Cretaceous sediments of the Transdanubian Range

Geological excursion
14–16 May 2009

Organized by the Sedimentological Subcommission of the Hungarian Academy of Sciences and the Hungarian Geological Society

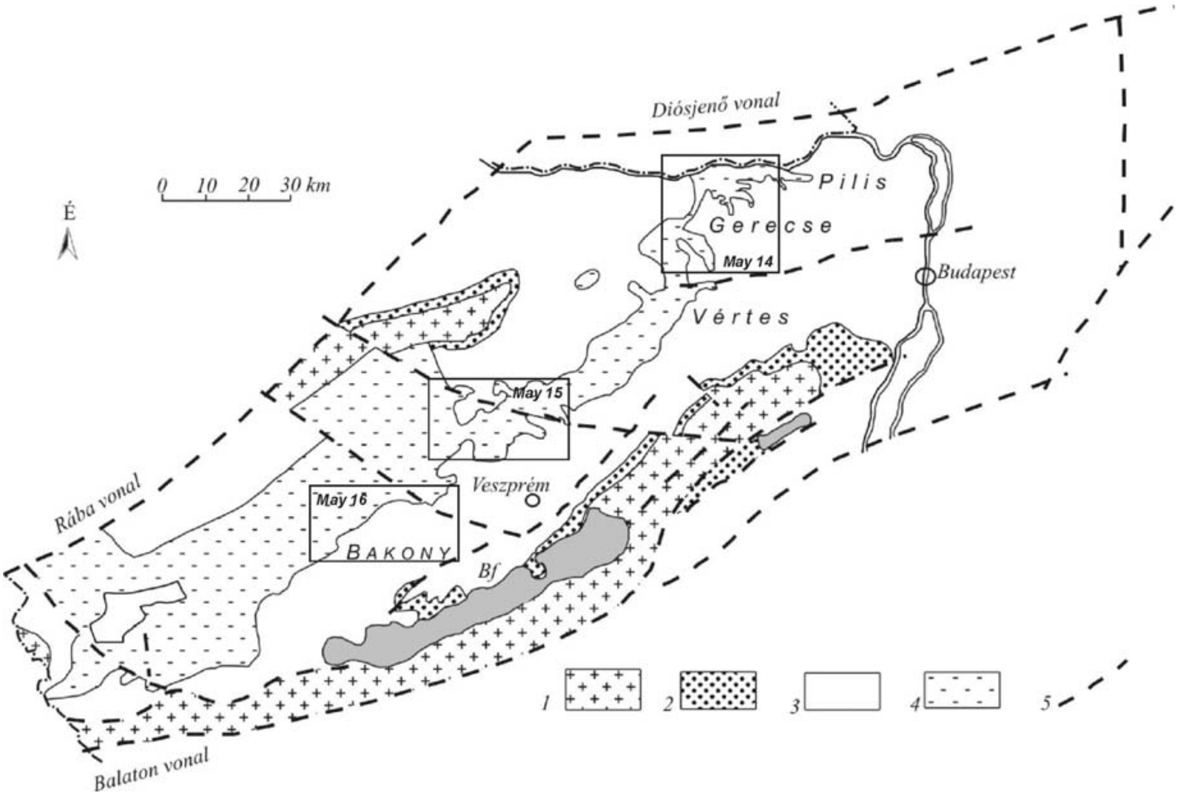
Field guide

Leaders:
Géza CSÁSZÁR[1], János HAAS[2], Andrea MINDSZENTY[3], Attila ŐSI[4], Márton PALOTAI[5], Tamás POCSAI[6], Ágoston SASVÁRI[6], Ottilia SZIVES[7]

[1]Geological Institute of Hungary
[2]Geological Research Group of the Hungarian Academy of Sciences, Eötvös University
[3]Eötvös Loránd University, Department of Applied Geology
[4]Hungarian Academy of Sciences – Hungarian Natural History Museum, Research Group for Paleontology
[5] Eötvös Loránd University, Department of Geology
[6]MOL (Hungarian Oil and Gas Company)
[7]Hungarian Natural History Museum Department of Palaeontology

Budapest, 2009

Programme

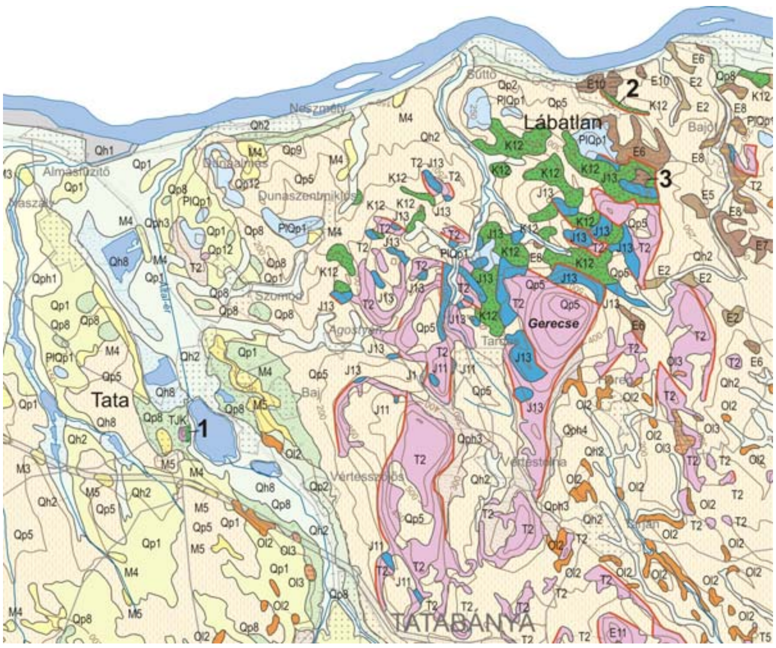


May 14 Gerecse Mountains

Stop 1. Geological Open Air Museum, Tata

Stop 2. Grindstone quarry, Lábatlan

Stop 3. Marl Yard, Bersek Hill, Lábatlan



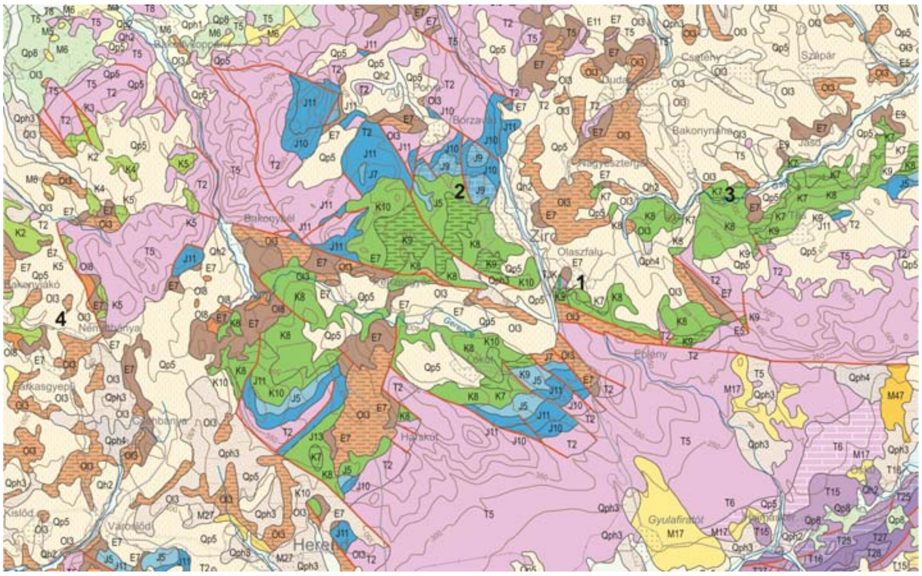
<u>May 15 Bakony Mountains</u>

Stop 1. Eperjes Hill, Olaszfalu

Stop 2. Abandoned quarry between villages Zirc and Borzavár

Stop 3. A quarry of Jásd

Stop 4. Iharkút, Dinosaur-bearing alluvial complex of the Csehbánya Formation



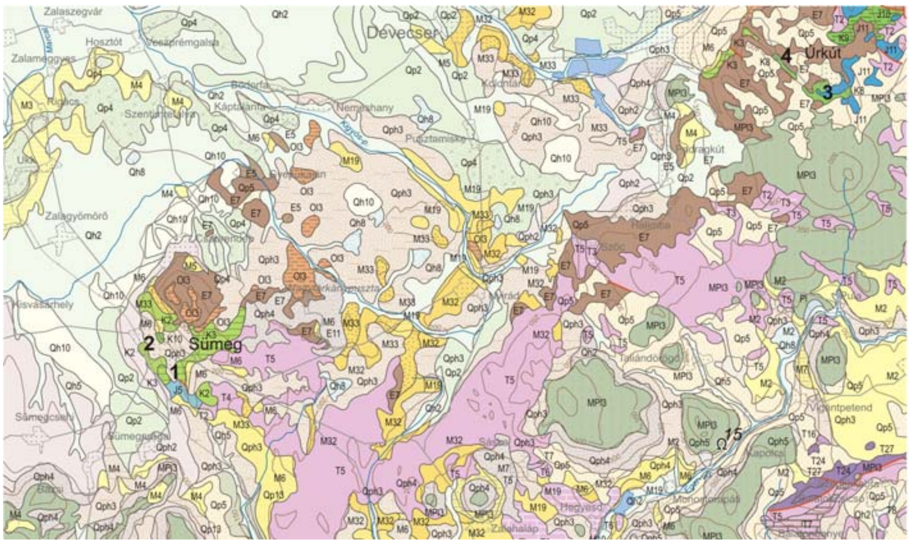
<u>May 16 Bakony Mountains</u>

Stop 1. Sümeg, Mogyorós Hill

Stop 2. Sümeg, Sintérlap quarry

Stop 3. Manganese slurry reservoir, Úrkút

Stop 4. A quarry on the south-western side of the road between Úrkút and Ajka



Introduction

Introduction to the geology of the Transdanubian Range Cretaceous

Géza CSÁSZÁR

The Jurassic history of the Transdanubian Range were characterized by disintegration of the long lasting (Middle to Late Triassic) carbonate platform thanks to the separation of Africa and North America and as a consequence Africa and Europe. This is the time of development of the South and North Penninic Ocean. This event has induced the general deepening of the prevailing part of the Tethys domain and the fundamental decrease of sedimentation rate in the same area, including the Pelso units and the Transdabubian Range within it. The opening of the Penninic oceans caused the closure of the Vardar/Meliata Ocean and the development of the early nappe structure in the late Middle Jurassic – early Early Cretaceous in the Alpine – Dinaric Region (Gawlick & Frisch 2003, Gawlick et al. 2007). This type of movements was strengthened during the closure of the Penninic ocean and this is the reason why large areas became carbonate platform. The latest event gave rise only to a gentle signal in the Transdanubian Range only ("Oxfordian breccia" and later the Felsővadács Breccia). Anyway it was the start of the change of the tectonic regime in the Transdanubian Range and also the decoupling of sedimentation there in the late Late Jurassic and formation of the South Bakony and the Gerecse Basins (Fig. 1).

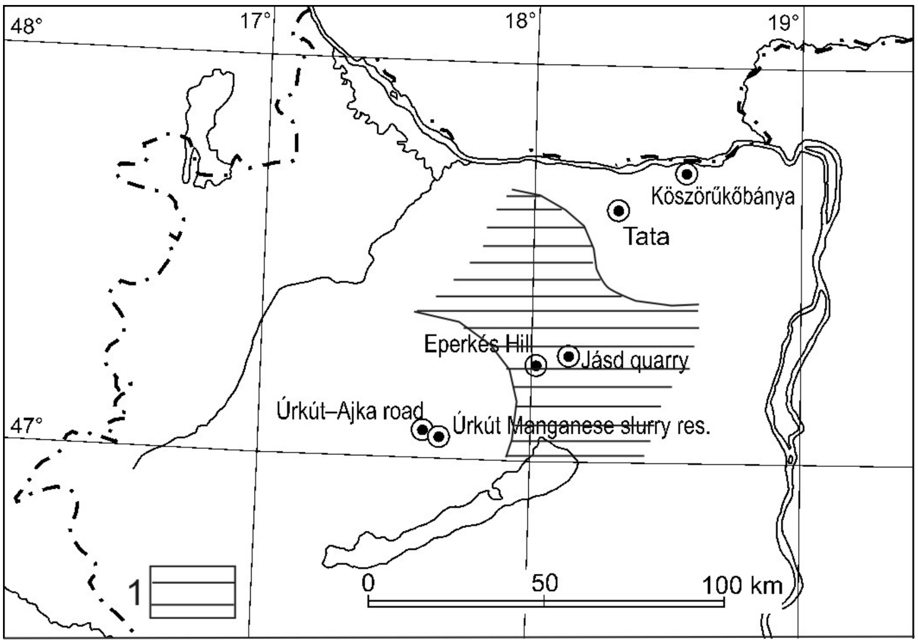


Fig. 1 Skatchmap showing the separation of the South Bakony and the Gerecse Basins when the Northern Bakony – Vértes segment became a submarine high in the early Early Cretaceous, Tansdanubian Range with indication of the sites to be visited. *Legend*: 1 – Submarine high with no sedimentation

In the south-western part of the range (South Bakony radiolarian limestone and clayey limestine of maiolica facies (Mogyorósdomb Limestone Formation and later Sümeg Marl) deposited while in the north-eastern part of the range the sedimentation turned into flysch type marl (Besek Marl Formation) and then sandstone (Lábatlan Sandstone). The elevation of the sea floor in the central part of the range continued in the Early Cretaceous and as a consequence of it sediments from the elevated area have been transported towards the basins. The current system must have been changed in the Aptian, probably due to the filling of the Maiolica basin in the South Bakony area and a crinoidal limestone (Tata Limestone Formation) was formed there and also on the submarine high of the Range while flysch type sedimentation continued in the Gerecse Mountains (Fig. 2). In the North Bakony, and on the SW part of the Vértes Foreland, the Tata Limestone directly deposited on various Jurassic formations or even on Dachstein Limestone. At several sites, especially on palaeoslopes, the basin floor was covered by bacterially excreted Fe-Mn crust of several centimetres in thickness.

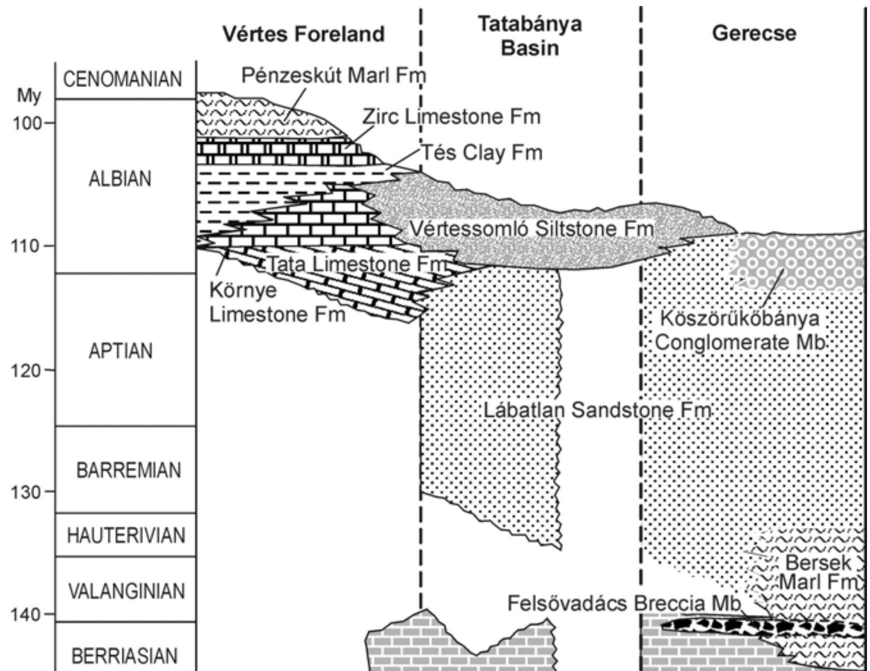


Fig. 2 Relation of the Cretaceous formations in the Vértes Foreland and the Gerecse Mountains

A radical change in sedimentation occurred in the Early Albian because of the compressional phase of Alpine orogenic movements that gave birth to synclinal form of the Transdanubian Range. The larger south-western part has been uplifted above the sea level in different measure for a relatively short time interval. On the substantially uplifted blocks, heavy erosion and intensive weathering was going on, while a small-scale erosion happened only on the less elevated areas between blocks. In the karstic traps of the Dachstein Limestone in the North Bakony, the Alsópere Bauxite Formation was formed and accumulated (Fig. 3).

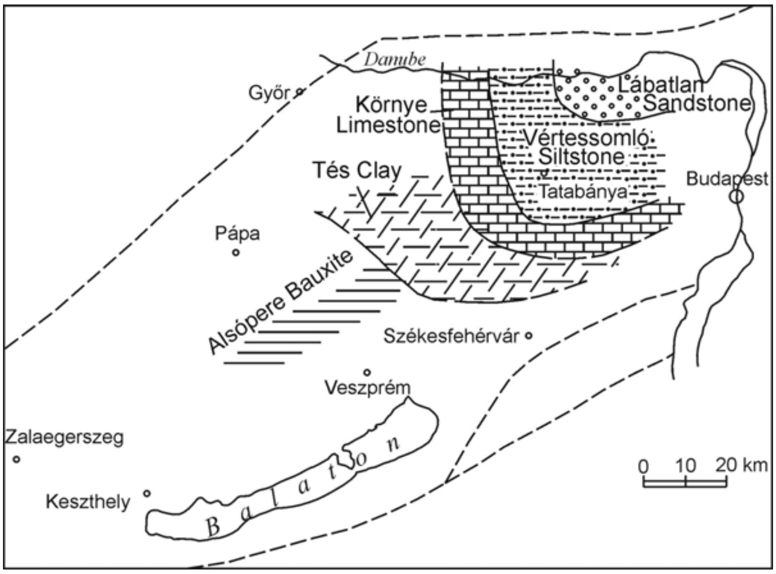


Fig. 3 Palaeogeograhic skatchmap showing the facies connection before the Albian transgression from the Vértes and Gerecse Basin area

In the flexural basin of the Gerecse Mountains clastic slope and basinal sedimentation still continued (Császár & Árgyelán 1994, Fogarasi 1995, Császár 2002 – Fig. 4). The Lábatlan Sandstone is capped by the Köszörűkőbánya Conglomerate Member with olistostrome-like limestone breccia intercalations (Fig. 5) from the Urgon type carbonate platform. It was edged by a poorly developed front reef. In the Vértes Foreland the Tata Limestone was replaced by the Vértessomló Siltstone of semi-restricted basin origin which was bordered towards the west by the Környe Limeston of shallow marine Urgon type platform carbonate (Görög 1995, Császár 2002 – Fig. 6).

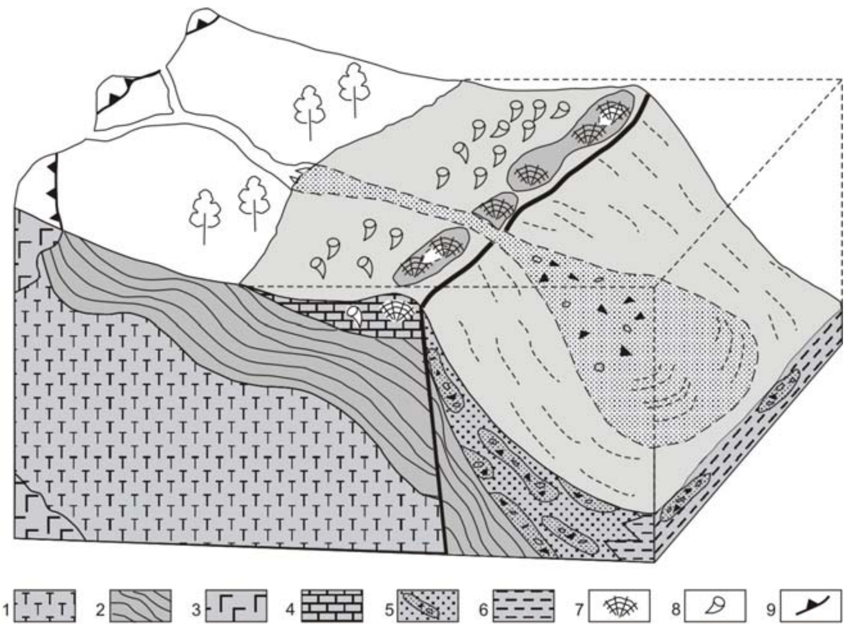


Fig. 4 Block diagram showing the land, carbonate platform and the Gerecse Forland Basin in the Albian. *Legend*: 1 – Triassic and older formations; 2 – Jurassic; 3 – Obducted oceanic basement; 4 – Cretaceous platform carbonates; 5 – Slope deposit; 6 – Basic sediment; 7 – Corals; 8 – Rudist bivalve; 9 – Obduction surface

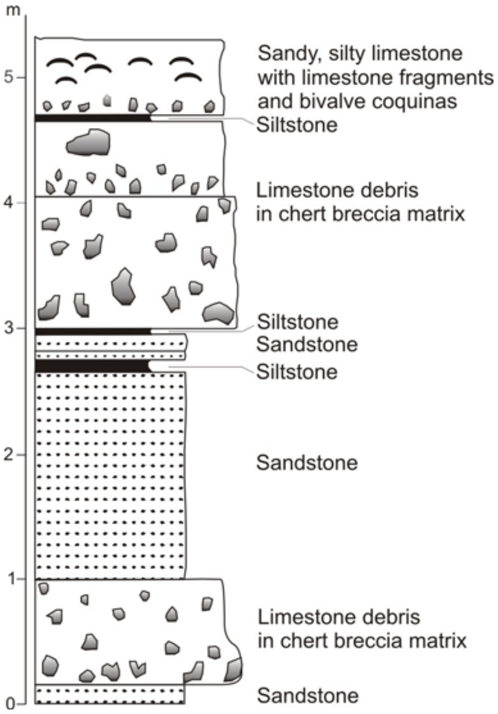


Fig. 5 Limestone breccia within the Köszörűkőbánya Conglomerate Member, Köszörőkő-bánya (grindstone quarry), Lábatlan

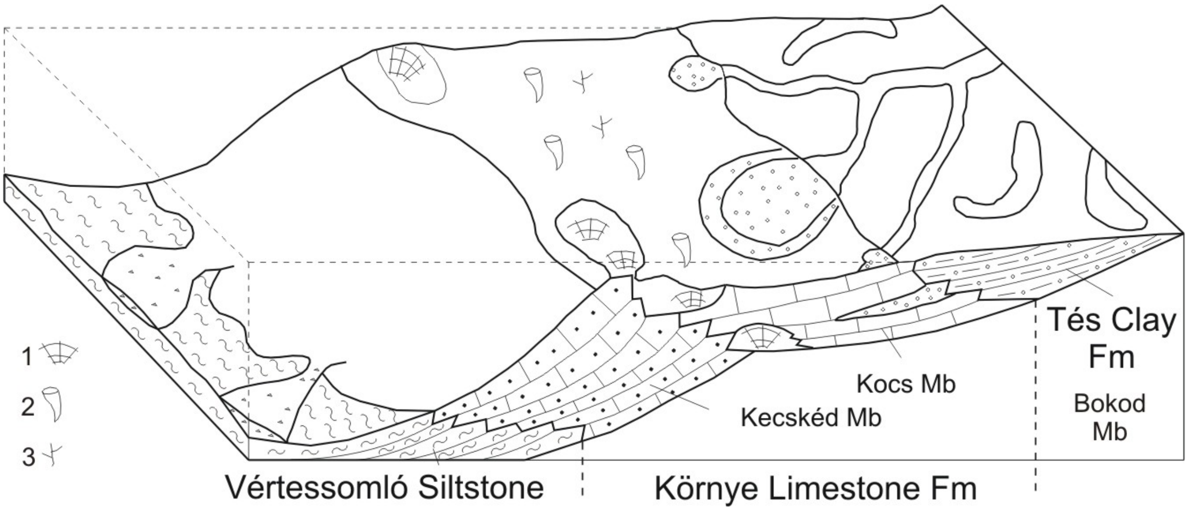


Fig. 6 Block diagram, showing prograding carbonate platform and related faces with basin floor fan in the Middle Albian, Vértes Foreland. *Legend*: 1 – Patch reef; 2 – Rudist bivalve; 3 – Green algae

The Alsópere Bauxite is covered by the Tés Clay of fluvial, lacustrine, brackish-water to shallow marine origin (Juhász 1983). Because of radical climatic changes, the Tés Clay was replaced by an other platform carbonate of Urgon facies (Zirc Limestone).

References

Császár, G. 2002: Urgon formations in Hungary with special reference to the Eastern Alps, the Western Carpathians and the Apuseni Mountains. – *Geologica Hungarica, Series Geologica* **25**, 1–209.

Császár, G. & Árgyelán, B.G. 1994: Stratigraphic and micromineralogic investigations on Cretaceous formations of the Gerecse Mountains, Hungary and their palaeogeographic implications. – *Cretaceous Research* **15**, 417–434.
Fogarasi A. 1995: Ciklussztratigráfiai vizsgálatok a gerecsei krétában: előzetes eredmények. – *Általános Földtani Szemle* **27**, 43–58.
Gawlick, H.-J. & Frisch, W. 2003: The Middle to Late Jurassic carbonate clastic radiolaritic flysch sediments in the Northern Calcareous Alps: sedimentology, basin evolution and tectonics – an overview. – *Neues Jahrbuch für Geologie und Paläontologie Abh*. **230**, 163–213, Stuttgart.
Gawlick, H-J., Schlagintweit, F. & Suzuki, H. 2007: Die Ober-Jura bis Unter-Kreide Schichtfolge des Gebietes Sandling-Höherstein (Salzkammergut, Österreich) – Implikationen zur Rekonstruktion des Block-Puzzles der zentralen Nördlichen Kalkalpen, der Gliederung der karbonatklastischen Radiolaritflyschbecken und der Entwicklung der Plassen-Karbonatplattform. – *Neues Jahrbuch für Geologie und Paläontologie Abh*. **243/1**, 1–70.
Görög, Á. 1995: A Vértes-előtér és a Gerecse-hegység kréta időszaki nagyforaminifera vizsgálata és sztratigráfiai értékelése. – *Általános Földtani Szemle* **27**, 85–94.
Juhász, M. 1983: Palynostratigraphic zonation of the Transdanubian Middle Cretaceous. – *Acta Geologica Hungarica* **26,** 41–68.

Rudistid limestones, bauxites, paleokarst and geodynamics. The case of the Cretaceous of the Transdanubian Central Range.

Andrea MINDSZENTY

The TCR is well known for its Cretaceous-Early Tertiary bauxites, which have been considered for long among the most important mineral commodities of the country. They belong to the group of karst bauxites (closely related to karstified carbonate rocks) and occur at major regional unconformities of Albian, Turonian/Senonian and Early Eocene age (Fig. 7).

All three bauxite events have traditionally been considered as introduced by (tectonically controlled) uplift and followed by likewise tectonically controlled subsidence and the concomittant relative sealevel rise. As a result of subaerial exposure a typical surface relief and also a karstic micro- and macroporosity was created and partially or completely filled by bauxites. The lithology of the transgressive sequences overlying the individual bauxite horizons is principally carbonatic, though it varies according to the antecedent paleotopography. In the case of the two Cretaceous bauxite horizons, wherever (and whenever) detrital influx was small enough to allow Rudistids to colonize the sediment surface, rudistid patch reefs were formed on the slowly subsiding seabottom. On further (accelerated) subsidence former rudistid bioconstructions gave way to bioclastic grainstones, and higher up to calcareous marls.

Bauxites, their bedrocks and also the covering limestones have been studied in details by generations of geologists mainly from the stratigraphical sedimentological and econo-

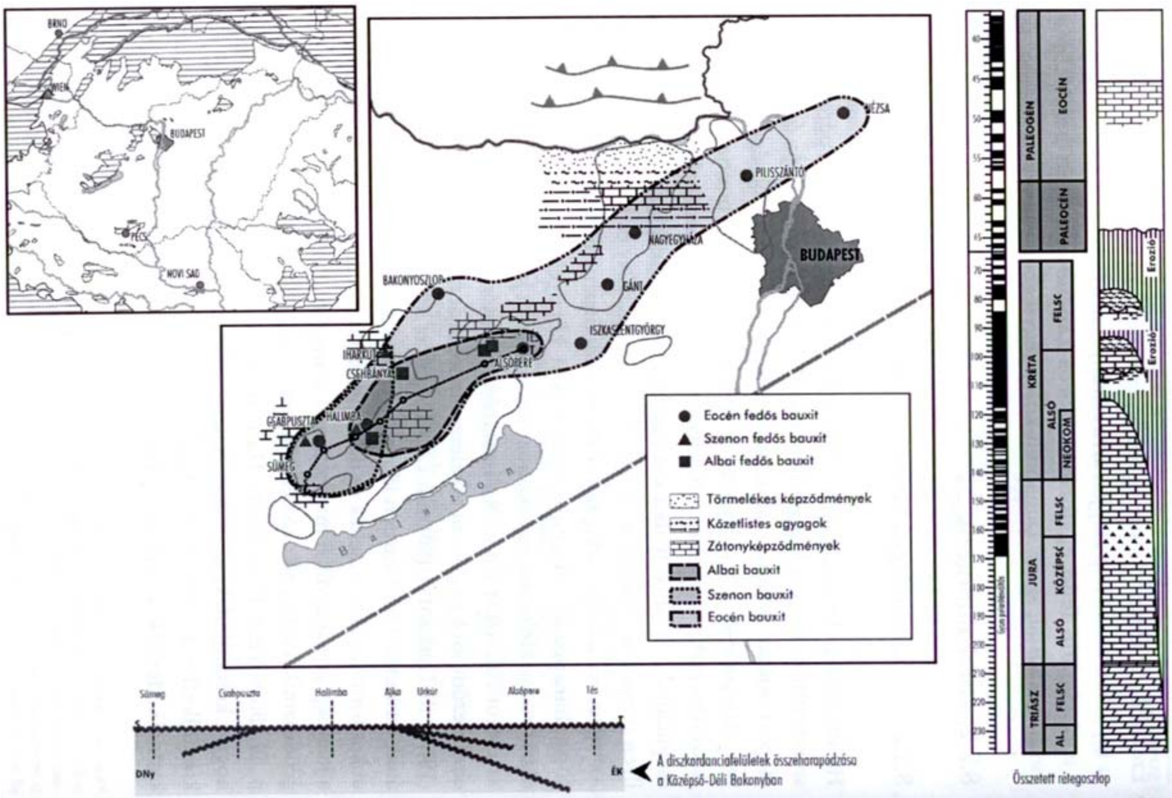


Fig. 7 Areal distribution of bauxites and related Mesozoic facies in the TCR

mic geological points of view. Interestingly enough only part of the information thus collected was incorporated into the currently available paleogeodynamic reconstructions. Little attention was paid, for example, to the anatomy of the bauxitiferous unconformities. The present study was an attempt to complete these reconstructions with the information provided by the most important unconformity related features (i.e. bauxites; alterations of their paleokarstic bedrock; and early diagenesis of their immediate cover).

