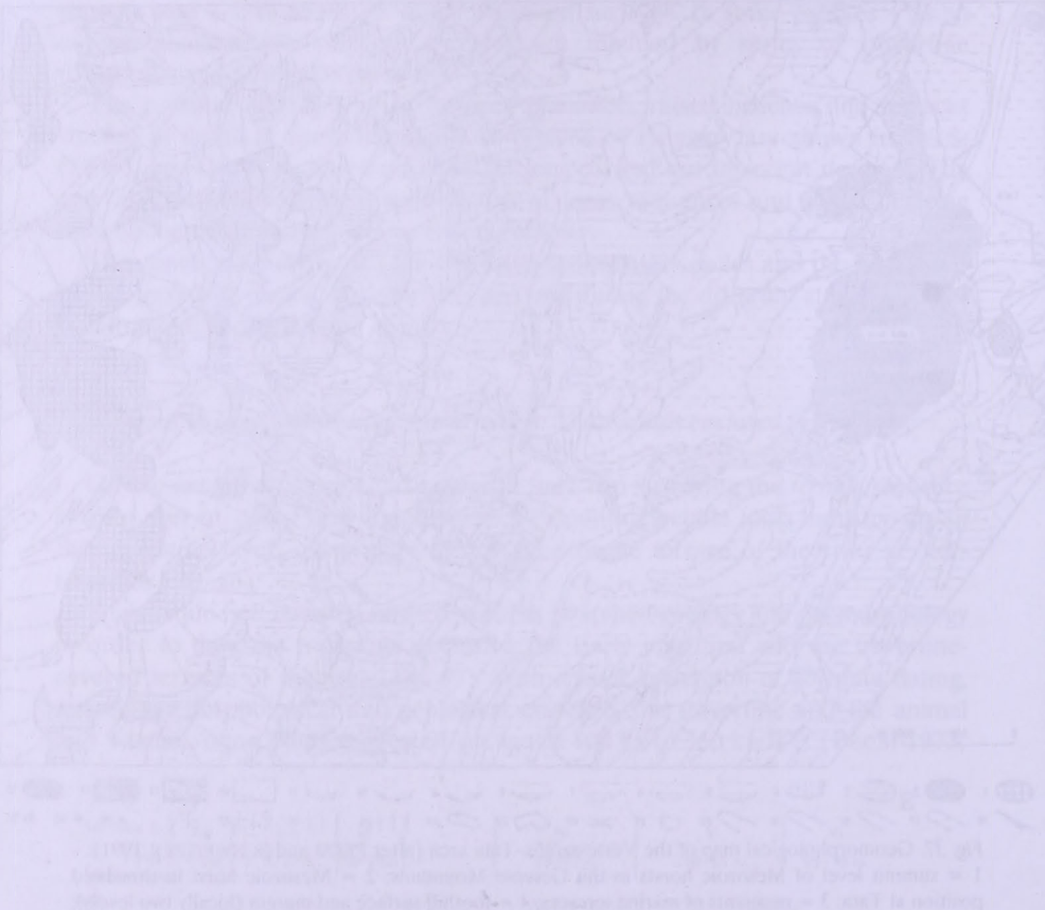


Fig. 37. Geomorphological map of the Vértesszőlős–Tata area (after [illegible] 1991). 1 = summit level of Mesozoic horsts in the Gerecse Mountains; 2 = Miocene [illegible] position at Tata; 3 = remnants of marine sequence; 4 = [illegible] surface and margin (locally two levels); 5 = terrace N. V [illegible] 6 = [illegible] terrace N IV; 8 = terrace N III; 9 = terrace N II/b; 10 = terrace N II/a; 11 = higher flood-plain, terrace N I; 12 = lower flood-plain; 13 = seasonally waterlogged flood-plain [illegible]; 15 = natural and artificial lake; 16 = gully; 17 = [illegible] valley; 18 = [illegible] valley; 19 = asymmetric valley; 20 = flat and broad [illegible] valley; 21 = [illegible]; 24 = [illegible]; 25 = steep slopes; 26 = gentle slopes; 27 = [illegible]; 28 = [illegible]; 29 = [illegible] Palaeolithic site; 30 = [illegible] Palaeolithic site; 31 = [illegible]

1990a; HENNIG et al. 1983, SCHWARZ and LATHAM 1984, SCHEUER and SCHWEITZER 1990). The finds were recovered from terrace No. V of the Tata river, a tributary of the Danube. The Lower Palaeolithic Vértesszőlős site was found during geomorphological investigations and now is presented in a local museum and in a comprehensive monograph (KRETZOI and DOBOSI 1990 [illegible]).

C) SURVEYING THE RELIEF AND LANDFORMS

1. LANDSCAPE AND GEOLOGICAL MONOGRAPHS OF HUNGARY

Published in the last third of the 19th and in the first half of the 20th century descriptions of whole countries and macroregions in physio-geographical overviews of the Carpathian Mountains and the enclosed basins contained relief and geomorphological characteristics and assessments in a massive quantity (HUNFALVY 1863–1865, 1886, *Photo 1c*; LÓCZY, sen. 1890–1899, 1913, 1918, *Photo 2b*; PRINZ 1914, 1926, 1936, *Photo 36*; CHOLNOKY 1918, 1924, 1936, *Photo 37*; KOGUTOWICZ 1930–1936; BENDEFY-BENDA 1933–1934, *Photo 38*; BULLA 1962; *Photo 11b*; BULLA–MENDÖL 1947, *Photo 39*).

Research on landscapes at a micro- and mesoregional level was organised by the Geographical Research Group of the Hungarian Academy of Sciences in the 1950s and early 1960s (ÁDÁM–MAROSI–SZILÁRD 1959; BORSY 1960; LÁNG 1955, 1956; PÉCSI 1959; PÉCSI–MAROSI–SZILÁRD [eds] 1958; PÉCSI and SÁRFALVI 1960, *Photo 40*).

In this series entitled *Földrajzi Monográfiák (Geographical Monographs,* see *Book series*) the description of geomorphological and geoecological conditions is also focal.

The concept and methodology of relief and landscape type research and assessment only took shape after a long series of experiments (PÉCSI 1979; MAROSI 1985b; GÖCSEI 1979; GÓCZÁN et al. 1983, 1984; MEZŐSI 1985c; KERTÉSZ and MEZŐSI 1989; JUHÁSZ 1988).

It was extended to the macroregional level in the sixties with a broad cooperation between geographical, geological and related institutions and individuals. The series editor of monographs, PÉCSI began the publication of results in 1967, entitled *Magyarország tájföldrajza (Landscapes of Hungary,* see in *Book series, Photo 41*). Geomorphology was predominant in the first volumes of the series. These volumes were aimed at the description of the physical conditions of the six macroregions of Hungary in a systematic way and mapping and evaluating the various landscape factors.

As a matter of fact, the geological and geomorphological chacpters in the monographs *Landscape of Hungary,* on *the physical geography and the geological* *series of macro- and* mesoregions[11] (*Photos 42–45, 21, 23, 25*) include the detailed geological-geomorphological description and assessment of Hungary also raise numerous theoretical and practical issues (*Photo 46a, b*).

2. GEOMORPHOLOGICAL MAPPING

For the pioneers of the geomorphological mapping of Hungary (ÁDÁM–MAROSI–SZILÁRD 1959; BORSY 1961; PÉCSI 1959) in its initial phase it was merely a supplementary activity for the publication of landscape monographs of the country, but soon became an independent trend to which a whole generation of geomorphologists contributed. A group of experts elaborated a uniform legend promoting detailed field surveys in 1963. Using this legend (PÉCSI 1963b) a considerable part of Hungary was mapped by geomorphologists within a period of 10 years at scales of 1 : 100,000 (ÁDÁM–MAROSI–SZILÁRD 1959; BORSY 1961) and 1 : 200,000. The experience gathered in geomorphological mapping was utilised on an international scale when – at the request of the Commission on the Geomorphology of the Carpatho-Balkan Region, PÉCSI (1977) prepared the 1 : 1,000,000 scale *Geomorphological map of the Carpatho-Balkan region* – with consultation of Hungarian specialists first of all the chief expert in tectonics GY. WEIN. This map finally was published in *Atlas of Danubian Countries,* edited by J. BREU at Wien, at a scale of 1 : 2,000,000 (PÉCSI 1980).

Detailed mapping of many meso- and microregions and catchments followed at 1 : 25,000 and 1 : 10,000 scales (*Figs 37–39*). The *Geomorphological map of Hungary* at 1 : 500,000 scale was published in 1972, 1976 by Cartographia, Budapest.

Geomorphological mapping and the relief assessment serving practical purposes urgently required landform type classification involving exact quantitative and qualitative parameters in morphological and genetic terminology and its consistent use. The results were published in theoretical-methodological and case studies (BUCZKÓ 1967, 1968; PÉCSI 1969b, 1976b, 1996b; JUHÁSZ 1976, 1995; MAROSI and SZILÁRD 1985; JUHÁSZ and KERTÉSZ 1985; MEZŐSI 1985c, *Fig. 16*; LEÉL-ŐSSY 1979, 1984; PÉCSI and JUHÁSZ 1974). A terminology of general orographic units for the country was elaborated for the map of *Relief types of Hungary* (JAKUCS–KERESZTESI–MAROS–PÉCSI–SOMOGYI 1989) while that for the genetic types of groups of landforms was summarised in the legend of the geomorphological map of Hungary. Both of these maps were published in the *National Atlas of Hungary* (PÉCSI [chief ed.] 1989, pp. 34–35).

[11] Geological description of the landscape of Hungary. Vols 1–6. 1935–1944; Annals of the Hungarian Geological Institute, 1871–1991. Vols 1–72; Annual Report of the Hungarian Geological Institute of Vols 125. 1877–1997; Geologica Hungarica Vols 1–23. 1914–1986.

Miscellaneous field studies and exploration of the geological and agrogeological map-series of Hungary, *Photo 45.*

For further detailed information see: List of Publications of the Geological Institute of Hungary 1869–1993. Budapest. Library of the Geological Survey of Hungary 1993. 94 pp.

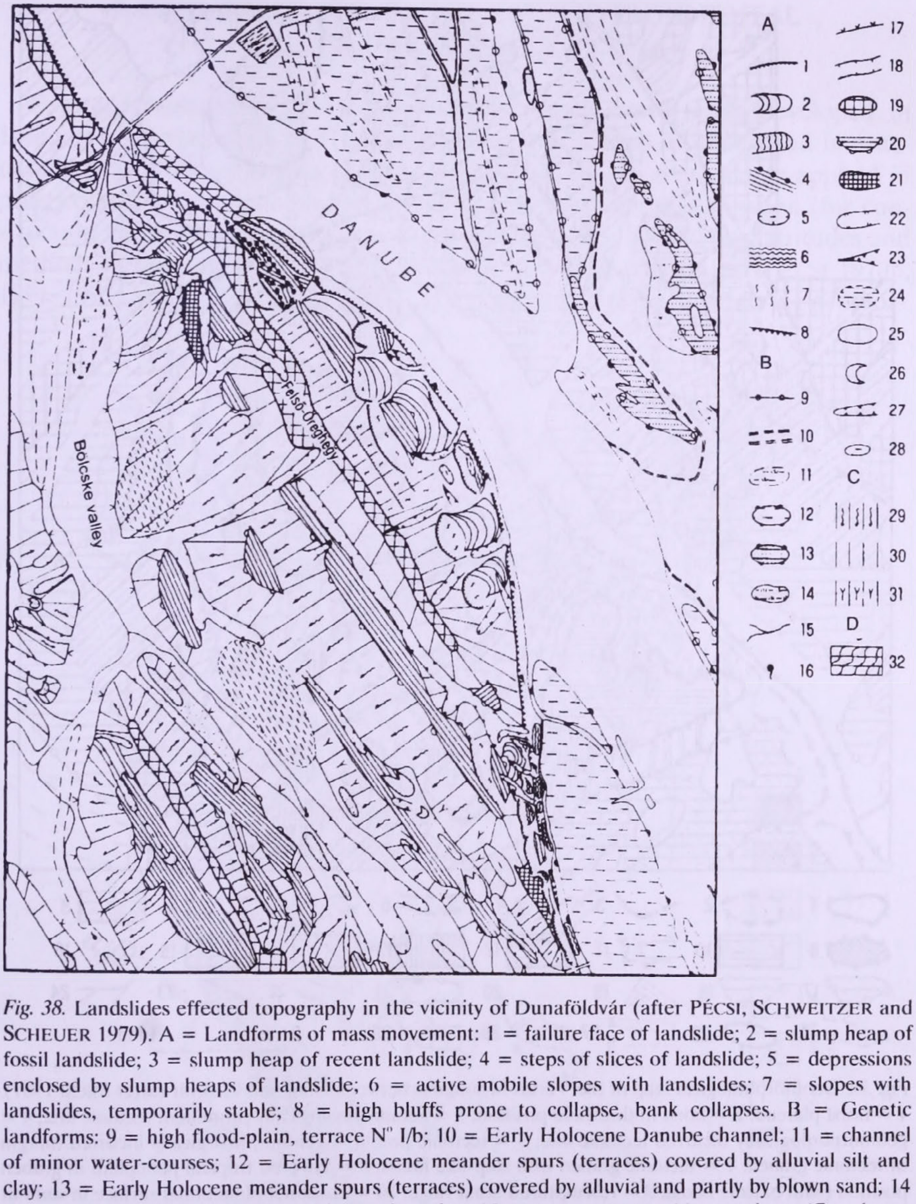


Fig. 38. Landslides effected topography in the vicinity of Dunaföldvár (after PÉCSI, SCHWEITZER and SCHEUER 1979). A = Landforms of mass movement: 1 = failure face of landslide; 2 = slump heap of fossil landslide; 3 = slump heap of recent landslide; 4 = steps of slices of landslide; 5 = depressions enclosed by slump heaps of landslide; 6 = active mobile slopes with landslides; 7 = slopes with landslides, temporarily stable; 8 = high bluffs prone to collapse, bank collapses. B = Genetic landforms: 9 = high flood-plain, terrace N° I/b; 10 = Early Holocene Danube channel; 11 = channel of minor water-courses; 12 = Early Holocene meander spurs (terraces) covered by alluvial silt and clay; 13 = Early Holocene meander spurs (terraces) covered by alluvial and partly by blown sand; 14 = boggy, water-logged terrains with meadow clay; 15 = water-courses; 16 = springs; 17 = lower boundary of valley floor; 18 = erosion valley; 19 = flat loess ridges; 20 = derasion step; 21 = erosion-derasion interfluvial ridge; 22 = derasion valley; 23 = erosion stream; 24 = depth of loessy-silty slope deposits; 25 = stabilized blown sand surface; 26 = blown sand dunes; 27 = wind furrows; 28 = deflation depressions. C = Slopes: 29 = slopes endangered by sheet erosion; 30 = slopes endangered by rill or gully erosion; 31 = stable slopes. D = man-made forms: 32 = artificial landfill

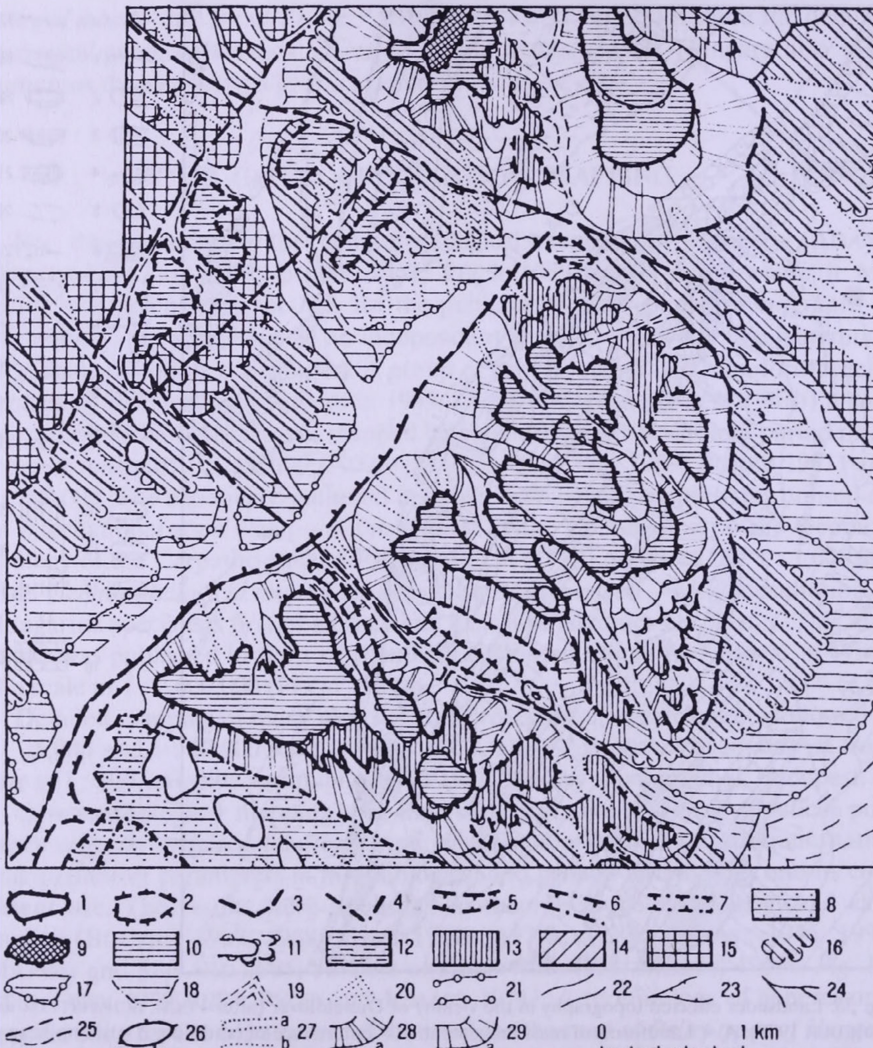


Fig. 39. Geomorphological map of the Vértes Mountains between Gánt and Csákvár (after PÉCSI 1987). 1 = horst plateau; 2 = horst in threshold position; 3 = geomorphologically prominent tectonic line; 4 = geomorphologically incurred tectonic line; 5 = tectonic line; 6 = geomorphologically incurred margin of tectonic graben; 7 = tectonic graben with step-like faults; 8 = covered tropical peneplain in graben position (with bauxite beds); 9 = resculptured horst ridge; 10 = erosional-planational surface in summit position; 11 = erosional-planational scarp; 12 = erosional-planational surface in threshold position; 13 = planated surface along horst margin; 14 = denudation level on spur; 15 = denudation level on interfluvial ridge; 16 = eroded pediment; 17 = higher alluvial fan terrace; 18 = lower alluvial fan terrace; 19 = alluvial fan terrace; 20 = debris fan; 21 = terraced valley; 22 = valley without terraces; 23 = gully; 24 = steep-walled karst walley; 25 = karst gorge; 26 = erosional-derasional surface remnant; 27 = derasional dry valley (a), karstic dry valley (b); 28 = rock slope (>15°); 29 = rock slope (10–05°); a = knickpoint on slope

3. ENGINEERING GEOLOGY AND ENVIRONMENTAL GEOMORPHOLOGY

Few geographical or geomorphological research trends have developed in Hungary so purposefully and has gained such a high level of inland and international recognition as geomorphological mapping. It was immediately applied in practice and it even became part of postgradual engineering education (for construction and environmental protection engineers). To this end new attitudes and methods of field geomorphological methods had to be elaborated (PÉCSI 1970b, 1971, 1975a, c; PÉCSI–JUHÁSZ 1978). The regular orders for engineering geomor-

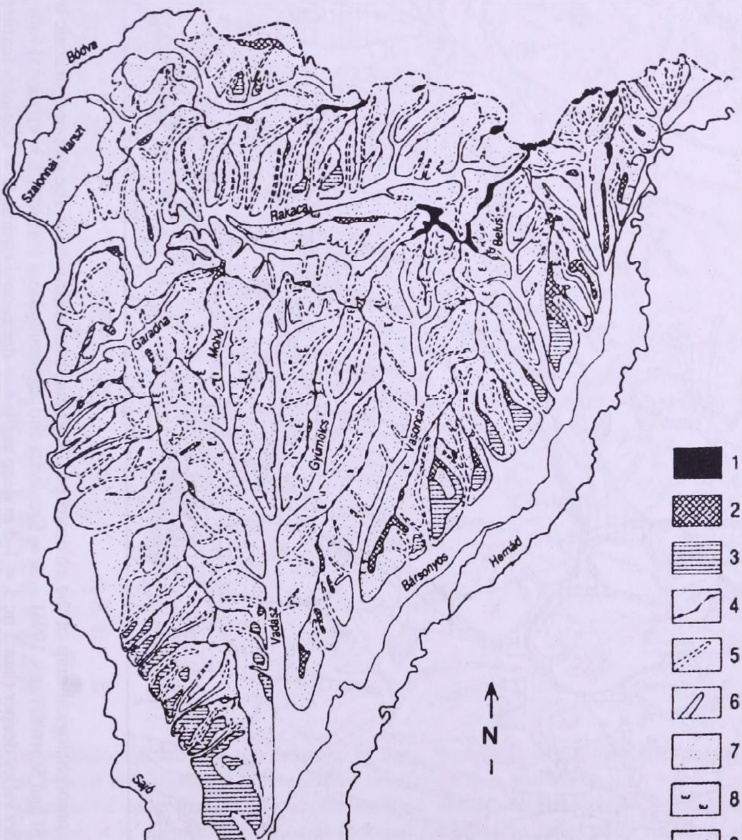


Fig. 40. Geomorphological map of the Cserehát with active and temporarily stabilised landslides (after SZABÓ 1996). – 1 = remnants of Late Pliocene foothill surfaces, mostly covere with gravel (above 300 m a.s.l. altitude); 2 = summit levels of broad interfluvial ridges (280–300 m a.s.l.); 3 = terrace levels of valleys and Pleistocene valley *glacis* formed by merging of terraces; 4 = narrow interfluvial ridges; 5 = derasional valleys; 6 = mostly erosional valleys; 7 = slopes undistinguished; 8 = active landslides; 9 = temporarily of finally stabilised or eroding landslide features (valley floors are unmarked)

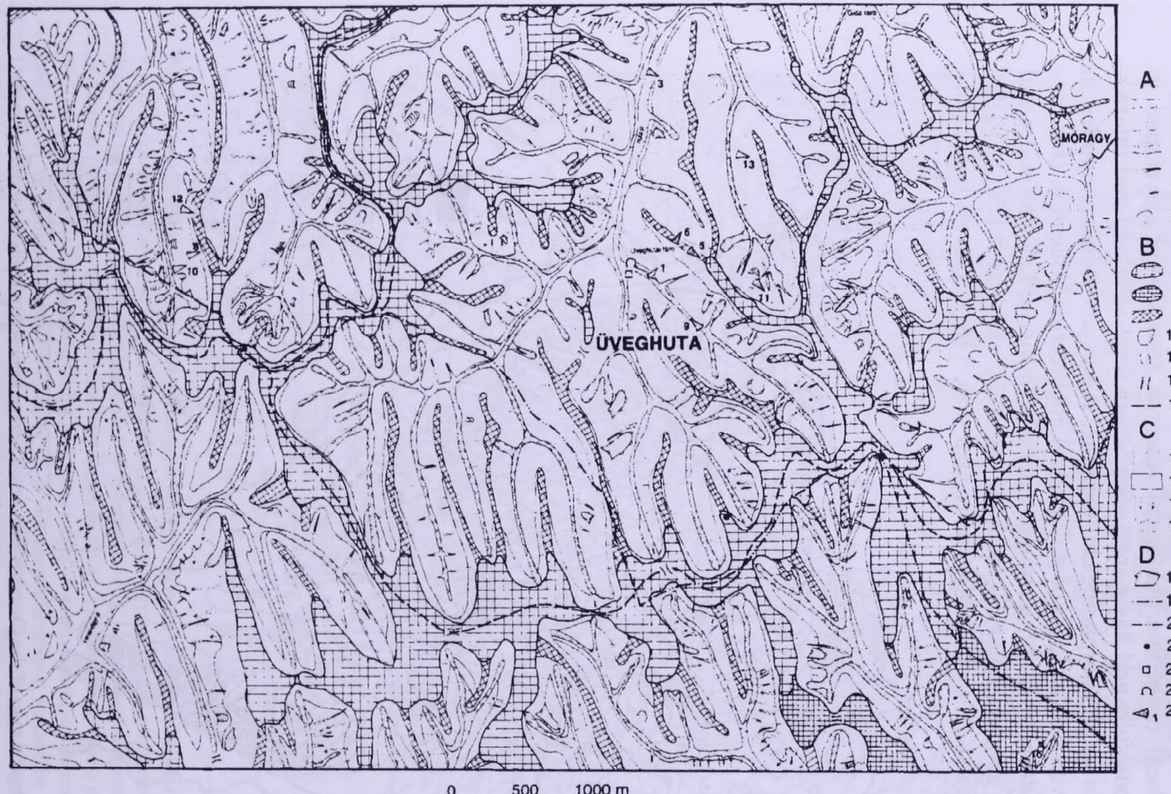


Fig. 41. Engineering geomorphological map of the environs of Üveghuta, site selection for the disposal of toxic waste of the Paks Nuclear Power Plant (after BALOGH, MAROSI and SCHWEITZER 1996). – A = Erosional and accumulational features: 1 = erosional valleys; 2 = erosional-derasional valley; 3 = derasional valley; 4 = dry valley deeper than 5 m; 5 = 1–5 m deep gully; 6 = derasional cirque. B = Complex features: 7 = summit level (ridge), 250–280 m a.s.l.; 8 = summit level below 250 m a.s.l; 9 = interfluvial ridge; 10 = gentle slope segment; 11 = landslide heap; 12 = dividing col; 13 = major divide. C = Slopes: 14 = slope undistinguished; 15 = steep slope segment; 16 = gully erosion hazard on slope; 17 = landslide hazard on slope. D = Other features: 18 = built-up are; 19 = borders of settlements; 20 = county border; 21 = borehole; 22 = exposure; 23 = planned object; 24 = photograph with the direction it was taken from

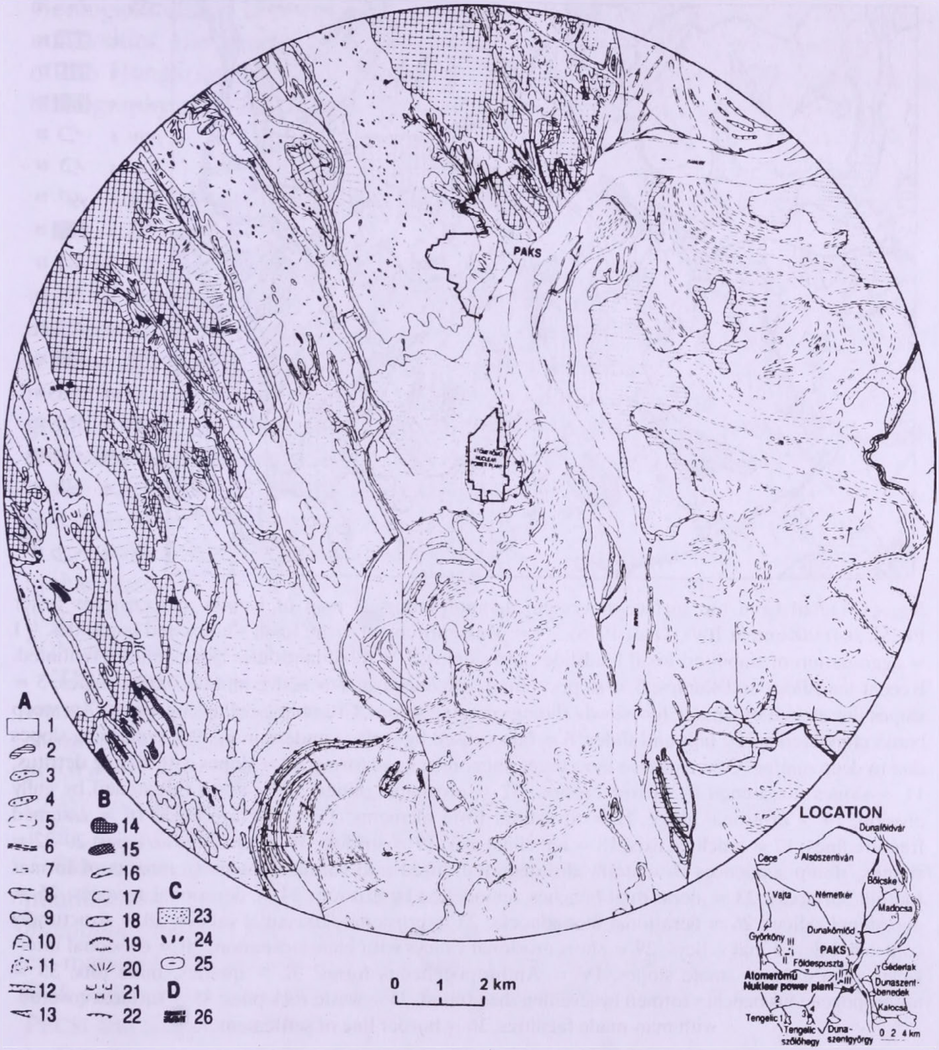


Fig. 42. Geomorphological map of the environs of Paks Nuclear Power Plant (after BALOGH et al. 1994). – A = Fluvial erosional and accumulation landforms: 1 = low flood plain level; 2 = former, cut-off or abandoned meanders; 3 = former upfilled meanders, intermittently inundated, with acquatic vegetation; 4 = former, cut-off or abandoned meander, in flood plain forest; 5 = former, upfilled meander, cultivated; 6 = former, upfilled meander, channelised; 7 = alkali flats, frequently covered by water; 8 = high flood plain; 9 = former terrace island on the flood plain; 10 = fluvial terrace; 11 = flat alluvial fan; 12 = broad and flat erosional valley; 13 = gully. B = Landforms of complex genesis: 14 = loess plateau; 15 = low interfluvial ridge; 16 = derasional dry valley; 17 = derasional niche; 18 = erosional-derasional valley; 19 = derasional col; 20 = slope, undistinguished; 21 = slope with stabilised fossil slump; 22 = unstable bluff. C = Lanforms of deflation: 23 = sand blanket; 24 = sand forms (longitudional dunes, blow-out, r esidual ridge); 25 = deflation hollows. D = Man-made landforms: 26 = sunken road

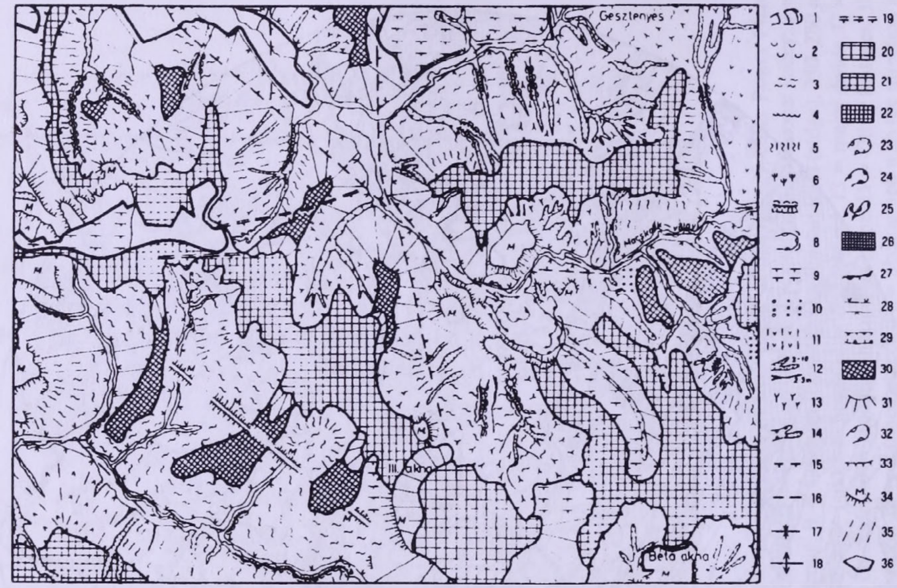


Fig. 43. Detail from the surface-movement geomorphological map of Komló and environs (after PÉCSI, JUHÁSZ and SCHWEITZER 1976). – I = Mass movement form: fossil slumps and landslides. – 1 = aggradation of stabilised fossil landslides and slumps; 2 = fossil landslides slopes undifferentiated. Recent landslides and slumps; 3 = slopes temporarily inactive; 4 = active mobile sliding slopes; 5 = slopes threatened by sliding; 6 = slowly sliding creeping slopes. Crumbling-collapsing forms; 7 = steep banks characterised by falls and slides; 8 = falls caused by surface undermining; 9 = collapsing slopes due to deep mining. Other surface movement phenomena and forms; 10 = slopes with sliding detritus; 11 = slopes threatened by furrow erosion; 12 = erosional gullies; 13 = areas threatened by gully erosion; 14 = erosional gorge. II = Structural form elements; 15 = fracture lines; 16 = assumed fracture lines; 17 = synclinal axis; 18 = anticlinal axis; 19 = striding. III = Other from types: 20–22 = slumps, slump sequences structurally disintegrated, lifted into various heights (remnants of former foothill surfaces); 23 = derasional benches remodelled by erosion; 24 = derasional terraces; 25 = derasional valleys; 26 = derasional monadnocks; 27 = erosional-derasional valleys; 28 = structurally controlled derasional valleys; 29 = short erosional valleys with high inclination; 30 = erosional inter-valley ridges; 31 = stable slopes. IV = Anthropogeneous forms: 32 = quaries, mine pits; 33 = anthropogeneous benches formed by levelling the ground; 34 = waste rock piles; 35 = surfaces covered with man-made facilities; 36 = border line of settlement

phological mapping called for the standardisation of the survey of areas with mass movements (PÉCSI, JUHÁSZ and SCHWEITZER 1976; ÁDÁM and PÉCSI 1985; SZABÓ 1985a, b, 1996).