Vertical and lateral facies relationships of bauxite and the covering limestones were studied in outcrops and boreholes. Field observations were supported by micropetrography, cathodoluminescence microscopy, stable isotope analysis and fluid inclusion studies. The results helped to fit previous observations into a coherent geodynamic framework - the one proposed as a working hypothesis earlier simultaneously by Tari (1994) and Mindszenty et al. (1994).

Areal extension of bauxites in the TCR shows that the majority of known deposits and indications belonging to the older (Albian) bauxite horizon are found in the North Bakony, Senonian deposits are restricted to the Southern part of the Bakony Hills whereas Eocene deposits are known from all over the area of the Transdanubian Central Range. The only place where the three horizons are not only present but also literally *merging* is the Halimba locality. Terrestrial formations related to the oldest (Albian) unconformity pinch out gradually towards the NE and are never present in the South. Senonian bauxites on the other hand show a pinch-out both towards S, NE and NW. When taking into consideration the facies distribution also of the marine formations contemporaneous with or immediatley overlying Cretaceous bauxites and when paying particular attention to the occurrence of rudistid limestones it is temptating to say that bauxites punctuating the Late Cretaceous sedimentary cycle of the TCR are, indeed, related to a migrating forebulge, in the apical zone of which we always find subaerial exposure and bauxite deposition giving way first to shallow water sediments (rudistid limestones) then to deeper water formations (marls) as on migration of the bulge uplift is followed by tectonically controlled subsidence. Merging of the unconformities reflects the migration of the bulge (Fig. 8). Even the two Albian limestone formations, slightly diachronous and displaying a distinct southward shift with time, can easily be incorporated into this picture. As shown by Császár 1986, 1995, the older one (Környe Limestone) occurs in the NE and has never bauxite deposits underneath. The younger one (Zirc Limestone) is thickest to the SW and is often the cover of the oldest (Albian) bauxites. This areal distribution suggests that the older limestone may have been formed on the flanks of the growing bulge whereas the younger one may reflect the backstepping of the reef as the bulge migrated to the SW. Interpretation of the third (Senonian) rudistid limestone (Ugod Limestone Formation) is less straightforward. The areal distribution of the Ugod limestone (known from the exploration practice and from studies by Haas 1979) reflects even more perfectly the shape of one (or two) elongate upbulging structures surrounded by the limestone buildups. The orientation of this Senonian bulge (and the associated bauxites) is, however, strikingly different from that marked both by the requienid reefs and the older bauxites. According to Tari (1994), who also concluded that the easiest way to explain the observed facies distribution is to think in terms of foreland type deformation, this change in strike would be the result of the rotation of the deformation having affected the TCR during late Cretaceous times.

In addition to the characteristic facies distribution Tari's main arguments for the foreland-type deformation were mainly structural geological. Data collected in the frames of the present study allowed to check the validity of the hypothesis from the side of sedimentary petrography and geochemistry.

Strategic points of the study were (i) to check paleokarst features in that area where the apex of the bulge is supposed to have had the longest duration (localities where the unconformities merge) and therefore expected to have produced most pervasive karstifica-

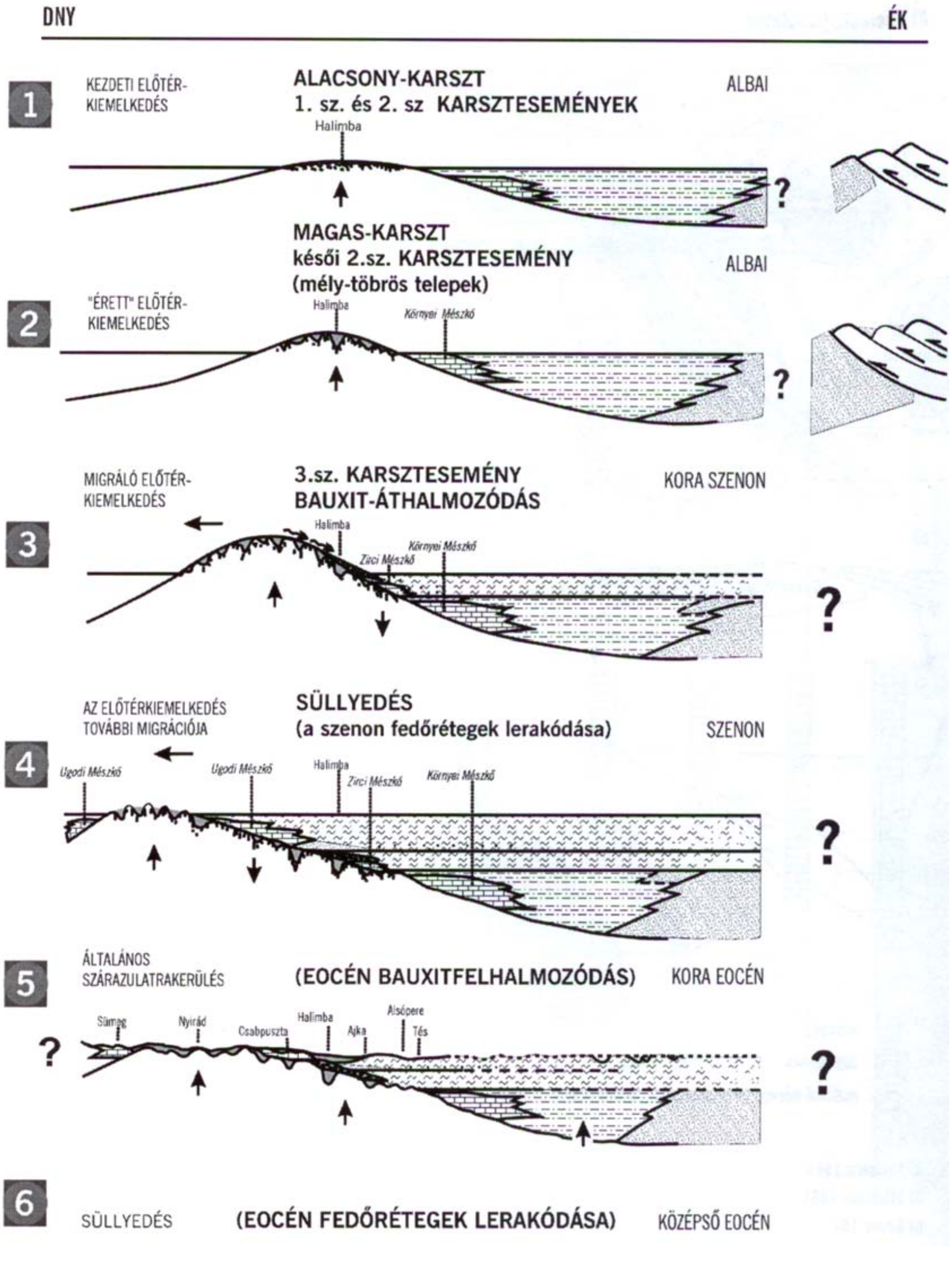


Fig. 8 Unconformity-bound facies as related to the hypothetic migrating Cretaceous foreland bulge of the TCR

tion (ii) to check rudistid limestones, deposited on the flanks of the forebulge, for early diagenetic meteoric or mixed marine/meteoric cements and this way to prove (or disprove) the influx of karst-related meteoric waters from the exposed apex of the bulge into the shallow marine diagenetic environment of the flanks.

ad (i): it was proved that karstification was most intense in the Halimba area, where the three unconformities merge. A karst profile of almost 200 meters thickness underlying the major (multiple) unconformity was shown to display the effects of several superimposed "epigenetic" phases of dissolution. The karstic porosity thus created was partly filled up by bauxites, carbonate silt, -sand, -conglomerates and several generations of cement.

ad (ii): meteoric influx of various proportions was proved in early diagenetic calcite cements of all the studied limestones. Accordingly also early dissolution ("diagenetic karst") of various intensity was detected in all of them. Both effects were most intense in the case of the Senonian limestone. Differences regarding the intensity of meteoric influence, were tentatively interpreted in terms of paleotopography which may have provided the necessary hydraulic head for the establishment of a more or less vigorous deep groundwater circulation which has interacted with diagenetic fluids of the marine-phreatic realm.

It is suggested that the above results are in accordance with the idea of a foreland-type deformation controlling Cretaceous sedimentation in the Transdanubian Central Range. In this context Albian bauxites and the related reef limestones can be considered as sediments deposited on the apex and the flanks of a migrating gentle forebulge whereas Senonian bauxites and the overlying limestones (reflecting a somewhat higher background relief) may have been deposited under the influence of more advanced deformation (thrusting, as in Tari 1994).

The presented case clearly shows, that the integration of unconformity related features into structural geological studies is, indeed, a powerful tool to test the validity of geodynamic hypotheses in areas where deformation resulted in unconformities/subaerial exposure and karstification. The reinforcement of the foreland hypothesis in the case of the Cretaceous of the TCR has its economic geological implications, too. It offers a logical explanation for the absence of Albian and Senonian bauxite deposits to the NE of the Környe–Oroszlány area, and accounts also for the observed pinch-out of Senonian deposits towards the NW this way helping to concentrate the efforts of exploration for Cretaceous deposits to the rest of the TCR.

References

Császár, G. 1986: Middle Cretaceous Formations of the Transdanubian Central Range. – *Geologica Hungarica* **23**, 1–295.

Császár, G. 1995: An overview of the Cretaceous research in the Gerecse Mountains and the Vértes Foreland. – *General Geol. Review* **27**, 133–152 (in Hungarian).

Haas, J. 1979: The Upper Cretaceous Ugod Limestone Formation in the Bakony Mountains. – *Ann. Hung. Geol. Inst.* **61**, 1–191.

Mindszenty, A., Knauer, J. & Matéfi-Steffler, M. 1994: Superimposed paleokarst phenomena in the Halimba basin (South Bakony, Hungary) – The anatomy of a multiple regional unconformity. – *15th Reg. Meeting IAS Napoli*, Abstracts, 285–286.
Tari, G. 1995: Alpine tectonics of the Pannonian Basin. – *Ph.D. Theses, Rice University, Houston, Texas, manuscript* 1–489 (thrusting, as in Tari 1994).

Changes in stress field of Transdanubian Range, Hungary from Jurassic to today

Ágoston SASVÁRI

The structural evolution of Transdanubain range can be composed from several investigations carried out in the whole mountain area. If we would like to take all observations in consideration, firts of all the geodynamic properties of the area must be studied. Focusing on paleomagnetic data published by Márton 1993, 1998, Márton & Márton 1983, 1989, Túnyi & Márton 1996 and Márton & Fodor 2003, it is clearly visible that major rotations in the Transdanubian area cannot be observed, only smaller ones due to local stress fields. That's why we can discuss all of structural observations taken from whole Transdanubian area based on Sasvári (2008).

JURASSIC: after discussing the results on the structural geology of the whole Transdanubian Range, tensional-transtensional stress states with north-northeast – south-southwest extension can be suggested for the Early and Middle Jurassic based on geometry of neptunian dykes studied by Lantos (1997) and Fodor & Lantos (1998). In the Late Jurassic change in stress parameters can be observed: the stress field shifted from tensional to to compressional or strike slip, and the direction of the compression was mainly north-south (Fülöp 1976, Bada 1994, Bada et al. 1996).

CRETACEOUS: The stress state of early Cretaceous – assuming minor undulation in the stress directions – was mainly similar to the Late Jurassic northeast-southwest trending one. Notable change occurred in the Aptian-Albian epoch in the stress properties: the shortening direction rotated counterclockwise through east-west to northwest-southeast trending one at the Late Albian age. Sasvári (2008) published the observed change of stress field from Gerecse Mountains; bedding-parallel striaes, duplex structures, inverse faulted beds and inverse striaes suggests compressional mechanism. Three compressional directions related to E–W, NE–SW and SE–NW shortening directions can be observed. Evidences of the deformation phases are clear visible in Ördöggát quarry, Gerecse Mountains: an internal, rotated block controlled by two parallel shear planes was cut by subhorizontal normal fault planes resulting in the rotation of the blocks synthetic to E–W shearing direction. Bedding parallel striaes, s-c schistosity observations are in good agreement with the shear mechanism and direction. Steep E–NE – W–SW as well as N–S trending fissures related to NE–SE compression can be observed composing a frequent network in the rotated block of Ördöggát quarry. Their geometry in the normal and oblique bedded rock is different – retilting of fissures proved primacy of fission (NE–SW compression) followed by tilting of shear controlled blocks (E–W compression). The last event resulting the syncline structure of Transdanubian Range can be related to NNW–SSE compression. The first, NE–SW compression can be Aptian, the E–W tranding early Albian, and the last one is supposed to late Albian. Based on vitrinit reflectance data and burial models, not sedimentary but tectonic burial of Gerecse Mountains can be supposed to late Aptian – early Albian age, in concordance with the well-known flexural deformation model of Mindszenty et al. (1994, 2000) and Tari (1994) which can be the base of deformation mechanism. Sparse and uncertain stress data on the Late Cretaceous and the Palaeocene are published with major contradictions. These cannot be precisely corporated in the structural evolution model of the Transdanubian Range, but the same NW–SE compression can be supposed for the late Cretaceous epoch.

EOCENE – OLIGOCENE – LATEST EARLY MIOCENE: supposedly stable strike-slip stress conditions with northwest – southeast trending shortening direction was present from the Eocene to the Ottnangian (Early Miocene) based on the observations of Bada (1994), Fodor et al. (1994), Bada et al. (1996), Sztanó & Fodor (1997), Márton & Fodor (2003), Kercsmár & Fodor (2005) and Kercsmár et al. (2006a, b).

MIDDLE MIOCENE – RECENT: in the Karpatian age (latest Early Miocene) variation in the stress conditions can be observed: the stress state changes from strike-slip to tensional or transtensional. In the Badenian age (early Middle Miocene) the stress properties varied again. The shortening direction rotates clockwise from the northwest-southeast to the northeast-southwest in the Sarmatian (late Middle Miocene). The tension-dominated stress regime seems to be common, but locally strike-slip stress fields can be observed. After the Badenian (early Middle Miocene) the tensional direction rotates also from northwest-southeast to the west-northwest – east-southeast, with the fluctuation of tensional – transtensional circumstances. (Bergerat et al. 1984, Bergerat 1989, Fodor et al. 1994, Bada et al. 1999, Fodor et al. 1999, Kiss 1999, Fodor & Magyari 2002, Sasvári 2003, Sasvári et al. 2007, Kiss & Fodor 2007).

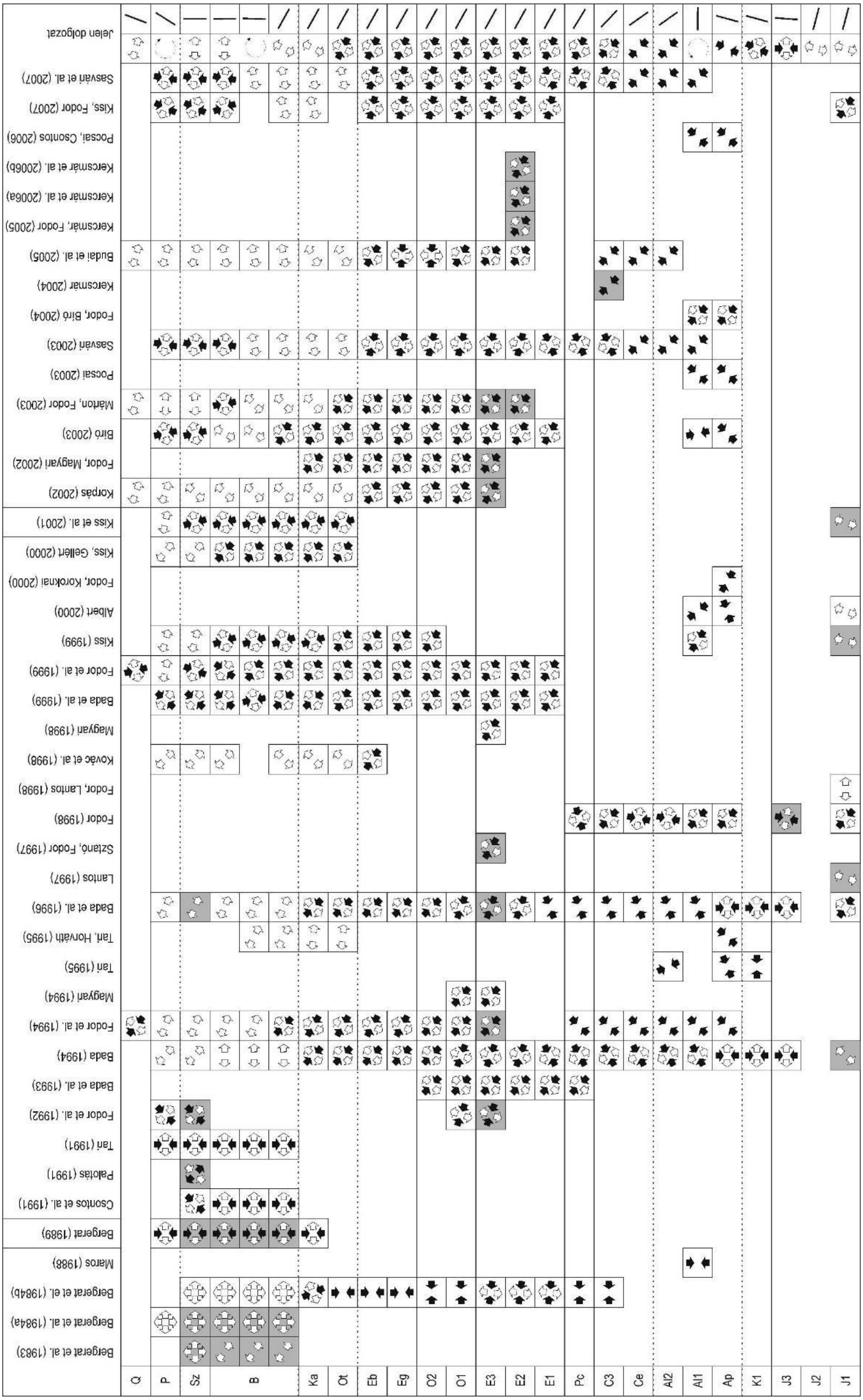


Fig. 9 Changes in stress field of Transdanubian Range, Hungary from Jurassic to today

Selected references on English, French or German

Bada, G. 1999: Cenozoic stress field evolution in the Pannonian Basin and surrounding orogens: inferences from kinematic indicatiors and finite element modelling. – *Doktori dolgozat, kézirat*, Vrije Univ, Amsterdam, 204p.

Bada, G., Fodor, L., Székely, B. & Tímár, G. 1996: Tertiary brittle faulting and stress field evolution in the Gerecse Mountains, northern Hungary. – *Tectonophysics* **255,** 269–289.

Bergerat, F. 1989: From pull-apart to the rifting process: the formation of the Pannonian Basin. – *Tectonophysics* **157,** 271–280.

Bergerat, F., Geyssant, J. & Kázmér, M. 1983: Une téctonique synsédimentaire originale du Miocène moyen des environs du Budapest, marqueur de l'extension du bassin pannonien. – *C. R. Acad. Sci. Paris* **296,** 1275–1278.

Bergerat, F., Geyssant, J. & Lepvrier, C. 1984a: Étude de la fracturation dans le bassin pannonien: méchanismes et étapes de sa création. – *Ann. Soc. Géol. Nord* **103,** 265–272.

Bergerat, F., Geyssant, J. & Lepvrier, C. 1984b: Neotectonic outline of the Intra-Carpathian basin in Hungary. – *Acta Geologica Hungarica* **27/3–4,** 237–249.

Csontos, L., Tari, G., Bergerat, F. & Fodor, L. 1991: Evolution of the stress field in the Carpatho-Pannonian area during the Neogene. – *Tectonophysics* **199,** 73–91.

Fülöp, J. 1976: The Mesozic basement horst blocks of Tata. – *Geol. Hung. Ser. Geol.* **16**, 1–228.

Kiss, A. & Fodor, L. 2007: Miocene dextral transpression along the Csesznek zone of the northern Bakony Mountains (Transdanubian Range, western Hungary). – *Geologica Carpathica* **58**, 465–475.

Márton, E. 1986: Paleomagnetism and ingenious rocks from the Velence Hills and Mecsek Mountains. – *Geophysical Transactions* **32**, 83–145.

Márton, E. 1993: The itinerary of the Transdanubian Central Range: an assessment of relevant paleomagnetic observations. – *Acta Geologica Hungarica* **37/1–2,** 135–151.

Márton, E. 1998: The bending model of the Transdanubian Central Range (Hungary) in the light of Triassic paleomagnetic data. – *Geophysical Journal International* **134,** 625–633.

Márton, E. & Fodor, L. 2003: Tertiary paleomagnetic results and structural analysis from the Transdanubian Range (Hungary): rotational disintegration of the Alcapa unit. – *Tectonophysics* **363,** 201–224.

Márton, E. & Márton, P. 1983: A refined apparent polar wander curve for the transdanubian central mountains and its bearing on the mediterranean tectonic history. – *Tectonophysics* **98,** 43–57.

Márton, E. & Márton, P. 1989: A compilation of paleomagnetic results from Hungary. – *Geophysical Transactions* **35/1–2,** 117–133.

Pocsai, T. & Csontos, L. 2006: Late Aptian-Early Albian syn-tectonic facies-pattern of the Tata Limestone Formation (Transdanubian Range, Hungary). – *Geologica Carpathica* **57/1,** 15–27.

Selected references on Hungarian

Albert, G. 2000: Az Északi-Bakony gyűrődései. – *Diplomadolgozat, kézirat*, ELTE Általános és Történeti Földtani Tanszék, 89p.

Bada, G. 1994: A paleofeszültségtér fejlődése a Gerecse hegység és kelet-délkeleti előterének területén. – *Diplomadolgozat, kézirat*, ELTE Alkalmazott és Környezetföldtani Tanszék, 137p.

Budai, T., Fodor, L., Csillag, G. & Piros, O. 2005: A Vértes délkeleti triász vonulatának rétegtani és szerkezeti felépítése. – *MÁFI Évi Jelentése a 2004. évről*, 189–202.

Fodor, L. & Lantos, Z. 1998: Liász töréses szerkezetek a Nyugati-Gerecsében. – *Földtani Közlöny* **128/2–3**, 375–396.

Fodor, L. & Magyari, Á. 2002: Késő-eocén – miocén szerkezetalakulás és üledékképződés a Sas-hegyen. – *Földtani Közlöny* **132/2,** 247–264.

Fodor, L. & Bíró, I. 2004: Sziklás eocén tengerpart a kréta korú Vértessomlói-rátolódás mentén (Szarvas-kút, Vértes). – *MÁFI Évi Jelentése a 2002. évről*, 153–162.

Fodor, L., Magyari, Á., Kázmér, M. & Fogarasi, A. 1992: Gravity-flow dominated sedimentation on the Buda paleoslope (Hungary): Record of Late Eocene continental escape of the Bakony unit. – *Geologische Rundschau* **81/3,** 695–716.

Fodor, L., Magyari, Á. Fogarasi, A. & Palotás, K. 1994: Tercier szerkezetfejlődés és késő paleogén üledékképződés a Budai-hegységben. A Budai-vonal új értelmezése. – *Földtani Közlöny* **124/2,** 129–305.

Fodor, L., Csontos, L., Bada, G., Győrfi, I. & Benkovics, L. 1999: Tertiary tectonic evolution of the Pannonian Basin system and neighbouring orogens: a new synthesis of palaeostress data. In: The Mediterranean Basins: Tertiary Extension within the Alpine Orogen). – *Geological Society Special Publication* **156,** 295–334.

Fogarasi, A. 1995: Üledékképződés egy szerkezeti mozgásokkal meghatározott kréta korú tengeralatti lejtőn a Gerecse hegységben – munkahipotézis. – *Általános Földtani Szemle* **27,** 15–41.

Kercsmár, Zs. 2004: A tatabányai vöröskalcittelérek szerkezetföldtani jelentősége. – *MÁFI Évi Jelentése, 2002,* 163–174.

Kercsmár, Zs. & Fodor, L. 2005: Syn-sedimentary deformations in the Eocene Tatabánya Basin, Central Hungary. – *Geolines* **19,** 60–61.

Kercsmár, Zs., Fodor, L. & Pálfalvi, S. 2006a: Középső-eocén szerkezetalakulás és medencefejlődés a Dunántúli Paleogén Medence ÉK-i részén (Vértes-hegység). – *VIII. Bányászati, Kohászati és Földtani Konferencia absztraktkötet, Sepsiszentgyörgy*, 212–214.

Kercsmár, Zs., Fodor, L. & Pálfalvi, S. 2006b: Tectonic control and basin evolution of the northern Transdanubian Eocene basin (Vértes Hills, Central Hungary). – *Geolines* **20,** 64–66.

Kiss, A. 1999: A Porvai-medence szerkezetalakulása. – *Diplomadolgozat, kézirat,* ELTE Alkalmazott és Környezetföldtani Tanszék, 91p.

Kiss, A., Gellért, B. & Fodor, L. 2001: Structural history of the Porva basin in the northern Bakony Mountains (Western Hungary): implications for the mesozoic and tertiary tectonic evolution of the Transdanubian Range and Pannonian Basin. – *Geologica Carpathica* **52/3,** 183–190.

Korpás, L., Fodor, L., Magyari, Á., Dénes, Gy & Oravecz, J. 2002: A Gellért-hegy földtana, karszt- és szerkezetfejlődése. – *Karszt és Barlang* **1998–1999/I–II.,** 57–93.

Lantos, Z. 1997: Karbonátos lejtő-üledékképződés egy liász tengeralatti magaslat oldalában, eltolódásos vetőzóna mentén (Gerecse). – *Földtani Közlöny* **127/3–4,** 291–320.

Magyari, Á. 1994: Késő-eocén hidraulikus breccsásodási jelenségek a Budai-hegység déli részén. – *Földtani Közlöny* **124/1,** 89–107.

Magyari, Á. 1998: Törökugrató: késő-eocén szinszediment pozitív virágszerkezet a Budai-hegység DNy-i peremén. – *Földtani Közlöny* **128/4,** 555–572.

Maros, Gy. 1988: A Vértes hegységi Vitány-vár környékének tektonikai elemzése. – *MÁFI Évi Jelentése az 1986. évről*, 295–309.

Márton, E. 1984: A Veelncei-hegység magmás kőzeteinek paleomágnesessége. – Magyar *Geofizika* **25**, 48–56.

Palotás, K. 1991: Üledék- és szerkezetföldtani vizsgálatok a Tétényi-fennsíki szarmatában. – *Diplomadolgozat, kézirat*, ELTE Általános és Történeti Földtani Tanszék, 103p.

Sasvári, Á. 2008: A Magas-Gerecse feszültségterének fejlődése a Dunántúli-középhegységről készült publikációk tükrében: irodalmi áttekintés. — *Földtani Közlöny* 138/2, 445–468

Sztanó, O. 1990. Submarine fan-channel conglomerate of Lower Cretaceous, Gerecse Mountains., Hungary. – *N. Jb. Geol. Paläont., Mh.* **7,** 431–446.

Sztanó, O. & Fodor, L. 1997: Lejtőüledékek a paleogén medence peremén: a felső-eocén Piszkei Márga (Nyergesújfalu, Sánc-hegy) ülepedési és szerkezeti viszonyai. – *Földtani Közlöny* **127/3–4,** 267–290.

Tari, G. 1991: Multiple Miocene block rotation in the Bakony Mountains, Transdanubian Central Range, Hungary. – *Tectonophysics* **199,** 93–108.

Tari, G. 1995: Eoalpine (Cretaceous) tectonics in the Alpine/Pannonian transition zone. In: Horváth F., Tari G. & Bokor Cs. (szerk): Extensional collapse of the Alpine orogene and Hydrocarbon prospects in the Basement ans Basin fill of the Western Pannonian Basin. – *AAPG International Conference and Exhibition, Nice, France, Guidebook to fieldtrip no. 6*, Hungary, 133–155.

Tari, G & Horváth, F. 1995: Middle Miocene extensional collapse in the Alpine-Pannonian transition zone. In: Horváth F., Tari G. & Bokor Cs. (szerk): Extensional collapse of the Alpine orogene any Hydrocarbon prospects in the Basement ans Basin fill of the Western Pannonian Basin. – *AAPG International Conference and Exhibition, Nice, France, Guidebook to fieldtrip no. 6*, Hungary, 75–101.

Túnyi, I. & Márton, E. 1996: Indications for large Tertiary rotation in the Carpathian – Northern Pannonian region outside the North Hungarian Paleogene Basin. – *Geologica Carpathica* **47**, 43–49.

Cretaceous and Cenozoic tectonics of the Bakony – a summary

Márton PALOTAI

This short guide briefly describes (1) the Cretaceous deformation history and (2) the Cenozoic tectonic evolution of the Bakony. To give an overview, however, the tectonics of a larger unit, the Transdanubian Range (TR, Fig. 10) will at least partly be addressed.

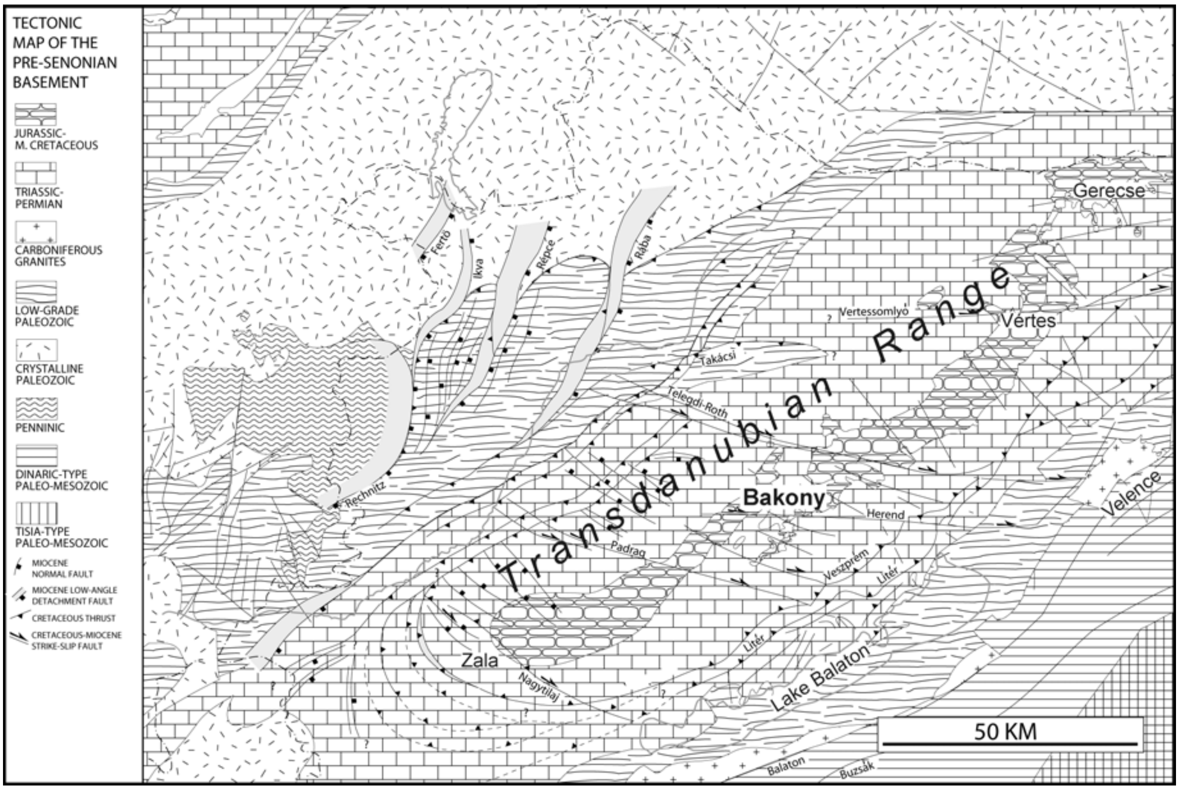


Fig. 10 Tectonic map of the pre-senonian basement of the Transdanubian Range and the Danube Basin (Tari 1995)

Cretaceous

While the Jurassic of the TR was characterized by rifting, this extension surely ceased in the Early Cretaceous, which is controlled by NE–SW (Sztanó 1990, Fogarasi 1995) or NNE–SSW (Fodor 1998) oriented compressive tectonics, caused by the propagation of S–SW vergent nappes related to the closure of the Vardar-Meliata ocean (Árgyelán 1995). This means that the change from rifting to thrusting occurred earlier in the Gerecse (Late Jurassic, as proposed by Bárány 2004) than in the Bakony, the whole Jurassic of which was traditionally though to be extensional. However, the possibility of Late Jurassic compression in the Bakony cannot be excluded either, as suggested by Palotai et al. (2006).