The survey of areas with landslide hazard allowed the description and classification of landforms of landslide origin and making case studies (PÉCSI 1971; PÉCSI, SCHEUER and SCHWEITZER 1979; SZABÓ 1982, *Fig. 40*; ÁDÁM and SCHWEITZER 1985; JUHÁSZ 1985a, b; MEZŐSI 1985c; BALOGH et al. 1989), (*Figs 41–43*).

Along with experts of the Geological Survey of Hungary (*Photo 51*), the Surveying and Soil Analysis Enterprise with the direction and subvention of the State

Geological Office (FODOR et al. 1981, 1982) and the geological departments of universities, the geomorphological team of the Geographical Research Institute of the Hungarian Academy of Sciences was also active (see the 45 items in the bibliography cited – ÁDÁM and PÉCSI 1985, *Photo 46b*).

4. CLASSIFICATION AND EVALUATION OF RELIEF TYPES

In Hungarian geomorphology the evolution of landforms had been a central topic of investigation for a long time. In addition, however, the demand for the assessment of landforms for various land utilization presented itself. A uniform terminology had to be outlined for the interpretation of landforms from a joint morphometric and genetic aspect for the purposes of geomorphological and orographic mapping. Also there *was a need for distinguishing between relief types and landscape types.* In many cases, relief types are less heterogeneous than landscape types, e.g. in plains, but an opposite case also occurs (JAKUCS et al. 1989, and BALOGH et al. 1989. National Atlas of Hungary, pp. 90–91 and pp. 26–27).

In addition to classification and description in a textual manner, a clearer hierarchic classification of geomorphological regions in Hungary (*Fig. 15*) and their map (PÉCSI and SOMOGYI 1969), and of landscape types in Hungary (PÉCSI, SOMOGYI and JAKUCS 1971) were compiled.

The concept and methodology of relief and landscape typology – see in National Atlas of Hungary, pp. 26–27 and pp. 90–91 – research and assessment only took shape after a long series of experiments (PÉCSI et al. 1971; PÉCSI and SOMOGYI 1969; LEÉL-ŐSSY 1979, 1984; MAROSI [ed.] 1979; GÖCSEI 1979; GÓCZÁN and PÉCSI 1984; LÓCZY 1989c; MEZŐSI 1985b, c; KERTÉSZ and MEZŐSI 1989; JUHÁSZ 1988; HORVÁTH 1991a).

There was also an urgent need of clarification of some genetic landform denominations. Thus, in the Hungarian geomorphological literature the *slopes of mountain forelands were called alluvial fan zones.* In the legend of geomorphological maps *glacis d'accumulation* was already distinguished from *glacis d'érosion* and *rock pediments* with a thin veneer of deposits (PÉCSI 1961, 1963a; BULLA 1962; PÉCSI and SZILÁRD 1970).

For the process of *denudation* the *term planation* was generally applied but it was not unambiguous even in the international usage and many synonyms were employed. In order to clarify the international terminology, a symposium with field excursion was organized in Hungary in 1967 (PÉCSI [ed.] 1970c). As an outcome of this meeting *erosion* or *planation surfaces, piedmonts became only descriptive orographic terms.*

In a genetic sense *the peneplain is interpreted in DAVIS' concept, the piedmont step (Piedmonttreppe) and the Primärrumpf in PENCK's concept.* The *tropical peneplain* according to BULLA (1954, 1958b) and BÜDEL's *doppelte Einebnungsfläche* (1957) are synonyms with the *etchplain* (WAYLAND 1934) and the *pediplain* (KING 1949) can only be applied to the landforms in a sense originally intended by

Fig. 44. Recent geomorphic processes (after LOVÁSZ 1985a). – 1 = intensive material transport by rainwater; 2 = intensive material transport by rainwater and landslide hazard; 3 = very moderate material transport by rainwater; 4 = moderate material transport by rainwater; 5 = no geomorphic change; 6 = deluvial accumulation; 7 = fluvial accumulation; 8 = deflation processes; 9 = geomorphic processes in the inner areas of settlements

authors of the concepts. Improper usage of terms leads to major misunderstanding.

Planation surfaces seem to exist in mountains and on ancient shields which cannot be referred to either of the above terms. According to PÉCSI (1970a, c, 1996a) the *erosion surfaces in the Transdanubian Mountains are mostly polygenetic plana-*

tion surfaces, resulted from various aplanational, deplanational processes, while in a plate tectonic sense considerable horizontal displacements occurred with some vertical uplift and subsidence. As a consequence of repeated tectonic movements, the planated geomorphological units were repeatedly buried and conserved and, later exhumed, became surfaces of erosion again (PÉCSI 1996b, *Fig. 47* on p. 47).

Starting with the 1960s the Commission on Geography HAS actively promoted *landscape evaluation of the individual regions* and a related assessment and *classification of landform types using practice-oriented methods.* These aims were pursued by the elaboration of maps of *morphometric dissection* (relative relief), of *slope categories* and *slope exposures* for hill and mountain regions (ÁDÁM 1983, 1985; BALOGH–KERTÉSZ–MEZŐSI 1987; LOVÁSZ 1981, 1985a, *Fig. 44*). PÉCSI (1975a, 1985a) has undertaken the formulation of the *tasks of environmental geomorphology* and of laying the theoretical-methodological foundations.

A modern and sophisticated method of land assessment was worked out by the team led by GÓCZÁN (GÓCZÁN–PÉCSI 1984; GÓCZÁN et al. 1988).

Theoretical-methodological foundations and application of *landscape evaluation with a physico-geographical approach* were laid in a close relation with the series entitled *Landscapes of Hungary* through a collaboration between the editors of the individual volumes and the authors. The system of landscape geographical components intertwined with each other was analyzed first by MAROSI and SZILÁRD (1967). In monographs on Hungarian landscapes an emphasis was made on a detailed analysis of components directly influencing the value of the given landscape, its natural potential, from the viewpoint of social production and utilization. Within the given climatic zone it is the soil and water factor interrelated with the basin topography.

Hungarian geomorphologists have played an important part in a national program of *investigations into the agroecological potential of the country,* as far as the elaboration of principles and methods were concerned and also in the identification of the agroecological regions (GÓCZÁN et al. 1979; PÉCSI 1979, GÓCZÁN 1981a; GÓCZÁN et al. 1988; LÓCZY and TÓZSA 1982).

Beside landscape evaluation from the agroecological aspect the series *Landscapes of Hungary* has provided a most detailed theoretical and practical analysis of the relief conditions of the country.

Another monograph entitled *Magyarország kistájainak katasztere (Inventory of the microregions in Hungary,* MAROSI–SOMOGYI [eds] 1990) presented a description on the topography of the *320 microregions of the country* from a different viewpoint but of a similar system and proportion (authors: ÁDÁM–JUHÁSZ–MEZŐSI and SZILÁRD). This inventory in a double volume gave a concise account of natural components (land, climate, soils, waters, natural vegetation) by microregions (*Photo 47*).

For ranking topography according to the requirements of the agriculture and sylviculture, methods and approaches were suggested by GÓCZÁN (1984) and PÉCSI (1986a). Demands of mountain tourism were taken into account for relief assessment by KERTÉSZ (1988) in his candidate's dissertation.

Attempts to work out research *principles and methods* for *site selection (Figs 41, 42) and environmental geological, geomorphological studies* aimed at *a safe disposal of radioactive waste* were made (SCHWEITZER and TINER [eds] 1966; MAROSI–MESKÓ [eds] 1997; ORMAI 1997; BALLA 1997; CHIKÁN 1997; TURCZI et al. 1997).

Remote sensing methods (application of aerial and satellite images) were instrumental in geological, geomorphological and geoecological investigations and mapping (MIKE 1967; CZAKÓ 1975; JAKUCS 1984; DOMOKOS 1984 *Photo 48*; GÁBRIS 1987; NEMERKÉNYI 1986; ORAVECZ 1981; BALOGH et al. 1989; ZELENKA 1998).

These new and efficient approaches helped identify geological formations and lineaments, landforms and have proven to be useful in the improvement of the quality and accuracy of ecological and geomorphological mapping.

5. ASSESSMENT OF THE PHYSICAL ENVIRONMENT

In the late 1970s and 1980s a new trend in applied studied emerged in the Geographical Research Institute of the Hungarian Academy of Sciences, under the heading of 'environmental assessment'. The objective was to translate the achievement resulting from twenty years of landscape surveys at various scale to the language of the actual users of land and portray the potentials of the environment for the activities of human society in an integrated manner (PÉCSI 1974). The development of environmental assessment ran parallel to international efforts towards land evaluation launched by the publication of the FAO guidelines in 1976 (LÓCZY 1989c). (The overlapping objectives are discernible in spite of the much narrower sense of the concept of 'land' in Hungarian – mostly restricted to agricultural land.)

In Hungary the conceptual foundations of environmental research from a physical geographical approach were provided by a novel interpretation of the total geographical environment as a complex of four subsystems (PÉCSI 1979, 1986a) and by the accompanying methodology proposed for the presentation of environmental potentials (PÉCSI–RÉTVÁRI 1980). In accordance with the predominantly physico-geographical approach (MAROSI 1985b) the first of the environmental factors to be evaluated was topography (PÉCSI 1984b; JUHÁSZ 1988; HORVÁTH 1990). Beginning with the 1970s, the rise of the quantitative approach in international geomorphology had a major influence on national research. As a reflection of those new developments and as a major preparatory step to relief assessment, morphometric investigations were gaining ground in Hungarian geomorphology, too (KERTÉSZ 1976; ÁDÁM 1983, 1985).

In accordance with the concept of the total geographical environment, it was soon recognised, however, that environmental conditions influence human activities through intricate interactions (GÓCZÁN 1981a, b) and, consequently, the range of factors included in the evaluation was extended to soils, near-surface rocks, climate, surface and subsurface waters, vegetation and mineral resources (GÓCZÁN et al. 1979; GÓCZÁN and PÉCSI 1984).

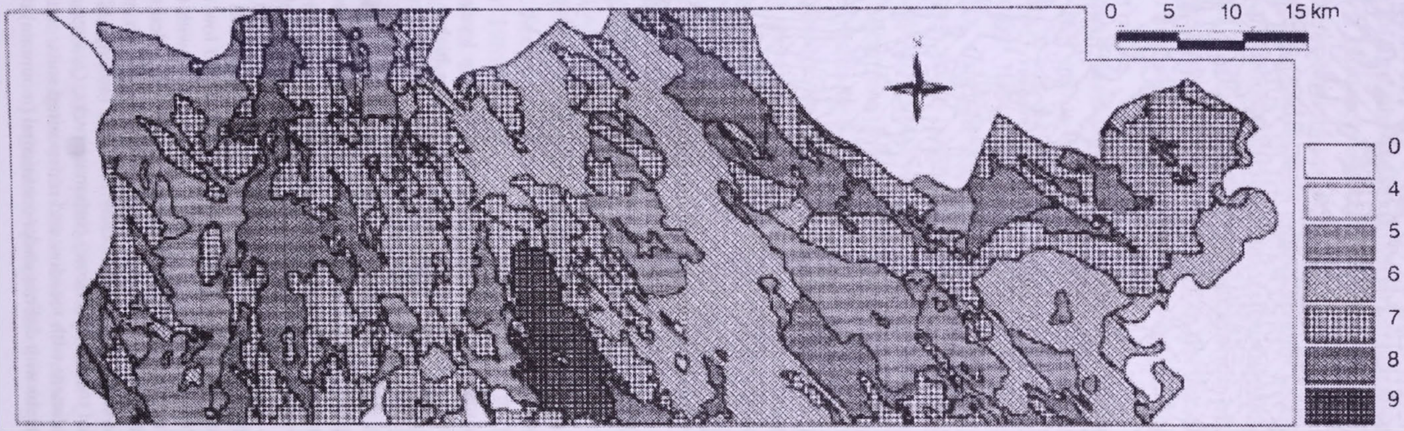


Fig. 45. Extract from the land suitability maf of Bács-Kiskun County (northern belt) for maize growing (soil conditions only – by Lóczy and Szalai 1995). 0 = unsuitable soils; 4–8 grades of increasing suitability among to soils of Hungary

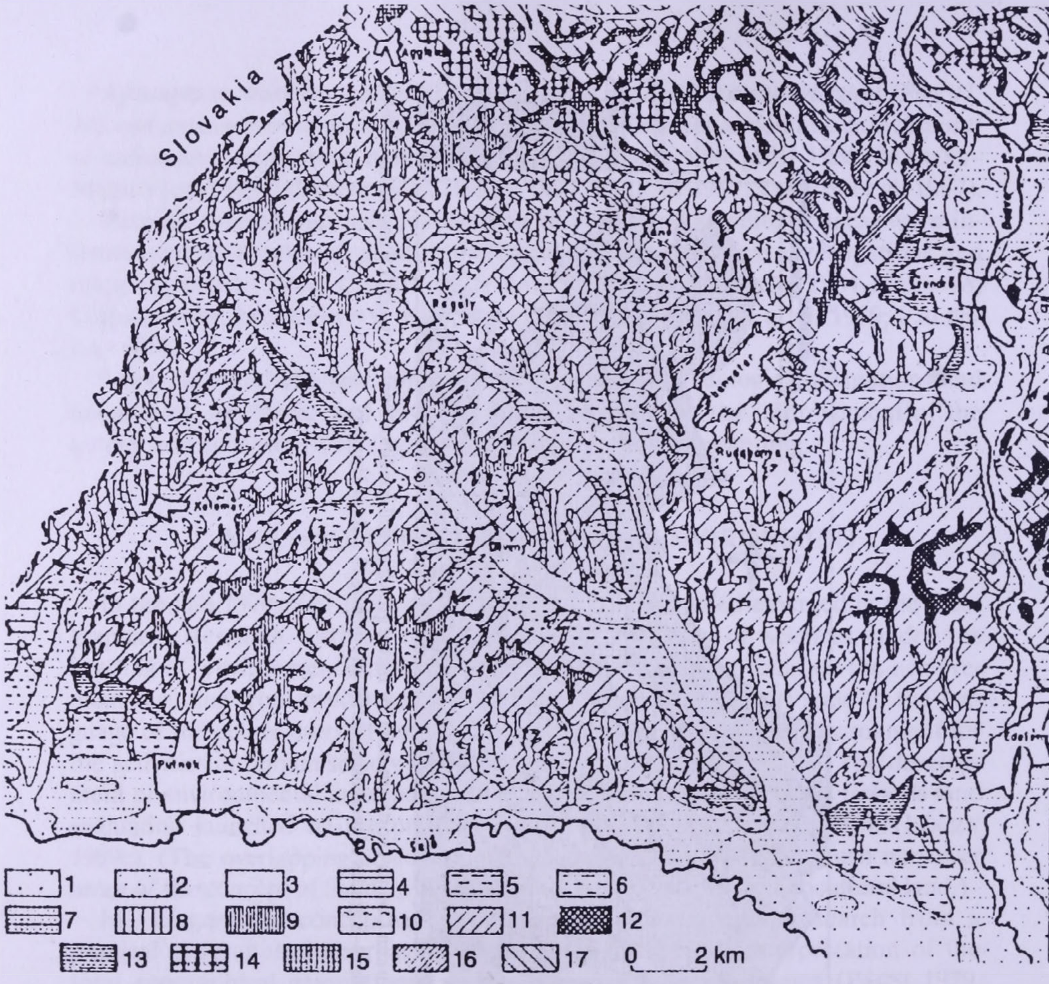


Fig. 46. Landscape topology (after MEZŐSI 1985c). – 1 = (lower) floodplain levels with floodplain vegetation, alluvial or – subordinateleadow soils, high groundwater level; 2 = higher floodplain levels with floodplain vegetation, locally groves, alluvial and meadow soils; 3 = waterlogged erosion valleys and gorges with floodplain alder forests; 4 = broad derasional and erosional-derasional valleys with alluvial meadow and redeposited soils used as meadows and pastures; 5 = low terraces with meadows soils of alluvial origin (ash and elm), groves and meadows; 6 = terrace surface with chernozem and *Acereto tatarici-Quercetum* vegetation; 7 = terrace surface with brown forest soils and locally *Quercetum-petraeae-cerris* forests; 8 = summit levels of hills and interfluvial ridges of unconsolidated Sarmatian-Pannonian deposits with *lessivé* brown forest soils and brown earth originally with *Quercetum-petraeae-cerris,* now locally used for farming; 9 = higher levels of hills and interfluvial ridges with degraded *lessivé* brown forest soils and brown earth; 10 = hill and low mountain slopes (above 12 per cent angle) on unconsolidated deposits, endagered by landslides, with truncated brown forest soils, dissected by a dense network of erosional-derasional valleys, degraded with *Quercetum-petraeae-cerris* vegetation; 11 = gentle hill slopes (below 12 per cent angel) with brown forest and redeposited soils, *Quercetum-petraeae-cerris* vegetation, locally used for farming; 12 = low summit levels and ridges of block mountains of mostly (Paleozoic) carbonate rocks, *Quercetum-petraeae-cerris* vegetation; 13 = slightly dissected pediment with meadow and redeposited soils, cultivated grassland locally with oak forest; 14 = karst plateaus with dolines under continental (mountain) climate, rendzina

The survey of the physical potentials of two districts in Veszprém county, implemented in a parametric system, was a pioneering attemt at a *comprehensive land evaluation for agricultural purposes* in Hungary.

The technique of rating land quality from 0 (ecologically unsuitable for the use in concern) to 9 (most suitable under the physical conditions of Hungary) was finalised in this stage. However, the integration of partial scores remained to be solved. Data from detailed field surveys in earlier decades were updated and employed in *land evaluation projects for large-scale arable farming* (LÓCZY 1984, 1988, 1989a, b).

Investigations, were directed at various potentials (winter recreation – GÓCZÁN–LÓCZY–MOLNÁR–TÓZSA 1983; geothermal energy – MOLNÁR and TÓZSA 1984; seismicity – LÓCZY–TÓZSA 1982; air quality – TÓZSA 1989; nature conservation – HEVESI 1984; land capability and soil erosion risk – KERTÉSZ and MEZŐSI 1991b; touristic potential – KERTÉSZ 1985; MARTON–ERDŐS 1990; GYURICZA 1995, 1997; landscape sensitivity – KERÉNYI and CSORBA 1991, 1996; acidification – VÁRALLYAY et al. 1993) and carried out for various spatial units (catchments, administrative units) using geographical information systems. Assessment has gradually become a useful corollary and a means of integration of findings in landscape studies (SZABÓ 1984; JUHÁSZ 1988, etc.).

A technical development, the availability of personal computers and workstation in geographical institutions (from the early 70s) have contributed to the advent of more advanced evaluations based on GIS (KERTÉSZ–MÁRKUS–MEZŐSI 1990). The project of agricultural zoning in Hungary (initiated by GÓCZÁN and continued by LÓCZY) was completed for the counties of Transdanubia. Later, using modern GIS technology, it was extended to Pest and Bács-Kiskun counties (LÓCZY–SZALAI 1993, 1995, *Fig. 45*).

New research centres of landscape ecology have developed at the universities of Debrecen, Szeged and at the Geographical Research Institute of HAS (BALOGH–LÓCZY 1989, 1992; LÓCZY–BALOGH 1990; JUHÁSZ 1992). Test areas have been analysed in detail for environmental potentials on the Tokaj (KERÉNYI 1981a) and Bükk foothills (CSORBA 1987, 1993) and on the Sajó–Bódva interfluve (MEZŐSI 1985c, *Fig. 46*) and in the northern foothills of the Mátra Mountains (MEZŐSI–RAKONCZAI [eds] 1997). Both projects are based on GIS application and reveal various landscape potentials (landscape stability and biodiversity, farming, recreation, etc.). Hazards of environmental pollution were evaluated (KERÉNYI–SZABÓ 1997).

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and brown forest soils, *Fagetum silvaticae hungaricum* and *Quercetum-petraeae-cerris* vegetation; 15 = summit levels and riges of dismembered Mesozoic horsts with rendzinas and *Fagetum silvaticae hungaricum* and locally lime and ash mixed forests; 16 = summit levels and ridges of Mesozoic horsts with brown forest soils, *Quercetum pubescent* and *petraeae-Querceto Carpinetum* vegetation; 17 = mountain slopes with truncated brown forest soils (subordinately rendzinas), locally barren, *Orneto-Quercetum-pubescentis-cerris* vegetation

The only national data base of sufficient detail availabe for land evaluation is the HUNSOTER (at 1 : 1,000,000 scale) a terrain and soil information system, compiled in the Research Institute for Soil Science and Agrochemistry of the Hungarian Academy of Sciences (VÁRALLYAY et al. 1994).

One of its recent applications has been a project with the goal of identifying areas to be designated for sustainable intensive farming, those with optimal conditions for extensive farming and nature conservation (ÁNGYÁN et al. 1998).

6. MINING AND GEOMORPHOLOGY

As a geomorphic process, mining dates back almost to the time of the appearance of the man in the Carpathian Basin. One of the most ancient establishment of purposeful mining was the dyeing stuff (red limonitic-hematitic clay) at Lovas (40–50 ka B.C., according to others: ca 80 ka B.P.). Flint quarrying of similar age has been proven on the Avas Hill (at Miskolc) and in the Bükk Mountains and of 6 or 7 ka B.P. has been found at Tata and Sümeg. The first mention of gold mining by the Agatirses, inhabiting the Maros valley, is from HERODOTOS. The Romans left behind traces of gold, silver, iron ore and salt mining in Transylvania between the 1st and 3rd centuries AD and were engaged in stone quarrying e.g. at Tardos and Dunaalmás. In the 3rd and 4th centuries the Quads practiced quarrying in the Garam valley. In the first quarter and third of the second millenium AD open-cast mining of building materials, of pottery clay sand of iron ore with the removal of a generally thin overburden was widespread. At the same time, rock salt and non-ferrous ores were produced by deep mining, salt was also obtained from concentrated solutions and gold was panned in rivers in the vicinity of the mines.

There is no information on the rate of overburden removal during mining and on the rate and areal extent of geomorphic changes caused. Given the nature of mining, the impacts deriving from the mining of dykes of some per cent metal content could not have been too extensive even if it is estimated *that Hungary was the foremost producer of gold* (1000 kg per year – 80 per cent of European production) *and second in silver production* (10,000 kg per year – 20 per cent) *in the second half of the 13th century.* From the turn of *the 16th century for ca fifty years* Hungarian silver and copper became important commodities on the international market (FALLER–KUN–ZSÁMBOKI 1997, *Photo 49*).

Although the impact of removed materials is not very significant, the utilisation of water power transformed the surface. *Major water-collecting systems were built.* Between 1732 and 1740 S. MIKOVINY planned and implemented a uniform system of 16 artificial lakes and 60 km of ditches – an outstanding technical undertaking, which provided water for mines and ore workings for almost 250 years. The lakes now serve recreation purposes but still recall mining once renowned. (The average implementation cost of a lake amounted to 50,000 Ft and – employing a workforce of 2,000 people – it took three years to establish the system.)

By the early *19th century gold and silver deposits had been exhausted* and the golden age of Hungarian mining came to an end. Copper production also declined compared to the 16th century levels but in the 1830s it was still the fourth in the world. The 2300 tonnes per year at the (early 1860s) declined to 200–300 tonnes per year within decades. Iron ore production, however, saw a rapid development: 2500 t/he early 18th century, 8500 t/y in 1780, 52,500 t/y in 1876 and 2,000,000 t/y in 1913, which involved major impacts on the environment.

Salt mining in medieval times – in addition to the exploitation of 'salt cliffs' was also remarkable underground and produced large cavities in salt diapirs. The output has increased substantially in the 18th and 19th centuries; by the turn of the century it was 180,000 t/y and between 1910 and by 1914 raised to 260,000 t/y.

Intensified construction called for more clay, limestone, marble, ornamental stones and sand, also supplying brickyards, cement works and glass factories. Road and railway building demanded basalts, various rock shards and gravels. Limestone is also needed by sugar manufacturing and metallurgy, which also employed materials for mould making.

The Trianon Peace Treaty deprived Hungary from all of its hydrocarbon fields, entire rock salt mining, most of its stone quarrying. Ore mining was reduced to its 2 per cent: iron ore production proceeded at Rudabánya, copper mining at Recsk (now temporarily closed) and manganese extraction also survived at Úrkút. In addition, variegated ore mining resumed at Gyöngyösoroszi and manganese mining started at Eplény.

Coal mining in Hungary has a tradition of more than two centuries: it began at Brennbergbánya, in the Alpine foreland. In the present-day area of Hungary lignite and brown coal seams of gentle dip are worked in the Hungarian Mountains and along their southern margins. Black coal is worked in the Mecsek Mountains (dip ranges from 0 to 90°). The amount of *coal production in historical Hungary* is shown in *Table 11*. Until present, more than 1.5 billion tonnes have been recovered (FALLER 1994). After the peak of 10,000,000 t/y during the first world war production dropped to its half and only in the first years of the second world war reached that amount again and culminated with more than 31,000,000 t/y in the mid-1960s (*Fig. 47*).

The geomorphic impact of mining depends on whether strip mining or deep mining technology is applied. The lasting impact of deep mining is primarily manifested in spoil accumulation and *surface subsidence.* The demage to surface structures should be avoided. As an example, the exraction of the coal seam of 9 m thickness under the Budapest-Királyhida (Bruck) main railway line is to be mentioned. *In the Tatabánya area* along a distance of 1 km coal mining took place with silt infilling, traffic was not hindered and *subsidence did not exceed some centimeters per month.* In some special cases subsidence due to mining may cause particular changes on the surface. For instance, at Várpalota shallow ponds and swamps formed where the groundwater recharged from the Bakony karst filled surface depressions. In the same area, abandoned opencast mines were filled with water to form ponds. The damage from opencast mining is temporary. Though *reclamation as a rule fails to restore the original condition,* it leads to a more organised situation of higher standard (ERDŐSI 1966, 1979).

Table 11. Coal mining in Hungary

Period	Black coal	Brown coal	Lignite	Total coal	
	Production in the individual periods (10^6 t)			From the beginning	
1765–1830	0,227	0,312	–	0,539	0,539
1831–1866	2,885	3,832	0,184	6,901	7,440
1867–1893	26,454	23,713	5,810	55,977	63,417
1894–1910	19,206	90,047	2,211	111,164	174,881
1911–1920	8,761	68,816	2,871	80,448	255,329
1921–1944	22,175	167,091	11,109	200,375	455,704
1945–1993	130,351	723,275	243,906	1097,332	1553,236
1994–1997	3,714	26,998	31,438	62,150	1615,386

Source: FALLER 1994. The last century of coal mining in Hungary. – In: Mining and metallurgy of the Carpathian Basin in the 20th century. Miskolc–Baja Mare. pp. 13–43. For 1765–1993. IKM communication for 1994–1997.

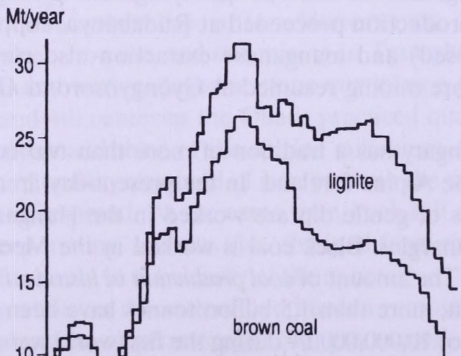

Fig. 47. Coal production in Hungary between 1938–1992 (after FALLER, KUN and ZSÁMBOKI 1997)

Strip mining is the most ancient form of mineral extraction and has resulted in transformations of the landscape of various degree. In electricity generation its significance has enormously increased since lignites of low calorific value still can be used to fuel power plants and mining technology developed machines of large capacity to reduce the costs of strip mining. The time series of the two major lignite mines (*Table 12*) underline that at Visonta, in order to produce one tonne of fuel, 8–10 m³ of overburden has to be removed, while at Bükkábrány this value is 3–4 m³ (*Figs 48–49*). When opening mining areas of several tens km³ of size, *the spoil has to be stored within the mining area and refilled into the pit continuously (annually 45 to 55 million m³). It obviously involves a major transformation in the topography of the areas affected.*

Table 12. Lignite production by large-scale open-cast mines and the amount of overburden removed

Year	Visonta		Bükkábrány		Total	
	Coal 10^3 t	Waste 10^3 m³	Coal 10^3 t	Waste 10^3 m³	Coal 10^3 t	Waste 10^3 m³
1974	5765	25 055			5765	25 055
1975	5404	33 762			5404	33 762
1976	6164	38 341			6164	38 341
1977	6784	42 395			6784	42 395
1978	7021	45 241			7021	45 241
1979	7414	45 592			7414	45 592
1980	7284	46 658			7248	46 658
1981	7279	52 111			7279	52 111
1982	7369	53 428			7369	53 428
1983	7007	53 181			7007	53 181
1984	7159	52 033			7159	52 033
1985	6475	54 892	70	881	6545	55 773
1986	5601	54 031	429	2 059	6030	56 090
1987	5426	53 227	969	1 936	6395	55 163
1988	4166	43 987	753	2 300	4919	46 287
1989	4191	44 081	1117	3 580	5308	47 661
1990	3160	29 306	1882	7 061	5042	36 767
1991	1842	24 322	3082	10 902	4924	35 224
1992	3472	36 651	3160	11 428	6632	48 079
1993	3812	36 384	3065	9 432	6877	45 816

Source: SZABÓ, 1993. Visszaemlékezés a Mátraalji Szénbányákra (Recollections of the Mátraalja coal mines). Bányászati és Kohászati Lapok – Bányászat, *126.* pp. 532–548.

In the second half of the 20th century *bauxite mining* (origins of which go back to the 1920s), the basis for aluminium industry, has developed rapidly. From the mid-1970s to the late 1980s it maintained its peak production at 3,000,000 t/y mostly from deep mining and to a smaller extent from strip mining in the South-Bakony and – subordinately – in the Vértes Mountains. At Pécs *uranium* ore was mined from 1957 to 1997 exclusively by deep mining (the extraction reached its peak with 800,000 t/y in the 1980s). The environmental impact of these activities (extraction and ore enrichment) are compacrable to coal mining but to a lesser extent.

The first achievements of *hydrocarbon exploration* within the present-day area of Hungary occurred in 1937, when the mineral oil production of short duration at Bükkszék and more lasting extraction in Zala began. From the mid-1970s to the

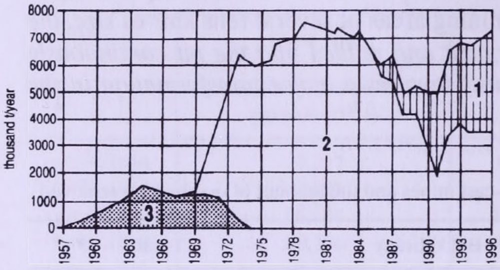

Fig. 48. Sopoil heaps amounts of open-cast mining of lignite at piedmont of Mátra and Bükk region between 1975–1994 (after FALLER, KUN and ZSÁMBOKI 1997; see Fig. 49)

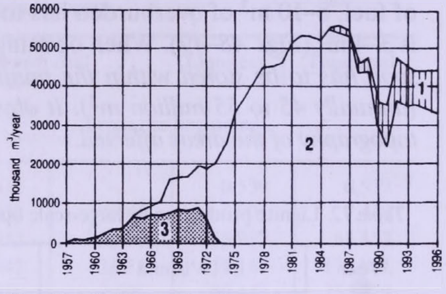

Fig. 49. Lignite production of open-cast mining at piedmont of Mátra and Bükk region between 1975–1994 (after FALLER, KUN and ZSÁMBOKI 1997) 1 = Bükkábrány; 2 = Visonta; 3 = Ecsed

mid-1980s a peak of 7,000,000 m^3 of natural gas and of 2,000,000 tonnes of crude oil was produced. *Although some subsidence may occur,* its geomorphic impact is negligible.

Table 13. Mineral extraction in Hungary (10^6 tonnes) as it appears in the national mineral reserves budget

	1977	1987	1992	1994
Hydrocarbons	8.6	9.1	6.8	7.0
Coal	24.4	23.9	16.4	13.7
Uranium ore	–	0.7	0.4	0.4
Carbon-oxide gas	0.2	0.2	0.4	0.4
Ores	3.8	3.3	1.8	0.9
Mineral resources	4.2	5.1	2.1	2.7
Building materials	77.2	61.1	25.7	36.8
Total	*118.4*	*103.4*	*53.6*	*61.9*

Source: Annual reports on the mineral resources reserves of Hungary. – Central Geological Office and Hungarian Geological Survey, Budapest 1989.

Much more significant impact can be attributed to building material industry (stone, gravel, sand, ornamental stone quarrying, *Figs 50, 51*) and extraction of construction materials (cement, lime and ceramics) and of other non-metallic and non-fuel minerals (*Table 13*). It is seen that more than two-thirds of the total mining output was supplied by this group of mineral resources. As a consequence of the economic crisis in the early 1990s, production was reduced to its 45 per cent but today a rising trend can be observed: it is 50 per cent in 1994 and 60 per cent of it is constituted by mining products (HEGYINÉ PANKÓ PADÁNYI–VITÁLIS 1984).

An intriguing although not easily answerable question has arisen: *how large an area has been affected by mining in Hungary*? If that area is assumed to be proportional to the area of mining plots, there are data sources for the period

1863–1945 (*Table 14*). It can be calculated that during these eight decades 0.2–0.4 per cent of the total area of Hungary was under the influence of mining. From the averages for five-year periods, as a matter of course, only 'snapshots' of a process can be obtained. As far as the total area affected is concerned, the investigation of spoil heaps may be a clue. They have to be studied since they are themselves products of the *anthropogenic influence on topography*, being mostly composed of useless overburden excavated from mines. Such spoil heaps are present in the environs of mines active during the past centuries and closed down afterwards. Another part of spoil heaps are indirectly related to mining as they are constitutes of wastes produced by the primary transformation of mining products (flue-ash from power plants, red mud from alumina plants, etc.). A common feature of those materials is that they are absolutely not usable and no technology exists for their economical recycling. With the advancement of technology these circumstances might change and spoil heaps may turn into secondary sources of raw materials.

Table 14. Donated plots for mining (ha) in the actual area of Hungary, 1863–1945

Period	Gold and silver	Iron ore	Coal	Other minerals	Hydro-carbons	Total	Treasury
1863–1865	7 589	5 291	9 312	2 997		25 289	5 595
1866–1870	9 401	5 369	10 212	1 552		26 534	5 921
1871–1875	9 503	7 112	22 516	1 984		41 115	7 445
1876–1880	9 554	8 963	33 645	2 786		54 948	8 227
1881–1885	9 808	9 432	36 321	2 929		58 510	8 525
1886–1890	10 745	10 523	37 098	3 020		61 386	8 520
1891–1895	12 287	29 404	39 157	3 467		65 895	8 640
1896–1900	13 729	12 981	44 682	3 758		75 150	12 261
1901–1905	15 144	15 525	47 400	4 514		82 585	10 794
1906–1910	15 860	16 829	50 814	5 442		88 945	11 998
1911–1915	16 834	18 829	56 883	7 448		99 989	14 409
1916–1917	16 956	19 483	59 919	8 948		105 346	15 770
1921–1925	492	701	21 182	314		22 689	1 996
1926–1930	204	840	23 005	556	2	24 609	2 200
1931–1935	204	817	23 794	932	14	25 584	2 289
1936–1940	215	2 212	25 915	1 147	160	29 049	2 788
1941–1945	2 297	2 913	26 898	1 227	1 923	35 288	5 320

Source: HALKOVICS 1997. A magyar bányászat történetének statisztikai adatsorai (Statistical time series on the history of mining in Hungary). – In: A magyar bányászat évezredes története (Millenia of Hungarian mining) Vol. I. OMBKE, Budapest, pp. 629–654.

In the second half of the 1980s this situation called for an inventory of spoil heaps and their evaluation as far as possible utilisation is concerned. The inventory showed that over the major part of the country as many as 3165 spoil heaps were recorded (*Table 15*) and the investigations for future utilisation covered the most important 1134 of them (in the case of the large lignite mines

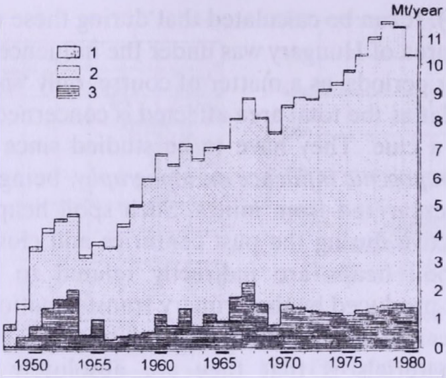

Fig. 50. Stone mines production between 1948–1980 (after FÜLÖP in FALLER, KUN and ZSÁMBOKI 1997). – 1 = ornamental stone; 2 = crashed gravel stone; 3 = building stone

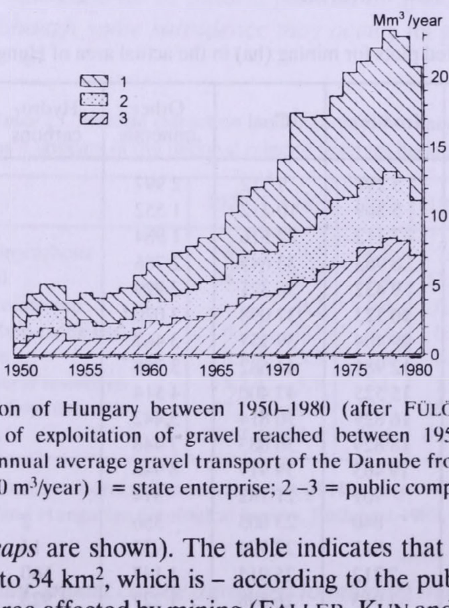

Fig. 51. Gravel production of Hungary between 1950–1980 (after FÜLÖP in FALLER, KUN and ZSÁMBOKI 1997). Peak of exploitation of gravel reached between 1950–1980 with more then 20 million m³/year (the annual average gravel transport of the Danube from Visegrád–Budapest is 15,000 m³/year) 1 = state enterprise; 2 –3 = public companies

only external *spoil heaps* are shown). The table indicates that the area of recorded spoil heaps amounts to 34 km², which is – according to the publication – less than 5 per cent of the total area affected by mining (FALLER, KUN and ZSÁMBOKI 1997).

Conclusions can still be made of the total affected area even if only a small portion of spoil heaps have been studied and major lignite mines of several tens of square kilometres area and stone, sand and gravel quarries (without spoil heaps) are not included. With regard to that, only ca 1 per cent of the total area of Hungary can be estimated as affected by mining. The total volume of the spoil heaps studied is close to 10^9 tonnes. The annual growth of these heaps (10×10^6 t/y) considerably exceeds the amount extracted (4×10^6 t/y). The further expansion of spoil heaps marks the presence of human influence on topography through mining even today.

Table 15. Inventory data of spoil heaps (surveyed until 1988 in more than half of the territory of Hungary; mine wasters and secondary raw materials)

	Number of localities	Area 10^3 m^3	Amount kt
Baranya	78	3 204	119 705
Bács-Kiskun	10	52	951
Borsod-Abaúj-Zemplén	153	9 554	187 869
Csongrád	10	4	19
Fejér	56	1 397	38 243
Győr-Sopron	62	285	3 611
Heves	119	2 496	154 221
Komárom	95	6 850	130 137
Nógrád	131	3 527	69 588
Pest and Budapest	132	2 134	45 336
Somogy	27	34	332
Tolna	17	60	1 232
Vas	36	110	1 514
Veszprém	166	4 509	174 363
Zala	42	112	1 330
Total	*1134*	*34 328*	*928 481*
road improvement, in filling	969	23 159	657 413
soil amelioration	115	2 716	84 963
Other	50	8 453	186 105

Source: Tájékoztató Magyarország 1989. I. 1-jei helyzet szerinti ásványi nyersanyagvagyonáról (Report on the mineral resources reserves of Hungary on January 1, 1989) Central Geological Office and Kungarian Geological Survey, Budapest 1989.

7. FLOOD CONTROL AND GEOMORPHIC EVOLUTION

In shaping of the surface of the Carpathian Basin rivers have always played a predominant part. The plains embraced by the Carpathians (Great and Little Hungarian Plains – together ca 120,000 km^2) were filled by inland seas, then lakes and finally their basins developed by fluvial accumulation, amounting to 400 m depth of deposits in the Little Plain and 700–800 m in the Great Plain.

On the maps of the first ordnance survey (end of 18th century) 38,600 km^2 of the present area of Hungary was permanently endangered by flooding. This is only 7 per cent less than the total territory of the Netherlands (41,548 km^2), a country engaged in thousands years of struggle with the sea. Recently, the impact of human activities also added to that of natural factors. The first major intervention into the lives of Hungarian rivers dates back to the 18th century, when, after the one hundred and fifty years of Ottoman occupation, economic development involved a rapid population growth, the expansion of cultivated land and the shrinking of natural vegetation. As a consequence, forest areas in the Carpathian Basin are estimated to have reduced by 50,000 km^2 in the 18th century (ca 15 per cent of the contemporary territory). This resulted in increasing runoff, reduced the time needed for the concentration of flow, a former flood levels have increased and floodplains expanded. At that time, several Great Plain settlements had to move to higher terrain (SOMOGYI 1962, 1967a, b, 1994).

Flood regulations along the Danube and Tisza rivers

The flood situation was aggravated by the expansion of agricultural land in the wake of growing demand for cereals during the Napoleonic wars. The extent of the hazard is illustrated by the flood disasters in Vienna (1830) and in Pest-Buda (1838). The nation-wide call for flood control started river regulation measures in the early 19th century. Experts were trained at the first engineering college of the world (Institutum Geometricum et Hidrotechnikum) founded in Buda (1782). In the organisation of the project the great Hungarian statesman, ISTVÁN SZÉCHENYI, played an eminent part.

On August 27, 1846 flood control and drainage activities along the Tisza river were started. The works transformed the physical conditions over vast areas and lasted with changing intensity and interruptions until World War I. Almost 37,000 km^2 of permanently or seasonally waterlogged area was drained and turned to cultural landscape. Out of the ca 30,000 km^2 of natural floodplains in the Great Hungarian Plain, almost 29,000 km^2 was freed from waterlogging (of these 21,000 km^2 belongs to present-day Hungary). The floods of the rivers forced between flood-control dykes, however, threaten ca 40,000 km^2 area with flooding. Excess water is drained through an almost 40 000 km network of drainage canals (31,000 km in the Great Plain). At their confluence with the rivers, 271 pumping stations of 600 m^3/sec total capacity (which equals the discharge of the Danube at low water at Budapest) promote the feeding of excess water back to the rivers (IHRIG 1952, 1973).

Three-quarters of former floodplains are used as arable land, while the rest is still forest, meadow and pasture. In flood protected areas 352,000 family homes (302,000 in the Great Plain), 2,900 km railways (2,600 km in the Great Plain) and 4,500 km public roads (3,900 km in the Great Plain) were built.

That intervention into nature is rightfully called the "*second Hungarian Conquest*" (SOMOGYI 1978). The measures that affected rivers involved *'high-water regulation'* i.e. the construction of flood-control dykes. Their length is 4,183 km in present-day Hungary, out of which 1,282 km are along the rivers of the Danube system and 2,901 km are along the Tisza and its tributaries. Naturally, beyond the present state borders dykes were also erected in considerable length. Regarding their length and the earth used for their construction, the impact of dykes is important in the flatland.

Before dyke construction fluvial accumulation spread over the entire floodplain, today it is confined to the active floodplain between the dykes. The area of the latter is ca 1,500 km^2, only 6 per cent of the original floodplains (25,100 km^2). During floods the rivers deposit all their load (of considerable amount) in this narrow zone. Before leaving Hungary, the Danube carries 10,200,000 m^3 of suspended and 24,000 m^3 bedload at Baja, while the Tisza transports 12,260,000 m^3 suspended and 11,000 m^3 bedload at Szeged (BOGÁRDI 1955).

Consequences of the river channel regulations

As opposed to the situation before flood control, accumulation in the river valleys of the Carpathian Basin has been greatly reduced since current velocity and entrainment capacity have increased in the trained channel. Because of a slower flow and floodplain forests, however, large amounts of load are deposited over the active floodplain during floods and *natural levees, riverbank dunes* and *point-bars* are built. Previously mineral and organic accumulations were equally important. Since the interventions rivers only carry mineral deposits and their accumulations are also fall into this category. On the other hand, river deposits cannot reach depressions in protected areas beyond the dykes and they are filled with the organic materials of local bogs which is a much slower process *(Photo 50).*

Although also affected by tectonic subsidence, former floodplains do not enjoy the balancing influence of fluvial accumulation characteristic prior to flood control measures. For that reason, protected floodplains occupy ever lower positions relative to their environs.

The process is more rapid along the Tisza river of higher load concentration (560 g/m^3) than along the Danube (130 g/m^3). According to the calculations by JAKUCS (1982) 4,500,000 m^3 of sediments accumulated over the lowland floodplains, which would mean ca 10 mm deposition over the present-day active floodplains. Fortunately, the process is regionally not so intense since rivers of increased gradient and velocity carry more load out of the Carpathian Basin as before. *Relief inversion* is also *typical of the protected areas* and *active floodplains,* where the latter rise above the former. The disadvantages for society, economy and flood control are evident (LÓCZY 1881).

The more rapid passage of even larger floods on Hungarian rivers is a result of *'medium-water regulation'* (regulation of the river channels). To that purpose a high number of meanders were cut off (altogether 607 along the rivers of present-day Hungary) and river length was reduced from 3,850 km to 2,300 km (nearly 40 per cent reduction). River mechanism has also been modified. Previously depositing (the Danube in the Little Plain, or the Körös rivers in the Great Plain) or meandering-and-depositing types (the Tisza in the Great Plain) were common. In the shorter channels of increased gradient the intensity of channel accumulation has become moderated even if the type of river mechanism did not change (e.g. along the Szigetköz section of the Danube). If the mechanism changed for more effective erosion, such as along most of the lowland section of the Tisza into meandering-and-incising type, channel deposition was replaced by channel incision. *Floods of the same dimension pass at 1 m lower levels along the Tisza now than before flood-control measures* (KVASSAY 1902; CHOLNOKY 1934; KÁROLYI 1960a, b).

The impact of 'medium-water regulation' is also manifested in meander evolution. Previously, meander development was unhindered but slow (because of low current velocity). River training accelerated meander evolution, like along the Sárköz section of the Tisza, where it takes now 150 years for meander formation until natural cutting of (*Fig. 26* – SOMOGYI 1974). As a consequence, meander evolution is even more rapid along sections of larger gradient and higher current velocity. The Tisza of lower velocity and more fine load cannot erode its channel so intensively as the Danube. This difference is also evidenced by maps. The oxbow north of Tiszaug was an active meander in 1786 as attested by the first military survey. When cut-offs were made here between 1853–66, the oxbow became located beyond the dykes. Consequently, the erosional-accumulational activity of the Tisza have not modified it much over the more than 70 years elapsed. The exampled shows that the Tisza of slow flow is less effective in meander formation than the Danube.

While *'high-water regulation' served flood control* and *'medium-water regulation' channel rationalisation,* the *goal of 'low-water regulation' is to remove obstacles to navigation.* Since this has not much to do with geomorphic processes, suffice it here to remark that the shorter Tisza conducts water more rapidly and its water level sank. For that reason, navigability is reduced to a much shorter section. In the case of the Danube, the (compared to water discharge) too wide new channel between training walls along the Szigetköz section hinders navigation during low water stages.

Flood-control measures have had a wide range of physical, ecological, economic and social impacts beyond the geomorphic consequences. These issues are treated extensively in literature (LÁSZLÓFFY 1938; RÁKÓCZI 1993; TÖRY–IHRIG 1951).

8. BOREHOLES AS A FUNDAMENTAL TOOL IN THE GEOCHRONOLOGICAL RESEARCH OF BASINS IN HUNGARY

In order to study the sedimentation and geomorphic processes in the plains of major sedimentary basins, the geological and lithological conditions of boreholes deepened for various purposes have to be evaluated and former paleogeographic features reconstructed. In the evaluation geological and geomorphological studies are closely associated.

Recently, *geophysical techniques* have been elaborated to provide new data from the analysis of the existing or some additional borehole sequences for the internal structure of basins. *Logging* in the borehole informs about the 'in situ' properties of rocks.

Boreholes purely for scientific purposes have only been drilled since the second half of the 19th century, when state geological surveys and research institutes were organised. These boreholes are necessary tools for decision-making and serve the safety of mining, water exploration and construction operations.

Boreholes which are eliminated after the completion of the drilling are documented in *'geological borehole diaries'*. Such boreholes were deepened for mining or scientific purposes. As an exception, the documentation of hydrocarbon exploration resembles to *'hydrogeological diaries'*, but as far as their purpose is concerned, they are also geological documents, in spite of the fact that a permanent structure (oil or gas well) occupies the borehole. *'Geological borehole diaries' are available in the Hungarian State Geological Institute (MÁFI).*

'Hidrogeological diaries' are officially collected by the Centre for Water Resources Research (VITUKI). Shallow preparatory boreholes for construction are usually not documented individually. *The expertises on soil mechanics officially stored in the Building Geological Archive of MÁFI.*

The three kinds of documentation are official documents of the Republic of Hungary and borehole data are available for all concerned, but first of all for the purposes of scientific research. The archives are important sources of information for *geologists and geomorphologists to gather knowledge on the area of Hungary and to process it at international standard.*

National Geological and Geophysical Archive

The information collected during geological and geophysical research, mineral resources or hydrogeological exploration is valuable and necessary for both practical and scientific purposes. Following repeated initiations from various organisations, in January 1952 the National Geological Archive was established. Documents of explorations by the MÁFI and other geological organisations are stored and processed there. The collection is invaluable and open to the public. The oldest documents are from the first half of the 19th century, while there are also tens of thousands of borehole descriptions, manuscript maps and exploration reports. In addition to the staff of MÁFI, the National Geological Archive serves representative of all disciplines of Hungarian earth sciences.

Information on the collection and services of the Archive is found in the MÁFI Guide Book (ERDÉLYI 1989, p. 81). Data on the most important deep boreholes have been published in the series 'Magyarország mélyfúrási alapadatai' (Basic data of deep boreholes in Hungary, BOHN [ed.] 1975–1990, Vols 1–25, Photo 21).

Already in the 19th century HALAVÁTS (1891b, 1896) processed and published the sequences of artesian wells in the southern Hungarian Plain initiating the preservation of valuable deep borehole documentation. LÓCZY, sen. (1912, pp. 113–134) also supported this idea. Evaluating the artesian wells from technical, stratigraphic, chronological and hydrogeological aspects in detail, HALAVÁTS provided an immeasurable contribution to the interpretation of formations in the Carpathian Basin. He claimed explicitly that the Great Plain Basin is filled in by terrestrial sediments of considerable thickness, underlain by lacustrine and marine deposits with subaerial intercalations. His works are often referred to by experts home and abroad. He set an example for recent (up to the second half of 20th century) descriptions of artesian wells and *boreholes of scientific purpose* from the aspects of geosciences (RÓNAI 1972, 1983, 1985c; JÁMBOR [ed.] 1987; PÉCSI and SCHWEITZER [eds] 1995).

The comprehensive analysis of exploration wells in the Carpathian Basin became an example to be followed also on an international scale (POGÁCSÁS et al. 1990, 1994; POSGAY et al. 1996). Among others, detailed chronostratigraphy is presented for the subaerial deposits, primarily for loess by PÉCSI (1993a, b) and BÁRDOSSY (Annual Report of the Geol. Inst. of Hungary for 1996. II. Budapest, 1997, p. 342).

Hydrogeological exploration wells

In the second half of the 19th century more and more water exploration wells were deepened. Particularly, physicians urged artesian drilling to provide drinking water for the population inhabiting the Great Plain of alkali-swamps as river regulation measures did not allow water intake from living waters anymore. Several enterprises undertook drilling all over the country, but those with several hundred metres' depth were deepened by some larger enterprises, among them the one of the ZSIGMONDY family, who also started documentation at an earlier date (ZSIGMONDY; see p. 157 in this volume).

In the 1950s the National Water Exploration and Drilling Enterprise (OVIFUV) was formed and operated its boreholes at various sites under governmental control which were professionally documented. A primary interest of the enterprise was to collect geological and technical data on all drilled wells in Hungary. A National Well Inventory (*Photo 19*) was compiled and gradually supplemented by the data of new wells (*Tables 16, 17*).

The inventory of deep wells in Hungary (URBANCSEK [ed.] 1963–1980, *Vols 1–11.* VITUKI, Budapest) includes geological, technical and water quality data of wells and their map locations. The volumes published since then (*Vols 12–22*) are accessible in the VITUKI library as manuscripts. These inventories are also of great intellectual value.

Table 16. Number of wells for drinking water supply since 1895 (NEPPEL 1997)

1895	1325	In the MÁFI archive (by HALAVÁTS), with documentation
1956	15965	Surveyed during MÁFI mapping for an area of ca 80,000 km^2 (Great and Little Hungarian Plan, hill regions)
1962	35000	OVIFUV inventory
1974	54873	National Well Inventory
1980	58564	National Well Inventory
1993	64749	National Well Inventory
1997	67751	National Well Inventory

Table 17. National Well Inventory in 1993 by counties (compiled by CSATÓ, MÁFI)

Budapest	1228	Komárom	1088
Baranya	1863	Nógrád	643
Bács-Kiskun	8958	Pest	5938
Békés	7272	Somogy	1574
Borsod-Abaúj-Zemplén	2951	Szabolcs-Szatmár	5619
Csongrád	5587	Szolnok	3393
Fejér	2661	Tolna	1812
Győr-Sopron	2433	Vas	1014
Hajdú-Bihar	6388	Veszprém	1563
Heves	1841	Zala	923

Approximately 20 per cent of the sequence is missing from the documented wells

9. RELIEF ASSESSMENT

The activities of the human society take place overwhelmingly on the land surface, that is why relief, its morphology is being in a constant transformation due to both natural processes and man-induced technical and economic change. Topographic conditions are assessed in accordance with land use quality and requirements. Over the past decades the importance of the assessment of landforms has increased in Hungary as well.

A diversified land use demanded the elaboration of methods of evaluation for relief conditions in the framework of *environmental impact assessment* procedures carried out by geomorphologists in collaboration with other experts in the sphere of earth sciences. Landforms (both macro- and microforms) were depicted on thematic maps derived from topographic charts, relating to different parameters of relief (*thematical classification of the relief*).

Starting with the 20th century, Hungarian geomorphological research had put an emphasis on the genetic classification of the relief. Morphometric assessment of landforms were worked out and applied only with the appearance of a new global problem of environmental impact assessments.

This shift of research trends had also been aimed at laying the scientific foundations of landscape evaluation, after the basic principles and methods had been elaborated (MAROSI and SZILÁRD 1967, PÉCSI 1964b, ÁDÁM 1985). More and more geomorphologists and landscape researches had been involved in these studies, especially in relation with the monograph series *Landscapes of Hungary.* During the 1970s a partial investigation of the physical environment including relief assessment became a new independent research trend, the basic principles of which were laid by GÓCZÁN (1971, 1981a), GÓCZÁN and PÉCSI (1984), MAROSI and SZILÁRD (1985), MEZŐSI (1985b, c).

Physical geographers and geomorphologists pioneered and developed concepts and methods for environmental assessment mapping during the 1970s and 1980s, their works were published in books and dissertations. The evaluation of relief and of natural environment in a broader sense remote sensing methods had also been involved (MIKE 1967; ORAVECZ 1981; NEMERKÉNYI 1986; TÓZSA 1989).

Using the traditional methods of land assessment and seeking new ones geomorphologists made a contribution of their own to determine fertility on the basis of the rank of values of relief for agricultural, sylvicultural or other types of land use (GÓCZÁN 1981b, PÉCSI 1984b, PÉCSI 1985a). Relief assessment and mapping serving environmental statement and suitability for recreational use were tested similarly.

Central planning or regional development aspects draw the attention of geomorphologists and the experts in geosciences to engineering geomorphological mapping of large settlements and the Budapest agglomeration (FODOR 1977). As the practice of physical planning demanded it, map series in support of foundation engineering had included engineering geomorphological maps as well (FODOR 1977; JUHÁSZ 1976; MEZŐSI 1985a; SCHWEITZER 1992; SCHWEITZER and TINER 1996). Among the most ambitious projects engineering geological and geomorphological map series of Budapest and of the Lake Balaton (*Photo 51*, published by the Geological Institute) must be mentioned.

Most of the experts, however, were engaged in environmental and relief assessment for agricultural purposes. This had led to the classification of landforms and identification of relief types and to their characterisation by certain parameters (BALOGH et al. 1989, LEÉL-ŐSSY 1984). Parametrisation of relief types was needed for the demarcation of landforms (plains, plateaus, hills, ridges and slopes) within a given region. Similar or different types might occur in a mixed pattern or separated from each other (see the map *Relief types* in the National Atlas of Hungary, *Photo 52*, pp. 26–27).

Maps of *landscape types* and relief types. In the landscape geographical (and landscape ecological) approach the ecotop is to be considered the basic unit. Various kinds and types of ecotops are organised into microregions regionally (PÉCSI–SOMOGYI 1969; PÉCSI et al. 1971; JAKUCS 1989; MAROSI–SZILÁRD 1983, 1985; MAROSI 1985b).

While the smallest topological unit (*geotops*) are labelled *morphotopes* or *morphofacies*, their spatial interrelationship results in morphological types on flood plains, terraces, in mountains, on slopes or foothills regionally (GÖCSEI 1979, BALOGH–LÓCZY 1989).

Investigations into landscape or morphological types (i.e. establishment, qualification or classification of morphological types) yielded significant theoretical and practical results (PÉCSI–SOMOGYI 1969; PÉCSI–MAROSI 1981).

Hungarian experts have played an important part in the progress of international cooperation (ÁDÁM KERTÉSZ was elected vice-president of ESSC, DÉNES LÓCZY became member of the IAG Executive Committee, MÁRTON PÉCSI was elected honorary member of the INQUA).

Along with the classification and typification of natural ecotopes and morphological microforms everyday activities called for the identification, demarcation and characterisation of man-made landforms and landscapes. These together were studied as relief types, forms and elements, because natural regions and distinct units, predominantly under man-induced natural processes appeared in patches over extensive territories as landscape elements having not yet reached their equilibrium (ERDŐSI 1969, 1979). Classification of morphographic elements (morphotopes) and their genetic evaluation (according to regional extension) involved an hierarchic systematisation of landforms. They were identified at the levels of microforms, group of microforms, mesoforms, macroforms, macroregions and subcontinents (PÉCSI–SOMOGYI 1969; MAROSI–SOMOGYI 1990).

Morphogenetic and morphostructural elements and types, morphosystems have recently developed predominantly under exogeneous influence. Their classification and systematisation have been urged by geomorphological mapping while a conceptual change has been brought about by the theory of global plate tectonics coming to the fore. A new terminology of landforms appeared in the legends of geomorphological maps of different scales (ÁDÁM–PÉCSI 1985; ÁDÁM–SCHWEITZER 1985; JUHÁSZ 1985; KIS–LÓCZY 1985; MEZŐSI 1985a; BALOGH–LÓCZY 1989; PÉCSI 1980, 1984b).

Relief assessment and mapping for different objectives e.g. for practical application, research and professional training resulted in various methodical elaborations for the past fifty years. These often conflicting trends and concepts call for their comparative analysis and evaluation (HORVÁTH 1991a).

The achievements of the Hungarian investigations of landforms can be found in geological descriptions of landscapes, in volumes published within the series *Landscapes of Hungary,* and in major works of the series published by the MÁFI. All of them are referred in the list of references of the present publication.

were distinguished or related types, forms and elements, because natural regions had distinct ... predominantly under man-induced natural processes appeared in processes ... landscape elements having not yet reached their equilibrium (Bernáth-Pécsi 1972). Classification of morphogenetic elements (morphotopes) and their genetic evaluation (according to regional extension) involved an inter-scale systematization of landforms. They were identified at the levels of microforms, group of microforms, mesoforms, macroforms, macroregions and subcontinents (Pécsi–Somogyi 1969; Marosi–Somogyi 1990).

Morphogenetic and morphostructural elements and types, morphosystems have recently developed predominantly under anthropogenic influences. Their classification and systematization have been urged by geomorphological mapping while a conceptual change has been brought about by the theory of global plate tectonics coming to the fore. A new terminology of landforms appeared in the legends of geomorphological maps of different scales (Ádám–Pécsi 1985; Ádám–Schweitzer 1985; Bulla 1965; Lóczy 1989; Marosi 1993; Lóczy 1990; Pécsi 1980, 1984b).

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D) PROMINENT GEOLOGISTS AND GEOMORPHOLOGISTS IN THE PAST STUDYING THE LAND EVOLUTION OF HUNGARY

BORSY, ZOLTÁN
(1925–1996)

He was professor at the University of Debrecen and an expert in the geomorphology of blown-sand regions in Hungary. As a representative of KÁDÁR's school in Debrecen, Z. BORSY.was primarily engaged in the study of sand regions, investigating the origin of sand landforms, in the classification of deflational features and in the analysis of sand movement (BORSY 1977, 1991). He continued and further developed the experiments on terrain models initiated by KÁDÁR. His regional physical geographical monographs and geomorphological maps (BORSY 1961) mostly concentrated on the Nyírség, Upper and Middle Tisza regions (see the volumes of Landscapes of Hungary: The Tisza Plain). Others of his main interests were the reconstruction of the Quaternary evolution of drainage pattern in Hungary (1990) and of Tertiary volcanic events and landforms.

The part BORSY took in the editing and publication of a new university textbook on general physical geography (BORSY ed. 1993) was fundamental. This book of reference filled a gap and replaced an almost half a century old – although more comprehensive – predecessor. Some other significant publications of BORSY see in *References* of this book.

(SZ. J.)*

Biography:

SZABÓ, J. (1996): DR. BORSY Z. 70 éves. (Z. BORSY is seventy years old). – Földr. Közl. Vol. CXX. (XLIV), *2–3.* pp. 197–214.

* Abbreviations used see on page 2.

BÖCKH, HUGÓ
(1874–1931)

Son of J. BÖCKH, he studied at the University of Budapest (between 1896 and 1898) and worked as an assistant to S. SCHMIDT He finished his doctoral dissertation on the geological conditions of Nagymaros and environs in Munich. He was invited to the Department of Mineralogy and Geology of the Selmecbánya Academy in 1899 and he worked there until 1914.

In order to supply his students with a textbook, he wrote a Geology in three volumes, which replaced J. SZABÓ's Geology (1883) and was in use until 1951 as the only manual of the discipline in Hungarian. In addition to survey the geology of Selmecbánya and its environs, he also contributed to the mapping projects of the Geological Institute. He was often commissioned to explore mineral occurrences.

A major turning point in his life was 1910, when he was contracted to study the natural gas basin in Transylvania. Until his death he kept on dealing with hydrocarbon exploration. Following the success of borehole sitings, he became the leader of exploration during World War I. Localities were also found in Transdanubia, Northeast Hungary and Croatia. Success was partly due to the application of EÖTVÖS' pendulum. For his achievements of great academic and economic significance in geological exploration, he was elected corresponding member of the Hungarian Academy of Sciences (1915).

After the war, with support from the British-Hungarian Oil Co. He resumed hydrocarbon exploration in the present-day territory of Hungary. After 1921 he led explorations and found several oil fields in the service of the Anglo-Persian Oil

Co. In 1929 He was invited to return home and to take over the directorship of the Geological Institute. He modernised the management of the Institute's activities including the methods of the geological mapping as well.

Among his statements on the geomorphic evolution of Hungary, his views on the development Nagymaros-Visegrád gorge of the Danube are still cited. He assumed that fluvial erosion had began as early as the Pontian or even before. Evidence is found (BÖCKH 1899, 1902) in the age and position of proven Danube gravels on the summits (380 m altitude) of the Danube Bend Mountains and their eroded nature. Based on his experience from the investigations of the Iranian Basin and its mountain frame he was a supporter and defender of the 'Tisia' theory (BALKAY, B. 1934). (B. G.–B. K.)

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BÖCKH, H. (1903): Geológia. Tankönyv I. Általános geológia (General geology). – Joerges Ágost özvegye és fia, Selmecbánya. 462 pp.

BÖCKH, H. (1909): Geológia. Tankönyv II. Stratigraphia. – Joerges Ágost özvegye és fia, Selmecbánya. Part I, 448 pp., Part II, pp. 449–897.