Synsedimentary thrusting and fault-related folding with NE–SW directed compression is recorded in the Upper Aptian–Lower Albian (Pocsai & Csontos 2006). WSW–ENE oriented compression in the northern part of the Bakony caused the formation of Aptian folds (Albert 2000). Mindszenty et al. (1994) interpreted the spatial shift of subaerial exposure and shallow marine limestone formation as on a flexural bulge in the foreland of advancing nappes in the Bakony during the Early – Middle Albian.

Shortly after this event, still in the Albian, the shortening direction rotated counterclockwise to northwest–southeast. This was related to the most important pre-Tertiary tectonic event in the region: folding of the TR and thrusting onto Austroalpine units (Horváth 1993; Tari 1994; Csontos & Vörös 2004). This resulted in a complex synclinal structure (Fig. 11) and the characteristic NE–SW trend of the range which already first was published by Lóczy (1925), and also means that the TR has to be regarded as the uppermost Austroalpine nappe (Tari 1994, Fodor et al. 2003).

Only few contradictional data constrain the Late Cretaceous structural evolution, assuming mainly compression-dominated stresses in various directions (e.g. Bada et al. 1996, Kercsmár 2004, Sasvári et al. 2007).

Cenozoic

After the Palaeocene and Early Eocene period of tectonic quiescence and denudation, well documented, partly synsedimentary strike-slip motions controlled by WNW–ESE to NW–SE oriented compression and perpendicular tension determined the Middle and Late Eocene tectonic evolution (Sasvári et al. 2007 and Kiss & Fodor 2007 in the Bakony; Fodor et al. 1994, Bada et al. 1996, Budai et al. 2005 in other regions of the TR). Similar conditions prevailed even throughout the Oligocene, likely until the Early Miocene (Sasvári 2008).

The current position of the TR is largely due to its Miocene extrusion from Alpine units (Ratschbacher et al. 1991) and related counterclockwise rotation, occurring in three main phases (Márton & Fodor 2003).

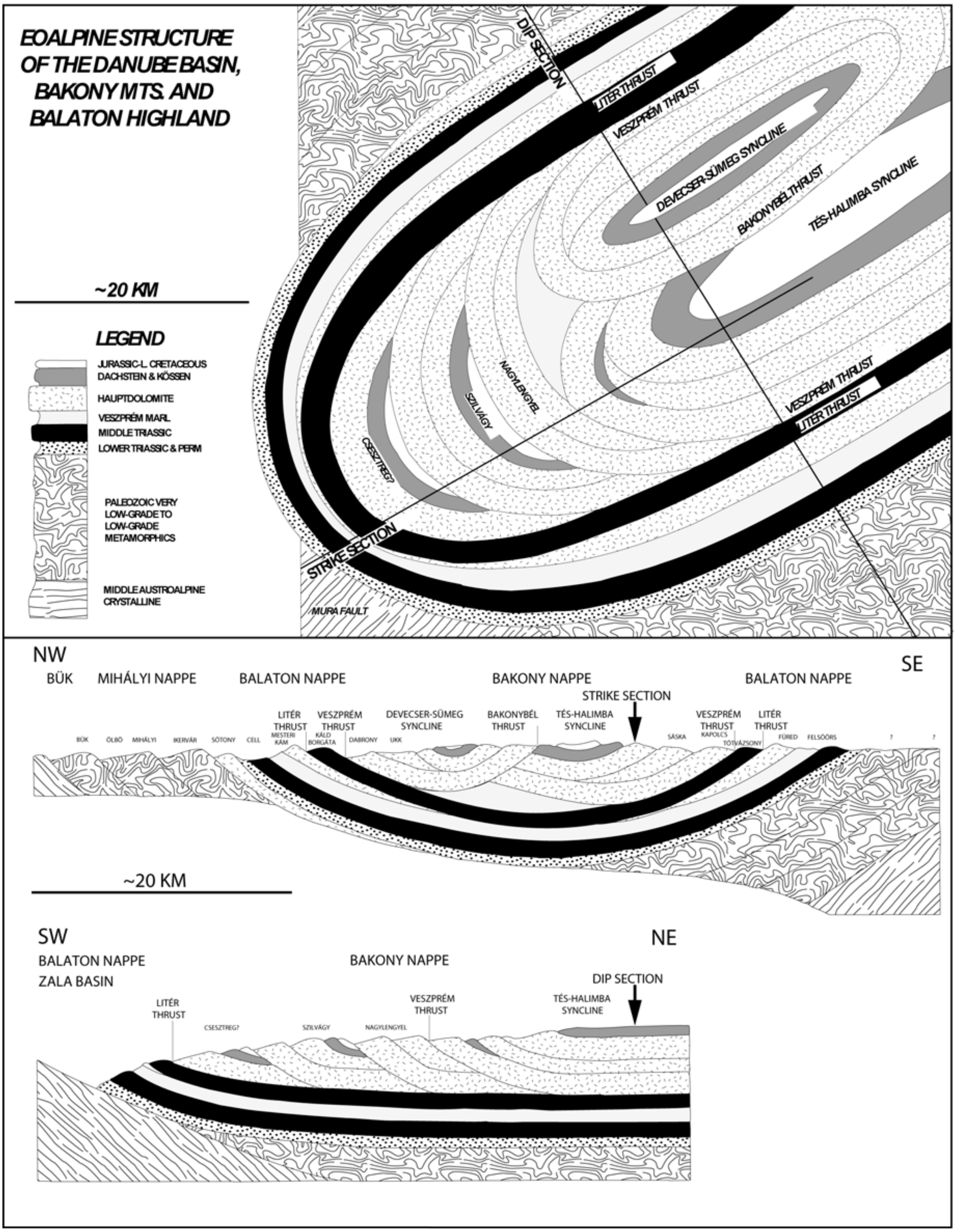


Fig. 11 Idealized character of Cretaceous thrusts in the Transdanubian Range (Tari 1995)

The bulk of Middle Miocene deformation was characterized by (partly asymmetrical) normal faulting and transtension (Fodor et al. 1999). A late Middle Miocene transpressive event activated NNW–SSE oriented dextral strike-slip faults, with a total displacement of up to 4.5 km on the largest one, the Telegdi Roth line (Sasvári et al. 2007; Fig. 10).

Tension dominated the Late Miocene: related NE–SW and N–S trending normal faults are often recognised in the surface morphology.

Neotectonic, i.e. Pliocene and even Quarternary inversion propagates northeastwards through the Pannonian Basin (Tari 1994, Fodor et al. 2005). Associated structures are important in landscape evolution.

References

Albert, G. 2000: Az Északi-Bakony gyűrődései. – *Unpublished MSc thesis*, *ELTE Dept. of Geology*, 89 p.

Árgyelán, B.G. 1995: A gerecsei kréta törmelékes kőzetek petrográfiai és petrológiai vizsgálata. – *Általános Földtani Szemle* **27**, 59–83.

Bada, G., Fodor, L., Székely, B. & Tímár, G. 1996: Tertiary brittle faulting and stress field evolution in the Gerecse Mountains, northern Hungary. – *Tectonophysics* **255**, 269–289.

Bárány, M. 2004: A jura-kréta határ gravitációsan átülepített képződményei az Északi-Gerecsében. – *Unpublished MSc thesis, ELTE Dept. of Geology*, 72 p.

Budai, T., Fodor, L., Csillag, G. & Piros, O. 2005: A Vértes délkeleti triász vonulatának rétegtani és szerkezeti felépítése. – *MÁFI Annual report* **2004**, 189–202.

Csontos, L. & Vörös, A. 2004: Mesozoic plate tectonic reconstruction of the Carpathian region. – *Palaeogeography, Palaeoclimatology, Palaeoecology* **210**, 1–56.

Fogarasi, A. 1995: Üledékképződés egy szerkezeti mozgásokkal meghatározott kréta korú tengeralatti lejtőn a Gerecse hegységben – munkahipotézis. – *Általános Földtani Szemle* **27**, 15–41.

Fodor, L. 1998: Late Mesozoic and Early Paleogene tectonics of the Transdanubian Range. – *Abstract book of the Carpathian-Balkan Geological Association 16th Congress*, Austria, p. 165.

Fodor, L., Magyari, Á., Fogarasi, A. & Palotás, K. 1994: Tercier szerkezetfejlődés és késő paleogén üledékképződés a Budaihegységben. A Budai-vonal új értelmezése. – *Földtani Közlöny* **124/2**, 129–305.

Fodor, L., Csontos, L., Bada, G., Győrfi, I. & Benkovics, L. 1999: Tertiary tectonic evolution of the Pannonian Basin system and neighbouring orogens: a new synthesis of palaeostress data. In: The Mediterranean Basins: Tertiary Extension within the Alpine Orogen. – *Geological Society Special Publication* **156**, 295–334.

Fodor, L. Koroknai, B., Balogh, K., Dunkl, I. & Horváth, P. 2003: A Dunántúli-középhegységi egység („Bakony”) takarós helyzete szlovéniai szerkezeti-geokronológiai adatok alapján. – *Földtani Közlöny* **133/4**, 535–546.

Fodor, L, Bada, G., Csillag, G., Horváth, E., Ruszkiczay-Rüdiger, Zs., Palotás, K., Síkhegyi, F., Tímár, G., Cloetingh, S. & Horváth, F. 2005: An outline of neotectonic structures and morphotectonics of the western and central Pannonian Basin. – *Tectonophysics* **410**, 15– 41.

Horváth, F. 1993: Towards a mechanical model for the formation of the Pannonian basin. – *Tectonophysics* **115**, 222–246.

Kercsmár, Zs. 2004: A tatabányai vöröskalcittelérek szerkezetföldtani jelentősége. – *MÁFI Annual report* **2002**, 163–174.

Kiss, A. & Fodor, L. 2007: Miocene dextral transpression along the Csesznek zone of the northern Bakony Mountains (Transdanubian Range, western Hungary). – *Geologica Carpathica* **58**, 465–475.

Lóczy, L. jun. 1925: A Dunántúl hegyszerkezetéről. – *Földtani Közlöny* **55**, 57–63.

Márton, E. & Fodor, L. 2003: Tertiary paleomagnetic results and structural analysis from the Transdanubian Range (Hungary): rotational disintegration of the Alcapa unit. – *Tectonophysics* **363**, 201–224.

Mindszenty, A., Knauer, J. & Mátéfi, S.M. 1994: Superimposed paleokarst phenomena in the Halimba Basin (South-Bakony, Hungary) – The anatomy of multiple regional unconformities. – *15th IAS Regional Meeting, Abstracts*, 285–286.

Palotai, M., Csontos, L., Dövényi, P. & Galácz, A. 2006: Az eperkés-hegyi felső-jura képződmények áthalmozott tömbjei. – *Földtani Közlöny* **136/3**, 325–346.

Pocsai, T. & Csontos, L. 2006: Late Aptian – Early Albian syn-tectonic facies-pattern of the Tata Limestone Formation (Transdanubian Range, Hungary). – *Geologica Carpathica* **57/1**, 15–27.

Ratschbacher, L., Frisch, W., Linzer, H.G. & Merle, O. 1991: Lateral extrusion in the Eastern Alps, Part 2: structural analysis. – *Tectonics* **10**, 257–271.

Sasvári Á. 2008: A Gerecse feszültségterének fejlődése a Dunántúli-középhegységről készült publikációk tükrében: irodalmi áttekintés. – *Földtani Közlöny* **138/2**, 147–164.

Sasvári, Á., Kiss, A. & Csontos, L. 2007: Paleostress investigation and kinematic analysis along the Telegdi Roth Fault (Bakony Mountains, western Hungary). – *Geologica Carpathica* **58**, 477–486.

Sztanó, O. 1990: Submarine fan-channel conglomerate of Lower Cretaceous, Gerecse Mountains., Hungary. – *N. Jb. Geol. Paläont.* **7**, 431–446.

Tari, G. 1994: Alpine Tectonics of the Pannonian basin. – *PhD Thesis, Rice University, Texas, USA,* 501 p.

Tari, G. 1995: Eoalpine (Cretaceous) tectonics in the Alpine/Pannonian transition zone – extensional collapse of the Alpine orogene and hydrocarbon prospects in the basement and basin fill of the Western Pannonian Basin. – *AAPG International Conference and Exhibition, Nice, France* – Guidebook to field trip No. 6, Hungary, 133–155.

Excursion

First day

Stop 1. Geological Open Air Museum, Tata

Géza CSÁSZÁR, János HAAS, Ottilia SZIVES

Kálvária Hill is a small fault-bonded Mesozoic horst. It is surrounded by Oligocene fluvial formations and deposits of the Late Miocene Pannonian Lake. Hot spring activity since the Ice Age has led to formation of caves within the horst and patches of travertine in the surrounding area. All these geological phenomena, together with prehistoric chert pits are visible in a tiny area in the central part of a picturesque baroque town, in the neighborhood of many historical sites.

In 1797, in his travelogue on Hungary, English traveler Robert Towson characterized Tata as a town built on red marble. In 1859, Austrian geologist Karl Peters was the first to publish descriptions of scientific value on the "red marble" of Tata and also he mentioned *Megalodus*-bearing Dachsteinkalk. At the same time, Franz Hauer reported new ammonite species from the Liassic limestone. In 1906, the famous Hungarian geologist, Lajos Lóczy sr. was the first to recognize the gray crinoidal limestone as an independent formation and determined its Cretaceous age. He supposed a steep, rocky coast existing here at the time of deposition of the crinoidal limestone unconformably overlying the Jurassic sequence. Nándor Koch's work "Geological conditions of the Kálvária Hill at Tata" (1909) was the first comprehensive treatise on this area. Relying on very rich fossil assemblages, he proposed a detailed stratigraphic subdivision for the Jurassic succession. Based on fossils, he assigned the gray crinoidal limestone to the Lower Neocomian. Later on, Somogyi (1914) re-evaluated the fauna and placed into the Aptian Stage.

In 1975 (1976 in English) József Fülöp summarized the litho- and biostratigraphy of the Mesozoic formations of the Kálvária Hill and the surrounding region in a richly illustrated monograph. In another work, in 1973, he also described the prehistoric chert pits and the unearthed archeological findings. Professor Fülöp continued the detailed study of the area until his unexpected death in 1994.

In the last decades, focusing on some special, hitherto unsolved problems, the study of the exposed sections continued. Cyclicity of the Dachstein Limestone and nature of the Triassic–Jurassic boundary were studied in detail (Haas 1995). A repeated collection of ammonites, other molluscs and brachiopods, and revision of the previously collected fauna were carried out to determine the range of the gap between the Triassic and basal Jurassic strata (Pálfy 1997). Based on studies of the rich ammonite fauna in the condensed basal layer of the gray crinoidal limestone, a revised chronostratigraphic evaluation was proposed (Szives 1999, Szives in Szives et al. 2007), together with the idea of the submarine origin of the basal erosional hardground. Detailed studies on the Jurassic neptunian dikes were carried out (Lantos 2005). New results of the geological investigations and geological sightseeing of the park were briefly summarized by Haas and Hámor (2001) and Haas (2007).

The small Tata horst is located in the northeastern part of the Transdanubian Range between two larger mountains: the Vértes and the Gerecse. East of the horst, a segmented graben-system filled by a 300–500 m-thick Eocene–Oligocene series occurs. To the West, towards the Kisalföld (Little Plain) along a series of faults, the Mesozoic basement subsided, reaching a depth of 6–7 km and covered by Neogene sequences.

Characteristics of Mesozoic formations of the Tata block reflect an intermediate setting of the area. In the Late Triassic, a predominant part of the Transdanubian Range belonged to the huge marginal carbonate platform of the Tethys (Dachstein platform-system). Disintegration of this platform initiated at the end of Triassic, leading to drowning of the platform, just at the Triassic–Jurassic boundary in the NE part of the TR, while the platform survived in its SW part. In Tata, the platform evolution came to an end at the Tr/J boundary and features of the predominantly ammonitico rosso-type Jurassic succession show close genetic relationships with those in the NE part of the Transdanubian Range (Gerecse Mountains). In contrast, the Lower Cretaceous sequences show closer affinity with those in the SW part of the range (Bakony Mountains).

In the neighborhood of the Tata horst, the Eocene formations have been lost due to intense denudation prior to the Oligocene. The Oligocene is represented by a fluvial succession of remarkable thickness. In the Late Miocene (Pannonian Stage in the Pannonian Basin), shallow lacustrine, gravely, sandy sediments containing a characteristic Congeria fauna were laid down. During the Quaternary, sedimentary sequences of varied lithology were formed. The Tata horst may have been uplifted to reach its present-day altitude in the Middle Pleistocene. It was followed by travertine deposition along the faults. In travertine beds, Paleolithic tools and bones of coeval animals were found at the foot of the Kálvária Hill.

Late Triassic platform limestones and Tr/J boundary

The Upper Triassic (Rhaetian) Dachstein Limestone is the oldest formation exposed on the Kálvária Hill (Fig. 12). The outcropping beds provide a superb example of the cyclic peritidal inner platform deposits. They show every characteristic of the Lofer cycles. The meter-scale cycles reflect probably high frequency sea-level oscillation triggered by orbital forcing (precession cycle).

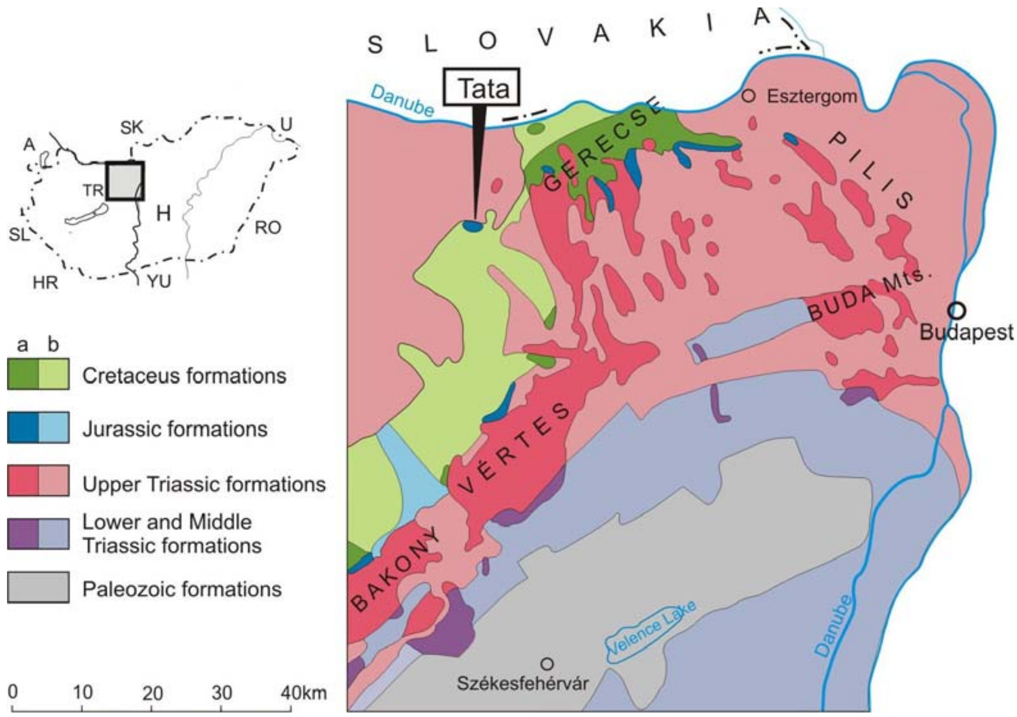


Fig. 12 A) Location of Tata within the Transdanubian Range, Hungary; B) Pre-Tertiary geological map showing the geological setting of the Mesozoic horst at Tata

In the northwestern part of the protected area, four and a half cycle are exposed on the steep wall of a former quarry. A disconformity surface occurs at the base of the cycles, as a rule. Few decimeter thick stromatolitic layers with desiccation phenomena overlie it. Rip-ups of microbial mat origin and tiny black pebbles are common. The thin basal layers are followed by a thicker subtidal one, containing plenty of Megalodonts, embedded usually in life position. In the topmost part of the cycles, the tidal flat facies, punctuated by subaerial erosion surfaces, returns. The uppermost cycle of the Dachstein Limestone is truncated. The very sharp and surprisingly flat truncation surface commonly cut the Megalodonts, suggesting that the erosion affected already lithified deposits. Solution cavities and moldic pores of Megalodonts in the topmost layer are filled by marine sediments of the overlying lowermost Jurassic layers. Although the truncation horizon appears to be parallel with the bedding planes of the Dachstein Limestone, detailed measurements of the sections revealed that in reality a very low angle angular unconformity does exist (Haas 1995).

Based on the previously described characteristics, the following scenario can be reconstructed for the Tr/J boundary interval. At the very end of the Rhaetian started the disruption of the Dachstein platform. Due to sea level drop at the end of the Triassic, the slightly tilted blocks were probably affected by subaerial erosion. Rising sea level in the earliest Hettangian led to inundation and hence the hard bottom was affected by submarine bioerosion. Biotic crisis after the massive extinction at the Tr/J boundary may have contributed to the drowning of the former carbonate platform and the long lasting lag-time during the Early to early Middle Hettangian.

A well-developed network of neptunian dikes cuts the Dachstein Limestone and the lowermost Jurassic beds. Pink wackestone or mudstone fills the fissures, originating form the overlying Jurassic sequence and also contains pieces of the host rock. Width of the dikes may reach 20–30 cm. Formation of neptunian dikes was connected to the extensional tectonics, leading to disintegration of the Dachstein platform during the Early Jurassic. In addition to the passive sediment deposition in the fissures, seismic shocks of earthquakes injected the unconsolidated fill of the dikes into the previously formed cavities of the host rock at high pressure (Lantos 2005).

Continuous Mediterranean-type Jurassic succession

A complete, gently dipping Liassic succession is exposed in a single continuous section in the part of the conservation area, whereas the Dogger and Malm layers are visible in the upper terrace of the park. So, walking in the park, the visitor may get an impression on a typical Mediterranean Jurassic sequence. Stratigraphic subdivision of the 43 m-thick sequence is presented in Fig. 13.

The basal layer of the Jurassic series is pinkish crinoidal limestone, 30–40 cm in thickness. It is overlain by a 20–30 cm-thick oncoidal bed, containing microbially encrusted fossils, predominantly ammonites and brachiopods. Concurrent occurrence of *Alsatites* s.l. and *Paracaloceras*? sp., found in the oncoidal bed, refers to an interval from the upper part of the Middle Hettangian to the lower part of the Upper Hettangian (Pálfy 1997).

The basal beds are overlain by about 10 m-thick, light pink, thick-bedded limestones (Pisznice Limestone). Along with scattered crinoid ossicles, benthic foraminifera are also

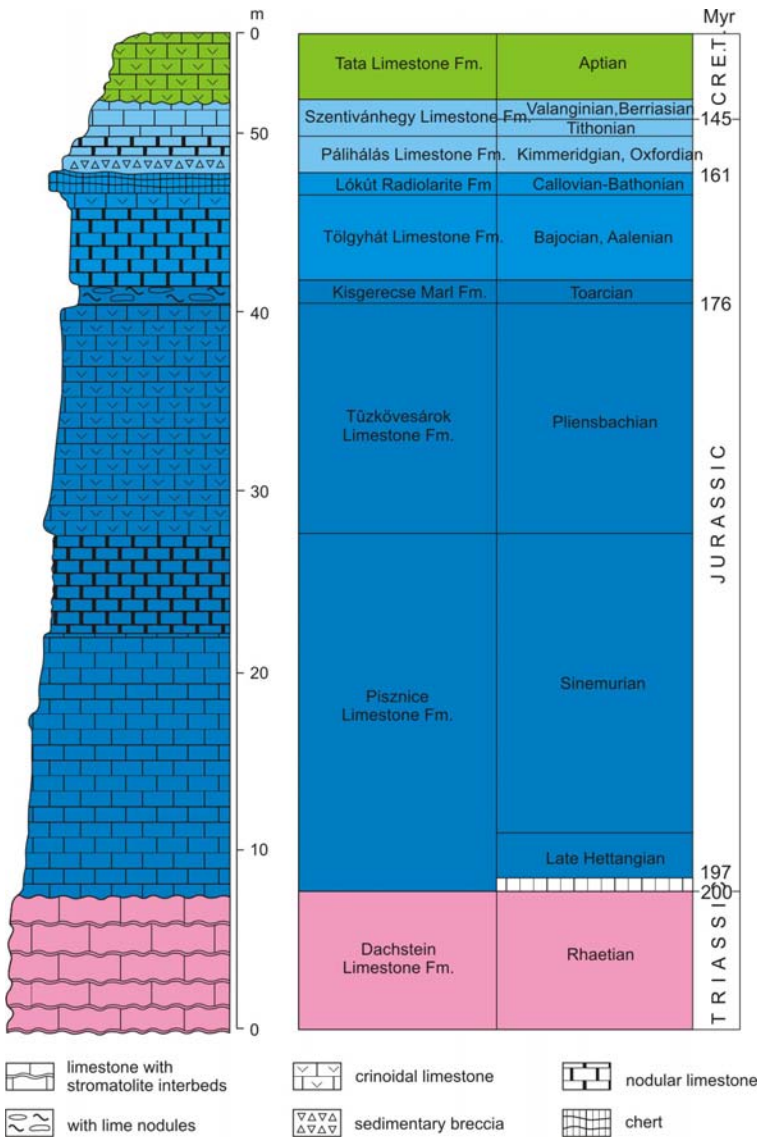


Fig. 13 Lithology and stratigraphy of the Mesozoic succession exposed on the Kálvária Hill, Tata

common. In these beds, dm-size lens-shaped filled cavities occur, parallel with the bedding. They are filled by bioclastic wackestone and mudstone internal sediment below, while the upper part of the cavity is lined by fibrous calcite and filled by drusy spare.

The 4 m-thick middle member of the Pisznice Limestone is made up of well-bedded, somewhat darker pink limestone with brachiopod and lenses of crinoid sand. It is overlain by about 6 m-thick red limestones, showing features of the “Ammonitico Rosso”. Uneven, commonly stylolithic bedding planes punctuate it. The layers are rich in brachiopods and ammonites. Tubular casts of burrowing organisms, perpendicular to the bedding planes, are abundant. Based on ammonites, this member was classed to the Upper Sinemurian (Géczy in Fülöp 1976).

The next unit of the Liassic series is made up of red crinoidal limestone of Pliensbachian age. It is characterized by an intensely bioturbated structure and a rich shallow marine microfossil assemblage with crinoids, benthic foraminifera, sponge spicules and ostracodes.

The basic change in the microbiofacies in the overlying less then 1 m-thick Toarcian marl layer suggests a sudden deepening. Instead of the benthic elements along with ammonites, pelagic *Bositra* valves and radiolarians become prevailing. It is covered by red nodular limestone (Tölgyhát Limestone) in a thickness of 5 m. Fe–Mn oxide nudules, 1–2 cm in diameter are common. Chondrites-type trace fossils occur on the bedding planes. Based on the rich ammonite fauna, the age of this unit is Aalenian--Bajocian (Fülöp, 1976). A half-meter thick allodapic crinoidite bed and an even thinner *Bositra* coquina layer end the Tölgyhát Limestone.

The Bathonian–Callovian interval is represented by a 1 m-thick, strongly condensed radiolarian chert bed. In this time interval, the sedimentary basin may have got below the CCD, reaching the maximum depth in the Jurassic. On the other hand, slump structures in the chert bed indicate articulated bottom topography.

The whole Malm succession is very condensed and its total thickness is not more then a few meters. The Oxfordian is represented by a grain-supported breccia bed, which can be interpreted as a toe-of-slope deposit. The Kimmeridgeian is red nodular limestone locally with smaller or larger lithoclasts and slump structures. The sequence is punctuated by Fe–Mn coated hard grounds with plenty of ammonites. The Ammonite-pavement is one of the main attractions of the geological garden. Moreover, the hard ground is segmented by neptunian dikes indicating renewal of the extensional tectonic movements in the Late Tithonian–Berriasian interval. The Tithonian–Berriasian sequence is not thicker than 1.5 m. It is made up of light gray and lilac–reddish *Calpionella* wackestone, rich in ammonites and brachiopods.

Cretaceous sediments

Palaeogeographically the Tata block is part of the Gerecse Mountains in the Jurassic, albeit it is neither a real basin (as the major part of the Gerecse), nor a submarine high as the Gorba High but a transitional area inbetween the two since the end of the Early Jurassic. The Lower Jurassic succession in thickness and development is the same as in the Gerecse. The continuation henceforth (from the Toarcian) is different from both the basin and the high. The rate of sedimentation in the Hettangian to Pliensbachian is 140 cm/Ma while in the Toarcian to Tithonian 35 cm/Ma although during the last interval the sedimentation is not lacunose like on the highs but more condensed than in the basin. From tectonic and sedimentological points of view the 0.5 m thick “Oxfordian breccia” bed is worth mentioning. It is extended not only in the Gerecse but it can be found also in the Bakony Mountains. The Szentivánhegy Limestone, the youngermost bed of the"Jurassic sequence" is Valaginian. According to Szinger et al. (2008), based on thin section study the 1.5 m thick formation can be subdivided into 3 parts. Lower part is biomicritic packstone with larger size echinoderm and mollusc fragments, the middle one is packstone/wacestone type with gastropods and embryonic bivalves, while the upper one is wackestone/packstone fith fine grained bioclasts. In dissolution residue and in thin section varied benthic and less plaktonic foraminifers also occur. Radiospirillinids are restricted for the Lower Cretaceous. The frequency of *Spirillina*, *Trocholina*, *Miliolina* and *Paalzowella* species, echinoderm fragments, embryonic bivalves gave evidences about the transportation from shallower environment. These data support the idea, mentioned above that the Tata block was in transitional position between the submarine high and the basin. In the condenced formation 5 biozones have been distinguished Fig. 14.

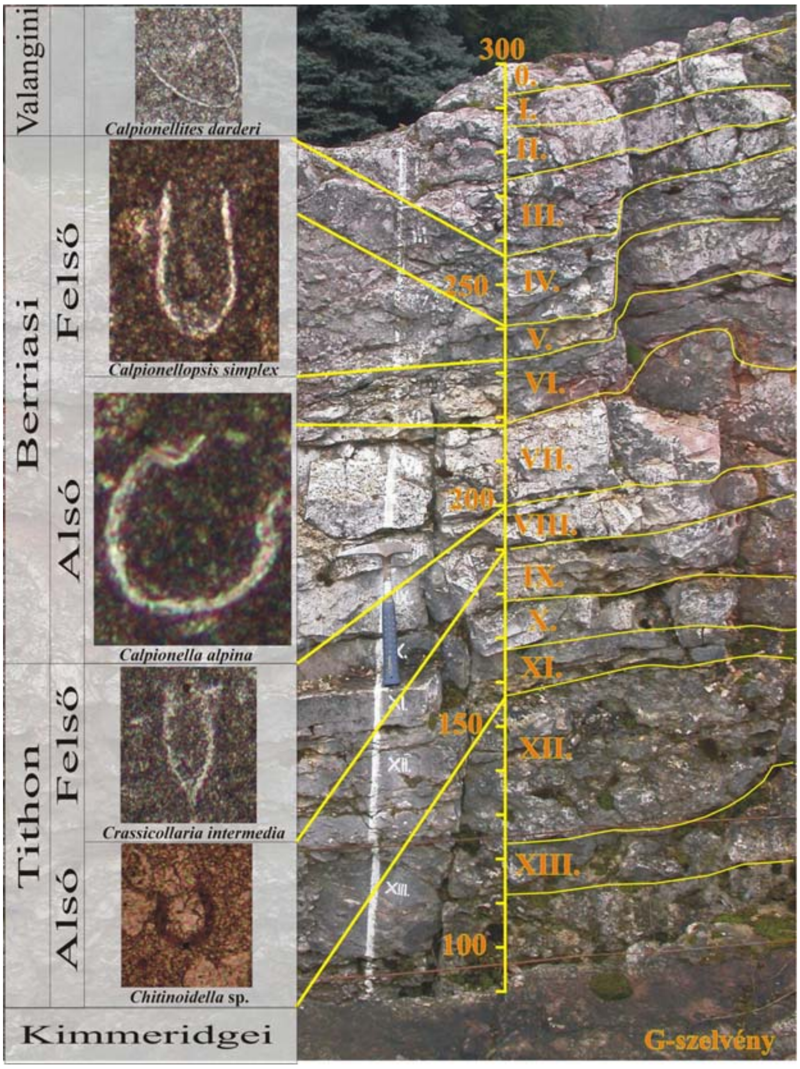


Fig. 14 Biozonation of the Szentivánhegy Limestone, Kálvária Hill, Tata

The next sequence here started in the Late Aptian/Early Albian, and this Late Aptian/Early Albian crinoidal limstone is a charactristic unit of the Hungarian Cretaceous sediments, so we discuss Tata Limestone here and at the next stop, at Eperkéshegy section as well in details.

The peculiarity of the depositional situation is that the crinoidal Tata Limestone is underlain by various type of rocks of varied ages from the Middle Jurassic till the Valanginian, deposited on the submarine erosional hardground surface of Tithonian-Berriasian sediments (Fig. 15).

Fig. 15 The grey Tata Limestone Formation (TMF) and the underlying reddish Tithonian-Berriasian sediments at Kálváriadomb, Tata

Since decades, this hardground was interpreted as the results of sub-aerial erosion. After extensive paleontological studies (Szives 1999, Szives et al. 2007) it turned out that the fossil accumulation at the base of the Tata Limestone is heavily condensed, in the basal lenses four Aptian and the lowermost Albian ammonite zones are documented, therefore the erosional surface must have been at least partly, a submarine product. This idea is supported by the planktonic foraminifers found in the thick Mn-Fe iron crusts, covered the base of the Tata Limestone (Görög & Szinger 2007). At the base of the formation several pebbles of varied origin also occur (Fig. 16).

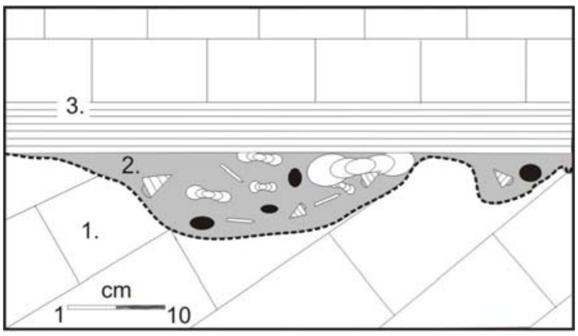


Fig. 16 Stratigraphic position of the fossiliferous basal pockets (2) situated between the underlying Tithonian limestone (1) and the overlying crinoidal Tata Limestone Formation (3)

In the local „deepenings" of the hardground, at the base of the Tata Limestone Formation, a highly condensed fossiliferous lenses trapped with excellent, size-sorted ammonite assemblage indicate Middle Aptian to Early Albian age (Fig. 17). Due to the bottom currents, microfossils are completely swept away from the fossiliferous lenses. The ammonite assemblage is fully descripted and figured (Szives 1999, Szives & Monks 2002, Szives et al. 2007, Szives 2008).

Fig. 17 Fossiliferous TMF basal lenses at Tata

The Tata limestone itself is a grey, coarse-grained silicified crinoidal limestone with three microfacies types. These microfacies marks a shallower environment than the older pelagic carbonates (Lelkes 1990). The three microfacies were formed in different depths (after Lelkes 1990): microfacies A is a fine-grained packstone with sponge spicules and this represent the deepest environment. Microfacies C is a variety of coarse-grained grainstones which can be interpreted as a shallow subtidal sediment. The most common is microfacies B, which is a transition between the A and B microfacies.

The deposition of the TLF marks the end of a long pelagic period of the area (Lelkes 1990), in the late Aptian-early Albian (Szives et al. 2007) the region was uplifted and become dominated mainly by benthonic forms, especially crinoids.

References

Fülöp, J. 1976: The Mesozoic basement horst blocks of Tata. – *Geol. Hung. Ser. Geol.* **16**, 228 p.

Görög Á. & Szinger B. 2007: Késő-jura – kora-kréta plankton foraminiferák a tatai Kálvária-dombról. – *10. Őslénytani Vándorgyűlés, Budapest*

Haas, J. 1995: Az Északi Gerecse felsőtriász karbonát platform képződményei (Upper Triassic platform carbonates of the northern Gerecse Mts.). – *Földt. Közl.* **125/3–4**, 259–293 (in Hungarian with English abstract).

Haas, J. 2007: Geological garden in Tata, Transdanubian Range, Hungary. – *Nova Acta Leopoldina* NF 94, **349**, 237–351.

Haas, J. & Hámor, G. 2001: Geological garden in the neighborhood of Budapest, Hungary. – *Episodes* **24**, 257–261.

Koch, N. 1909: Die geologischen Verhältnisse des Kalvarienhügels von Tata. – *Földt. Közl.* **39/5**, 285–307.

Lantos, Z. 2004: Liassic neptunian dikes and redeposited basin deposits. – PhD *Thesis, Eötvös Loránd University, Budapest* (in Hungarian with English abstract).

Lelkes, Gy. 1990: Microfacies study of the Tata Limestone Formation (Aptian) in the northern Bakony Mountains, Hungary. – *Cretaceous Research* **11**, 273–287.

Lóczy, L. 1906: Geológiai megfigyelések a tatai Kálvária-hegyen (Geologic observations on the Kálvária Hill, Tata). – *Földt. Közl.* **36**, 206–207 (in Hungarian).

Pálfy, J. 1997: Age of the Jurassic basal layers in the Kálvária Hill, Tata. – *Manuscript, Hung. Mus. Nat. Hist.*, Budapest (in Hungarian).

Peters, K. 1859: Geologische Studien aus Ungarn. II. Die Umgebung von Visegrád, Gran, Totis und Zsámbék. – *Jahrb. Geol. Reichanst.* **10**, 4.

Somogyi, K. 1914: Das Neokom des Gerecsegebirges. – *Jahrb. Ung. Geol. Anst.* **22/5**, 295–370.

Szinger, B., Görög, Á. & Császár G. 2008: Late Jurassic – Early Cretaceous sections from Tata (Pelso Unit, Hungary): Sedimentology, marine palaeontology, palaeoenvironment. – *11. Őslénytani Vándorgyűlés, Budapest*

Szives, O. 1999: Ammonite biostratigraphy of the Tata Limestone Formation (Aptian–Lower Albian), Hungary. – *Acta Geol. Hung.* **42/2**, 401–411.

Szives, O. 2008: Two new species of *Constrictoceras* nov. gen. (Ammonoidea) from the Early Cretaceous (Aptian) of Hungary. – *Geobios* **41**, 297–305.

Szives, O. & Monks, N. 2002: Heteromorphs of the Tata Limestone Formation (Aptian-Lower Albian), Hungary. – *Palaeontology* **45/6**, 1137–1149.

Szives, O. (ed.): Szives, O., Csontos L., Bujtor L. & Főzy, I. 2007: Aptian-Campanian ammonites of Hungary. – *Geologica Hungarica series Paleontologica* **57**, 1–188.

Towson, R. 1797: Travels in Hungary, with a short account of Vienna in the year 1793. – London.

Stop 2. Grindstone quarry, Lábatlan

Orsolya SZTANÓ, Ottilia SZIVES

Introduction

Stop 3 is on Bersek Hill, in a huge exposure producing for the local cement factory. Stop 2 is next to the village, where grindstone was quarried in the old days.

In the Gerecse Mts the Mesozoic comprises a second-order transgressive-regressive cycle. High rate of basin subsidence was accompanied by the built up of an extremely thick succession of shallow carbonate platform deposits in the Late Triassic (to be visited at the Tata Geological Park). In the Early Jurassic this platform rifted, and small submarine highs with non-deposition, fault-controlled slopes with Hierlatz-type coarse-grained crinoideabrachiopode-bearing limestones and small basins with pelagic ammonitico-rosso type limestones were formed. These basins were the deepest in the Mid/Late Jurassic, when deposition of radiolarite and siliceous limestones took place. For the Late Jurassic the pelagic carbonate deposition got restored. As the Jurassic was the period of extension, with the onset of the Cretaceous compression began, as indicated by the siliciclastics derived from obducting and colliding plate fragments.

The Cretaceous siliciclastics are divided into four major units. The first is a thin breccia, generated by gravitational redeposition of Late Jurassic limestones, cherts and volcanics (Felsővadács Member in Berriasian). It is overlain by marls intercalated with thin bedded turbidites and slump deposits (Bersek Marl Formation of Valanginian-Hauterivian). The following unit is made up of sandy turbidites (Lábatlan Sandstone Formation of Barremian), which is overlain by thick bedded sandstones and conglomerates (Köszörűkőbánya Member of Late Aptian – Early Albian).

Grindstone quarry

In the Lábatlan-36 borehole (Árgyelán 1995) as well as in the quarry alternating conglomerate, sandstone and siltstone layers are seen (Fig. 18), with four different facies units. The bulk of gravel is well rounded chert with some palaeo-basalts, -gabbros which together with the chrome-spinells of the sandstone beds were derived from an ophiolithic suit (Árgyelán 1995). In varying quantities hardly rounded fossiliferous limestone boulders of coeval reefal origin are also abundant. The silty beds as wells as the siltsone clast contain large foraminifera and nannofossils revealing the Aptian/Albian age (Sztanó & Báldi-Beke 1992). In the borehole facies A and C alternated, while in the outcrop sedimentary structures of A, B, C and D can be studied (Sztanó 1990).

Facies A is massive greenish grey sandstone. Cross-bedding of planar, solitary sets up to the thickness of 0.4 m in thickness and silty intercalations are present. These are supposed to be formed by high-density turbidity currents. In the siltstones small-scale slump folds occur in the central part of the quarry revealing some gentle slopes.

The clast-supported, graded conglomerate bed (facies B) is 5m thick on an average. Large sole marks, 20 cm wide grooves above the underlying siltstones are noteworthy at the NE quarry edge, and a several meter deep incision into the underlying siltstones marks the thalweg in channel-cross section at about the central part of the quarry. Clast imbrica-

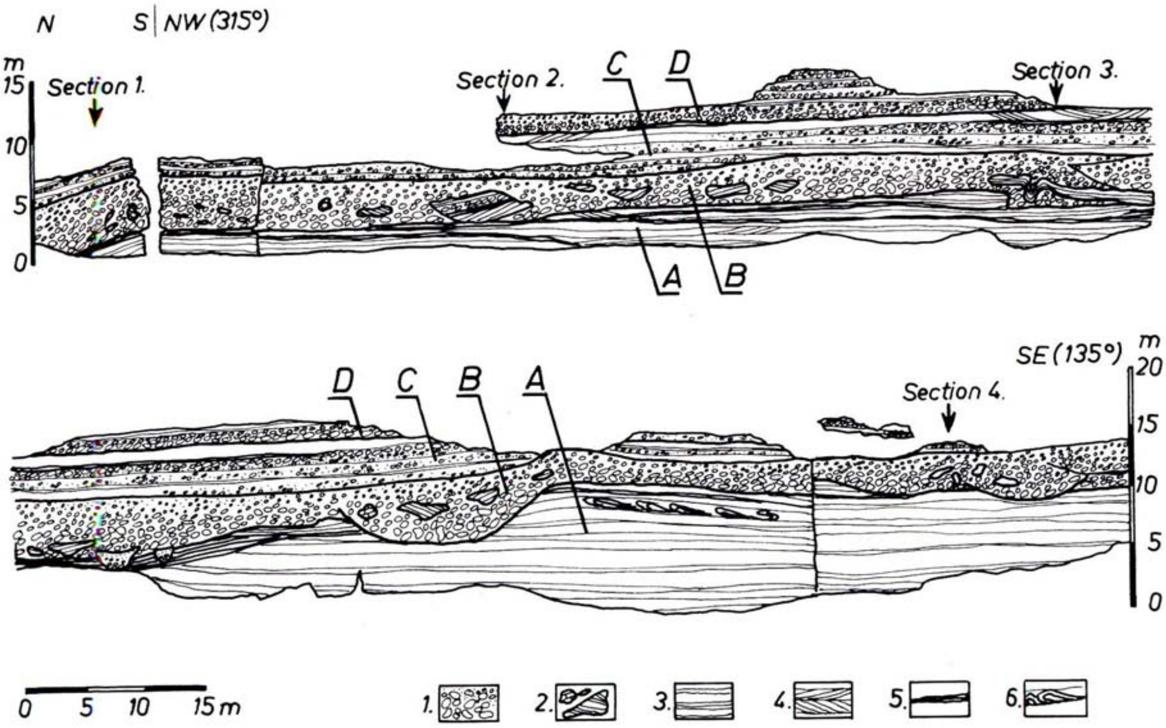


Fig. 18 Profile of Grindstone Quarry. 1. Conglomerate, 2. limestone olistholits and intraformational rip-up clasts, 3. sandstone, 4. crossbedded sandstone, 5. siltstone, 6. slumps

tion of a(p)a(i) type, common rip-up mud-clasts, large intraformational slabs of sandstone and even bedded sandstones and conglomerates indicate the erosive power of the high-density gravelly turbidity current. The large slabs had been eroded from undercut channel walls.

In general the topmost layers above the main conglomerate (B) are alternating conglomerates and sandstones of smaller thickness (facies C).

In some of the uppermost beds an abrupt change in the ratio of rock-forming components occurs (facies D). The quantity of the limestone pebbles increases to 60% with a subordinate amount of chert pebbles and other lithoclast. One these beds can be seen at the SE quarry end, where this composition is associated with normal grading. The same composition also occurs in matrix-supported inversely graded beds pointing to small-volume debris flows. Thus alternation or even flow transition of debris flows and turbidity currents may have taken place. In contrast to the change of composition, no significant difference in the palaeocurrent direction (imbrications) was measured. Transport direction from NE to SW was determined mainly by means of long axis type pebble imbrication. Tectonic rotation of the area was determined by palaeomagnetic measurements (Márton & Márton 1985), so the original transport might have been from SE to NW.

Facies A, C and D may have deposited on sheet-like terminal lobes or shallow mid-fan channel-fills. Facies B is interpreted as a channel fill at about the mid-fan / upper-fan transition. True upper-fan deposits with a large quantity of overbank fines are not knows from the area.

The Lábatlan Lbt-36 borehole was penetrated in the quarry-yard and three, definetly different age-data were published recently. The integrated nannofossil, foraminifer and ammonite data of Sztanó & Báldi-Beke (1992), Görög (1995) and Főzy et al. (2002) which indicated late Barremian-early Aptian age are in strong contrast with the Aptian-Albian or early Cenomanian nannofossil data of Félegyházy & Nagymarosy (1991, 1992). According to the most recent ammonite and nannofossil data (Főzy et al. 2002) the age of the borehole ammonite fauna clearly represent late Barremian-early Aptian age.

Therefore, Lbt-36 borhole doesn’t reach in depth – so practically younger – than the top succession of the Bersek Hill which will be visited as the next stop today. This means the Bersek Hill elevated quite high, so there should have been serious post-Early Aptian tectonic movements between the two, rather close blocks of Köszörűkőbánya and the Bersek Hill, unfortunatelly it is not have been traced yet

References

Árgyelán, G. 1995: Petrographical and petrological investigations of the Cretaceous clastic sediments of the Gerecse Mountains, Hungary. – *Általános Földtani Szemle* **27**, 59–83.

Félegyházy, L. & Nagymarosy, A. 1991: New data on the age of the Lower Cretaceous formations of the Gerecse Mountains (Hungary). – *Geologica Carpathica* **42**, 123–126.

Félegyházy, L. & Nagymarosy, A. 1992: Calcareous nannoplankton stratography of Lower Cretaceous formations in the Gerecse Mountains. – *Acta Geologica Hungarica* **35/3**, 251–262.

Főzy, I., Fogarasi, A. & Szives, O. 2002: A Lábatlan–36 fúrás felső-barrémi–apti rétegsorának integrált ammonitesz és mészvázú nannoplankton biosztratigráfiája. [Integrated ammonite and calcareous nannofossil biostratigraphy of the borehole Lábatlan–36 (Upper Barremian–Aptian, Transdanubian Range, Hungary).] – *Földtani Közlöny* **132/1**, 45–56.

Görög, Á. 1995: A Vértes-előtér és a Gerecse-hegység kréta időszaki nagyforaminifera vizsgálata és sztratigráfiai értékelése. – *Általános Földtani Szemle* **27**, 85–94.

Márton, E. & Márton P. 1985: Tectonic and palaeoclimatic aspects of palaeomagnetism studies in the Transdanubian Central Mountains. – *Acta Geologica Hungarica* **28**, 59–70.

Sztanó, O. 1990: Submarine fan-channel conglomerate of Lower Cretaceous, Gerecse Mts., Hungary. – N. *Jb. Geol. Paläont. Mh.* **1990/7**, 431–446.

Sztanó, O. & Báldi-Beke M. 1992: New data prove Late Aptian – Early Albian age of Köszörűkőbánya Conglomerate Member, Gerecse Mountains, Hungary. – *Annales Universitatis Scientiarum Budapestiensis de Rolando Eötvös Nominatae, sectio Geologica* **29**, 155–164.

Stop 3. Marl Yard, Bersek Hill, Lábatlan

Orsolya SZTANÓ

From the three levels of the quarry system facing northward the lower and the upper can be visited. The general lateral persistency of bedding is interrupted by huge erosional surfaces in the lower part and by slumping in the upper part of the sequence.

In the lowermost yard three types of sediments can be distinguished. Grey thin-bedded argillaceous marl, alternationg with calcareous marl and cm-thick fine to medium grained sandstone beds. In the marl aptychii and internal moulds of ammonites can be collected, suggesting depositional depth between ACD and CCD. The two types of marls make up couplets, which are in turn organized into thickening to thinning boundles of about 5, also showing increasing to decreasing carbonate content. The varying carbonate content of the marl is regarded as the result of varying bioproduction in the photic zone, thus may reflect orbitally-controlled climatic forcing during deposition (Fogarasi 1995a). The thin sandstones are sharp based, often graded, and were produced by turbidity currents. At first a depositional environment around the outerfan or at the basin plain was suggested. However, bedding is not uniformly parallel and continuous. In the lower yard and also at left-hand side going up to the second yard on the eastern side large-scale, low-angle erosional surfaces, oblique beds of the same lithology are seen. In some of these geometries, multiple pinching out can be detected, and/or the dip degree of strata is increasing gradually upwards and finally fit to the original bedding. These erosional scours are interpreted as slump scars with back-filling, and as large slump sheets (Fig. 19). These morphologic elements can be formed only on submarine slopes, and the presence of the scars indicates even the upper slope (Fogarasi 1995b).

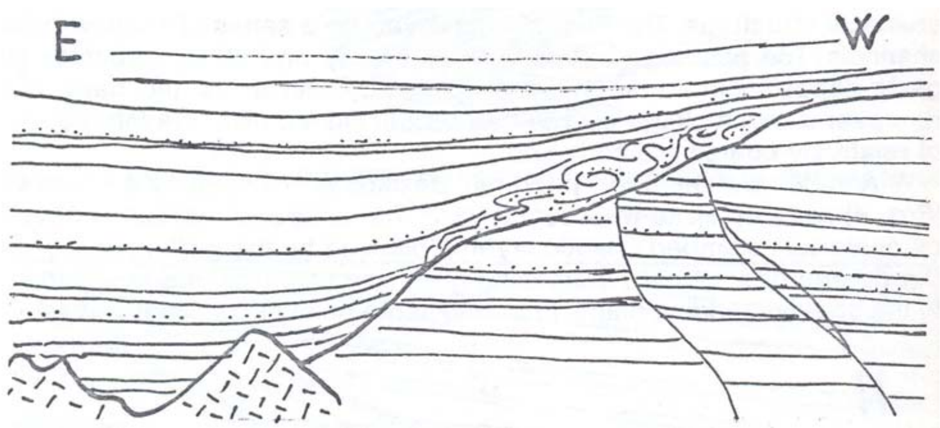


Fig. 19 Eastward facing slump scar

Upwards the colour changes from grey to variegated lilac, purple and green, parallel with the increase of the sand content. In the upper yard the sand-dominated formation can be studied. The formation begins with a huge and internally complex slump of 5 m of thickness. The erosion at the base of the slumped unit removed several marl layers (altogether deposits of an ammonite zone got eroded). Fold axes cannot be measured, thus the direction of the palaeoslope cannot be estimated from this feature. The greenish gray sandstone beds comprise thickening upwards cycles. The individual beds are about 10–40 cm thick, and various elements of incomplete Bouma sequences (Ta, Tb, Tc and their combinations) can be observed. Palaeocurrent directions from NE (present) were mearured from sole marks. The purple marls between the sandstone beds contain trace fossils (*Fucoidea*, *Zoophycos*, *Chondrites*, *Palaeodyction*, etc.) and a large variety of ammonoid moulds.

The uppermost coarse-grained bed is different from the others. It already contains lots of limestone clast derived from a coeval carbonate platform.

The sandy turbiditic successions known from the Bersek-hill and from small natural outcrops in the Gerecse Mts, as well as the overlying 400 m thick sand-dominated member known only from a nearby boreholes, indicate a dramatic increase in the depositional rate and a change in the environment. The relatively thin-bedded turbidites with equally thick shale intercalations were formed in an outerfan or lobe fringe environment, while the massive and thick-bedded turbidites of the Neszmély-4 borehole were deposited on the midfan. The transition towards the topmost, conglomeratic part of the succession was also demonstrated by a borehole (Lábatlan-36), drilled in the yard of the Grindstone quarry.

References

Fogarasi, A. 1995a: Sedimentation on tectonically controlled submarine slopes of Cretaceous age, Gerecse Mts., Hungary – working hypothesis. – *Általános Földtani Szemle* **27**, 15–41.

Fogarasi, A. 1995b: Cretaceous cyclostratigraphy of Gerecse Mts.: Preliminary results. – *Általános Földtani Szemle* **27**, 43–58.

Second day

Stop 1. Eperjes Hill, Olaszfalu

Géza CSÁSZÁR, Tamás POCSAI, Ottilia SZIVES

The site acted as the western margin of the Jurassic submarine high from the middle Early Jurassic till the early Early Cretaceous. It consists of highly lacunose Jurassic to early Early Cretaceous succession. There is a coincidence of the separation of the basins from the highs and the formation of the Penninic (Ligurian) ocean which happened in the middle Jurassic, when here, along a normal fault at the western margin of the submarine high thick scarp breccia developed from the Dachstein Limestone, the Lower Jurassic Kardosrét Limestone and Hierlatz Limestone. The poor late Middle Jurassic sediment supply was unable to fill the large holes among the big blocks. This is the reason why Oxfordian or Early Kimmeridgian sediments are found among the uppermost breccia bodies (Császár et al. 2007 – Fig. 20).

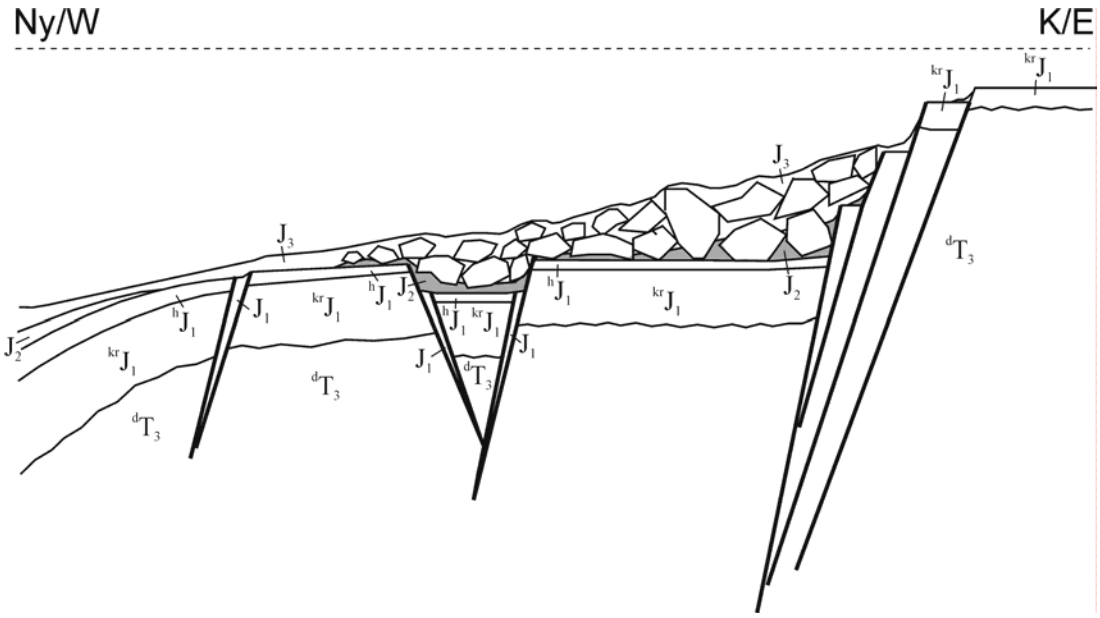


Fig. 20 A palaeogeograhic cross section with scarp breccia, Olaszfalu, Eperjes Hill in the Middle Jurassic. *Legend*: J_3 – Upper Jurassic; J_2 – Middle Jurassic; $^{h}J_1$ – Hierlatz Limestone; $^{kr}J_1$ – Kardosrét Limestone; J_1 – Lower Jurassic in general; $^{d}T_3$ – Dachstein Limestone

The Jurassic lacunose sedimentation was followed by an ephemeral sedimentation on the Eperjes Hill in the Early Cretaceous that produced small, coral- and worm colony-bearing lenses (Mizák 2002, Császár et al. 2002), and Brachiopod-bearing Barremian crinoidal limestone (Somody 1989). The sedimentation became more or less continuous only from the end of the Late Aptian, or perhaps from the beginning of the Early Albian (Szives 1999, 2001).

The area became land during the Early-Albian when the Tata Limestone (possibly together with the underlying, very thin and spotty Jurassic rocks) completely eroded from the eastern continuation of the Eperjes Hill. This is the time interval of karstification and the formation and accumulation of the Alsópere Bauxite Formation on the Ámos High situated on the southeastern limb of the syncline was formed this time (Fig. 3), thanked to the late Early Cretaceous compressional tectonic phase. The terrestrial sedimentation is followed by deposition of fluvial, non-marine and brackish-water clay-marl and marl (Tés Clay Formation) which are evidenced here by boreholes only. It is replaced by the Urgon platform carbonates namely by the Zirc Limestone Formation which is represented by its rudistid (mainly *Agriopleura* species) lower member (Eperkéshegy Limestone Mb) and the benthic foraminifera-bearing middle member (Mesterhajag Limestone Mb) – including 4 *Orbitolina* species (Görög 1996) – on the top of the Eperjes Hill (Császár 2002). Younger Cretaceous (Pénzeskút Marl Formation) is found on the surface to the East of the Eperjes Hill.

Tata Limestone, syn-tectonic sedimentation in a Late Barremian-Late Aptian compressional regime – a general overview

Main characters of the Tata Formation

Tata Formation mainly consists of orange to grey, fine to coarse grained crinoidal limestone. At some places brachiopod and/or ammonite-rich pockets are found at its base; otherwise the formation is very poor in macrofossils. Based on palaeontological investigations, the age of the Tata Limestone is Late Aptian to Early Albian(?) (see Fig. 21). On the base of the TLF at Eperkéshegy, also preserved a size-sorted, heavily condensed ammonite fauna (Fig. 22). The ammonite record here is very limited (Szives 2001, Szives et al. 2007), both in taxon variability and number of the specimens as well. Some new, early forms of the later radiated heteromorphic Hamitidae of the Albian had been described (Szives & Monks, 2002) together with the well-known late Aptian genera *Ptychoceras* and *Melchiorites*.