BÖCKH, H. (1917): Brachiantklinálisok és dómok kimutatása torziós mérleggel végzett nehézségi mérések adatai alapján (Exploration of brachianticlines and domes through gravity measurements by torsion balance). – Bány. Koh. Lapok *50*. pp. 265–278.

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BÖCKH, JÁNOS
(1840–1909)

He studied mining engineering at the Selmecbánya academy, worked at the Ministry of Finances in Vienna and completed a two-year course in geology. After the Compromise (1867) he asked for a position in Hungary and started to work at the department of mining and after 1869 in the newly organised Geological Institute. Being director between 1882 and 1908, he was responsible for the building of the headquarters of the Hungarian Royal Geological Institute, a palace in the Stefánia Street.

He was first of all a mapping geologist, who studied the geological structure of unexplored regions, over most of Transdanubia. His statements remained valid for a long time. BÖCKH was the first to provide a solution for the drinking water supply problem of a town (Pécs) based on the detailed study of hydrogeological conditions. He worked together with K. HOFMANN, who investigated magmatic rocks during the mapping of South Bakony and Mecsek Mountains.

In 1885 he made a proposal for the waterworks on the left bank of the Danube in the area of the Hungarian capital, and after 1877 he mapped the geology of Krassó-Szörény county. He was the first to show interest for oil occurrences in Austro–Hungary (Iza valley and Sósmező in Háromszék county 1894–1895; Galicia, 1896). His achievements in the geological exploration of the Great Hungarian Plain were appreciated by the Hungarian Academy of Sciences and he was elected a corresponding member in 1876.

(B. G.–B. K.)

Major works:

BÖCKH, J. (1872): Fót–Gödöllő–Aszód környékének földtani viszonyai (Geological conditions of the Fót–Gödöllő–Aszód area). – Földt. Közl. 2. pp. –18.

BÖCKH, J. (1876): Pécs városa környékének földtani és vízi viszonyai (Geological and hydrological conditions of the environs of Pécs city). – Annual Report of the Hungarian Geological Institute. Vol. *4*. No. 4.

BÖCKH, J. (1897): A geológia fejlődésének rövid története Magyarországon 1774–1896 (A short history of geology in Hungary). – Földt. Közl. *17*. pp. 4–15.

BÖCKH, J. (1908): A petroleumra való kutatások állása a magyar szent korona országaiban (State of oil exploration in the countries of the Hungarian holy crown). – Annual Report of the Hungarian Geological Institute. *16*. pp. 369–479.

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IGLÓI SZONTÁGH, T. (1910): Nagysúri BÖCKH. J. élete és munkálkodása (Life and works of J. BÖCKH of Nagysúr). – Földt. Közl. *40*. pp. 3–28.

SCHAFARZIK, F. (1914): BÖCKH J. emlékezete (Memory of J. BÖCKH). – Az MTA elhunyt tagjai fölött tartott emlékbeszédek (Memorial speeches on the members of the HAS). – Vol. *16*. No. *12*. pp. 1–40.

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BULLA, BÉLA
(1906–1962)

He was a pioneer of climatic geomorphology in Hungary. His name stands as a hall-mark for a period in the development of Hungarian physical geography, particularly geomorphology. His career also began well before World War II.

He got interested in geomorphology as a student of J. CHOLNOKY, and succeeded him as professor at the Budapest University, became head of department in 1941, guided the Geographical Research Group of the Hungarian Academy of Sciences for eight years (1954–1962), acted as president of the Hungarian Geographical Society between 1952 and 1956 and was elected a corresponding member of the Hungarian Academy of Sciences.

BULLA (1939) launched large-scale analytical investigations in periglacial phenomena, loess and terrace geomorphology in the 1930s. He was the first to provide a comprehensive picture on the periglacial phenomena and landforms in the Carpathian Basin.

His achievements are remarkable in the study of the origin, regional distribution and chronological subdivision of the loess mantle in Hungary, in the explanation of accumulation and erosion features (BULLA 1937–1938).

He was a major proponent of *climatic geomorphology* both in Hungary and abroad. Drawing on his results in the survey of periglacial loess and terrace morphological investigations, he proclaimed that intricate geomorphic evolution patterns take place on rhythmically changing climatic regions. He described the main features of geomorphic evolution since the Neogene for the Carpathian Basin (BULLA 1956a).

The complexity of his attitude is also manifested in the assumption of the dialectic interplay of several factors in the formation of fluvial terraces (BULLA 1956b).

Thoroughly criticising the theories of W. M. DAVIS and W. PENCK and also relying on his own field work, he revealed the discrepancies in the Davisian concept of geomorphological cycles as well as in PENCK's morphological analysis. BULLA pointed out their onesided approach and identified elements in the theories which hinder the further development of the discipline. He created *his own synthesis, the comparative, functional, dynamic theory of rhythmic geomorphic evolution* (BULLA 1954a); on this basis he proposed a climatic geomorphological zoning and formulated the climatic theory of tropical relief planation (BULLA 1958). In BULLA's opinion, landforms in the major climatic belts change according to the type and rate of weathering and matter transport. Thus, typical assemblages of sculptural landforms depending on climate are developed (1954a, 1954b).

According to his tropical planation theory, the typical extensive planation surfaces are products of (sub)tropical denudation, while he regarded terraced river valleys as landforms typical of geomorphic evolution in the temperate belt (1956b).

This research trend was not meant to replace structural geomorphology, which emphasizes the role of endogeneous influences in geomorphic evolution. However, BULLA concentrated geomorphological analysis primarily on the study of *exogeneous agents*.

BULLA provided several general and detailed descriptions of his climatic geomorphological concept both orally and in publications (1954a, 1962, 1968). Through his university lectures and textbooks he did not only influence the attitudes of his students but the selection of topics in Hungarian geomorphological research and the interpretation of the origin of landforms to this day. Major achievements of his activity were the establishment of a *school in geomorphology* and the explanation of the topography of Hungary from climatic geomorphological aspect, which raised Hungarian geomorphology to international level.

His students began to investigate the geomorphological regions of Hungary applying his principles and methods and explained landform types. During these activities BULLA's theses were gradually further developed or corrected.

Major products of his activity are the textbook or manual of geomorphology (1954) and his Physical Geography of Hungary (1962), published some weeks before his death and unsurpassed since. Both books are equally used by researchers, teachers and students even today. Further major works see *References* of this book.

(M. S.–P. M.)

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MARÓSI, S. (1962): BULLA B. 1906–1962. – Földr. Ért. *11*. pp. 1–4.

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CHOLNOKY, JENŐ
(1870–1950)

Prominent figure in Hungarian geomorphology, professor of geography in Kolozsvár (today: Cluj in Romania) (1910–1919) and then in Budapest (1921–1941), originally he was a civil engineer. However, inspired by LÓCZY's university lectures, he turned towards *physical geography* at an early stage of his career. He never stopped to underline *the importance of a training in engineering for geographers and regarded a knowledge in soil mechanics indispensable for any kind of geomorphological research.*

He took over the task of guiding the Lake Balaton project from LÓCZY. Among his achievements some have stood the test of time: the explanations he offered to the oscillation of lake level, to the seiche phenomenon observable on the lake, to the changing colours of lake water and to freezing mechanisms are equally valid today.

In his favourite field of activity, in geomorphology, he was the best advocate of W. M. DAVIS in Hungary (CHOLNOKY, 1926, 1930). He contributed to almost all branches of geomorphology and in his regional works proposed models for the geomorphic evolution of the landscape units in the Carpathian Basin.

His results in the study of *fluvial erosion* comprise the identification of *river mechanisms* for the various reaches, an explanation for terrace formation and the first synthesis concerning the evolution of the terrace systems of the Danube and its tributaries.

When conducting a research project on the Great Hungarian Plain, he elaborated a theory on the *laws of blown-sand movements* and published it in one of his benchmark papers (CHOLNOKY 1910).

His name is also associated with the recognition of the significance of wind erosion in the Pliocene *semidesert geomorphic* development of the landscapes of Hungary. Drawing from the experience gathered during the exploration of Central Asian regions, the concept adopted by L. LÓCZY and particularly by J. CHOLNOKY was that for some period of the Pliocene eolian geomorphic evolution of semideserts also prevailed in the Carpathian Basin. CHOLNOKY cited the 'meridional' valleys of Transdanubia (in Zala and Somogy counties) as evidence of his deflation theory.

In international comparison, he was one of the first to put forward a scientific explanation to the mechanism of polygonal patterned ground formation under periglacial climate (CHOLNOKY 1911). In his papers on hillslope evolution he emphasized the need for the study of processes. In karst geomorphology he is remembered, first of all, for pointing out the impact of lithological variation in the evolution of karst features (CHOLNOKY 1919).

A major product of his comprehensive activities as a researcher and professor is the first geomorphology text-book written in Hungarian (The Science of Landforms, 1926). His journey to China at the end of the 19th century places him among the outstanding Hungarian geographical explorers. A profilic writer of academic and popular papers, he was the author of 53 books and 160 scientific treaties. Over the past 120 years it was during his professorship that the number of geography students reached its peak at the Budapest University.

CHOLNOKY was a well-known personality both home and abroad. For a long period he was active as president of the Hungarian Geographical Society. He was elected member of the Hungarian Academy of Sciences. He participated in many international conferences and was awarded honorary membership from the British Royal Geographical Society and the Austrian Geographical Society.

His intellectual heritage has not possibly been surpassed in diversity and richness ever since. The most important scientific books of CHOLNOKY see in *References* of this book.

(S. S.–SZ. A.)

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LÁNG, S. (1970): A földrajzoktatás múltja az ELTE-n. – Acta Geogr. Sc. Univ. ELTE (with full publications of CHOLNOKY).

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EGYED, LÁSZLÓ
(1914–1970)

A doctor of mathematics from the Budapest University (1932), he worked between 1940 and 1950 at the Hungarian Oil Industry Ltd. as a geophysicist. In 1949 he was commissioned with the organisation of a university Department of Geophysics. He was appointed professor in 1956. His career began with the evaluation of gravity and geomagnetic measurements. After 1953 his investigations concentrated on elaborating the theory of the expanding Earth. He collected physical and geological evidence for his theory and became one of the major forerunners of plate tectonics. In Hungary, his department was the first workshop of geophysical research in this field. He launched paleomagnetic investigations in Hungary and established a modern seismological observatory network. He also attempted to re-determine the constant of gravity. He emphasized the primary control tectonic lines exert on the alignments of river valleys and networks.

EGYED was the founder and co-president of the Association of Hungarian Geophysicists, member of the presidium of COSPAR, dean of the Faculty of Natural Sciences at Eötvös L. University, corresponding member (1960) and member (1970) of the Hungarian Academy of Sciences.

(B. G.)

Major works:

EGYED, L. (1955): Geofizikai alapismeretek (Basic knowledge in geophysics). – Tankönyvkiadó, Budapest. 536 pp.

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EÖTVÖS, LORÁND
(1848–1919)

L. EÖTVÖS, a world famous physicist and geophysicist, an outstanding figure of Hungarian natural sciences, including geosciences, constructed an instrument of detect the position of geological structures and landforms buried under sediments (salt diapirs, mineral oil and natural gas domes) from the surface, without expensive boreholes. EÖTVÖS' pendulum remained an indispensable tool in oil exploration for many decades and, according to A. MESKÓ (1998), it has played a decisive part in finding several million barrels of oil reserves in the United States and gained an international appreciation for EÖTVÖS.

His activities in the spatial analyses and mapping of gravity are outstanding and he also constructed another instrument (a magnetic translatometer). EÖTVÖS devised a technique for studying the distribution of another geophysical force, geomagnetism. He investigated the relationships between the two forces. His measurements with the pendulum had increased exactitude by three orders of magnitude. The international unit for gravity field gradient (10^{-9} gal per cm) is named after him as well as the EÖTVÖS effect, which describes the change of weight for bodies in motion related to the Earth. Last but not least, the Budapest university also bears his name. He was president of the Hungarian Academy of Sciences between 1889 and 1905. A memorial session was organised on the 150th anniversary of his birth and papers on his achievements and on his role in scientific policy by his followers are collected in number 1998/7 of *Magyar Tudomány* (Journal of the Academy).

(P. M.)

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KENYERES, Á. (ed.) (1969): EÖTVÖS L. Magyar Életrajzi Lexikon. *Vol. I.* Akadémiai Kiadó, Budapest. pp. 432–433.

FÖLDVÁRI, ALADÁR
(1906–1973)

A graduate of the Péter Pázmány University of Arts and Sciences, Budapest (1929), he was assistant to A. VENDL at the Department of Mineralogy and Geology. He proposed a modern method for the identification of grains of unconsolidated sediments and studied the distribution. Mineral composition and origin of manganese ores in Hungary. In 1935 he made observations on the geology of the Pyrenees. For his investigations there he was elected a corresponding member of the Real Academia de Ciencias Exactas in 1941.

From 1938 he worked in the geological mapping projects of the Geological Institute. He personified the modern petrologist, who views the entirety of geological processes when reconstructing rock formation. After 1945 he was active in the discovery and exploration of radioactive ores. In 1949 he was appointed to the Department of Mineralogy and Geology, Kossuth L. University, Debrecen, where he reorganised activities with much enthusiasm. In 1966 he was invited to the Department of Mineralogy and Geology, University of Heavy Industry, Miskolc, and in 1971 he became head of Department of Geology and Stratigraphy. He had to organise two departments one after the other. With his weaker health he could not work in the field extensively. He studied schlier formations. FÖLDVÁRI died during a field trip with students to the Caucasus, where at high altitude his heart stopped.

(B. G.)

Major works:

FÖLDVÁRI, A. (1932): Die Manganerz-lagerstätten des Bakonygebirges in Ungarn. – Földt. Közl. *62*. pp. 1–26.

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FÜLÖP, JÓZSEF
(1927–1994)

Geologist born in Bük. A village of Western Transdanubia, university professor, academician, leading personality in the geological research in Hungary during 35 years. He came from the early generations formed professionally by the new-type education in geology which, based on a dialectic philosophy of this discipline became established in the Eötvös L. University by E. VADÁSZ after the Second World War.

He began his university years in 1946 studying geography and economics. An assistant professor at the outset of his career, he was then appointed Director of the Geological Institute of Hungary leading the activities of it from 1958 to 1969.

Entrusted in 1968 with the duty of directing the Central Office of Geology as President, he gave management to the full range of geological activities of the country up to 1984. During the years 1984–1990 he was Rector of the Eötvös L. University.

His life-work encompasses the organization and direction of a great number of domestic research programmes, giving impetus for and co-operating in many of them and editing professional publications. He backed a wide range of publishing actively, being also the promoter of international scientific programmes.

The Mesozoic stratigraphy of the Transdanubian Central Range occupied always a prominent place within the range of his multifold research activities, with a special emphasis put on the Cretaceous formations. Along with monographs on the Bakony Mountains, Villány Mountains and the Tata region, his studies dealing with the Jurassic and Cretaceous formations of the Vértes and Bakony, his works summarizing the results of investigations concerning the Hungarian Mesozoic are of outstanding importance.

As the years passed on his scientific activity got broader dimensions by being extended over the fields of the methodology of geological scientific explorations, and research on the megastructural setting of Hungary. His contributions to the theoretical foundations of stratigraphical classification, to the science-historical aspects of the geology, to the connections of the geology with paleoarcheology, and his recognition of the rapidly emerging importance of the nature conservation are to be mentioned here.

Under his direction the methodology of the detailed and complex geological mapping was introduced into the surveying practice of the Geological Institute of Hungary. He was one of the initiators of the edition of the 1: 500 000 scale Geological Atlas of Hungary. The National Key Section Programme launched on his initiative is of outstanding importance both from the view of stratigraphy and nature conservation.

The copiously illustrated booklets presenting the then actual state of the geological raw-material resources of the country were published in the frame of the publication programme launched by FÜLÖP.

It has been the paramount goal of his scientific path to accomplish a new summary of the geology of Hungary. He strove for the realisation of this idea by executing a critical summary of the new knowledge which had been accumulated during the previous decades, and by the systematic filling up of the still existing gaps in it establishing exposures of key-section quality and by performing the necessary sampling. Laboratory tests and evaluating. Until the premature end of his life he could complete only the first four of the envisaged eight volumes of this monograph meant for use both as a manual and for purposes of professional education.

(B. K.)

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HALAVÁTS, GYULA
(1853–1926)

A graduate of the Mining Academy of Selmecbánya, he worked as a mapping geologist in the Hungarian State Geological Institute between 1874 and 1918 and mapped parts of southern Hungary and then the southern zone of the Transylvanian Basin (ca 15 000 km^2). He did not neglect paleontological investigations and studied the Pontian fauna.

More closely associated with his name are the stratigraphic-paleontological evaluations of artesian wells in the Great Hungarian Plain. Along with the leader of the project of boring, B. ZSIGMONDY, he described the stratigraphy of wells, dated strata, established the origin of sediments and water, measured water yields, temperatures and chemical compositions. His works promoted the exploration of the structure of the Great Plain. He pointed out the risks of incorrect boring for aquifers and the reasons for decreasing yields in certain wells. With SCHAFARZIK he re-edited the geological map sheets of the environs of Budapest for the Geological Institute and took advantage of new road-cuts and gravel quarries for expanding geological knowledge. He surveyed the 20 m thick gravel beds of Szentlőrinc with Mastodon and found Pannonian clay or sand underlying it and strongly weathered volcanic trachite among the gravels. As far as the disturbances of the upper part are concerned, he accepted INKEY's views.

HALAVÁTS identified two gravel accumulations over surfaces of various altitude and location: a) one with *Mastodon borsoni* (contemporaneous with Pannonian *Congeria* beds) and b) one with *Elephas meridionalis* (a much younger, Quaternary formation).

L. LÓCZY, sen. appreciated his research into artesian wells. HALAVÁTS was the first to identify subaerial deposits (previously described as marine-lacustrine) in the Great Plain. In his opinion artesian wells are fed by Levantan sand aquifers. HALAVÁTS and his followers were wrong to reconstruct the Pleistocene alignment of the Paleo-Danube along the Vecsés–Monor–Cegléd–Szolnok line. (It has not been confirmed by boreholes.) According to LÓCZY, he wrongly described Pliocene gravels as the debris fans of a river flowing into a lake. The horizontal gravel beds of Lőrinci are not deltas. LÓCZY also evaluates the gravel beds around Budapest with *Mastodon arvernensis* and *M. borsoni* and also with *Hypparion* cf. *Gracillis* and places them into the Pliocene of Central and Southern Europe (certainly older than Levantan, Upper Miocene, i.e. older than 5.6 Ma in present-day chronology).

(B. G.)

Major works:

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HOFMANN, KÁROLY
(1839–1891)

Descendant of a traditionally miner family and one of the prominent geologists of the first generation of geological mapping. He took his doctorate in 1863 at the University of Heidelberg. In 1864 was appointed professor of the Department for Geology and Mineralogy at the Budapest Technical University. From 1869 on he was second senior geologist for geological mapping at the Royal Hungarian Geological Institute, founded recently. The coal basins in Transylvania and in the Buda-Kovácsi Hills were surveyed at scales 1: 144,000 and 1: 75,000 and high quality geological maps were construed by him (1871). HOFMANN pioneered the modern volcanological and petrographical studies on the basalts of the Southern Bakony (1878). He became corresponding member of the Hungarian Academy of Sciences in 1871.

(K. L.)

Major works:

HOFFMANN, K. (1871): A Buda-Kovácsi hegység földtani viszonyai (Geology of the Buda-Kovácsi Hills). – Magyar Királyi Földtani Intézet Évkönyve I. (Yearbook of the Hungarian Royal Geological Institute). pp. 199–273.

HOFMANN, K. (1878): A déli Bakony bazalt kőzetei (Basalts of the South Bakony). – Magyar Királyi Földtani Intézet Évkönyve III. pp. 339–525.

Biographies:

BÖCKH, J. (1891): K. HOFMANN (1839–1891). – Magyar Királyi Földtani Intézet Évi Jelentése 1890-ről. (Annual Report of Hungarian Royal Geological Institute). 8 p.

TELEGDI ROTH, L. (1892): HOFMANN K. (1839–1891). – Földt. Közl., *22.* pp. 65–79.

VENDL, A. (1939): 100th anniversary of birth: HOFMANN K. – Földt. Közl. *69.* pp. 62–64.

CSIKY, G. (1966): Commemoration of 75th anniversary of death: HOFMANN K. – Földt. Közl., *96. 2.* pp. 243–245.

CSIKY, G. (1997): HOFMANN, K. Magyar Tudóslexikon A–Zs. (ed. NAGY, F.) Better. MTESZ, OMIKK, Budapest, pp. 389–390.

HORUSITZKY, FERENC (1901–1971)

A graduate of the Budapest University, he worked as assistant to K. PAPP (1924–1934) and at the Sorbonne in Paris (1928–1930). In 1934 he was appointed to the Hungarian State Geological Institute, where he was primarily engaged in dating and systematisation of Miocene rocks. He made essential statements on the hydrological contacts between deep karst water in the North Hungarian Mountains and the aquifers of the Pannonian Basin.

Between 1946 and 1951 he was professor of the Department of Geology at the University of Szeged and between 1950 and 1952 at the Department of Geology and Stratigraphy of the Technical University of Heavy Industry at Sopron. When the University moved from Sopron to Miskolc, he returned to the Geological Institute and worked there to his death.

From 1933 onward he studied the environs of Budapest, the hills on the left bank of the Danube, then the Cserhát Mountains and the southern Nógrád Hills. His papers on tectonics of the Buda Mountains and Triassic formation in Hungary are worth mentioning.

(B. G.)

Major works:

HORUSITZKY, F. (1939): A Budapest környéki Duna-balparti dombvidék földtani képződményei (Geological formations of the left-bank hills of the Danube in the environs of Budapest). – Annual Report of the Hungarian Geological Inst. for 1933–1935. pp. 941–971.

HORUSITZKY, F. (1943): A Budai-hegység hegységszerkezetének nagy egységei (Macrounits of mountain structure of the Buda Hills). – Discussions in the Hungarian Geological Inst. Budapest. pp. 1–12.

HORUSITKY, F. (1958): Budapest környékének geológiája (Geology of the environs of Budapest). – In: Budapest természeti képe (Physical conditions of Budapest) (ed. by PÉCSI, M.). Akadémiai Kiadó, Budapest. pp. 61–91.

Biographies:

BOGSCH, L. (1972): Memory of DR. F. HORUSITZKY. – Föld. Közl. *102.* pp. 223–230.

RÓNAI, A. (1973): Memory of Dr. F. HORUSITZKY. – Annual Report of Hungarian Geological Inst. 1971. pp. 13–20.

HORUSITZKY, HENRIK (1870–1944)

His agrogeological map of Magyarszögyén-Párkánynána (prepared in collaboration with B. INKEY and I. TIMKÓ) won the Medaille d'Or of the Paris World Exhibition in 1902. HORUSITZKY's principle in agrogeological mapping was that soil formation is controlled by parent materials and the origin of soils has to be evaluated at mapping. When soil mapping according to climatic zones gained ground, he emphasised that soil formation and properties cannot be explained solely by climatic influences. On the first international Agrogeological Conference in Budapest (1909) GLINKA urged soil mapping by climatic zones, while RAMMAN underlined the geological basis. To the end of his life, HORUSITZKY remained at geologically founded mapping.

During the great phylloxeria epidemics at the end of the 19th century, the Geological Institute organised agrogeological survey of wine-producing regions, to which HORUSITZKY also contributed with the mapping of the Balaton area, the southern Great Hungarian Plains and the environs of Belényes (Transylvania). In addition to mapping, he studied the origin of loess and its distribution. His field trips included the loess areas of Hungary. He interpreted the infusion loess widespread in the Great Plain as 'floodplain swamp loess', whose material was accumulated by the floods of lowland rivers and partly by wind. His results were published in the Annual Reports of Hungarian Geological Institute (MÁFI) and in geological and hydrological journals.

After retiring he prepared his main work, the geological map of Budapest. The Pest part required 1271 sites of observation and was published in the Hidrológiai Közlöny in 1935 and the Buda part followed in 1938. The geological map of Pest at 1: 25 000 scale included a full street network with sampling sites. The samples were petrographically identified, water in boreholes analysed and groundwater levels measured. Geological age is shown in the usual colouring. The Buda part also includes a full street network but it was made at 1:10 000 scale with geological ages and sampling sites. Loess areas are hatchured. The maps are supplied with a memoir volume. The geological map of Budapest shows the area of the capital within the 1938 boundaries. The reliability of the map was proved by the construction of underground lines. For a long time it was the best source of geological information about Budapest used by generations of geologists.

(B. G.)

Major works:

HORUSITZKY, H.–INKEY, B.–TIMKÓ, I. (1902): Magyarszögyén és Párkánynána környékének agrogeológiai térképe (An agrogeological map of the environs of Magyarszögyén and Párkánynána). – Publication of the Hungarian Geological Institute. 22 p.

HORUSITZKY, H. (1903): A diluviális mocsár löszről (On diluvial swamp loess). – Földt. Közl. *33.* pp. 209–216.

HORUSITZKY, H. (1929): Az agrogeológia múltja és feladata hazánkban (History and tasks of agrogeology in Hungary). – Földt. Közl. *59.* pp. 13–25.

HORUSITZKY, H. (1935): Budapest Duna balparti részének talajvize és altalajának geológiai vázlata (Groundwater and geological sketch of Budapest. East of the Danube). – Hidr. Közl. *15.* 147 pp. + two map sheets at 1: 25,000 scale.

HORUSITZKY, H. (1903): Budapest Duna jobbparti részének talajvize és altalajának geológiai vázlata (Groundwater and geological sketch of Budapest. West of the Danuba): – Hidr. Közl. *18.* 342 pp. + two map sheets at 1:10 000 scale.

Biographies:

SÜMEGHY, J. (1944/45): Memory of H. HORUSITZKY. – Földt. Közl. 73–74. pp. 1–6.

DOBOS, I. (1983): Activities of the two HORUSITZKYS in hydrogeology. – Földtani Tudománytörténeti Évkönyv. *9.* pp. 175–181.

VITÁLIS, GY. (1994): Commemoration on H. HORUSITZKY on the 50th anniversary of his death. – Hidrogeológiai Tájékoztató. pp. 5–6.

HUNFALVY, JÁNOS
(1820–1888)

He established the Department of Geography at the University of Budapest. HUNFALVY was a graduate of German universities (Berlin and Tübingen). He started to lecture at the Technical University of Budapest and in 1870 moved to the University of Sciences and Philosophy, where he set up the first geography department in Hungary. HUNFALVY established the trend of landform study and described the landforms of Hungary in three volumes of his *Description of the Physical Conditions of Hungary* (1863–65). He was a representative of K. RITTER's idealistic approach, the influence of which – thanks to HUNFALVY's successors – did not persist in Hungarian geography. Since 1858 corresponding and from 1865 member of the Hungarian Academy of Sciences. He published some more fundamental books and many articles in the geographical domain (the most important ones see in *References* of this volume).

(G. GY.–S. S.)

Biographies:

SOMOGYI, S. (1997): HUNFALVY J. Magyar Tudóslexikon A–Zs. (ed. NAGY, F.). Better, MTESZ, OMMIK. Budapest. pp. 398–399.

BULLA, B. (1954): Néhány szó a magyar földrajztudomány haladó hagyományairól. (On the progressive traditions in Hungarian Geography). – Földr. Közl. II. *(78) 1.* pp. 1–10.

INKEY, BÉLA
(1877–1921)

Founder of agrogeological mapping in Hungary, INKEY established the soil mapping department of the Hungarian Royal Geological Institute (Hungarian Geological Institute, MÁFI). In 1906 he was elected vice-president of the International

Geological Congress in Mexico and he guided the field trips at the First International Agrogeological Conference, organised in Budapest. INKEY's successful academic and organisational work was appreciated. In 1887 he became members of the Hungarian Academy of Sciences.

He was the first to formulate the principles and methods of soil mapping in Hungary. As a basic principle he held that 'granite weathers into the same loam soil as produced by a Tertiary clayey-sandy series'. His agrogeological mapping started from the geological survey of the area. When mapping, for instance, the soils of the environs of Pestszentlőrinc, he also described the geological conditions. He thought necessary the detailed profiling of Tertiary and Quaternary sediments. South of Budapest, in addition to the detailed knowledge on Pannonian-Pontian deposits, he emphasised the importance of the study of gravel pits and their sequences. He analysed – based on J. SZABÓ's (1858) work – the Szentlőrinc gravels with typical calcareous crust. He was the first to point out wedge-like disturbances of stratification, called by him 'sandy funnels with lime accumulation'.

Being a good observer, he recognised glacial striae at Rödersdorf (near Berlin) the evidence for the movement on inland ice. In spite of analogies, he did not assume that the disturbances of stratification in the Szentlőrinc gravel could have been caused by ice movement. It was obvious for him that the area of Budapest has never been covered by ice, so he looked for other explanations.

One of the explanations proposed by him was that local arching before the depoisiton of deluvial sediments led to a slow sliding of the overlying material. The other explanation was that calcareous precipitation* in the upper strata meant loading and folding may have resulted.

Referring to SZABÓ (1858), INKEY dated the Szentlőrinc gravels as Upper Tertiary and its deposition – based on *Mastodon borsoni* and *Mastodon arvernensis* tooth finds from the Szentlőrinc gravel quarry – as Upper Pliocene. He placed the deposition of the upper disturbed and more clayey strata into the diluvium (i.e. early Pleistocene – INKEY 1892).

INKEY was a forerunner of soil evaluation for agroecological potential: he assessed and classified soils according to fertility and economic use.

(B. G.–P. M.)

Major works:

INKEY, B. (1914): Magyarországi talajvizsgálat története (A history of soil studies in Hungary). – Budapest. Földtani Intézet alkalmi kiadványa. pp. 1–56.

INKEY, B. (1885): Nagyág környékének földtani és bányászati viszonyai (Geological and mining conditions in the vicinity of Nagyág). – Budapest, Természettudományi Társaság. pp. 1–108. + 3 maps.

INKEY, B. (1885): Nagyág und seine Erzlagerstätten. – Budapest. Verlag der K. V. Naturwiss. Ges. pp. 111–175.

Biographies:

TREITZ, P. (1927): Memory of B. INKEY of Palin. – Földt. Közl. *54*. pp. 5–12.

SZÉKYNÉ FUX, V. (1978): INKEY B. – Földtani Tudománytörténeti Évkönyv. *6*.

IRMÉDI-MOLNÁR, LÁSZLÓ
(1895–1971)

L. IRMÉDI-MOLNÁR was graduated at the University of Szeged as a teacher in geography. At the State Institute of Cartography (later Military Cartography) he took part in 1:25 000 scale topographical surveying and compiled several sheets of a popular World Atlas published by the same institution. It was here that he wrote a textbook on the classification of orographic features serving as a basis for relief representation on large-scale maps and published later in a number of editions.

He took the initiative in organising an independent education of civil cartographers. As a result of his proposal the Department of Cartography at the Faculty of Natural Sciences at Eötvös L. University (Budapest) was established of which he became the first professor. He regarded cartography a free standing new academic discipline. This department set up in 1953 was among the first separate chairs of cartography in the world. The education programme, curriculum of studies and methodology for training cartographers still operating today, was started by him. His students made up the first generation of the leading specialists of the Hungarian cartography.

(P. V. Á.)

* At that time, naturally INKEY could not recognise that the calcareous precipitation was coupled with a covering of bentonite in many places, cryoturbated in the Pleistocene.

Major works:

IRMÉDI-MOLNÁR, L. (1945): Magyarország hegy-vízrajzi térképe (Physico-geographical map of Hungary), 1: 500 000. – Budapest.

IRMÉDI-MOLNÁR, L. (1951): Hegyidomtan (Classification of orographic features). Tankönyvkiadó, Budapest. 74 pp.

IRMÉDI-MOLNÁR, L. (1970): Térképalkotás (Map creation). – Tankönyvkiadó, Budapest. 450 pp.

Biography:

KARSAY, F. (1995): IRMÉDI-MOLNÁR L. professzor élete és munkássága (The life and activity of Prof. L. IRMÉDI-MOLNÁR). – ELTE Térképtudományi Tanszék és MH Térképész Szolgálatfőnökség. Budapest. 85 pp.

KATONA, MIHÁLY
(1764–1822)

M. VARGA's fellow teacher in Komárom, KATONA further developed VARGA's activities in physical geography with new thoughts and chapters. In his text-books written in Hungarian and being still modern, he provided knowledge which was in advance of his age. He was among the first to found Hungarian earth sciences, primarily physical geography, the evolution of the earth surface. KATONA's geogony (description and origin of the Earth) includes thoughts on the position of continents and oceans and the possible reasons for their drifting apart. As opposed to neptunists and plutonists, he regarded the evolution of the surface as an outcome of simultaneously active exogeneous and endogeneous forces. In his opinion continental massifs formed in the fluid internal mass of the Earth and uplifted or subsided (KATONA 1824). His geogony suggests that he must have assumed magmatic currents to explain continental drift.

Cartographers producing navigational world charts and geographers describing and explaining the shape of continents inevitably recognised the similar alignments of coastlines, at least along the W and E coasts of the Atlantic Ocean. KATONA sounded revolutionary ideas on the physical geography of the crust and on geomorphology: in his view volcanic activity is associated with internal thermal processes of the Earth and thus deductively he was the first proponent of endogeneous magma currents. B. BULLA voiced that it is highly desirable to evaluate KATONA's works in detail and perhaps to publish them in *facsimile* edition.

(P. M.)

Major works:

KATONA, M (1824): Közönséges természeti földleírás (An ordinary physical description of the Earth). – Pest. 606 pp.

KATONA, M. (1824): A Föld matematikai leírása (A mathematical description of the Earth). – – Komárom.

Biographies:

BULLA, B. (1954): Néhány szó a magyar földrajztudomány haladó hagyományairólé (On the progressive traditions in Hungarian geography). – Földr. Közl. *2. (78). 1.* pp. 1–10.

BELUSZKY, P. (1964): Memory of M. KATONA. – Földr. Közl. *12. (88). 4.* pp. 363–364.

KENYERES, Á. (ed.) (1969): KATONA M. – Magyar Életrajzi Lexikon. Akadémiai Kiadó, Budapest. 879 pp.

KÁDÁR, LÁSZLÓ
(1909–1989)

He was the first Hungarian geomorphologist to experiment on a terrain model. As professor of geography, established a new school in geomorphology at the University of Debrecen after World War II. In 1933 he participated in L. ALMÁSY's expedition to the Sahara to classify the sandforms and then studied various blown-sand areas in Europe (KÁDÁR 1957, 1958, 1966).

He described new landforms on both desert and semifixed blown-sand surfaces (such as Lybian dunes, coastal and wandering dunes, parabolic dunes, wind furrows and blow-outs) and raised new considerations about the evolution of these features.

Later he focused his attention on fluvial processes (KÁDÁR 1955, 1957). Beginning with the early fifties he pioneered model experiments in Hungary and investigated stream sinuosity and alluvial fan formation. As opposed to generally held views, he explained terrace formation with stream autodynamics and identified a series of terrace types. Interpreting terraces as local phenomena, he refused to accept the existence of through terraces. From his results accumulated he developed a new system of geomorphic evolution through fluvial action, which rested on two cardinal points: the way of sediment transport (dissolved, suspended, salted, rolled or tracted) and the nature of river bed stages (destructional, accumulational, variational and neutral). Lacking partial investigations and appropriate measurements, he could not resolve the contradictions emerging in conjunction with his hypothesis, viz. certain landforms being associated with certain ways of sediment transport and particular ways of transport being matched by well-defined landforms under the mentioned trends of geomorphic evolution.

His main work is a text-book on biogeography *(Photo 52)*, which reflects his comprehensive geoecological approach, also embracing geomorphological aspects. This colourful personality undertook important functions in geographical circles, including the presidency of the Hungarian Geographical Society for a decade.

(SZ. J.)

Major works:

KÁDÁR, L. (1965): Biogeography (in Hungarian) – Tankönyvkiadó, Budapest. 407 pp.

KÁDÁR, L. (1965): Other significant publications see *References* in this volume.

Biographies:

BORSY, Z. (1989): In Memoriam KÁDÁR L. – Földr. Közl. Vol. XXXVII (CXIII). *4.* pp. 331–384.

GÁBRIS, GY.–SZABÓ, J. (1994): Some thoughts about the eolitic desert surface formation (based on the research of L. KÁDÁR and the observations of the 1993 Gilf Kebir expedition). – Földr. Közl. Vol. CXVIII (CLII). *3–4.* pp. 169–196.

KÉZ, ANDOR
(1891–1968)

Developer of methods in morphological research of river terraces, he was Professor of Geography for a long period first in Budapest and then in Debrecen. His name is associated with the first field methodology of river terrace research (KÉZ 1937, 1942). Recognising the major role of Pleistocene climatic changes in geomorphic processes, he underlined the influence of climatic factors (in addition to tectonic control) in terrace formation (KÉZ–BULLA 1936). (P. Z.)

Major works:

KÉZ, A. (1935): A vízfolyások szakaszjellegei (Stream channel gradations). – Földr. Közl.

KÉZ, A.–SZÁVA-KOVÁTS, E. (1953): Általános természeti földrajz I. kötet. (General Physical Geography, vol. I). – Tankönyvkiadó.

For further works see *References* in this book.

Biographies:

PINCZÉS, Z. (1966): A. KÉZ is 75 years old. – Földr. Ért. *15.* pp. 509–510.

PINCZÉS, Z. (1969): KÉZ A. (1891–1968). – Föld. Ért. *18.* pp. 3–4.

KOCH, ANTAL
(1843–1927)

A most successful figure of the investigation and explanation of the geological evolution of the land of Hungary, after 1872 professor of the Kolozsvár University and researcher of the geology and geomorphology of Transylvania for 20 years. His valuable work is the detailed geology and geomorphology of the volcanic Danube Bend Mountains (KOCH, 1872). The geology of Fruška Gora and the monograph on the Tertiary formations in the Transylvanian Basin, still often referred to by researchers. He was the first to publish the paleogeography and evolution of the Transylvanian Basin (KOCH, 1894). From his lecture notes at the Budapest University he planned to write a geology of Hungary but could not accomplish this task. (His student and follower, E. VADÁSZ finished his geology of Hungary as a handbook and a university text-book.)

He was elected corresponding (1875) and then member of the Hungarian Academy of Sciences (1894). After the death of J. SZABÓ he became head of Department of Geology and Paleontology at the Budapest University (1895). KOCH further developed SZABÓ's life-work. In E. VADÁSZ's words KOCH was 'an absolute master of teaching'. He published papers on the geology of various landscapes of Hungary (the Lower Danube area, Bakony Mountains and other mountains of the country). For a long time he worked as president of the Hungarian Geographical Society and was dedicated with the title of honorary member.

His activities in spreading knowledge on the values and landforms of Hungarian land were appreciated by his contemporaries and are still held in esteem by geologists of today.

(B. G.–P. M.)

Major works:

KOCH, A. (1880): Az 1880 október 3-i középerdélyi földrengés (Earthquake in Central Transylvania, October 3, 1880). – Orvos-természettudományi Értesítő, Kolozsvár. pp. 1–155.

KOCH, A. (1885): Erdély ásványainak kritikai átnézete (A critical overview of the minerals of Transylvania). – Orvos-természettudományi Társulat, Kolozsvár. 211 pp. Reprinted in 1990: Miskolc, Herman Ottó Múzeum kiadása.

KOCH, A. (1896): A Fruška Gora geológiája (Geology of Fruška Gora). – Mathematikai-Természettudományi Értesítő. *26.* 479–572.

Biographies:

PÁLFY, M. (1928): Memory of A. KOCH. – Földt. Közl. *58.* pp. 7–14.

PÁLFY, M. (1928): Memory of A. KOCH, member of H.A.S. – Az MTA elhunyt tagjai fölött tartott emlékbeszédek (Memorial speeches on the members of the HAS). – Akadémiai Kiadó. Budapest. Vol. *20.* No. *8.* pp. 1–40.

VADÁSZ, E. (1943): KOCH A. – Földt. Közl. *73.* pp. 1–10.

CSÍKY, G. (1974): KOCH. A. – Földt. Közl. *104. 2.* pp. 221–225.

KOCH, SÁNDOR
(1896–1983)

Receiving his doctorate from the Péter Pázmány University of Arts and Sciences in Budapest in 1920, he started to work for the Minerals section of the Hungarian National Museum and in 1932 became the leader of the President's Office of the Museum. In the centre of his activities the collection and study of the localities, origins and forms of occurrence of minerals in the Carpathian Basin were found.

In 1940 he was appointed to the Department of Mineralogy and Petrography of the Szeged University, where his first task was to establish a mineral collection at the University and to use it in teaching. In 1945 he reorganised the Department and – to replace the destroyed collection – supplied minerals from all the mines and quarries of historical Hungary through his own collecting work or from donations from previous students and set up an outstanding mineral collection for the Carpathian Basin, which now bears his name.

Parallelly, KOCH devoted much energy to teaching and research. He identified the minerals fülöppite, kiscellite and mátraite. He also paid attention to hold popular lectures about his favourite minerals and acted as honorary member of the Society for the Dissemination of Scientific Knowledge. He wrote several books on mineralogy. For his merits in University education, he received various decorations, including the Kossuth Prize from the Government, and was made *honoris cause* doctor of the University.

(B. G.)

Major works:

VENDL, M.–KOCH, S (1935): A drágakövek (Precious stones). – Term. tud. Társ., Budapest. 468 pp.

KOCH, S. (1952): A magyar ásványtan története (An history of mineralogy in Hungary). – Akadémiai Kiadó, Budapest. pp. 1–119.

KOCH, S.–SZTRÓKAY, K. I. (1967): Ásványtan I–II. (Mineralogy). – Tankönyvkiadó, Budapest. 936 pp.

KOCH, S. (1966): Magyarország ásványai (Minerals of Hungary). – Akadémiai Kiadó, Budapest. 419 pp.

KOCH, S.–GRASSELLY, GY.–DONÁTH, É. (1950): Magyarországi vasérc-előfordulások ásványai (Minerals in the iron ore localities of Hungary). – Acta Min. Petr. *4.* pp. 1–49.

KOCH, S. (1983): Die Edelsteine der ungarischen Krone. – Insignia Regni Hungariae, Budapest. 145 pp.

Biographies:

GRASSELLY, GY. (1984): KOCH S. 1896–1983. – Földt. Közl. *114.* pp. 433–438.

GRASELLY, GY. (1997): KOCH S. – Magyar Tudóslexikon (ed. NAGY, F.), – Better, MTESZ, OMIKK, Budapest. pp. 475–476.

KOGUTOWICZ, KÁROLY
(1886–1948)

Member of a cartographer family of international reputation, he also became a geographer. His father, M. KOGUTOWICZ was the founder of the Hungarian Geographical Institute, and after his death (from 1908) Károly became its director. This institution, modernised by him, published a series of maps used in education, the high quality of which was acknowledged by the Commission on World Map in Paris (1913). He became professor at the University of Szeged in 1923, its dean in 1929 and rector in 1941. His activities and field of research could be grouped in three categories.

– In the first place studies on landscapes of the Carpathian Basin should be mentioned. Between 1925 and 1932 his field works covered 40 000 km^2 investigated by modern physical and human geographical methods. Results of these studies of rather human geographical than of physical geographical character are to be considered a major contribution. Today it can be viewed as pioneering landscape development and man-and-environment interrelationship. These activities were reported in a (regretfully non-published) lecture delivered at the IGU Congress in Amsterdam.

– The second group comprises the adoption of modern methods and experimenting new topics in Hungarian geography, facilitated by his command of foreign languages. He was among the first ones to apply aerial photos, landscape historical approaches in geographical analysis, particularly in studies of human settlements.

– The third group includes social activities which might be a basis of the geographical education even nowadays. The foundation of the Commission on Great Plain Studies in 1925 belongs to this field. In the frame of these efforts KOGUTOWICZ not only contributed to the solution of scientific problems in soil geography or hydrology but took an active part of projects aimed at soil amelioration, dissemination of methods of biological protection in fruit production, afforestation over the Great Plain. Between 1921 and 1930 a popular scientific journal entitled *Föld és ember* (Earth and Man) was published under his editorship.

(M. G.)

Major works:

KOGUTOWICZ, K. (1930): Dunántúl és Kisalföld írásban és képben (The Transdanubia and the Little Plain through description and pictures). – Atheneaum, Budapest. 289 and 329 pp.

KOGUTOWICZ, K. (1934): Szeged város építési problémái (Problems of construction in Szeged). – Szeged, 37 pp.

KOGUTOWICZ, K. (1943): Bevezetés a földrajztudományba (An introduction to the geographical science). – Franklin, Budapest. 128 pp.

KOGUTOWICZ, MANÓ (1851–1908)

Founder of educational cartography in Hungary, he excelled with his marvellous drawing skills from students of the Military Academy of Vienna. He served as officer of the imperial army in Olmütz (today: Olomouc) but had to leave because of a heavy debt. He moved to Sopron, where – with the assistance of GY. JANUSZ – he drew the maps of counties Vas and Sopron which brought him a nationwide appreciation. Soon he settled in Budapest and, as cartographer of POSNER's publishing house, prepared wall maps of 30 counties by 1890. The superb quality of these maps is due – in addition to the skills of cartographers – to the fact that map sheets of the military survey at 1:75 000 had also been available by that time. Their hachures helped to present topography, slope direction and inclination. The steeper is the gradient, the denser are the hachures.

In 1890 a cartographic enterprise called *Hungarian Geographical Institute* was established as a branch of the Hölzel Company in Vienna and in 1901 it was reorganised as a joint-stock company. The company was supported by a considerable loan from ALBIN CSÁKY, minister of education. KOGUTOWICZ had the ambition to replace the exclusively German-language maps with Hungarian ones of good quality at schools. First he produces the orographic map of Hungary, whose quality was guaranteed by L. LÓCZY. A series of wall and hand maps for various countries appeared, followed by school atlases, made in cooperation with J. CHOLNOKY. Parallelly, historical wall maps and atlases as well as globes were published. Collecting maps of the school atlases, in 1902 a Complete Geographical Atlas appeared, subsequently reproduced in five editions. KOGUTOWICZ's pioneering works were awarded by the Grand Medal of the Millenium in 1896 and by the Medaille d'Or of the Paris World Exhibition in 1900.

In 1898 30 people worked in his printing house and their number grew to 60 by 1908. It is certain that KOGUTOWICZ drew a good number of maps himself but he also had assistance. With the appearance of contour maps, hachures were applied in conjunction with hypsometric colouring. With shading added later, a plastic presentation of topography became possible.

KOGUTOWICZ kept pace with the development of cartography and his name became associated with good maps. His hard work, however, undermined his health and he died at 57 in 1908. The directorship of Hungarian Geographical Institute Ltd. was taken over by his son K. KOGUTOWICZ, who learned cartography from his father. (K. B. GY.)

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KISARI BALLA, GY. (1995): KOGUTOWICZ MANÓ térképei (M. KOGUTOWICZ's maps). – Author's publication, Budapest. Tótfalusi Tannyomda. 214 pp.

Catalogue of M. KOGUTOWICZ's maps (including almost 500 maps drawn by himself, a detailed biography, bibliography and description of the age).

BUKA, A. (1997): KOGUTOWICZ, M.–NAGY, F. (eds): Magyar Tudóslexikon A–Zs. Better, MTESZ, OMIKK, Budapest. pp. 476–477.

KRENNER, JÓZSEF
(1839–1920)

He studied at the Faculty of Architecture of the Polytechnicum at Vienna. He attended mineralogy courses at Brezina and prepared his doctoral dissertation at Quenstedt in Tübingen. He returned to Hungary in 1866 and was appointed to the Minerals and Fossils Collection of the National Museum, where he worked to his death.

In 1870 he was invited to the Department of Mineralogy and Geology of the Technical University in order to lecture to students of civil and chemical engineering. After the death of J. SZABÓ he became had of the reorganised Department of Mineralogy and Geology until 1913, when he retired.

KRENNER devoted whole of his life to the study of minerals. He knew most of minerals in his age and even decided in debates between international experts. He described 16 new minerals from sites in Hungary. He reported on his results mostly at the Academy of Sciences but published them only years later. In more detailed books on mineralogy the minerals first described by him still occur. Most of his mineral descriptions were edited for publication by K. ZIMÁNYI. As a university professor, KRENNER studied the landslides of Óbuda and the origin of the Dobsina Ice Cave. He have been elected corresponding member (1874) and member (1888) of the Hungarian Academy of Sciences.

(B. G.)

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LÁNG, SÁNDOR
(1913–1982)

An outstanding expert of regional geomorphology. CHOLNOLY's regional geomorphic aspect of research and BULLA's climatic geomorphological concept was followed by S. LÁNG, who succeeded the latter as head of department of physical geography in Budapest. His pioneering work is a comprehensive description of the geomorphology and evolution of mountains of volcanic origin in Hungary (Börzsöny, Cserhát and Mátra) in regional monographs (LÁNG 1955b, 1958, 1967). In addition, he extended his geomorphological investigations to almost all other regions of Hungary.

LÁNG was the first of Hungarian geomorphologists to map and *analyse relative relief* in the mountains of volcanic origin in Hungary and, on this basis, classified and dated surfaces of erosion. He assumed that the Davisian low peneplain could have been developed even in Neogene volcanic mountains (e.g. the Mátra) and was only uncertain in the matter whether the Davisian or the Penckian concept explains better the surfaces of planation in the volcanic mountains (LÁNG 1955b, p. 50). LÁNG placed the planation (sic!) of the Mátra Mountains to the late Miocene – early Pliocene but stressed the absence of correlative sediments (andesite debris). He explains this absence with the predominance of denudation under late Miocene tropical and subtropical (warm and rather humid) climate and the removal of correlative material in the form of fine red silt. He believed that the rivers accumulated alluvial fans of quartz gravel ('peneplain gravels') over the truncated Neogene volcanic surfaces.

In those times, no uniform terminology of planation or classification of landforms were generally accepted. In areas of young volcanism it was not correct to mention piedmont step blocks or Neogene blocks. LÁNG (1967, pp. 71–75) assumed the existence of Lower and Upper Miocene, Sarmatian and Pannonian subtropical "planation remnants" and "planated blocks" and thought that these landforms are linked with the piedmont zone, as "marker geomorphological horizons" to Pliocene pediments. LÁNG doubted BULLA's view that (sub)tropical peneplanation could last to the late Pliocene.

LÁNG's main works see in *References* of this book.

(SZ. A.–P. M.–G. GY.)

Biographies:

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LÓCZY, LAJOS sen.
(1849–1920)

The second professor of physical geography and geomorphology at the Budapest University (between 1889 and 1909) was L. LÓCZY, sen., who graduated as a geologist from Zurich. His Professors at the university were E. von der LINTH and A. HEIM. LÓCZY was the director of the Hungarian State Geological Institute (1909–1909), he is known as a great figure of Hungarian geoscience. His eventful life reached a phase of upswing when, returning from B. SZÉCHENYI's expedition to Eastern Asia (1877–1880), he presented the scientific results of this venture (*Description of the physical conditions and countries of the Chinese Empire,* Budapest, 1896, *and Scientific results of Count* B. SZÉCHENY's *expedition to Eastern Asia,* 1877–1880, Budapest–Vienna, 1890–1899 in three volumes). Among other observations, LÓCZY found that the so-called *Hanhai strata* of the Eastern Turkestan basin are not inland sea deposits – as it had been believed world-wide – but products of prolonged sheet-wash under arid climate preserved over a long geological period. He also saw a relationship between these arid deposits and the formation of the neighbouring Loess Plateau of North China.

He made lasting observations on the loess landforms, including the impacts of karstification processes in loess. When studying the mountain ranges of Eastern Tibet and Southeastern Asia, he suggested the existence of a range parallel with the Himalayas and located somewhat to the north. Soon S. HEDIN discovered this range and named it Transhimalayas. For his books on the Asian expedition, LÓCZY was awarded with the Chihachev Prize by the French Geographical Society and received honorary membership from the British Royal Society.

LÓCZY at the Budapest University taught geomorphology and regional geography. He brought a new approach into university geography, the analytical and evolutionary concept of landform investigation. LÓCZY added new examples from his own experience to RICHTHOFEN's ideas. The number of his students who chose the study of landforms equals that of geologists.

As President of the Hungarian Geographical Society, LÓCZY organised a commission for the investigations of the physical and social environment of *Lake Balaton,* the largest lake in Central Europe. From the results of this research (1891–1943) a *monograph series of 32 volumes* was produced and two detailed maps on the geology and geography of the vicinity were drawn. The first volume on the geological and geomorphological evolution of the lake environs was written by LÓCZY himself. This monograph series, prepared in the true Humboldtian conception, made Lake Balaton one of the most profoundly studied lakes of the world.

The contributors to the Balaton monograph series realised that desert conditions played a fundamental part in the Pliocene geomorphic evolution of the Carpathian Basin (the period is correlated with the Messinian Salinity Crisis today). Several authors refused to accept this concept until modern investigations in the 1970s confirmed it.

It was LÓCZY who introduced field research methodology into Hungarian geomorphology. When he took over the directorship of the Geological Institute, he had already had a ready programme to re-survey the geology and geomorphology of Hungary. This project was broken by World War I. He pioneered the exploration of the rich natural gas fields of the Transsylvanian Basin. He recognised the role of an 'intermediate mass in the tectonic evolution of the Carpathian Basin.

A sign of appreciation of his life-work is the fact that the highest-ranking medal awarded to Hungarian geographers by the Geographical Society is named after him – "Lóczy's Medal".

Main works of LÓCZY see in *References* of this book.

(M. S.–S. S.–G. GY.–L. D.)

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LÖRENTHEY, IMRE
(1867–1917)

He began his career at the Kolozsvár University and in 1893 he became an authority in paleontology at the Department of Geology and Paleontology of the Budapest University, working with M. HANTKEN and A. KOCH. He collected fossils in several countries of Europe, mostly of the Pontian faunae in the Alps. His geomorphological statements on the origin, stratigraphical position and age of gravels in the Budapest area are important. In the above topic LÖRENTHEY as professor worked together with L. LÓCZY, sen.'s assistant, J. CHOLNOKY. A memorable debate between them was the problem of gravels with *Mastodon* finds, also studied by others before them.

In addition to correspondence they also consulted during joint field work, particularly on the age of the Rákosszentmihály–Sashalom gravels. Relying on his stratigraphical investigations and SCHAFARZIK's reports on research in the Cserhát Mountains, LÖRENTHEY (1904) was on the opinion that the Sashalom gravel and conglomerate underlies the Miocene Upper Rhyolite Tuff. (At Sashalom the conglomerate outcrops from below the eroded rhyolite tuff.) He found the conglomerate in the old gravel pit older than the rhyolite tuff, having different sphericity and mineral composition than the gravels with *Mastodon* finds (at Cinkota, Lőrinc, Csömör or Kőbánya – see LÖRENTHEY 1904. pp. 237–139. profiles 1 and 2).

LÖRENTHEY also collected weathered andesite from the gravel with conglomerate under the rhyolite tuff. It is in contradiction with J. SZABÓ's (1858) dating of gravels in the neighbourhood, i.e. gravels below the Leitha Limestone (Upper Miocene Badenian) lack andesite (trachyte), only distinguished by SZABÓ in gravels above the Pontian clay. (B. G.–P. M.)

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MAJZON, LÁSZLÓ
(1904–1973)

He received his doctoral degree from the Pázmány Péter University of Budapest in 1933. In 1932 he began to work in the laboratory of the Geological Institute, where he organised and led the evaluation of deep boreholes. Between 1948 and 1952 he was director of the Institute and to his death he worked in the scientific laboratory of the National Oil and Gas Industry Trust.

He was early to recognise from his investigations that the Kiscell Clay, held to be a uniform deposit earlier, consists of strata of different age, distinguishable from each other by the analysis of foraminifers. The identification and classification of Foraminiferidae ranging from the Upper Paleozoic to the Miocene, but focusing on the Oligocene, and the relationships between foraminifers and regional geological development became the centre of his activities. (B. G.)

Major works:

MAJZON, L. (1933): Leányfalu és környéke harmadkori üledékeinek geológiai és paleontológiai leírása (Geological and paleontological descriptions of Tertiary deposits at Leányfalu and environs). – Doctoral dissertation, Budapest.

MAJZON, L. (1966): Foraminifer vizsgálatok (Investigations of foraminifers). – Akadémiai Kiadó, Budapest. 939 pp.

Biography:

BOGSCH, L. (1974): MAJZON L. emlékezete (Memory of L. MAJZON). – Földt. Közl. *104.* pp. 381–387.

MAURITZ, BÉLA
(1881–1971)

A student of J. KRENNER at the Budapest University of Arts and Sciences, he subsequently studied the contemporary modern optical and chemical methods in mineralogy at German universities for five years. On returning to Hungary he performed research at the Department of Mineralogy and Petrography of the Budapest University of Arts and Sciences and at the Department of Mineralogy and Geology of the Technical University of Budapest. In 1915 he was appointed to the latter department, where he was active until his retirement in 1949.

MAURITZ' activities as a researcher are focused in two directions: description of minerals, goniometric analyses, petrographic systematisation of rocks based on chemical analyses. On the other hand, he provided regional petrographic evaluations for the Mecsek and Mátra Mountains and the syenite stock of Ditró, Transylvania. He carried out detailed investigations in magmatic differentiation.

Deprived from his job at the University, he was employed by the Hungarian State Geological Institute and then by the Hungarian Museum of Natural History. He became corresponding member of the Hungarian Academy of Sciences in 1913, member in 1923 and honorary member of the Hungarian Geological Society in 1942.

(B. G.)

Major works:

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SZÉKY-FUX, V. (1997): MAURITZ B. – Magyar Tudóslexikon (ed. NAGY, F.). – Better, MTESZ, OMIKK, Budapest. pp. 568–569.

NOSZKY, JENŐ sen.
(1880–1951)

Outstanding surveyor geologist of the North Hungarian Mountains graduated in 1906 from the Budapest University of Sciences. As school teacher entered into a contract with the Hungarian Royal Geological Institute and accordingly to it he mapped the Cserhát and Mátra Mountains between 1908–1920.

After changing his position he was appointed Director of Collection for Geology and Mineralogy at the National Museum of Hungary (1920–1942). He published excellent regional monographs on the geology of the Mátra Mountains (1927) and the Cserhát Mountains (1940). Stratigraphic works of fundamental importance and new palaeontological syntheses on the Oligocene and Miocene were done by him.

(B. K.–K. L.)

Major works:

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NOSZKY, J. sen. (1927). A Mátra-hegység geomorphológiája (Geomorphology of the Mátra Mts.). – Debreceni Tisza István Tudományos Társulat Honismereti Bizottsága Kiadványa, III. 149 pp.

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Biography:

SCHRÉTER, Z. (1951): Memory of NOSZKY, J. sen. – Földt. Közl. *81.* pp. 232–237.

PANTÓ, GÁBOR
(1917–1972)

He received his doctor's degree from the Pázmány Péter University of Budapest in 1940. He began to work in the Geological Institute as a geologist in 1941. His mapping and research activities covered the whole territory of Hungary. In North Transylvania he studied the ore occurrences in the internal region of the Eastern Carpathians and mica localities in the Radna Mountains. At Balánbánya he recognised a richer ore reserve. On the territory of present-day Hungary he evaluated the ores resources at Nagybörzsöny, Rudabánya, Recsk, Parádfürdő and Zengővárkony. After 1950 he mainly studied magmatites. He was the first to address the problem of ignimbrites in Hungary. He reevaluated volcanism in the Tokaj Mountains and explored natron gabbro in the Bódva valley and anhydrite at Perkupa.

He had extensive international contacts and participated on all geological congresses after 1948. In 1967 he was appointed professor to the Department of Mineralogy and Geology of the Kossuth L. University, Debrecen, where he could share his knowledge with his students and colleagues. For his academic achievements he was elected corresponding member of the Hungarian Academy of Sciences in 1965. His early death broke a promising career and prevented him from writing his synthesis of novel attitude on the origin of young volcanic mountains in Hungary.

(B. G.)

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Biography:

SZÉKY-FUX, V. (1973): DR. PANTÓ G. emlékezete (Memory of DR. G. PANTÓ). – Földt. Közl. *103.* pp. 108–116.

PAPP, KÁROLY
(1873–1963)

Doctor of the Budapest University of Arts and Sciences in 1900, he was assistant to L. LÓCZY at the Technical University between 1895 and 1900 and geologist in the Hungarian Royal Geological Institute from 1900 onward. In 1898 he participated in Mór DÉCHY's expedition to the Caucasus. In his study tours abroad he visited the institutes of FRECH, ZITTEL and CAPELLINI.

As a mapping geologist he paid attention to the careful recording of data. His maps primarily present his achievements in the famous 'golden quadrangle' (the Transylvanian Erzgebirge area). He was commissioned with explorations for potassium salts in Transylvania, but he found the Kissármás gas field instead, which still produces natural gas. He prepared the reports on the iron ore and black coal reserves of Hungary for the geological world congresses in Stockholm (1910) and Toronto (1913). The report was also published in Hungarian in an extended version.

In 1915 PAPP was appointed to the Department of Geology of the University and in 1917 he also became head of Department of Paleontology and acted as such until his retirement in 1945. He was elected corresponding member of the Hungarian Academy of Sciences in 1920. (B. G.)

Major works:

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PRINZ, GYULA
(1882–1973)

Prominent geomorphologist and explorer of L. LÓCZY's school. He started his university studies in Budapest, but visited F. von RICHTHOFEN as a student and completed his education in Breslau (today: Wrocław in Poland), attending lectures by J. PARTSCH and F. FRECH. Having obtained the doctor's degree there, he became a lecturer in Budapest (1904), then professor at several universities (Pozsony, today: Bratislava in Slovakia), Pécs, Kolozsvár (Cluj, Romania) and, after World War II, Szeged. He also became a member of the Hungarian Academy of Sciences.

In his academic activities three fields of interest are recognisable. First of all, as a field geologist-geomorphologist he studied Mesozoic formations in Hungary and then the tectonic-stratigraphic-morphological conditions during expeditions to the middle and southern parts of the Tien Shan and Nan Shan and to the Tarim and Gergana basins (1906–1910).

– He set up the goal to clarify the relationship between the extensive *Central Asian* peneplains and the presumed folded ranges incorporated in them. He studied the structure and geomorphology of the was mountain system, the *Bolor* in Central Asia. He described the glaciation in this area, according to the then prevailling polyglacial concept. Regrettably, the geographical descriptions and detailed geographical surveys made during the expeditions were only published in 1939. For his part, the experiences gathered in Central Asia proved to be decisive for all his later career.

– PRINZ's greatest achievement is undoubtedly his *'Tisia theory'*, named after the river Tisza and elaborated in the 1920s. It claims that the Carpathian ranges were forced to fold in their characteristic wreath form by an intermediate crystalline mass, the Tisia, then rising in the area of the present Carpathian Basin (*Fig. 1*).

According to PRINZ, tht Tisia is "ancient planated mountains which are built up of the ruins of the Hercynian mountain system... became less dissected to the end of the Permian. There was marine deposition from the Triassic to the Cretaceous and thus... a tableland formed. Although the Tisia was a strong mass, it was also denuded. It thrusted against the ring of mountain chains outwards and simultaneously uplifted, eventually fragmented and most of it subsided."

The Tisia theory was taught for almost half a century to explain geomorphic evolution at all levels of education and was applied in research in the geosciences. Although recent plate tectonic concepts divert from PRINZ's views to various degree, some (e.g. T. SZALAI 1960; T. SZEDERKÉNYI 1984, 1996; S. KOVÁCS 1984) are influenced by his approach to the development of the Carpathians and the enclosed basin.

– A third field where his contributions were of pioneer nature is the geomorphological study of urbanising areas (first the environs of Budapest and then of Szeged).

For major works see *References* of this book.

(M. S.–S. S.–SZ. T.)

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RAISZ, ERWIN, J.
(1893–1968)

E. J. RAISZ was born in Lőcse, Hungary (now Levoča Slovakia). He received his architect diploma at the Royal Polytechnicum in Budapest in 1914. He saw the World War I through, thereafter he worked as an architect. In 1923 he emigrated to the United States of America. He earned his living by drawing maps. Parallel he acquired the Master of Arts degree in Geology at the Columbia University. In 1929 he received the doctorate in geology. From 1930 on he had been teaching cartography for two decades at the Harvard University.

His book General Cartography (1938) constitutes one of the early summary of the discipline cartography.

Since 1950 he set up a cartographic workshop at his home, besides he lectured at several state universities (Virginia, Florida, Britisch Columbia). He compiled a number of maps, atlases. On his maps he used also a new representation technique (triangle with sides of equal length) and new projections (orthoapsidal).

He has secured a place in the history of cartography with his landform maps. He thought, he would be able to represent to elements of the terrain in pictorial-diagrammatic fashion most expressively. His method is the renewal of the early pictorial way of terrain representation (17th century), combining it with the geomorphological features. He classified the terrain elements into 40 classes and for each type he worked out the pictorial form sign expressing the features of the landscape most descriptively. While drawing his maps he fitted the conventional form signs into the real space and thrived to shape the actual image of the landscape visible from above (*Fig. 17*) from an airplane or the space. Using this technique very expressive, beautiful maps were made. His technique requiring profound geomorphological knowledge and high degree artistic sense has not become general in the practice outside of USA.

(P. V. Á.)