In western zones, the base of the formation could be Late Aptian, in eastern outcrops it is proven to be Early Albian (Szives in Szives et al. 2007). At the Eperkés Hill, Olaszfalu and Kálvária Hill, Tata some small pockets at the unconformity may yield Middle-, Late Aptian fauna as well (Császár et al. 2008, Somody 1987, Szives et al 2007). In western zones (Sümeg and environs) the sedimentation was continuous from the underlying pelitic,

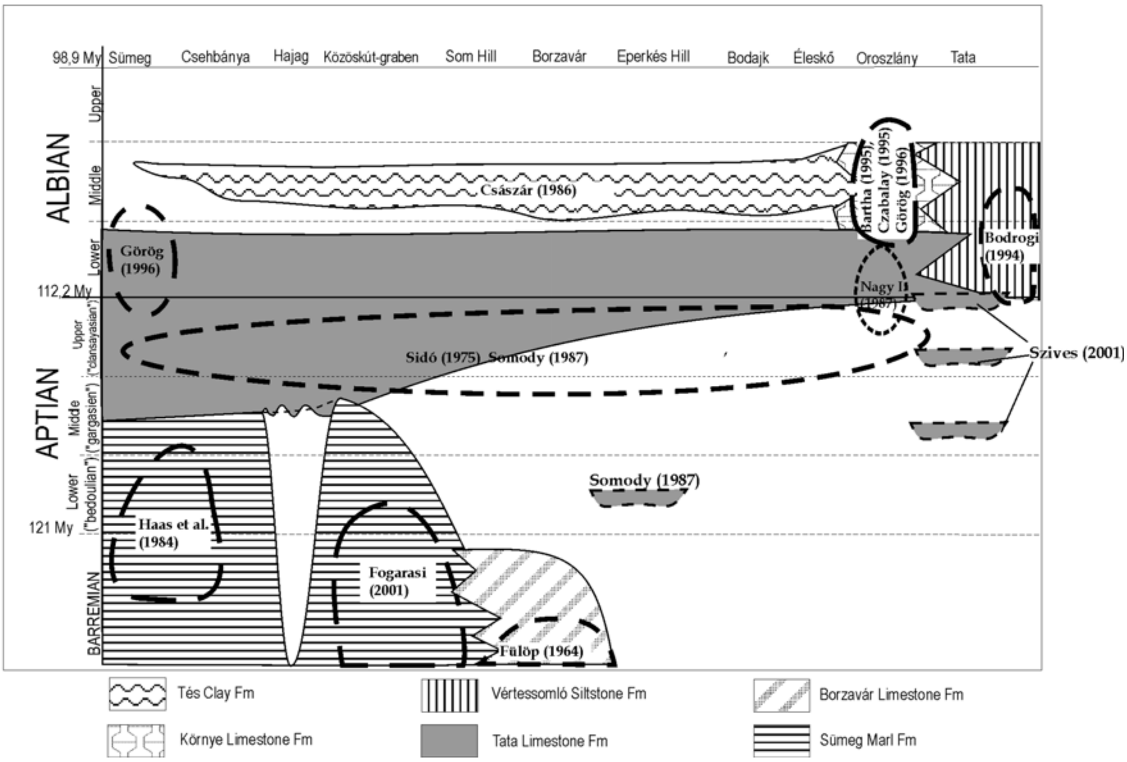


Fig. 21 Age and startigraphical relations of the Tata Limestone, based on literature

Fig. 22 Deposition of TMF at Eperkéshegy, the hammer indicates the hardground which the TMF is overlain

glauconitic Sümeg Marl, the age of which is Barremian to Early Aptian (Haas et al. 1984). In the Borzavár-Zirc area the Tata Limestone overlies a crinoidal limestone of late Valanginian to early Hauterivian aged Borzavár Formation (Főzy & Janssen, 2005), which could be a heteropic facies to the lower part of the Sümeg Marl. In the other areas the basis of the formation is erosional, at some places the erosion surface cuts down to Jurassic rocks or even deeper. At some places the biodetrital limestone overlies directly the Upper Triassic Dachstein Limestone. It is remarkable that there could be a major hiatus even at places surrounded by Sümeg Marl exposures.

The top of the formation is either a marked unconformity, or a facies transition. In the eastern areas the Tata Formation passes upward to a rudistid patch reef (Környe Formation) and further to the east to dark basinal silt (Vértessomló Formation) (Császár 1986, Mindszenty et al. 2001) which known only from borehole sections. Both of these formations have an Early to Middle Albian age (Görög 1996, Bodrogi and Fogarasi 2002, Szives et al. 2007). The facies transition between TLF and the overlying Vértessomló Siltstone Formation can be well observed in the tectonically repeated borehole section of Vértessomló Vst-8 borehole, penetrated in the Vértes Foreland. Unfortunatelly this borehole section doesn't contain any ammonite evidence related to the age of both sedimentary units. The Vértessomló Siltstone also was penetrated by several fossiliferous borehole sections drilled in Vértes Foreland as well, with ammonite specimens of *Douvilleiceras mammillatum* (Schlotheim, 1813), *Cleoniceras cleon* (d'Orbigny, 1841) and numerous *Beudanticeras* and *Parasilesites* specimens (for further ammonoid data of Aptian-Campanian sedimentary units see Szives et al. 2007). In other places to the west (at the Bakony Mountains, except Sümeg and environs), the Tata Limestone is covered by dark brackish, shallow marine marl (Tés Formation). Mindszenty et al. (2001) suggested that the facies belts moved to the west during Middle-Late Albian, due to a forebulge and fold-thrust propagation.

There is significant extraclast content in the formation. This is eventually manifested as spectacular breccias near the base of the formation (Fig. 23). The extraclasts originated from older members of the Mesozoic sequence. Average size of these detrital limestone fragments is different in each outcrop: at some places they are coarse grained (with boulder size limestone fragments), making up thick breccia bodies. At other places the extraclasts are represented by only some well sorted and well rounded, sand-grain sized limestone

Fig. 23 Poorly sorted, matrix supported limestone conglo-breccia from the Tata Limestone, Pénzesgyőr, Som Hill

fragments in the crinoidal matrix. The coarser members were interpreted so far as shallow marine transgressive basal breccias (Fülöp 1976).

Lelkes (1981, 1983) made a detailed microfacies study of the formation. He described three main microfacies types. According to him the deepest environment (~100 m) produced a sponge-bearing, micritic limestone ("A"-type). This was observed only at two distal places. The bulk of the formation was ranged to a medium grained, well sorted, cross-bedded, hummocky bedded bioclastic grainstone with extraclasts ("B"-type) deposited in shallow and medium depth (30–100 m). The shallowest (10–30 m), coarse grained heavily recrystallized grainstone with minor extraclasts ("C"-type) was also described only from a couple of exposures around the Hajag Mountains.

Deformation of the Tata Limestone basin

It is remarkable that most significant breccia localities are found in more complete Upper Jurassic – Lower Cretaceous successions, while Tata Limestone without breccias may cut down deep into the Mesozoic succession. The deeper marine breccia bodies appear to be localised along quick changes in the basement lithology, in other words along the limits of main pre- or syn-Tata structures. They are often on the lower, basinal part and very rarely on the uplifted regions.

The Tata Limestone is generally thinner, where it overlies older Jurassic and Triassic formations above uplifts. Facies are shallow water type with frequent cross-bedding. Extraclasts are present only as very small, rounded fragments.

The thicker sequences cover an Upper Jurassic-Lower Cretaceous succession with less or no hiatus in the basinal regions. These areas with less erosion are interpreted as of deeper basin facies, filled with thicker crinoidal limestone and marl. At the margins of these basins there are often coarse grained, graded breccia interbeds in a more clayey matrix (eg. Cseh-1 borehole). These breccia bodies were originated from the adjacent uplifted zones and are interpreted as scarp breccias.

In our view (Pocsai & Csontos 2006) the assumption of a syn-sedimentary topography during the deposition of the Tata Formation explains the observations on the facies, palaeo-transport and breccia occurrence. The localized deep water/slope breccias suggest that there were steep features in topography. Two hypotheses can be put forward to explain the topographic differences. The first suggests NW–SE trending, SW-dipping normal faults, the second suggests NW–SE trending, mainly NE dipping thrust faults. The presence of folds of NW–SE axial trend strongly supports the second possibility. Asymmetric erosion and facies differences could be explained by tilted normal fault blocks, but then the folds remain unexplained.

Detailed tectonic studies in the Transdanubian Range show that in the Barremian - Early Albian time interval there were possibly two almost orthogonal folding events (Albert 2000). One of the folding phases had a NW–SE to NNW–SSE axial direction and the other had NE–SW axial direction. Both seem to be covered by the Mid-Late Albian unconformity and shallow water marls. The second event produced long wavelength folds dominating the structure of the Transdanubian Range. The first one yielded much smaller folds and coeval thrusts (Albert 2000).

The Transdanubian Range is traditionally linked to the Eastern (Upper Austroalpine nappes, see Fodor et al. 2003) and/or to the Southern Alps. Strong genetic links exist towards the Dinaric platform as well. Except the Southern Alps, all of these regions are characterised by widespread shear and nappe formation, compressional movements in the pre-Middle Albian period. Westnorthwest-eastsoutheast trending shortening was proven in the Graz Palaeozoic, in the Gurktal Palaeozoic, the Greywacke-zone of the Eastern-Alps (eg. Neubauer 1987, Ratscbacher 1986). The Dinaric margin underwent NE-vergent shear followed by SW-vergent shear and folding prior to Albian (Csontos et al. 2004). In both places 120 to 100 Ma metamorphism indicates an Early Cretaceous nappe stacking episode (Fritz 1988, Milovanvic 1984, Belák et al. 1995, Kralik et al. 1987). The different shear directions all parallelize after the subsequent, paleomagnetically indicated rotations are taken into account (Márton et al. 2002, Márton and Fodor 1995, Csontos et al. 2004). In other words, the whole broader region is characterized by compression during the Early Cretaceous; therefore the presence of normal faults or extensional systems seems unlikely.

References

Albert, G. 2000: Folds of the Northern Bakony Mountains – *Master Thesis, ELTE Department of Physical and Historical Geology*, 97 p. (in Hungarian).

Belák, M., Pamić, J., Kolar-Jukovsek, T., Pécskay, Z., & Karan, D. 1995: Alpinski regionalnometamorfni kompleks Medvednice (SZ Hrvatska). – *First Croat. Geol. Congr. Proc.* **1**, 67–70, Geol. Institute, Zagreb.

Bodrogi, I. & Fogarasi, A. 2002: New data on the Lower Cretaceous of the Gerecse Mts. (Hungary) and the Lackbach section (Austria). – *Proceedings of the 6th International Cretaceous Symposium: Aspects of Cretaceous Stratigraphy and Paleobiogeography*, Vienna, 295–313.

Császár, G. 1986: Middle Cretaceous formations of the Transdanubian Central Range: stratigraphy and connection with bauxite genesis. – *Geologica Hungarica series Geologica* **23**, 295 pp. MÁFI, Budapest (in both Hungarian and English).

Császár, G. 2002: Urgon formations in Hungary with special reference to the Eastern Alps, the Western Carpathians and the Apuseni Mountains. – *Geologica Hungarica, Series Geologica* **25**, 1–209.

Császár G., Főzy I. & Mizák J. 2008: Az olaszfalui Eperjes földtani felépítése és fejlődéstörténete. – *Földtani Közlöny* **138/1**, 21–48.

Császár G., Mizák J., Barczi A., Vona M., Bauer N., Kenyeres Z. & Penksza K. 2002: Az Eperjes-hegy élettelen és élővilága. – *Eötvös Loránd Tudományegyetem*, Budapest, 62 p.

Császár G., Főzy I. & Mizák J. 2008: Az olaszfalui Eperjes földtani felépítése és fejlődéstörténete. – Geological settings and history of the Eperjes Hill, Olaszfalu, Bakony Mountains. – *Földtani Közlöny* **138/1**, 21–48 (in Hungarian with English abstract).

Csontos, L., Gerzina, N., Hrvatovic, H., Schmid, S. & Tomljenovic, B. 2004: Structural evolution of the Intrenal Dinarides: a preliminary study based on selected regions. – *Proceedings of the 5th International Symposium on Mediterranean Geology, Thessaloniki* **Vol.1**, 377–380.

Czabalay L. 1995: A study on the molluscan fauna in cretaceous rocks in the Gerecse Hills and the Vértes Foreland including its comparison with the environment. – *Általános Földtani Szemle* **27**, 109–131 (in Hungarian with English abstract).

Fodor, L., Koroknai, B., Balogh, K., Dunkl, I. & Horváth, P. 2003: Nappe position of the Transdanubian Range Unit ("Bakony") based on structural and geochronological data from NE Slovenia. – *Földtani Közlöny* **133/4**, 535–547 (in Hungarian with English abstract).

Fogarasi, A. 2001: Lower Cretaceous calcareous nannoplankton biostratigraphy, Transdanubian Range, Hungary. – *PhD Thesis*, 95 p. (in Hungarian with English abstract).

Főzy, I.& Janssen, N. 2005: A zirci Márvány-bánya cephalopodás padja és a Borzavári Mészkő Formáció kora. – *Földtani Közlöny* **135/3**, 353–360.

Fülöp, J. 1964: Lower Cretaceous (Berriasian – Aptian) formations of the Bakony Mountains. – *Geol. Hung. Ser. Geol.* **Tomus 13**, 1–77 (in Hungarian).

Fülöp, J. 1976: The Mesozoic basement horst blocks of Tata. – *Geol. Hung. Ser. Geol.* **Tomus 16**, 1–228.

Fritz, H. 1988: Kinematics and geochronology of Early Cretaceous thrusting in the nortwestern Paleozoic of Graz (Eastern Alps). – *Geodinamica Acta* **2**, 53–62.

Görög, Á. 1996: Cretaceous *Orbitolinids* of Hungary, stratigraphical and palaeoecological review. – *PhD Thesis, ELTE Department of Palaeontology,* 329 p. (in Hungarian with English abstract).

Haas, J., Edelényi, E.J., Gidai, L., Kaiser, M., Kretzoi, M. & Oravecz, J. 1984: Geology of the Sümeg area. – *Geol. Hung. Ser. Geol.* **Tomus 20**, 353 p.

Kralik, M., Krumm, H. & Schramm, M. 1987: Low grade metamorphism in the Northern Calcareous Alps and in the Greywacke zone: Illite-cristallinity data and isotopic ages. *In: Flügel, H. W. & Faupl, P. (eds.): Geodynamics of the Eastern Alps,* 164–178.

Lelkes, Gy. 1981: Quantitative petrography and depositional environment of the Tata Limestone Formation (Aptian) in the Northern Bakony Mountains. – *PhD Thesis*, 44 p.

Lelkes, Gy. 1983: Quantitative petrography and depositional environment of the Tata Limestone Formation (Aptian) in the Northern Bakony Mountains – *MÁFI Annual Report 1983*, 303–313. (in Hungarian with English abstract).

Márton, E., & Fodor, L. 1995: Combination of palaeomagnetic and stress data – a case study from North Hungary. – *Tectonophysics* **242**, 99–114.

Márton, E., Pavelić, D., Tomljenović, B., Avanić, R., Pamić, J. & Márton, P. 2002: In the wake of a counterclockwise rotating Adriatic microplate: Neogene paleomagnetic results from northern Croatia. – *Int. J. Earth Sciences (Geol. Rundsch.)* **91**, 514–523.

Milovanović, D. 1984: Petrology of low grade metamorphic rocks of the middle part of the Drina-Ivanjica Palaeozoic. – *Glas. Prir. Muz. Srp Zemlje*, Beograd **39,** 1–139.

Mindszenty, A., Csoma, A., Török, Á., Hips, K. & Hertelendi, E. 2001: Rudistid limestones, bauxites, paleokarst and geodynamics – The case of the cretaceous of the Transdanubian Range. – *Földtani Közlöny* **131/1-2**, 107–152 (in Hungarian with English abstractÍ).

Mizák J. 2002: Az olaszfalui Eperjes üledékhézagainak vizsgálata, földtani térképezés, természetvédelem. – *Diplomamunka*, ELTE Regionális Földtani Tanszék, 116 pp. Budapest.

Neubauer, F. 1987: The Gurktal thrust system within the Austroalpine region – Some structural and geometrical aspects. – *In: Flügel, H. W. & Faupl, P. (eds.): Geodynamycs of the Eastern Alps*, 226–236.

Orbigny, A. d'. 1840–1842: Paléontologie Francaise. Terrains Crétaces. I. Céphalopodes. – Masson, Paris, 662 pp, 148 pl. 1840: pp. 1–120; 1841: pp. 121–430; 1842: pp. 431–662.

Pocsai, T. & Csontos, L. 2006: Late Aptian–Early Albian syn-tectonic facies-pattern of the Tata Limestone Formation (Transdanubian Range, Hungary). – *Geologica Carpathica* **57**, 15–27.

Ratscbaher, L. 1986: Kinematics of Austro-Alpine cover nappes: changing translation path due to transpression. – *Tectonophysics* **125**, 335–356.

Schlotheim, E.F. von 1813: Beitrage zur Naturgeschichte der Vernsteirungen in geognostischer Hinsicht. – In: Leonhard, C.C. von: *Taschenbuch für die gesammte Mineralogie mit Hinsicht auf die neuesten Entdeckungen herausgegeben von Dr. Carl Caesar Leonhard.* pp. 3–134. pls. 1–4.

Somody, Á. 1987: Aptian brachiopods in the Northern Bakony Mts. – *Master Thesis, ELTE Department of Paleontology*, 104 p. (in Hungarian with English abstract).

Somody, Á. 1989: A survey of the Aptian Brachiopoda form the Northern Bakony Mountains (Hungary). – *Fragmenta Mineralogica et Palaeontologica* **14**, 41–62.

Szives, O. 1999: Ammonite biostratigraphy of the Tata Limestone Formation (Aptian-Lower Albian), Hungary. – *Acta Geologica Hungarica* **42/4**, 401–411.

Szives, O. 2001: Complex palaeontological review of the Ammonites fauna found in the basal layers of the Tata Limestone Formation. – *PhD Thesis, ELTE Department of Palaeontology*, 127 p. (in Hungarian with English abstract).

Szives, O. (ed.): Szives, O.; Csontos L.; Bujtor L. & Főzy, I. 2007: Aptian-Campanian ammonites of Hungary. *Geologica Hungarica series Paleontologica* **57**, 1–188.

Szives, O. & Monks, N. 2002: Heteromorphs of the Tata Limestone Formation (Aptian-Lower Albian), Hungary. – *Palaeontology* **45/6**, 1137–1149.

Szives, O. (ed.): Szives, O., Csontos L., Bujtor L. & Főzy, I. 2007: Aptian-Campanian ammonites of Hungary. – *Geologica Hungarica series Paleontologica* **57**, 1–188.

Stop 2. Abandoned quarry between villages Zirc and Borzavár

Géza CSÁSZÁR

The basin type Early Cretaceous succession of the South Bakony is getting shallower north-eastwards. This shallower and at the same time lacunose facies is developed in the Zirc Basin (Császár 2005, Fig. 24). The Maiolica type facies of the Mogyorósdomb Limestone is well developed in the Lókút Basin, at the same time it is replaced by the Borzavár Limestone Formation. It is violet and yellow in colour with plenty of crinoid fragments, among others well preserved calyxes of new species described from here. It also contains Brachiopods and Ammonites. The lack of calpionellids, the community and their preservation conditions indicate a relatively shallow in part separated basin with gentle water agitation. It may also contain chert nodules. The formation is capped by a hard ground surface and after an unknown gape the sedimentation is continued by shallow marine limestone of echinoderm ossicles (sea urchins and crinoids) with varied frequency of Brachiopod shells. There is a very small angular unconformity between the two formations and there are a few subangular pebbles at the base of the Tata Limestone Formation. The cross-bedding found in the upper part of the small cliff shows alternating current direction in the shallow basin. According to the most recent paleontological data (Főzy & Janssen, 2005), ammonites and belemnites from Borzavár Quarry indicates Late Valanginian to Early Hauterivian age of the Borzavár Limestone Formation.

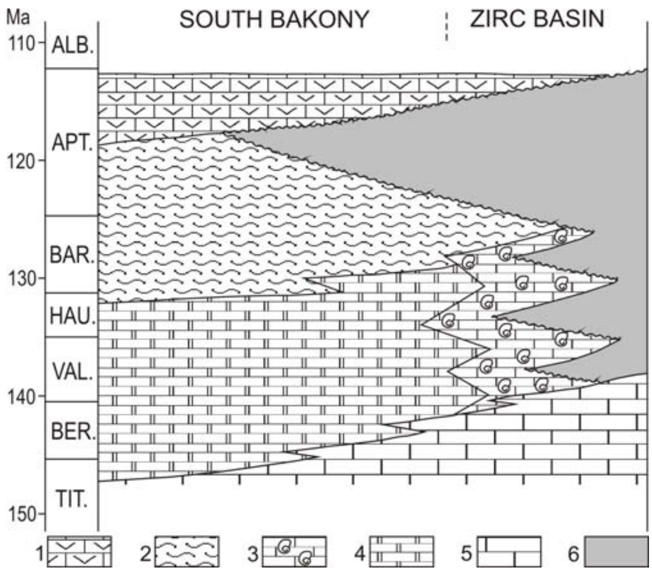


Fig. 24 Connection between the Mogyorósdomb Limestone, Sümeg Marl and the Borzavár Limestone Formation in the Zirc Basin. ***Legend:*** ***1*** **– Tata Limestone Fm; 2 –Sümeg Marl Fm; 3 – Borzavár Limestone Fm; 4 – Mogyorósdomb Limestone Fm; 5 –Szentivánhegy Limestone; 6 Gap**

A more condensed development of the Borzavár Limestone is known to occur in the "Marble quarry" on the Pintér Hill, at the northern margin of Zirc. The age of the 40 cm thick succession consisting of a couple of beds with full of ammonites represent Early Cretaceous. There is no consensus in the time span of these beds among palaeontologists, determind the elements of the associations so far.

References

Császár G. 2005: Magyarország és környezetének regionális földtana. I. Paleozoikum paleogén. – *ELTE Eötvös Kiadó, Budapest*, 328 p.
Főzy, I. & Janssen, N. 2005: A zirci Márvány-bánya cephalopodás padja és a Borzavári Mészkő Formáció kora. – *Földtani Közlöny* **135/3**, 353–360.

Stop 3. A quarry of Jásd

Géza CSÁSZÁR, Ottilia SZIVES

There are two profiles in the quarry of Jásd.

The 1st one comprises the middle and upper segment of the Zirc Limestone Formation, the 2nd one its upper segment and the basal beds of the Pénzeskút Marl Formation. The Zirc Limestone is represented by its Urgon type middle (Mesterhajag Limestone) and its non Urgon type upper (Gajavölgy Limestone) members. The Mesterhajag Mb is thick-bedded with lack (or scarce) of megafossils with abundant microfossils, especially benthic foraminifera (*Orbitolina texana*, *Nezzezata* sp., Textularidae, Miliolidae, etc. – Fig. 25). The texture in thin sections is prevailingly wackestone with plenty of pelletal and intraclastic grains, more over bioclasts and microfossils. The upper 2 m of the Mesterhajag Mb is called "lower faunal horizone" of ochre-yellow to yellowish-brown in colour. The lack of sorting, the increased biota content, and the upward increase of grain size are its typical features. Its most common fossil is the *Rhynchostreon* sp. of lumachelle-like appearance, but in addition to this several other fossils may occur, among others solitary corals. Close to the upper boundary of the Mesterhajag Mb there are greenish-grey, glauconitic limestone (lenses) or cavity fills derived from the overlying member rank unit.

The Gajavölgy Member is a grey to greenish-grey, heavily glauconitic limestone occasionally with pebble-like rock fragments of the underlying limestone at its erosional base. The limestone is bioturbated and contains carbonized plant remains, echinoids, pyrite nodules and fine to medium-grained sand size dolomite and limestone fragments of Trias-

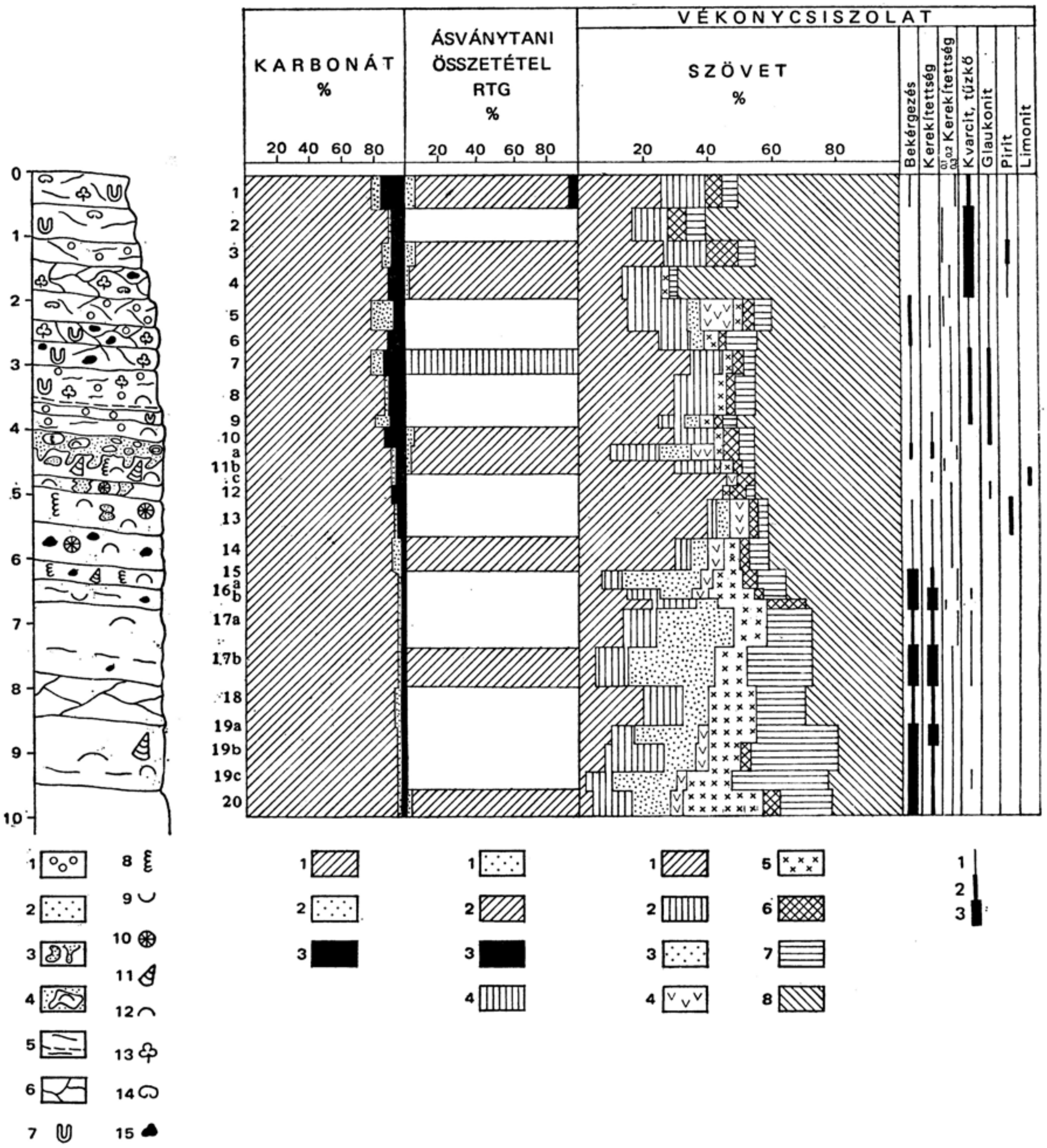


Fig. 25 Columnar section of the middle and upper member of the Zirc Limestone Fm, with the results of investigation, a quarry of Jásd.
***Legend: Columnar section*: 1 – Alien calcareous sand; 2 – Glauconite; 3 – Glauconitic cavity fill; 4 – Fossiliferous limestone fragment in glauconitic limestone; 5 – Clay intercalation; 6 – Fractured, clayay surface; 7 – Worm-tracks; 8 – Calcareous worm-tubes; 9 – Orbitolina; 10 – Corals; 11 – Gastropods; 12 – Bivalves; 13 – Carbonized plant remains; 14 – Sea urchins; 15 Pyrite and limonite noduls. *Carbonite*: 1 – calcite; 2 – Dolomite; 3 – Insoluble residue. *Mineralogical composition*: 1 – Quartz; 2 – Calcite; 3 – Siderite; 4 – Goethite. *Texture in thin section*: 1 – Micrite; 2 – Microsparite; 3 – Sparite; 4 – Mosaic sparite; 5 – Intraclasts; 6 – Extraclasts; 7 – Pelletal grains; 8 – Fossils. Frequency: 1 – Spars; 2 – A few; 3 – Mean; 4 – Frequent**

sic age. In thin sections echinoderm fragments are the predominant fossil constituent. The ratio of benthic microfossils are decreased in comparison with the underlying Mesterhajag Member, while number of planktonic organism (Calcisphaerulidae and planktonic forams: *Hedbergella delrioensis*, cf. *Rotalipora* sp., *Praeglobotruncana* sp.) rapidly increased.

The cavity fills in the Mesterhajag Mb and its erosional upper boundary are indications for a sea level drop and its overlying rock type for a rapid sea level rise. The occurrence of reworked Triassic dolomite and limestone fragments is very important from geological history point of view, because it is the first indication for the elevation of the south-eastern limb (wing?) of the Transdanubian syncline above the sea level and for the erosion in the Late Albian.

In the 2nd profile (Fig. 26), which is often cited as „Jásd-1 quarry", is the Gajavölgy Member of deep subtidal origin is overlain by the Pénzeskút Marl Formation. Its basal 40–50 cm thick bed is a condensed horizon characterized by a matrix with full of glauconite grains in which rock fragments derived from the Gajavölgy Mb, often phosphatized ammonites and small size echinoids are concentrated. Due to the extreme fossil abundancy of the basal bed, the ammonite fauna is well described (Scholz 1979; Szives et al. 2007), although best preserved specimens are mainly not from this locality. Recent ammonite data (Szives et al 2007) does not support the previously reported (Horváth 1985, 1989; Bodrogi 1989) Cenomanian age of the Pénzeskút Marl Formation at *any revised sections or boreholes* included Jásd-1 quarry, but further macro- and microfossil investigations together with isotope studies are on the way together with the search of new localities.

The glauconitic basal bed is covered by silty, nodular dolomitic marl of varied carbonate and decreasing glauconite content, also contains abundant macrofauna. Focusing on Jásd-1 quarry, it is sure that ammonites are from this dolomitic marl and not from the glauconitic basal bed. We can only guess about the exact collecting place and bed numbering concerning the ammonite profile, even if the bed number is given on the original label of each specimen. There are some questionnable forms in the purely Late Albian ammonite assemblage which were previously reported only from Lower Cenomanian deposits elsewhere (for example a single specimen of *Graysonites horvathi* n. sp.).

The faunistic composition of the ammonite assemblage from Jásd-1 quarry suggests Late Albian age, with typical *Stoliczkaia (S.) dispar* Zone forms, but does not let us to determine neither the exact subzonal age (from Szives et al. 2007) nor the paleoecological circumstances including water depth. Based on microfossil data (Bodrogi, 1989), the water depth might have achieved the bathyal zone.