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RÓNAI, ANDRÁS
(1906–1991)

In the first part of his life, he acted as a student and successor of P. TELEKI, professor at the Department of Economic Geography of the University of Economics and director of the Institute of State Sciences (Államtudományi Intézet), founded by TELEKI. He edited the physical and economic geographical map of the Danubian countries at 1:1 000 000 scale (1945) with memoirs (written with G. TELEKI). Thus he contributed to the methodology of thematic mapping. His career was broken after World War II, when he became a hydrogeologist and lowland geologist in the Hungarian State Geological Institute. There he developed and led the Department of Lowland Geology, and directed the complex survey and mapping of the lowlands of Hungary. Since the aquifers of the Great Plain basins are of decisive importance in water storage and supply, his research also extended to the study and mapping of hydrogeological conditions of the country. Thus he also became an international authority in hydrogeology.

He studied the fill of the basin, their evolution and regional differences. He was the leader of the 1:100 000 scale geological mapping project of Hungarian lowland to depict the entire Quaternary sequence and its main properties. His activities in this field were rewarded by the honorary membership of INQUA. He published more than 100 works of utmost importance, some of them are essential sources of information.

Through organising the processing of information from boreholes in the Geological Institute he gained highest team. An internationally acknowledged achievement was the analyses of more than a thousand metre deep subaerial sequences (Vésztő, Dévaványa, Mindszent and Csongrád). He was successful in the chronostratigraphy of Quaternary and Upper Neogene (Pliocene) subaerial sediments and paleosols in the basins of Hungary.

Major works see in *References* of this book.

(S. S.–P. M.)

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SCHAFARZIK, FERENC (1854–1927)

Founder of the engineering geology in Hungary, he was an assistant to J. SZABÓ from 1876, where he got acquainted with the petrographic research methods of his master. He was invited to the Royal Hungarian Geological Institute to conduct geological mapping and in the same year he started with the geological survey of the lower reaches of the Danube in the Carpathian Basin (Alduna), a work he continued till the end of his life.

He received the title of *Privatdozent* of engineering geology at the department headed by J. KRENNER in the Budapest Technical University in 1890 and was responsible for teaching dynamic geology, tectonics and hydrology. In 1904 he became professor of the Department of Mineralogy and Geology at the same university and retained this title until his retirement in 1926.

SCHAFARZIK's activities embraced several branches of geology. He was a pioneer in the study of usability and utilisation of rock met in the historical Hungary (Carpathian Basin). For practical use, together with S. GESELL they compiled a detailed domestic petrological catalogue (1885) in which he described 420 rocks. Based on the data collected during two decades he published a detailed description of 2305 stone quarries in Hungary with the assessment of quality of the worked or workable rocks and their actual price. He did not consider this inventory a finished piece of work but kept on updating it till the end of his life.

He was also a noted hydrogeologist who was responsible for the delineation of the protected area of the mineral springs at Budapest.

SCHAFARZIK studied the pyroxene-andesites of the Cserhát Mountains and rocks in the vicinity of Selmecbánya. His outstanding achievement was a microscopic analysis of the rock samples of the Caucasus collected by himself during the third expedition led by M. DÉCHY in 1886 and published in a book entitled *Kaukasus* published in Berlin (1905).

In the frame of the Hungarian Geological Society he organised a commission on earthquakes which existed between 1879 and 1903. He was the president of the Society in 1910–1916, became corresponding member of the Hungarian Academy of Sciences in 1902 and a regular member in 1916.

His activities were highly appreciated by colleagues and followers. The interpretation of distribution and emergence of geological formations had always been in the very focus of his scientific interest. Apart from detailed studies of the Cserhát and Pilis mountains, SCHAFARZIK summarised the experience gained during the mapping of the Southern Carpathians and explained the formation of the Iron Gate of the Danube.

(B. G.)

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SCHMIDT, ELIGIUS ROBERT
(1902–1973)

Scientist born in Karánsebes, Kossuth-prize winner. After his secondary school years in Temesvár he continued his studies on the Faculty of Mining and Forestry of the Technical University in Sopron graduating from there with the diploma of engineer in mining and geology in 1929. Completing his studies with a scholarship in Vienna, in 1932, he was appointed department geologist of the Geological Institute of Hungary where he served in this quality until 1944. After having been entrusted by the state authorities with various commissions of mining engineering and geological character he joined the Institute anew in 1951 as its senior research associate filling this post until his death.

He brought forth works of lasting value on two fields. One of them is the hydrogeology of the great basins, the other one is embodied in his geotectonical research leading him to the principles of geomechanics. These two disciplines are interconneted in a very close manner. He could detect the inadequately known geological setting of the deep basins, first of all their structural build-up by interpreting the caracteristics of the underground waters.

The extraordinary conditions of temperature and pressure existing in the underground water reservoirs, the direction of the flows in them and their solved material content all are giving evidences on the permeability of the rocks taking part in the basin filling sequences, moreover on their contiguous or disturbed setting. He demonstrated the close interrelation existing between the hydrogeological character and the structural build-up of the great basins in the frame of the Alpine-Carpathian and Dinaric ranges.

(B. K.)

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SCHRÉTER, ZOLTÁN
(1882–1970)

Prominent geologist, academician a real polymath character.

Born in Dombóvár, on his mother's side he descended from a family of miners. He graduated from the Faculty of Natural History and Geography of the University of Sciences in Budapest, taking his doctorate in geology and paleontology. In 1906 he obtained a post in the Chair of Mineralogy and Geology of the Technical University of Budapest at the same time joining the Hungarian Geological Institute spending henceforth a considerable part of his sixty active years there. Paleontology and stratigraphy were especially liked by him but also his mine surveys, mapping, geomorphological observations, his life-work as a whole is qualifying him as one of the most eminent personalities among the geologists of the country.

His life-work had many facets covering the fields of archeology, speleology, seismology, geomorphology, engineering geology and mineralogy as well. The geological surveys in many areas are of fundamental importance and indispensable even today (e.g. those in the surroundings of Budapest, in the Vértes Mts., in the B-kk Mts. and the foreland of the latter are to be mentioned are linked to his name.

It is his discovery that the thermal springs of Buda could be active as early as in the Post-Oligocene time. His coal-geological and hydrocarbon explorations are not only of importance and success, but qualified him as one of the best experts in the geology of the northern and north-eastern part of Hungary.

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'SIGMOND, ELEK
(1873–1939)

Founder of modern soil chemistry in Hungary, an internationally acknowledged pedologist, he completed his studies in chemical engineering at the Technical University of Budapest in 1895 and obtained doctor's degree in Kolozsvár. In 1899 he began to work in the Plant Production Experimental Station in Magyaróvár. He started to study salt-affected soils in 1902 and his whole life was devoted to their amelioration. He travelled for longer study trips to the USA, Africa and Western Europe. His name is associated with the classification of soil types in Hungary according to their origin, the *'principle of dynamic soil systematisation'.*

In 1908 he was invited to be professor at the Department of Agricultural Chemical Technology. He contributed to the success of the First International Agrogeological Conference, organised in Budapest in 1909. As a consequence, at the second conference in Stockholm he was elected president of the international soil investigation committee (until 1935). From 1926 to 1935 he led research at the National Chemical Institute and organised several laboratories to reveal the properties of soils in Hungary by modern methods.

'SIGMOND summarised his knowledge and experience on soil research in several books, which were also successful abroad. The monograph on his soil classification system was published in Hungarian in 1934 and in English in 1938. His activities acknowledged both in Hungary and abroad have been recently summarised by L. MÓRA (1997). He became university professor, corresponding member (1915), and member (1925) of the Hungarian Academy of Sciences.

(B. G.)

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SZABÓ, JÓZSEF
(1822–1894)

In his age the knowledge close to present-day geology could be obtained at the Academy of Mining in Selmecbánya (1842–1846). Before that he studied law and philosophy at the Budapest University. However, he soon abandoned his job as a lawyer and his interests in mining law for geology, mineralogy and – what is now called – engineering geology.

His career was temporarily broken by his position in L. KOSSUTH's Ministry of Finances during the War of Independence. He was a founding member of the Hungarian Geological Society (1848). Only in 1862 was he appointed an university professor at Budapest for the Department of Mineralogy. SZABÓ is regarded one of the most outstanding Hungarian geologists, founder of geology in Hungary and initiator of a scientific school in geology. He founded Hungarian professional geological language, published and edited several books, text-books and papers. Several new geological and mineralogical discoveries are associated with his name and he launched geological research and mapping in Hungary.

In the field of geomorphology he produced regional monographs (on the environs of Budapest, Tokaj-Hegyalja) and systematised the volcanic rocks of Hungary. He related geological and topographic analyses with water exploration and the evaluation of soil conditions.

He was an international pioneer of the application of contemporary geological research. As a result of his activities in scientific research and organisation, he was elected secretary general and then president of the Geological Society and worked as dean and then rector at the University. He became corresponding (1858) and later ordinary member (1867) of the Hungarian Academy of Sciences.

He had very influential recognitions (1858) on the appearance of the Danube in the Hungarian Basin. In his opinion the gravel deltas or alluvial fans with weathered andesite (trachyte) gravels around Budapest could have been deposited in the Pontian (now: Lower Pannonian of the Miocene), when the river broke through the Visegrád Gorge. It is evidenced by *Mastodon bolsoni* and *M. arvernensis* tooth fragments and petrified and redeposited wood remnants. He also assumed (SZABÓ 1862) that the Great Hungarian Plain was connected to the Pontian Sea in the Romanian Plain through the Iron Gate gorge, which functioned like the Bosphorus in the Lower Pannonian (SZABÓ 1858, 1862). His opinion influenced the researchers who studied the origin of the Danube later (INKEY, HALAVÁTS, LÓCZY, LÖRENTHEY). So *he thought that the Visegrád and the Iron Gate gorges of the Danube already existed in the Pontian* (Upper Miocene) and resulted from the internal, differentiated subsidence of the Carpathian-Balkanic region and the related river antecedence.

(B. K.–P. M.)

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SZABÓ, PÁL ZOLTÁN
(1902–1965)

He was a karst geomorphologist and the founder of the first academic institution for regional research. The Transdanubian Research Institute of the Hungarian Academy of Sciences was established in Pécs in 1940. The director of the Institute P. Z. SZABÓ was the first to sound the opinion that the buried cockpit karst surfaces which are common in the Transdanubian Mountains (with bauxite and Upper *Cretaceous and Eocene limestone covers) are remnants* of ancient etchplain. His research into paleokarst geomorphology makes him a forerunner of applied and climatic geomorphology in Hungary (SZABÓ, P. Z. 1960). He guided the Hungarian Geographical Society (1962–1965).

(L. GY.)

Major works:

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SZÁDECZKY-KARDOSS, ELEMÉR
(1903–1984)

He founded the geochemical education and research in Hungary. He graduated at the Faculty of Natural History of the Pázmány Péter University, Budapest.

Between 1927 and 1949 full professor of the Academy of Mining and Forestry Engineering at Sopron, then rector of the Technical University for Heavy Industries at Miskolc in 1950. Between 1951 and 1969 full professor and head of the Department for Mineralogy and Petrology, then that of the Department for Petrology and Geochemistry and between 1955 and 1974 director of the Laboratory for Geochemical Research of the Hungarian Academy of Sciences, founded by him.

Since 1950 he was member of the Hungarian Academy of Sciences. Between 1965 and 1975 he was first the secretary, later the president of the Department for Earth and Mining Sciences of the Academy.

He achieved outstanding results in several branches of the earth sciences, first of all his works on sedimentary, igenous and metamorphic rocks, on coal petrology and geochemistry have to be mentioned. One of his most outstanding work is the handbook "Geochemistry" (Budapest, 1955) being so far the only geochemical manual in Hungarian. In Hungary he recognised first the permafrost phenomena in Pleistocene periglacial soils and their remarkable role in the evolution of morphology. In his book "Coal petrology" (Budapest, 1952) he created new aspects in classifying the brown coals. In his manual entitled "Structure and evolution of the Earth" (Budapest, 1968) he presented his theory on the relationship of rock formation and of the dynamics of the Earth on the basis of the global tectonic view. His concept aiming at the integration of earth sciences developed already in the seventies and this was summarized in his work "Geonomy" (1975).

Having developed the universal law of cyclicity he revealed the general relationship of space-time-velocity. The essence of this work was published as Appendix in the "Geological and Cosmological Cycles" by F. Benkő (Budapest, 1984). He just edited his works of his last years when departed. This work was published as a posthumus work entitled "The universal relationship of phenomena" (Publishing House of the Hungarian Academy of Sciences, 1989). He was rewarded by several medals: honorary member of the Geological Society of Hungary, Austria and of the GDR, SZABÓ J. medal, honorary doctor of the Budapest University of Science, owner of the Leopold von BUCH commemorative medal.

Further works see in *References* of this book.

(Á. P.–P. T.–P. M.)

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SZALAI, TIBOR
(1900–1980)

Director of the Hungarian State Geological Institute (1946–1980), he was a devoted paleontologist and structural geologist, engaged in the tectonic conditions of rock strata. All his activities were deeply influenced by the period (1928–1931) spent in the Collegium Hungaricum in Vienna, where he got acquainted with the views of the paleontologist O. ABEL and of L. KOBER, professor of tectonics.

The results of his studies there are summarised in his work 'Der Einfluss der Gebirgsbildung auf die Evolution des Lebens' published in Berlin in 1936. Although later he worked in almost all geological disciplines but most of his successes were achieved in paleontology and tectonics. He published a large number of papers, out of which the 'Geotektonische Synthese der Karpaten' (Geofizikai Közl. 7. 1958) and 'Die Tisian und das Zwischengebirge des Karpatenbecken' (Geofizikai Közl. 1961) are to be mentioned. His colleagues and followers regarded him a defender and further developer of the Tisia (intermediate mass of the Carpathian Basin) concept. But he also mediated between other geological disciplines and physical geography (an example is his paper on the tectonics and development of East Alpine and Carpathian blocks in Földr. Közl. 1969). He was aware of new results in geographical research and was often involved in their discussions (see his contribution to B. BULLA's presidential address in Földr. Közl. 1958). He wrote obituaries of lasting merit about his contemporaries (LÓCZY Jr. RÉTHLY, BENDEFY, PÁVAI-VAJNA, HOFMAN, WEIN) and evaluated their achievements with great objectivity.

Further major works see in *References* of this book. (S. S.)

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SZÉKELY, ANDRÁS
(1925–1997)

A representative of the climatic geomorphology in Hungary was a chief of the Department of Physical Geography, Eötvös L. University, Budapest. As a disciple of B. BULLA (after having taught at a secondary school he became a postgraduate student in 1953) he dealt with the intriguing topics of the time: he studied river terraces and denudation surfaces of the volcanic Mátra Mountains. Later periglacial geomorphology became his major research topic but he never stopped to be insterested in volcanic morphology. He travelled abroad extensively (visited all the continents except Australia) and performed research work during field trips. SZÉKELY was engaged presumably in volcanic morphological observations and investigations. Hit last, posthumus work also dealt with this topic and was a summary of his activities of long decades. With his tutorial work at the university for more than fourty years he launched career of several generations, and along with teachers of geography in secondary schools he was a professor of many of the present-day research workers.

(G. GY.)

Major works:

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GÁBRIS GY.–HEVEI, A. (1997): Megemlékezések DR. SZÉKELY Andrásról (Commemorations about DR. A. SZÉKELY) – Földr. Közl. CXXI/XLV. *3–4.* pp. 243–244.

SZENTES, FERENC
(1907–1982)

F. SZENTES graduated from the University of Economics with a teacher's diploma learning also geology during the time of his studies. He was the first in Hungary who wrote his Ph.D. thesis on economic geology. As early as during his studies a post of unsalaried junior assistant was offered to him in the Economic Geological Institute of that University by L. LÓCZY Jr. After obtaining his Ph. D. degree he became there the assistant of LÓCZY. From 1936 to 1971 he served in the Geological Institute of Hungary as research associate at first, being promoted to senior research associate some years later. In 1958 he was appointed Head of the Map Plotting Department.

F. SZENTES took part in regional geological explorations and evaluating activities attached to them, covering numerous regions of the country. He took part in the geological mapping of the rolling country built up by Tertiary sediments in the North of Hungary prospecting for oils, natural gas and rock salt. Later he devoted himself emphatically to the solution of tectonial problems taking part in research activities of such kind both within the national territory and abroad.

Among the maps plotted under his guidance the 1: 300,000 scale geological map of Hungary, the 1: 500,000 geological map of Budapest, and the 1: 200,000 scale series of geological maps completed in accordance with unificated international directives are to be mentioned as outstanding ones.

Major works see in *References* of this book.

(B. K.)

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TELEGDI ROTH KÁROLY
(1886–1955)

Son of Professor L. TELEGDI ROTH, educator of generations of geologists took his doctorate in 1909 at the Technical University of Budapest. Between 1907 and 1909 he performed geological mapping and coal explorations in Transylvania and in the Transdanubian Range. The excellent palaeontological description of the Upper Oligocene fauna of Eger (1912) and the introduction of the term "infraoligocene denudation" in the Transdanubian Range (1927) are linked to this activity. Being professor of the Debrecen University between 1927 and 1936 he published the first modern geological synthesis on Hungary in 1929. In 1936 he was appointed head of Department for Mining and Exploration of the Ministry of Industry. His activity shown up there should be characterized by the slogan "the best man on the best place". A new period of mineral exploration was started by him. Discovery of the oilfields of Bükkszék, Budafa and Lovászi, description of new bauxite-horizons, and opening of new collieries (Kisgyón, Mór) and bauxite mines (Nyírád, Alsópere) are linked to his name. He was Member of the Hungarian Academy of Sciences since 1934, professor of the Department for Palaeontology in the Budapest University from 1947–1955. Author of the first textbook of Palaeontology, written in Hungarian (1953).

(K. L.)

Major works:

TELEGDI ROTH, K. (1934): Adatok az Északi Bakonyból a magyar középső tömeg fiatal mezozoos fejlődéstörténetéhez (Data from the North Bakony to the Upper Mesozoic evolution of the Median Mass in Hungary). – Matematikai és Természettudományi Értesítő, III. pp. 205–252.

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TIMKÓ, IMRE
(1875–1940)

Having graduated from the Budapest University he started to work for the Hungarian State Geological Institute in 1898 and acted there till the end of his life.

Between 1898 and 1907 he was preoccupied with agrogeological mapping, later (until 1925) he was engaged in the theory and practice of climazonal soil mapping. From 1925 TIMKÓ devoted his energy to the study of salt affected soils. He accompained P. TREITZ on the study trip in Russia (1906) when they got acquainted with the climazonal soil mapping by GLINKA. Another field trip in Russia (1912) covered large distances from Saint-Petersburg to Baku and from Voronezh to the Karakorum desert; a section with participation of GLINKA himself. TIMKÓ presided the session on soil mapping during the First International Conference on Agrogeology (Budapest, 1909) and organised field presentation.

He conducted agrogeological mapping in the surroundings of Budapest, on flatland areas of the country and on the southern slopes of the North Hungarian Mountains. During the World War I. TIMKÓ was involved in the study of soils in Transylvania (Mezőség and the mountain frame). Paleosols intercalated in loess are reddish browns soils in his interpretation. Alkalic soils, their use and improvement were in the focus of his activities in the 1920s and 1930s.

(B. G.)

Major works:

TIMKÓ, I. (1904): Az Ecsedi-láp (Ecsed-marsh). – Földr. Közl. XXXII. pp. 369–581.

TIMKÓ, I. (1908): Adatok síklápjaink agrogeológiájához (Data on the agrogeology of Hungarian moorlands). – Földt. Közl. XXXVIII. pp. 345–360.

TIMKÓ, I. (1914): Erdély központi részének talajviszonyai (Soil conditions in the central part of Transylvania). – Földt. Int. Évi Jel. (Annual Report of the Hungarian Geological Institute). pp. 412–430.

Biographies:

ENDRÉDY, E. (1940): TIMKÓ, I. + 1940. II. 2. – Földt. Int. Évi Jel. 1939/40. (Annual Report of the Hungarian Geological Institute for the years 1939/40). 128 pp.

KENYERES, Á. (ed., 1969): TIMKÓ I. – In: Magyar Életrajzi Lexikon (Hungarian Biographical Encyclopedia). – Akadémiai Kiadó. Budapest. p. 866.

LÓCZY, L.: Igazgatói jelentés 1940 évről (Director's report on 1940). – Hungarian Geological Institute (MÁFI).

TREITZ, PÉTER
(1866–1935)

A graduate of the Academy of Economics, he started to work for the Hungarian State Geological Institute in 1890, at the newly established Department of Agrogeology. He made himself master of geology during mapping activities he had been involved in. In the course of a study trip in Germany he got acquainted with the "Prussian" method of soil mapping based on properties of the uppermost horizon. Later TREITZ studied Swedish and Russian "climazonal" methods of mapping and became a first representative of the concept of climazonal soil formation in Hungary.

During the First International Conference on Agrogeology held at Budapest in 1909 the participants presented contemporary trends of this science. Previously TREITZ participated in a study tour in Russia in 1906 where he investigated soil types in detail and reported on the possibilities to apply his experience in domestic cicrumstances. He remained an adherent of the climazonal soil mapping for all of his life. Another field of research he was preoccupied with was the genesis of alkali soils and methods of their improvement. His foremost achievement was the taxonometric and methodical elaboration of soil mapping subsequently adopted by the International Society of Soil Science and TREITZ was elected honorary member. He was the president of the Section of Cartography of the Hungarian Geological Institute (MÁFI).

(B. G.)

Major works:

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TREITZ, P. (1900): A talajnemek osztályozásáról (On the classification of soils). – Földt. Közl. *30.* pp. 147–162.

TREITZ, P. (1903): Description agrogéologique de la partié de la Grande Alföld, entre le Danube et Tisza. – Földt. Közl. *33.* pp. 3–25.

TREITZ, P. (1903): Talajgeográfia (Geography of soils). – Földr. Közl. *41.* pp. 1–53.

TREITZ, P. (1924): Magyarázó az átnézetes klímazonális talajtérképhez (Explanations to the general climazonal soil map). – Földt. Int. kiadványa. Budapest. pp. 1–67.

TREITZ, P. (1927): Preliminary Report on the alkali-land investigation in the year 1926. – Földt. Int. kiadványa. Budapest. pp. 1–30.

TREITZ, P. (1929): Csonka-Magyarország termőtalaja (Soils of Hungary). – Szerző kiadása. Budapest. pp. 1–35.

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KENYERES, Á. (1969): TREITZ P. – In: Magyar Életrajzi Lexikon (Hungarian Biographical Encyclopedia).. Akadémiai Kiadó, Budapest Vol. II. p. 912.

VADÁSZ, ELEMÉR
(1885–1970)

Master of most geologists in the post-war generation, he published a handbook and university text-book on the geology of Hungary on two occasions (1958 and 1960), where provided an overview and also a detailed presentation of the geological volution and structure of the Hungarian land and of its neighbourhood. During his activities embracing half a century he synthesised the results achieved by the researches of a former era and of his contemporaries and students as well.

After the fall of the Soviet Republic in Hungary in 1919 he had to leave the university and was appointed as full professor of the Pázmány Péter University, Budapest, only in 1946. In addition to teaching and book writing he was also dean (1948–49) and rector (1949–1950). For a decade (1949–1958) he was elected as active, later as honorary president of the Geological Society of Hungary.

For his text-books, organisational and university education activities he was twice rewarded with the first degree of the Kossuth Prize (1948 and 1952). For his text-book "Geology of Hungary" (1960) he received the J. SZABÓ Medal.

He elaborated the geology and coal seam stratigraphy of the Mecsek Mountains in his monograph (1935). As pioneer in Hungary and internationally accepted expert of bauxite geology he studied major bauxite deposits in Europe and considered bauxite as a product of lateritic weathering and its accumulation in paleokarst sink-holes as debris redeposition of surface water courses. His concept was confirmed by recent genetic investigations on bauxite by his followers and students (BARABÁS 1970; BÁRDOSSY 1977; ERDÉLYI 1965). Subsequently to redeposition, the bauxite formation proceeds under tropical savannah climate. In the concept of VADÁSZ and of his followers the bauxite formation in Hungary allows the assumption of the planation model of relief evolution. Like vast ships, the cockpit and tower karst surface of the Transdanubian Mountains buried under bauxite were shifted the former tropical savannah environment to the recent position without considerable tilting (PÉCSI 1996b).

His activities considerably affected a wide circle of Hungarian geoscientists and many geologists rely upon his achievements even today. Maybe his statements need complementation or correction but his work as a whole opened a new era in the history of Hungarian geological sciences. His text-books and education gave new impetus to geologist training at university level in the early fifties. He decisively contributed to the early flourishing of geology in Hungary.

For major works see *References* of this book.

(Á. P.–P. M.)

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VARGA, MÁRTON
(1766–1818)

On graduating from the Royal Academy of Győr, he was a teacher in high school at Komárom and taught several subjects in Hungarian. They are authors of Hungarian text-books of very high level. He is considered KATONA's forerunner in explanational physical geography, including geomorphology.

After Komárom, he moved to Gyor and then was active at the Academy of Nagyvárad (today Oradea belonging to Romania) for more than a decade (1798–1809) and published his physical geography of the Earth (1809). His books – in present interpretation – cover the field of physical geography, where he tried to reconcile the rivalling contemporary concepts of plutonism and neptunism. He was a pioneer in studying exogeneous geomorphic forces and – according to B. BULLA – was 'one of its founders worldwide'. VARGA's concepts also influenced natural sciences other than geography, but, first of all, his contemporaries, including M. KATONA, who developed his ideas further. In the Reform Age M. VARGA was acknowledged for his pioneering achievements in founding natural sciences in Hungary and today his works are appreciated again by science historians.

(P. M.)

Major work:

VARGA, M. (1809): A csillagos égnek és a földgolyóbisának az ő tüneményeivel együtt való természeti előadása és megismertetése (A physical presentation of the starry sky and the globe with their phenomena). – Nagyvárad. 365. pp.

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BULLA, B. (1954): Néhány szó a magyar földrajztudomány haladó hagyományairól (On the progressive traditions in Hungarian geography). – Földr. Közl. *2*. pp. 1–10.
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VENDL, ALADÁR
(1886–1971)

He was a student of J. KRENNER, A. KOCH and J. CHOLNOKY at the Budapest University of Arts and Sciences and parallelly of F. SCHAFARZIK at the Technical University, and in 1908 he worked as an assistant to SCHAFARZIK. In his doctoral dissertation of sedimentology he studied the soil and rock samples collected during the expeditions by A. STEIN, S. HEDIN and R. MILLEKKER.

Between 1912 and 1926 he was employed by the Hungarian State Geological Institute as a mapping geologist. He was a corresponding member (1923), ordinary member (1931), vice-president (1943–1945) of the Hungarian Academy of Sciences. In 1926 SCHAFARZIK retired and VENDL followed him at the Department of Mineralogy and Geology of the Technical University.

VENDL complemented magmatic and sediment petrography with methods necessary for engineering geological planning and construction. He studied the mineralogical, chemical properties and grain size distributions of sand, loess and clay deposits. His classical petrographic investigations are associated with the granites of the Velence Hills and the Southern Carpathians. His hydrogeological activities resulted in the delimitation of a joint protective zone for the spas of Budapest and the composition and origin of sulphatic groundwater in Buda. He proposed a procedure to reduce the concentration of sulphates in water. Another of the methods elaborated by him aims at establishing the strengths of magmatic rocks and employed for various quarries in Hungary.

(B. G.)

Major works:

VENDL, A. (1914): A Velencei-hegység geológiai és petrográfiai viszonyai (Geological and petrological conditions of the Velence Hills). – Annual Report of the Hungarian Geological Institute (MÁFI). *22*. 170 pp.
VENDL, A. (1927): Die Typen der ungarischen Rhyolithe. – Neues Jb. f. Min. etc. *55*. pp. 183–249.

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MAURITZ, B.–VENDL, A. (1942/43): Ásványtan (Mineralogy) I–II. – Egyetemi Nyomda. Budapest. 516 + 503 pp.

VENDL, A. (1951 and 1962): Geológia (Geology) I–II. – Tankönyvkiadó, Budapest. 1st edition: 655 pp.; 4th edition: 559 pp.

VENDL, A. (1958): A százéves Magyarhoni Földtani Társulat története (History of the hundred-year-old Hungarian Geological Society). – Budapest Technical University, Budapest. 276 pp.

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BIDLÓ, G. (1973): A. VENDL. – Periodica Polytechnica. Vol. *17.* pp. 311–320.

BIDLÓ, G. (1997): VENDL A. – Magyar Tudóslexikon (Encyclopedia of Hungarian Scholars). (ed. NAGY, F.). – Better, MTESZ, OMIKK, Budapest. 846 pp.

VITÁLIS, ISTVÁN
(1871–1947)

He graduated from the Budapest University in 1895 as a teacher of biology and geography and in 1904 became assistant to L. LÓCZY, H. BÖCKH, professor of the Academy of Mining and Forestry at Selmecbánya invited him to teach at the Department of Mineralogy and Geology of the Academy. In 1910 he published his first papers in paleontology and remained to be engaged in this discipline all through his life.

In 1912 he was appointed professor of the Academy and in 1914, when BÖCKH left, he was solely responsible for geology teaching. VITÁLIS took part in hydrocarbon exploration in Transylvania, but exploration for coal in Hungary remained to be his main area, where he could also take advantage of his knowledge in paleontology.

After 1920, when Selmecbánya was annexed to Czechoslovakia, through decades of hard work he established a Department of Geology at the new academy and then university in Sopron with its collection and demonstration material. His activities of practical significance were coal exploration in the area of Bicske, Zirc and Esztergom and launching of lignite mining in the Mátraalja (at Visonta). He pointed out that young coal seams of poor thermal value were affected by volcanic activity and coking resulted in their higher thermal value. In his book 'Coal occurrences in Hungary' he summarised his experience and the volume written in easy style was also of interest to foremen in mines.

He was also involved in bauxite and manganese explorations and Pannonian stratigraphy and sounded his opinion in terminological debates. He preferred the term Pontian stage. Rewarding his achievements in exploring the mineral wealth of Hungary (coal, bauxite, gold, silver and copper), he was elected an ordinary member of the Hungarian Academy of Sciences in 1945. He was president and then honorary member of the Hungarian Geological Society.

(B. K.)

Major works:

VITÁLIS, I. (1904): Adatok a Balaton-Fölvidék bazaltos kőzeteinek ismeretéhez (Contributions to research on the basaltic rocks in Balaton Uplands). – Földt. Közl. *34.* pp. 377–399.

VITÁLIS, I. (1911): Die Basalte der Balatongegend. Resultate der wissenschaftlichen Erforschung des Balatonsees. Bd. I. 190 pp.

VITÁLIS, I. (1932): A Halimba vidéki bauxitok és hasznosításuk (Bauxites at Halimba and their use). – Bány. Koh. Lapok. *65.* pp. 362–392.

VITÁLIS, I. (1933): A recski arany-, ezüst- és rézércbányászat (Gold, silver and copper mining at Recsk). – Bány. Koh. Lapok, *66.* pp. 145–155; pp. 169–180; pp. 193–201.

VITÁLIS, I. (1939: Magyarország szénelőfordulásai (Coal occurrences in Hungary). – Faculty of Mining, Metallurgy and Forestry of Palatine Joseph Technical and Economic University, Sopron. 407 pp.

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VENDEL, M. (1948): VITÁLIS I. emlékezete (Memory of I. VITÁLIS). – Földt. Közl. *78.* pp. 3–16.

VITÁLIS, GY. (1971): Megemlékezés VITÁLIS Istvánról (1871–1947) születésének 100. évfordulóján (Commemoration of I. VITÁLIS on the 100th anniversary of his birth). – Bány. Koh. Lapok, *104.* pp. 190–191

VITÁLIS, SÁNDOR
(1900–1976)

Kossuth prize winner geologist, university professor, D. Sc. in Geology and Mineralogy. He graduated from the Faculty of Natural History and Geography of the University of Sciences in Budapest in 1922. In the same year he took his doctorate in mining geology. In 1942 he was entitled Reader of the University of Sciences in Szeged.

S. VITÁLIS conducted coal explorations in the Pécs, Komló, Kárász and Szászvár areas of the Mecsek Mts., moreover in Austria. Entrusted with the direction of the country-wide coal exploration in 1946 he was organising and managing the domestic exploration for coal and other mineral raw-materials and he initialized the reambulation of the geological mapping in the Great Hungarian plains until 1952 when arrested and convicted on tramped-up charges he was imprisoned. Subsequently to his release he was appointed Professor of the Chair of Applied Geology in the University of Sciences in Budapest.

He devoted himself also to the hydrogeology of Hungary solving the geological problems of water supply for mining sites, towns and industrial projects. The thermal waters of Sikonda and Püspökfürdő were explored by him.

The number of his publications runs over 100. He was member or president of more than 20 professional committees and owner of the Commemorative Medal of the OMBKE – Hungarian Mining and Metallurgical Society.

(K. L.)