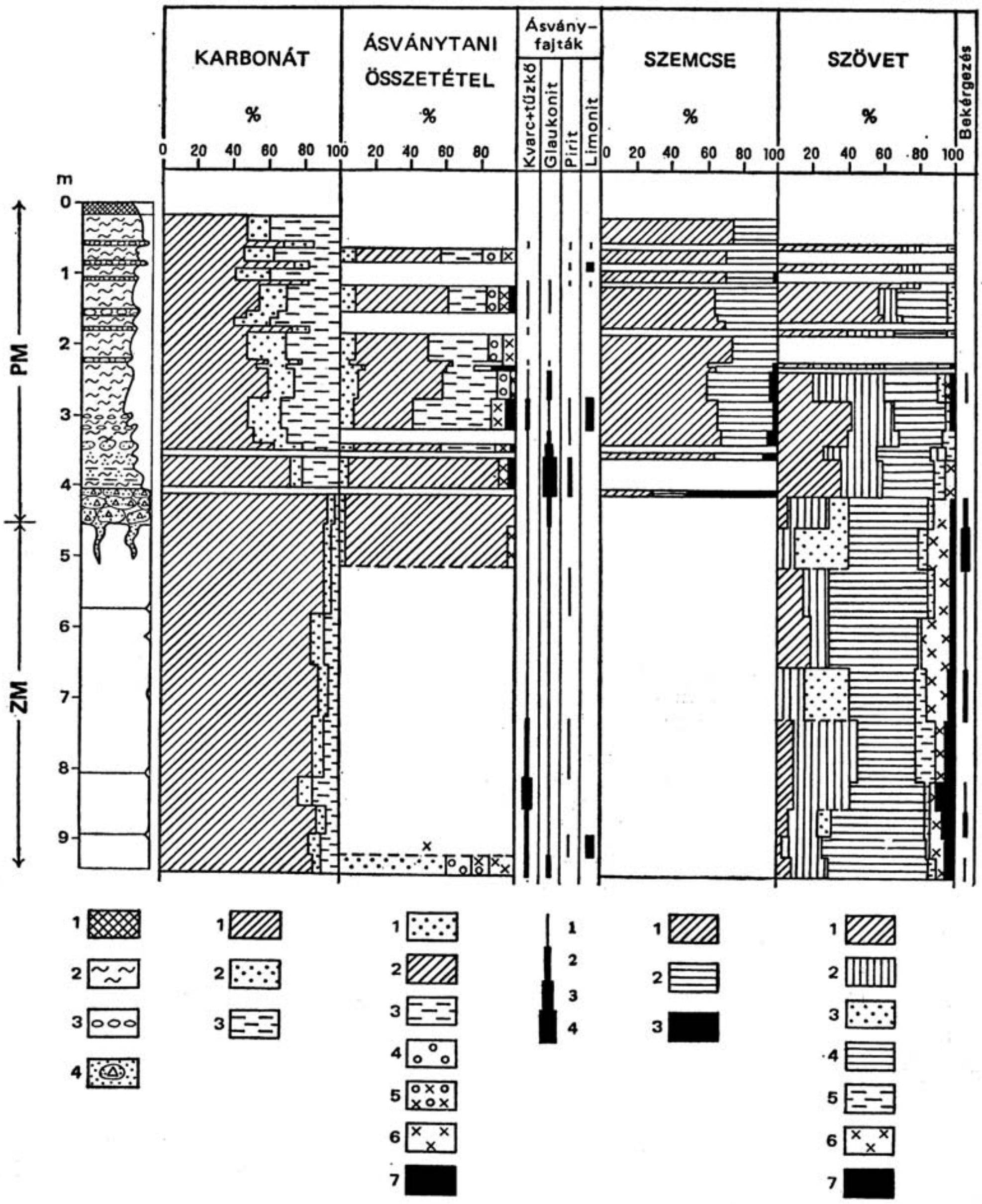


Fig. 26 Columnar section of the upper member of the Zirc Limestone Fm and the base of the Pénzeskút Marl Fm in the same quarry of Jásd like Figure 25.
***Legend: Columnar section*: 1 – Soil; 2 – Marl; 3 – Nodular limestone; 4 – Reworked rock fragment; ZM – Zirc Limestone Fm; PM – Pénzeskút Marl Fm; *Carbonite*: 1 – calcite; 2 – Dolomite; 3 – Insoluble residue. *Mineralogical composition*: 1 – Quartz; 2 – Calcite; 3 – Dolomite; 4 – Montmorillonite; 5 – Illite-montmorillonite; 6 – Illite; 7 – Chlorite (X: from insoluble residue. *Frequency of mineral species*: 1 – Spars; 2 – A few; 3 – Mean; 4 – Frequent. *Grains:* 1 – Clay; 2 – Silt; 3 – Sand. *Texture in thin section*: 1 – Micrite; 2 – Microsparite; 3 – Sparite; 4 – Bioclasts; 5 – Pelletal grains; 6 – Intraclasts; 7 – Extraclasts**

Overall, the fossil assemblages suggest that an extreme thick fossiliferous sedimentary unit deposited during the Late Albian and later, at many areas, eroded. The 2nd Albian eustatic sea level change – this time global one – made an end of the Zirc Limestone Formation in the Late-Albian and the sedimentation continued with hemipelagic Pénzeskút Marl Formation. According to several signals this global sea level rise was also preceded by a short term sea level drop again.

References

Bodrogi, I. 1989: A Pénzeskúti Márga Formáció plankton Foraminifera sztratigráfiája. Planktonic foraminifera stratigraphy of the Pénzeskút Marl Formation. – *A Magyar Állami Földtani Intézet Évkönyve* **63/5**, 127 p.
Horváth, A. 1985: Ammoniten-Stratigraphie der Pénzeskut Mergel-Formation. – *Österreichische Akademie der Wissenschaften Schriftenreiche der Erdwissenschaftlichen Kommissionen* **7**, 149–170.
Horváth, A. 1989: Zur Lebensweise der Ammoniten der Pénzeskut-Formation (Alb-Cenoman), Ungarn. In: Wiedmann, J. (ed.) 1989: Cretaceous of the Western Tethys. – *Proceedings of the 3rd International Cretaceous Symposium Tübingen, 1987,* 469–482.
Scholz, G. 1979: Die Ammoniten des Vracon (Oberalb, Dispar-Zone) des Bakony-Gebirges (Westungarn) und eine revision der Wichtigstein Vracon-arten der West-Mediterranen Faunenprovinz. – *Palaeontographica Abteilung A* **165**, 1–136.
Szives, O. (ed.): Szives, O., Csontos L., Bujtor L. & Főzy, I. 2007: Aptian-Campanian ammonites of Hungary. – *Geologica Hungarica series Paleontologica* **57**, 1–188.

Stop 4. Iharkút, Dinosaur-bearing alluvial complex of the Csehbánya Formation

Attila ŐSI, Andrea MINDSZENTY

Introduction

For over 15 years Iharkút was one of the largest open-cast mining sites of the Bakony Bauxite mines with ca. 400 000 tons of bauxite produced annually. Mining operations exposed the Late Cretaceous cover of the bauxite. The soft silty-clayey alluvial complex attracted the attention of devoted young palaentologists and thus Iharkút became a significant vertebrate-bearing fossil site soon. Simultaneously with the exploitation of bauxite, systematic excavations for fossils, conducted by A. Ősi and logistically supported by the Mining Company, were carried on for the past nine years in the area of baxuite deposits Németbánya-II and III. By 2007 the Mines have run out of commercial-grade reserves in these two deposits and recultivation with the idea of keeping the fossil site available for further research has begun.

In a palaeontological point of view, four main aspects of the Iharkút vertebrate-bearing site should be emphasized that are as follows:

1, The fauna is Santonian in age thus, as the only one in the European Late Cretaceous it fills the gap between older (Cenomanian) and younger (Campano-Maasrichtian) faunas.

2, The abundance of armoured dinosaurs is exceptional. With the five partial skeletons and hundreds of isolated bones of this herbivorous animal the Iharkút site is the richest in Europe.

3, The Iharkút site provided the first evidence for the fresh-water appearence of the pycnodontiform fishes and mosasaurs in the Late Cretaceous.
4, Besides the high-level taxa of vertebrates known both from Iharkút and other localities of Europe, the Hungarian site gave the first evidence of the crocodylian Hylaeochampsidae and a new family frogs.

General geology and stratigraphy

The occurrence is situated on the northern flanks of the synclinal structure of the Bakony Range (Fig. 27A). It is an elevated NW–SE striking elongate block built up by Late Triassic dolomites/limestones cross-cut by several NNW–SSE and E–W striking normal- and strike-slip faults. It is surrounded by downfaulted areas on three sides and bounded by the uplifted forested mass of the so called High Bakony to the NE. Jurassic and Early Cretaceous strata are known further off in the basement of the adjoining basins and to the NE in the High Bakony only.

The bauxite fills deep (50 to 90 m), tectonically controlled sinkholes on the karstified surface of the Late Triassic dolomite (Fig. 27B). This bauxite-filled paleokarst surface is the manifestation of one of the three major regional unconformities of the Transdanubian Central Range, each of which can be correlated with major tectonic events recognized in this particular segment of the ALCAPA (Alpine-Carpathian-Pannonian) structural domain. The Iharkút paleokarst is thought to have formed as a result of subaerial exposure related to flexural deformation and thrusting in early Late Cretaceous times. Compression and uplift were followed by an extensional phase and related subsidence: in Santonian times the karst terrain became gradually converted into an alluvial basin and covered by the sediments of the Csehbánya Formation. The Csehbánya Formation in turn is overlain by a classical transgressional sequence beginning with coal seams, shallow-water marls (Jákó Marl Formation) and then by pelagic Globotruncana marls (Polány Marl Formation) (Gellai et al. 1985, Haas & Jocha-Edelényi 1979, Tari 1993, 1994, Mindszenty et al. 2000).

Higher up in the stratigraphic sequence we find Middle Eocene (Lutetian) conglomerates and limestones which unconformably rest on the surface of the eroded Mesozoic formations. Middle Eocene strata are separated by another unconformity from Late Eocene conglomerates (considered as parts of a submarine fan). In the higher cover we find Oligocene clays, siltstones, sandstones and conglomerates (again an alluvial comp-

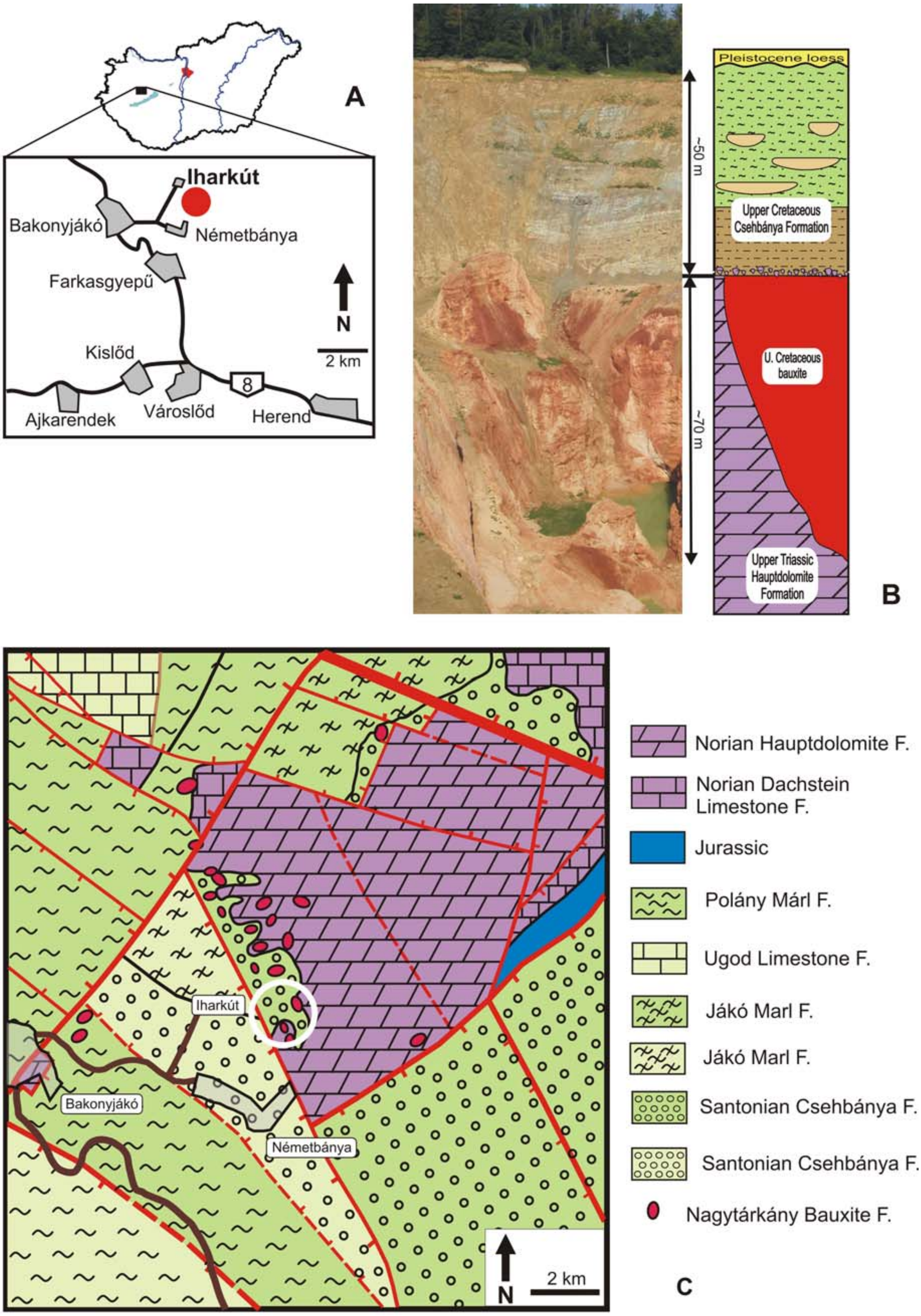


Fig. 27 A, Locality map showing the Iharkút vertebrate site. B, Shematic section of the open-pit Németbánya III (Middle Eocene conglomerates and limestones and Late Eocene conglomerates occur northwards.) C, Geological map of the Iharkút area (after Császár et al. 1978)

lex). A thin discontinuous blanket of Pleistocene loess covers the greater part of the area (Fig. 27B).

The Dinosaur-bearing Csehbánya Formation

The Formation is known, mainly from boreholes, in two NE–SW striking elongate embayments, each of approximately 60 x 15 km extension, one of them within the area of the Transdanubian Central Range the other, to the NW next to the town of Pápa. Its maximum thickness reaches 200 metres. Coarse-grained channel conglomerates were reported from the Csehbánya basin (next to the Iharkút block) only, the rest is all fine overbank sediments (Haas & Jocha-Edelényi 1979, Gellai et al. 1985, Jocha-Edelényi 1988) The Iharkút bauxite occurrence was the only place where as a result of open-cast mining the lowermost 50 m of the Formation could be studied also in surface exposures.

Deposition of the Csehbánya Formation began in the Santonian (Occullopollis-Complexiopollis-zone, Siegl-Farkas 1991). This stratigraphic position was approved also by paleomagnetic measurments carried out by Szalai (2005). Overlying the Iharkút bauxite the Csehbánya F. begins with 20 cm of a basal dolomite breccia (Fig. 27B), immediately followed upwards by fine silty-clayey overbank sediments organized into more-or-less regular, meter- to two-meter thick, paleosol-capped alluvial cycles interrupted by occasional shallow (2 to 3 m deep 30 to 60 m wide) fine sandy channels and thin (0,5 to 1 m thick) fine-sand-sheets (Fig. 28). The abundance and depth of such cross-cutting channels and sand-blankets increase upwards. Coarse sands and/or pebbles are rare, the latter restricted to the above mentioned channels. Tabular- or through cross-bedding is likewise rare. There are no desiccation cracks, and even secondary carbonate accumulation is not apparent (observable in thin sections only), however, smaller or larger ripped-up clay-clasts of the flood-plain are abundant at the base of some of the channels. Most paleosols – particularly those in the upper part of the exposed thickness – are hydromorphic, often aggadational. Fine-grained organic rich layers interpreted as flood-plain ponds and/or abandoned channels occur also in these upper levels. Discrete well-drained paleosol horizons were encountered predominantly in the lower 20 m of the exposed cover sequence only.

Most of the vertebrate fossils were recovered from an about 3 m thick, lenticular bed made up by coarse pebbly sand and organic rich silt and clay, interpreted as a shallow channel or pond filled up by episodic muddy debris flows, silt and sand (Fig. 28). The

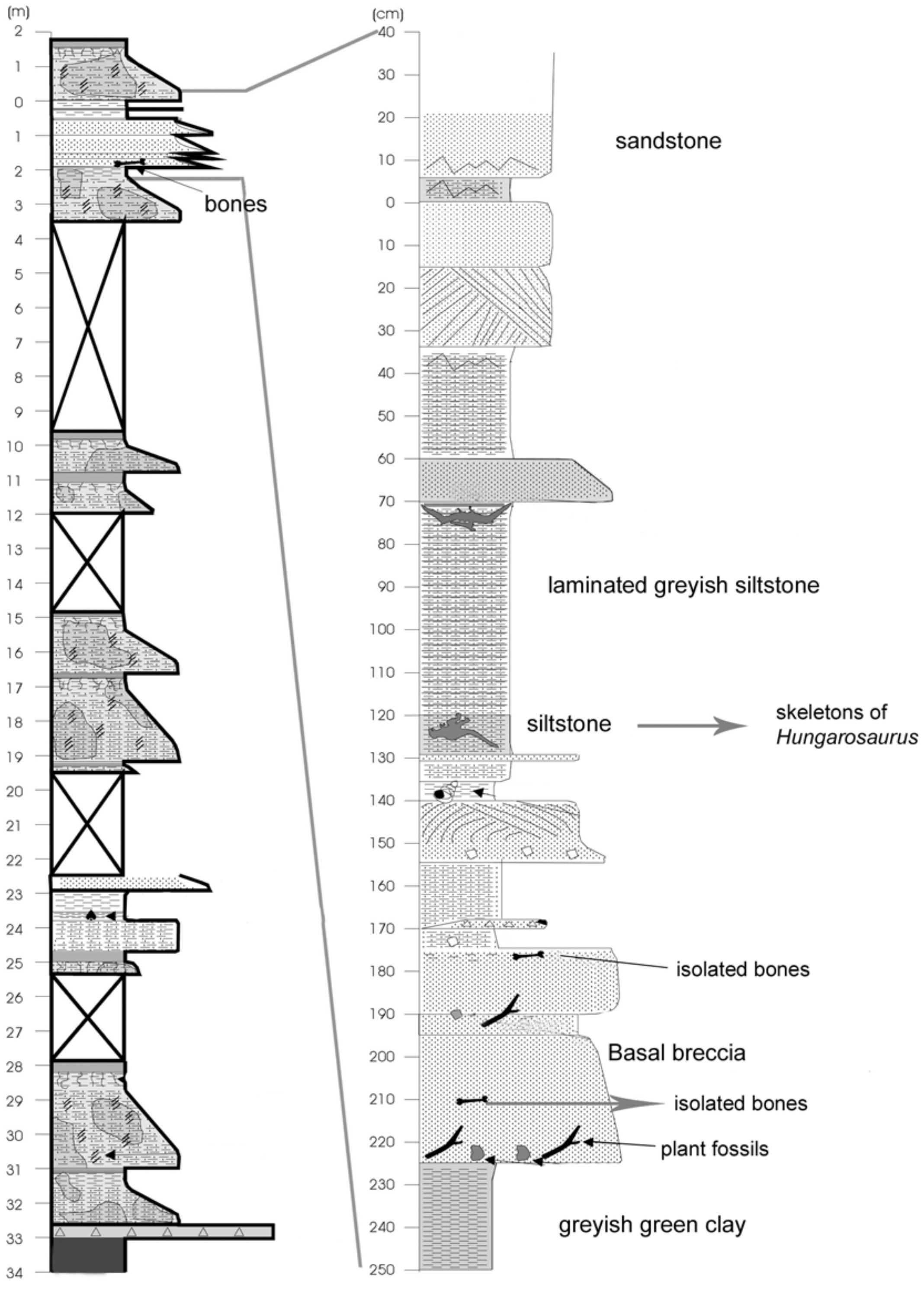


Fig. 28 Geological profile of the bone-yielding beds in the Upper Cretaceous Csehbánya Formation (after Tuba et al. 2006)

lower surface of this bed is clearly erosional, it cuts into the floodplain. Above, there follows a 20 to 50 cm thick silty-sandy layer rich in bones, bone fragments, plant debris (also charcoal) and clay flakes. At the bottom it is of chaotic structure, however its upper part is fining upward and passes into a dark-coloured, first cross laminated then parallel or wavy laminated silty clay, then clay. This fining upward sequence with the bone-bed-like layer at the bottom and laminated silt and clay on top is repeated several times. The individual coarser grained layers (20 to 40 cm thick each) are separated by 10 to 50 cm thick dark grey silty clay beds. Two partial skeletons of the armoured dinosaur, *Hungarosaurus* (see below) was recovered from such a dark grey muddy layer, while the rest of the rich vertebrate fossil fauna (mainly fragments and/or intact but disarticulated fragments) were all embedded in the bone-and-clay-breccia layer (Fig. 28). The fossil-rich succession is covered by a „sterile” sand layer above which the paleosol-capped alluvial cycles continue.

Diagenetic features/preservation

Most fossil bones recovered from the Csehbánya Formation are pyritized and very well preserved. Pyrite is the first diagenetic phase filling the cavities of the bone. It is followed by a later calcitic cement. Mineralization has not destroyed the original bone structure: Haversian channels and pyritized lacunae could be easily identified in thin section. Even the original bone-apatite (hydroxil-apatite nano-crytals) are preserved and could be proved by TEM (Tuba et al. 2006). Pyrite as an early diagenetic phase is abundant also in the enclosing sediments: pyritic concretions and disseminate pyrite were often encountered in the dark-grey to black organic-rich muddy-silty sediments, particularly in the fossil-rich shallow channel/pond.

Depositional environment

The predominance of fine overbank sediments, the abundance of hydromorphic paleosols, the presence of extensive fine-sand-sheets and only very shallow channels and the absence of lateral accretion structures suggest that the depositional environment must have been the flood-plain of a very low-gradient perennial river. Intercalated sand sheets are interpreted as crevasse splays. The upward increase of hydromorphy together with the increasing abundance of slightly coarser grained channel sands and crevasse splays point to accelerated subsidence and at the same time perhaps some tectonic uplift in the backgrounds. The absence of desiccation cracks and the subordinated amount of pedogenic carbonate accumulation shows that the climate must have been humid, however, with occasional flash-flood like episodes (as shown by the structure of the fossil-rich channel/pond-fill) suggesting some seasonality. This is further supported by paleobiological data (Ősi & Weishampel in press).

Pyritization of most bones and the overall predominance of pyrite as an early diagenetic mineral phase both in bones and the enclosing sediment calls for high concentrations of SO_4 in the pore-water – something quite unusual in alluvial environments normally characterized by siderite rather than pyrite. To postulate a river-dominated delta with occasional marine incursions would be the easiest solution. However, the fossil assemblage, recovered up to now, furthermore the stable isotope composition in the enamel of some aquatic vertebrates do not show either clearly marine or brackish elements therefore this hypothesis has to be discarded. It is suggested that saline pore-waters were introduced into the still unconsolidated sediment on shallow burial when as a result of accelerated subsidence relative sea-level began to rise. That this is a plausible explanation is shown also by the transgressional sequence overlying the Csehbánya Formation.

The fauna

Discovered in the year of 2000, the Iharkút area represents the single known Mesozoic continental vertebrate locality in Hungary and the only known, systematically excavated vertebrate site with a Santonian age in Europe. Field works (prospecting, excavation, screen-washing) of the last nine years provided one of the most abundant (more than 4000 bones and teeth) and diverse vertebrate faunas of the Late Cretaceous of Europe including 25 different taxa of lepisosteid and pycnodontiform fishes, albanerpetontid amphibians, bothremydid turtles, mosasaurid and teiid lizards, ziphosuchian and eusuchian crocodylians, non-avian theropod, ornithopod and nodosaurid dinosaurs, enantiornithine birds, and azhdarchid pterosaurs.

Lepisosteid fishes (Fig. 29B, C) have been identified on the basis of isolated conical teeth with sometimes lance-shaped tip and of rhomboidal ganoid scales and vertebrae. Pycnodontiform fish remains are most frequently flat, oval-shaped teeth but often complete jaws (prearticulare) are also preserved (Fig. 29A). The pycnodontyform remains from Iharkút especially important in a paleobiological an paleogeographical aspects, because they are the second occurrence of this generally marine group in Europe discovered in freshwater environment (Makádi et al. 2006, Gulyás 2008). (Pycnodontiform fishes from similar depositional conditions have been also mentioned from the Early Cretaceous of Las Hoyas, in Spain [Poyato-Ariza et al. 1998]).

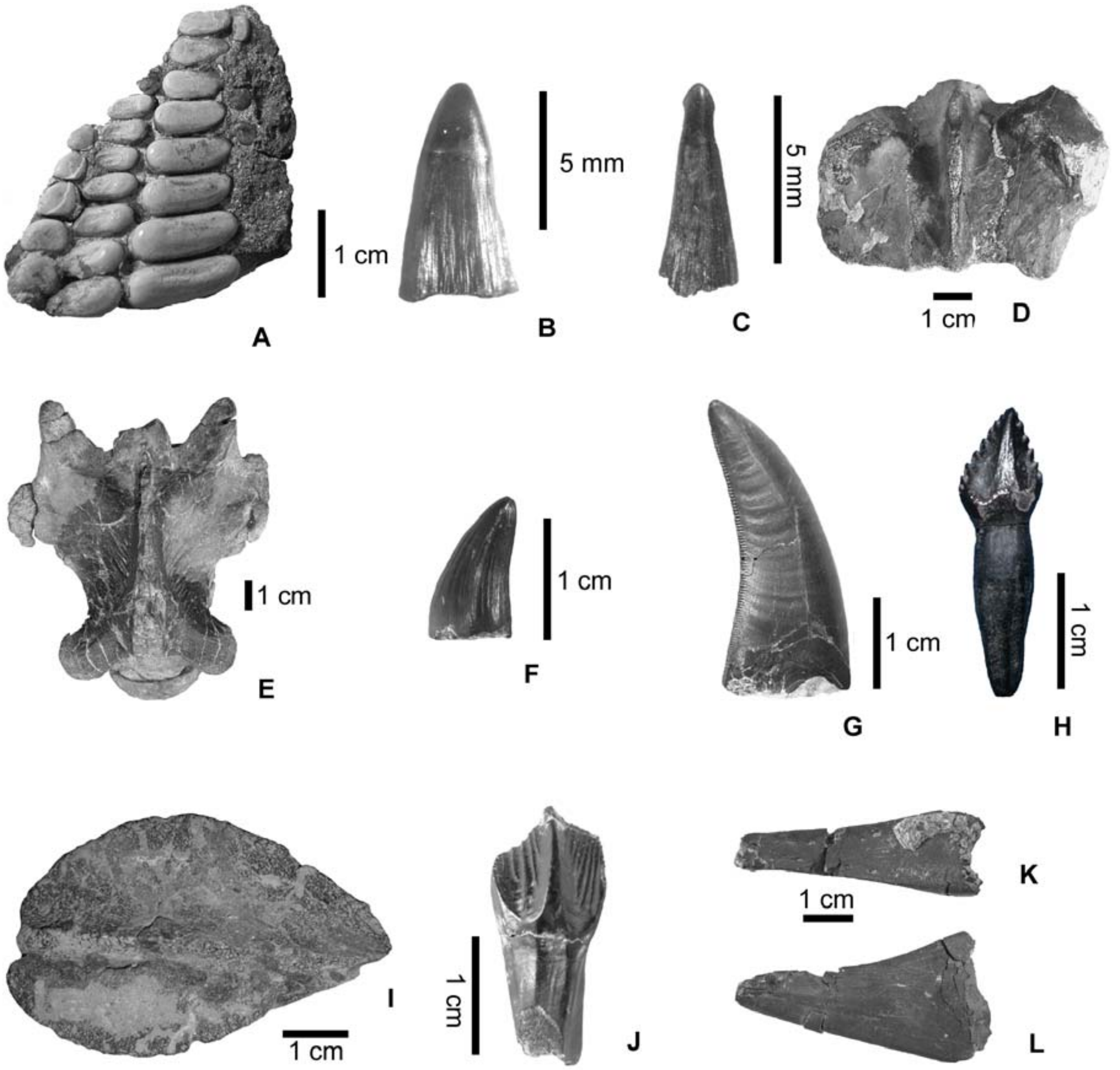


Fig. 29 Some of the most frequent vertebrate fossils from the Late Cretaceous Iharkút locality (after Ősi 2006). A, Pycnodontiformes indet. left lower jaw in occlusal view; B-C, Lepisosteidae indet. teeth; D, bothremydid turtle carapax fragment in ventral view; E, Mosasauridae indet. dorsal verebra in dorsal view; F, Alligatoroidea indet. tooth in ?anterior view; G, basal tetanuran tooth in ?lateral view; H, *Hungarosaurus tormai* tooth in ?lingual view; I, *Hungarosaurus tormai* dermal armour element in dorsal view; J, Rhabdodontidae indet. dentary tooth in lingual view; K, *Bakonydraco galaczi* tip fragment of the mandible in occlusal; L, and lateral view

Being one of the most productive methods to discover microvertebrate remains, screen-washing of at least three different bone-yielding strata provided among others dozens of amphibian bones. Fragmentary mandible and skull elements of an albanerpetontid form are frequent in the site. Systematic excavation also unearthed some important amphibian specimens (parts of the pelvic girdle and limb bones) which have been identified as the representatives of a new family of frogs (Szentesi 2006).

Dominance of different groups of reptiles is characteristic for the Iharkút fauna, as is usual in most Mesozoic continental vertebrate faunas around the world. Most of the reptilian families discoverd in the locality occur in other European Late Cretaceous continental localities as well, on the level of genera, however, several differences have been documented (Ősi 2004). Remains of turtles (especially their plastron and carapax fragments; Fig. 29D) are the most frequent vertebrate fossils in Iharkút. Besides these shell fragments, complete skull and mandibles, vertebrae, pelvic and limb elements were also discovered that helped to clarify the systematic position of this bothremydid turtle (Botfalvai 2005; Rabi & Botfalvai 2006).

Squamates are represented at least by several taxa, from among which a mosasaur (Fig. 29E) is the most peculiar. Remains of this group were usually found in shallow marine sediments. Frequent (both juvenile and adult) fossils of the Iharkút mosasaur (Fig. 29E), however, indicate that this animal certainly adapted to freshwater environment, similar to the pycnodontiform fishes (Makádi 2005).

Up to the present, remains of sebecosuchian, hylaeochampsid (Fig. 30) and alligatoroid (Fig. 29F) crocodylians have been identified from the Iharkút locality (Ősi & Rabi 2006). The relatively wide-spread sebecosuchid form, *Doratodon* sp. known also from Spain, Austria and Romania is represented by fragmentary cranial elements and isolated, anteroposteriorly serrated triangular teeth (Rabi 2009). The most peculiar taxon of crocodylians discovered in Iharkút is a small-bodied, heterodont eusuchian, *Iharkutosuchus makadii* Ősi, Clark & Weishampel, 2007 (Fig. 30) possessing unique, multicusped teeth in its jaws (Fig. 30B). It is the closest relative of *Hylaeochampsa vectiana* from the Barremian of the Isle of Wight, and they together represent one of the most basal groups of the modern crocodylians (Ősi 2008a).