Biography:

FEJÉR, L. (1997): VITÁLIS S. Magyar Tudóslexikon A–Zs. (Encyclopedia of Hungarian Scholars). (ed. NAGY, F.). – Better, MTESZ, OMMIK. Budapest. 855 pp.

WEIN, GYÖRGY
(1912–1976)

He is one of the first initiators in setting up a plate tectonic and kinematic model for Hungary. He graduated in 1933 from the Budapest University of Sciences. At the beginnings as assistant of K. TELEGDY ROTH in the Debrecen University, he mapped the Neogene volcanics of the Northeastern Range. He took his Ph.D. in 1934 on the Tithonian formations around Zirc in the Transdanubian Central Range.

Between 1939 and 1945, as consultant of the Hungarian Geological Institute and private firms as well he performed geological mapping and mineral prospections in Transylvania and in Kárpátalja (today Ukranian Carpathia).

After a short break in his professional activity at the end of the war, in 1946 he set out to geological explorations anew. Then he was assistant professor of the University of Sciences in Budapest. As leader of the coal-exploration in the Mecsek Mountains, between 1949 and 1957 he had an important role in the increase of known coal reserves, moreover the finding of new coal deposits in the Komló and Máza regions are linked to his name. The first uranium prospections in the Mecsek Mountains were directed by him, too.

After joining the Hungarian Geological Institute in 1958 definitively, he published excellent regional syntheses on the geology and structure of the Southeastern Transdanubia. Major changes in his activity are represented by his basement-studies done together with A. RÓNAI and K. SZEPESHÁZY in the course of the complex survey of the Great Plain of Hungary.

The results of these studies led him to the formulation of the first plate tectonic and kinematic model of the Pre-Neogene basement of Hungary and to the definition of the Mid-Hungarian line. His fundamental study on the structure of the Buda Hills serves as guideline for later generations geologists.

(B. K.–K. L.)

Major works:

WEIN, GY. (1968): Die Tektonic von Südosttransdanubien. – Jahrbuch der Geologischen Bundesenstalt, Wien. *111.* pp. 91–113.

WEIN, GY. (1969): Tectonic Review of the Neogene Covered Areas of Hungary. – Acta Geol. Hung. *13.* pp. 399–436.

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KENYERES, Á. (ed.) (1985). WEIN, GY. Magyar Életrajzi Lexikon. Akadémiai Kiadó, Budapest. 850 pp.

ZSIGMONDY, VILMOS
(1821–1888)

The path of life of the eminent mining engineer and geologist who was born in Pozsony (today Bratislava) was really a very adventurous one. He studied in Selmecbánya where he took his mining engineer's diploma at the Mining Academy. During the Hungarian War of Independence in 1848/1849 being then mine supervisor in Resicabánya he had guns and ammunition manufactured for the Hungarian army, for which later be was sentenced to six years of imprisonment in fortress. After his release he spent 10 years at the private colliery of Annabánya where he had grown up to a country-wide known expert on mining engineering.

His book dealing with the theory and practice of mining is the first textbook on the topic written in Hungarian. Besides his studies on the coal exploration based on geology and on mining methods, he devoted himself mostly to the development of drilling techniques.

After the time when several boreholes of experimental character and of shallow or moderate depth (ranging 10–150 m) had been drilled, by using up-to-date methods he became the pioneer of the artesian drilling in Hungary. Many well-known drillings, a lot of thermal wells and exploratory boreholes, those e.g. in Harkány, Margitsziget, Zsilvölgy, Ránk–Hermány, Fiume, Buziásfürdő, Hódmezővásárhely, are linked to his name. The drilling of the artesian well of the Városliget (1872) in Budapest was an outstanding undertaking. He was uncle of engineer B. ZSIGMONDY and they together had drilled a lot of artesian wells in many regions of the Austro-Hungarian Empire.

By his activity he became a well-known expert of the planning and drilling of artesian wells not only within the country but also throughout Europe. He formulated pioneer theories about the formation of the thermal waters and concerning the complex and interrelated problems of the ascending and descending karstic waters.

(B. K.)

Major works:

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ZSIGMONDY, V. (1871): Tapasztalataim az artézi szökőkutak fúrása körül (My experiences in drilling of artesian wells). – MTA székfoglaló előadás (HAS inaugural lecture). Pest.

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[illegible] Zsigmondy, Vilmos, Zsigmondy, Lajos, Budapest, [illegible] The drilling of the artesian well of the Városliget [illegible] [illegible] The well reached [illegible] depth [illegible] [illegible] deepest [illegible] of [illegible] Europe.

[illegible] the planning and drilling of [illegible] wells [illegible] [illegible] the thermal well of [illegible] the [illegible] of the [illegible] and [illegible] of [illegible] [illegible].

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ZSIGMONDY, VILMOS (1821–1888)

The path of life of the eminent mining engineer and geologist who was born in Pozsony (today Bratislava) was really a very adventurous one. He studied in [illegible] where he graduated [illegible] mining engineer's diploma at the Mining Academy. During the Hungarian War of Independence in 1848/1849, being then mine inspector, in Besztercebánya he had guns and ammunition manufactured for the Hungarian army (for which later he was sentenced to six years of imprisonment in fortress). After his release he went to work at the private colliery of Ajnácskő where he had [illegible] of a [illegible] mining engineering.

His book dealing with the driving and [illegible] drilling as the first textbook on the subject in Hungarian. Besides his studies on the coal exploration based on geology and on mining methods, he devoted himself mostly to the development of drilling techniques.

After the time when several boreholes of experimental character [illegible] of moderate depth (ranging 10–150 m) had been drilled, by using up-to-date methods he became the pioneer of the modern drilling in Hungary. Much well known drillings were of thermal water and exploratory boreholes drilled [illegible] in Harkány, [illegible]

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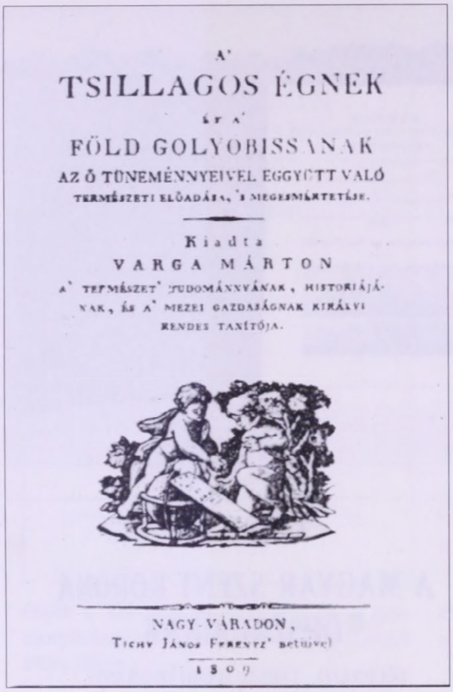
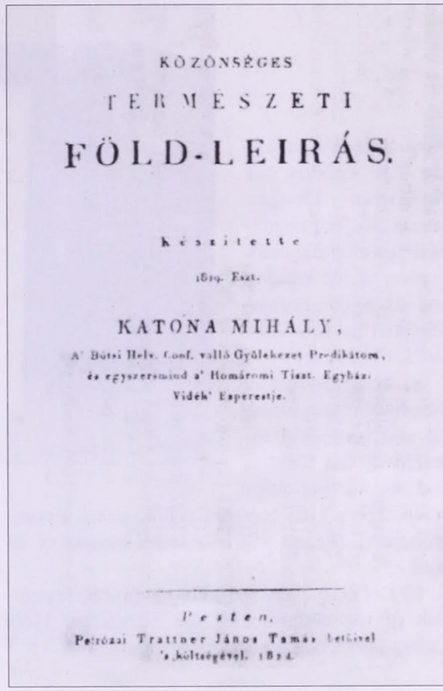


A'
TSILLAGOS ÉGNEK
ÉS A'
FÖLD GOLYOBISSÁNAK
AZ Ő TÜNEMÉNNYEIVEL EGGYÜTT VALÓ
TERMÉSZETI ELŐADÁSA, 'S MEGESMÉRTETÉSE.

Kiadta
VARGA MÁRTON
A' TERMÉSZET' TUDOMÁNNYÁNAK, HISTORIÁJÁNAK, ÉS A' MEZEI GAZDASÁGNAK KIRÁLYI RENDES TANÍTÓJA.

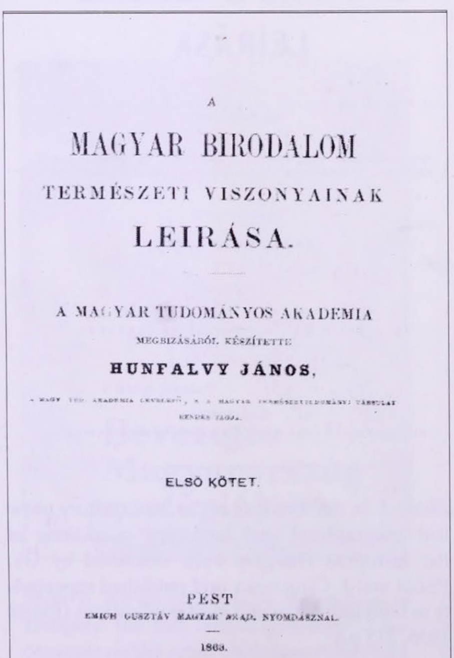
NAGY-VÁRADON,
Tichy János Ferentz' betüivel
1809



KÖZÖNSÉGES
TERMÉSZETI
FÖLD-LEIRÁS.

Készítette
1819. Észt.
KATONA MIHÁLY,
A' Bótsi Helv. Conf. valló Gyülekezet Prédikátora, és egyszersmind a' Komáromi Tiszt. Egyház-Vidék' Esperestje.

Pesten,
Petróczi Trattner János Tamás betűivel 's költségével. 1824.



A
MAGYAR BIRODALOM
TERMÉSZETI VISZONYAINAK
LEIRÁSA.

A MAGYAR TUDOMÁNYOS AKADEMIA
MEGBIZÁSÁBÓL KÉSZÍTETTE
HUNFALVY JÁNOS,

ELSŐ KÖTET.

PEST
EMICH GUSZTÁV MAGYAR AKAD. NYOMDÁSZNÁL.
1863.

Photo 1. Pioneering textbooks on physical geography in Hungarian
a) A manual by M. VARGA published in Nagy-Várad (1809, 305 p.)
b) A textbook completed by M. KATONA (1819) and published in Pest (1824). c) On behalf of the Pest University and the Hungarian Academy of Sciences J. HUNFALVY published physical geography of the Hungarian Empire in three extensive volumes (1863–1865)

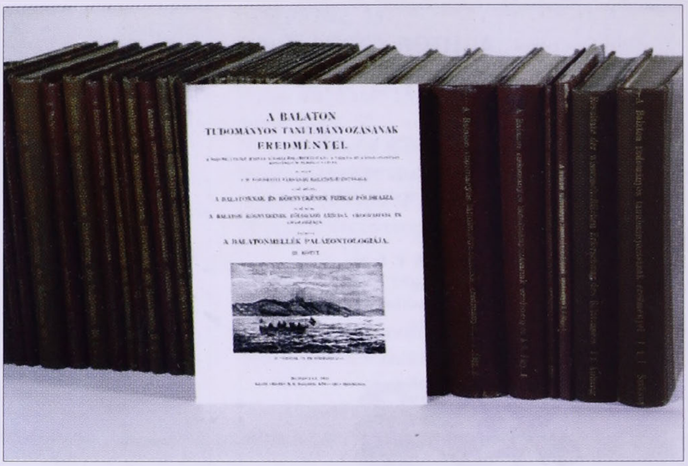
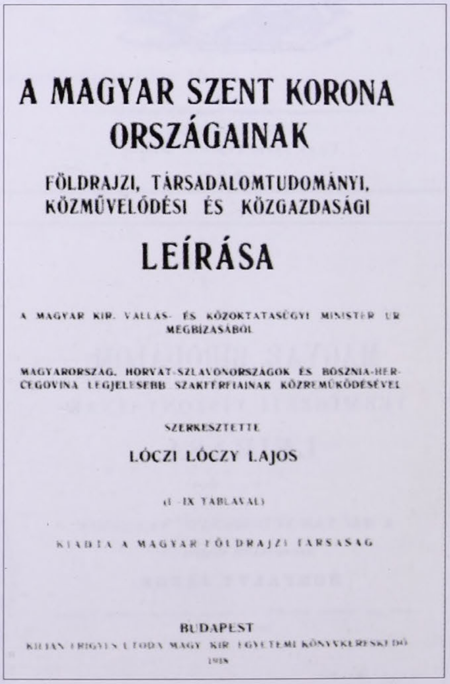


Photo 2. On the turn of the 20th century the Hungarian Geographical Society organised geoscientific elaboration of the country and its major regions (directed by L. LÓCZY and J. CHOLNOKY)

a) Achievements of the physical geographical and geological research of the Balaton and its surroundings (1916, 716 p.). 25 volumes representing a comprehensive studies still is a series unique of its kind

b) L. LÓCZY, sen. (ed.) Geographical description of the countries of the Hungarian Holy Crown (1918, 528 p.)



A MAGYAR SZENT KORONA ORSZÁGAINAK

FÖLDRAJZI, TÁRSADALOMTUDOMÁNYI, KÖZMŰVELŐDÉSI ÉS KÖZGAZDASÁGI

LEÍRÁSA

A MAGYAR KIR. VALLÁS- ÉS KÖZOKTATÁSÜGYI MINISTER ÚR MEGBÍZÁSÁBÓL

MAGYARORSZÁG, HORVÁT-SZLAVONORSZÁGOK ÉS BOSZNIA-HERCEGOVINA LEGJELESEBB SZAKFÉRFIAINAK KÖZREMŰKÖDÉSÉVEL

SZERKESZTETTE

LÓCZI LÓCZY LAJOS

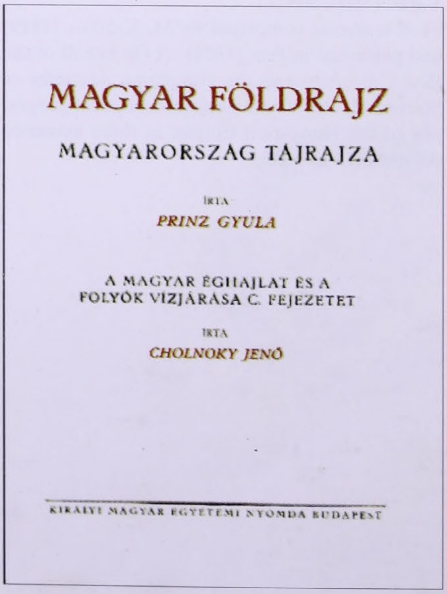
(I–IX TÁBLÁVAL)

KIADTA A MAGYAR FÖLDRAJZI TÁRSASÁG

BUDAPEST

KILIÁN FRIGYES UTÓDA MAGY. KIR. EGYETEMI KÖNYVKERESKEDŐ

1918



MAGYAR FÖLDRAJZ

MAGYARORSZÁG TÁJRAJZA

ÍRTA

PRINZ GYULA

A MAGYAR ÉGHAJLAT ÉS A FOLYÓK VÍZJÁRÁSA C. FEJEZETET

ÍRTA

CHOLNOKY JENŐ

KIRÁLYI MAGYAR EGYETEMI NYOMDA BUDAPEST

Photo 3. In the first half of the 20th century physical geographical and landscape conditions of the historical Hungary were described by GY. PRINZ and J. CHOLNOKY and published repeatedly as both individual and joint publications (PRINZ 1936, 315 p.)

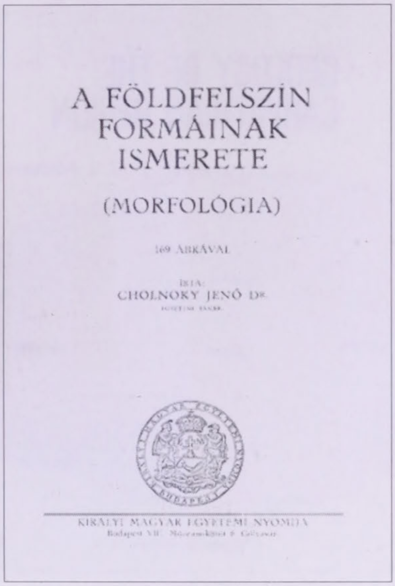


Photo 4. The first manual on general geomorphology in Hungarian (J. CHOLNOKY 1926, 296 p.)

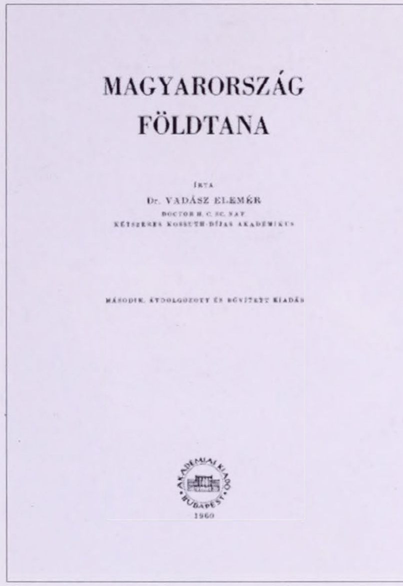


Photo 5. The first detailed synthesis on the geology of Hungary (by E. VADÁSZ 1960, 646 p.)

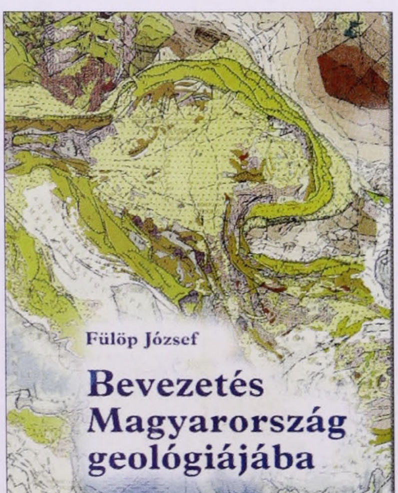


Photo 6. An introduction to the geology of Hungary: the first critical summary of the concepts on the relief evolution of Hungary (by J. FÜLÖP 1989, 286 p.)

Photo 7. Explanatory notes to the maps entitled: The geology of Hungary without the Cenozoic; Tectonic geological structure of Hungary (ed. by J. HAAS 1996, 186 p.)

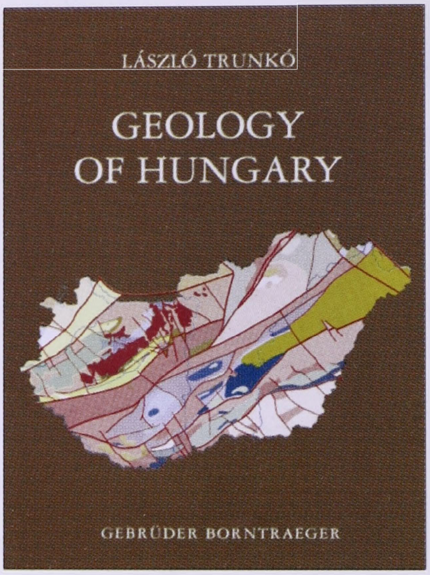


Photo 8. The first book on the geology of Hungary issued in foreign language written by L. TRUNKÓ (in German: 1969, 269 p., in English: 1996, 464 p.)

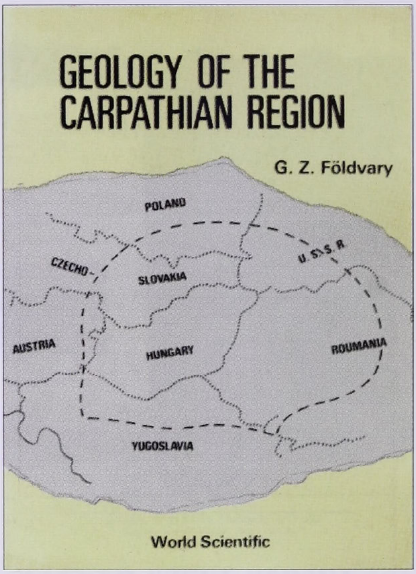


Photo 9. Monograph and history of the research in geology of the Carpathian region presented by G. Z. FÖLDVÁRY(1988, 569 p.)

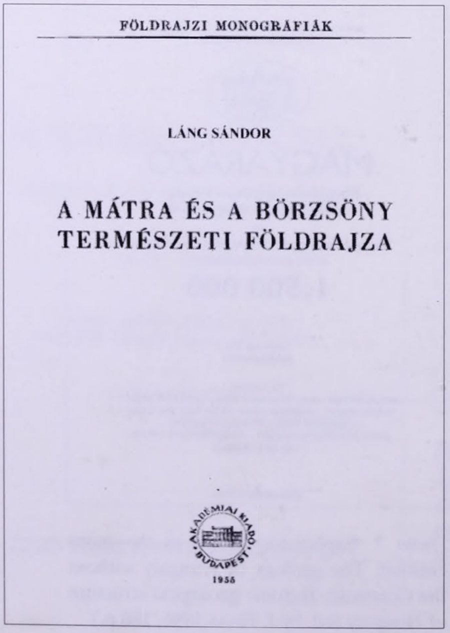
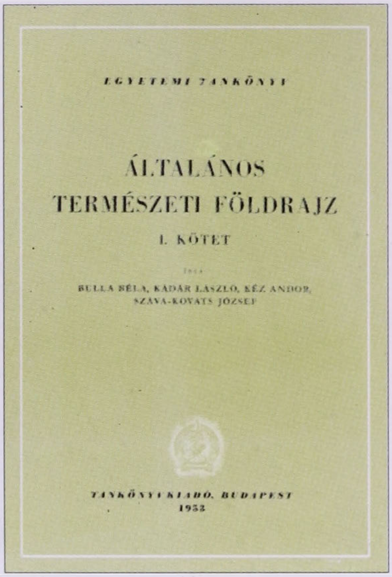


Photo 10. Physical geography of the volcanic mountains Mátra and Börzsöny with a section on geomorphic evolution written by S. LÁNG (1955a, 512 p.)



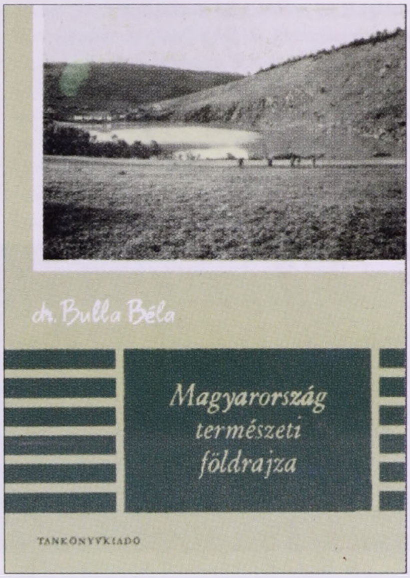


Photo 11. Textbooks by B. BULLA a) on geomorphology (1954, 519 p.) and b) on physical geography of Hungary (1962, 423 p.) served basic manuals both in university teaching and research for several decades

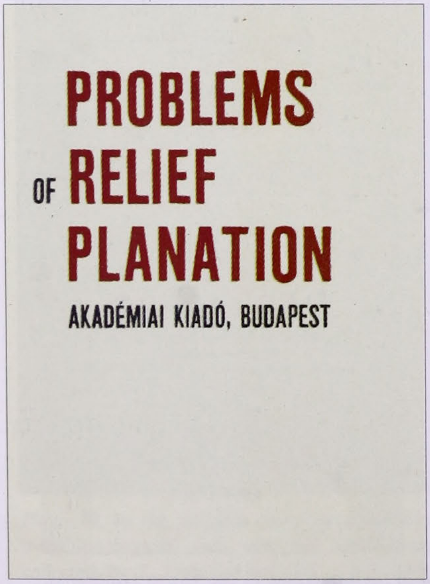


Photo 12. Proceedings of the International Pediment Symposium held in Budapest, Hungary (ed. by M. PÉCSI 1970c, 151 p.)

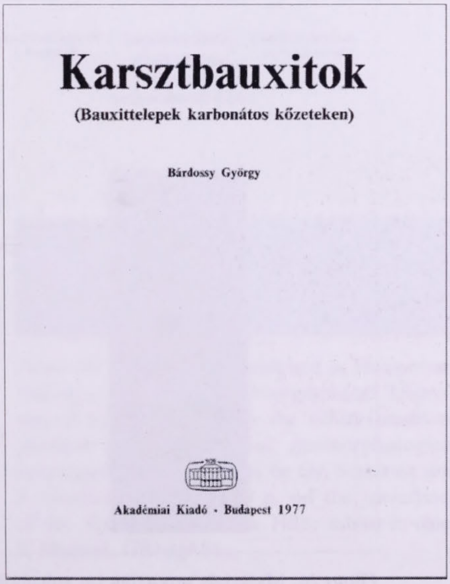


Photo 13. A book on bauxites developed upon karstic surfaces written by Gy. BÁRDOSSY (1977, 413 p.) (In English 1982)

Photo 14. Tropical tower karst (1) buried by Lower Oligocene Sandstone (2) in summit level position. Buda Hills, Hungary (PÉCSI 1970c)

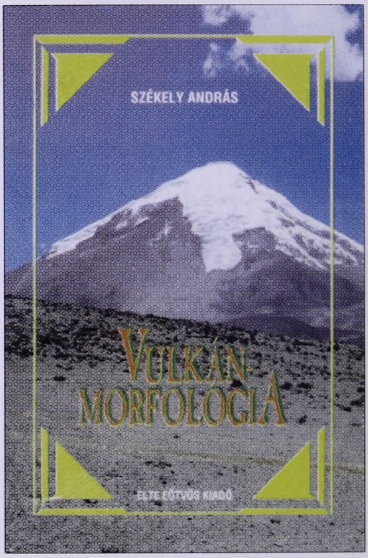


Photo 15. A contribution to volcanology is a synthesis of A. SZÉKELY's lifetime activities (1997, 234 p.)

Photo 16. Materials reporting on volcanological investigations in the North Hungarian Mountains a) A book on the volcanology of Mátra and Börzsöny mountains by I. KUBOVICS and GY. PANTÓ (1970, 302 p.) b) Explanatory notes to the detailed geological map of the Börzsöny and Visegrád mountains, ed. by L. KORPÁS (1998, 216 p.)

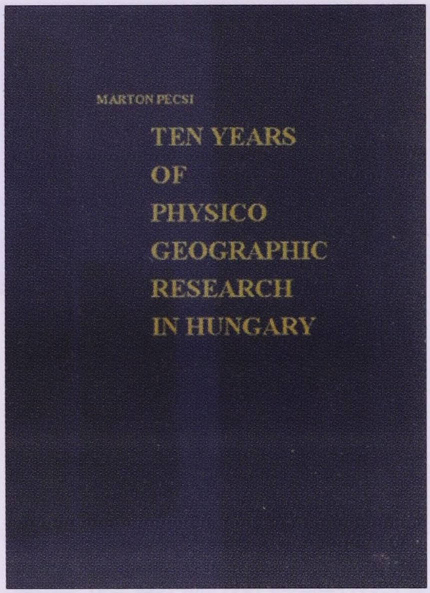


Photo 17. Publication of a series in English entitled *Studies in Geography in Hungary* was launched by the Geographical Research Institute (GRI) HAS in the mid-1960s. The first volume reported on the achievements in the field of geomorphology during the first decade of the institute's activities (ed. by M. PÉCSI 1964c, 132 p.). An overwhelming part of the 29 volumes published so far have dealt with research on relief evolution

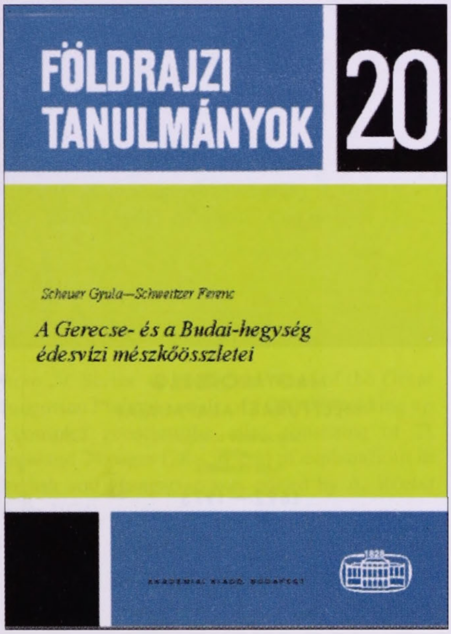


Photo 18. In the series (published in Hungarian) *Földrajzi Tanulmányok* (Geographical Essays) several items reported on the achievements of physical geographical and geomorphological investigations (e.g. an essay by Gy. SCHEUER and F. SCHWEITZER 1988, 129 p. on the travertines of the Gerecse and Buda Hills; editor-in-chief S. MAROSI, GRI HAS)

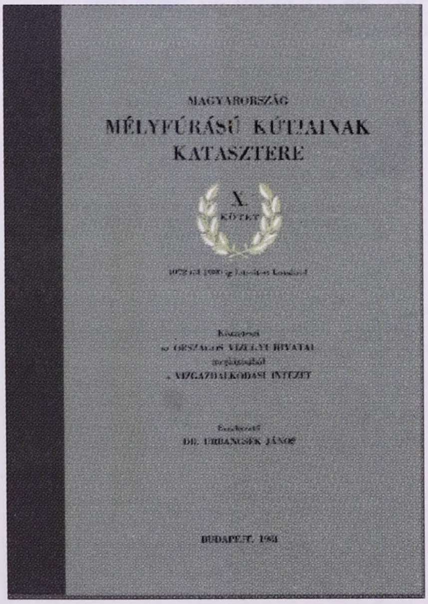


Photo 19. In the national inventory of artesian wells geological and technical data were collected by J. UURBANCSEK (ed., 1963–1980). After the publication of 11 volumes by VITUKI the rest of the series (vols XII–XXII) survived in manuscripts and contain invaluable information

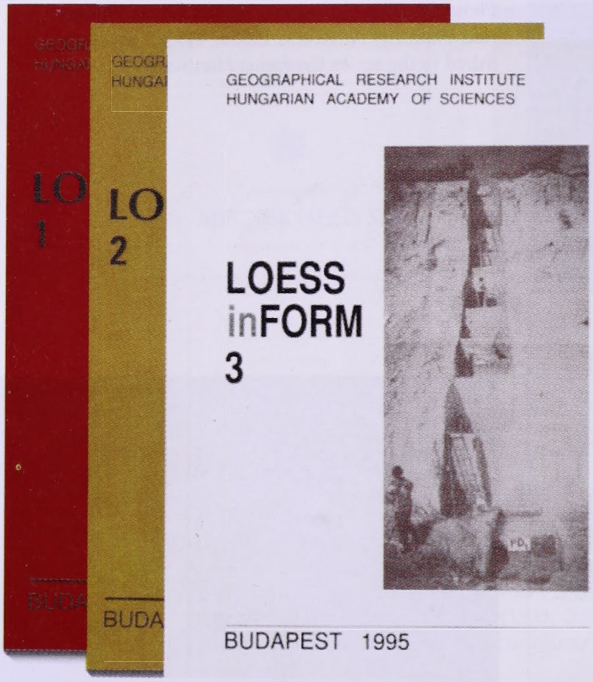


Photo 26. Loess inForm N1 (ed. by N.I. KRIGER and M. PÉCSI 1987) contains Russian approaches, concepts, methods and criteria of loess research and a chronological subdivision of loesses; N2 and N3 within the same series (ed. by M. PÉCSI and F. SCHWEITZER 1991, 1995) summarises research activities by American and Hungarian experts (published by GRI HAS)

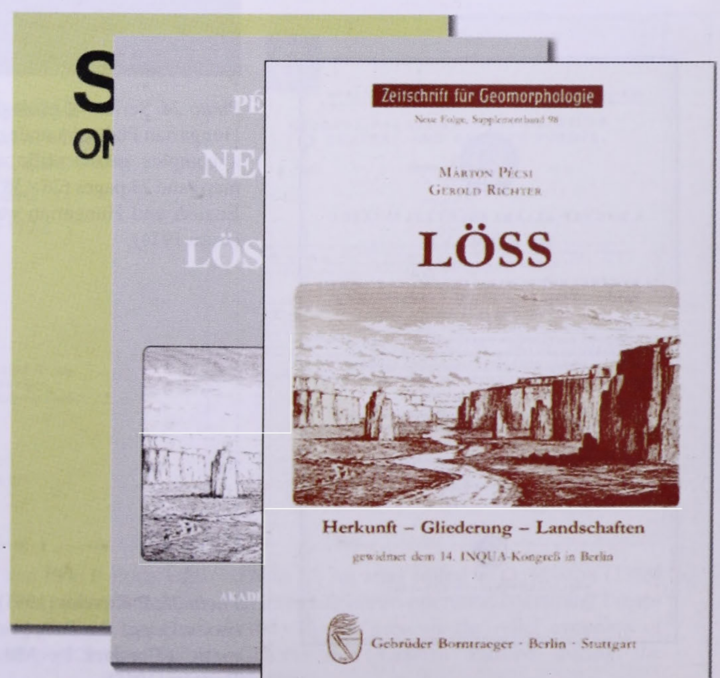


Photo 27. Studies on Loess (1979) reported on the IGCP Symposium on loess held in Hungary as *Acta Geologica Hungaricae* 22; *Negyedkor és Löszkutatás* (with an extensive summary in English entitled Loess and Quaternary) was written by M. PÉCSI (1993); *Löss* (by M. PÉCSI and G. RICHTER) is a recent manual on loess research (1996)

Photo 28. Subdivision of the Pleistocene in Hungary based on vertebrate fauna was performed by D. JÁNOSSY (1979). Published in English by Akadémiai Kiadó, Budapest and Elsevier Science, Amsterdam, 1986

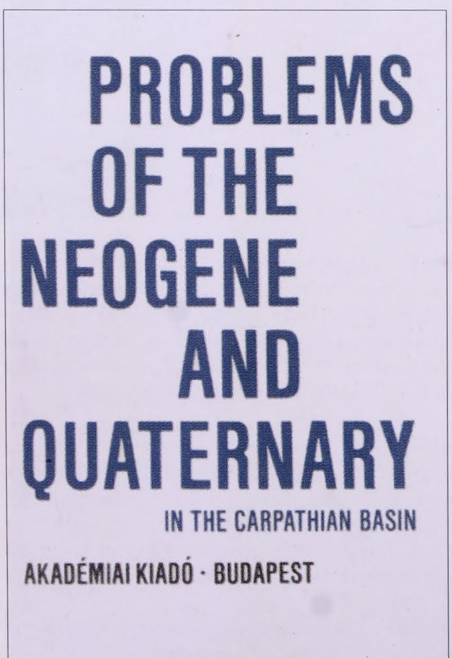


Photo 29. Volumes as part of the *Studies in Geography in Hungary* dealing with Neogene and Quaternary geomorphological and geological formations were published by Akadémiai Kiadó (editor-in-chief: M. PÉCSI)

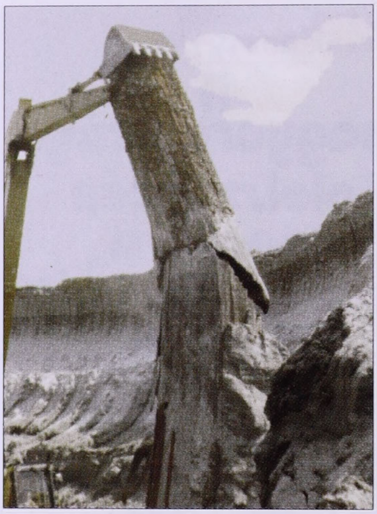
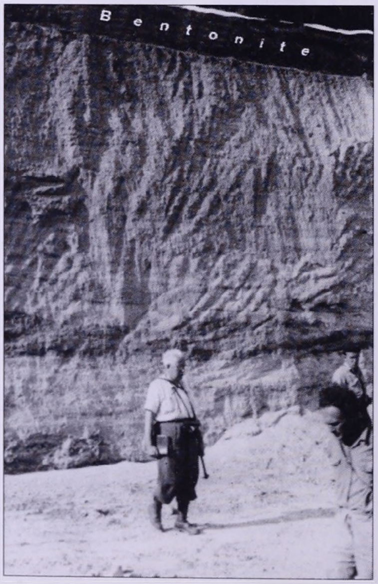


Photo 30. Lithostratigraphic position of bentonites in the foreland of the North Hungarian Mountains and formed during the Late Neogene

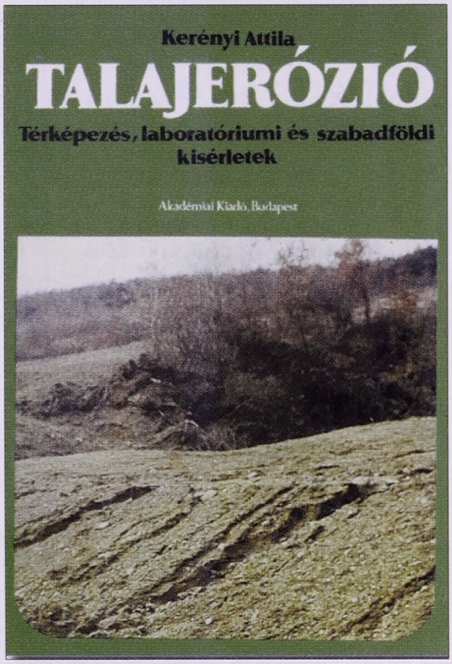
a) In the Mátra foreland, in the opencast lignite mine sequoias formerly with 2,5–3 m diametre and 10–15 m height buried during a natural disaster are frequently encountered. They are to be found in the so-called lignite seam 0 covered by highly micaceous sand. This (fluviatile and eolian) sand is probably of Upper Miocene origin, having formed presumably during the Bérbaltavárium stage (KRETZOI et al. 1982) under semi-arid and warm climatic conditions. This sand horizon is superimposed by lignite seam 1 and bentonite. In certain profiles (mine K_2) lignite seams 1, 2 and (partially) 3 survived as well and these lignites are overlain by bentonite and bentonite clay. Also bentonite clays are underlying red clays repeatedly occurring in two or three horizons. These red clays are of terrestrial origin and probably formed during the Pliocene (photo by M. PÉCSI)

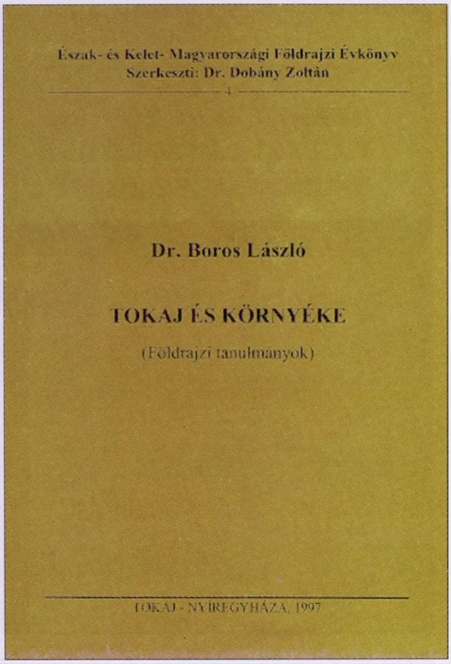


b) North of Budapest, in the gravel pit at Kerepestarcsa, the uppermost gravel horizon is superimposed by a tripartite bentonite layer. In some places this is delta-like Danube gravel of oblique bedding, in other spots within the same quarry it is fan-like gravel of horizontal stratification (photo by M. PÉCSI)

c) In the cover of the above described series of gravel heavily cryoturbated bentonite and bentonite clay occur. The predominantly horizontally bedded gravel and sand of alluvial fan is 15 to 20 m thick resembling mastodon-bearing gravel. Experts seen on the photo are L. KÁDÁR (left), A. SZÉKELY (right, in the fore), Z. BORSI (behind the latter). Photo by M. PÉCSI, 1963. A couple of years earlier similar gravel was investigated in the same place by B. MAURITZ, F. HORUSITZKY, F. SZENTES and M. PÉCSI and considered it mastodon-bearing formation of gravel of Danubian roundness. Today these gravels are claimed Upper Pannonian ones.

Regarding the origin and age of gravels depicted on 30 b) and c), studies go back to more than one hundred years and opinions are highly diverting (see chapter B1 of the present volume)





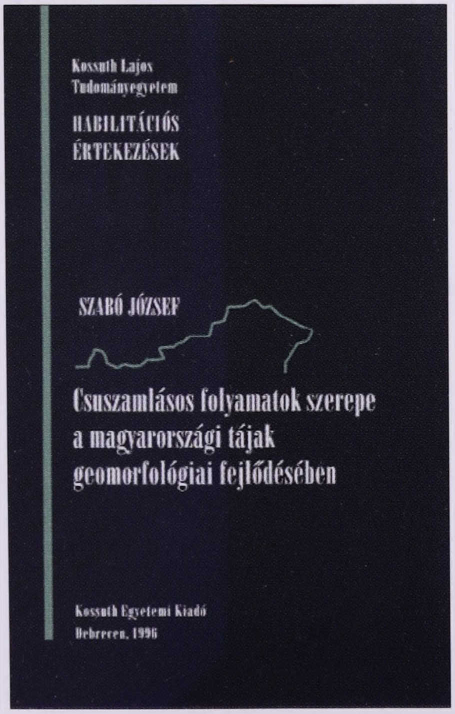
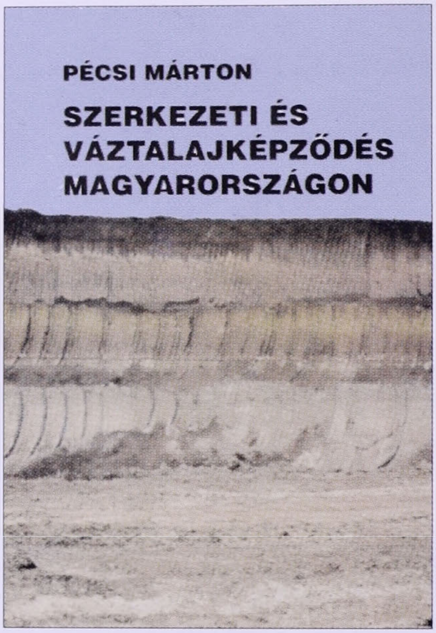


Photo 31. The analyses of soil erosion processes a) A. KERÉNYI 1991b; b) L. BOROS 1997 and studies of surface mass movements, and c) J. SZABÓ 1996 have been completed with field experiments and measurements

Photo 32. Rainfall simulation experiments to calculate the average K-values (Á. KERTÉSZ, G. RICHTER, R. G. SCHMIDT et al. 1997)



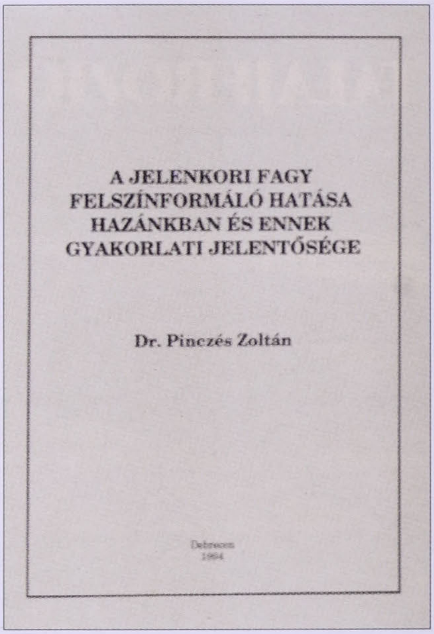


Photo 33. Effect of permafrost on soil formation and surface evolution a) during the Pleistocene (M. Pécsi 1997b) and b) in the Holocene (Z. Pinzsés 1994)

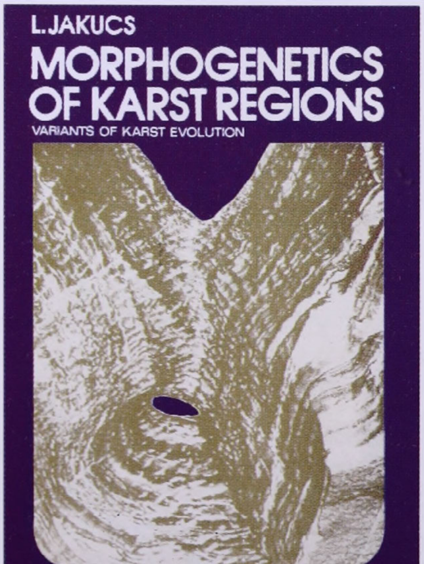


Photo 34. A handbook on karst regions written by L. Jakucs (1977a, 284 p.)

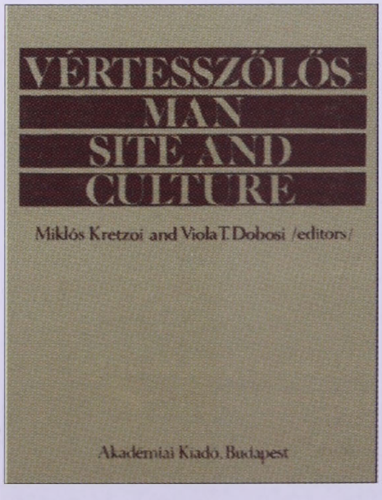
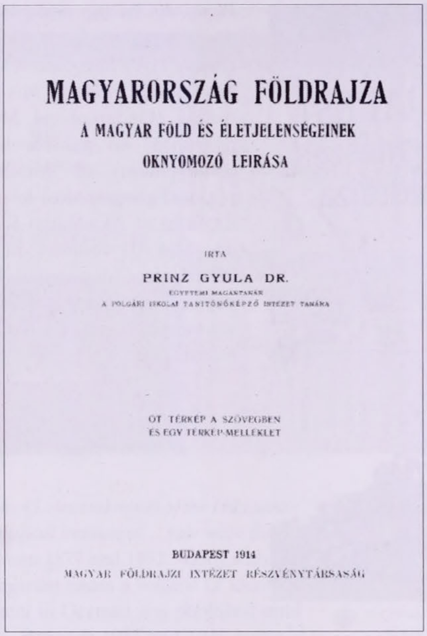


Photo 35. The celebrated remnants of the Vértesszőlős paleolithic culture are enclosed in travertines lying on the V terrace of the Tata river (Által-ér), a tributary of the Danube. A comprehensive monograph was edited by M. Kretzoi and V. T. Dobosi (1990, 655 p.)


MAGYARORSZÁG FÖLDRAJZA

A MAGYAR FÖLD ÉS ÉLETJELENSÉGEINEK

OKNYOMOZÓ LEIRÁSA

IRTA

PRINZ GYULA DR.

EGYETEMI MAGÁNTANÁR

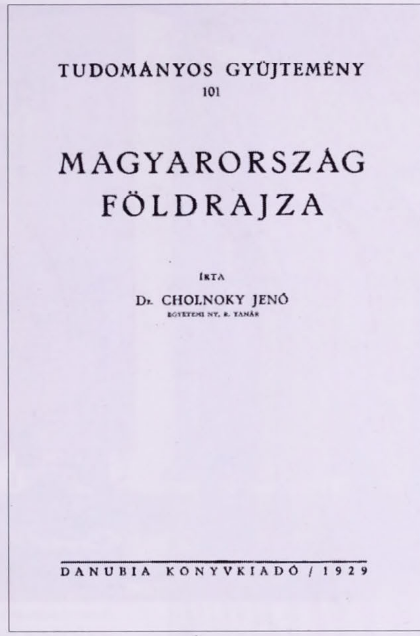
A POLGÁRI ISKOLAI TANITÓNŐKÉPZŐ INTÉZET TANÁRA

ÖT TÉRKÉP A SZÖVEGBEN

ÉS EGY TÉRKÉP-MELLÉKLET

BUDAPEST 1914

MAGYAR FÖLDRAJZI INTÉZET RÉSZVÉNYTÁRSASÁG


TUDOMÁNYOS GYŰJTEMÉNY

101

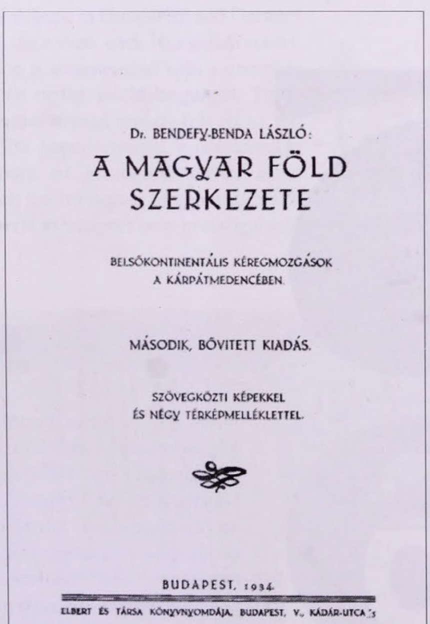
MAGYARORSZÁG FÖLDRAJZA

ÍRTA

Dr. CHOLNOKY JENŐ

EGYETEMI NY. R. TANÁR

DANUBIA KÖNYVKIADÓ / 1929


Dr. BENDEFY-BENDA LÁSZLÓ:

A MAGYAR FÖLD SZERKEZETE

BELSŐKONTINENTÁLIS KÉREGMOZGÁSOK

A KÁRPÁTMEDENCÉBEN.

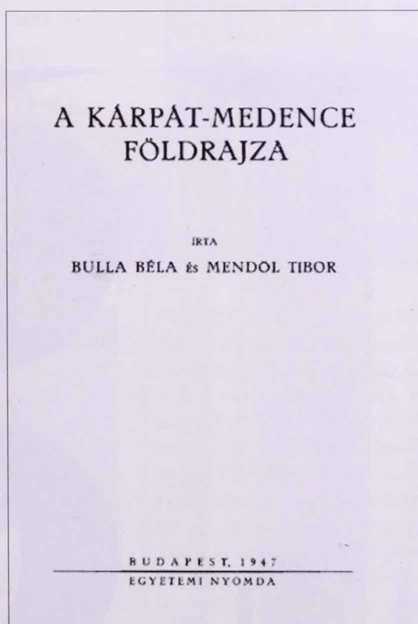
MÁSODIK, BŐVITETT KIADÁS.

SZÖVEGKÖZTI KÉPEKKEL

ÉS NÉGY TÉRKÉPMELLÉKLETTEL.

BUDAPEST, 1934.

ELBERT ÉS TÁRSA KÖNYVNYOMDÁJA, BUDAPEST, V., KÁDÁR-UTCA 5


A KÁRPÁT-MEDENCE FÖLDRAJZA

ÍRTA

BULLA BÉLA és MENDÖL TIBOR

BUDAPEST, 1947

EGYETEMI NYOMDA

Photos 36–39. Summaries on the geography of the historical Hungary was given by GY. PRINZ (1914, *Photo 36*) on geography, relief and geology were provided by J. CHOLNOKY, (1929, *Photo 37*), L. BENDEFI-BENDA (1934, *Photo 38*) and B. BULLA and T. MENDÖL (1947, *Photo 39*)

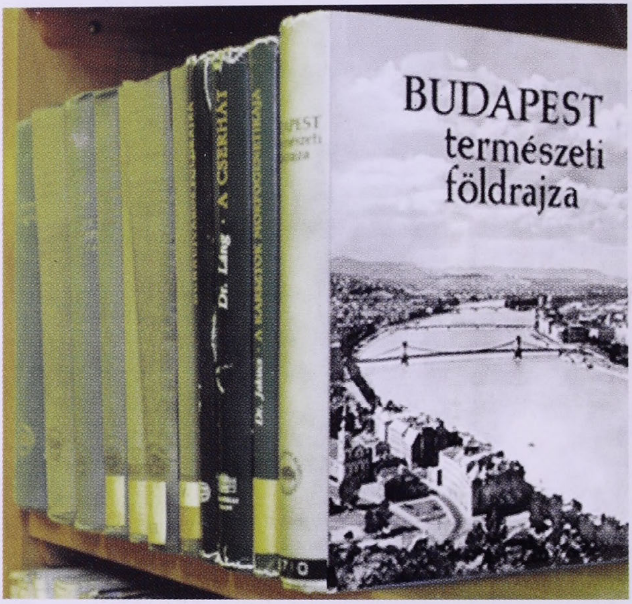


Photo 40. In the mid-1950s the Commission on Geography HAS launched a series entitled *Földrajzi Monográfiák* (Geographical Monographs) to publish the achievements of detailed regional geographical investigations at Akadémiai Kiadó. The 10 volumes published were dominated by physical geographical and geomorphological studies of mesoregions

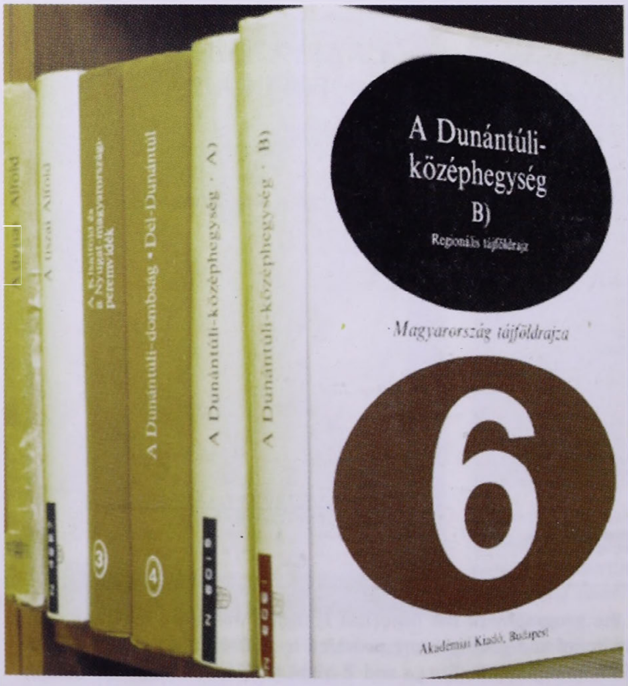


Photo 41. A series entitled *Magyarország tájföldrajza* (Landscapes of Hungary) launched in 1967 contained an overview of physico-geographical endowments, resources and landscape geographical evaluation from the aspect of changes in relief, natural environment and land use. Edition of the seventh volume is under way (series editor: M. PÉCSI)

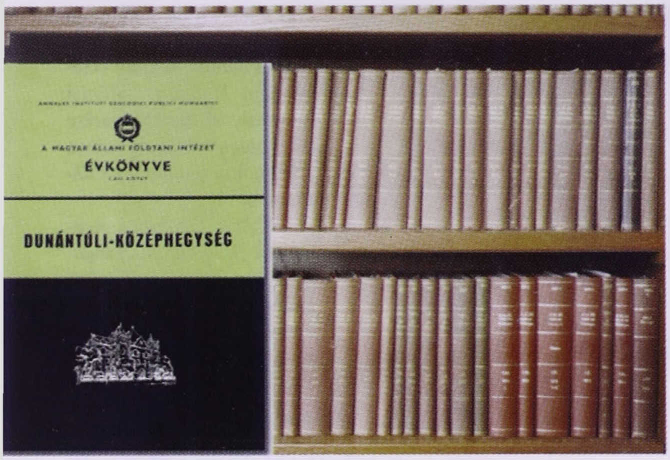


Photo 42. Annals of the Hungarian Geological Institute are a series of yearbooks comprising 72 volumes published between 1871 and 1991. Parallel with the Hungarian text there are explanations in English, French and German, occasionally in Latin and Russian. These yearbooks present field surveys in an objective manner at a high scientific level

Photo 43. Annual report of the Hungarian Geological Institute of... year were issued between 1877 and 1992. Along with the Hungarian issues a volume of identical content in German was published until 1935. Between 1935 and 1945 it was a joint volume in Hungarian and German and, since then, each Hungarian contribution is accompanied with a summary in one of the world languages. These extensive annual reports (on about 300 to 500 pages) contain a considerable amount of geological survey maps which has been used by generations of experts to support new investigations

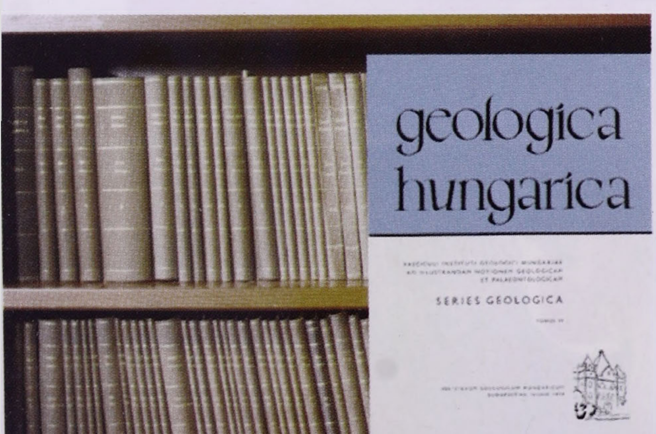
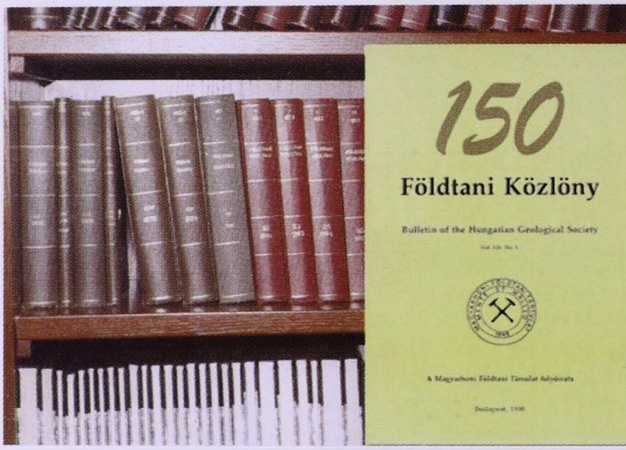


Photo 44. A two-partite series by MÁFI is *Geologica Hungarica*. 23 volumes of *Series Geologica* was issued between 1914 and 1986; and 53 volumes of *Series Paleontologica* were published between 1928 and 1992, both in Hungarian with a complete translation into foreign languages. These volumes of studies presented comprehensive achievements by well-known experts in geosciences and often served as a basis for international collaboration



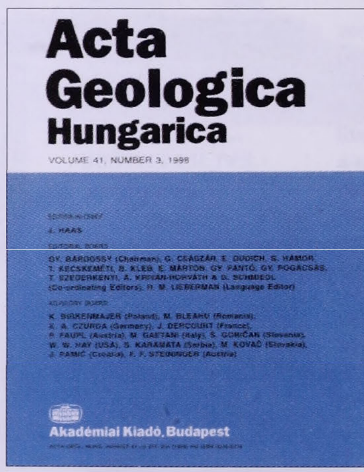


Photo 45. Other geological scientific publications:

a) *Földtani Közlöny* (Geological Bulletin), official quarterly of the Hungarian Geological Society since 1870; editor-in-chief: G. CSÁSZÁR.

b) *Acta Geologica Academiae Scientiarum Hungaricae* is a journal in foreign languages sponsored by the HAS. It has been published as a quarterly since 1956; editor-in-chief: J. HAAS.

c) Several other textual and cartographic materials by MÁFI (in a manuscript form) are contained in *Publications of the Geological Survey of Hungary* (produced by the library of the Institute). Part of these works were prepared with participation of specialists from other institutions (e.g. International post-graduate course of UNESCO in engineering geology, 22 volumes, 1975).

As a whole MÁFI publications played a decisive part in the output of geosciences for the past 125 years

Photo 46. a) Geographical Review *(Földrajzi Közlemények)* 125-year-old journal of the Hungarian Geographical Society in which geomorphological studies about Hungary are published regularly; editor-in-chief: A. Nemerkényi. b) Geographical Bulletin (*Földrajzi Értesítő*) is a quarterly of the GRI HAS regularly publishing results of research in the field of geomorphology; editor-in-chief: S. Marosi

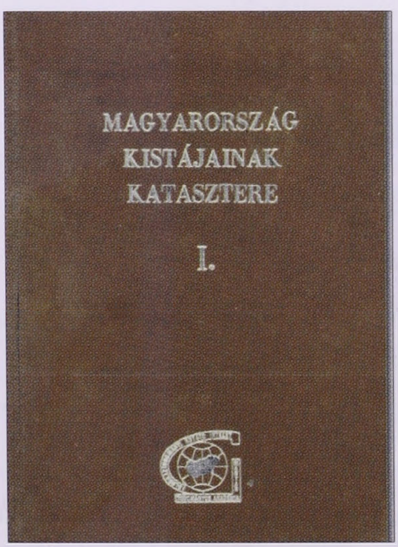


Photo 47. 230 microregions of Hungary are introduced through physical geographical endowments and resources making up an inventory of monographic character; eds: S. Marosi and S. Somogyi (1990)

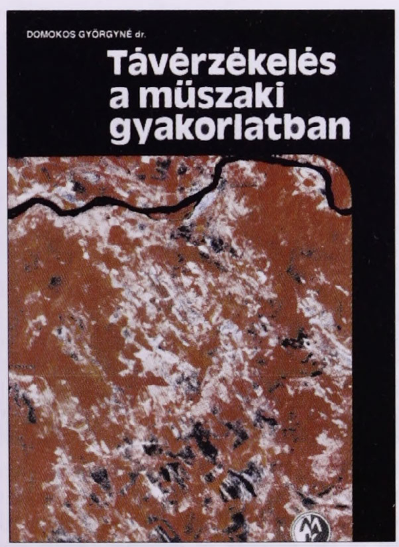


Photo 48. A new technique for the assessment and evaluation of geographical environment by remote sensing; ed.: Mrs. M. Domokos (Budapest, 1984)

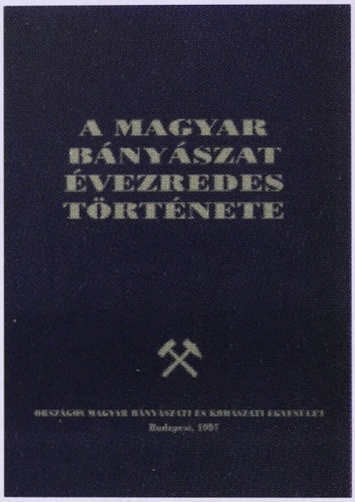


Photo 49. During the thousand years of the Hungarian mining considerable transformation of surface took place; about one billion cubic m of rocks and unconsolidated deposits were removed in order to expose workable mineral reserves

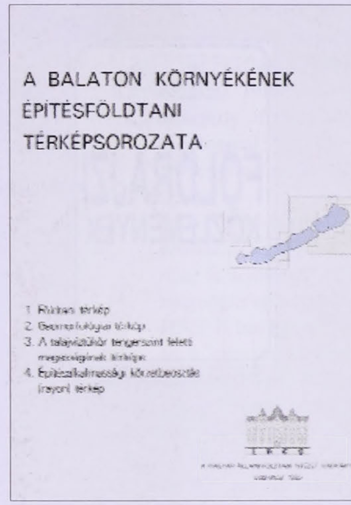


Photo 51. Geological map series published by the State Geological Institute serving relief assessment and environmental evaluation aimed at the protection and safety planning of the built environment. One of them deals with the environment of Lake Balaton

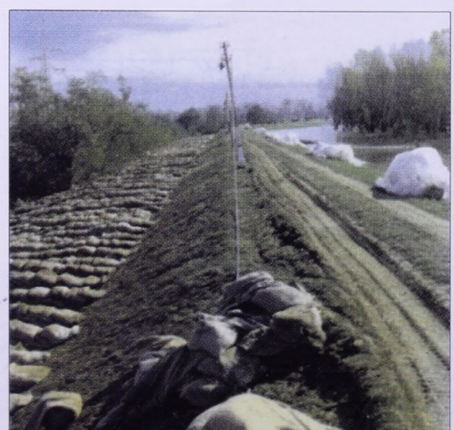


Photo 50. Dyke of flood protection of a river in the Great Hungarian Plain (Photo by P. LIEBE). Length of these facilities exceeds 4000 km while that of the network of drainage canals almost reaches 40 000 km. In the course of these construction works and river channel regulation activities 1.8 to 2 billion cubic m are estimated to have been moved (oral communication of L. ALFÖLDI and P. LIEBE)

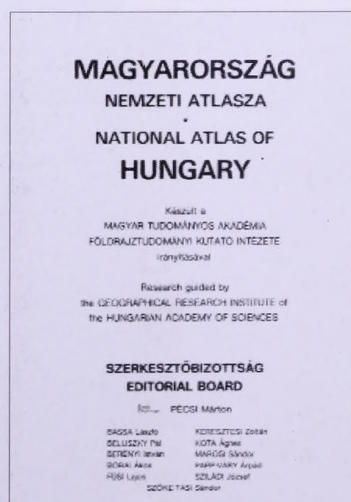


Photo 52. The *National Atlas of Hungary* (1989; editor-in-chief: M. PÉCSI) contains geological and geomorphological map series depicting stages of the development of the Hungarian land

Relief of Hungary, its present-day topography and the evolution of its distinct landform has been subject of scientific investigations and interpretations for the past one and a half hundred years or so. The Hungarian Geological Society was founded in 1848 and the Hungarian Geographical Society celebrated its 125th anniversary in 1997. Both associations held jubilee sessions presenting the results of studies on the relief evolution, endowments, usability of the homeland. For a present and future rational use of the Hungarian land it is indispensable to possess a substantiated knowledge of its past evolution.

Aims of the present volume are outlined in its Preface. Along with working hypotheses and concepts of our predecessors and of the present generation of researchers, methods and techniques developed by them are introduced through the most prominent achievements in the domain of the evolution of landforms and environments. The basic and most instructive investigations are described and analysed from the perspective of past, present and future scientific and practical initiatives and are targeted at researchers, experts and teachers dealing with geology and geomorphology. Our goal was a more precise understanding and further development of geoscientific concepts and methods.

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