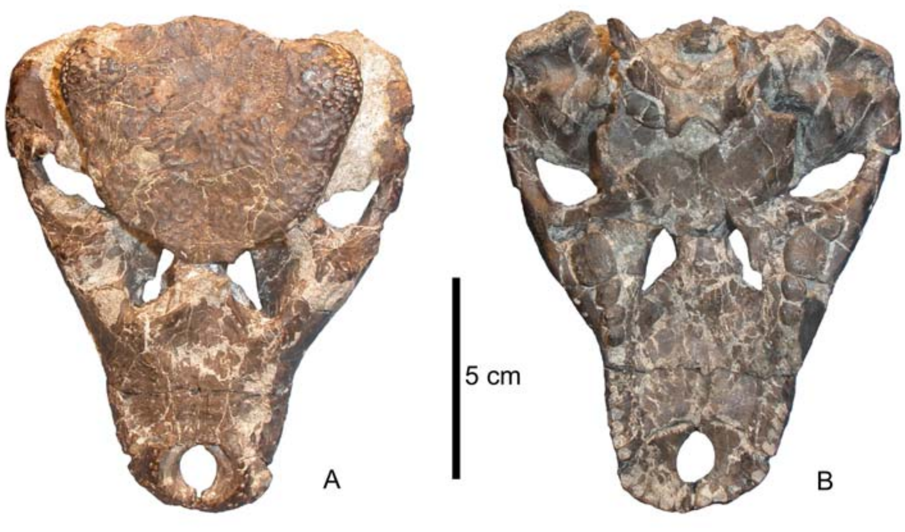


Fig. 30 Holotype skull of the basal, heterodont eusuchian crocodylian, *Iharkutosuchus makadii* from the Upper Cretaceous Csehbánya Formation, Iharkút, Bakony Mts

Dinosaurs, as the emblematic fossils of the Santonian Iharkút locality are known by two plan-eater forms of the Ornithischia and three different groups of carnivorous theropods. One of most characteristic feature of the Iharkút fauna is the great number of Ankylosaur bones. Five partial skeletons, and hundreds of isolated bones (mainly dermal armour elements) and teeth of a primitive nodosaurid ankylosaur, *Hungarosaurus tormai* have been found (Ősi 2005; Fig. 29I, H). Based on several fragmentary mandibles, teeth, vertebrae, fragments of the pectoral and pelvic girdles, and limb bones, a small-bodied rhabdodontid ornithopod was also a member of the Iharkút fauna (Fig. 29J). Comparaison of these remains with those of the two European genera *Zalmoxes* and *Rhabdodon*. indicate some differences. Similarly to sauropods, hadrosaurs appear to be also missing from Iharkút ecosystem.

Basal tetanuran teeth (Fig. 29G) are among the most frequent theropod remains indicating a 4-5 m long animal of the group that could have been the top-predator on land. An other primitive group of theropod dinosaurs, the Abelisauridae with Gondwanan affinities, is known by a single but diagnostic ungual phalanx. Remains of small-bodied theropods, such as teeth, vertebrae, pectoral girdle and limb bones can be referrd to the paravians (and probably into the Dromaeosauridae). Up to know, no material can be referred to the otherwise wide-spread sauropods. Based on almost a dozen of isolated limb bones, avian theropods are an important group in the Iharkút ecosystem. Some of these bird remains can be referred to the primitive group of Enantiornithes. Strongly different sizes of a few isolated limb bones indicate that a smaller thrush-sized bird together with a much larger enantiornithine existed in the area (Ősi 2008b).

Pterosaurs, usually rare elements of the European Late Cretaceous vertebrate communities are represented in Iharkút by a medium to large-sized azhdarchid pterosaur, *Bakonydraco galaczi* (Ősi et al. 2005). Up to know, more than 40 tip fragments (Fig. 29K, L), plus several isolated vertebrae and limb bones of *Bakonydraco* have been unearthed suggesting that this azhdarchid was very common in this area. During the excavations and screen-wasing of the last nine years no evidence of mammals have been found in Iharkút. Comparative anatomical and phylogenetic data taken from the vertebrate material suggest that the Iharkút area, perhaps together with other islands in the Apulian archipelago, existed as a refugium during the Santonian (Ősi & Rabi 2006, Ősi 2009).

The flora

Besides the vertebrate remains systematic excavations and screen-washing provided several plant fossils including carbonized tree trunks, twigs, well-preserved leaves and seeds. Preliminary studies suggest that both gymnosperms and angiosperms appear in the flora of the Iharkút ecosystem. A 7,5 metre long carbonized tree trunk have been identified as *Araucaria* sp. Most of the leave specimens can be related to the Laurales, but the presence of other taxa such as the Fabaceae, Hamamelidaceae, Salicaceae as well as the Pandanaceae was also proved (Duleba 2008).

Baranyi & Bodor (2008) studied the micro- and mezofossils of plants which further improved our knowledge on the age and the composition of vegetation of this ecosystem. After the work of Knauer & Siegl-Farkas (1992) focused on the Csehbánya Formation, these new investigations of extracted pollen/sporomorpha directly from the bone-yielding beds well supported the Santonian age of the vertebrate remains.

References

Baranyi, V. & Bodor, E. 2008: Mikro- és mezofosszíliák sztratigráfiai jelentősége és taxonómiai kérdései az iharkúti maradványok példáján. – *TDK dolgozat, ELTE.*

Botfalvai, G. 2005: Bothremydidae indet. from the Upper Cretaceous of Hungary (Csehbánya Formation). – *3rd Meeting of the EAVP, Kaupia,* Abstract **14**, 71.

Császár G., Haas J. & Jocháné Edelényi E. 1978: A Dunántúli Középhegység bauxitföldtani térképe a kainozoós képződmények elhagyásával (Bauxite geological map of the Transdanubian Central Range) scale: 1:100 000 – *MÁFI kiadvány*.

Duleba, M. 2008: Felső kréta növények az iharkúti lelőhelyről. – *Szakdolgozat, ELTE, Őslénytani Tanszék*, 72 pp.

Gellai, M., Knauer, J., Tóth, K. & Szantner, F. 1985: Az iharkúti bauxitterület rétegtani viszonyai. – *Földtani Közlöny* **115**, 23–44.

Gulyás, P. 2008: Freshwater pycnodontiform fishes from the Upper-Cretaceous (Santonian) Csehbánya Formation (Iharkút, Bakony Mountains, Hungary). – *6th Meeting of the EAVP, Spisska Nova Ves*, Abstract. p. 108.

Haas, J. & Jocha-Edelényi, E. 1979: A dunántúli középhegységi felsőkréta üledékciklus ősföldrajzi elmezése (Paleogeography of the Late Cretaceous sedimentary cycle in the Transdanubian Central Range). – *MÁFI Évi Jelentése 1977-ről (Annual Report of the Hungarian Geological Institute)*, 217–224.

Jocha- Edelényi, E. 1988: History of evolution of the Upper Cretaceous Basin in the Bakony Mts at the time of the terrestrial Csehbánya Formation. – *Acta Geologica Hungarica* **31/1–2**, 19–31.

Jocha-Edelényi, E. 1991: Palaeogeographic maps of the Senonian bauxite horizon. Scale: 1:250 000 – *MÁFI edition* (in Hungarian).

Knauer, J. & Siegl Farkas, Á. 1992: Palynostratigraphic position of the Senonian beds overlying the Upper Cretaceous bauxite formations of the Bakony Mts. – *Annual Report of the Hungarian Geological Institute of 1990,* 463–471 [in Hungarian].

Makádi, L. 2005: A new aquatic varanoid lizard from the Upper Cretaceous of Hungary. – *3rd Meeting of the EAVP*, Abstract. Kaupia, **14**, 106.

Makádi L., Botfalvai G. & Ősi A. 2006: A Late Cretaceous continental vertebrate fauna from the Bakony Mountains: fishes, amphibians, turtles, and squamates. – *Földtani Közlöny* **136/4**, 487–502 [in Hungarian].

Mindszenty, A., Csoma, A., Török, Á., Hips, K. & Hertelendi, E. 2000: Flexura jellegű előtéri deformációhoz köthető karsztbauxit szintek a Dunántúli-középhegységben (Rudistid limestones, bauxites, paleokarst and geodynamics. The case of the Cretaceous of the Transdanubian Central Range) – *Földtani Közlöny* **131/1–2**, 107–152 (in Hungarian, with English abstract).

Ősi, A. 2004: Dinosaurs from the Late Cretaceous of Hungary – similarities and differences with other European Late Cretaceous faunas. – *Revue de Paleobiologie* **9**, 51–54.

Ősi, A., 2005: *Hungarosaurus tormai*, a new ankylosaur (Dinosauria) from the Upper Cretaceous of Hungary. – *Journal of Vertebrate Paleontology* **25/2**, 370–383.

Ősi, A. 2006: Iharkút, the first Hungarian Late Cretaceous continental vertebrate locality. – *Excursion guide for the 4th Anual EAVP Meeting, Budapest, Hantkeniana*, 116–120.

Ősi, A. 2008a: Cranial osteology of *Iharkutosuchus makadii*, a Late Cretaceous basal eusuchian crocodyliform from Hungary. – *Neues Jahrbuch für Geologie und Paleontologie* **248/3**, 279–299.

Ősi, A. 2008b: Enantiornithine bird remains from the Late Cretaceous of Hungary. – *Oryctos* **7**, 55–60.

Ősi, A. 2009: The Late Cretaceous continental vertebrate fauna from Iharkút, western Hungary – a review of the newest results. In Godefroit, P. and Lambert, O. (eds): Tribute to Charles Darwin and Bernissart Iguanodons: New perspectives on Vertebrate Evolution and Early Cretaceous Ecosystems. Brussels, Belgium. p. 76.

Ősi, A., Weishampel, D.B. & Jianu, C.M. 2005: First evidence of azhdarchid pterosaurs from the Late Cretaceous of Hungary. – *Acta Paleontologica Polonica* **50**, 777–787.

Ősi, A. & Rabi, M. 2006: A Late Cretaceous continental vertebrate fauna from the Bakony Mountains: crocodiles, dinosaurs, pterosaurs and birds. – *Földtani Közlöny* **136/4**, 503–526 [in Hungarian].

Ősi, A., Clark, J.M., & Weishampel, D.B. 2007. First report on a new basal eusuchian crocodyliform with multi-cusped teeth from the Upper Cretaceous (Santonian) of Hungary. – *Neues Jahrbuch für Geologie und Paleontologie* **243/2**, 169–177.

Ősi, A. & Weishampel, D.B. (in press): Jaw mechanism and dental function in the Late Cretaceous basal eusuchian *Iharkutosuchus*. – Journal of Morphology.

Poyato-Ariza, F.J., Talbot, M.R., Fregenal-Martínez, M.A., Meléndez, N. & Wenz, S. 1998: First isotopic and multidisciplinary evidence for nonmarine coelacanths and pycnodontiform fishes: palaeoenvironmental implications. – *Palaeogeography, Palaeoclimatology, Palaeoecology* **144**, 65–84.

Rabi, M. 2005: Alligatoroidea indet. from the Upper Cretaceous of Hungary (Csehbánya Formation). – *3rd Meeting of the EAVP*, Abstract. Kaupia **14**, 93.

Rabi, M. 2009: Presence of sebecosuchian crocodyliforms in the Late Cretaceous of Europe. 83. *In* Godefroit, P. and Lambert, O. (eds): Tribute to Charles Darwin and Bernissart Iguanodons: New perspectives on Vertebrate Evolution and Early Cretaceous Ecosystems, Brussels, Belgium.

Rabi, M. & Botfalvai, G. 2006: A new bothremydid (Chelonia: Pleurodira) fossil assemblage from the Late Cretaceous (Santonian) of Hungary – additional studies in the historical paleobiogeography of Late Cretaceous bothremydids. – *4th Meeting of the European Association of Vertebrate Paleontologists, Budapest. Hantkeniana,* 61–65.

Siegl-Farkas, Á. 1991: Bauxite deposits and Senonian Formations in Hungary (Palynological analysis). – *Acta Geologica Hungarica* **34/4**, 345–350.

Szalai, E. 2005: Paleomagnetic studies in Iharkút. *Manuscript, Eötvös Loránd University, Department of Environmental Geology* [in Hungarian].

Szentesi, Z. 2006: Late Cretaceous amphibians from the Csehbánya Formation (Iharkút, Bakony Mountains). – *9. Symposium of Hungarian Paleontologists*. Abstracts, pp. 20–21 [in Hungarian].

Tari, G. 1994: Alpine tectonics of the Pannonian Basin. – *Unpublished PhD Thesis, Rice University, Houston,Texas,* 1–489.

Tari, G., Báldi, T. & Báldi-Beke, M. 1993: Palaeogene retroarc flexural basin beneath the Neogene Pannonian Bason: a geodynamic model. – *Tectonophysics* **226**, 433–455.

Tuba, Gy., Kiss, P., Pósfai, M. & Mindszenty, A. 2006: Preliminary data on the diagenesis of Cretaceous dinosaur bones from the Bakony Mts, Hungary. – *Földtani Közlöny* **136**, 1–24 [in Hungarian].

Third day

Stop 1. Sümeg, Mogyorós Hill

János HAAS

Sümeg is a nice town at the southwestern end of the Southern Bakony Mountains. The medieval castle sitting on the top of a horst that is made up of Cretaceous limestones is the main attraction of the local tourism (Fig. 31).

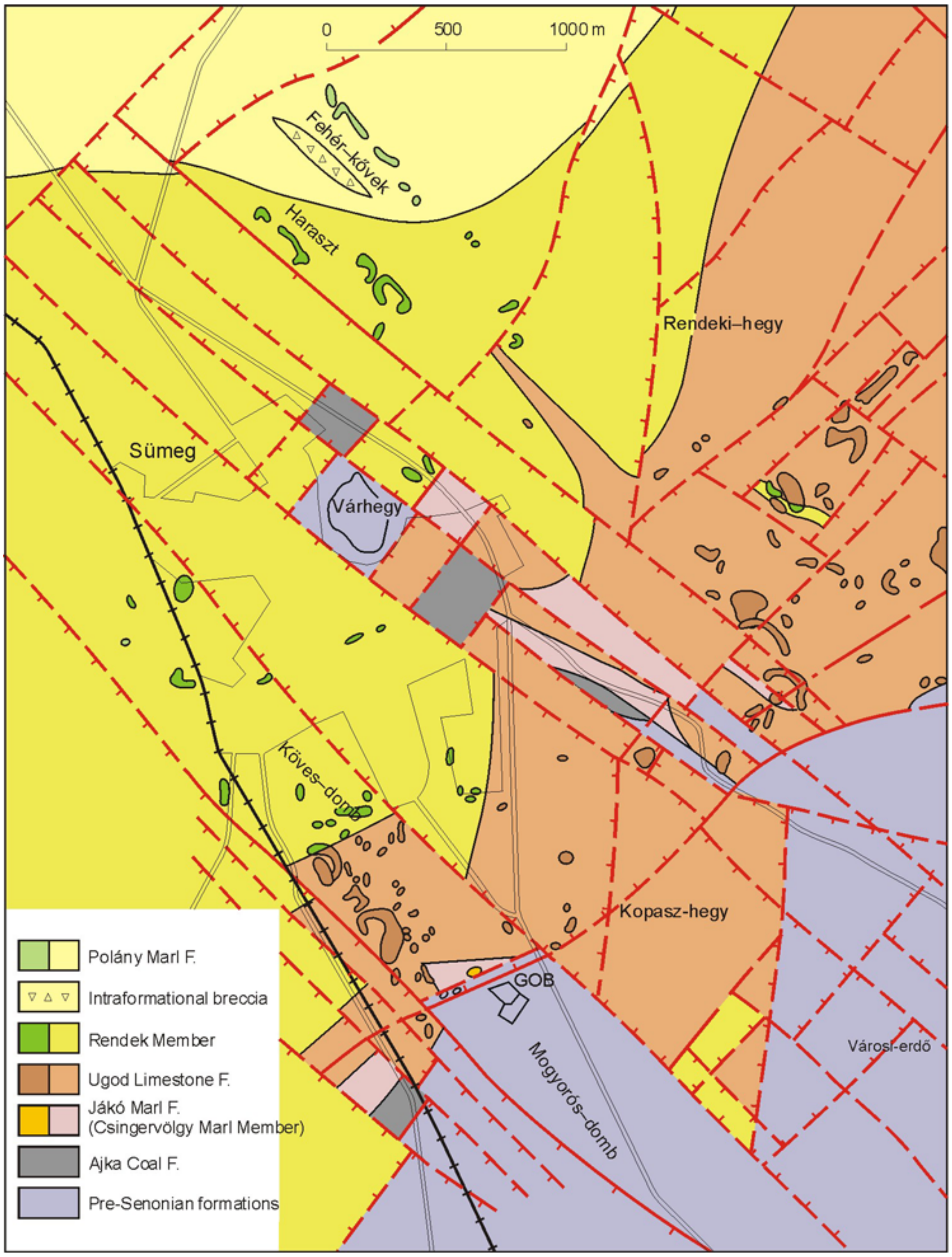


Fig. 31 Pre-Tertiary map of the Sümeg area, showing location of Vár-hegy (Castle Hill), Mogyorós-domb (Mogyorós Hill) and Köves-domb (Köves Hill)

The Mogyorós Hill is located south to the town (Fig. 32). There is an artificial trench exposing a continuous section from Middle Jurassic radiolates, through Malm Ammonitico

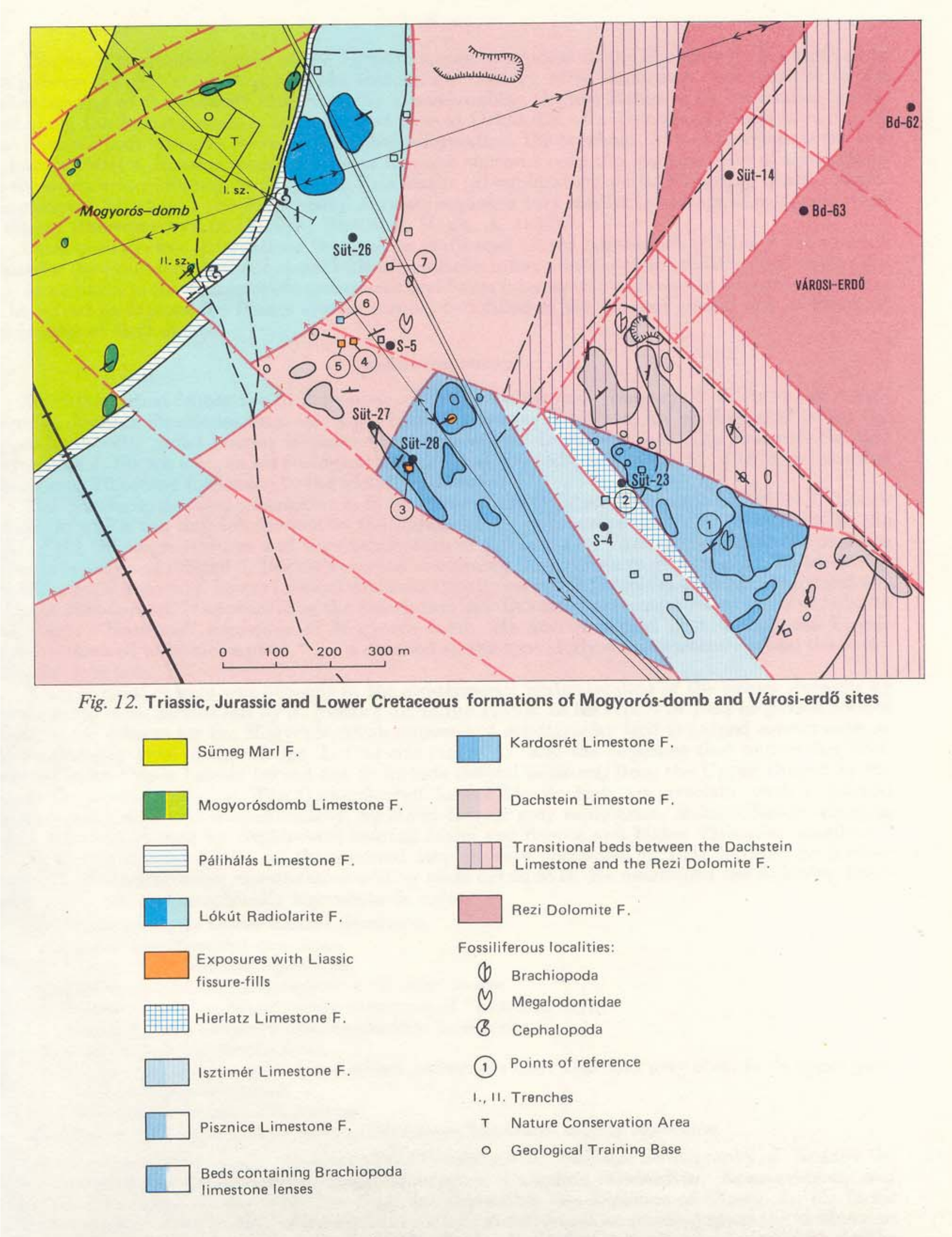


Fig. 32 Pre-Tertiary map of the Mogyorós Hill, and location of the key-section

Rosso-type limestones to the Upper Tithonian to Hauterivian Mogyorósdomb Formation (Fig. 33). It is a limb of a large scale synclinal structure that is why the layers are in a nearly vertical position. Harmonic folding could be observed in the section north to the fence of the protected archeological pits. At present in this part of the section the exposure

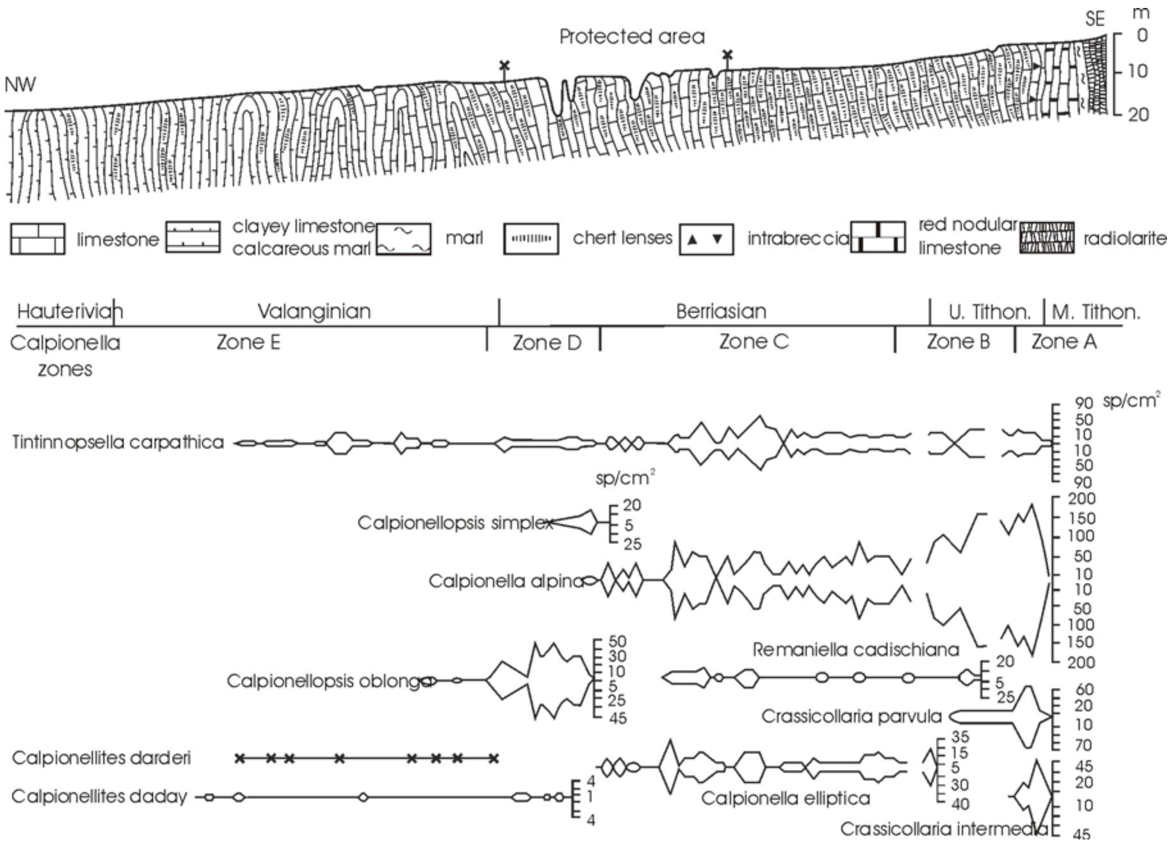


Fig. 33 The Mogyorós Hill section. The diagrams show quantity of the most important calpionellids species and the changes in the quantity of calpionellids and radiolarians

conditions are poor. The unearthed prehistoric chert pits in the Berriasian part of the section provide the best exposure for the Maiolica-type cherty limestones.

At the SE end of the trench black radiolaritic chert layers, representing the topmost part of the Lókút Radiolarite formation are exposed (Fig. 33). Based on a borehole drilled near to this place the stratigraphic thickness of the Lókút Formation is about 30 m and it is underlain by Bositra limestone of the Eplény Formation. The age of the radiolarite formation is probably Bathonian to Oxfordian but there is no biostratigraphic evidence for this. It is overlain by light grey marl, 2.5 m in thickness that is assigned to the Oxfordian but it is also not proved.

The next 10 m thick interval is red nodular limestone, rich in moulds of Ammonites (Pálihálás Limestone Formation) (Fig. 33). The limestone is abundant in fragments of Saccocoma. Based on Ammonites this formation can be assigned to the Kimmeridgean to Lower Tithonian (Vigh 1984).

It is overlain by the Mogyorósdomb Limestone Formation that is made up of grayish-white cherty limestone. This trench is the stratotype section of this formation. There is a gradual transition between the two formations. Calpionellids appear in great number about

1 m, whereas the firts chert nodules occur 1.4 m above the formation boundary. Based on Calpionellids the Jurassic-Cretaceous boundary could be recognized about 2.5 m above formation boundary (Fülöp 1964, Haas et al. 1985). The Berriasian part the formation is visible within the fenced area. Here limestone, cherty limestone and chert layers alternate. The limestone layers are typified by wackestone textures, although the micritic matrix is made up mostly of Nannoconus. Calpinellins and Cadosinas are also abundant in some of the layers, whereas the others are rich in calcified radiolarians. The radiolarian-bearing beds are usually silicified and contain chert nodules. However, calpionella-rich layers may also be silicified due to diagenetic mobilization of SiO_2. The alternation of Calpionellonid-rich and Radiolarian-rich layers in the Berriasian may reflect orbitally forced climatic changes (Haas et al. 1994).

Based on Calpionellids the Valanginian stage was clearly evidenced for the higher part of succession exposed north to the fence of the archeological sites. Prints of Hauterivian Ammonites were reported by Fülöp (1964) from the more argillaceous topmost part of the section.

The Mogyorósdomb Limestone formation represents a typical deep pelagic basin facies deposited under the ACD. It is constrained by lack of ammonites, while aptychii occur (Fig. 34). However, the depth of ACD in the Early Crataceous is unknown.

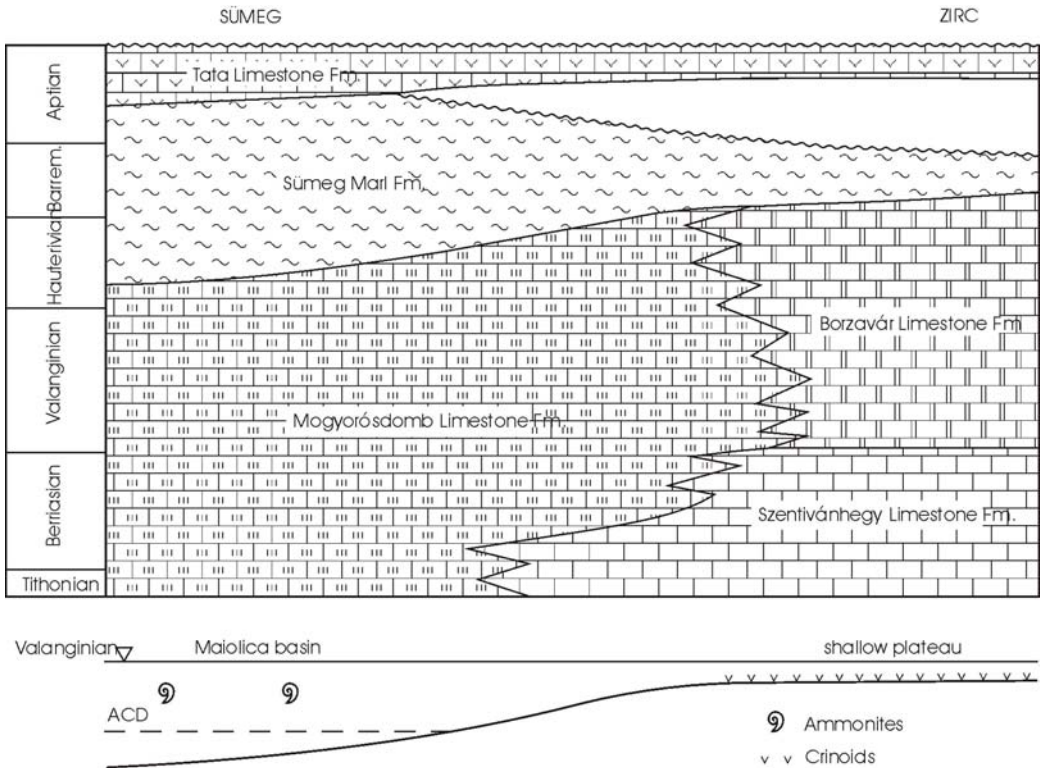


Fig. 34 Conceptual section showing the time/space relations of the Lower Cretaceous formations in the Bakony Mts and the paleogeographic position of the facies areas in the Valanginian

The chert pits were made by prehistoric people 4000 to 6000 years ago during the Neolithic and Copper Age. They excavated the chert for tool and weapon making. They developed narrow pits along the strike of the beds following the best quality chert occurrences and used stag-horn mining tools.

References

Fülöp, J. 1964: Unterkreide-Bildungen (Berrias-Apt) des Bakony-Gebirges. – *Geol. Hung. Ser. Geol.* **13**, 193 p.
Haas, J. & J. Edelényi, E. (eds.): Haas, J., J. Edelényi, E., Gidai, L., Kaiser, M., Kretzoi, M. & Oravecz, J. 1985: Geology of the Sümeg Area. – *Geol. Hung. ser. Geol.* **20**, 365 p.
Haas, J., Kovács, L. & Tardi-Filácz, E. 1994: Orbitally forced cyclical changes in the quantity of calcareous and siliceous microfossils in an Upper Jurassic to Lower Cretaceous pelagic basin succession, Bakony Mountains, Hungary. – *Sedimentology* **41**, 643–653.
Vígh, G. 1984: Die biostratigraphische Auswertung einiger Ammoniten-Faunen aus dem Tithon des Bakonygebirges sowie aus dem Tithon-Berrias des Gerecsegebirges. – *Ann. Inst. Geol. Publ. Hung.* **Vol. LXVII**, 1–210.

Stop 2. Sümeg, Sintérlap quarry

János HAAS

The abandoned quarry is located on Kövesdomb, in the southwestern part of the town (Fig. 35). At present it is a protected geological trail. Steeply dipping beds of the Lower Cretaceous Tata Limestone are exposed in the western wall of the quarry. In the eastern wall, the angular and erosional disconformity between the Tata Limestone and the Campanian succession is well visible (Fig. 36). There is a conglomerate unit at the base of the Campanian sequence that is overlain by rudist limestone beds containing a very rich and spectacular fauna. In the northern wall of the quarry the rudist limestone is covered by pelagic limestone layers. The whole quarry records a peculiar local paleogeographic setting prevailed in the Campanian.

Slightly folded Tata Limestone having a dip of 40-45^{o} can be observed in the western wall of the quarry. The rock is composed mostly of crinoid ossicles and other biogenic components (benthonic and planktonic foraminifera, mollusc shell fragments, bryozoans, red algal detritus etc.) and a remarkable amount of sand-sized extraclasts deriving from the deeper part of the Mesozoic succession; clasts derived from the Kimmeridgian to Barremian interval are prevailing. Based on core data, the Tata Limestone gradually progresses from the Barremian to Aptian Sümeg Marl of pelagic basin facies in the environs of Sümeg (Haas et al. 1985). Occurrence of Globigerinelloides algerianus in these beds indicates Late Aptian age of the formation. High energy shallow ramp was the depo-

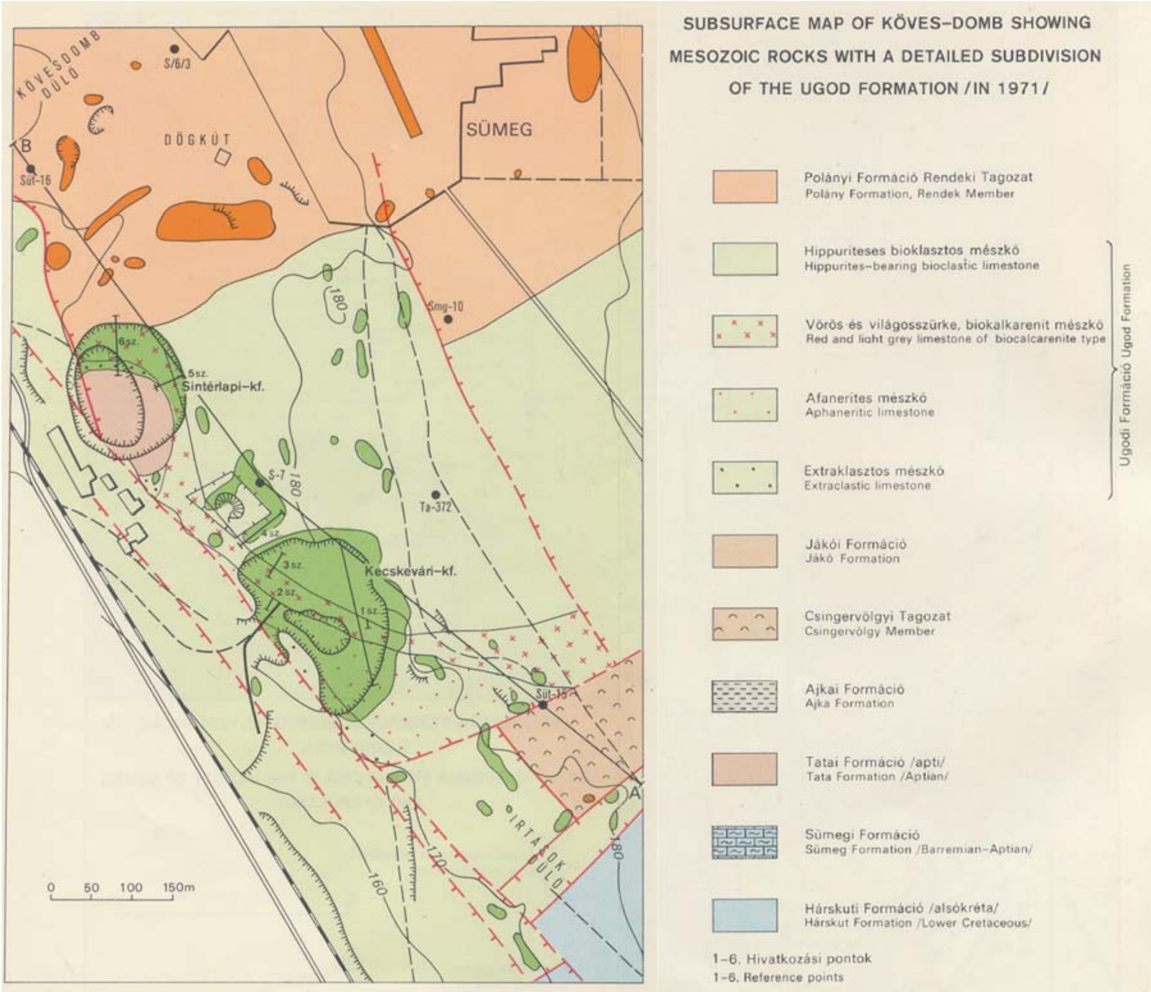


Fig. 35 Pre-Tertiary geological map of the Köves Hill showing location of the Sintérlap quarry

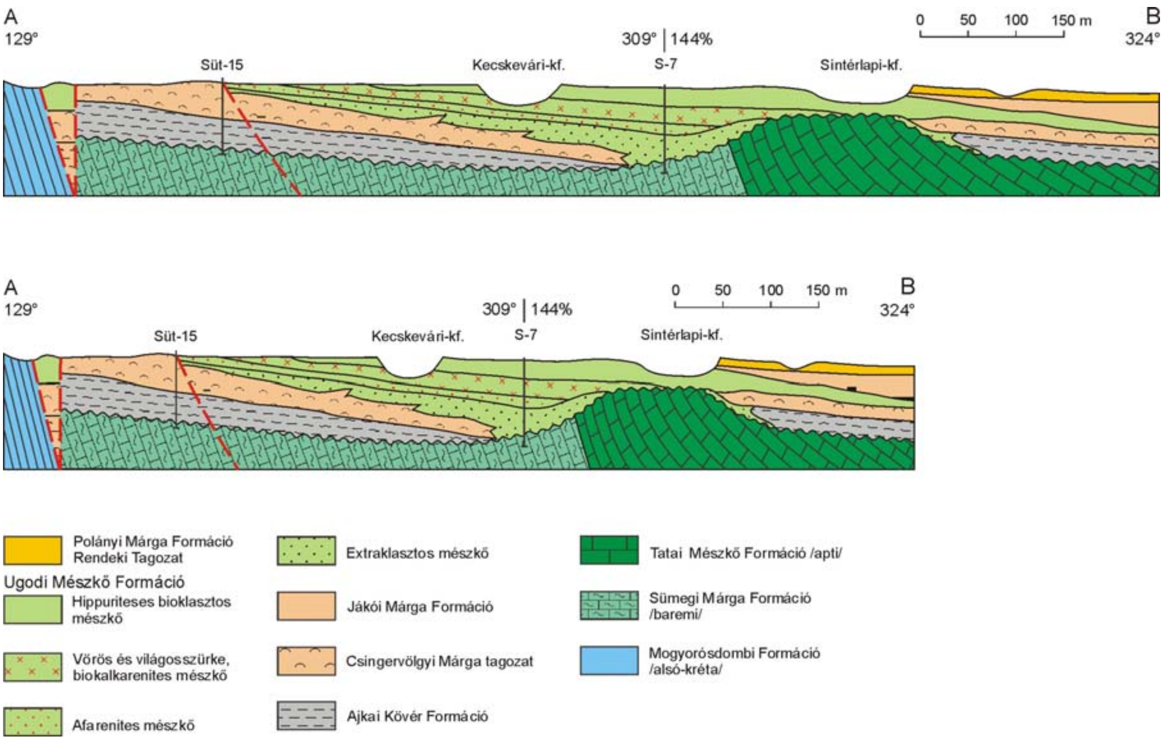


Fig. 36 Cross section of the Köves Hill

sitional environment. The appearance of Jurassic to Lower Cretaceous clasts in the Aptian deposits suggests onset of intense syngenetic tectonic movements. The main folding stage, however, took place subsequent to the deposition of the Tata Limestone and led to folding of the whole Jurassic to Lower Cretaceous succession.

The folding was followed by an extensional tectonic phase still prior to the Campanian transgression which resulted in the formation of red calcite-filled fissures, which can be observed at several parts of the quarry.

Pre-Senonian tectonics and connected erosion created an articulated topography that controlled the Senonian sediment deposition for a long time both on regional and local scale (Fig. 37). The NW part of the Sümeg area which was located in the axial zone of the synform of the Transdanubian Range was in a relatively deep position. This depression was surrounded SE-ward by a relatively elevated dolomite plateau and a slope linked the two morphological units. The Late Santonian transgression started in the depression with deposition of coal-bearing sequences and extended onto the slope gradually, reaching the dolomite plateau during the Campanian and gave rise to the formation of extended rudist platforms (Haas 1979).

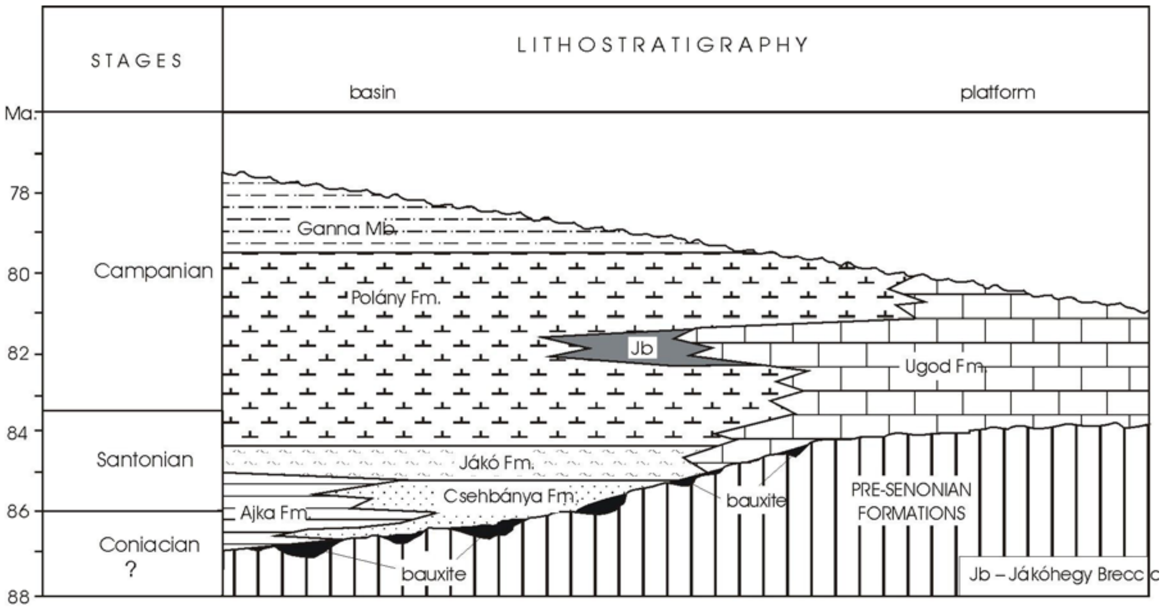


Fig. 37 Time/space relations of the Senonian formations in the Bakony Mts, showing the outstanding importance of the preceding topography in the facies distribution

Paleogeographically the area of the Sintérlap quarry was located on a gentle slope between the basin and the high. However, at this place a local basement elevation developed, which modified the general pattern. Along the southern slope of this small basement block a breccia apron was formed, containing gravel-sized fragments of the Tata

Limestone in Campanian limestone matrix. On the top of the high, the rough surface of the Tata Limestone is directly overlain by the rudist-bearing Ugod Limestone. Northward the rudist limestone body pinches out interfingering with deeper water argillaceous deposits.

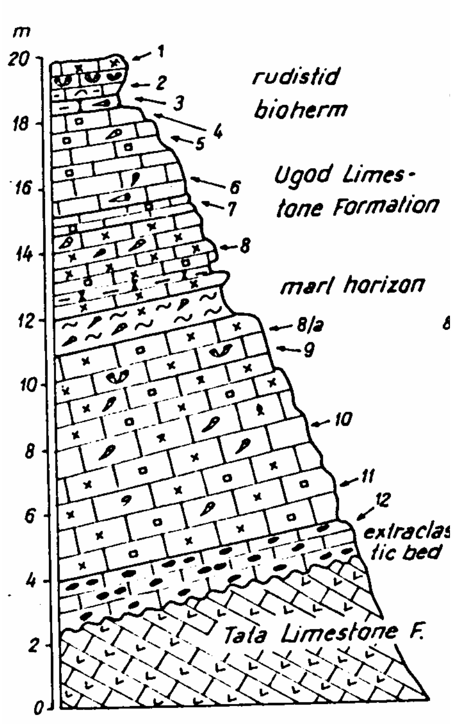


Fig. 38 Measured section of the eastern wall of the quarry

In the southeastern part of the quarry limestone breccias containing pebble-sized fragments of the underlying formation and large gastropods (Trochacteon) and rudists are visible directly above the Tata Limestone (Fig. 38). These basal beds are overlain by argillaceous limestones and marls containing large amount of complete and fragmented rudists. The upper part of the succession exposed in the eastern wall of the quarry is made up of calcarenite-calcirudite with large Hippurites valves. In the uppermost bed rudist bioherms occur, consisting clusters of rudists embedded in life position (Fig. 38).

In the northern wall, the Tata Limestone is directly overlain by rudist limestone beds, whereas in the topmost part of the exposed sequence these beds are covered by thin-bedded argillaceous limestones containing pelagic microfossils (calcisphaerulids and planktonic foraminifera) that can be assigned to the Polány Marl Formation (Fig. 36). The lower part of the Polány Marl yielded an excellent ammonite assemblage of *Glyptoxoceras indicum* (Forbes 1846), *Scaphites hippocrepis* II-III (de Kay), *Menabites* sp. among others. The ammonite record clearly and exactly indicates middle Early Campanian age, with the presence of the index ammonite (Szives & Főzy in Szives et al. 2007).

References

Forbes, E. 1846: Report on the fossil Invertebrata from Southern India, collected by Mr. Kaye and Mr. Kunliffe. – *Transactions of the Geological Society of London* (series 2) **7**, 97–174.

Haas, J. 1979: The Ugod Limestone Formation in the Bakony Mountains. – *Ann. Hung. Geol. Inst.* **LXI,** Műszaki Kiadó, Budapest, 171p.

Haas, J. & J. Edelényi, E. (eds.): Haas, J., J. Edelényi, E., Gidai, L., Kaiser, M., Kretzoi, M. & Oravecz, J. 1985: Geology of the Sümeg Area. – *Geol. Hung. ser. Geol.* **20**, 365 p.

Szives, O. & Főzy, I. 2007: Campanian stage. *In*: Szives, O. (ed.): Szives, O., Csontos, L., Bujtor, L. & Főzy, I. 2007: Aptian – Campanian ammonites of Hungary. – *Geologica Hungarica series Paleontologia*, faciculus **57**, 125–131.

Stop 3. Manganese slurry reservoir, Úrkút

Géza CSÁSZÁR

The Southern Bakony succession of the Createaceous shows significant differences comparing to the Northern one. The underlying rocks are represented by Jurassic limestones of varied ages and radiolarite. The oldest Cretaceous formation is the Tés Clay the lower, member rank part of which is composed of reworked and weathered Jurassic cherts and limestone fragments with variegated clays of non-marine origin. The upper part of the formation is grey, marine clay, clay-marl and marl. The uppermost bed impregnated by manganese, crops out in the section of the slurry reservoir (Fig. 39 and 40). It is followed by a transitional interval between the Tés Clay and the Úrkút Member of the Zirc Limestone Formation. These transitional beds made up of calcareous marl and clayey limestone, devoid of macrofauna or contain just a few gastropod shells. The considerable quantity of sponge spicules and the dominance of arenaceous forms amongst the foraminifers indicate a fore-slope sedimentary environment.

The specialty of the Úrkút Limestone Mb is that it is a heteropic facies of the complete Zirc Limestone Formation although its thickness exceeds 200 m as far as the Zirc Limestone in the Northern Bakony is appr. 50 m. The latter one can be subdivided vertically into 3 member rank units while varied facies in the Úrkút Mb repeatedly occur in the succession.

The upper portion of the section is dominated by two monogeneric beds containing *Toucasia* and *Eoradiolites* species respectively. The bed of the third type is abundant in gastropod shells (*Nerinea*, *Nerinella* and *Nododelphinula*), rich in both species and specimens as summarized by Czabalay (1989 unpublished report). The giant gastropod *Adizoptyxes coquandiana* (D'ORBIGNY) is found in rock-forming quantity in the uppermost beds in the cliff and on the plateau.

Remains of characeans in two intercalating beds suggest of freshwater origin, and in case of two other beds with tiny forams only brackish-water origin. Coming out from these data it is very probable that the sedimentation of these limestone beds took place basically in shallow marine to brackish-water, nearly tranquil lagoon, turned into freshwater environment at least two times.

A few storm-related breccia horizons intercalate in the section, cemented by red clay of palaeosoil origin. Two of these intercalations are qualified to be of brackish-water, and

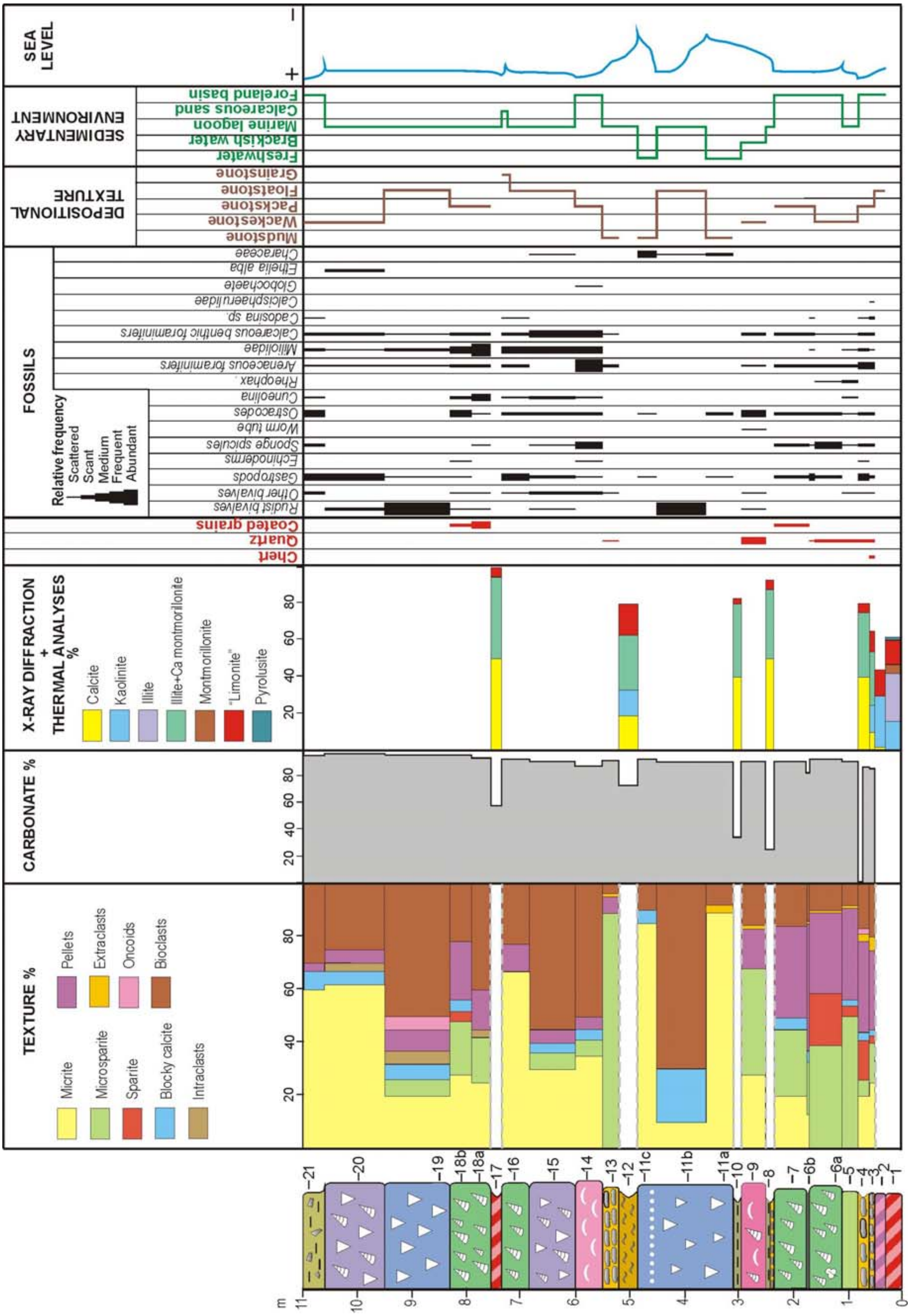


Fig. 39 Columnar sections of the Úrkút Member of the Zirc Limeston Fm at the Manganese Slurry Reservoir with transition from the Tés Clay, Úrkút

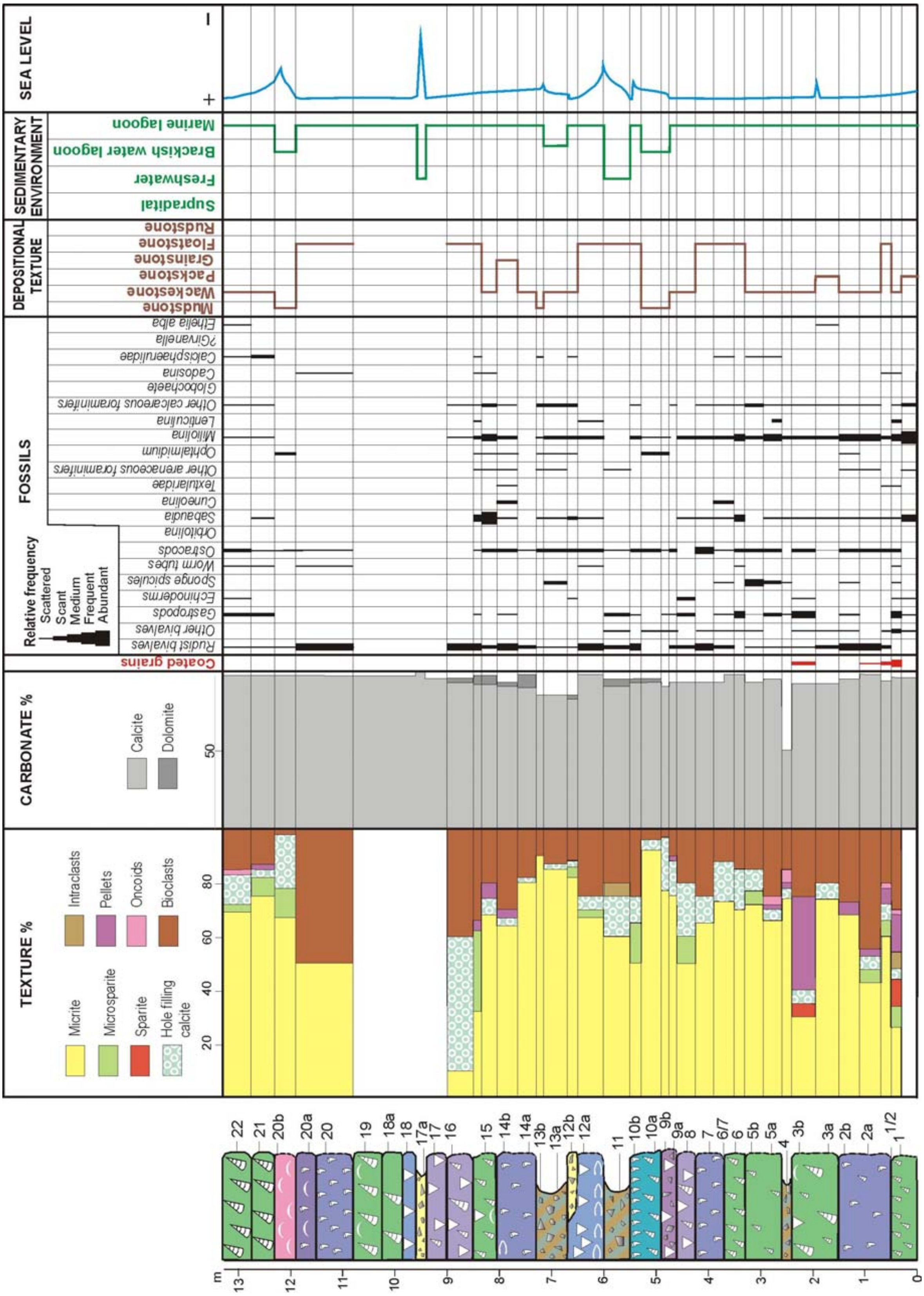


Fig. 40 Columnar sections of the Úrkút Member of the Zirc Limeston Fm at the Manganese Slurry Reservoir with transition from the Tés Clay, Úrkút

one of them freshwater origin. The hypothesis concerning the deposition in the intertidal, shallow subtidal and supratidal zones is supported by the occurrences of root traces. Based on the predominant biomicritic to biopelmicritic wackestone microfacies, these rocks – apart from the storm breccia – are interpreted as having been formed in a gentle-agitated lagoon. Intercalation of bauxitic clay is an indication of the closness of the coastal zone behind of which bauxitization process was going on in the Middle Albian (during the sedimentation of the succession described above).

References

Czabalay, L. 1989: Korrelation der Pachyodonten Faunenzonen des Urgons der westlichen Tethys. – In: Wiedmann, J. (ed.): Cretaceous of the Western Tethys. – *Proceedings 3rd International Cretaceous Symposium, Tübingen 1987*, 431–451.

Stop 4. A quarry on the south-western side of the road between Úrkút and Ajka

Géza CSÁSZÁR

The Úrkút Limestone Mb is exposed in a string of quarries located at the south-western flank of the valley (Fig. 41). The most exciting feature of the 10 m-thick Urgon type limestone cropping out here is the biostrome formed by several generations of Chondrodonts in life position. The development of the lower biostrome was ended by a relative fall in sea level. During the exposure period the consolidation of lime mud proceeded "immediately" so that when the sea encroached, it met a uniform, hard-grounded sea-floor morphology. This process inevitably resulted in pelecypod shells sticking out of the sea-floor, being entirely cut off, some of the fragments of which exclusively make up the basal clastics of the next bed.

The other peculiarity of the section is that it does not contain rudist shells but does contain gastropods of *Acteonella baconica* CZABALAY. The texture of the limestone is dominated by biomicritic to biopelmicritic wackestone, mudstone and rarely floatstone which are evidence for a tranquil shallow lagoon environment. The occurrence of characeans show freshwater-lacustrine intercalations. There are also transitional (brackish-water) sedimentary environment. The shrinkage pores are the products of the intertidal sedimentary environment.

The proper age of these beds, the entire Úrkút Member, and their relation to the Pénzeskút Marl Formation are unknown.

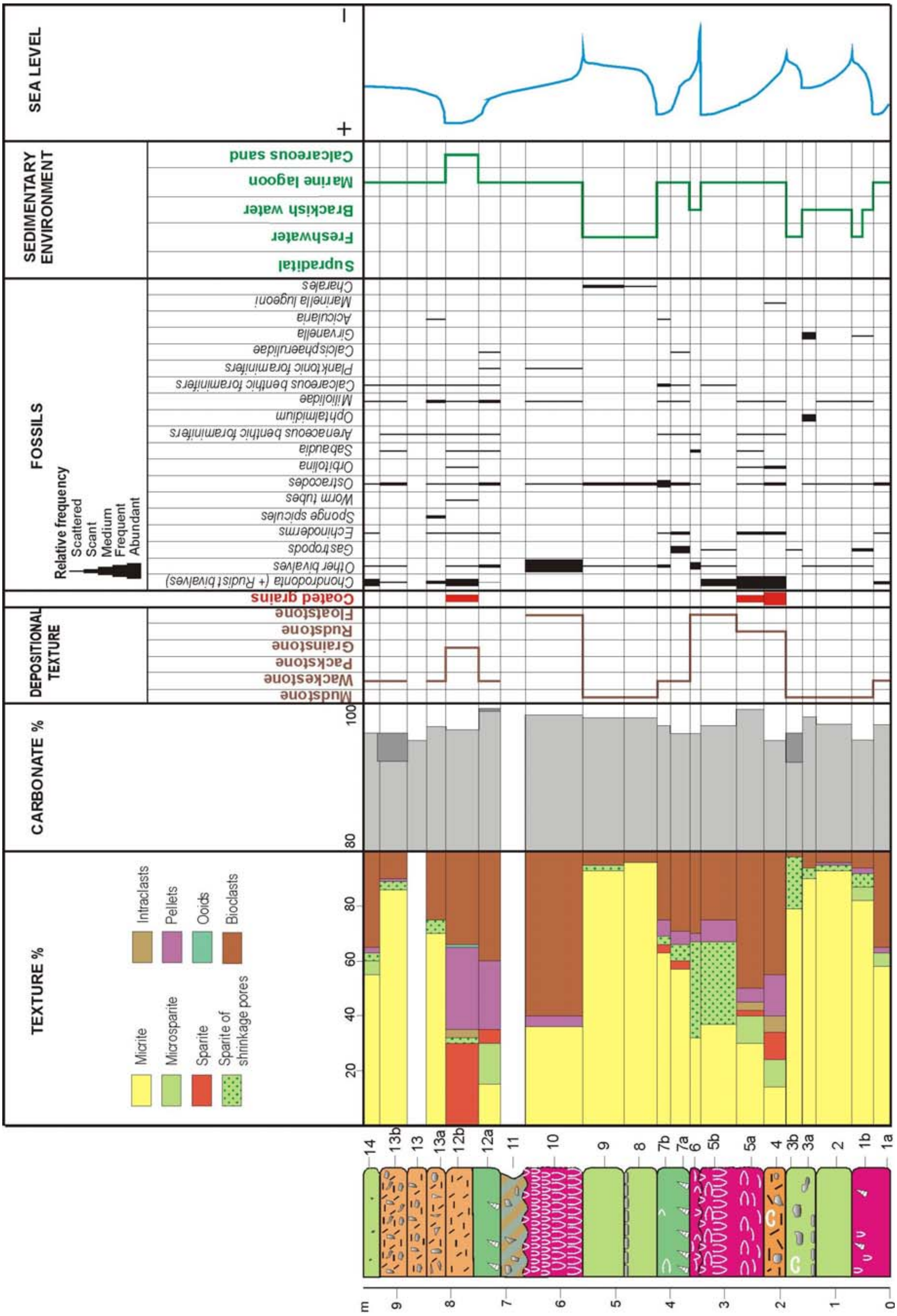


Fig. 41 Columnar section of the upper part of the Úrkút Member in a quarry close to the road between Úrkút and Ajka